MONITORING OCEAN BIOLOGY AND NATURAL RESOURCES AUTONOMOUSLY AND EFFICIENTLY USING UNDERWATER GLIDERS

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The University of South Florida (USF) College of Marine Science operates a fleet of six Teledyne Webb Research Slocum gliders as cost-effective research platforms for sampling the water column. Underwater gliders are autonomous robots that traverse the water to collect a suite of physical (e.g., temperature and salinity) and chemical (e.g., nutrients and dissolved oxygen) data to better understand the environment of coastal and open oceans. Over the past decade, the USF glider group has added sensors to obtain biological data (e.g., fluorometers, acoustic telemetry receivers, echosounders, and passive acoustic monitors) to help survey and monitor marine organisms. The data collected on these glider missions has been used in the forecasting of red tide blooms, detection of tagged aquatic animals, collection of biomass data, and recording of fish and marine mammal sounds in the Gulf of Mexico (GoM) and the Atlantic Ocean. Here we describe how our glider fleet has obtained critical biological data and is continuously evolving to better assist in addressing ecosystem-level challenges associated with global environmental changes.

Most of the USF glider missions in the GoM are cross-shelf deployments that sample the water column to directly measure or derive salinity, temperature, density, oxygen, chlorophyll-*a*, and colored dissolved organic matter (CDOM; Figure 1). Each of these parameters has been used to monitor water column variables to assist in forecasting blooms of the toxic alga *Karenia brevis*, also known

