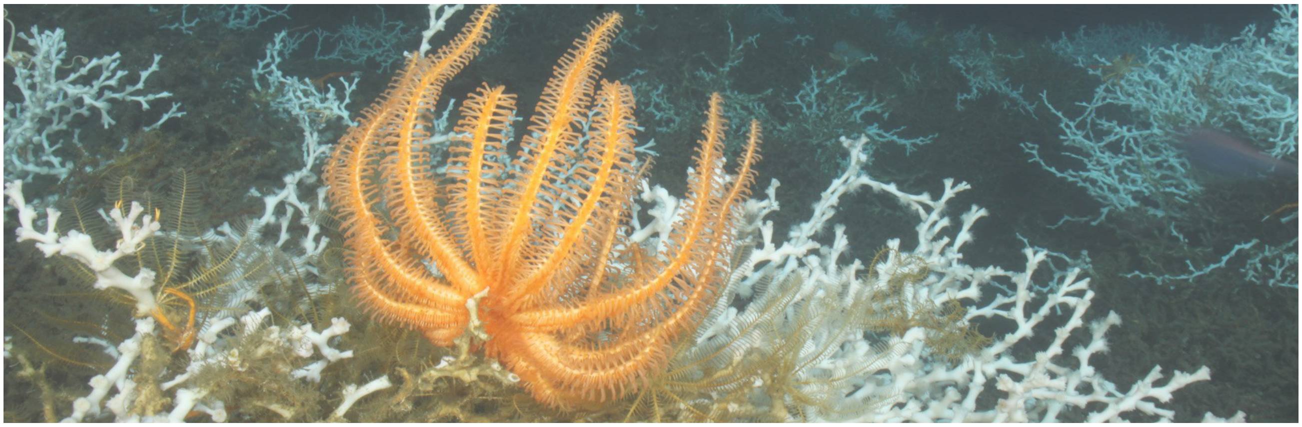


# 7. Southeast Atlantic and Gulf of Mexico Region Acidification Research

**Leticia Barbero[1,2], Christopher R. Kelble[2], Denis Pierrot[2], Rik Wanninkhof[2]**

[1]NOAA/OAR, Cooperative Institute for Marine and Atmospheric Studies, University of Miami, Miami, FL

[2]NOAA/OAR, Atlantic Oceanographic and Meteorological Laboratory, Miami, FL

**Technical contributors: Astrid Schnetzer[3], Beth Stauffer[4]**

[3]Department of Marine, Earth, and Atmospheric Sciences, North Carolina State University, Raleigh, NC

[4]Department of Biology, University of Louisiana at Lafayette, Lafayette, LA

## Abstract

The Southeast Atlantic and Gulf of Mexico Region encompasses continental shelf waters extending from the North Carolina to Florida coasts on the Atlantic seaboard and the marginal sea bounded by the U.S. Gulf Coast. While these two regions experience different stress factors with regards to ocean acidification (OA), they share similar needs with regards to local community engagement (or lack thereof), active research, and data availability. The regional influence of the Northward flowing Gulf Stream and southward flowing Labrador Sea currents in the Southeast Atlantic dominates the biogeochemical signatures of coastal waters in this region while the Gulf of Mexico is strongly influenced by the loop current and riverine inputs, which contribute to eutrophication and hypoxia. Impacts to coral reefs and the recreational and industrial fishing industries, and potential prevalence and frequency of harmful algal blooms are some of the issues this region faces that are potentially affected by increasing ocean acidity. NOAA's Southeast Atlantic and Gulf of Mexico research goals are to:

- Expand OA monitoring using both traditional and new autonomous technologies to observe critical regions, including the ocean sub-surface and bottom water layer, to better characterize regional processes and improve fundamental understanding;
- Characterize ecosystem impacts and adaptive potential of species, with an aim to identify indicator species that can be used for early detection of unfavorable ecosystem conditions; and
- Use new knowledge to develop socioeconomic impact assessments of OA on recreation, tourism and aquaculture industries.

