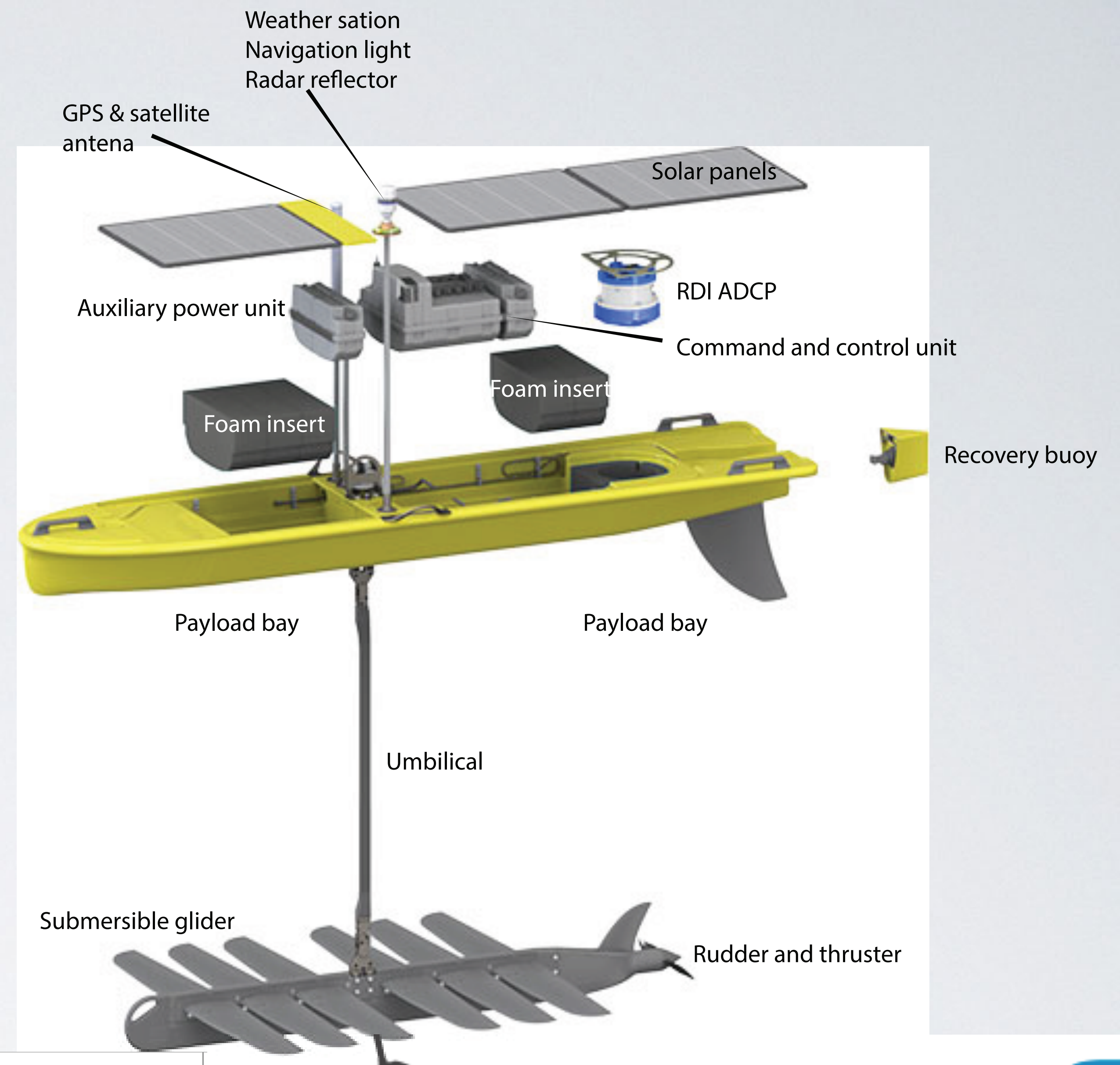
UNDERSTANDING SOUNDSCAPES

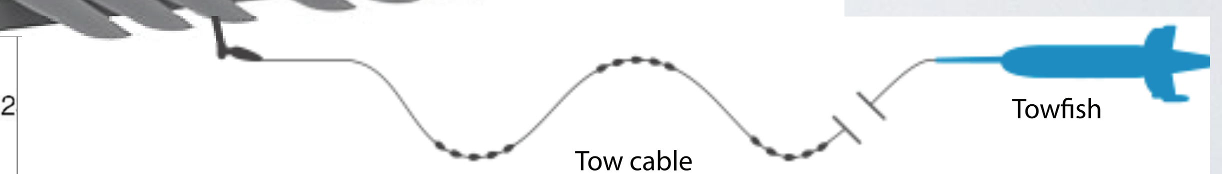
Wave Glider and Acoustic Technology

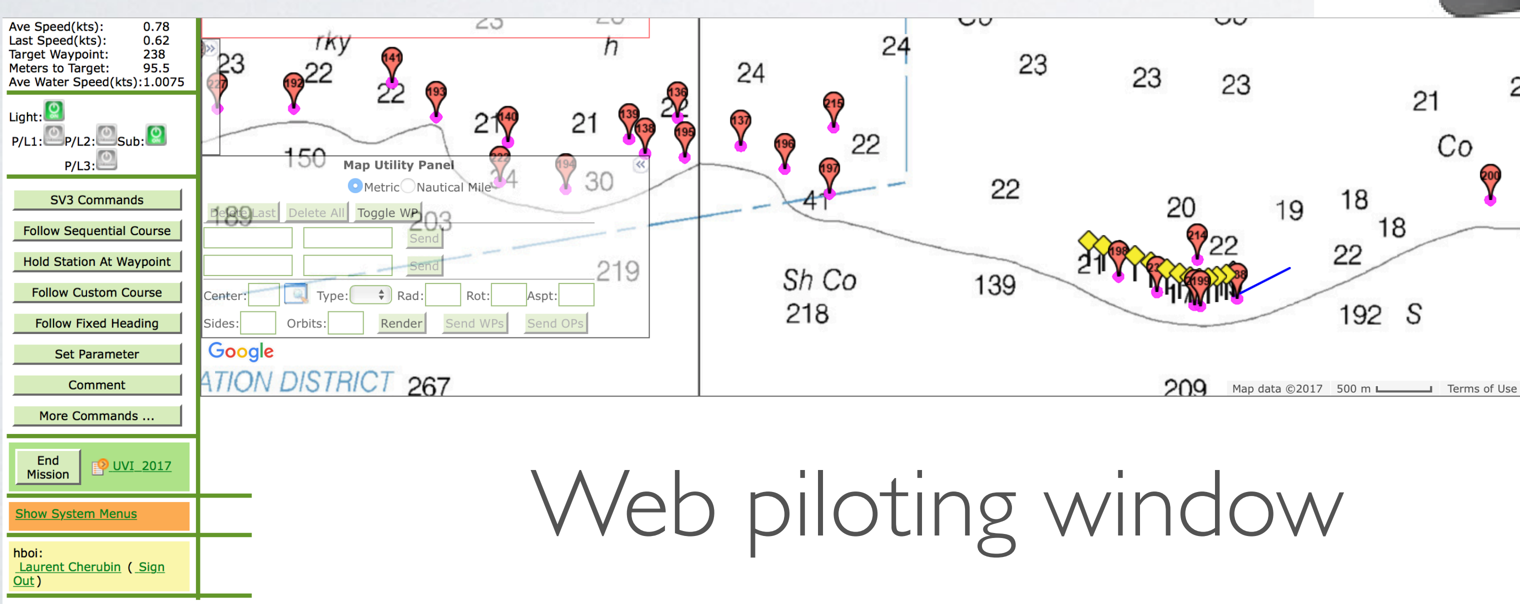
Laurent Chérubin, SAFMC HP, May 22nd, Charleston, SC