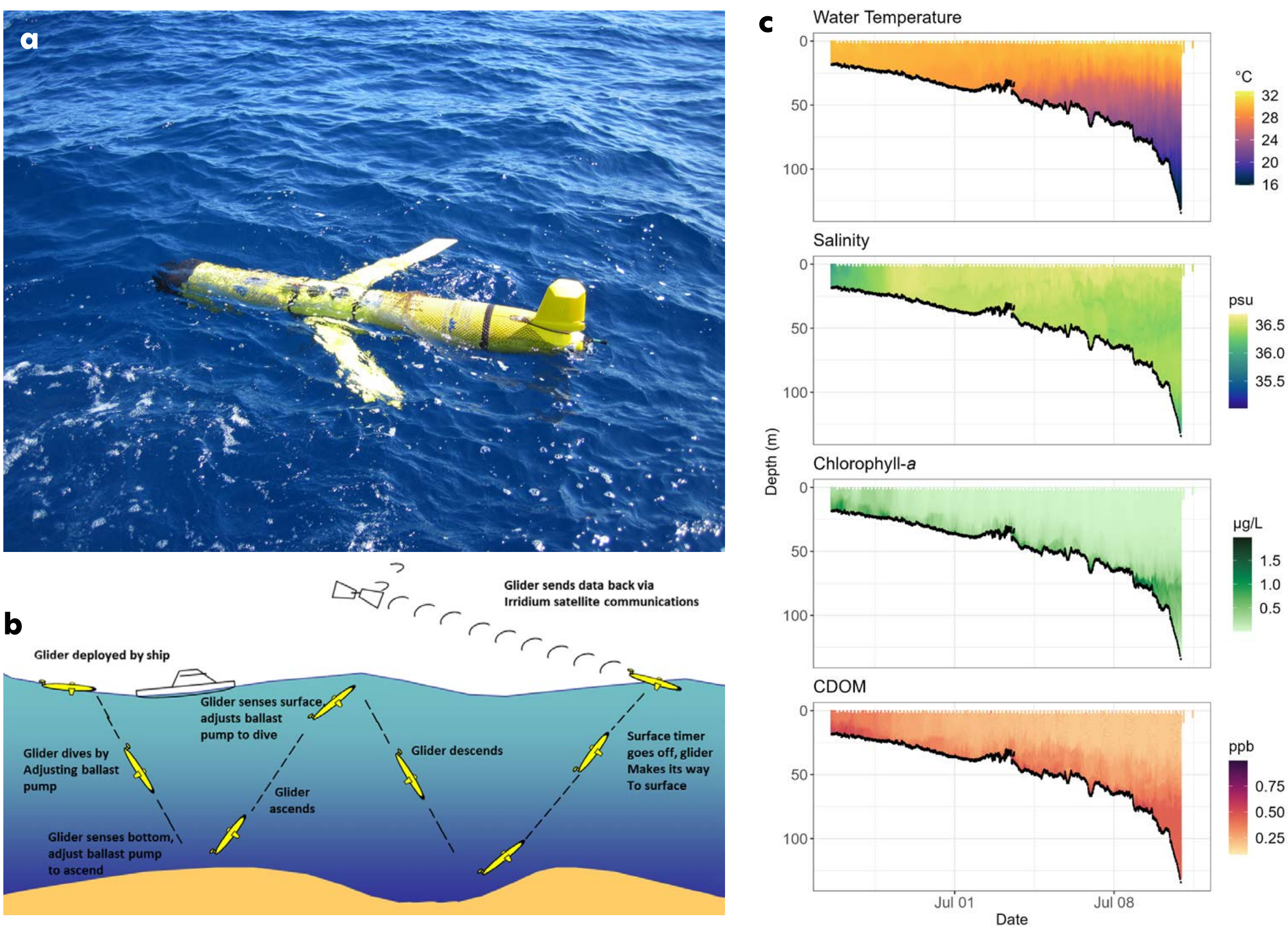


FIGURE 1. Gliders (a) are autonomous tools that (b) systematically profile the ocean water column while collecting (c) important data such as temperature, salinity, chlorophyll-*a*, and colored dissolved organic matter (CDOM).

as red tide. Our group collaborates with the Florida Fish and Wildlife Conservation Commission (FWC) harmful algal bloom monitoring and research program as part of the College of Marine Science's Center for Red Tide Tracking and Forecasting to acquire continuous water column observations in support of modeling and nutrient analyses. Water property glider observations, such as those listed above, confirm water column dynamics predicted by eastern GoM models. For example, a 2018 across-shelf transect identified upwelling circulation favorable for transporting deep-water nutrients that likely contributed to the intensity and location of a red tide outbreak on the west Florida shelf (Weisberg et al., 2019). Since 2018, USF gliders have totaled over 1,500 glider days, contributing to tracking red tide blooms and their effects.

Acoustic telemetry receivers have become a regular part of USF glider fleet deployments, with loaned or donated receivers detecting marine organisms that are implanted with acoustic transmitting tags. Since 2014, detected tag identification numbers and associated data have been submitted to the Ocean Tracking Network (OTN) and Integrated Tracking of Aquatic Animals in the Gulf of Mexico (iTAG) groups for research, monitoring, and management. By working directly with the FWC Fish and Wildlife Research Institute, we have successfully detected 231 red snappers tagged and released in the GoM by the Movement Ecology and Reproductive Resilience Lab, providing key contextual environmental data for these fish detections, including location, depth, and water temperature. In addition, these glider-based receivers have detected another 211 unknown tags owned by other members of the network, such as academic, state, and federal institutions. By working with OTN and iTAG, 56 of these detections have been identified and the managing researchers notified of the detection location, time, and corresponding water column environmental data collected. These data are critical to understanding the tagged animal's migration and residency activity needed to improve and reach management targets (Figure 2).

Passive acoustic monitoring (PAM) devices on gliders that record ambient ocean sounds, including fish and

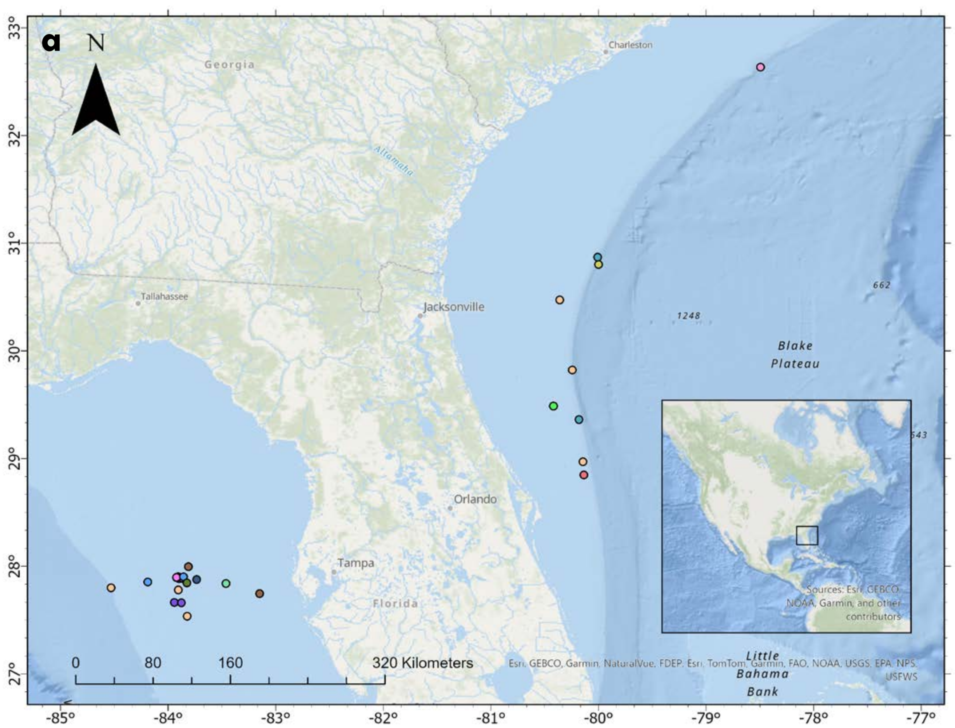
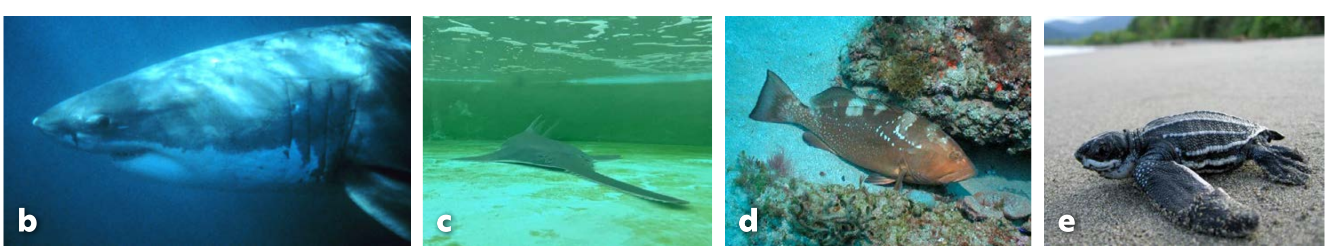