## Acidification in the Atlantic and Gulf of Mexico Region

The Gulf of Mexico (GoM) includes coastal areas of Florida (FL), Alabama (AL), Mississippi (MS), Louisiana (LA) and Texas (TX) and is a semi-enclosed marginal sea with coastal and open ocean waters. The eastern side of GoM includes the West Florida shelf, measuring up to 250 km while the Northern and Western GoM shelves are much narrower. The Southeast Atlantic region (SE) is composed of the coastal areas of North and South Carolina, Georgia, and the East coast of Florida and is characterized by a shelf width on the order of tens of kilometers. It is bound by the Gulf Stream, which flows northeastward along the shelf edge before detaching at Cape Hatteras, NC. The Gulf Stream is influenced by contributions from the SE and GoM region, although the influence of these regional inputs to OA variability has yet to be directly researched. Research described in this chapter excludes the Gulf of Mexico coral reefs in the keys and in the Flower Garden National Marine Sanctuary, which are instead addressed collectively with the Caribbean corals in *Chapter 8: Florida Keys and the Caribbean Region*.

Slope water composition in the Southeast Atlantic region is a varying mix of predominantly Gulf Stream and Labrador Sea water, as well as inputs from coastal marshes. There is significant interannual variability in the region, primarily driven by the influence of different water masses, which affects OA conditions (Wang et al., 2013; Wanninkhof et al., 2015). Seasonal phytoplankton blooms do not occur regularly, and biologically driven carbon dioxide ($CO_2$) uptake is less pronounced than in Atlantic coastal areas farther north (see *Chapter 9: Mid-Atlantic Bight Region* and *Chapter 10: New England Region*). The acidification rate in the South Atlantic Bight is higher than in the open ocean due to the combined effects of increased temperature in the middle and outer shelves, and lateral land-ocean interactions in the inner shelf (Reimer et al., 2017). Recent work using pH data collected for over a decade in two estuaries in North Carolina showed variations in pH linked to increasing river discharge and highlighted the importance of eutrophication (Van Dam & Wang, 2019). Dredging, water management, and associated activities in inlets and port areas (e.g., in Port Everglades) can cause underappreciated impacts on OA in South Florida. These activities can have coastal co-stressor effects (e.g., due to input from eutrophied, organic-rich freshwater canals and rivers) that can lead to enhanced acidification and impact local reefs and other organisms of economic interest (Enochs et al., 2019). This same area has had persistent harmful algal blooms (HABs) in the past decades (Kramer et al., 2018), but studies relating them to OA have been inconclusive.

In the GoM, ocean water enters through the Yucatan channel and exits through the Florida Straits. Main features affecting water circulation in the GoM include the meandering Loop Current, which often sheds anticyclonic eddies that drift westward and can impact the shelf, and riverine input, particularly from the Mississippi-Atchafalaya river system, which provides large volumes of fresh water, nutrients and sediments. This riverine input can lead to eutrophication, hypoxia, and enhanced acidification (Cai et al., 2011). On the West Florida shelf riverine and groundwater input with high phosphate from natural deposits can have a unique signature of biologically mediated OA. Most of the coastal acidification studies in the GoM have focused in the northern and eastern coasts (e.g., Cai et al., 2011; Huang et al., 2013, 2015; Lohrenz et al., 2010; Feely et al., 2018; Hu et al., 2018; Robbins et al., 2018). Less data are available in the Western GoM shelf, with the exception of some estuarine work (McCutcheon et al., 2019) and very little data beyond surface measurements in deep waters of the GoM. The GoM also presents considerable regional variability. The West Florida Shelf exhibits supersaturated aragonite levels that vary between 2 and 5, both at surface and subsurface levels (Robbins et al., 2018) whereas the Northern GoM presents a steeper drop in saturation levels that is enhanced due to hypoxia (Cai et al., 2011; Feely et al., 2018). OA conditions in the GoM can vary significantly on an annual scale because of interannual variability in wind, temperature, precipitation, and water mass distributions (Muller-Karger et al., 2015; Wanninkhof et al., 2015).

Overall, the various observation- and model-derived estimates for the region agree in terms of their broad patterns, but there remain discrepancies between different estimates, which indicate that continued physical, chemical, and additional biological observational data in conjunction with modelling efforts are necessary in the region (e.g., Xue et al., 2016; Laurent et al., 2017; Lohrenz et al., 2018; Chen et al., 2019).