AUTONOMOUS SURFACE VEHICLE

Liquid Robotics
SV3 Wave Glider





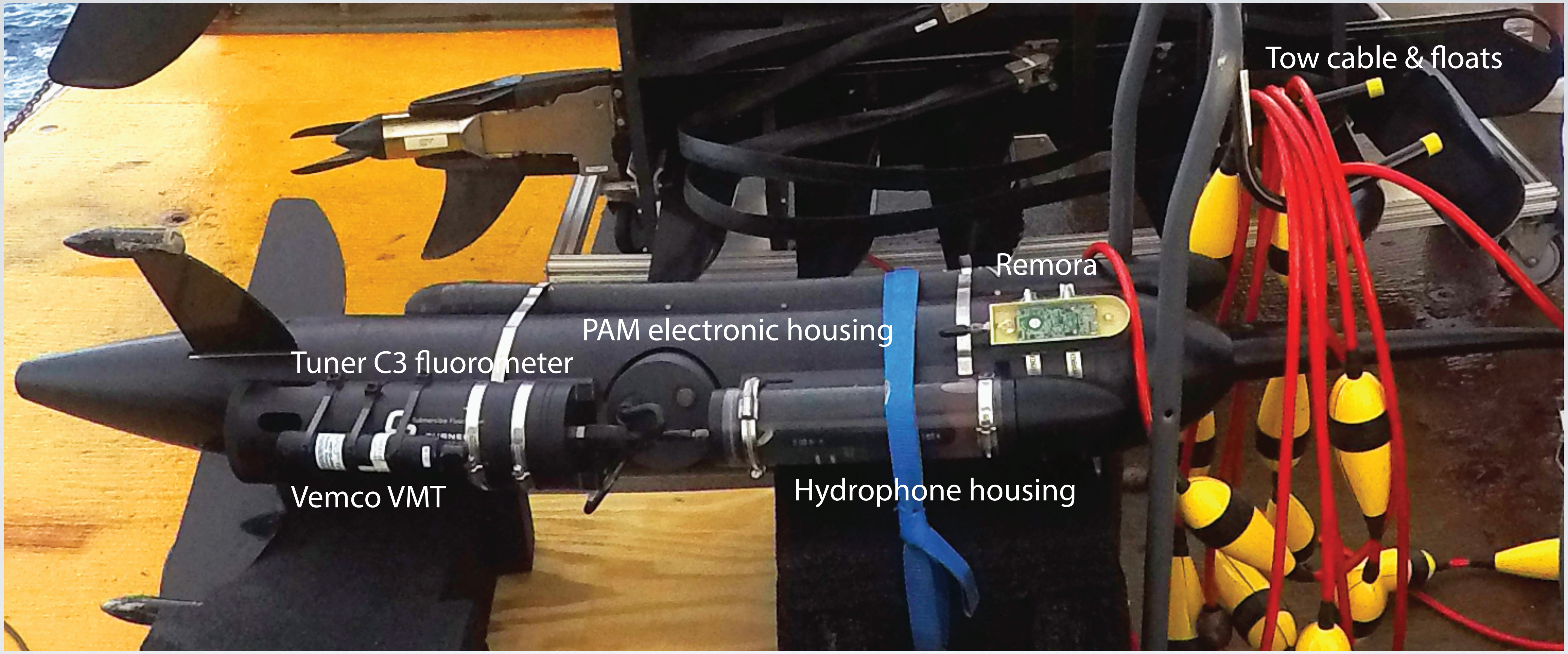


Web piloting window

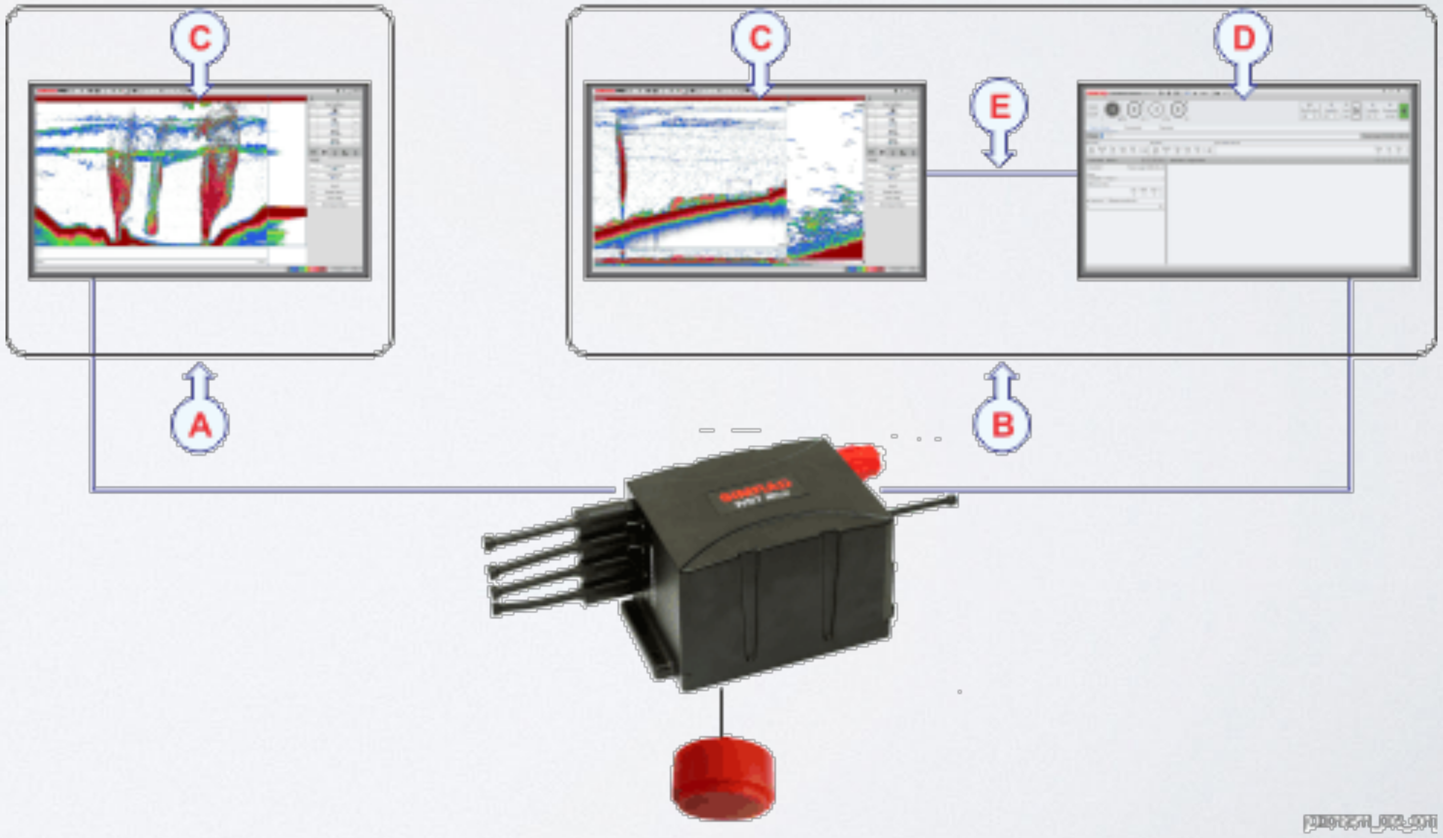
SV3-HB001 Communications

TimeStamp	Structure ID	Target	SOG (kt)	POG (deg)	Desired ...	Sub Hea...	Water Sp...	Current Speed (...	Current Heading...	Lat (deg)	Lon (deg)	Command	Rea
2/15/2017 02:30:54	Telemetry6	238	0.616	80	96	96	0.7960	0.31	305.75	18.18808	-64.95744		
2/15/2017 02:25:54	Telemetry6	238	0.538	77	99	99	0.7540	0.37	306.25	18.18794	-64.95823		
2/15/2017 02:20:54	Telemetry6	238	0.57	87	95	98	0.7800	0.30	298.30	18.18780	-64.95888		
2/15/2017 02:15:54	Telemetry6	238	0.577	99	105	101	0.8390	0.32	284.47	18.18776	-64.95963		
2/15/2017 02:10:54	Telemetry6	236	0.648	109	111	113	0.9260	0.32	299.74	18.18788	-64.96037		
2/15/2017 02:05:54	Telemetry6	236	0.797	111	110	115	0.9810	0.24	306.38	18.18816	-64.96121		
2/15/2017 02:02:17	0	0	0	0						0.00000	0.00000	Write Console ...	%thr
2/15/2017 02:00:54	Telemetry6	236	0.952	113	115	111	1.2970	0.33	285.71	18.18852	-64.96224		

- Propelled by wave action
- Powered by the sun
- Satellite and GSM real-time data transmission


Tow cable & floats
Remora
PAM electronic housing
Tuner C3 fluorometer
Vemco VMT
Hydrophone housing


exo
exo 1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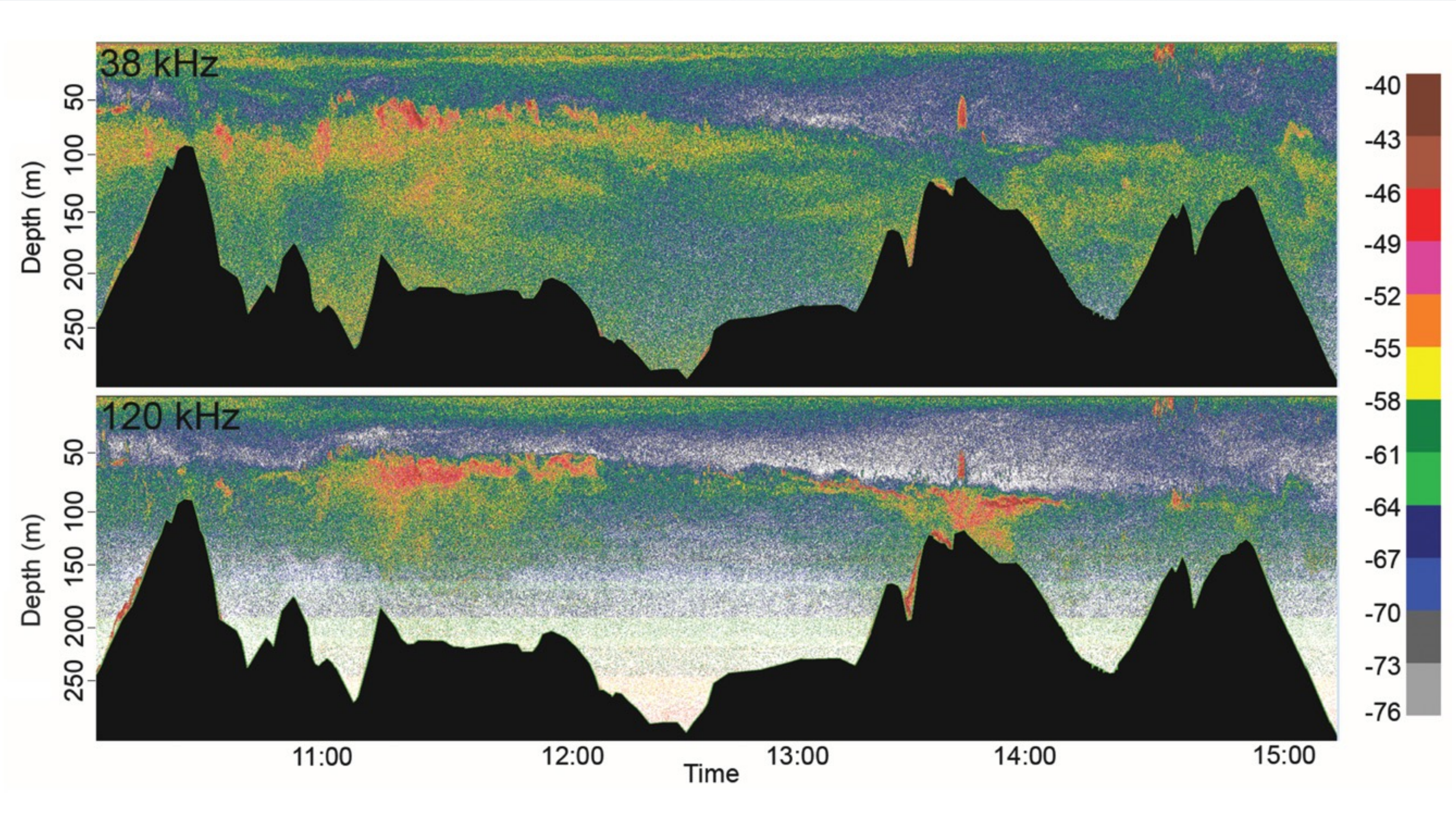


