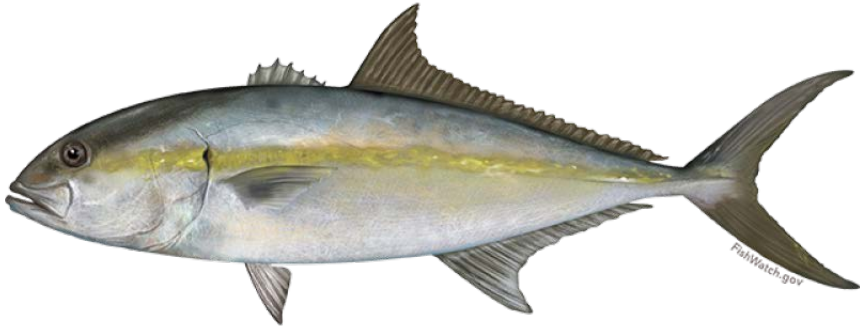
NOAA FISHERIES



Sea Grant

Greater Amberjack Abundance, Distribution, and Movement in U.S. Waters in the South Atlantic and Gulf of Mexico

S. Powers, M. Albins, K. Boswell, J. Buckel, M. Catalano, G. Chiu, M. Dance, M. Drymon, J. Hoenig, S. Midway, S. Murawski, N. Phillips, J. Rooker, E. Saillant, S. Scyphers, L. Stokes, G. Stunz, T. Switzer, D. Wells

Northeastern University
Mississippi State University
Florida International University
University of South Alabama
NC State University
The University of Southern Mississippi
Southern Methodist University
Texas A&M University Corpus Christi
University of South Florida
Auburn University
VIMS William & Mary Virginia Institute of Marine Science
Louisiana State University
Texas A&M University Galveston Campus
Florida Fish and Wildlife Conservation Commission

Rationale

- Reef fish management in SE US has been contentious
- Disagreements regarding stock status and catch levels
- Caused public to question scientific basis for management decisions
- Stakeholder buy-in is critical to effective management
- In response, US Congress has funded two large scale studies to provide independent estimate of absolute abundance, help guide future management, build stakeholder confidence:
    - Great Red Snapper Count – GoM (completed)
    - Great(er) Amberjack Count – GoM and SA (ongoing)

GAJ Count

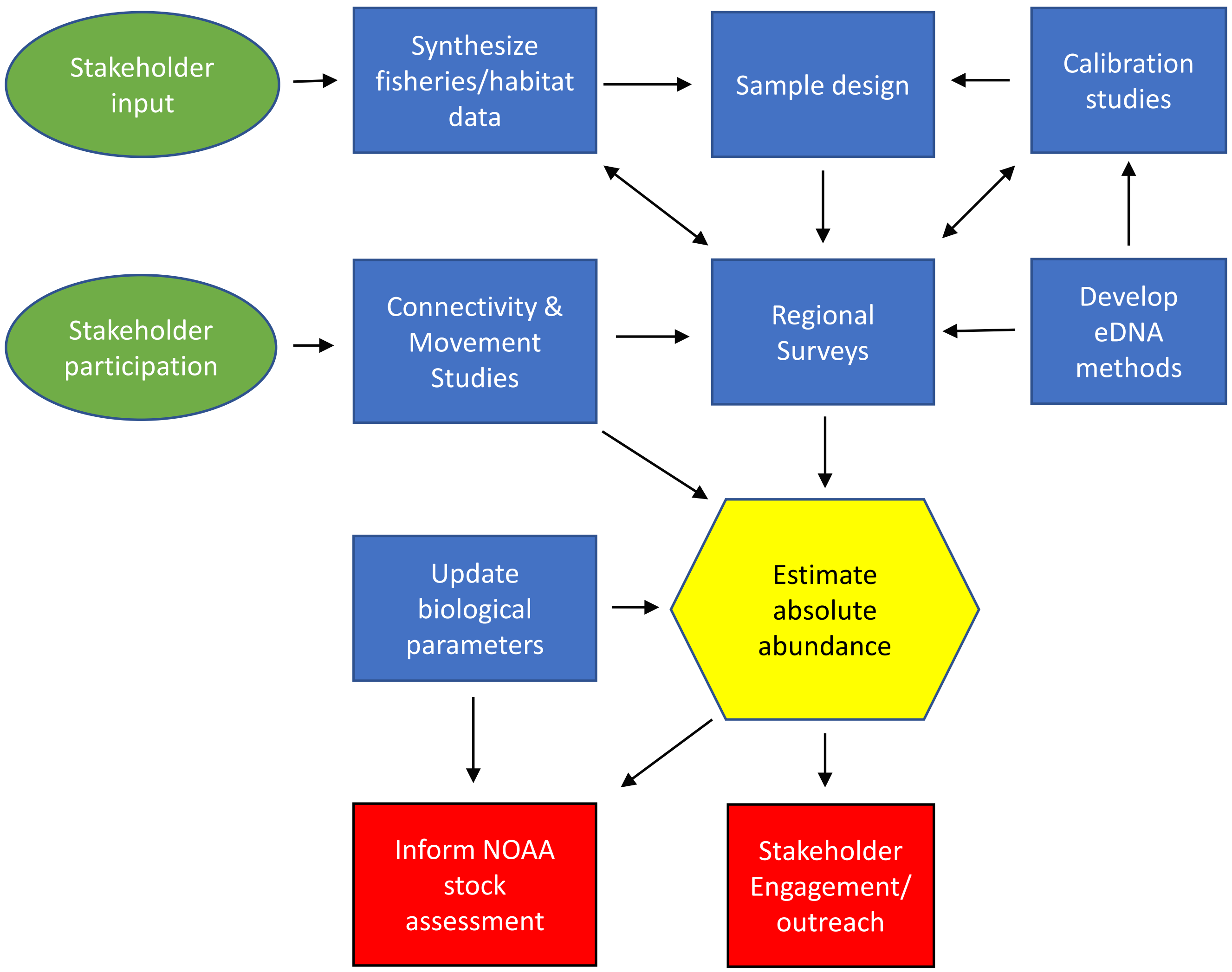
- Builds on successes and lessons-learned from GRSC
- Overarching goals:
  - Provide independent estimate of GAJ absolute abundance in US GoM and SA using fisheries independent sampling
  - Expand general biological knowledge (spatial ecology, movement, connectivity, growth, mortality, etc.) of GAJ to inform management decision making and to address key assumptions of abundance estimate

Phased approach

- Phase I
- Phase II
- Phase III

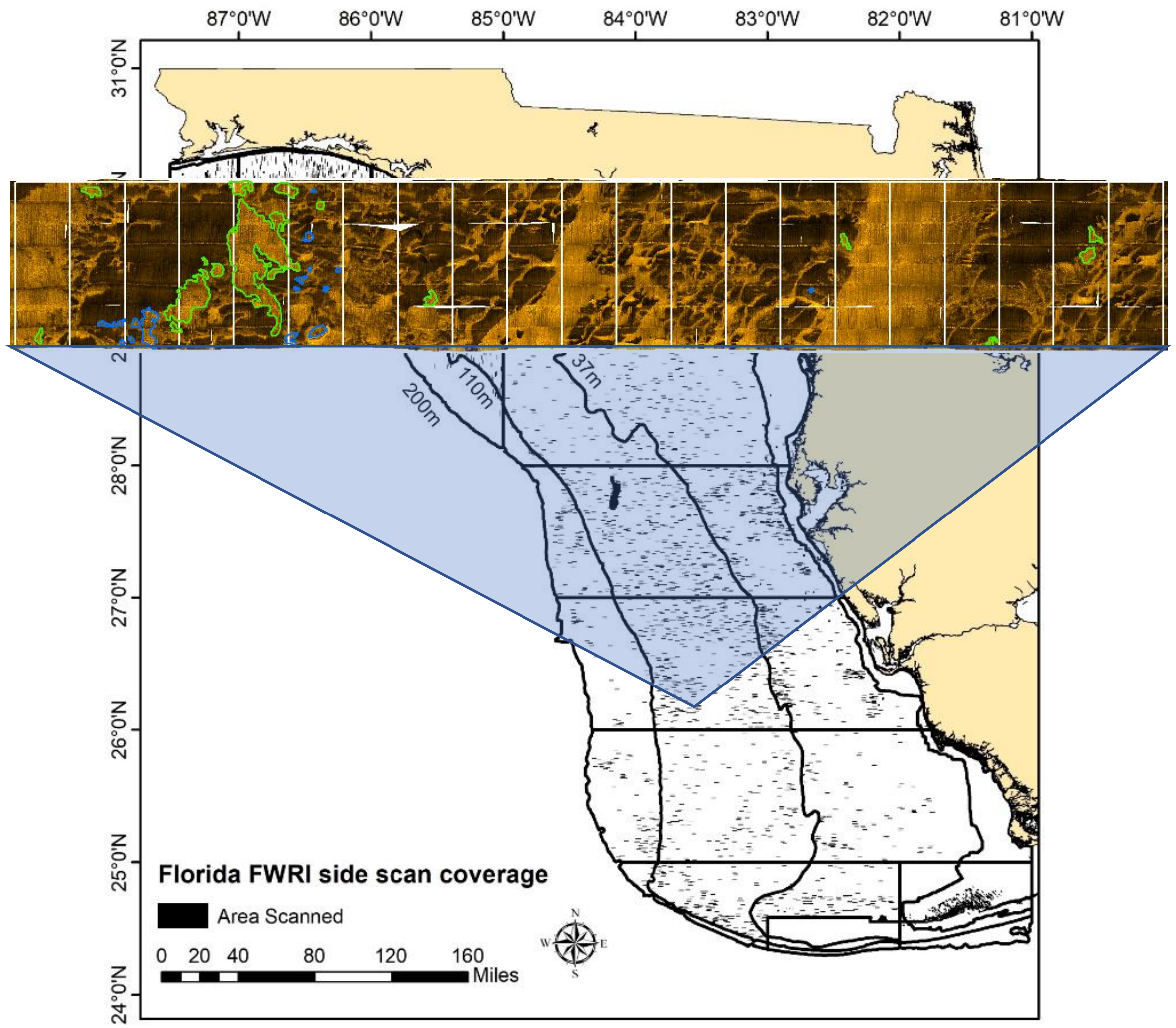
Key features:

- **Adaptable** to differences across regions and habitats
- **Scalable** from local to regional
- **Efficient** sample design based on existing catch data and stakeholder knowledge



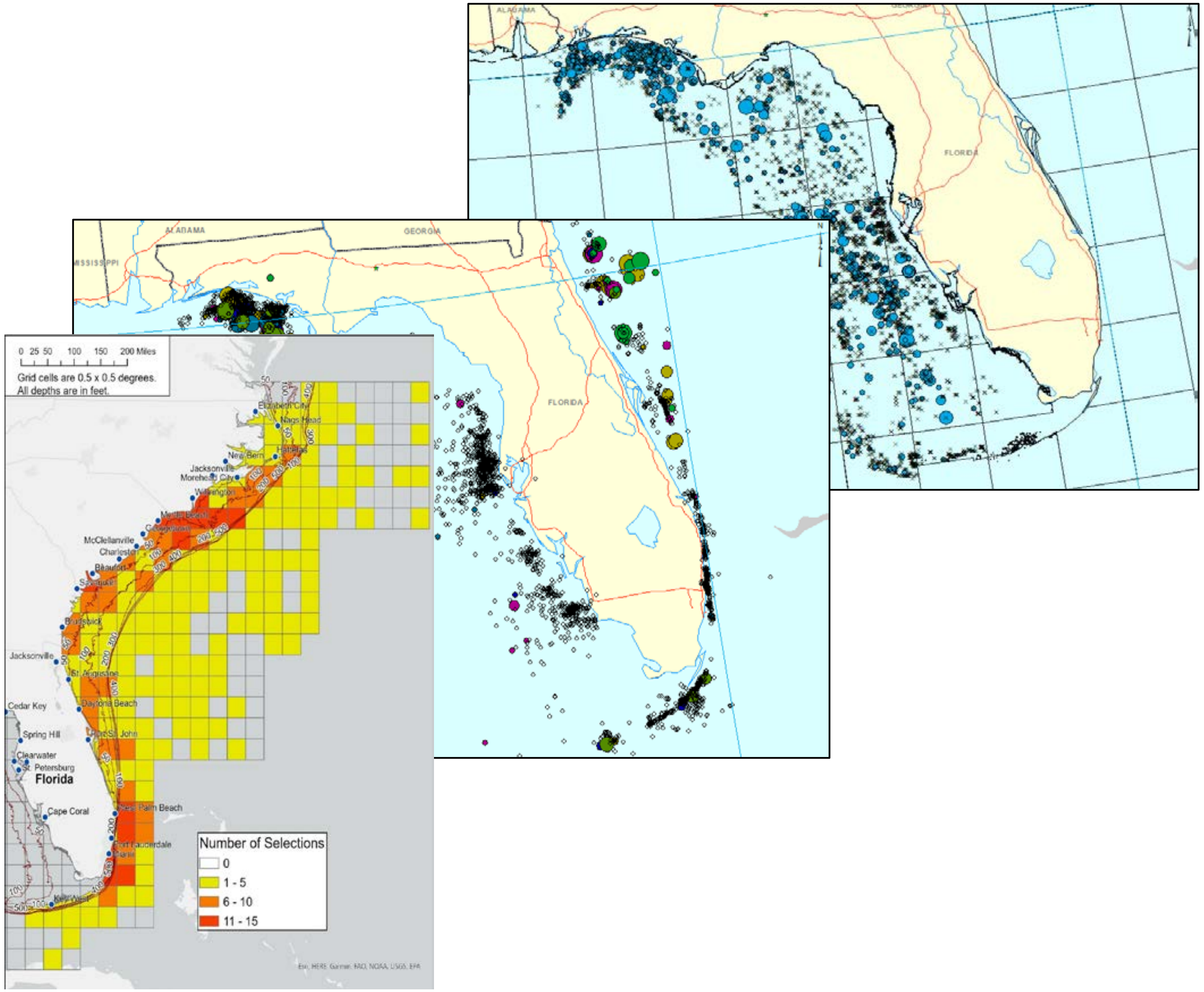
Objective 1: Synthesize habitat data

- No existing comprehensive maps for entire region
- Existing sources of habitat data
  - partial coverage
  - variable resolution
- Compile existing habitat data into comprehensive GIS product across GoM-SA region
- Inform sampling design, and ultimately, final estimates



Objective 2: Synthesize abundance data

- Existing fishery dependent and fishery independent catch data
- Existing stakeholder knowledge (LEK)
- Inform expectations in terms of presence/absence, relative abundance and variance
- More efficient sample design
  - Sample more where abundance and variance are high
  - Sample less where these are low

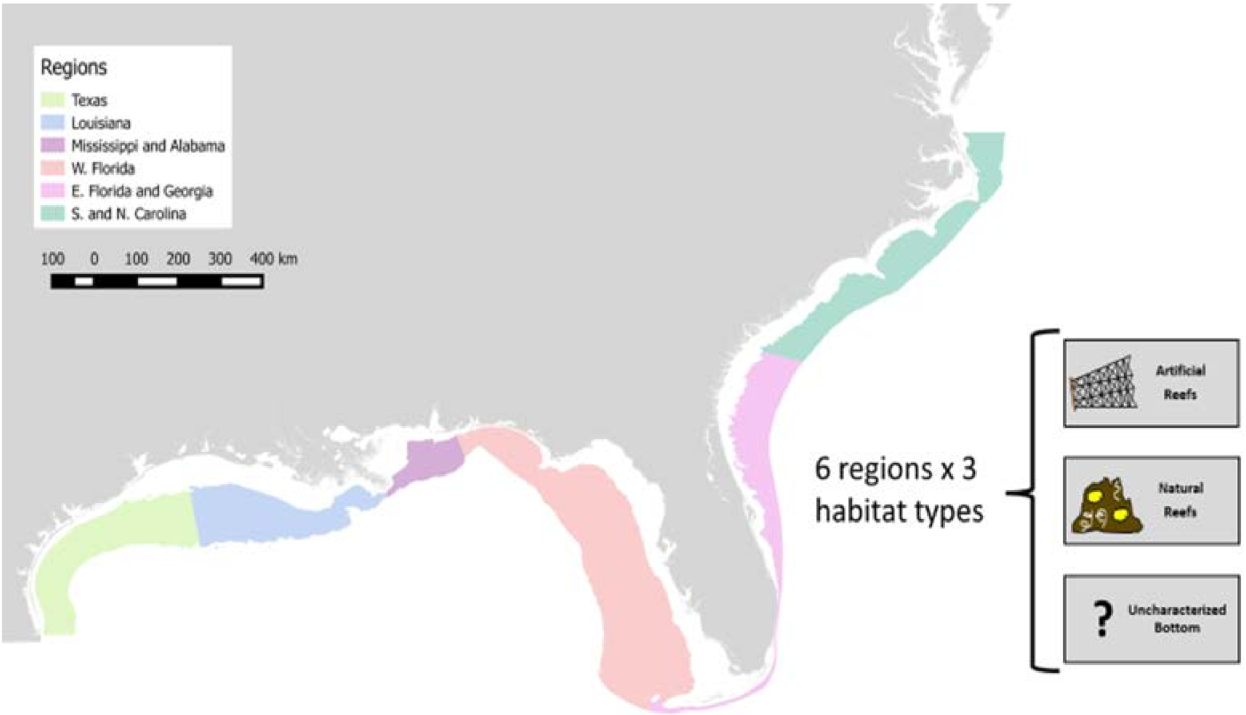


Objective 3: Estimate absolute abundance

- Sample design and framework
- Abundance sampling methods
- Calibration of gears

Sample design and framework

- Initial default (minimum) sample design is based on stratified random or cluster sampling by…
  - Region (TX, LA, MS-AL, West FL, East FL-GA, SC-NC)
  - Habitat type (artificial structure, natural structure, uncharacterized bottom)

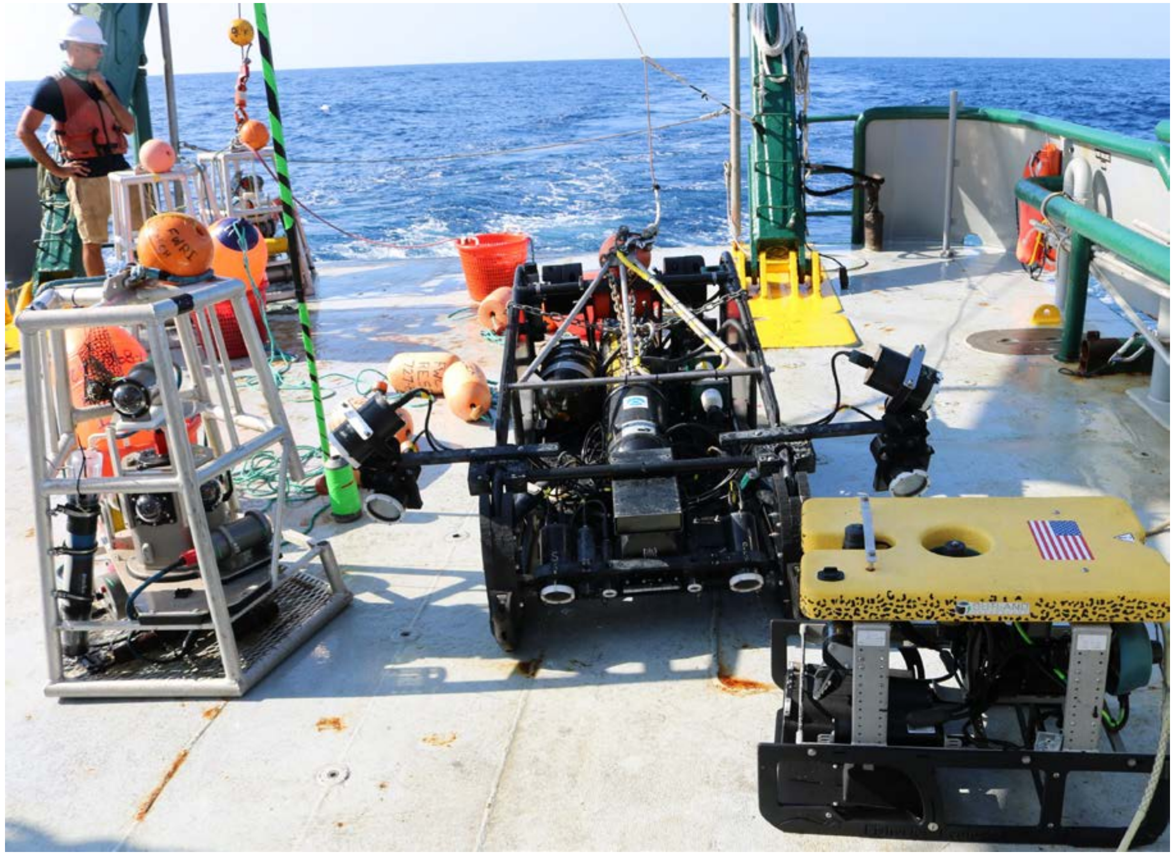


Abundance sampling methods

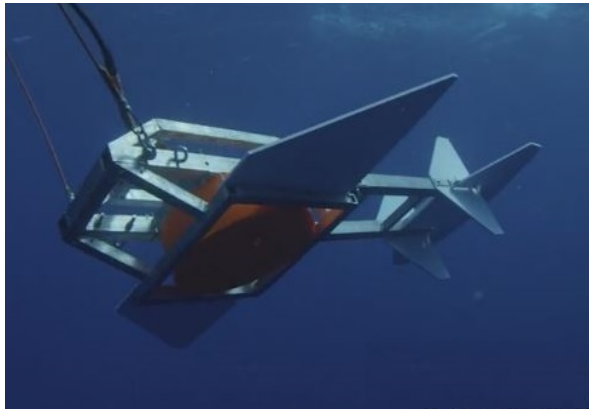
- Core approach: combine video (stationary, ROV, and towed) and active acoustics to measure density of GAJ
- Specific type of video is habitat- and region-specific due to advantages of each gear type
  - E.g. towed cameras effective for sampling large swathes of low-relief habitat, ROV effective for sampling high-relief artificial habitat
- Assess efficacy of emerging eDNA technologies
- Gears calibrated to each other and to a “ground-truth” abundance metric (Lincoln-Peterson estimate from VPS array)