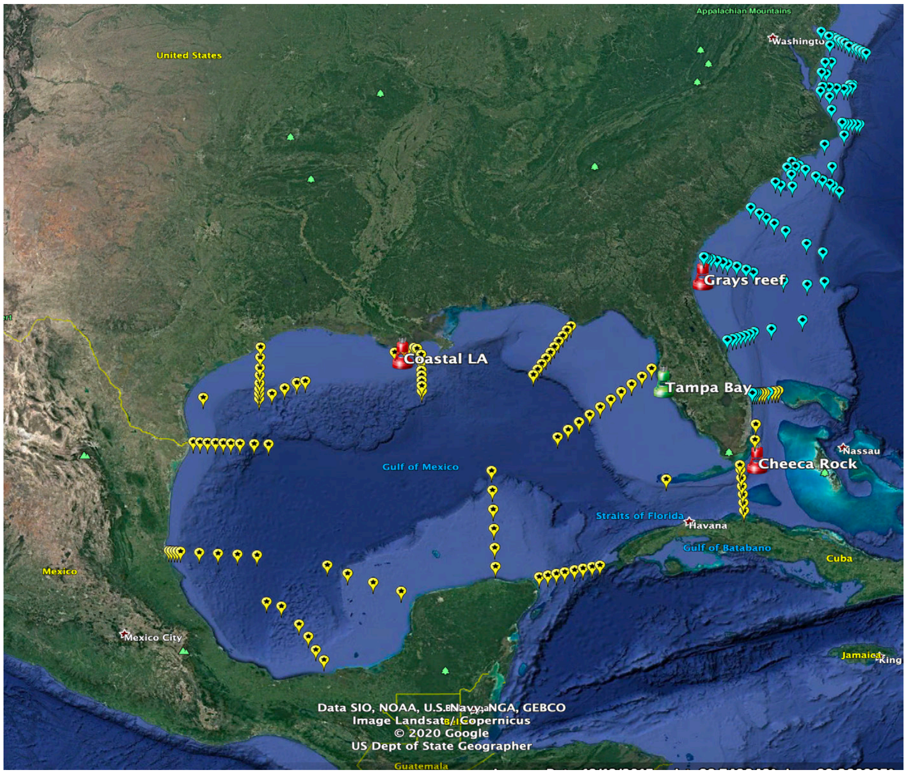


**Figure 7.1.** Location of NOAA-funded buoys (in red) in Gray's Reef, Cheeca Rocks and Coastal Louisiana; non-NOAA funded buoy (in green) in Tampa Bay; and transects occupied as part of East Coast Ocean Acidification (ECOA) and Gulf of Mexico Ecosystems and Carbon (GOMECC) research cruises (blue and yellow pins, respectively).

## *Environmental Change in the Southeast Atlantic and Gulf of Mexico Region*

Most OA observations in the Southeast and GoM coastal regions have focused on the chemical characterization of the area, particularly through NOAA and United States Geological Survey (USGS) efforts. NOAA-supported OA monitoring in the region currently includes: a) synoptic research cruises b) underway $p\mathrm{CO_2}$ systems installed on ships of opportunity, and c) coastal buoys (**Figure 7.1**). NOAA-led OA synoptic cruises have been carried out in the summertime every four years since 2007 in the East coast (East Coast OA (ECOA) cruises) and the Gulf of Mexico (Gulf of Mexico Ecosystems and Carbon Cycle Cruise (GOMECC)) and they collect mostly physical and chemical data along a series of coastal transects (Wang et al., 2013; Wanninkhof et al., 2015). However, the GOMECC cruise (GOMECC-3), conducted in July-August of 2017, incorporated significant biological sampling in conjunction with OA water sampling, strengthening the link between OA forcing and impacts. NOAA-funded cruises in South Florida as part of the South Florida Ecosystem Restoration Program also collect OA samples along the FL keys and offshore of the Everglades several times per year. The USGS has participated in several cruises to study the effects of OA on marine organisms and habitats in the West Florida Shelf and northern Gulf of Mexico regions (Robbins et al., 2018). NOAA funds two underway $p\mathrm{CO_2}$ systems installed on NOAA fisheries ships RV *Gordon Gunter* and RV *Henry H. Bigelow* involved in regular fisheries surveys. In addition to these, NOAA supports underway $p\mathrm{CO_2}$ systems through its Ship of Opportunity Program (SOOP). These systems are installed on a variety of ships including scientific and commercial vessels that have also collected data in the Southeast and Gulf of Mexico regions. As a result, over 90% of available surface $p\mathrm{CO_2}$ data in the Gulf of Mexico has been collected through NOAA-funded efforts since 2008. Surface water samples for carbonate chemistry analysis are also collected on these ships on an opportunistic basis. Additionally, ships of opportunity provide platforms for maintenance of three NOAA OA monitoring buoys in the region (Sutton et al., 2019), and collect data for biogeochemical modeling efforts. The buoys are located off the Georgia coast in Gray's Reef ($p\mathrm{CO}_2$ record started in 2006, pH sensor added in 2011), in the Florida Keys at Cheeca Rocks ($p\mathrm{CO}_2$ and pH record started in 2011) and in coastal Louisiana ($p\mathrm{CO}_2$ and pH record available since 2011). A fourth OA buoy is located in Tampa Bay, FL, and is maintained by Dr. Kim Yates, from the USGS. **Figure 7.1** shows the location of the buoys as well as the transects occupied in the ECOA and GOMECC cruises. Although none are in use in the region, a variety of autonomous platforms equipped with a variety of OA sensors are being explored in other regions. Examples of such platforms include wave gliders for surface measurements, saildrones and BGC-Argo profiling floats, which could provide an excellent means to increase data availability in areas such as the deep GoM.

