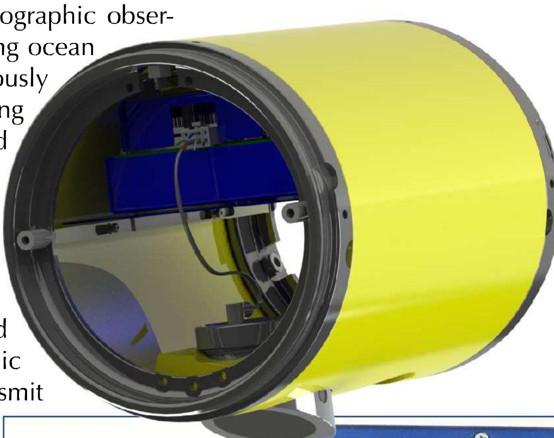
Echosounder for Biological Surveys Using Ocean Gliders

Extending Fishery Ecosystem Assessments to Remote Places

By J. Christopher Taylor • Chad Lembke

AUVs are part of a rapidly growing fleet of platforms to extend, complement and guide oceanographic observations and ecosystem assessments. Profiling ocean gliders are capable of sampling continuously through the ocean's water column by gliding on wings and adjusting their buoyancy and attitude.



ASL AZFP echosounder and custom transducer installed in Slocum glider hull section.

Slocum electric ocean gliders by Teledyne Webb Research (TWR) are specifically configured to operate in shallow continental shelf environments (less than 200 m). Deployments can last over a month and transit hundreds of kilometers with periodic surfacing to obtain location by GPS, transmit near-real-time oceanographic data, and allow mission adjustments through the Iridium satellite communications system. To record oceanographic physical and chemical parameters for assimilative ocean circulation models, other technologies include optical sensors to measure radiance and irradiance, dissolved matter backscatter and chlorophyll, as well as passive acoustic recorders for animal vocalizations and anthropogenic ocean noise.

Government agencies have used ship-based echosounders to assess fish populations and map fish and plankton biomass in the water column over large spatial scales to address ecosystem and fishery management goals. Costs, sea conditions and safety can limit the use of research vessels for fishery assessments, making the development and application of fishery echosounders in autonomous platforms an area of targeted research.

Recent development of small form factor echosounders may provide additional means to collect active acoustic (e.g., fishery sonar) data using ocean gliders to detect biomass of marine organisms in the water column in remote locations where limited resources prohibit use of large research vessels, or as part of a growing sustained ocean observations network. The glider system can also function in weather and sea conditions that are suboptimal for research vessels.

Researchers at NOAA's National Ocean Service, National Marine Fisheries Service and University of South Florida collaborated with TWR and ASL Environmental Sciences (ASL) to integrate a low-power echosounder into a Slocum electric glider. The goal was to evaluate the functionality of a glider-based simultaneous survey of oceanographic water column variables and continental shelf benthic and pelagic plankton and fish biomass.