APPLICATION

Fisheries

Green et al., TOS, 2014

A WAVE GLIDER APPROACH TO FISHERIES ACOUSTICS

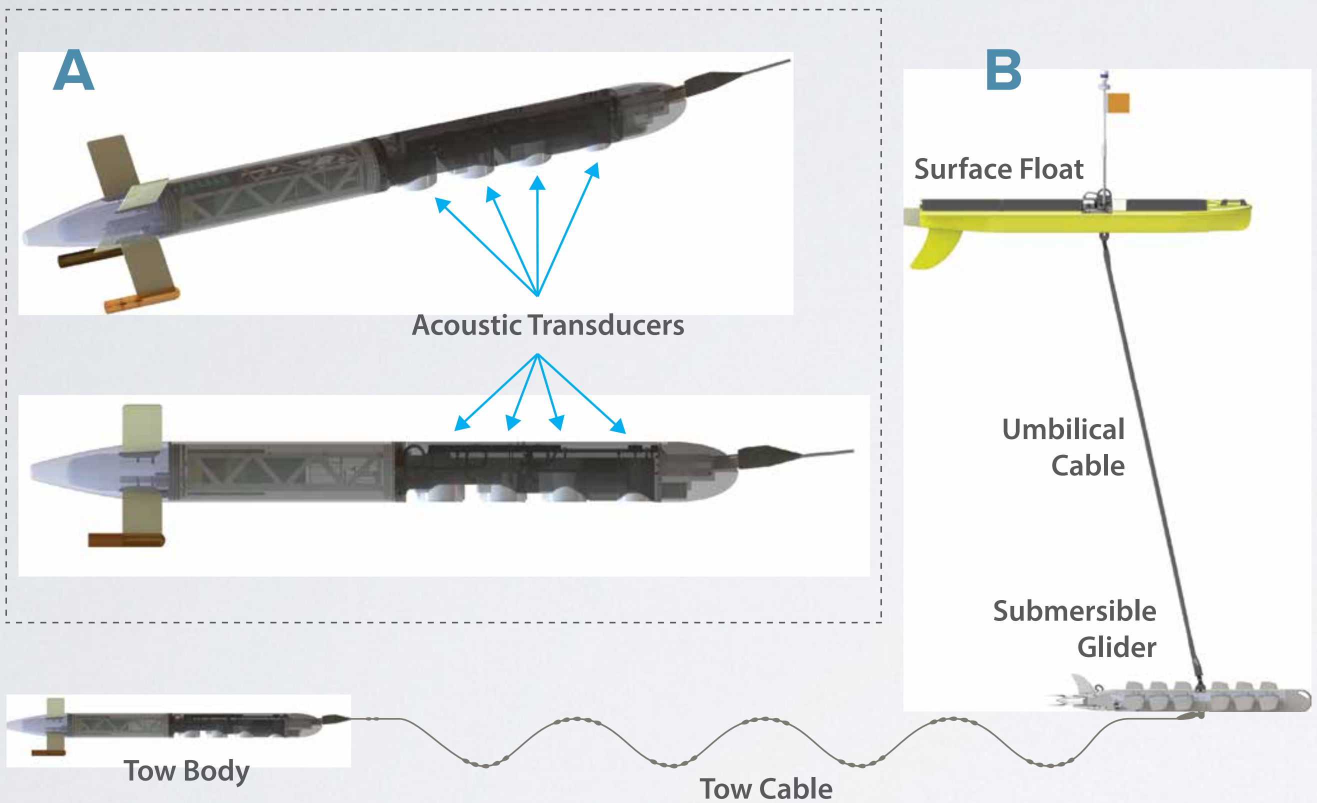
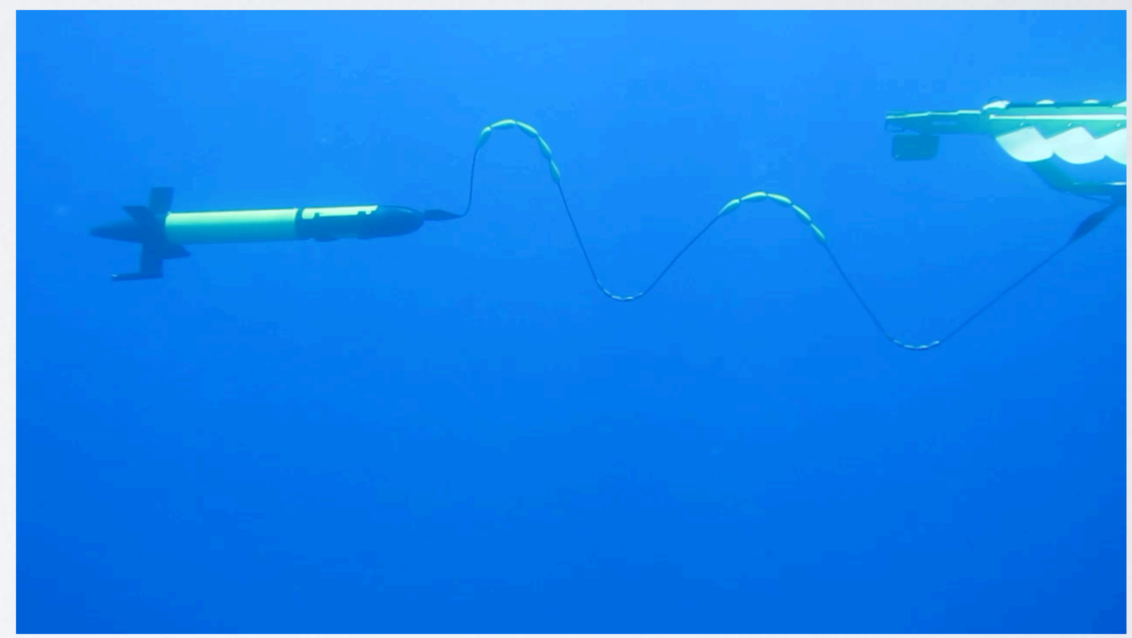


FIGURE 3. (A) Four-frequency version of the BioSonics DT-X SUB echosounder packaged in the pressure case of a custom-built tow body. Isometric and side views of the tow body are shown, with the four transducers of the echosounder labeled. (B) Side view of the tow body deployed from the Wave Glider's submersible glider with a sinusoidal-shaped tow cable.