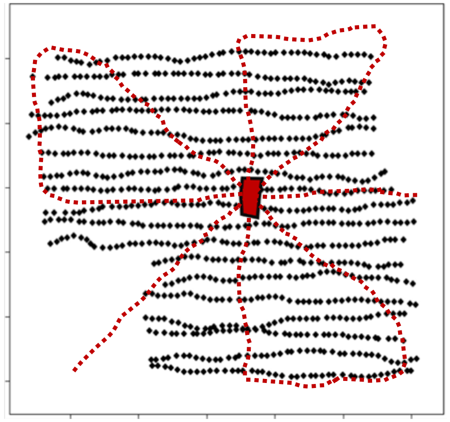
Video

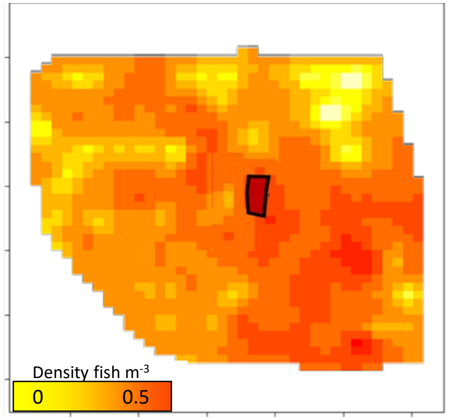
- Video types for different habitats
  - Baited drop cameras – artificial and natural reefs, all regions
  - ROV mounted cameras – artificial and natural reefs, GoM regions
  - Towed cameras – uncharacterized bottom, all regions
- Dedicated efforts to understand potential biases and how they influence probability of detection:
  - Attraction/avoidance
  - Influence of bait
  - Enumeration methods
  - Identification difficulties
- Calibration studies and coupling with active acoustics help to address these



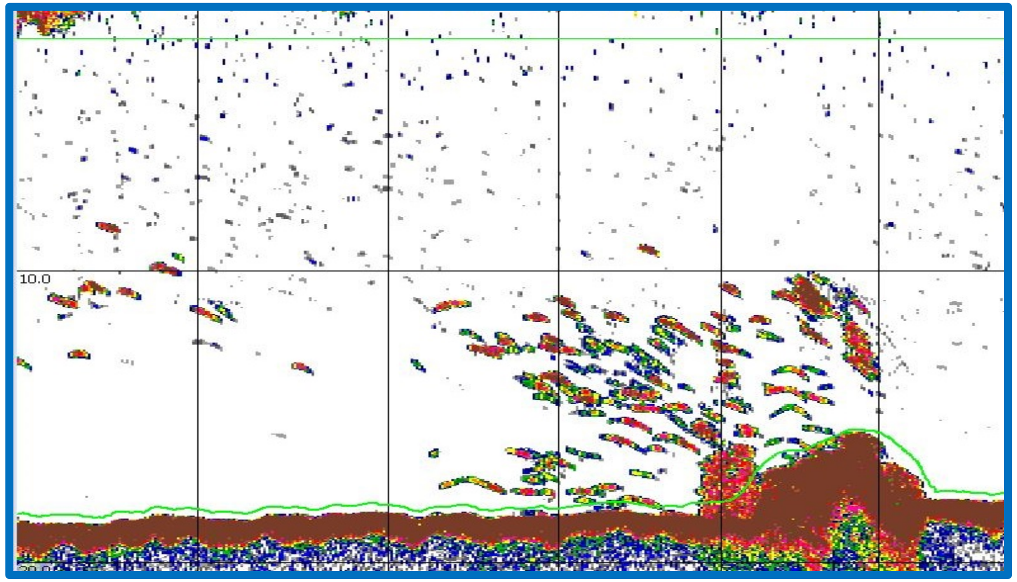
Active acoustics



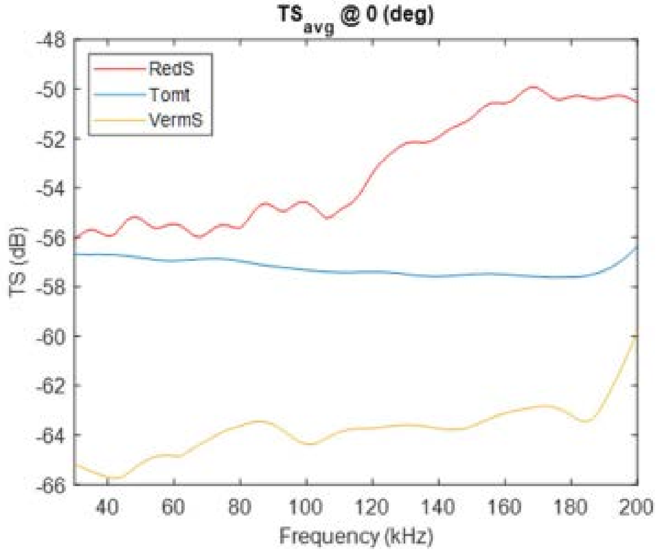




Depth



Distance along transect

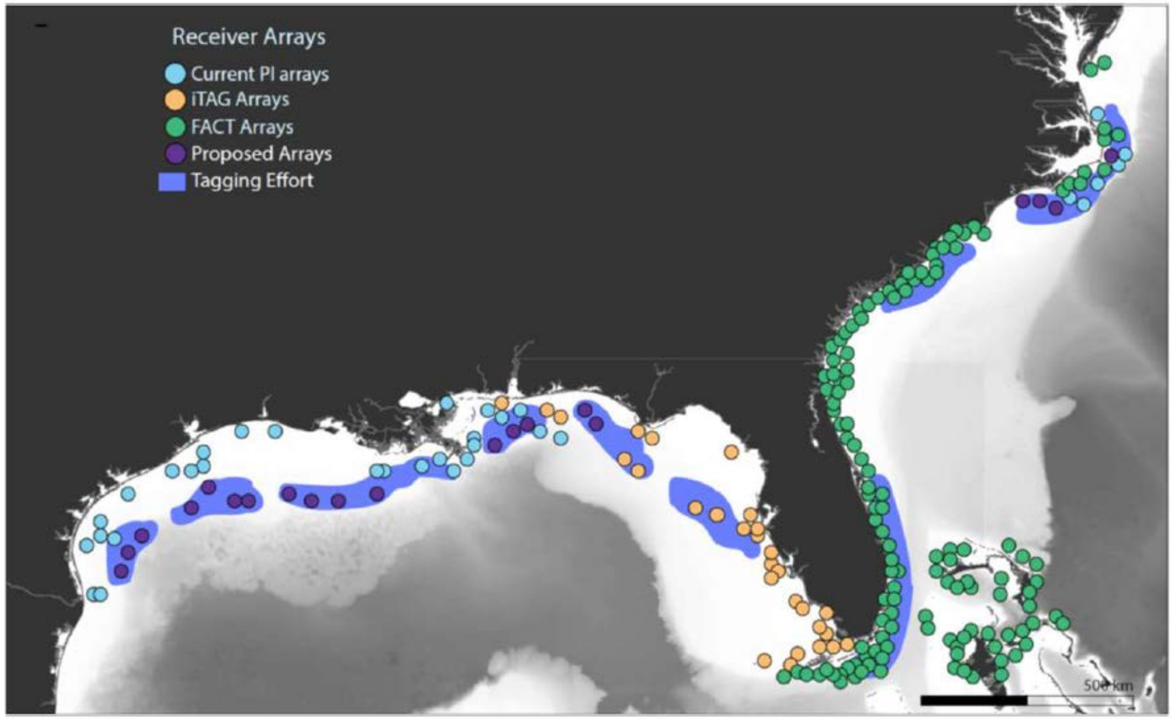


Calibration of gears and methods

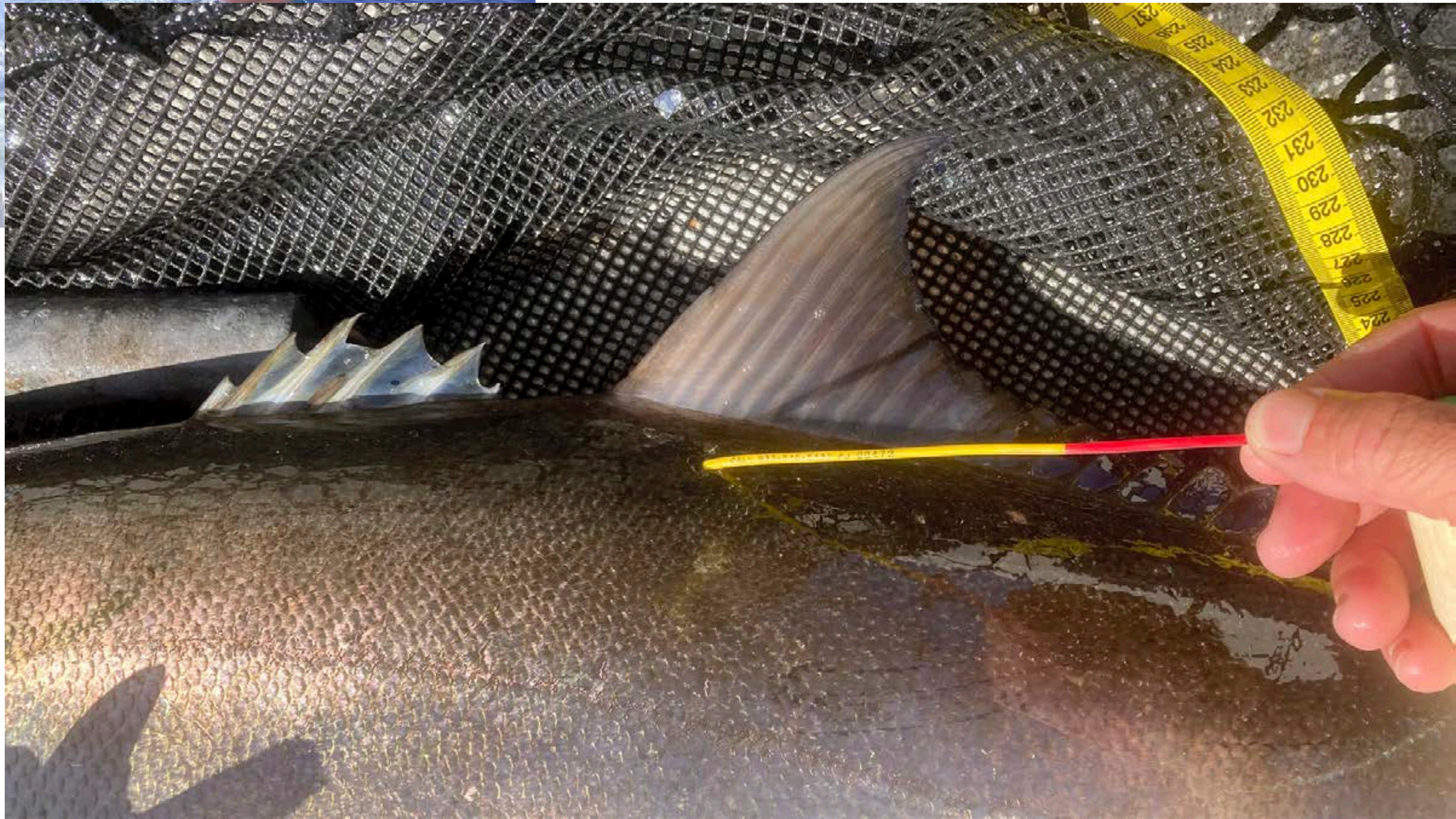
- Comparisons of camera gears
  - Baited vs. un-baited stationary cameras
  - Stationary vs. ROV
  - Stationary vs. towed
  - ROV vs. towed
- Active acoustics vs. all camera gears
- All gears (cameras and active acoustics) vs. ground-truth (Lincoln-Peterson estimate of abundance within a VPS array)
- eDNA vs. all other gears

Objective 4: Movement, connectivity, & mortality

- GoM and SA managed as separate, non-mixing stocks, but little known about migratory behavior and population connectivity
- Combined strategy:
  - Internal acoustic tags + extensive receiver array
  - High-reward external tags
  - Population genetics
- Opportunity for angler engagement



$250

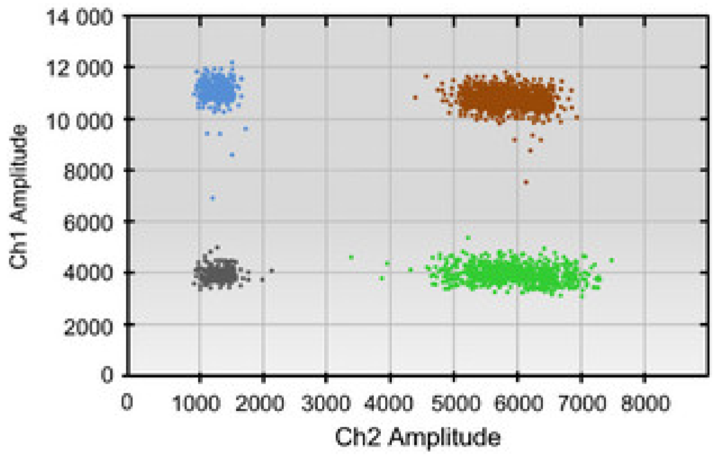


1-833-515-5137

https://agriculture.auburn.edu/research/faas/quantitative-fisheries-lab/greater-amberjack-project-tag-reporting/

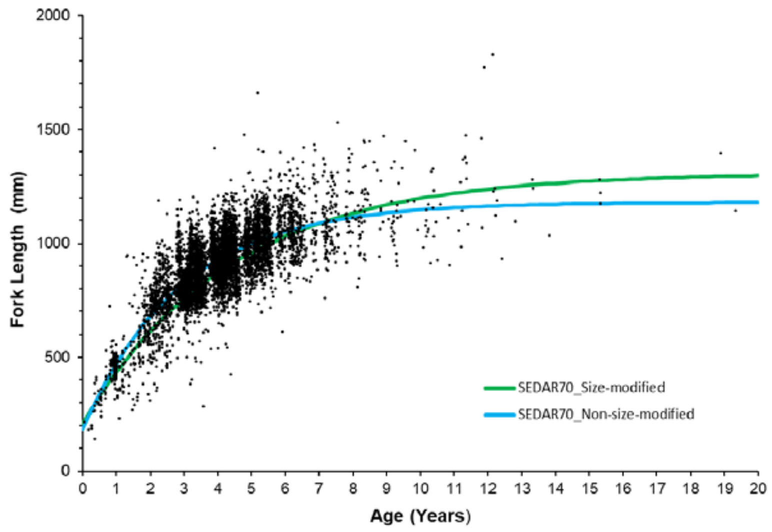
Objective 5: Environmental DNA

- Investigate efficacy of, and use, eDNA to assess presence and relative abundance of GAJ and closely related species
- Develop novel eDNA tools (ddPCR assay) specific to GAJ and compare performance to other gears during calibrations and regular surveys
  - Confirm identification of species
  - Estimate "sampling" vs. "structural" zeros
  - Provide relative abundance estimates
- Proving ground for the use of eDNA tools to study distribution and abundance of marine fishes



Objective 6: Update biological information

- Recent stock assessments recommended expanded demographic sampling of GAJ
- Age and growth information from W-GoM has been extremely limited
- Will use fishery dependent and fishery independent collections to update biological information and refine age-length keys
- Archive samples that can be used (with additional funding) to update reproductive indices (fecundity, spawning season, etc.)