From Moorings to Moving Platforms

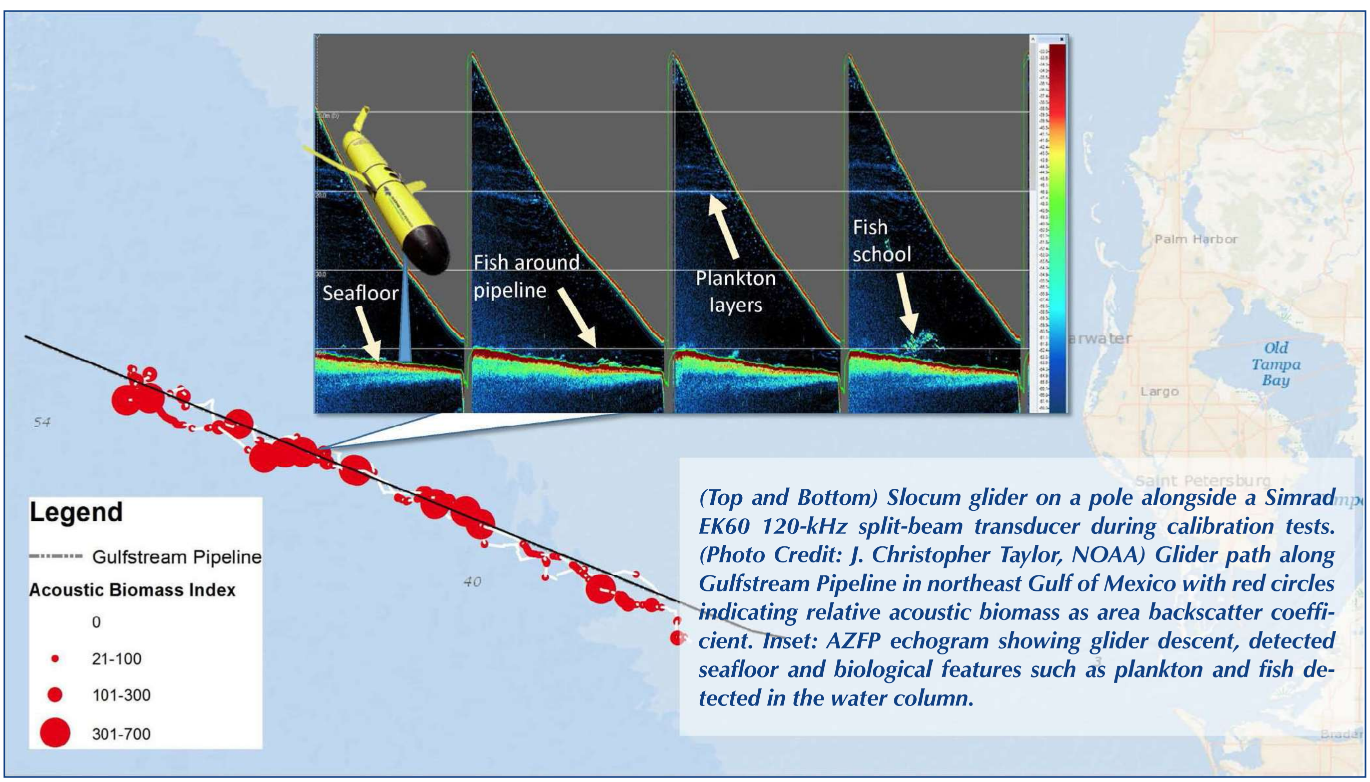
ASL has spent more than 20 years developing its multi-frequency Acoustic Zooplankton Fish Profiler (AZFP) in remote and autonomous mooring deployments. The resulting low-power and small form factor echosounder allows for extended operations at acoustic frequencies of 38 kHz to 2 MHz. The AZFP is equipped with onboard data storage and software (AZFPLink) that allows for flexible mission control, including pulse length, pulse transmission rate, data-logging range, duty cycle and mission duration limited only by power supply.

An AZFP transceiver and control module was adapted for installation in a science bay of a Slocum electric glider manufactured by TWR. The module can handle up to four frequency channels, though for this initial evaluation a single channel operating at 200 kHz was selected. A custom-built 7°-beam-width transducer was constructed to use an existing downward “ECO Puck” port commonly available in Slocum gliders. The single-beam transducer was pitched 22.5° forward to account for angle of attack by the glider during descents through the water column, resulting in downward vertical transducer beam orientation during glider descent.

The glider power management system supplies 12 VDC power to the AZFP. The glider science computer uses a signal trigger to initiate the echosounder transmission and logging during descents and suspends operations on glider ascent. Acquisition parameters for the AZFP were set prior to the glider mission, but could be changed during the mission by conveying a parameter set as a text file via satellite communication to the AZFP by serial connection. This allows for periodic parameter changes such as pulse length, transmission rate and logging range when operational or environmental conditions dictate a need to optimize echosounder functionality. During normal glider surfacings, in addition to glider performance, CTD and optical sensor data, the status and pulse transmission counts of the AZFP are conveyed to provide feedback to the user on AZFP functionality. Due to Iridium satellite bandwidth limitations, raw echosounder data currently must be downloaded from the glider afterward.

Calibration, System Performance

To ensure consistent measures of the magnitude of backscatter that are comparable across other fishery acoustic systems, the glider AZFP was calibrated using a 38.1-mm-diameter tungsten carbide sphere as a standard acoustic target. During a short mission in December 2016, the glider was



(Top and Bottom) Slocum glider on a pole alongside a Simrad EK60 120-kHz split-beam transducer during calibration tests. (Photo Credit: J. Christopher Taylor, NOAA) Glider path along Gulfstream Pipeline in northeast Gulf of Mexico with red circles indicating relative acoustic biomass as area backscatter coefficient. Inset: AZFP echogram showing glider descent, detected seafloor and biological features such as plankton and fish detected in the water column.

Slocum glider deployed for pilot mission in the eastern Gulf of Mexico.

attached to an overboard pole and deployed from an anchored research vessel. The standard target was suspended under the AZFP transducer. For comparison, a Simrad EK-60 split-beam echosounder operating at 120 kHz was mounted to the same pole and used to confirm target strengths for the sphere, while also providing positioning information of the target relative to the single-beam AZFP transducer. The calibration was repeated at several transmission pulse lengths that may be used during missions of various water depth ranges. AZFP signal gain offsets were adjusted so that the observed target strength matched theoretical target strength at 200 kHz, nominally -38.9 dB.