Green et al., TOS, 2014

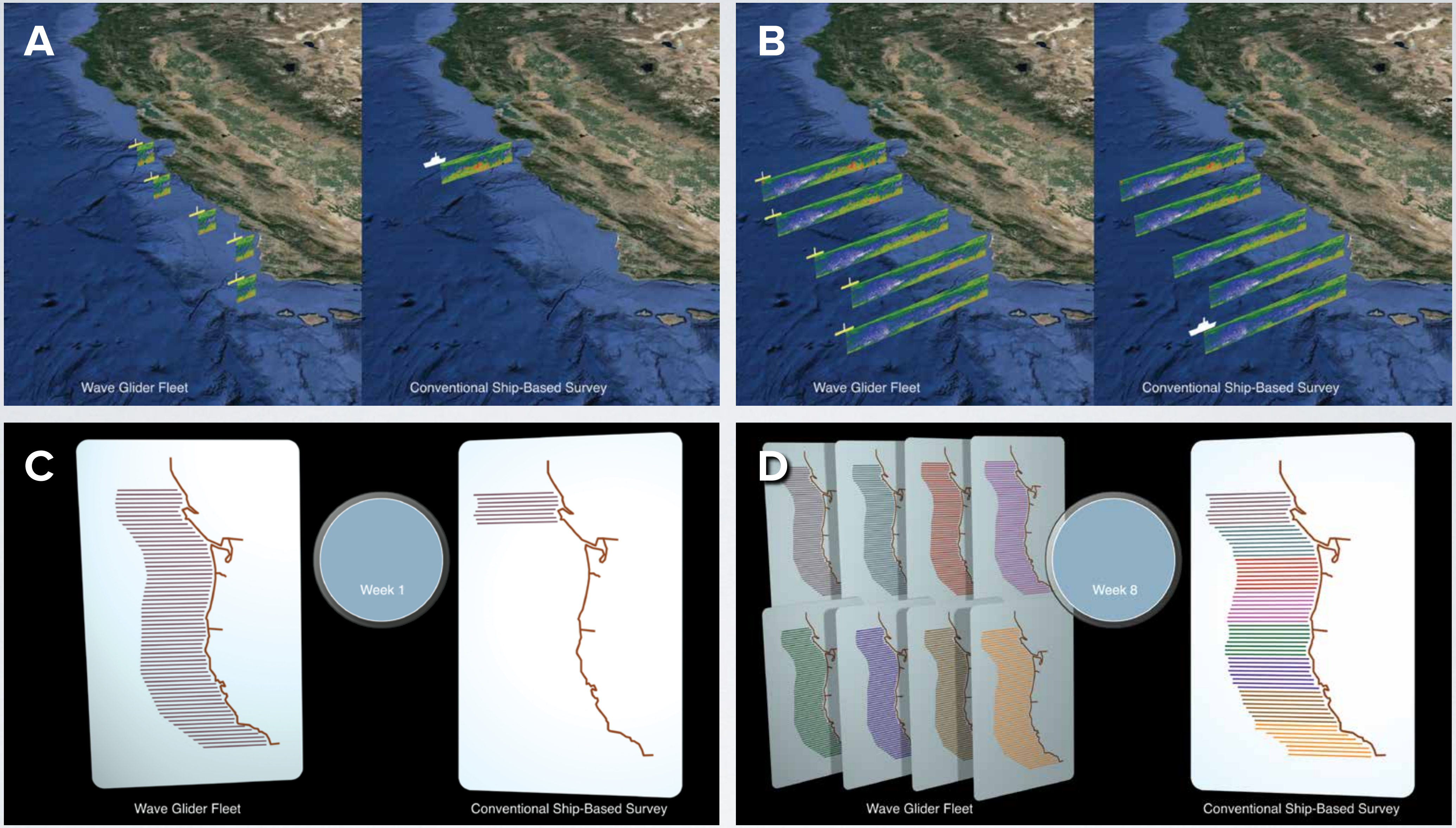
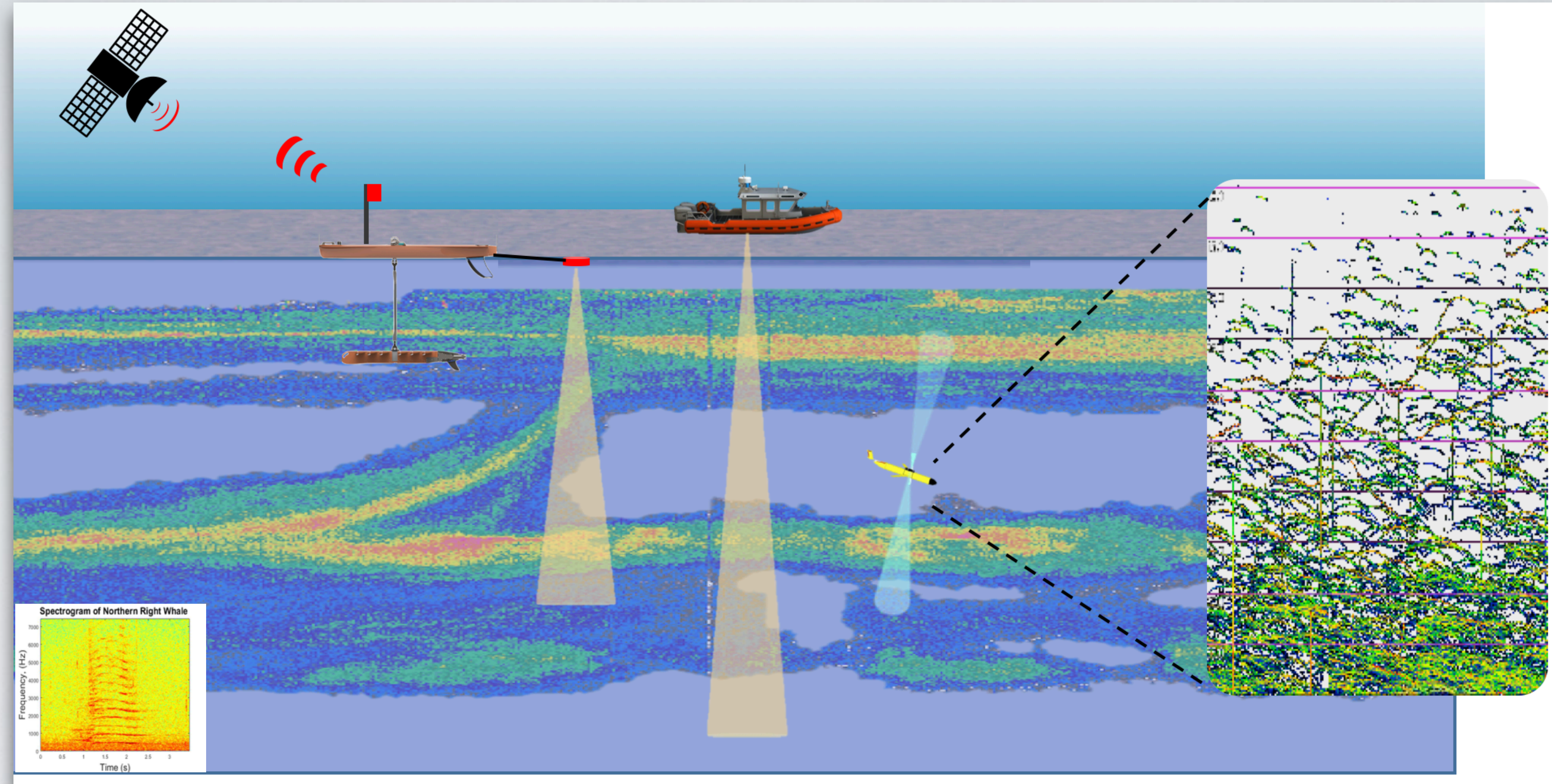


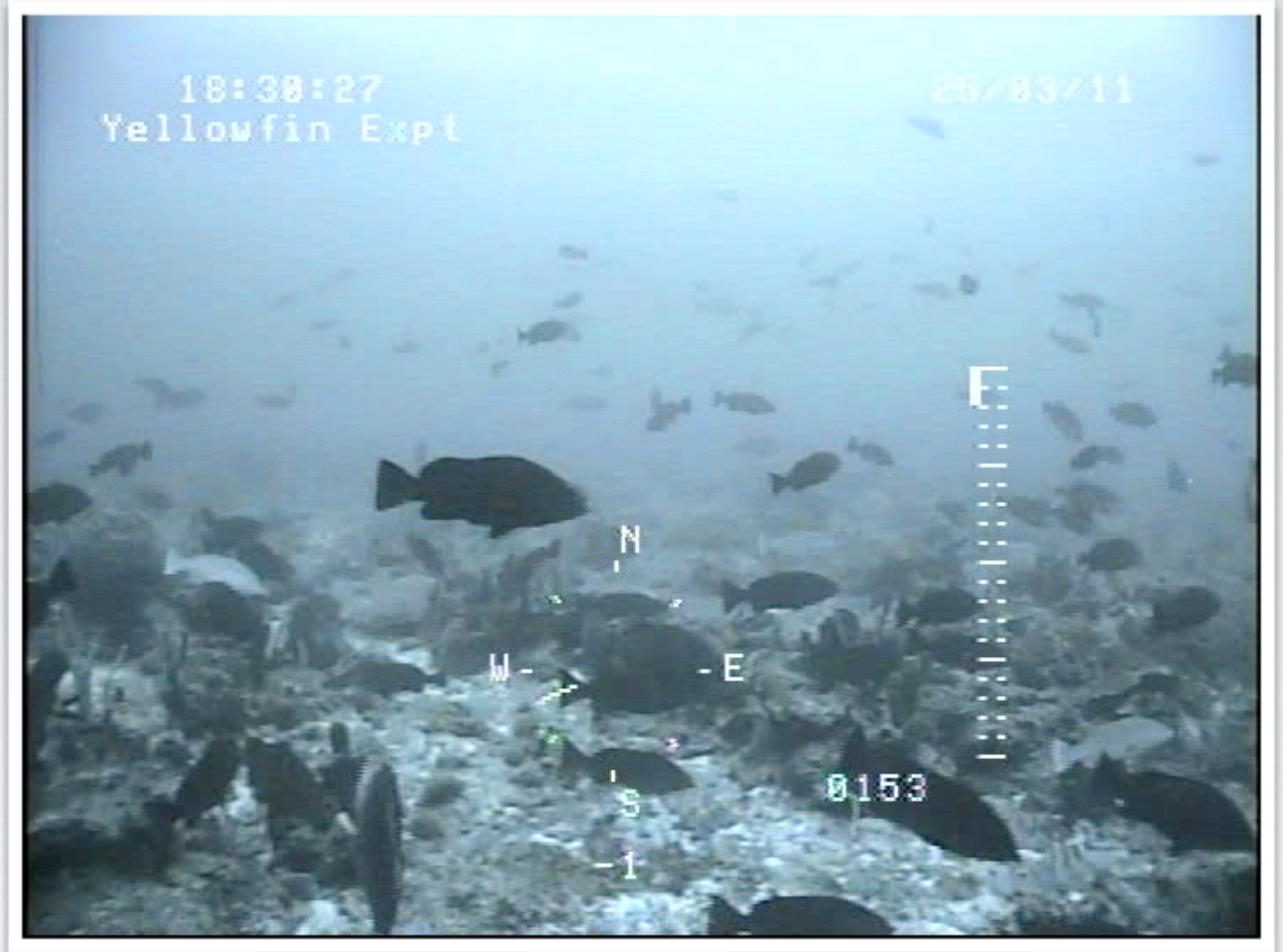
FIGURE 5. (A) Assuming an average cruising speed of 7.5 knots, an FSV covers five times the distance along a single survey line as a Wave Glider cruising at 1.5 knots for the same length of time. (B) Five Wave Gliders, each running its survey line at 1.5 knots, can complete five lines in the same amount of time that a single FSV completes the same five lines (**Video 1**). (C) With a fleet of Wave Gliders, each one running a survey line, a full acoustic stock assessment of the West Coast Exclusive Economic Zone (EEZ) can be completed in one week, the same amount of time that an FSV would need to complete ~12.5% of the survey. (D) A fleet of Wave Gliders can complete the equivalent of eight near-synoptic surveys of the West Coast EEZ during the eight weeks that it takes an FSV to complete one full acoustic stock assessment survey of the West Coast EEZ (**Video 2**). Each color corresponds to the survey lines completed during a given week.