Objective 7: Stakeholder engagement

- Working closely with established groups (e.g., GAJ Visioning Team, Sea Grant Reef Fish Extension Collaborative, etc.) to facilitate communication and cooperation with stakeholders
- Start-to-finish:
  - GAJ Visioning Team collected stakeholder input – used to formulate goals of RFP – Funded research is responsive to priorities of RFP
  - Incorporation of LEK in study design
  - Active engagement with for-hire fishing sector to provide platforms for scientific sampling
  - Dependent on commercial and recreational anglers for high-reward conventional tag returns
  - Dedicated effort to communicate results broadly at conclusion of study

Expected impacts and application of results

- Large-scale survey using novel integrated sampling approaches
- Leverage existing data sets and ongoing research to augment data collection and cost effectiveness
- Primary benefits:
  - Independent, robust estimate of absolute abundance of age 1+ GAJ in GoM and SA
  - Improved understanding of spatial and habitat-related distribution of the species
  - Improved understanding of population and movement dynamics of GAJ in region
  - Development of an approach and analysis framework that can be applied to future GAJ abundance estimates and those for other reef-fish species
- Secondary benefits:
  - Estimates of GAJ growth, mortality, site fidelity, population connectivity
  - Improved understanding of reef fish community structure across study region

Preliminary results and Sample Design

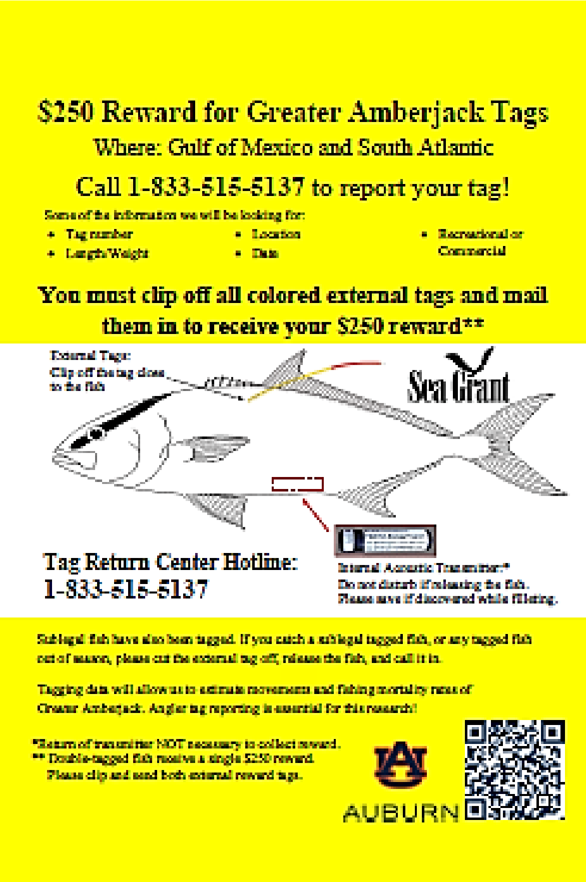
Preliminary results and Sample design

- Conventional tagging
- Acoustic tagging
- Population genetics
- eDNA
- Active acoustics
- Calibration studies
  - Florida
  - Mississippi/Alabama
- Habitat data synthesis
  - Eastern GoM
  - Western GoM
  - South Atlantic
- Abundance data synthesis
- Sample design for abundance estimates

Conventional tagging

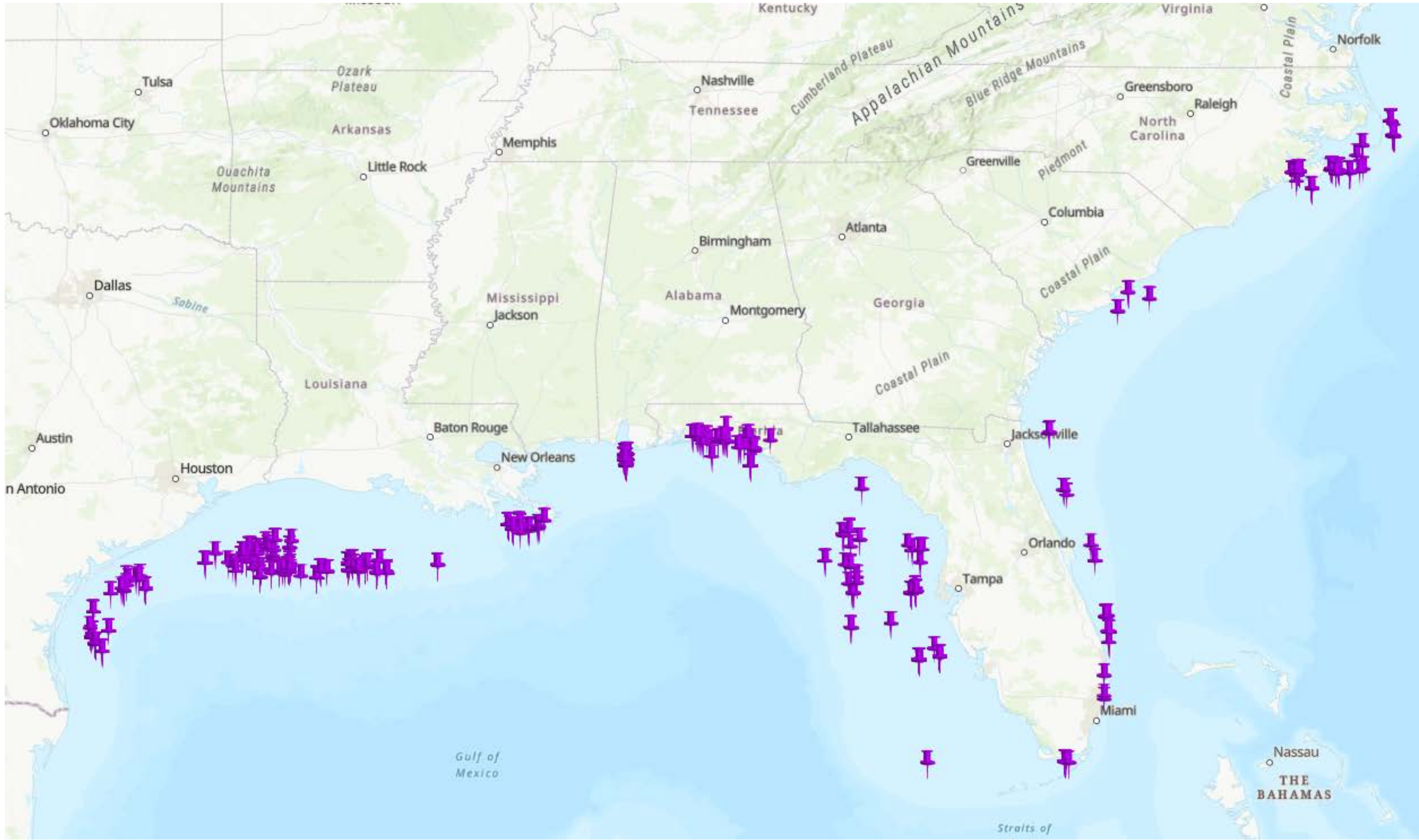
Objectives:

- Estimate the regional and sector specific (commercial, recreational) fishing mortality rates of Greater Amberjack in the Atlantic Ocean and the Gulf of Mexico
- Assess length-based vulnerability to capture, harvest, and discard
- Evaluate rates of movements of Greater Amberjack among regions



Conventional tagging

- 695/1200 conv. tags out
- 318/330 acoustic tags out
- $250 reward
- Total tag returns: 39
  - ATL: 9
  - EGOM: 17
  - WGOM: 13
- 1/20 shed tags
- Remaining tags out over Summer 2023
- Build Bayesian multi-state mark-recapture model
- Incorporate acoustic tag data



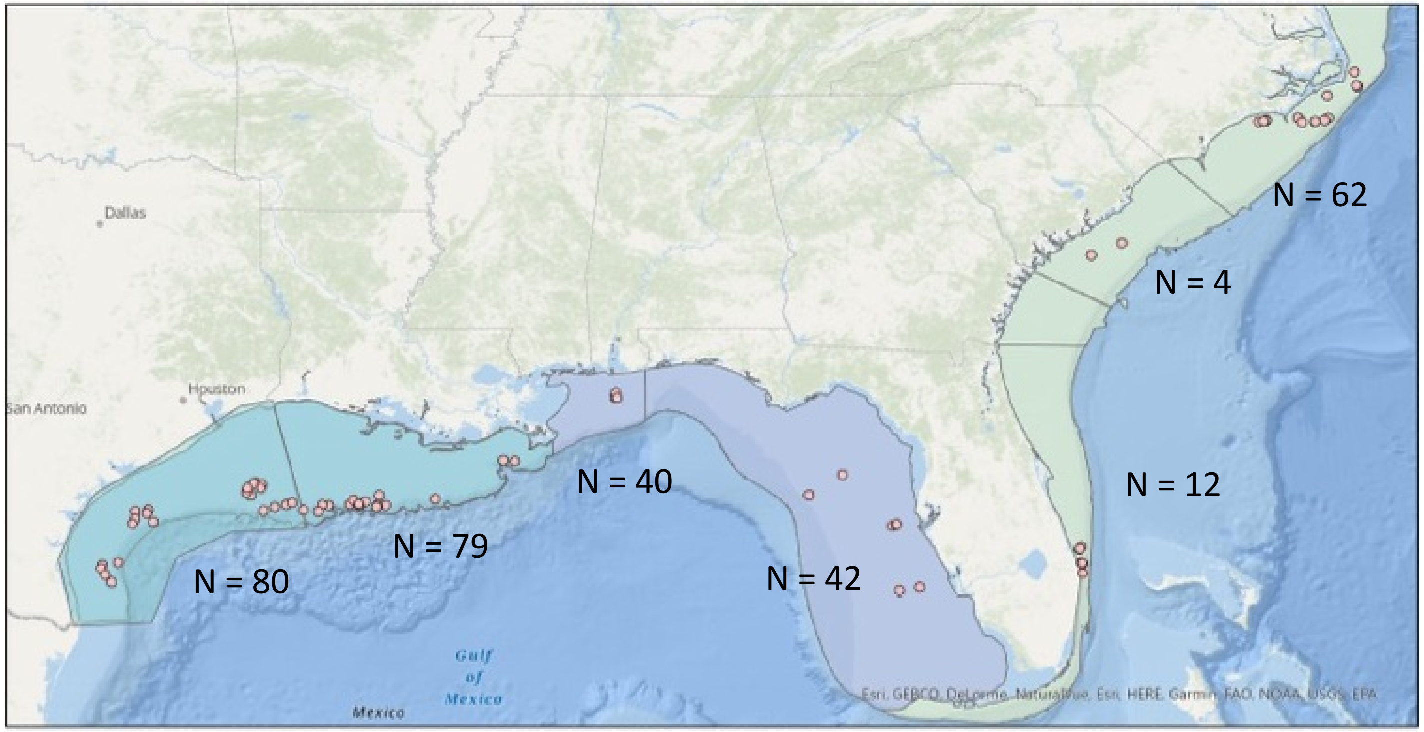
Acoustic tagging

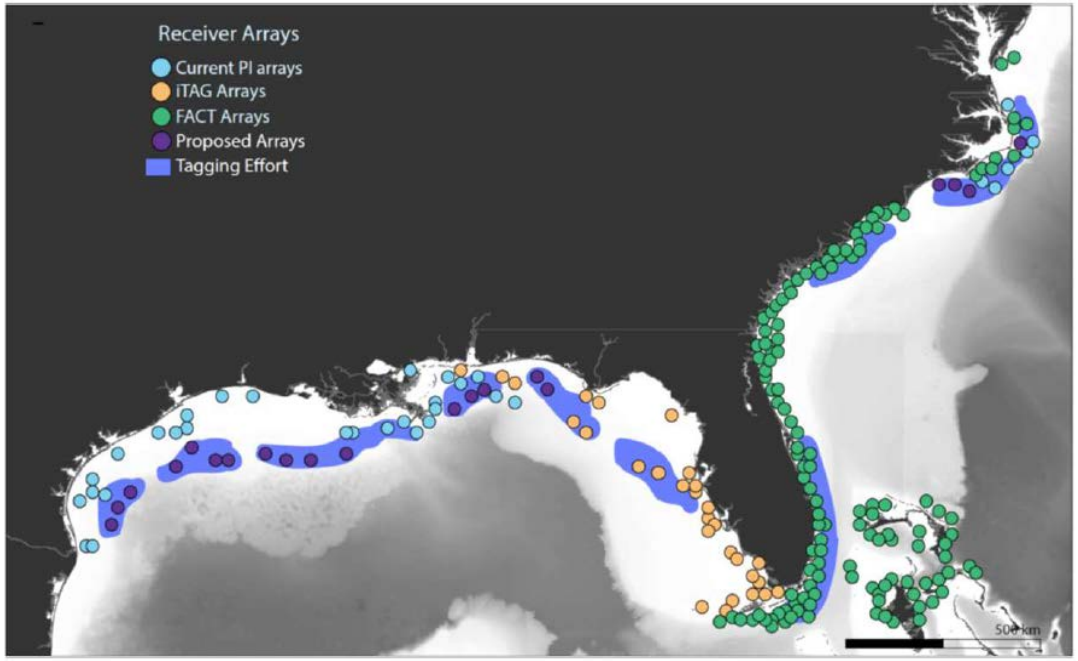
Objectives:

- Residency period/site fidelity by region, structure type, fish size
- Estimates of movement and exchange within and between regions (SA, EG, WG)
- Estimate mortality (F and M)
- Post-release mortality estimates
- Depth use across habitat types and regions

Acoustic tagging

- 318/330 tags out
- Coordination with iTAG and FACT
- Receiver downloads spring/summer 2023
- Deploy remaining tags





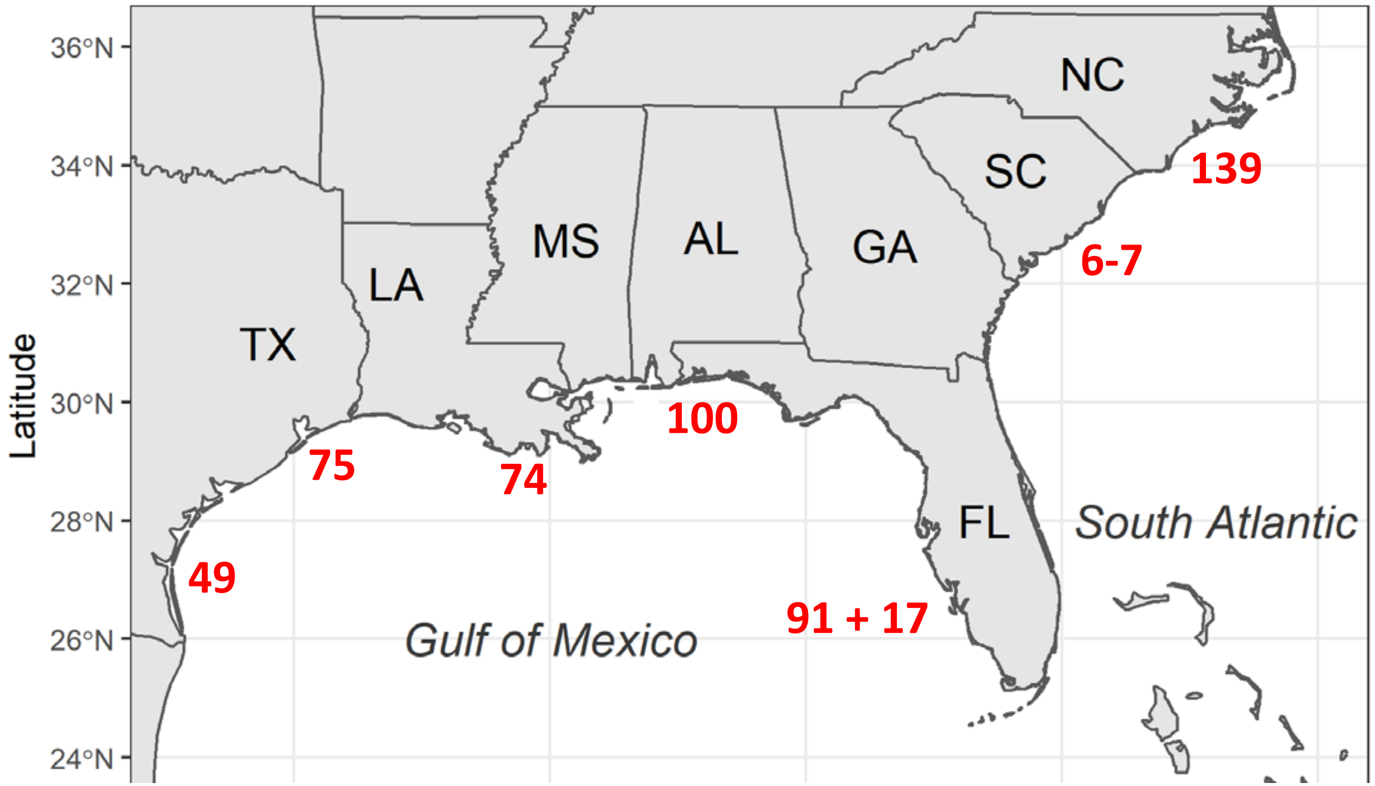
Population genetics

Objectives:

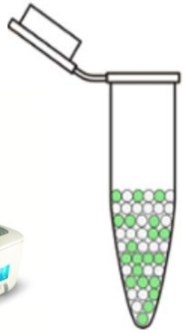
- Develop genomic resources to interpret genome scans in greater amberjack
    - Draft genome assembly
    - Linkage map
- Survey population genetic structure in GoM and SA waters
    - Sample geographic populations and assay samples at 2,000 to 10,000 SNP
    - Analyze genetic stock structure and connectivity: identify units, infer migrants and migration patterns, analyze variation under selection

Population genetics

- Progress on reference genome
- Sample population
  - Tagging project
  - Fishery dependent
- To do:
  - Complete reference genome
  - Complete linkage map
  - Assay population sample using dd-RAD sequencing
  - Analyze genetic stock structure and connectivity
- Note: samples archived for future analysis (parentage)

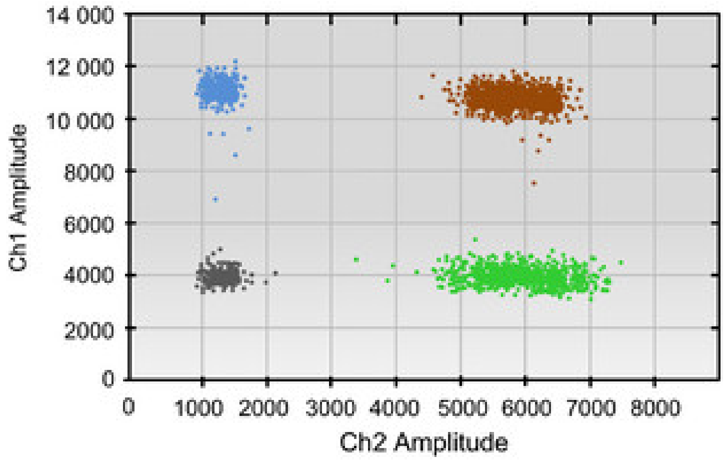


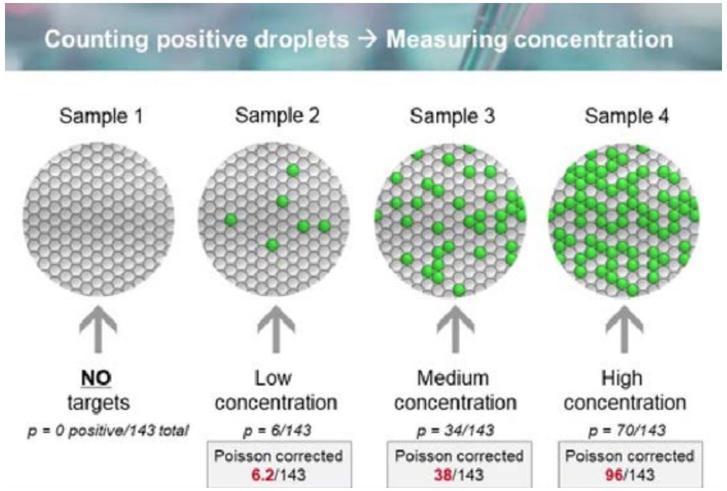
eDNA



Objectives:

- Evaluate capacity for eDNA tools to detect, discriminate and quantify target DNA
- Develop ddPCR assay
- Work out sampling tools and techniques for system
- Collect field data in concert with other gears
    - Calibration
    - Abundance sampling



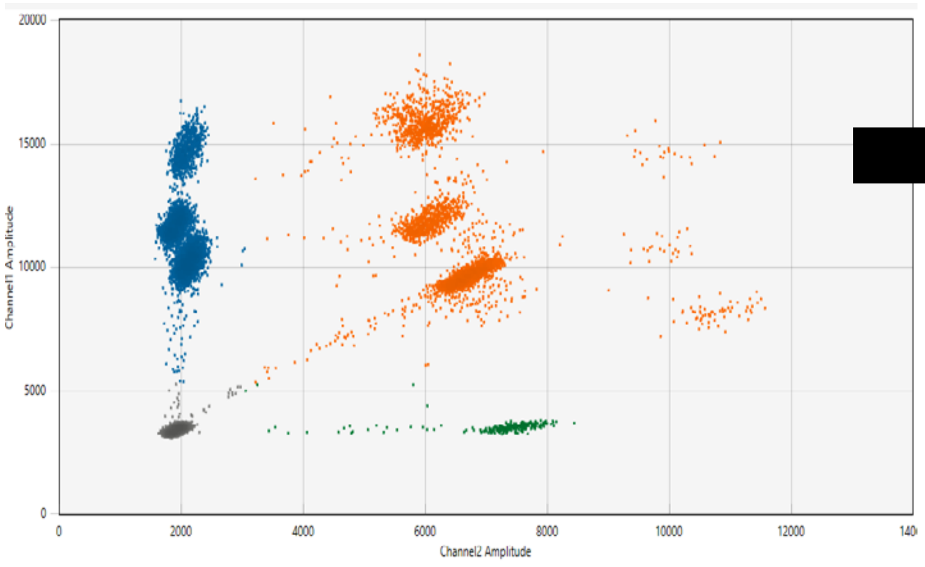


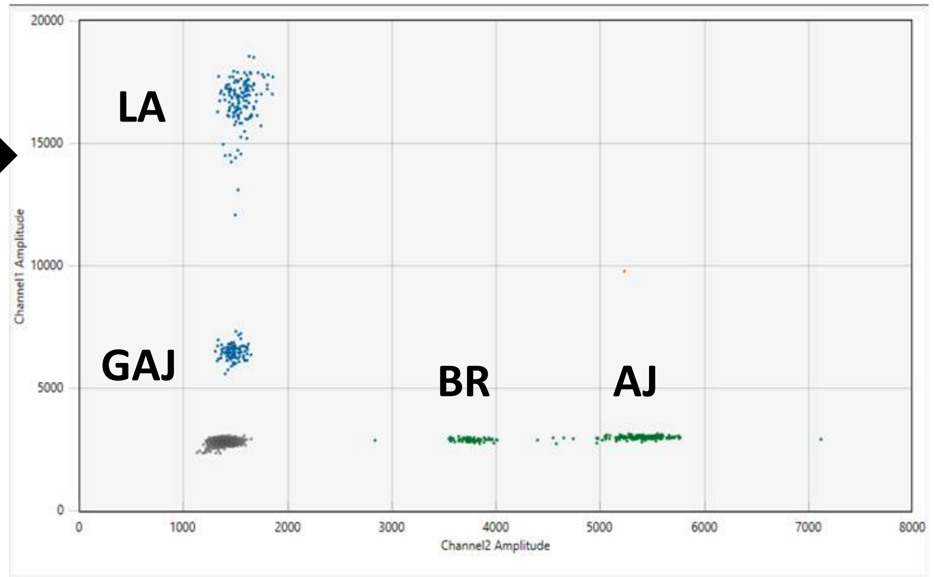
eDNA assay

- Four probes
- > 10 combinations tested
  - ddPCR conditions optimized
  - Cross-test on 24 non-target species including bait and other *Seriola* spp.