FIGURE 2. (a) A map of the Ocean Tracking Network (OTN) and Integrated Tracking of Aquatic Animals in the Gulf of Mexico (iTAG) species detected by University of South Florida gliders. The legend includes common names and the numbers detected. Examples include (b)white sharks, (c) smalltooth sawfish, (d) red grouper, and (e) a leatherback turtle. *(b,d,e) courtesy of NOAA Fisheries; (c) courtesy of Mote Marine Laboratory*



marine mammals, have been used extensively. Since 2009, USF recordings have detected red grouper, toadfish, marine mammals, and anthropogenic sounds (Wall et al., 2017). During a 2023 GoM glider mission, a PAM device detected the endangered Rice's whale, whose numbers are likely fewer than 100 individuals throughout the GoM (Soldevilla et al., 2024). Collaborating with the NOAA Southeast Fisheries Marine Mammal and Turtle Division, we detected hundreds of calls from these protected whales over a two-month glider deployment. These critically important data help management organizations to better understand Rice's whale distribution and to plan for a recovery of their population.

More recently, we have worked with acoustic manufacturers and NOAA's National Center for Coastal Ocean Science researchers to equip gliders with compact fisheries echosounders that have the potential to provide information about fish and zooplankton biomass within their field of view. These glider-based echosounders are being evaluated as a cost-effective method for surveying broad spatiotemporal ranges to augment the work of traditional acoustic methods on oceanographic research vessels. Initial observations have demonstrated that these combined oceanographic tools can detect plankton and fish biomass in the pelagic and near-benthic environments, thus expanding fishery ecosystem assessment and management to remote places (Taylor and Lembke, 2017). Adapting sensors to new platforms typically results in benefits and compromises, in this case using a mobile platform makes analysis more challenging, but glider mission endurance and the ability to concurrently sample the entire water column with a suite of sensors provide unique capabilities. For example, the ability to energize the echosounder below a thermocline allows the glider to potentially achieve higher echo detection quality than if the echosounder were energized from the ocean surface aboard a ship. Moreover, a glider is always equipped with physical sensors that enable calculation of critical sound speed information for precise correction and enhancement of the echosounder's biomass detections.

While originally developed as physical oceanographic tools for monitoring the water column to validate and improve circulation models, diverse payload-capable gliders collect a suite of measurements on oceanographic properties, providing a wealth of data analysis opportunities. The examples highlighted above allow a glimpse at the potential for sustained monitoring or for sentinel exploration to add insight into biological processes. The ability to concurrently collect biological, physical, and chemical data on a single, high-endurance, cost-effective platform is invaluable to fisheries and other natural resource monitoring programs.

USF's growing fleet of underwater gliders is made possible through support and collaboration of federal and state organizations as well as regional ocean observing networks like the Southeast Coastal Ocean Observing Regional Association and the Gulf Coast Ocean Observing System. While scientists who go to sea are the foundation of oceanographic research, autonomous robots, such as gliders, are cost-effective, risk-reducing tools capable of sampling in all seasons and in all weather types and from the surface to near the seafloor, while traversing large distances over periods of weeks to months. This unique format has firmly established the critical role of gliders as ocean observing tools and demonstrated their diverse applicability in monitoring marine organisms.

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