It’s not only cheaper but it is much more efficient!



ECOSYSTEM-BASED SURVEYS

Deep Scattering Layers and foraging behavior of cetaceans using both passive and active acoustics

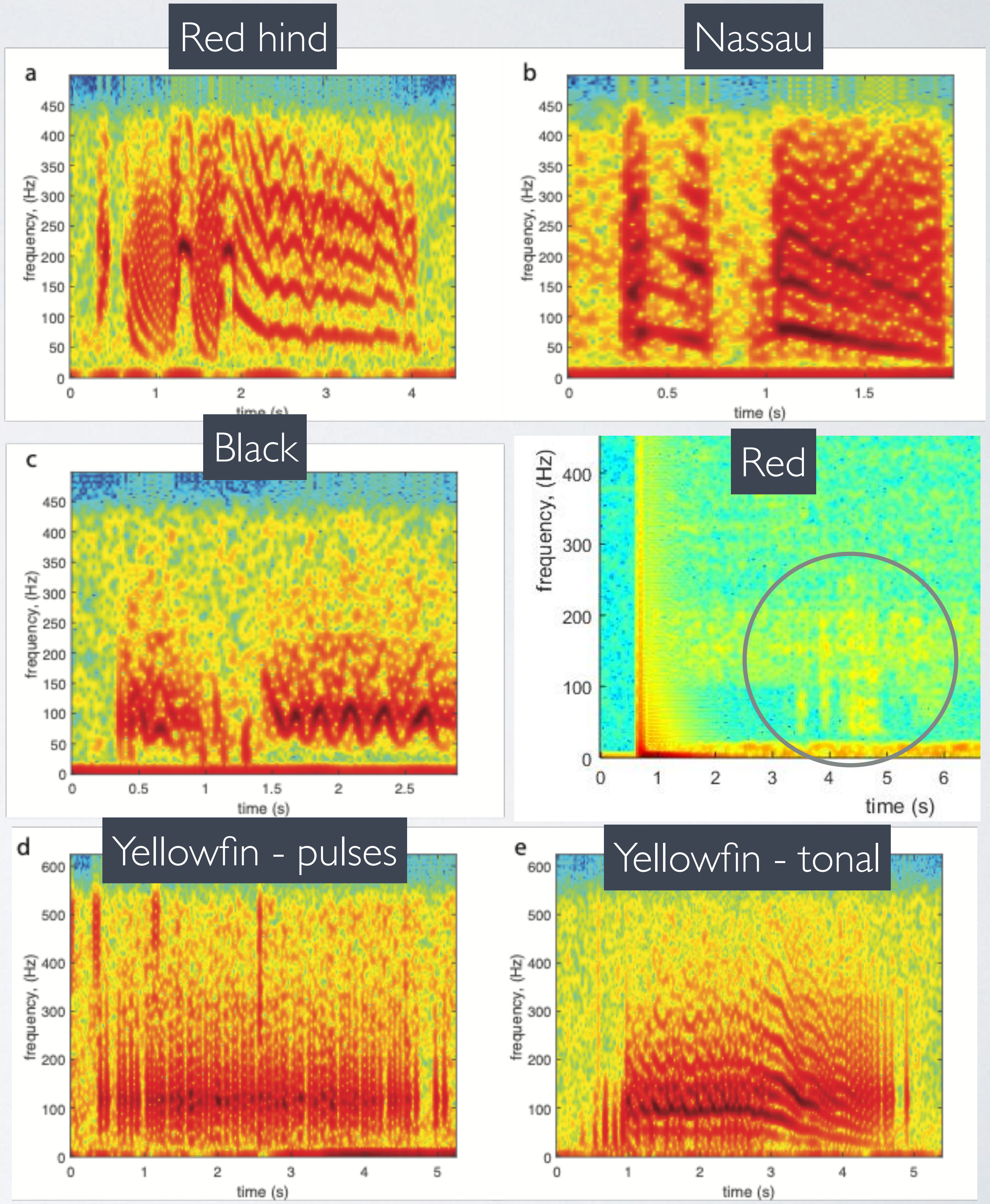


FISH SPAWNING AGGREGATIONS

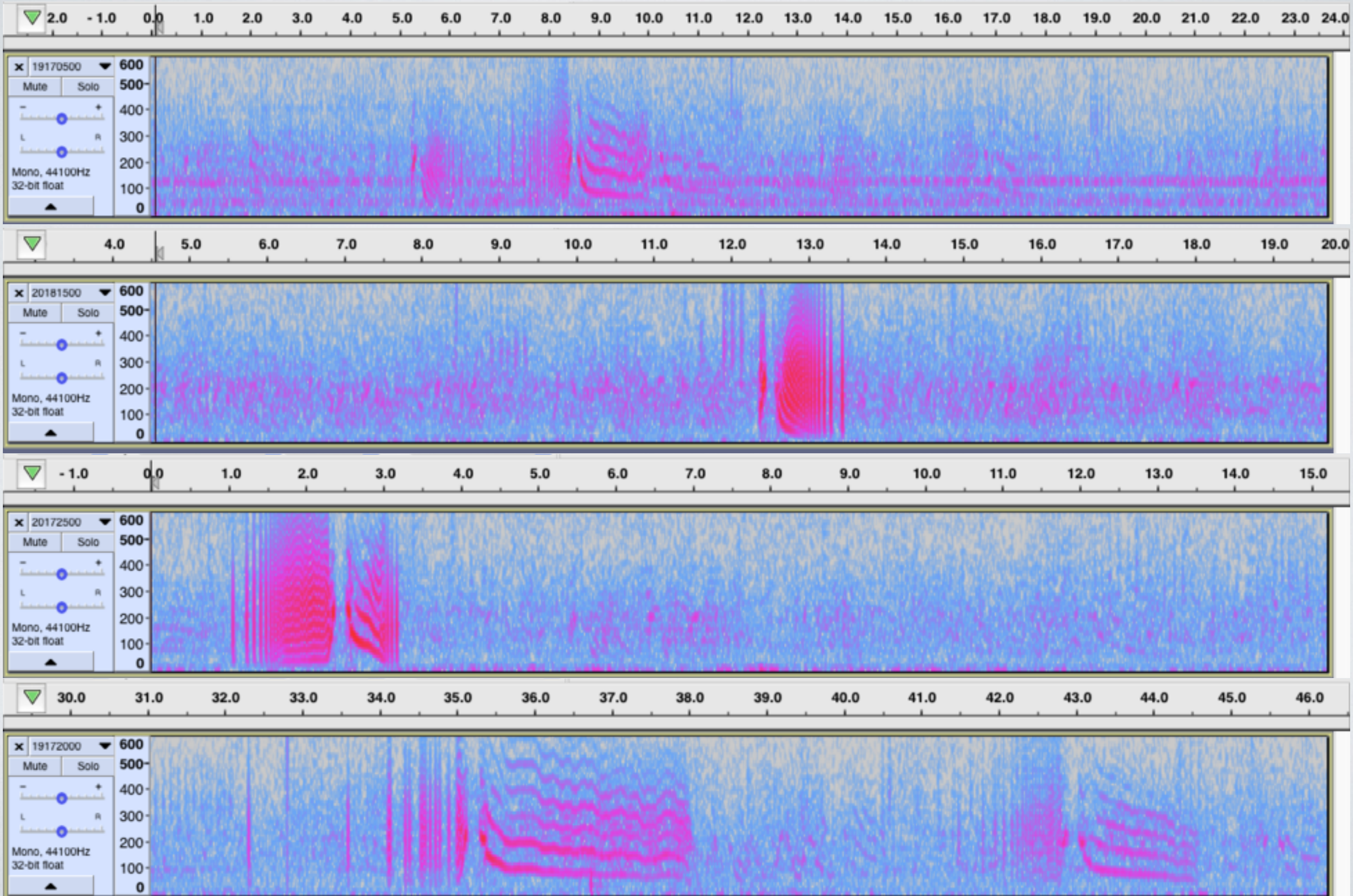
Using fish courtship associated sounds (CAS) to detect spawning aggregations