primer **4 probes** **primer**

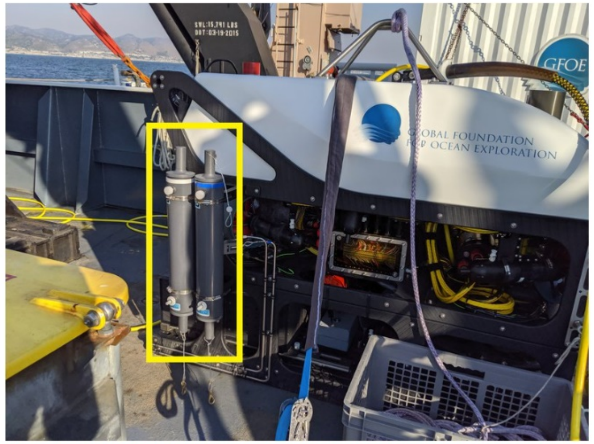
ATGCATGCATGCATGC**AAAA**ATGCATGC**ATGCATGC**
ATGCATGCATGCATGC**TTTTT**ATGCATGC**ATGCATGC**
ATGCATGCATGCATGC**GGGG**ATGCATGC**ATGCATGC**
ATGCATGCATGCATGC**CCCCC**ATGCATGC**ATGCATGC**





eDNA sampling

- Calibration used triplicate Niskin drop sampler
  - Collection/transport of large volumes
  - Filtering occurs on ship or in lab
- Ideas for increasing sampling efficiency
  - Active in-situ pumping system
  - Passive stationary or active towed filter array
  - Mounted on ROV or stationary camera

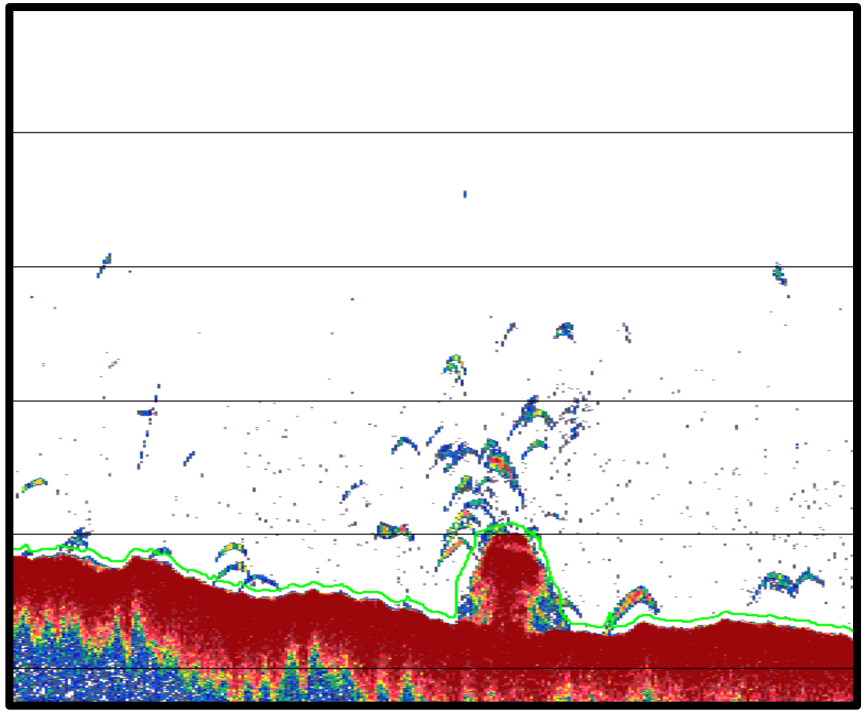


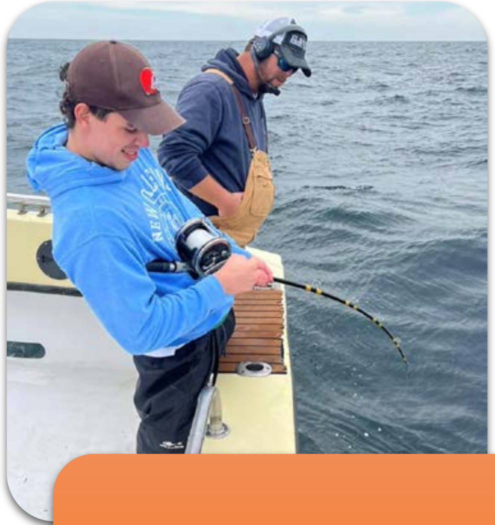
Niskin bottles on the Global Foundation for Ocean Exploration remotely operated vehicle *Yogi. Image courtesy of the Surveying Deep-sea Corals, Sponges, and Fish Habitat Off the U.S. West Coast expedition.* Download larger version (jpg, 6.3 MB).

Active acoustics

Objectives:

- Work through calibration data to:
  - Test abundance estimation
  - Characterize wideband response
  - Optimize survey design
- Process CT scans
  - Currently running on FIU cluster

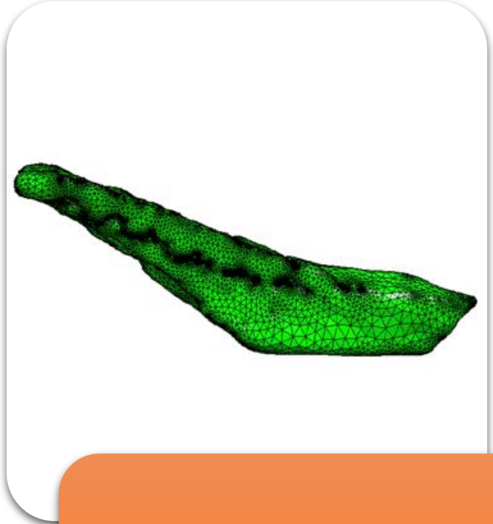




GAJ Collection

CT Scanning

Model Processing



Backscatter Modeling

Example Output

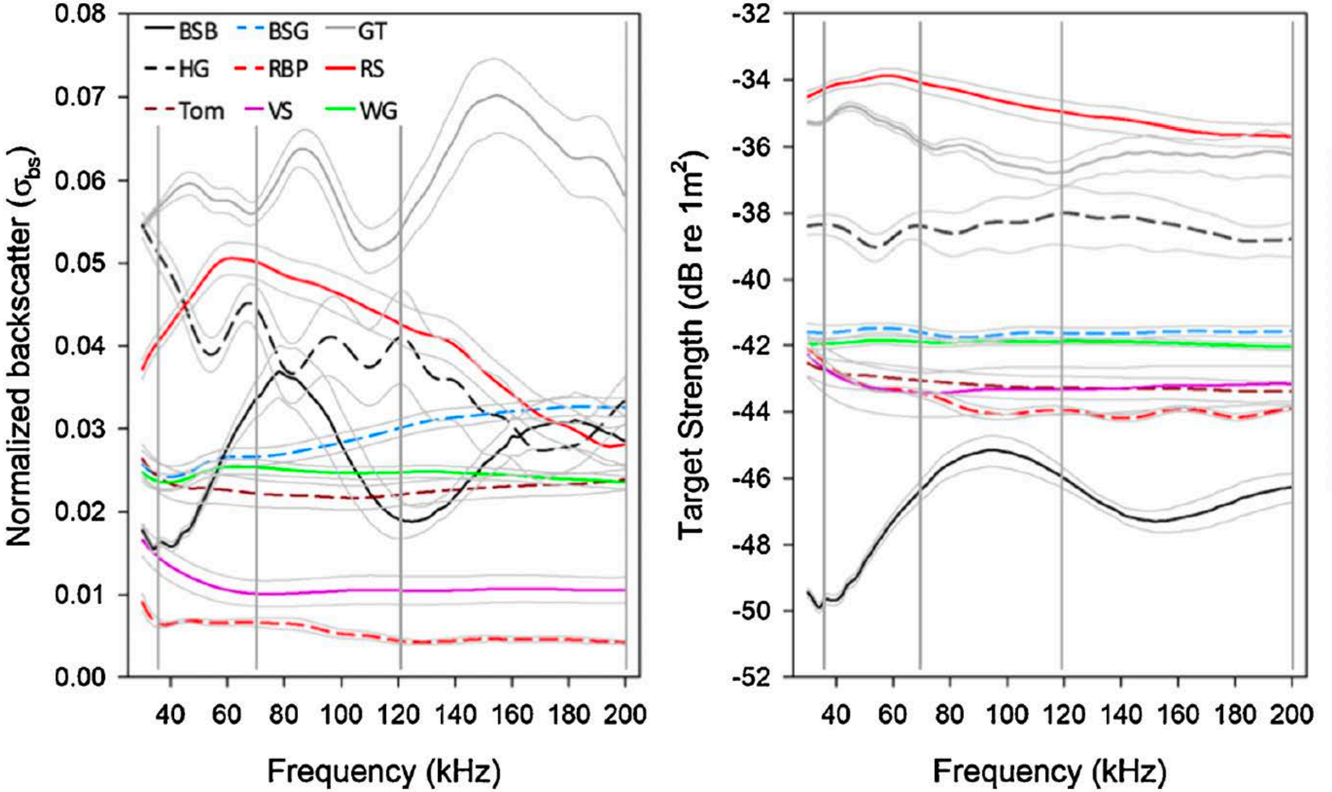


Fig. 6. Species specific averaged σ_{bs} response (m^2) with 95 % confidence intervals (broken lines) around the mean (solid line). Vertical reference lines represent nominal operating frequencies in fisheries acoustics (38, 70, 120, and 200 kHz).

Boswell, KM, *et al*. 2020. Examining the relationship between morphological variation and modeled broadband scattering responses of reef-associated fishes from the Southeast United States. *Fisheries Research* 228: 105590.

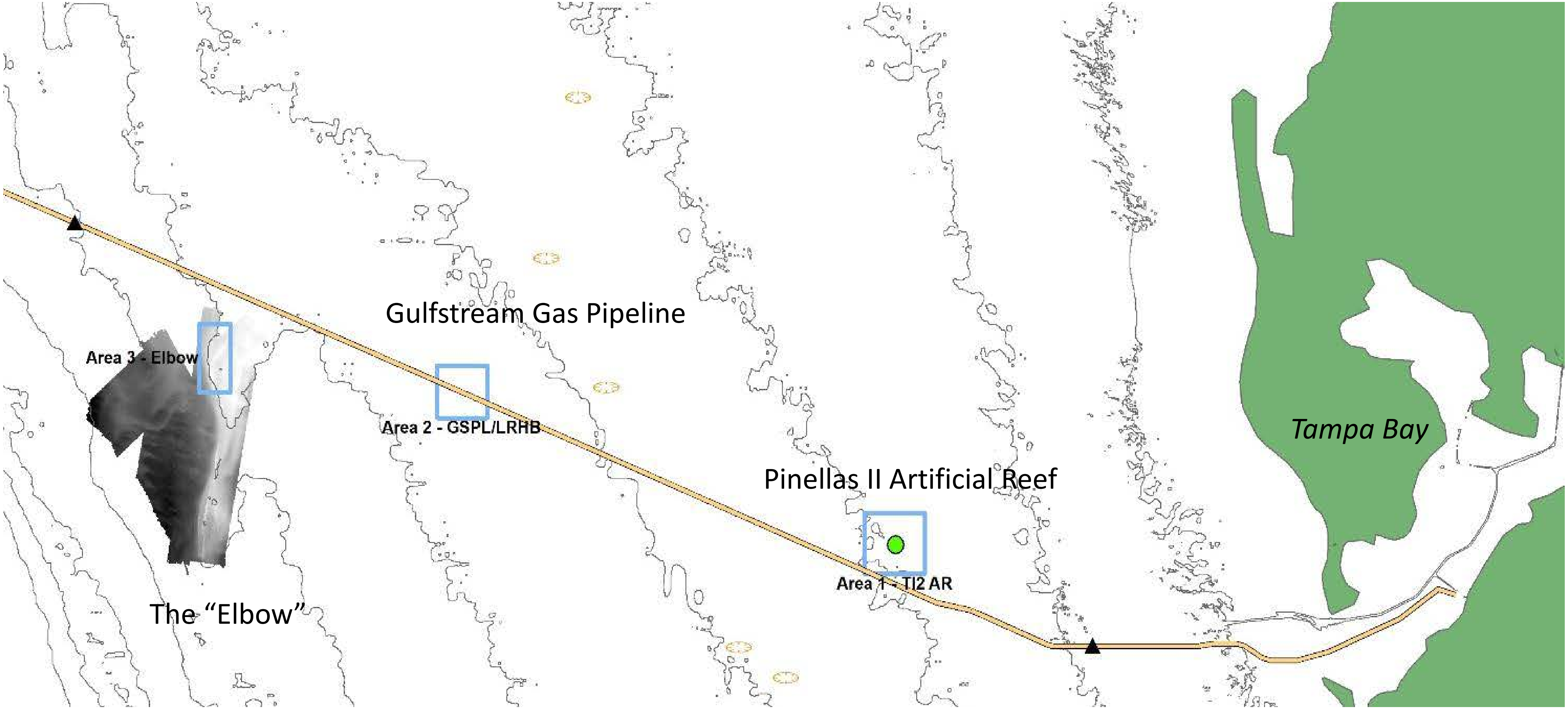
Preliminary results: Calibrations

Calibration: Florida (May 4-10, 2022)

Objectives:

- Test gears
- Deploy multiple gears same-time, same-place
- Compare results among gears
- Estimate calibration factors

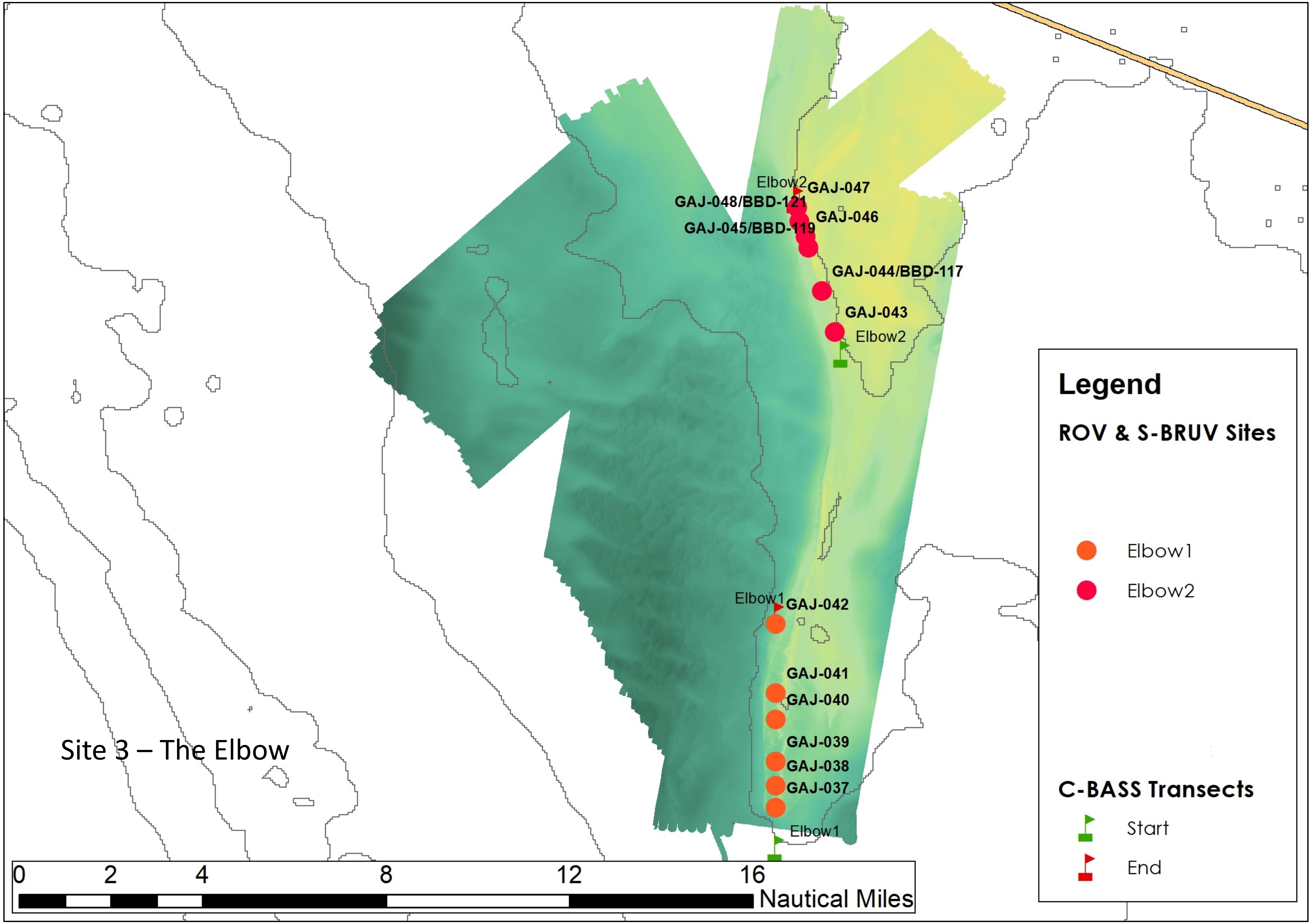
Survey Areas



Sampling protocol

- Each gear sampled every day, order randomized
- Echosounder running continuously
- C-BASS not deployed on artificial reef site

Site	1st Gear	2nd Gear	3rd Gear
Site 1 (Artificial)	S-BRUV	~~C-BASS~~	ROV
Site 2 (Artificial)	~~C-BASS~~	ROV	S-BRUV
Site 3 (Pipeline)	ROV	C-BASS	S-BRUV
Site 4 (Pipeline)	ROV	S-BRUV	C-BASS
Site 5 (Elbow)	S-BRUV	C-BASS	ROV
Site 6 (Elbow)	ROV	C-BASS	S-BRUV