Observing capabilities over the last decade have greatly improved the spatial coverage of carbonate chemistry measurements made in the region and contributed toward the foundational understanding of the large-scale regional trends from different source waters in the region, and the impacts of riverine inputs and eutrophication on OA conditions in the region. Quantifying and understanding the high natural variability, and teasing apart anthropogenic impacts from natural variability, including from water mass composition, biological activity, and river discharge remain research foci of OA drivers and co-stressors in the region.

The ECOA and GOMECC cruises as well as several other OA cruises in the Northern GoM collect high-resolution water column data, and take place during the summer season in order to provide an interannual comparison without confounding factors from seasonal variability. As a result there are insufficient observations from other seasons to adequately characterize seasonal variability in subsurface waters and the open ocean end-member (**Figure 7.2**). Moreover, there are presently no OA buoys in the Western GoM, representing a major regional sampling gap.

Nearshore estuarine and coastal regions in the GoM and Southeastern Atlantic have also been relatively undersampled. This includes mangroves, marshes, and some estuaries that provide a wealth

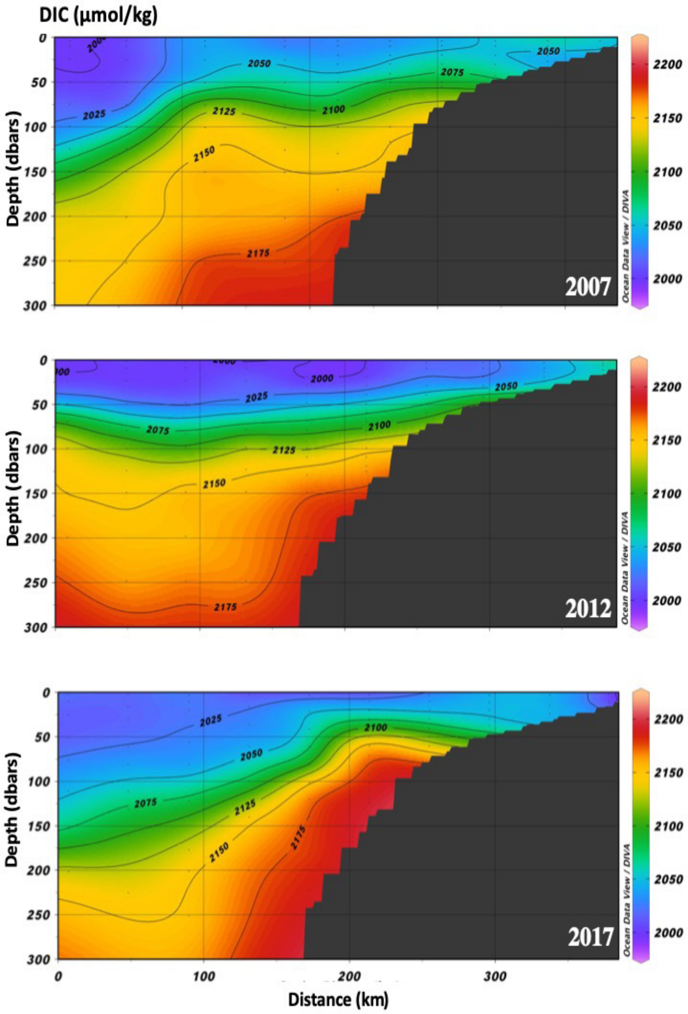
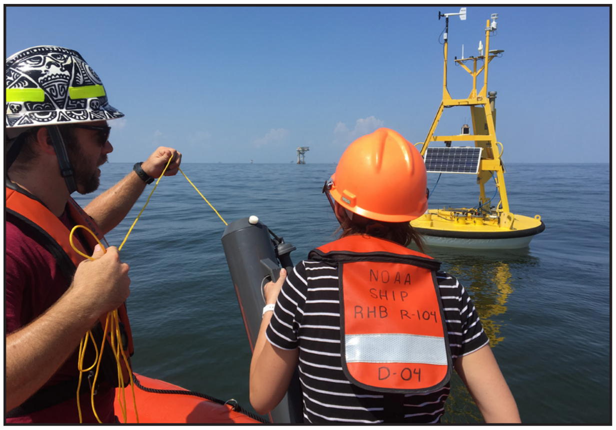