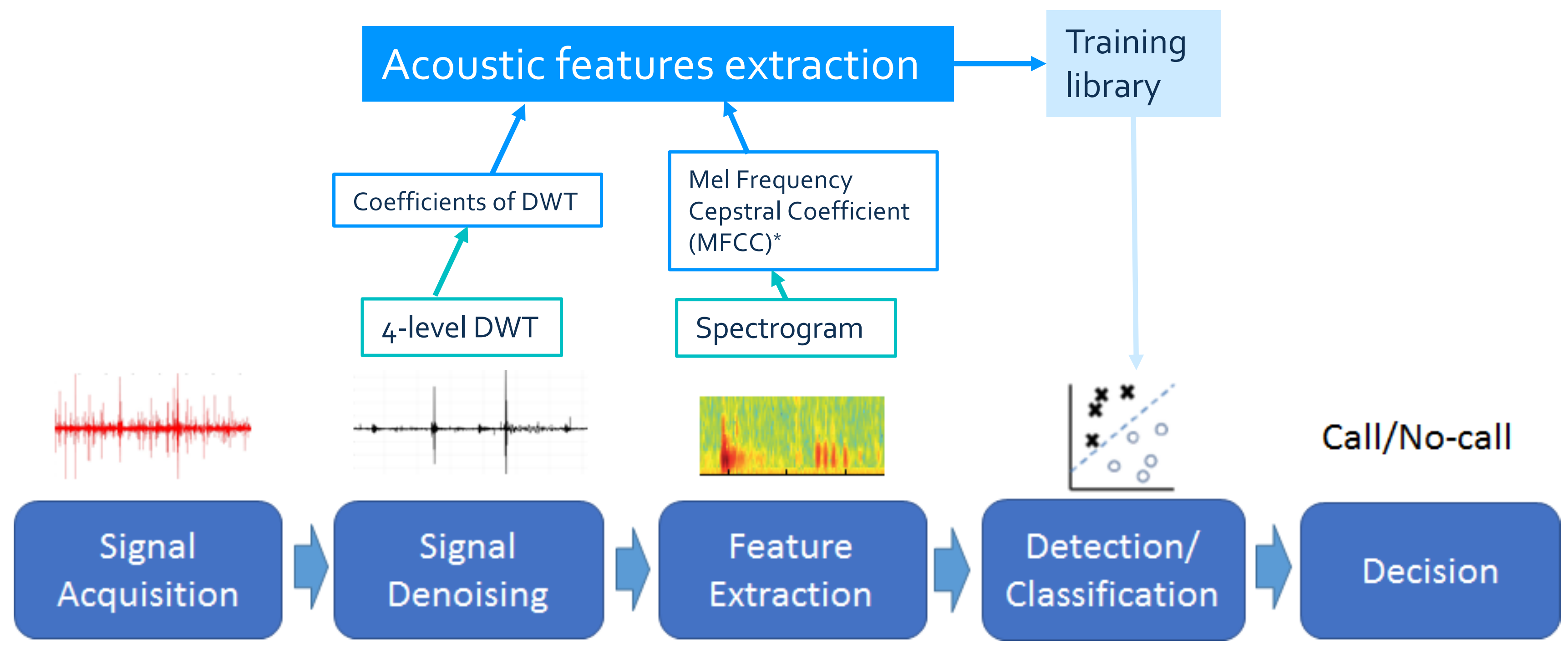
GROUPER SOUNDS

- Many fishes produce calls during spawning
- These sounds that are species specific may be used by different taxa for individual and mate recognition
- Groupers are sound producing species that form large spawning aggregations
- Their courtship associated sounds (CAS) provide an opportunity to assess the presence of groupers, hence the status of their aggregations by monitoring their sound.



GROUPER DIALECT?





MFCC: converts a linear scale spectrogram into a mel-scale spectrogram using the formula

$$f_{mel} = 2595log_{10}(1 + \frac{f}{700})$$

LEARNING GROUPER DIALECT

Fish Acoustic Detection Algorithm Research (FADAR)

MACHINE LEARNING APPROACH

An approach for automatic classification of grouper vocalizations with passive acoustic monitoring

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Grouper, a family of marine fishes, produce distinct vocalizations associated with their reproductive behavior during spawning aggregation. These low frequencies sounds (50–350 Hz) consist of a series of pulses repeated at a variable rate. In this paper, an approach is presented for automatic classification of grouper vocalizations from ambient sounds recorded *in situ* with fixed hydrophones based on weighted features and sparse classifier. Group sounds were labeled initially by humans for training and testing various feature extraction and classification methods. In the feature extraction phase, four types of features were used to extract features of sounds produced by groupers. Once the sound features were extracted, three types of representative classifiers were applied to categorize the species that produced these sounds. Experimental results showed that the overall percentage of identification using the best combination of the selected feature extractor weighted mel frequency cepstral coefficients and sparse classifier achieved 82.7% accuracy. The proposed algorithm has been implemented in an autonomous platform (wave glider) for real-time detection and classification of group vocalizations. © *2018 Acoustical Society of America*. https://doi.org/10.1121/1.5022281

[JFL] Pages: 666–676

I. INTRODUCTION

Mature adults of many fish species swim long distances and gather in high densities for mass spawning at precise locations and times.[1] This widespread reproductive strategy is typically shared among the groupers, which are both keys to the trophic balance of marine ecosystems and targeted by humans. Worldwide depletion of large predatory fishes has already caused top-down changes in coral reef ecosystems and biodiversity loss.[2,3] Moreover, most known fish spawning aggregations (FSAs) sites are shared by many species at different times[4] and as such, represent breeding hotspots. It is critical that their role in the persistence of marine populations be elucidated. FSAs share common features such as large body-sized individuals, strong site fidelity, and geomorphological attributes, (i.e., shelf-break, capes).[5,6] Once located, they are easily over-exploited and depleted[7,8] ICRS 2004. Despite numerous historical records of Caribbean-wide FSAs[9–23] only a few are viable to date and many remain unprotected.

These FSAs in the Caribbean Sea, Gulf of Mexico, and the Bahamas Region (i.e., the intra-America seas) are where a number of vocalizing grouper species such as the Nassau (*Epinephelus striatus*), yellowfin (*Mycteroperca venenosa*), red hind (*Epinephelus guttatus*), and black grouper (*Mycteroperca bonaci*), among others, aggregate to spawn. Most of these species spawn during the winter and spring months in the northern hemisphere. The timing of spawning is usually cued to the moon and daylight, but also to water temperatures and the local current conditions. Because FSAs often occur at remote locations, at dusk, and are in water depths between 30 and 80 m, near the shelf break, spawning activities and fish population are challenging to observe, and thus to monitor.

Studies have shown that more than 800 fish species can produce sounds for diverse purposes.[24,25] Most of the sounds are emitted at low frequencies,[26] usually below 1000 Hz. However, some pulses can reach 8 kHz[27,28] or present more complex characteristics.[29] In addition, these emissions are typically broadband short-duration signals (see Fig. 1). Fish generate sounds through several mechanisms, which depend on the species and a variety of circumstances, such as courtship, threats or defending territory.[30] Passive acoustics sensors can record species-specific acoustic signals associated with fish behaviors. The analysis of recordings of the sonorous species at FSAs has recently become a new approach in addition to underwater visual observations to monitor fish activity, such as courtship behavior, presence, and residence time. This approach is also used to scout the shelf edge where FSAs are likely to exist, which could reveal unknown aggregation sites or the recovery of overfished FSAs along with the species that visit the FSA.[31] Passive acoustic recordings are usually conducted at fixed stations with long-term acoustic recorder that can last several months underwater. Large volumes of acoustic data are usually generated and are manually classified using sounds spectrograms for visual identification and auditory classification, which can be tedious, time consuming, and prone to errors.

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Automatic classification of grouper species by their sounds using deep neural networks

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Abstract: In this paper, the effectiveness of deep learning for automatic classification of grouper species by their vocalizations has been investigated. In the proposed approach, wavelet denoising is used to reduce ambient ocean noise, and a deep neural network is then used to classify sounds generated by different species of groupers. Experimental results for four species of groupers show that the proposed approach achieves a classification accuracy of around 90% or above in all of the tested cases, a result that is significantly better than the one obtained by a previously reported method for automatic classification of grouper calls.

[DRB]
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1. Introduction

Fish species produce sounds for multiple purposes, including courtship, navigation, and defending their territories from intruders.[1–5] Some groupers (fish family) produce courtship associated sounds (CAS) during spawning aggregation (Fig. 1) that are species specific. These sounds are in the 10–500 Hz frequency range and have distinctive characteristics as can be seen in sample spectrograms in Fig. 1. For instance, red hind (*E. guttatus*) calls are within the 100 to 200 Hz band.[6] The calls contain tonal segments that are produced at a variable pulse rate. Nassau grouper (*E. striatus*) calls consist of a pulse train with a varying number of short individual pulses and tonal sound in the 30 to 300 Hz band.[7] Yellowfin groupers (*M. venenosa*) produce calls similar to those of Nassau groupers, although they are longer in duration with frequencies ranging between 90 to 150 Hz.[8] Black groupers (*M. bonaci*) make at least two variations of frequency, modulated tonal calls between 60 and 120 Hz, but the calls have a longer duration than those of Nassau groupers.[9]

Passive acoustic monitoring (PAM) techniques have been used for many years to study the behavior of fishes.[10–14] A particular application of the PAM technique is to observe the reproductive cycles of fishes, including groupers. Many fish species swim long distances and gather in high densities for mass spawning at precise locations and times. This widespread reproductive strategy is typically shared among the groupers. Studying these spawning aggregations is vital to conservation efforts aimed at reversing worldwide depletion of endangered fishes and sustain marine biodiversity.

In an earlier work, we designed an automated classification algorithm, FADAR (Fish Acoustic Detection Algorithm Research), which is capable of identifying fours species of grouper in their natural environment with a classification accuracy around 82%.[15] FADAR consists mainly of three stages: signal denoising, feature

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Classification of Red-Hind Grouper Call Types Using Random Ensemble of Stacked Autoencoders