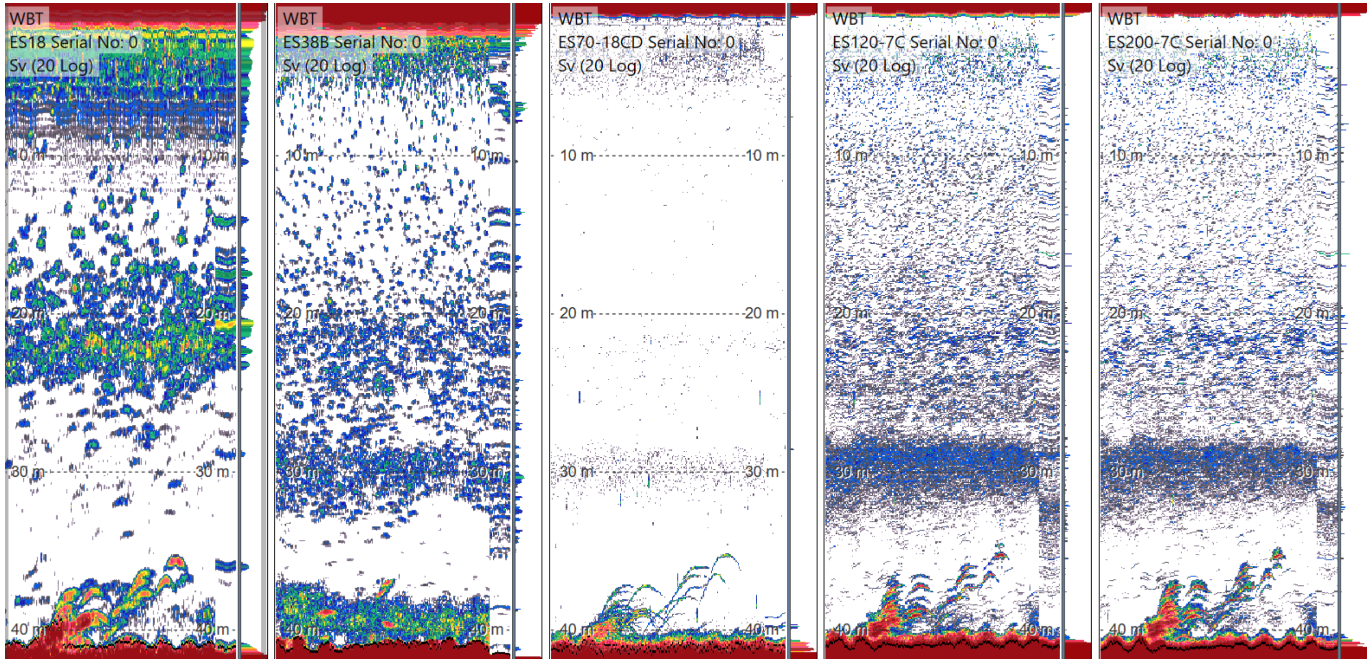

Elbow2
GAJ-047
GAJ-048/BBD-121
GAJ-046
GAJ-045/BBD-119
GAJ-044/BBD-117
GAJ-043
Elbow2
Elbow1
GAJ-042
GAJ-041
GAJ-040
GAJ-039
GAJ-038
GAJ-037
Elbow1
Site 3 – The Elbow
0
2
4
8
12
16
Nautical Miles
Legend
ROV & S-BRUV Sites
Elbow1
Elbow2
C-BASS Transects
Start
End

Preliminary results

- *Seriola* species (Greater amberjack, Almaco Jack, Banded rudderfish) seen at all locations
- All gear systems functioned as designed/expected
- Water visibility generally good to excellent
- ROV and C-BASS (except habitat, 75% complete) video reads are done, S-BRUVs are in progress; EK analyses done

Preliminary results

- ROV
  - *S. dumerili*: 99; *Seriola* spp.: 3
  - Many mixed schools of *Seriola*
  - Highest counts on artificial reefs, much lower on pipeline and Elbow (flat hardbottom, small ledges)
- C-BASS
  - *S. dumerili*: 4; *Seriola* spp.: 7
  - Linking fish to habitat observations
- Echosounder
  - many fish observed, but not categorized to species level
  - working out *Seriola* acoustic signatures
  - Application of abundance models to “always-on” track data problematic
- S-BRUV
  - Video reads not finished



Next steps

- Finish S-BRUV video reads
- Compare S-BRUV to ROV counts
- Parse C-BASS data for overlap with other camera gears and compare
- Test alternative echosounder survey patterns at next calibration

Main takeaways

- Water clarity was good and once video reads are completed, we expect to have data to inform calibration factor estimates among camera gears
- Always-on echosounder of limited value for calculating areal abundance; need to use patterned (parallel lines or flower) survey for spatial models of abundance

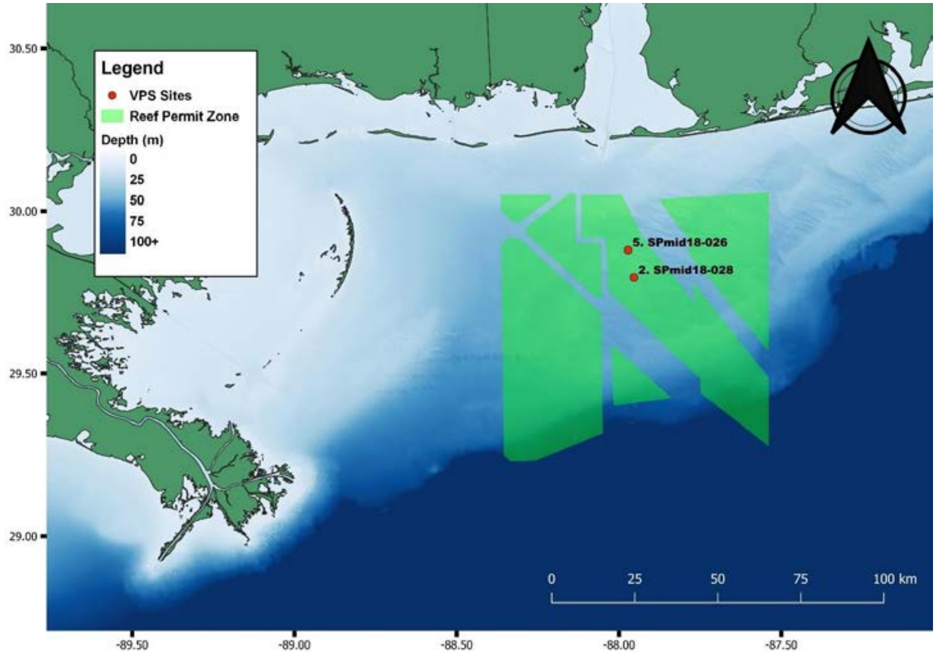
Calibration: Mississippi/Alabama (Aug. 21-Sept. 2)

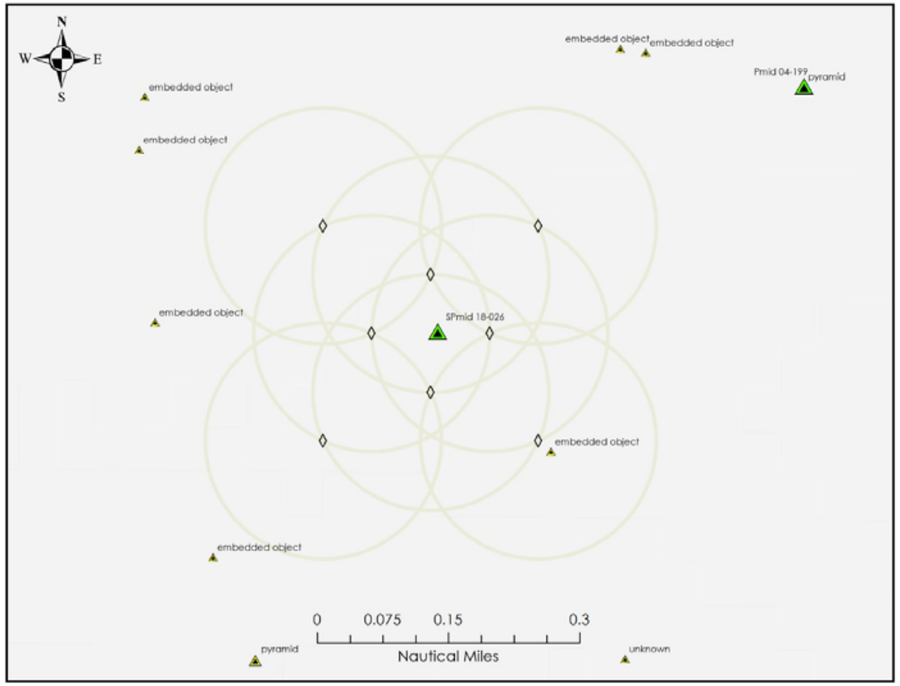
Objectives

- Establish two VPS arrays with acoustically tagged *S. dumerili*
- Deploy multiple camera gears near concurrently in arrays
- Run two different echosounder survey patterns (parallel lines, flower) near concurrently in arrays
- Use VPS triangulated positions in combination with observations of tagged and untagged S. dumerili from camera gears to calculate Lincoln-Peterson abundance estimates as “ground truth”
- Use VPS triangulated positions to quantify behavioral changes in response to gear deployments
- Trial eDNA sample collection and assay efficacy at sites with known *S. dumerili*

Methods

- VPS arrays deployed at two sites
- “Super pyramids” 25’ tall, 15’ base
- 8 receivers per site
- Min range ~ 250m
- Min coverage area ~20 hectares
- Acoustic + dart tags: 18 & 20 fish
- Dart tags: 5 & 3 fish



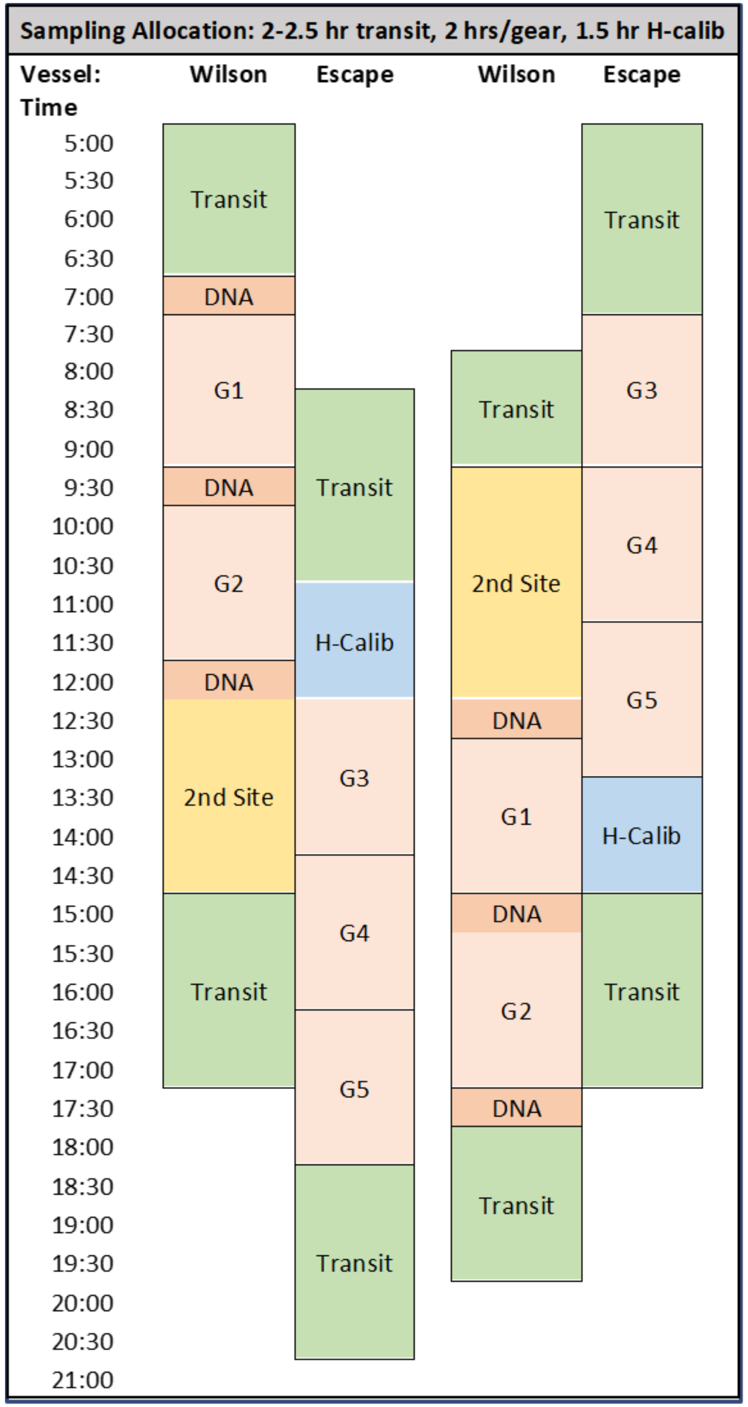


Methods

- Two vessels
  - Escape:
    - ROV (AL/MS)
    - Drop Cam (Western GoM)
    - Active acoustics (All regions)
  - Wilson:
    - Trap Cam (SERFS)
    - S-BRUV (SA and FL)
    - eDNA (AL/MS)

Methods

- One site designated as primary each day (alternate days)
- All gears deployed at primary site, with opportunistic deployments of “Wilson” gears at secondary site
- Vessel, gear order randomized each day except eDNA (before, after, and between other gears)

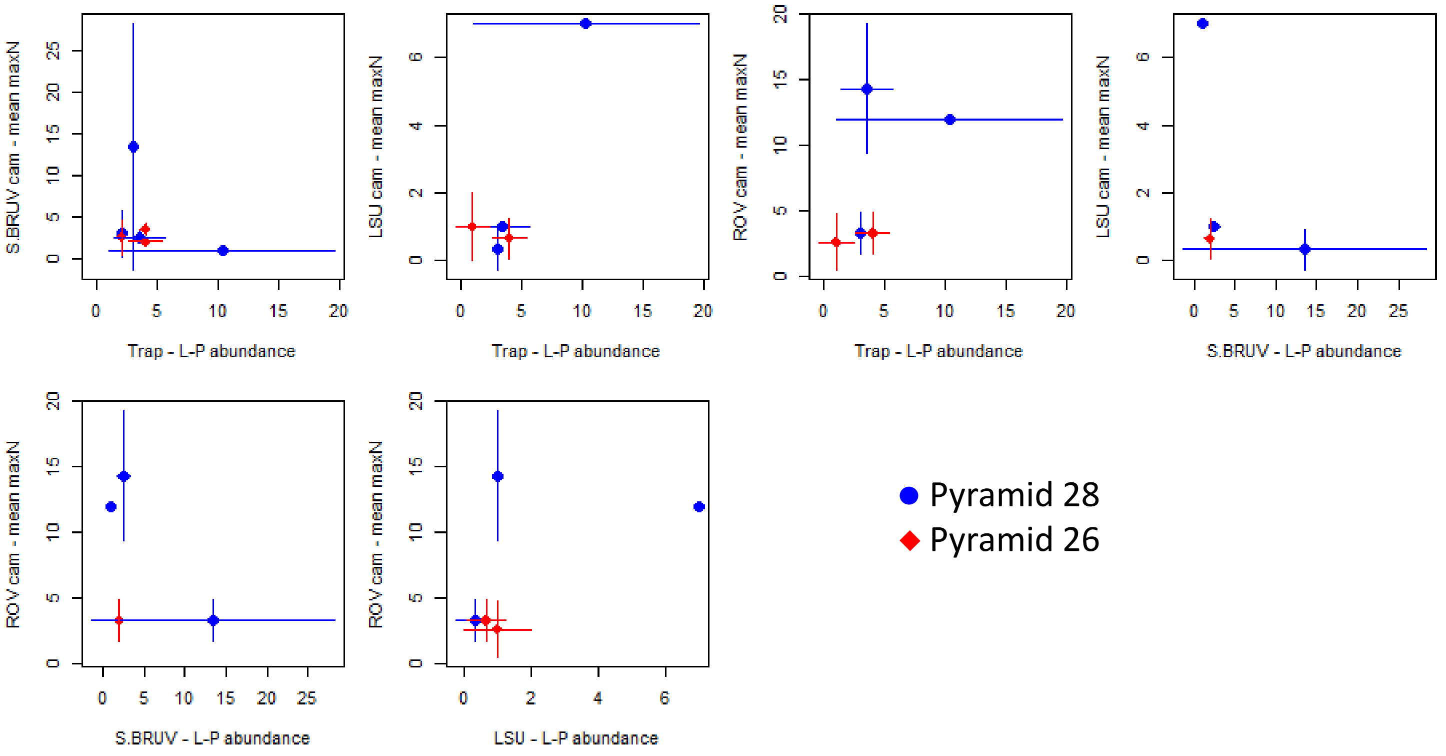


Preliminary results: camera gears

- Bait
  - Half of the S-BRUV drops were baited with the other half unbaited
  - No obvious difference in counts
- Proximity to reef
  - Half of the S-BRUV drops and half of the Trap Cam drops were near the reef (within 20 m) and half were far from the reef (~100 m away)
  - Near counts were substantially higher than far counts (mostly zeros)
- Time period
  - For some gears (Drop Cam, Trap Cam, S-BRUV), separate maxN counts were made for different periods over the deployment
  - Descent period had higher but more variable counts than bottom and ascent periods
  - Ascent period had lowest counts (mostly zeros)

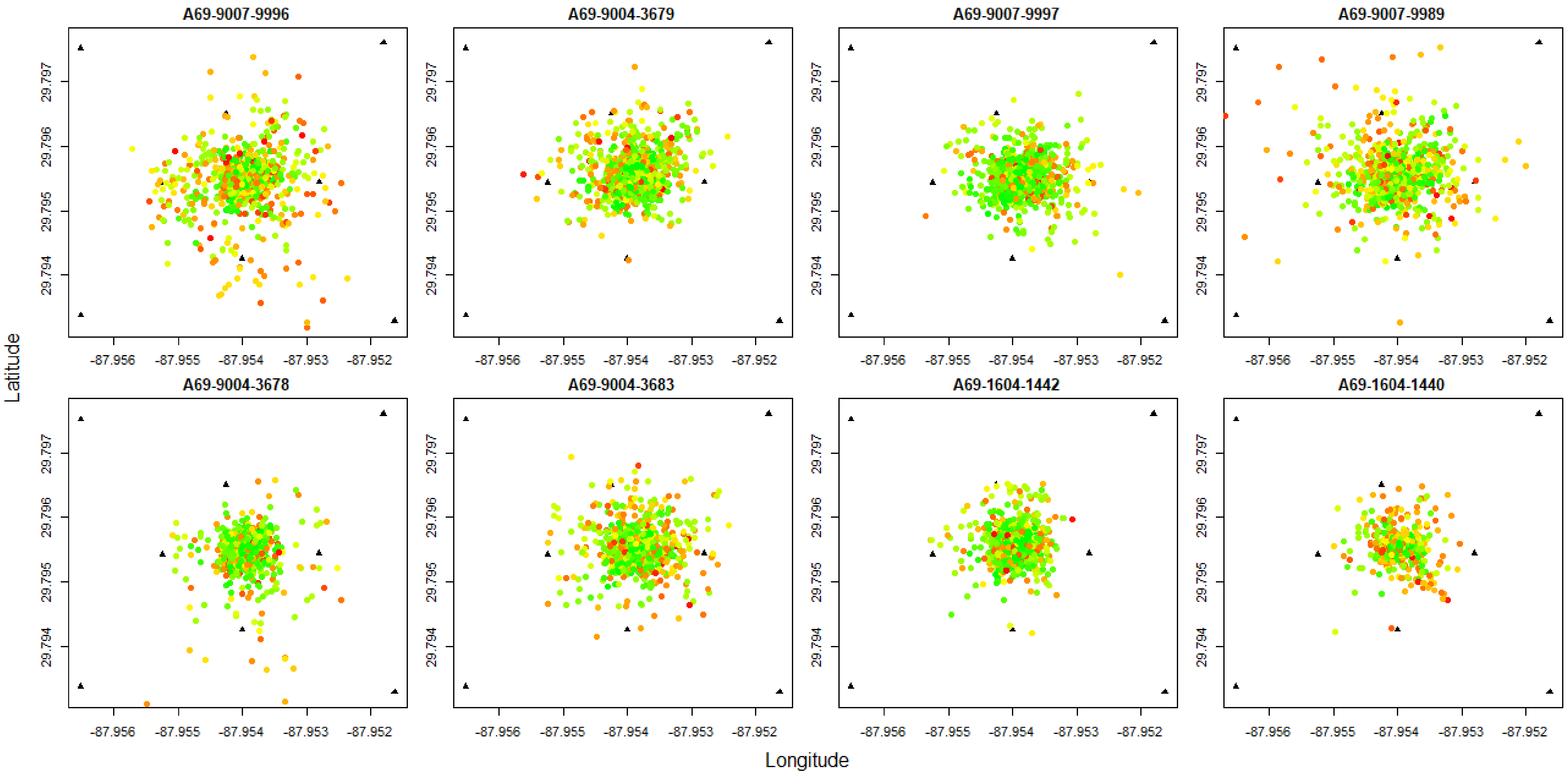
Preliminary results: camera gears

- Location
  - All gears had higher counts on Pyramid 28 than Pyramid 26
- Camera gear comparisons
  - ROV counts were generally higher than counts from other camera gears
  - Other than a general trend of higher counts on Pyramid 28, there were no strong correlations among camera gears
  - We believe that this will resolve with more concurrent samples at a larger number of sites



Preliminary results: VPS array

	Pyramid 26	Pyramid 28
Tagged (dart)	5	3
Tagged (acoustic + dart)	18	20
Detected	12	19
Positions	12	17
Stationary and/or outside array	4	6
Moving (low persistence)	1	0
Moving (moderate persistence)	2	4
Moving (high persistence)	5	7