**Figure 7.2.** Concentration of dissolved inorganic carbon (DIC) off the West Florida shelf measured during the Gulf of Mexico Ecosystems and Carbon Cruise (GOMECC). Increased concentrations are observed in the subsurface over time. Surface measurements cannot capture changes in subsurface waters.

of ecosystem services in this region, but are also data poor environments for OA. The majority of recreational fishing and tourism occurs in these data poor nearshore waters; thus, increased sampling is commencing for nearshore waters. The GoM and Southeast Atlantic region have a combined 22 National Parks that have observational infrastructure, support, and outreach opportunities. Of these, 7 have started collecting OA samples in coordination with the synoptic GOMECC and ECOA cruises, once every 4 years. There are two National Marine Sanctuaries (NMS) in the GoM, the Florida Keys NMS and the Flower Garden Banks NMS that are coral reef areas heavily instrumented for OA research and monitoring (see Chapter 8: Florida Keys and Caribbean Region). However, there are no similar monitoring efforts in place for cold-water corals in the Gulf of Mexico, which live at depths between 300 and 600 m, and which have been identified as being particularly vulnerable communities to OA because they are already naturally exposed to lower pH levels (Lunden et al., 2013; Georgian et al., 2016). In the Southeast Atlantic region Gray's Reef NMS off the Georgia coast has a buoy with OA-monitoring systems.



NOAA researchers collect a water sample near an acidification buoy during a Gulf of Mexico/East Coast Carbon research cruise. Credit: Leticia Barbero/NOAA

The in-situ observing data in the region are used in existing modeling efforts including the OA Product Suite developed for the Greater Caribbean region and now extended to include the East Coast. The OA Product Suite utilizes satellite data and a data-assimilative hybrid model to produce monthly maps of surface water carbonate system components. Modeling results include studies in the Gulf of Mexico by Xue et al. (2016), who showed the GoM to be an annual sink for $CO_2$ with a flux of $1.11 \pm 0.84\ 10^{12}$ mol C $yr^{-1}$, and by Laurent et al. (2017), who showed the recurring development of an extended area of acidified bottom waters in summer on the Northern GoM shelf that coincides with hypoxic waters. Global data synthesis and process-based global models have also provided estimates for coastal U.S. regions including the GoM and Southeast (see Table 1 in Fennel et al., 2019). More recently, modeling efforts are being supported to address seasonal patterns of the carbon system. Modeling results agree in general terms with observation estimates, and offer the opportunity to upscale the observations in time and space. However, the models still show significant discrepancies in some regions, specifically in the period from 2010 to 2017 depending on the model. Sustaining current modeling efforts and increasing the modeling portfolio to include nowcasts and forecasts, as well as integrating ecosystem parameters, extending to the East coast, and including robust validation is a priority to predict the expected changes in the region as a result of OA.

### *Research Objective 7.1: Improve characterization of OA parameters in important economic, cultural, and recreational regions*

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

***Action 7.1.1:*** Develop and establish protocols that are complementary to ongoing synoptic cruises to extend regular observations of pertinent OA parameters into the nearshore environment. Focus sampling in Essential Fish Habitats for species predicted to be significantly impacted by OA, and in select National Parks and National Marine Sanctuary sites (specifically in the northern GoM where hypoxia and OA act as co-stressors).