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MACHINE LEARNING APPROACH

Classification of call types per species

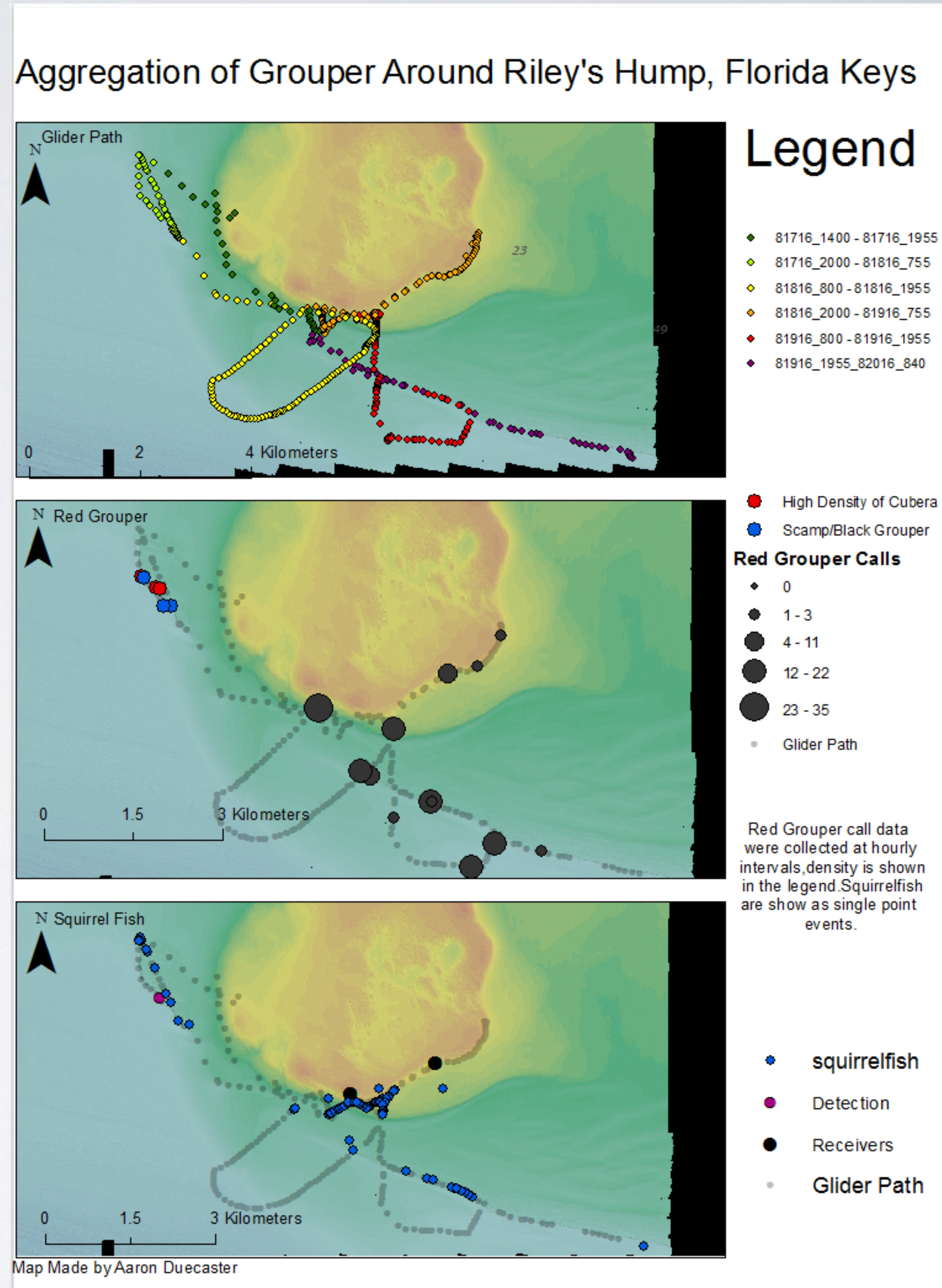
PASSIVE ACOUSTIC MONITORING SYSTEM

- **Tool**
  - ➡ An autonomous system that can be used as sentinel to monitor aggregations, more so if they are spawning aggregations, keeping in mind that aggregations are ephemeral, but predictable and site specific as far as we know from Eulerian studies!
  - ➡ Concurrently measures environmental data (T, S, U,V, Chl-a, CDOM, DO, pH, air temp, atmospheric pressure, wind speed and direction)
  - ➡ Use signal detectors that can be operated in real-time, to identifies species and the nature of the aggregation
  - ➡ Use complementary sensors for in-situ validation and abundance estimates
- **Outcomes**
  - ➡ Comprehensive vision of the spatial extent and temporal dynamic of FSAs
  - ➡ Consistent, efficient, low-cost unmanned assessment of FSAs status through time
  - ➡ Real-time alert system of boat traffic/fishing activities
  - ➡ Ultimately, abundance estimates!