A69-9007-9996
A69-9004-3679
A69-9007-9997
A69-9007-9989
A69-9004-3678
A69-9004-3683
A69-1604-1442
A69-1604-1440
29.797
29.796
29.795
29.794
-87.956
-87.955
-87.954
-87.953
-87.952
Latitude
Longitude

Lincoln-Petersen density estimate

- Standard L-P mark-recapture density estimator

$$N = \frac{nK}{k}$$

…where n is the number of fish tagged, K is the number of fish recaptured and k is the number of recaps that were tagged

- Assumes that system is closed, so no tagged fish die or leave system between tagging event and recapture event

VPS L-P density estimate (Shertzer et al, 2020)

- Use acoustically tagged fish to estimate loss factor (combined effect of emigration, mortality, etc.) for all tagged fish
- Apply this factor to number of fish initially tagged to get estimate of number of tagged fish at time of recapture event

$$n = n_a + n_d$$

…where n_a is the initial number of acoustically tagged fish and n_d is the initial number of dart tagged fish

$$n' = n'_a + \frac{n_d n'_a}{n_a}$$

…where n'_a is the number of acoustically tagged fish present based on the VPS position data and n' is the new estimate of the total number of tagged fish present during a recapture event

- Then use this estimate of tagged fish present during the recapture event in the L-P density estimator…

$$N' = \frac{n' K}{k}$$

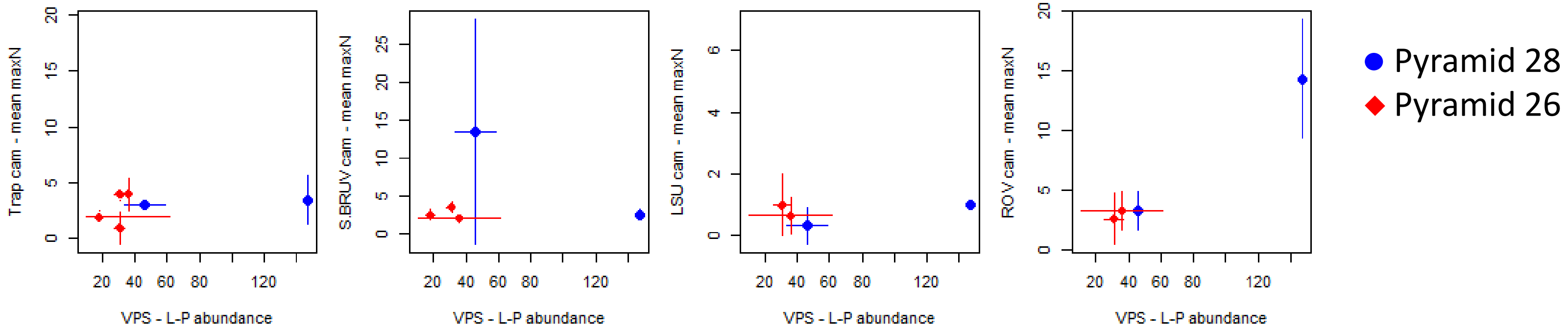
…to estimate N' or the number of fish present during the recapture event

VPS L-P density estimate

- Few samples where tagged fish were observed; highest number of tagged fish was 1
  - ROV: 5 of 13
  - LSU cam: 0 of 14
  - Trap cam: 2 of 29
  - S-BRUV: 2 of 31

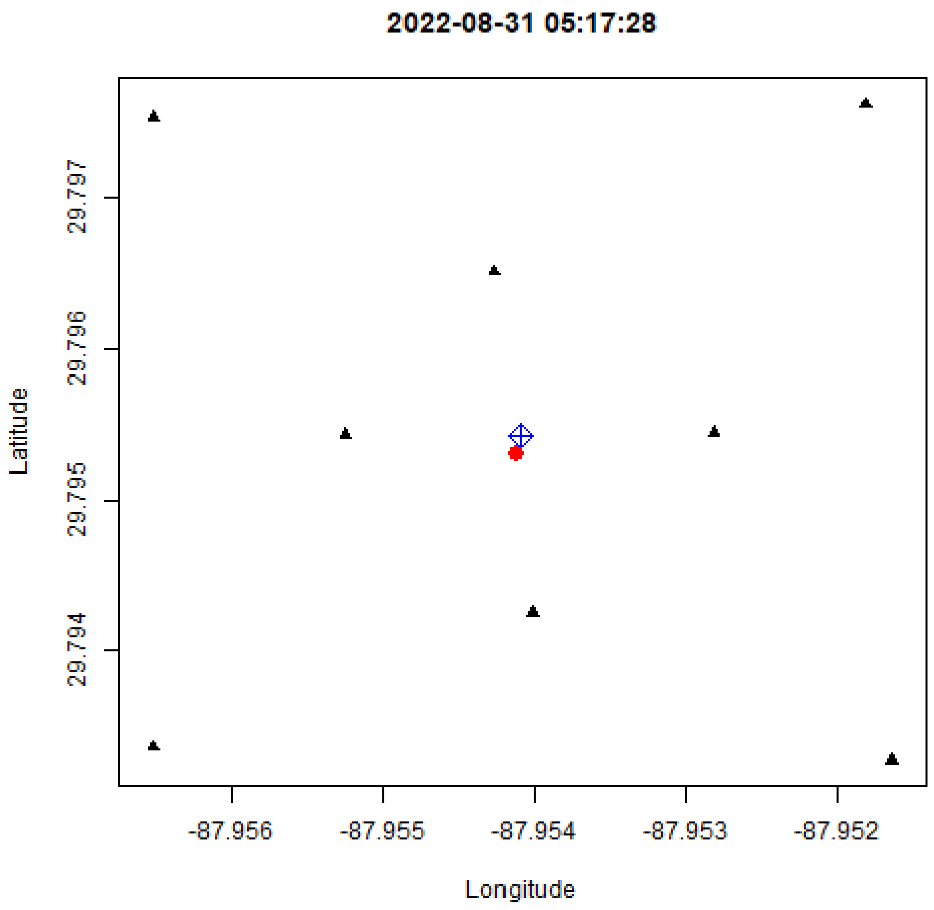
VPS L-P density estimate

VPS L-P estimates		
	Pyramid 26	**Pyramid 28**
8/29	31 (S-BRUV)	
8/30	54 (ROV); 18 (S-BRUV)	
8/31		37, 55 (ROV)
9/01	35 (ROV); 27 (Trap)	
9/02	18 (Trap)	147 (ROV)



VPS behavioral response to gears

- Analyze changes in behavior during gear deployments
- Changes in step length and direction before, during, and after deployment of different gears
- Estimate gear-induced change in density
  - More relevant for continuous vs. discreet habitat patches



Active acoustics

Objectives:

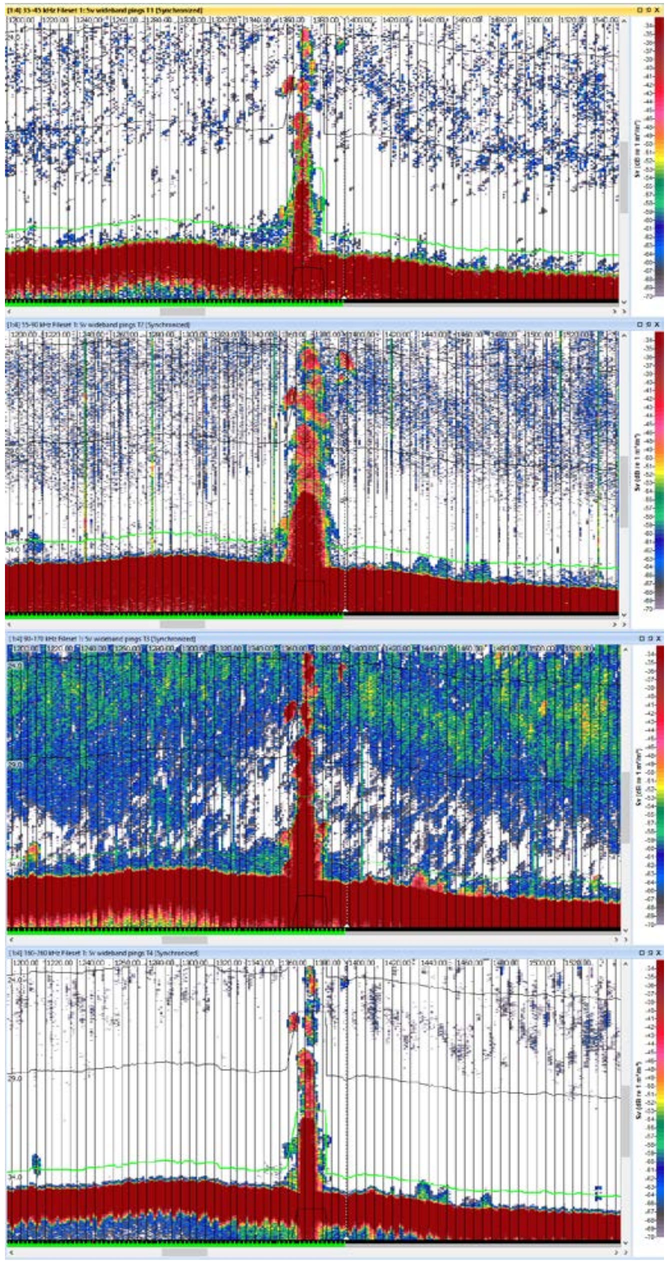
- Test abundance estimation
- Characterize wideband response
- Optimize survey design

Data collection:

- Completed one of each survey type each day (3 on SP28, 2 on SP26)
- Four frequencies treated independently
    - 38 (35-45 kHz)
    - 70 (45-90kHz)
    - 120 (90-170kHz)
    - 200 (160-260kHz)

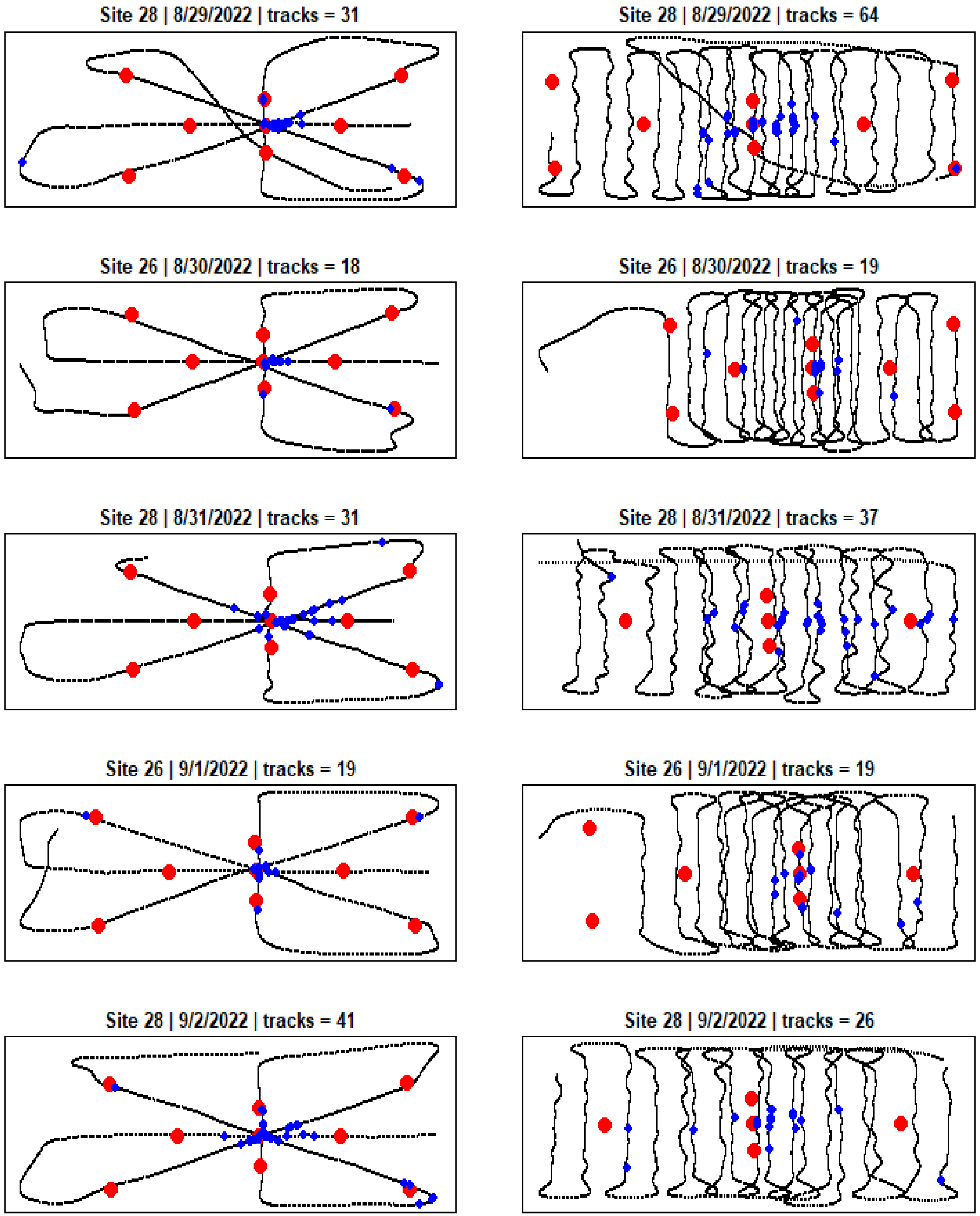
Active acoustics

- Beam angle
  - Interaction with depth to determine beam width
  - Can also affect interference related to structures
- Frequency
  - Depending on acoustic signatures, determines ability to observe targets
  - Higher frequencies have higher bandwidth
    - Detect wider range of target types
    - Cost: reduced operational depth
- Results of CT scans combined with calibration results will help us optimize



Active acoustics

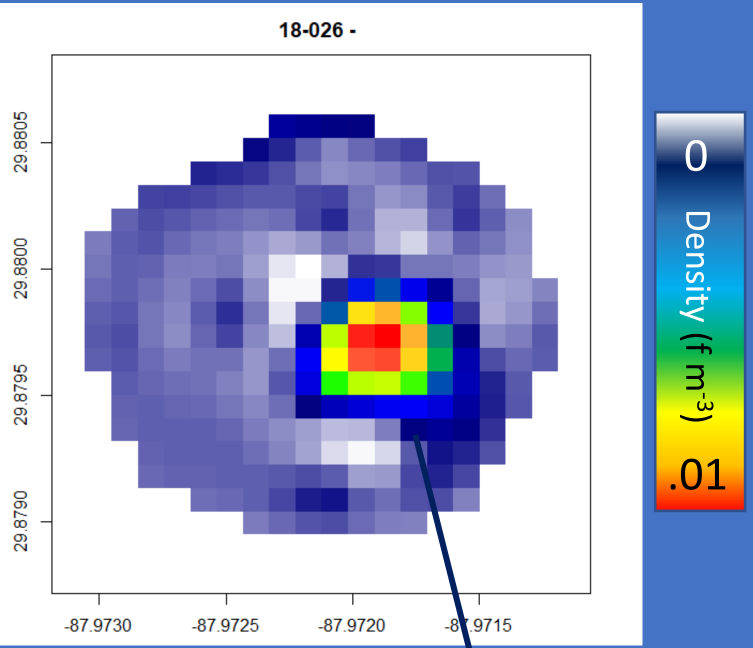
- Fish track counts variable but within reasonable range (18-64 fish per survey)
- Need spatial model to interpolate for density estimates



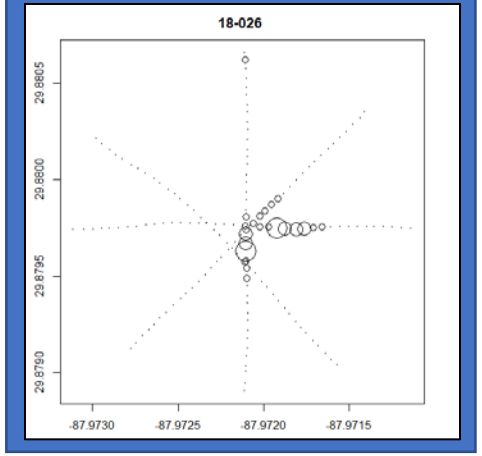
Spatial Modeling for Abundance Estimation:

- Considered kriging – exponential decay – GAM
- GAM shown to perform well on isolated structures and continuous reefs
- Evaluated across all 4 transducers independently
- Estimates of density (f m^{-3}) are scaled to survey volume for abundance

Density predicted for each cell in grid

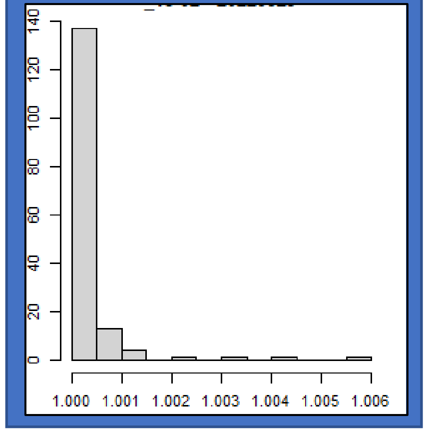


Density evaluated in 5x5m cells (#fish / cell volume)

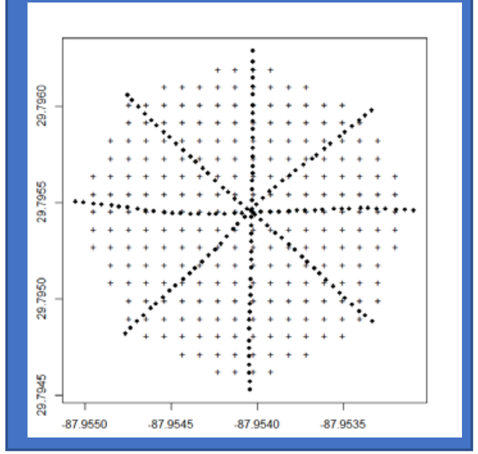


GAM used to model fish density: y ~ s(Lat, Lon)