***Action 7.1.2:*** Explore options, including private and/or industry partnerships, to add an OA buoy or alternative observing platform in the Western GoM to extend coverage of coastal sites that are presently composed of buoys in the Florida Keys, West Florida Shelf (a non-NOAA asset), and the Mississippi-Atchafalaya area.

***Action 7.1.3***: Explore options to add a monitoring site in the SE region within the estuarine environment near to Grays Reef to establish a nearshore-offshore contrasting monitoring site.

***Action 7.1.4:*** Establish OA and water quality monitoring stations at inlets and near commercially and recreationally important estuaries (e.g., oyster bed leases, public clam beds, shellfish hatcheries) to monitor coastal acidification and eutrophication co-stressors in areas where fresh water systems are highly impacted by human activities and strongly influence coastal oceans.

### *Research Objective 7.2: Improve the characterization of the Open Ocean*

Currently, open ocean monitoring is limited to the OA synoptic cruises that take place once every four years. Exploring autonomous technologies may provide a platform to vastly increase open ocean observing in the deep and shelf waters. Better understanding of the open ocean within the region can also contribute to the understanding of coastal acidification processes, as coastal acidification can be studied by considering a conservative mixing line with a two end-member system of open-ocean and freshwater inputs.

***Action 7.2.1:*** Evaluate capabilities of autonomous sensor(s) for surface to deep water observing (3000 m) and observing in the vicinity of cold-water coral communities.

***Action 7.2.2:*** Establish plan to deploy BGC-Argo floats in the GoM region, following the rationale in *Chapter 2: Open Ocean Region* (*Objective 2.3*). Leverage GOMECC and other cruises to perform *in-situ* calibrations and improve quality control procedures for the data, while greatly increasing data availability for the open ocean end-member in the GoM.

### *Research Objective 7.3: 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.

***Action 7.3.1:*** Leverage existing cruises (e.g., Southeast Area Monitoring and Assessment Program, ecosystem monitoring and restoration, oceanographic) to increase sample collection between synoptic surveys, particularly in wintertime when observations have historically been particularly limited.

***Action 7.3.2:*** Evaluate methods to measure how upwelling of deep GoM waters onto the shelf affect OA in shelf ecosystems that are also affected by riverine acidification impacts.

***Action 7.3.3:*** Expand the number of observations by increasing frequency of synoptic cruises to sample during other seasons (initially winter) to improve intra-annual sampling and add subsurface sensors to existing buoys, moorings, and autonomous platforms.

### *Research Objective 7.4: 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. Models also provide critical information that can be translated and used to inform decisions and management practices. Continued development and use of existing regional models and the creation of new models that enhance geographic coverage within the region are needed.

***Action 7.4.1:*** Develop, apply, and improve existing models and validate models with direct observations to assess and improve model skill to best project OA within the region.

***Action 7.4.2:*** Incorporate OA and associated biogeochemistry into ecosystem models to help predict OA impacts on valuable components of the marine ecosystem.

***Action 7.4.3:*** Increase utilization of satellite data, tools, and products in support of status estimates and now-casts.

***Action 7.4.4:*** Coordinate research with university researchers to build consensus regarding regional OA projections.

## *Biological Sensitivity*

Studies of OA impacts on organisms in the region, with the exception of some coral reef systems in the Florida Keys and Flower Garden NMS (Chapter 8), have been sparse. Changes in chemical factors directly impact the physiology of filter feeders, benthic foragers and fish (e.g., oysters, blue crab or menhaden) and also alter food web structure and the quality and quantity of food for many of the intermediate consumers and commercially important species (Hansen et al., 2019; Caron & Hutchins, 2012). Initial characterizations of food web structure - from phyto- to zooplankton - were performed during the 2017 and 2018 synoptic OA GOMECC-3 and ECOA-2 cruises across the GoM and Southeast Atlantic region. GOMECC-3 also included targeted sampling for pteropods and larval ichthyoplankton, along with rate measurements of carbon flow from primary producers to crustacean prey. Incorporation of rate-based measurements, specifically, allow for more investigation of the role of these biological communities and food webs as sinks of or links to carbon cycling in the region (Sherr & Sherr, 2002; Steinberg & Landry, 2017). Altogether, this information provides insights into how food webs and carbon transfer are altered in regions affected by eutrophication-driven acidification and hypoxia. Maps of ichthyoplankton distribution are reflective of spawning regions for fish, and can be used for studying effects of OA on marine fish populations such as stock displacement to avoid acidified waters. These data build directly on programs such as Southeast Area Monitoring and Assessment Program (SEAMAP) and would provide more power to efforts to depict changes in species ranges and patterns of distribution during the larval life stages and beyond.