Noise profiles under normal glider operations revealed +6 dB signal over background noise at ranges comparable to other 200-kHz echosounders. Backscatter and target strengths expected from zooplankton and other low-energy scatterers (-90 dB) would be detected to a range of 70 m. Fish and other higher energy scatterers (more than -60 dB) would be detected at ranges greater than 100 m from the glider.

Pilot Glider Mission

A 14-day pilot mission was conducted along a pipeline in the northeast Gulf of Mexico on the West Florida Shelf from July 29 to August 12, 2016. The mission transited the Gulfstream Pipeline in 27 to 65 m of water. The glider path zigzagged over the pipeline and surrounding rocky rubble that attracts reef-associated sponges and soft corals, as well as fishery species like snappers and groupers. The AZFP was set to transmit pulses at 1 Hz, or about one transmission per 25-cm linear distance. The 7° transducer beam has a swath of 12 percent or approximately 12 m at 100-m range. If a fish were ensonified, it would have been likely that several sequential transmissions would reflect from the fish and provide multiple measures of backscatter and estimate of target strength. To optimize vertical resolution to detect fish in close proximity to the seafloor, the shortest calibrated pulse length of 150 microseconds was used. Data were logged to a maximum range of 100 m.

Data Analysis, Visualization

AZFP data were read into Echoview acoustic analysis software, which provides a collection of semiautomated image and signal-processing algorithms for single-beam echosounder data. First, glider position, depth and orientation data were read and synchronized to the raw transmission and backscatter data. Because the glider only provides GPS position information on each surfacing in normal configuration (about every 2 to 3 hours), Echoview assumes linear trajectory and constant speed between surfacings and applies interpolated GPS coordinates to each pulse transmission. Glider depth and orientation were recorded at 1 Hz and were paired directly with each pulse transmission and used to correct for range and depth of ensonified seafloor and objects in the water column. Even though the AZFP logs data only on glider descent, there were frequent occasions when the AZFP logged data at the surface prior to engaging the descent. The pitch of the glider was used to filter data, accepting only pulse transmissions when the glider was between 15° and 45° of horizontal (typical glider descent is at 22.5° from horizontal). Maximum backscatter for each pulse was used to mark the range and depth of the seafloor and exclude the seafloor backscatter from measures of backscatter in the water column originating from biological organisms. Other sources of noise and interference were also noted in the echogram, including interference from the glider system and pulse transmissions from the glider's 170-kHz altimeter. These sources of interference were minimal, and background noise removal algorithms in Echoview were used to further clean the data. The final product was an echogram that projects backscatter in the water column from within 1 m of the glider to the seafloor along the entire mission path.

Relative acoustic biomass, measured as area backscatter coefficient corrected for range and beam width, was estimated along the glider path at 50-m intervals and plotted on a nautical chart to show hotspots of biological biomass along the glider path. Acoustic backscatter was processed in two ways. First, low-density backscatter likely from individual fish was analyzed by detecting single targets and estimating their target strength, an acoustic measure generally proportional to fish size. Individual targets were assigned a GPS coordinate and position in the water column and stored in a database. Schools of fish were identified, delineated with a polygon and assigned the centroid as a GPS coordinate. The area in the polygon was integrated for total acoustic backscatter, an indicator of fish density in the school. Lower backscattering layers likely representing plankton were also noted in the echograms. Biological features identified through this analysis were then related to oceanographic features such as water density stratification and peaks in chlorophyll.

Conclusion

The AZFP integrated glider represents a novel ocean ecosystem survey tool available to fisheries research. This project has demonstrated the utility of a low-power, small form echosounder in detecting indicators of biomass for plankton and fishes in the pelagic and near-benthic environments. While it cannot replace the full capabilities of fisheries research vessels, the unmanned system could extend marine ecosystem acoustic surveys beyond the range and endurance of vessels. Ocean gliders are less limited by sea conditions and could extend surveys of fishery resources outside typical survey seasons (e.g., winter in the Atlantic Coast). Indicators or biomass hotspots mapped by the glider AZFP could guide additional sampling by research vessels carrying additional tools, such as nets or video systems to assess species abundance. With additional research in multiple-frequency acoustics for species classification, and evaluating onboard data processing, new biological metrics could be collected on board ocean gliders, allowing for near-real-time simultaneous and synoptic measures of oceanographic features and the biological resources they support.

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