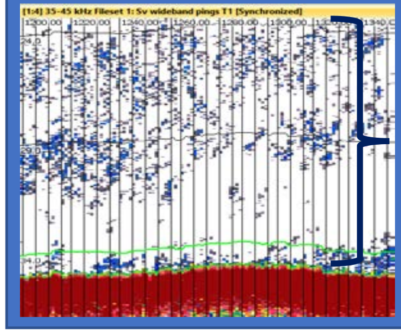
Tweedie and Gamma*



Grided convex hull generated for predictions



Depth x cell area x density = cell abundance

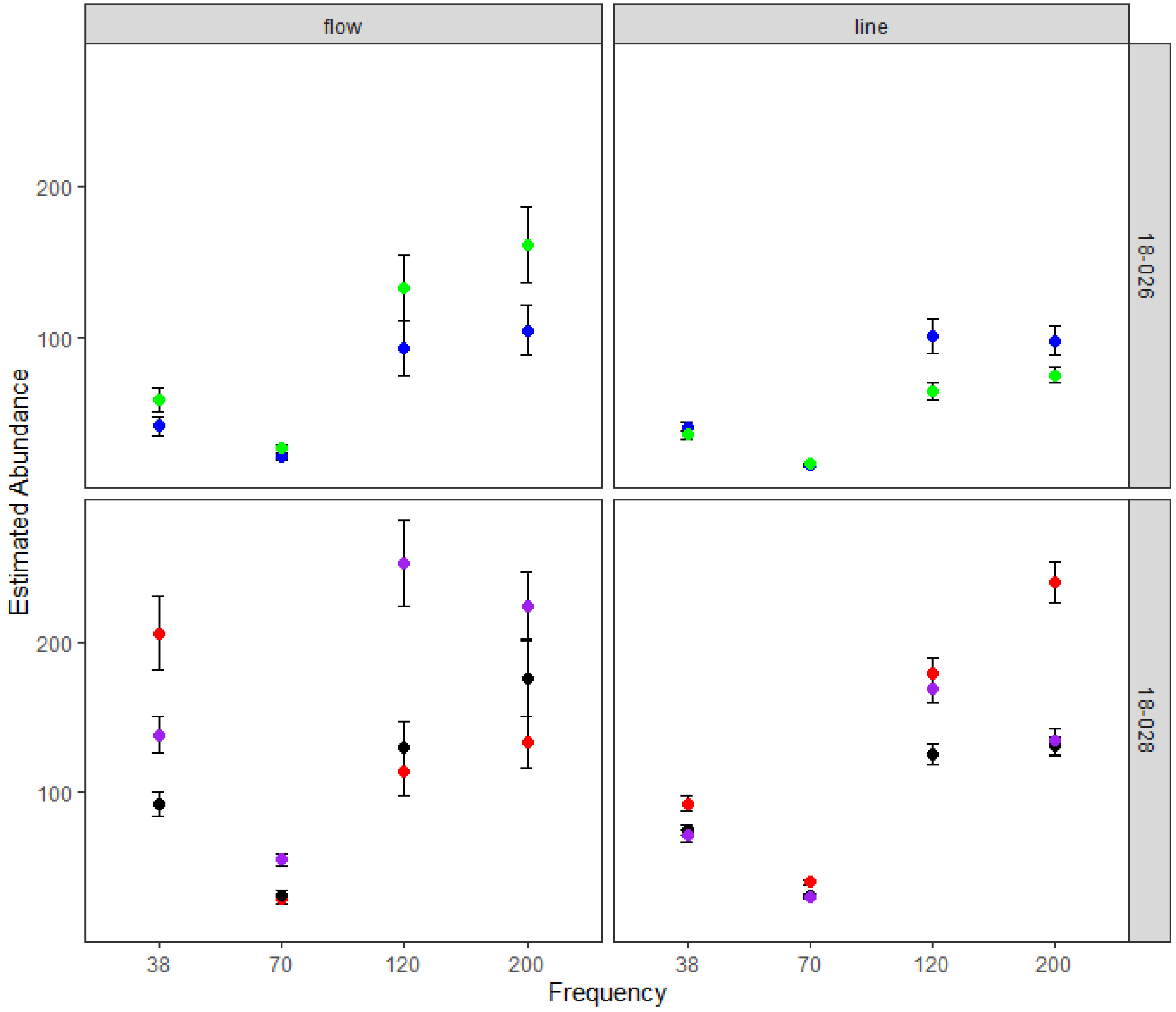


Abundance Estimate = sum of cell abundance

*CV estimated from model predictions

Active acoustics

- High variability in predicted density among frequencies
  - Interplay between detectability and beam angle (volume sampled)
- Weak correlations between predicted density and ROV counts, except for 120 kHz
- Preliminary results for 70 kHz echosounder are similar to those from the VPS L-P abundance estimates
- Parallel lines give similar results to flower survey, but with substantially lower variance (but note that the total area covered was higher for parallel lines)



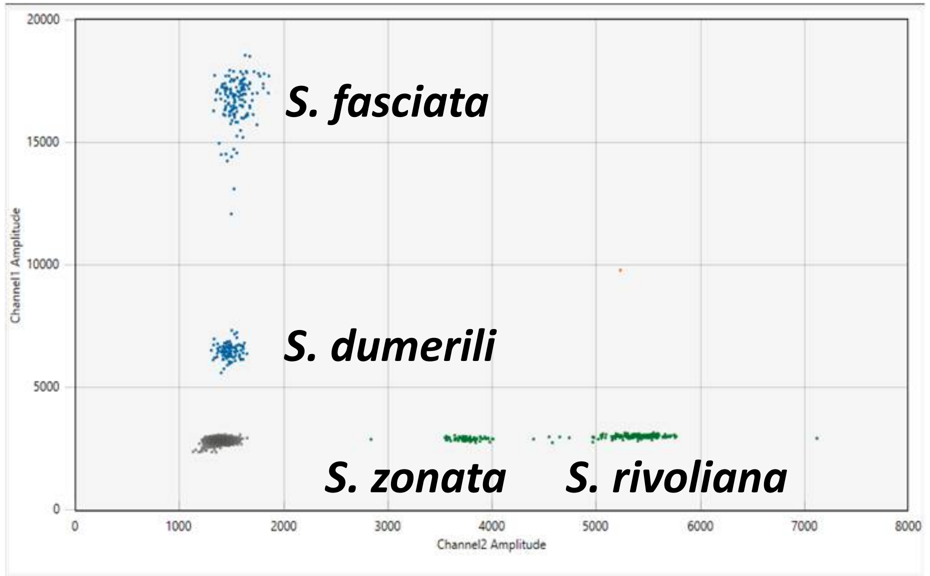
Active acoustics

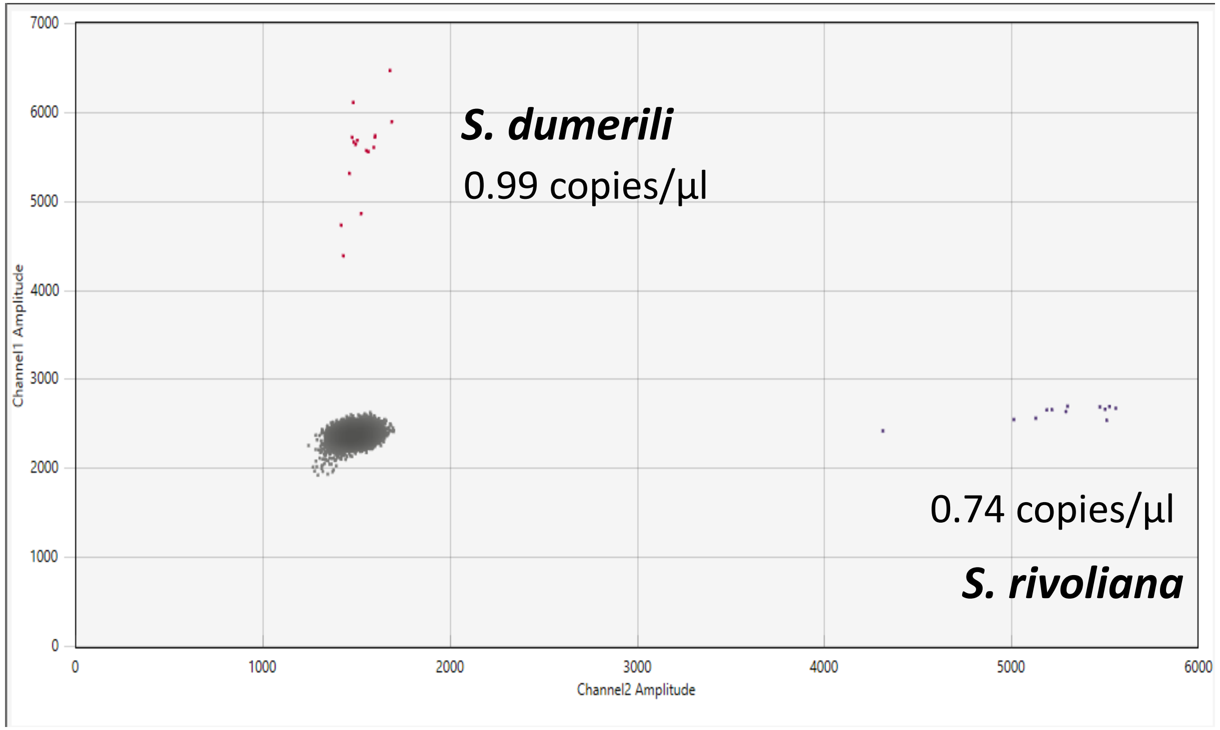
Next steps:

- Standardize beam angle across frequencies to isolate “beam volume dependent detectability” observed in analysis
- Evaluating alternative spatial models
- Calibrate against camera gears across a wider range of fish densities

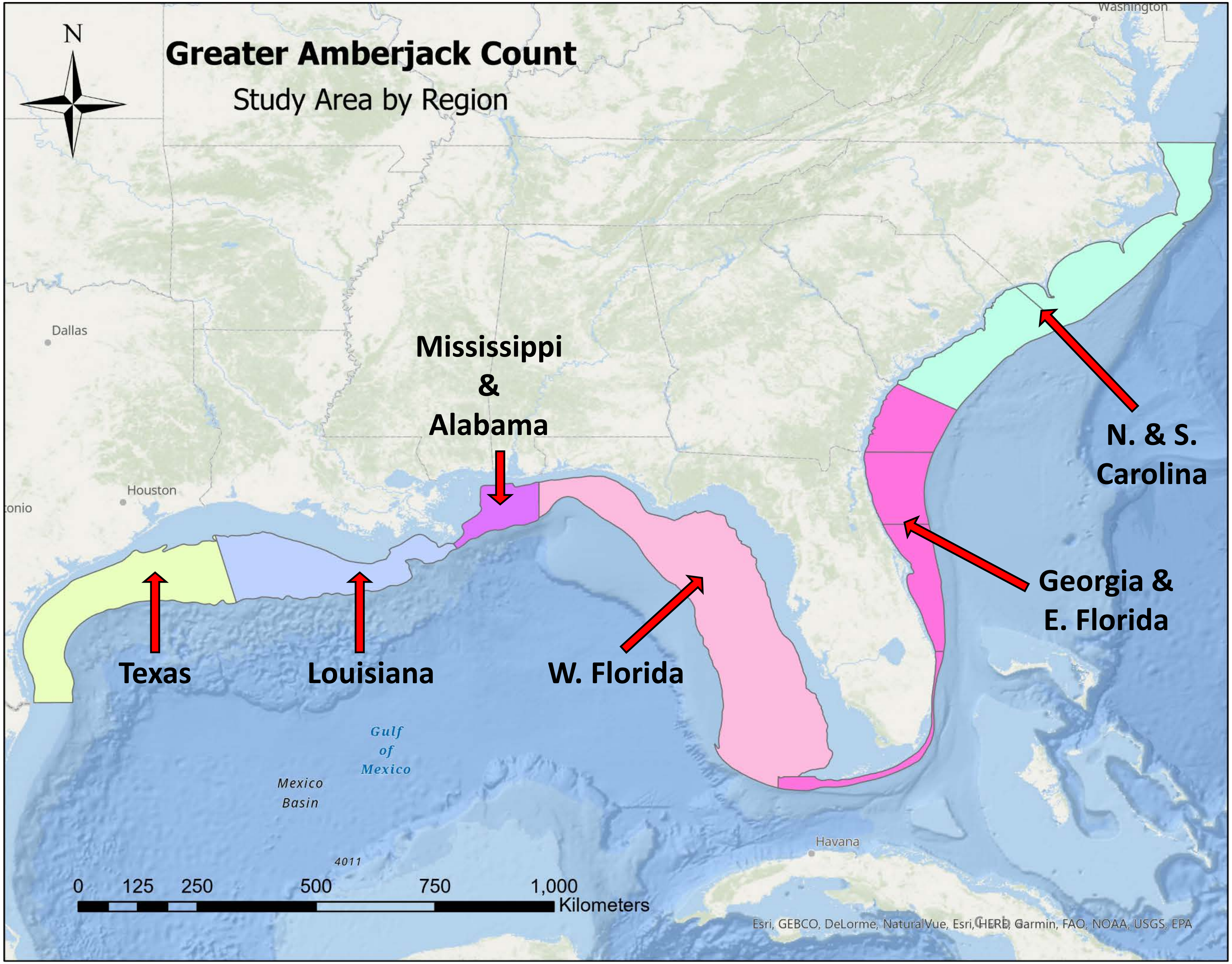
eDNA

- Of six processed samples (from one day at each site)
  - 4 positive for *S. dumerili*
  - 3 positive for *S. rivoliana*
- Plans to increase detectability
  - Reduce filter pore size
  - Sample downcurrent of site
  - Increase replicate samples
  - Improve cost efficiency





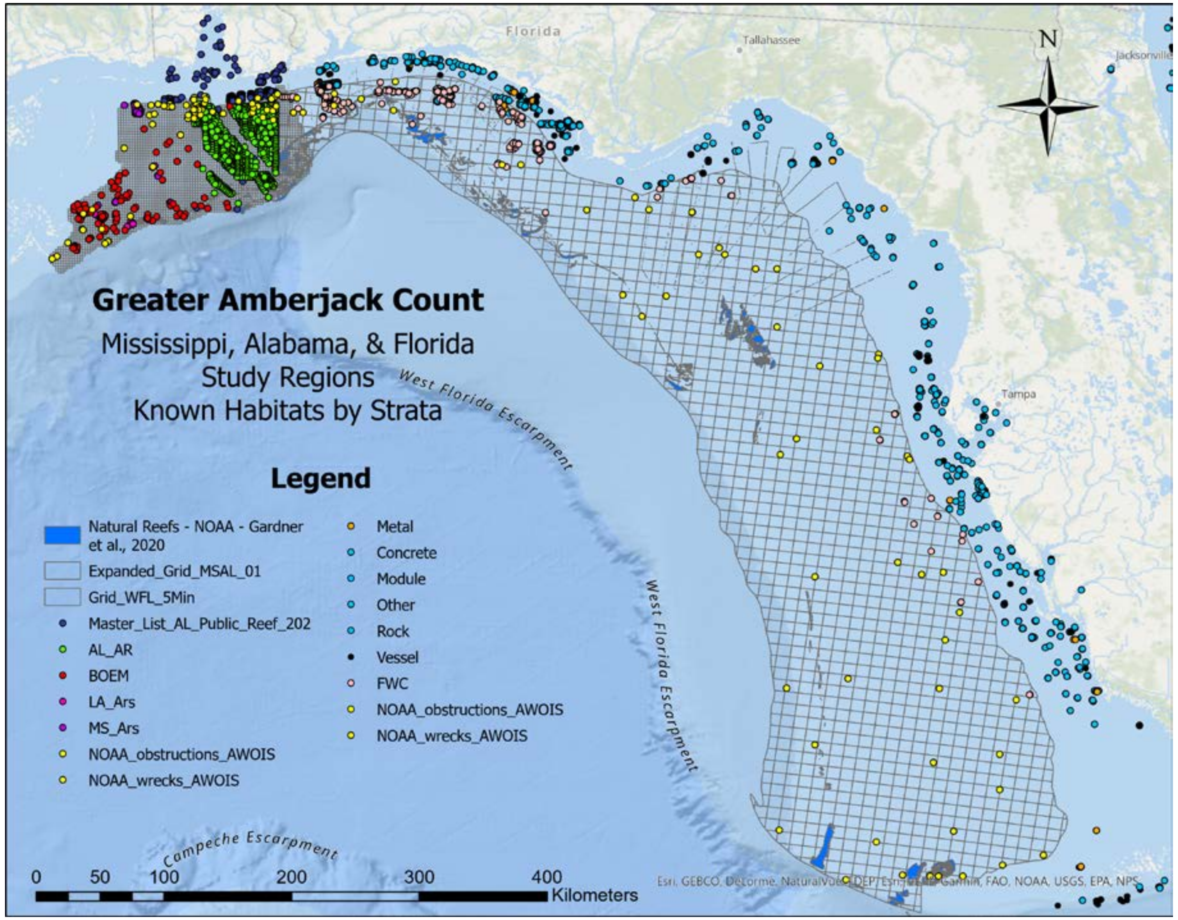
Synthesis of existing habitat and abundance data



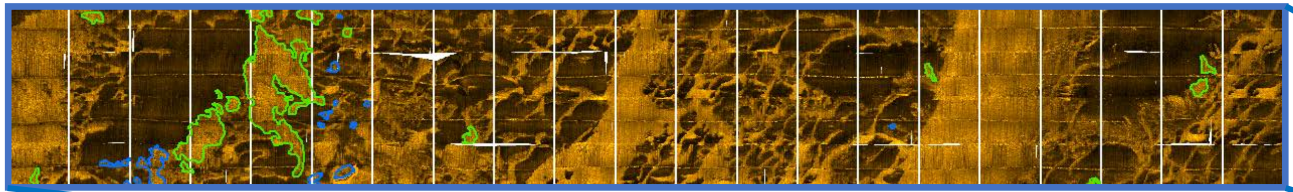
N
Greater Amberjack Count
Study Area by Region
Washington
Dallas
Houston
onio
Mississippi
&
Alabama
N. & S.
Carolina
Georgia &
E. Florida
Texas
Louisiana
W. Florida
Gulf
of
Mexico
Mexico
Basin
4011
Havana
0
125
250
500
750
1,000
Kilometers
Esri, GEBCO, DeLorme, NaturalVue, Esri, HERE, Garmin, FAO, NOAA, USGS, EPA

Habitat synthesis: Eastern GoM regions

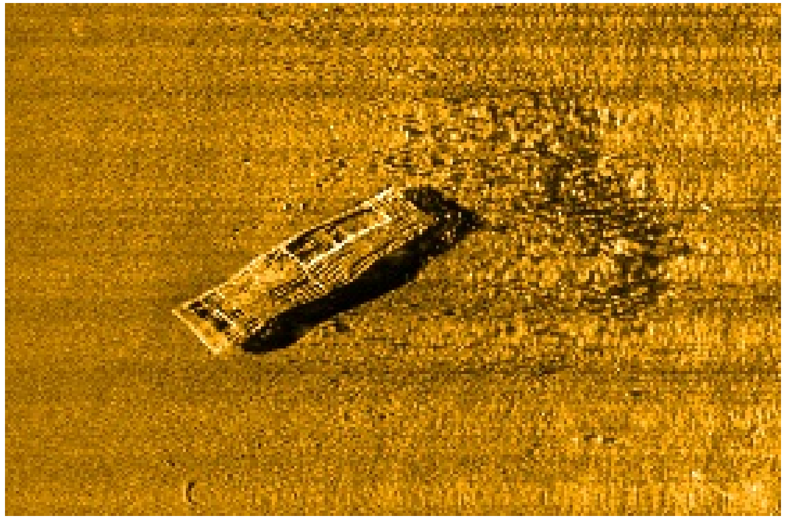
- Lists of artificial reef location/type/size (FWC, AL-MRD, BOEM, NOAA-ENC)
- Scaleable habitat data: manually digitized SSS habitat maps for randomly selected grid cells (FWC, USA)
- Will use to…
  - Select sampling sites
  - Estimate areal extent of natural habitats
  - Estimate number and types of artificial habitats
  - Extrapolate habitat-specific GAJ abundance estimates