Given the lack of a systematic study of OA impacts on plankton and commercially important species in this region, impacts of OA on fisheries and aquaculture industries in the region are also poorly understood. With high saturation state variability predicted for subtropical regions relative to higher latitudes, understanding the impacts of saturation state on such species will be critically important for the region. High levels of OA variability could lead to greater impacts on organisms that have a smaller tolerance to OA. Identifying such highly OA-sensitive indicator species could actually be beneficial to tracking small and/or early shifts in the marine carbonate system. The Southeast Fisheries Science Center (SEFSC) has conducted a climate vulnerability assessment for marine fishery species in the GoM and initiated one in the SE (Lovett et al., 2016), which can guide the proposed *in-situ* observing activities (*Research Objective 7.3*) and indicator species research (*Research Objective 7.6*) proposed for the region.

Oil drilling, dredging and restoration efforts both in the GoM and SE region can interact with OA and potentially have compounding impacts on organisms and ecosystems. While funding is available for research on OA, oil spills, or hypoxia, there are no coordinated calls to promote and encourage interdisciplinary research. HAB events also pose a recurring problem in the GoM and Southeast region. Florida and other Gulf Coast states experience fish kills and neurotoxic shellfish poisoning from *Karenia brevis* and other HAB species (Weisberg et al., 2019). Harmful cyanobacteria and their toxins (primarily microcystin) have also been detected in low salinity estuaries in Louisiana and Florida (Bargu et al., 2011; Riekenberg et al., 2015) and shown to accumulate in commercially-important consumer species (i.e., blue crab) that are also impacted by OA (Garcia et al., 2010). The economic impact of HABs resulting in public health issues, commercial fishery closures, and recreational tourism reduction has been reported as upwards of ~$50 million/year (Anderson et al., 2000). Laboratory studies of *Karenia brevis*, the major HAB species in the Gulf of Mexico, in connection with OA have shown conflicting results, with some concluding that at higher $p\mathrm{CO}_2$ concentrations *K. brevis* growth rates are significantly increased, although toxin production itself appeared to not be linked (Errera et al., 2014), while others did not observe a significant response in growth, or cellular composition of carbon and nitrogen (Bercel & Kranz, 2019). Although ongoing efforts to study the relationship between OA and HAB occurrence are taking place in other regions, no similar effort is currently taking place in the GoM.

Small boat operations as part of the Gulf of Mexico Ecosystems and Carbon Cruise aboard the NOAA ship Ronald H. Brown. Credit Marisa Gedney/NOAA

### Research Objective 7.5: Increase understanding of the impacts of OA on ecosystem productivity and food webs

Because plankton communities are the base of marine food webs, shift in response to OA impact energy flow and ecosystem function (Roman et al., 2012). As the quantity and quality of plankton prey are altered, managed and commercially important species are affected.

***Action 7.5.1:*** Characterize plankton communities (from phytoplankton to larval fish) along spatial gradients of eutrophication-driven acidification and hypoxia through regular sampling on GOMECC, ECOA, and other cruises to allow for attribution to OA and/or eutrophication stressors versus seasonal or other episodic drivers (e.g., tropical storms, flood, drought).

***Action 7.5.2:*** Quantify changes in carbon flow to higher trophic levels (e.g., crustaceans and fish) via modeling studies and shipboard observations during GOMECC and ECOA cruises. Conduct shipboard experiments to determine biological community composition during antecedent conditions (not just conditions at the time of sampling) and to understand how rates (e.g., primary productivity, zooplankton grazing) change in response to OA, eutrophication, HABs, and hypoxia, which are critical to parameterize ecosystem models.