FINDINGS

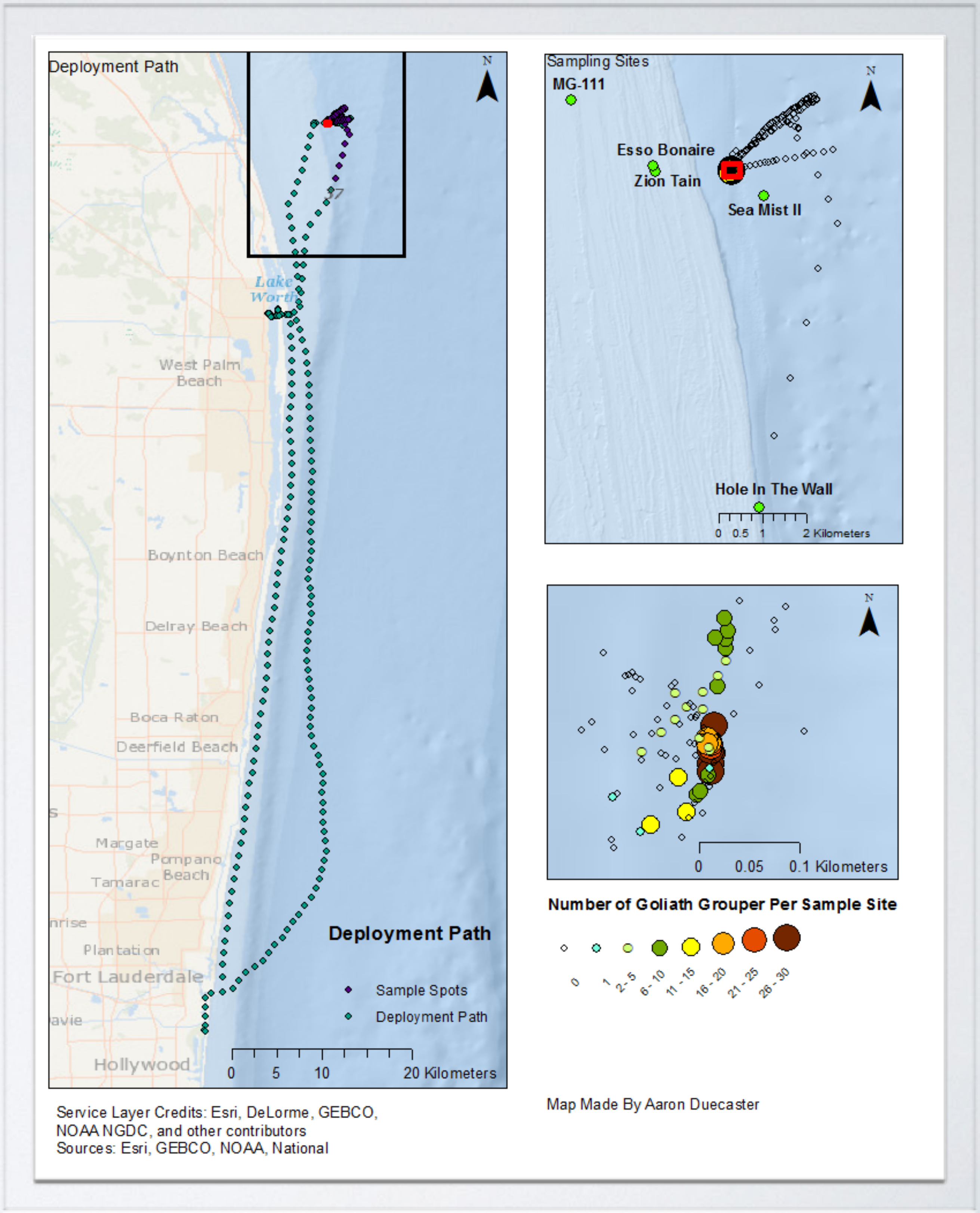
SPECIES DISTRIBUTION

FWC cruise



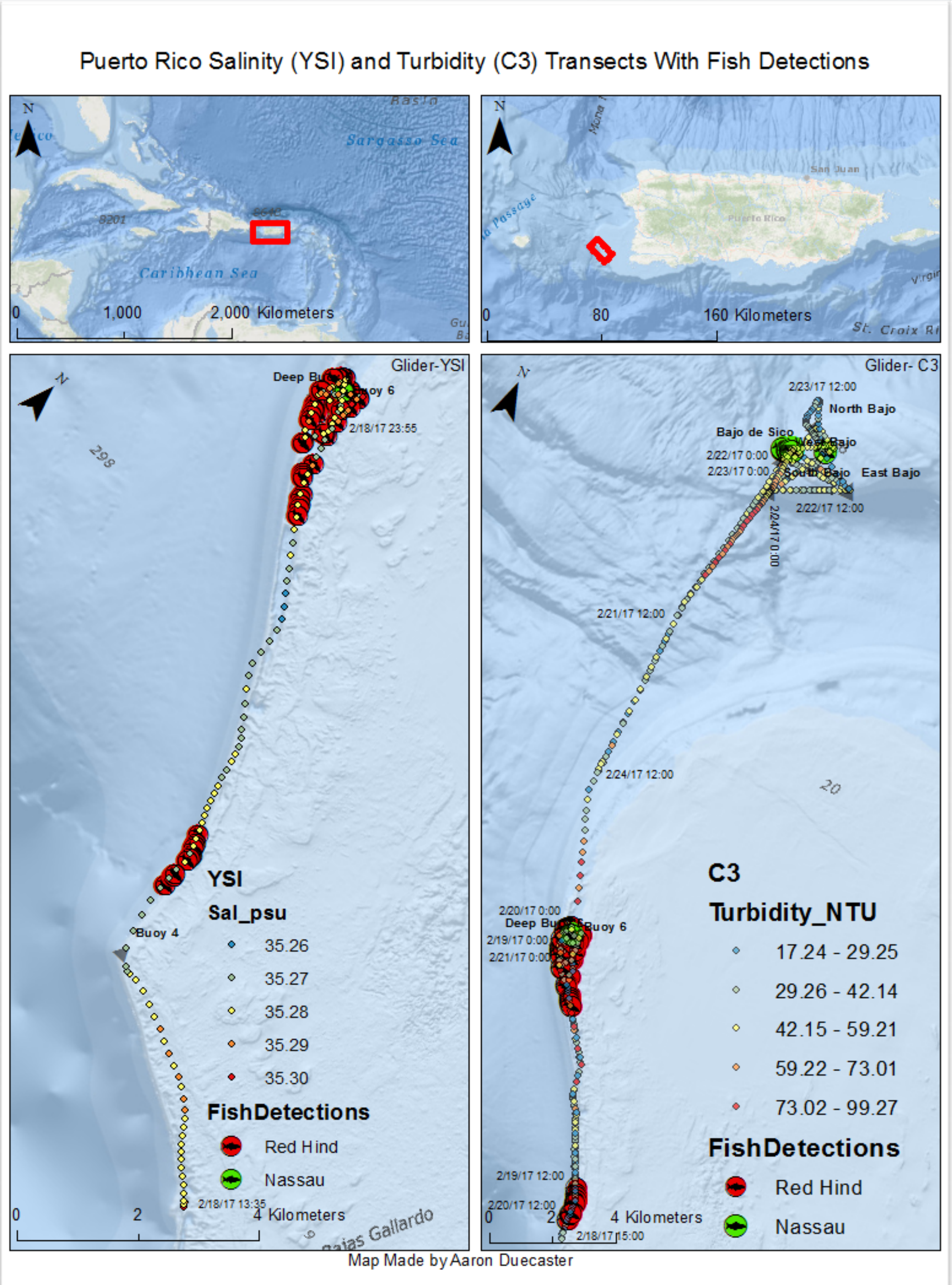
SPAWNING AGGREGATION SITE

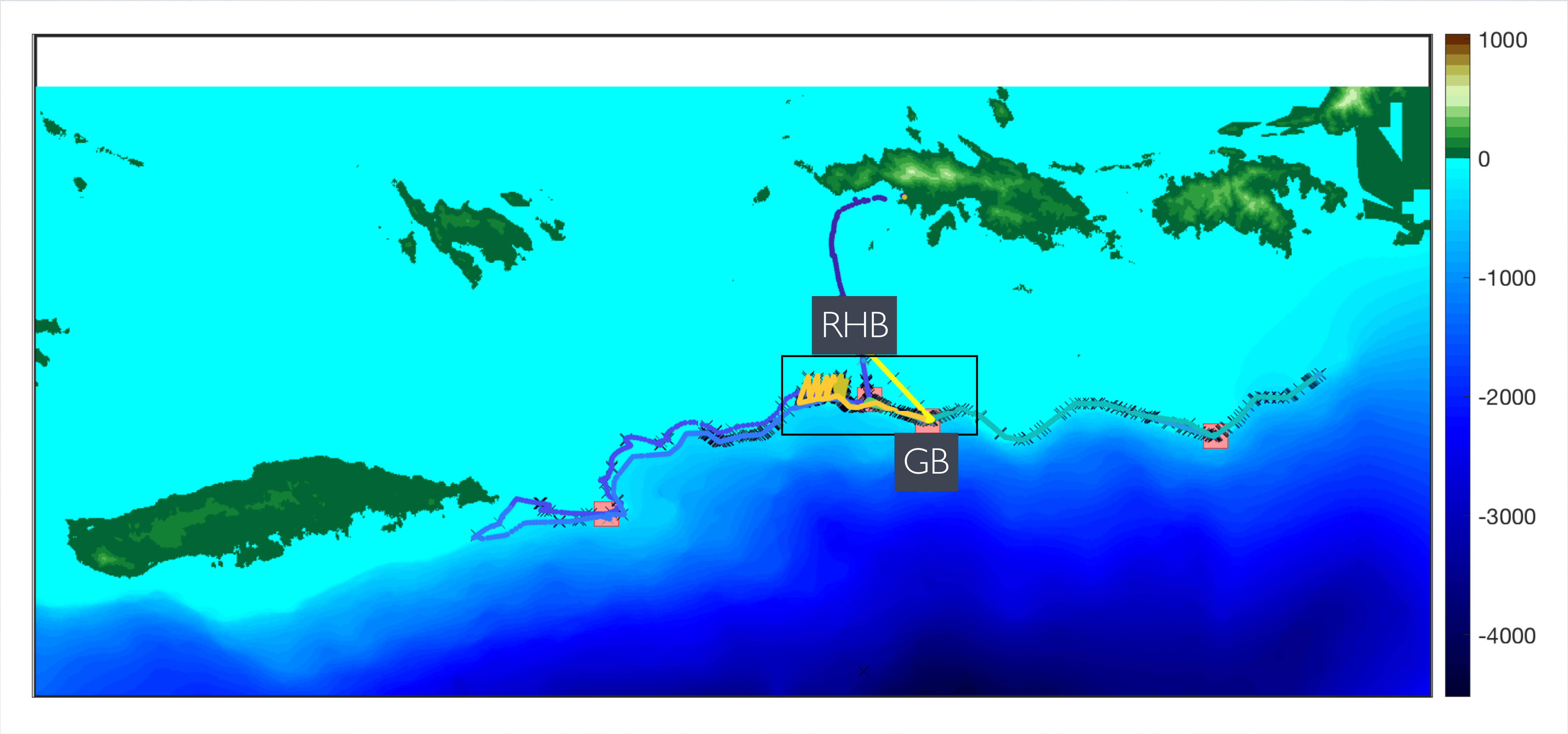
Goliath Grouper



DISTRIBUTION OF FSAs

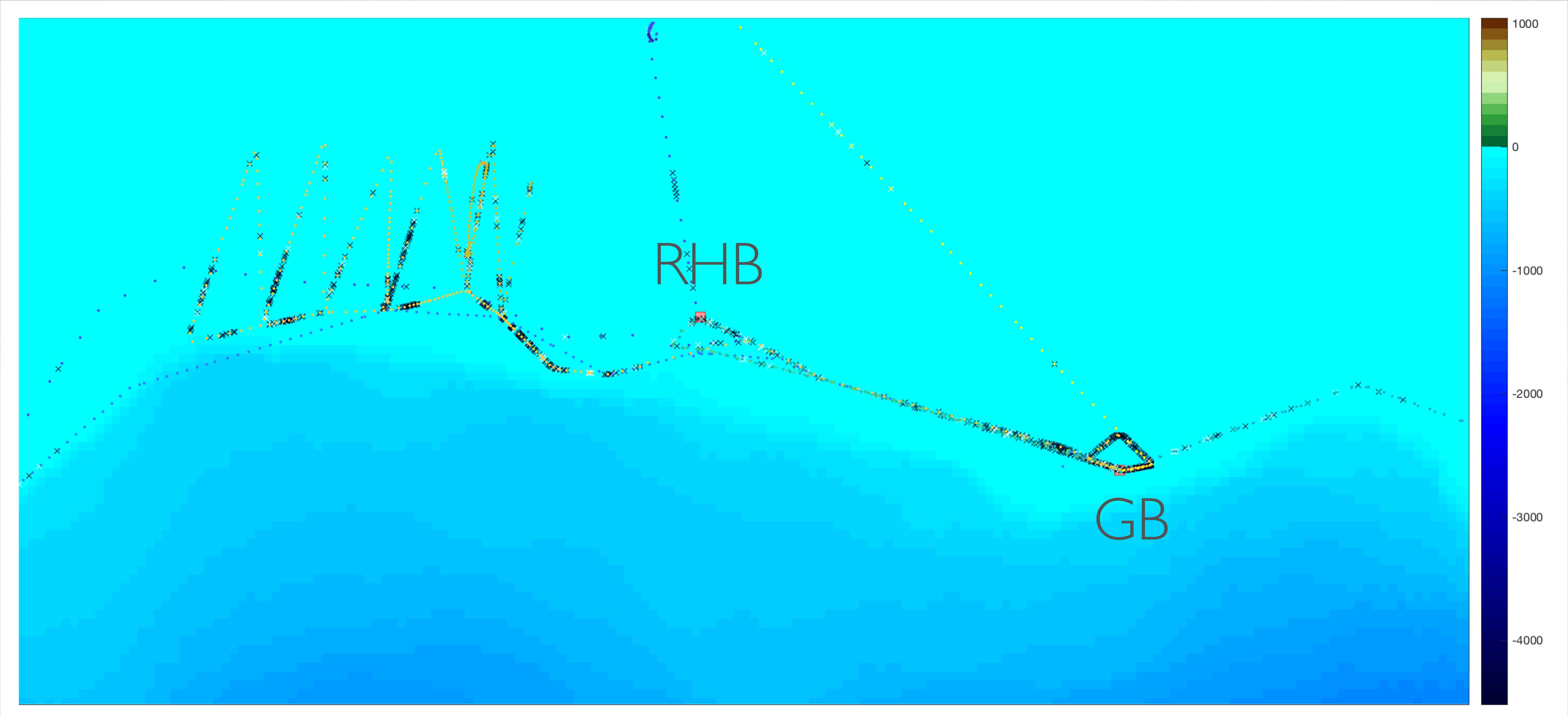
Puerto-Rico





FSAs AND TRANSIENT AGGREGATIONS

US Virgin Islands



FSAs AND TRANSIENT AGGREGATIONS

US Virgin Islands

SUMMARY

- Autonomous surface platforms such as the wave glider provide low-cost, persistent access to FSAs and real-time information on fish presence and the surrounding habitat
- Active and passive acoustics data collected from an autonomous surface platform such as the wave glider are complementary tools that can help:
  - Estimate population abundance levels as a function of the number of spawning adults with environmental or ecological input, which can provided a framework to predict recruitment and define harvest strategies within an ecosystem context.
  - Elucidate mechanistic relationships between fish species and their surrounding oceanic habitats, to provide a solid understanding of fish behavior, population dynamics, and life history with an ecosystem perspective.