***Action 7.5.3:*** Synthesize existing information from previous cruises and ongoing research and monitoring in the region. Coordinate collection of biological data (e.g., plankton tows, 'omics-approaches and rate measurements) for future GOMECC, ECOA, and other cruises. Identify regions where shifts in carbon chemistry are associated with changes in plankton community structure and function.

### Research Objective 7.6: 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 to investigate ecosystem impacts that may result from food web changes.

***Action 7.6.1:*** Incorporate plankton and neuston net tows, and 'omics sampling as part of the standard suite of parameters included in GOMECC/ECOA cruises.

***Action 7.6.2:*** Incorporate carbon chemistry sampling as part of the standard suite of parameters included in already ongoing SEFSC ecosystem monitoring efforts such as SEAMAP cruises and add DIC/TA/pH water sampling to the suite of samples already being collected.

***Action 7.6.3:*** Conduct laboratory studies to examine OA impacts in combination with other co-stressors, such as temperature and nutrients, on potential indicator species identified via field observations.

### Research Objective 7.7: 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.

***Action 7.7.1:*** Target species of interest to conduct experimental studies to establish responses to OA and inform species vulnerability assessments.

***Action 7.7.2:*** Develop assessments using a multi-stressor framework to include combinations of effects such as eutrophication, river runoff, hypoxia, or increased HABs.

***Action 7.7.3:*** Incorporate these results into ecosystem models models to drive hypotheses about how changes in indicators species and plankton dynamics will affect commercial and recreational fishery species.

***Action 7.7.4:*** Build monitoring capacity for regionally significant HAB species to be measured during synoptic OA cruises and implement OA sampling in other opportunistic or ongoing cruises organized in relation to HABs already occurring along the Florida coast.

***Action 7.7.5:*** Support isolation and cultivation-based laboratory experimentation of local HAB species to examine species-specific and community responses to carbonate chemistry conditions.

***Action 7.7.6:*** Quantify socioeconomic impacts from predicted changes in HABs and their toxicity due to OA.

## Human dimensions

While there are several studies that deal with socioeconomic impacts as a result of acidification in coral reef regions, there are currently no non-coral studies in the GoM and the Southeast region that quantify potential socioeconomic impacts from OA on fisheries of interest in the region. Ekstrom et al. (2015) identified the coastal communities of TX, LA, MS and Northern FL as being highly socially vulnerable to OA impacts, despite a lower marine ecosystem exposure than other U.S. coastal regions. However, no specific socioeconomic studies have been released yet. Local communities in the SE such as those of Gullah/Geechee descent consume marine species vulnerable to OA (e.g., oysters, blue crab) for sustenance and as part of cultural traditions. This type of activity could be included as part of the evaluation and research of socioeconomic impacts as an opportunity to build relationships and partnerships with vulnerable communities. Stakeholder engagement efforts should be cognizant that the region experiences threats from multiple drivers, some of which have a more direct impact than OA. Therefore efforts to engage stakeholders and identify needs should take a multi-stressor approach. By improving the understanding of stakeholder needs strategic investments can be made in capacity building and targeted research that is responsive to the needs within the region.

A commercial shrimp fishing vessel off of the U.S. southeast coast. Credit: NOAA

### *Research Objective 7.8: 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.

***Action 7.8.1:*** Evaluate the socioeconomic impacts from from key species being impacted by OA either directly or in through food web interactions (*Research Objective 7.7*).

***Action 7.8.2:*** Conduct socioeconomic research to quantify the impacts of OA for specific fisheries, including direct (fishermen/aquaculture) and indirect (related service industries) impacts.

***Action 7.8.3:*** Based on outcomes from above, involve local stakeholders and raise awareness about OA to increase community resilience and proactively develop OA mitigation plans for affected ecosystems, industries, and economies.

# References

*[INTRO] = Introduction;*

*[NAT] = National Ocean & Great Lakes;*

*[OO] = Open Ocean Region;*

*[AK] = Alaska Region;*

*[ARC] = Arctic Region;*

*[WC] = West Coast Region;*

*[PAC] = U.S. Pacific Islands Region;*

*[SAG] = Southeast Atlantic & Gulf of Mexico Region;*

*[FLC] = Florida Keys and Caribbean Region;*

*[MAB] = Mid-Atlantic Bight Region;*

*[NE] = New England Region;*

*[GL] = Great Lakes Region*

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