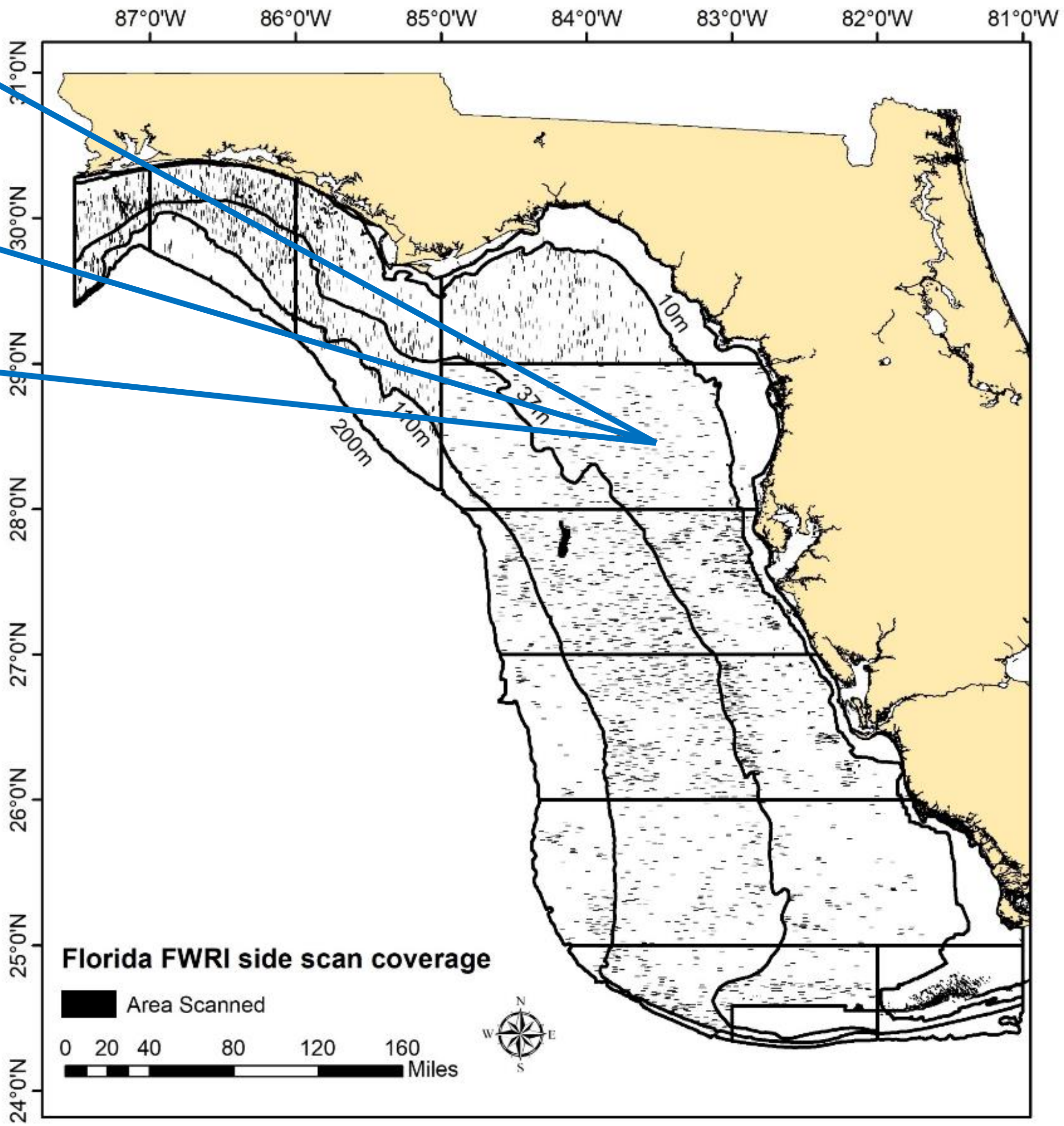


West Florida: scaleable habitat data

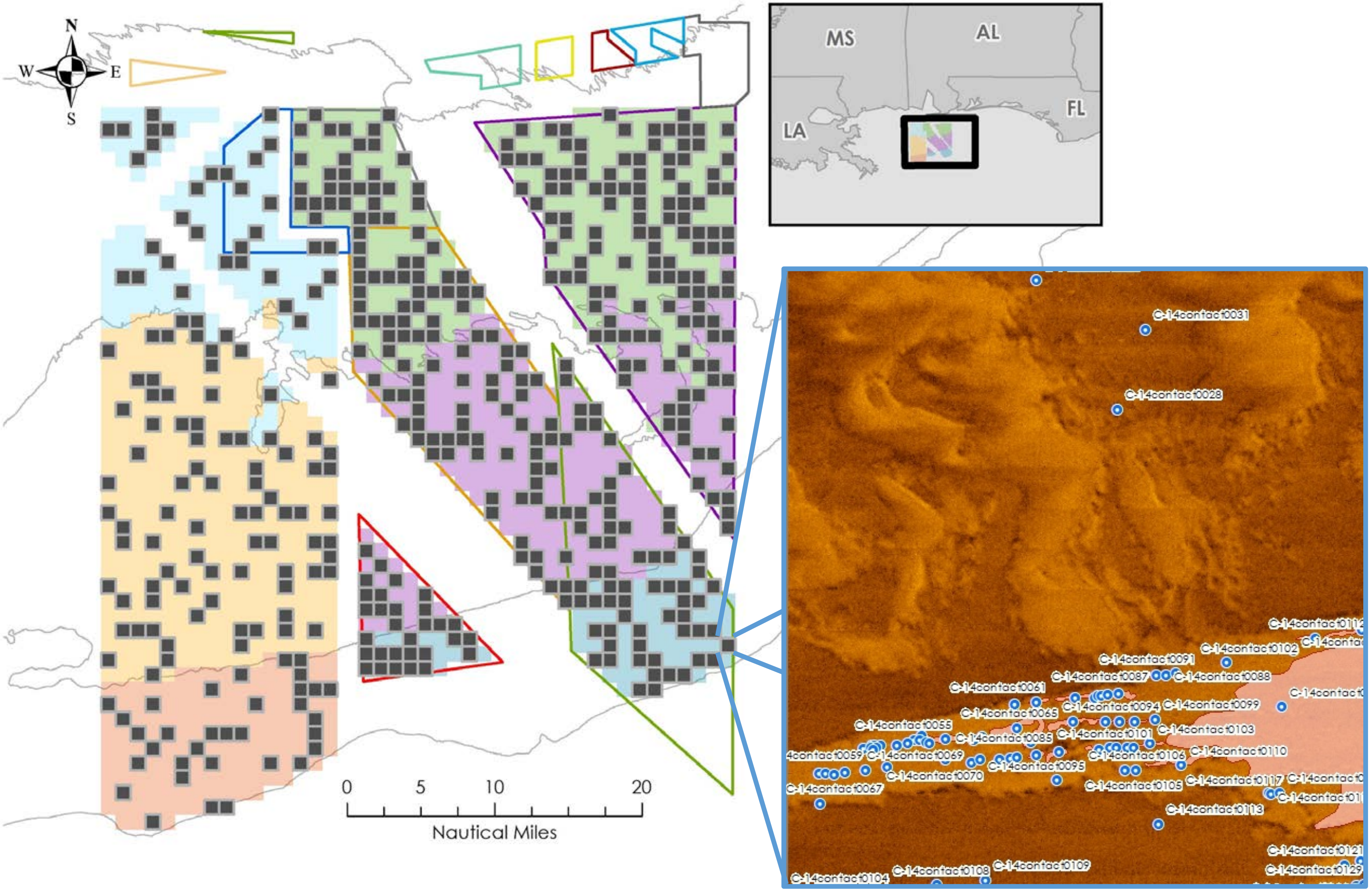


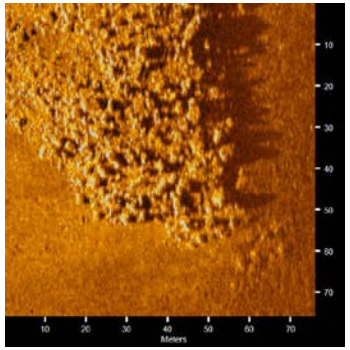
Klein 3900 SSS @ 445 kHz

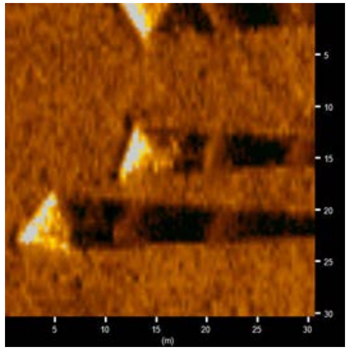


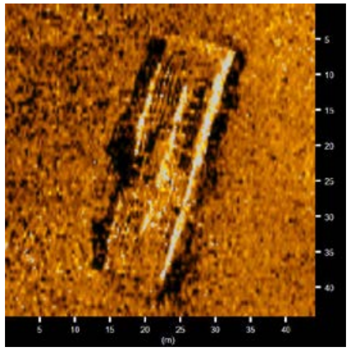


Alabama: scaleable habitat data



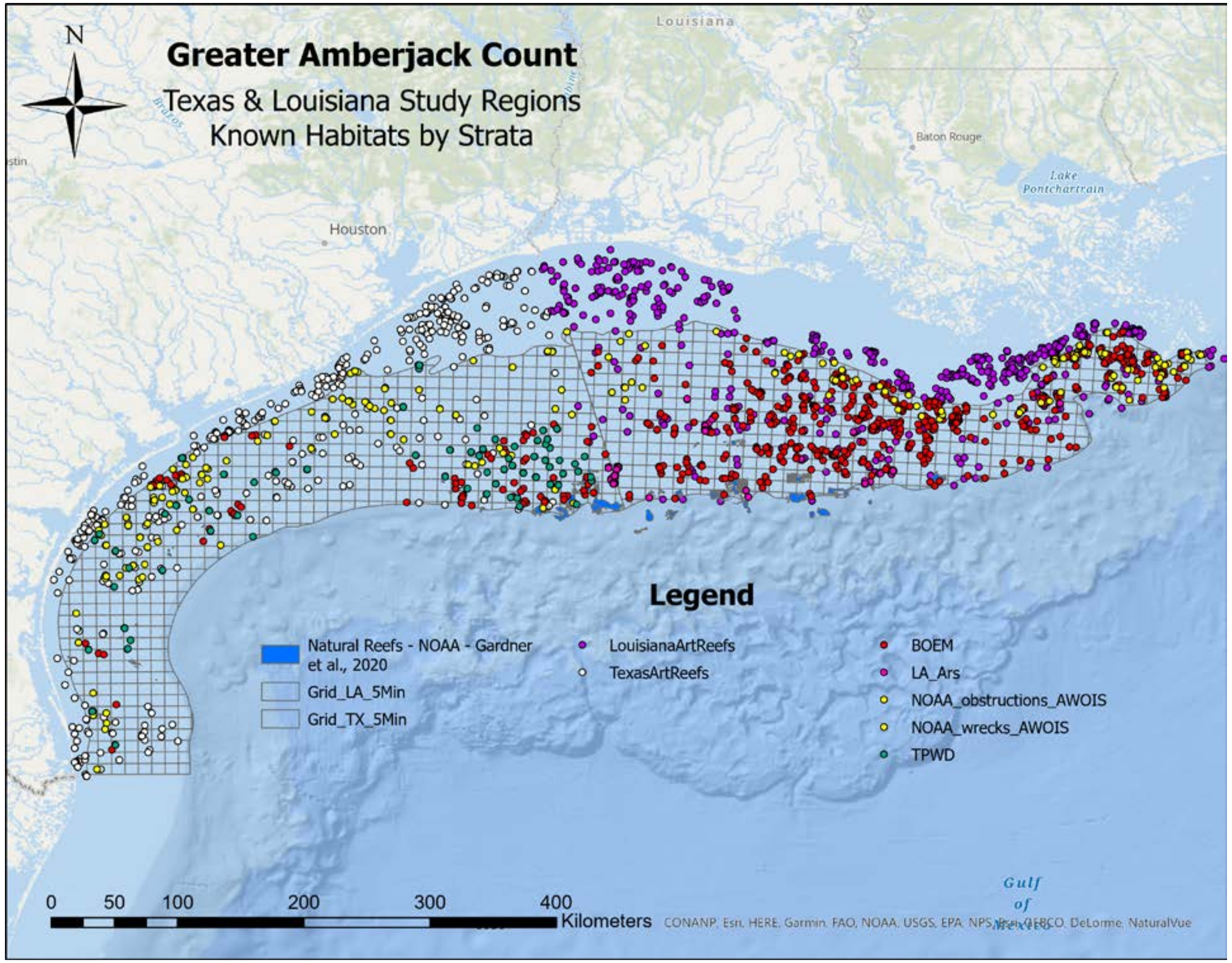






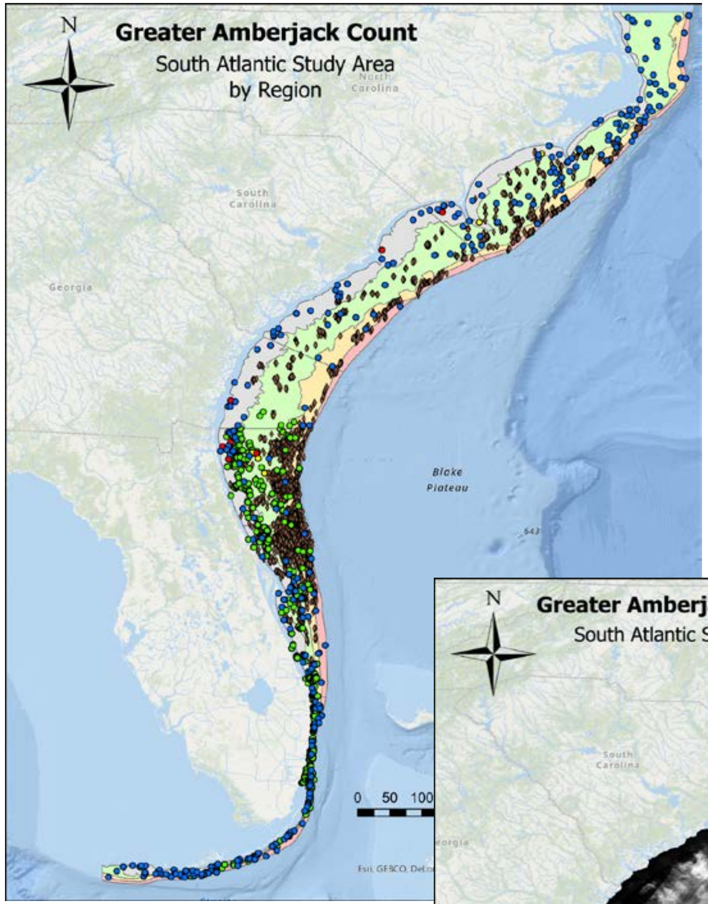
Habitat synthesis: Western GoM regions

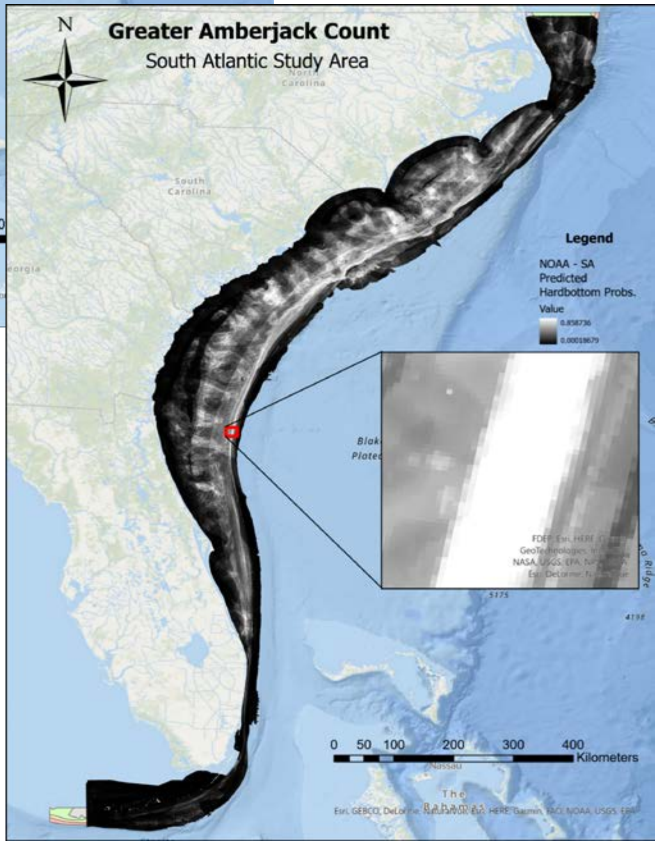
- Lists of artificial reef location/type/size (LDFW, TPWD, BOEM, NOAA-ENC)
- Scaleable maps of natural habitat location and extent (LDFW, TPWD, Gardner et. al. 2022)



Habitat synthesis: South Atlantic

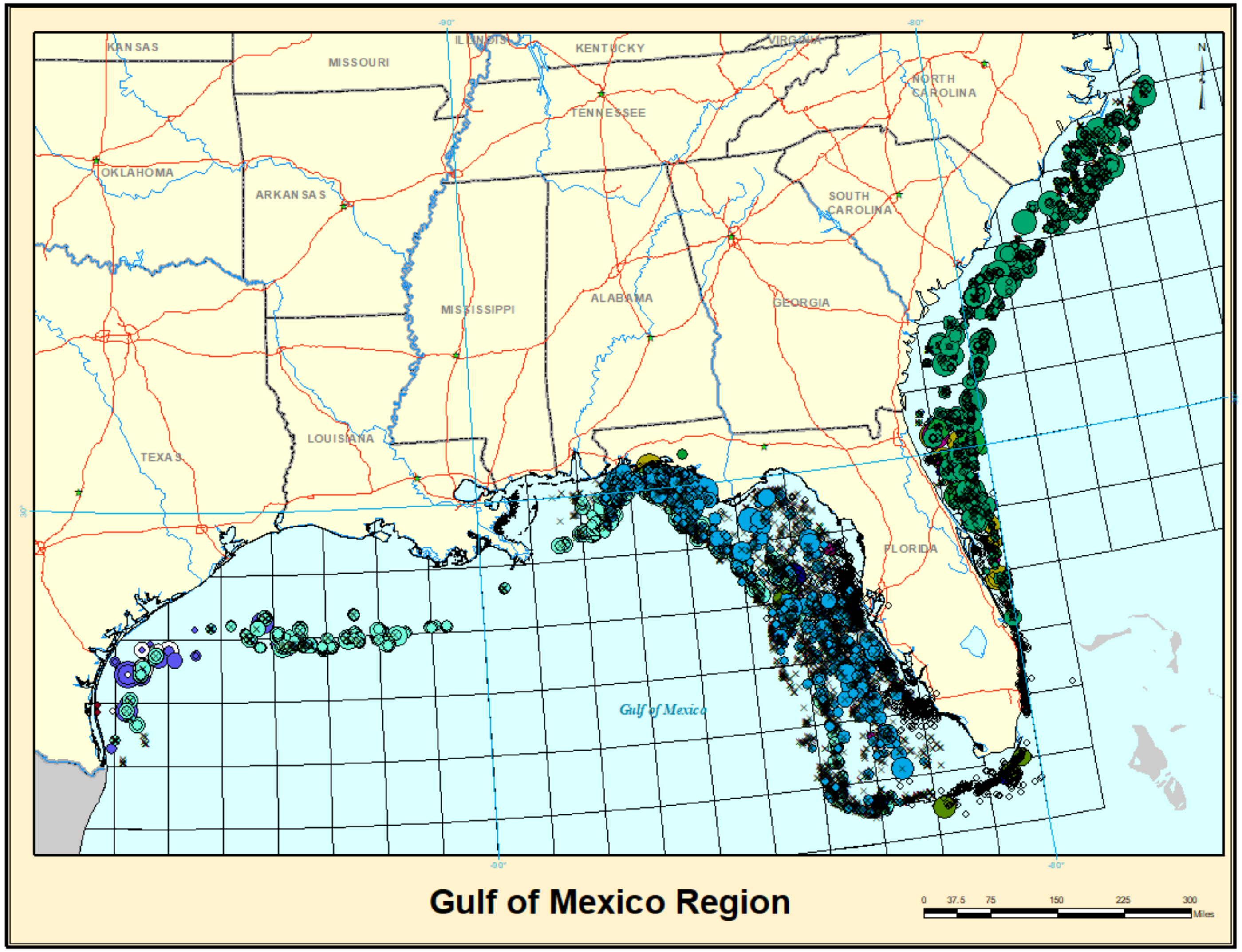
- List of artificial reef locations/types/sizes (NOAA-ENC, FWRI)
- List of known natural reef point-locations (NOAA-SERFS, FWRI)
- Location and extent info for natural-reefs comes from prob. models (NCCOS)
- No scaleable habitat map products





Abundance synthesis: all regions

- SERFS, G-FISHER, Project PIs, Observer data (FL only)



Sample design

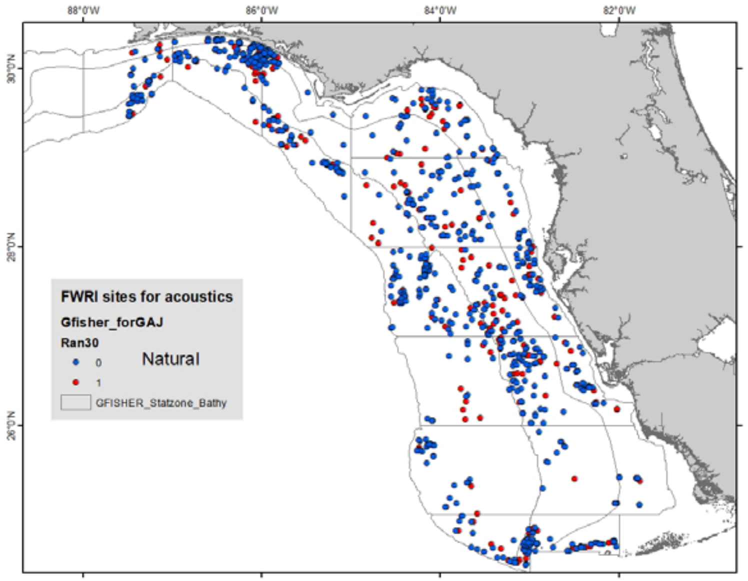
Sample design

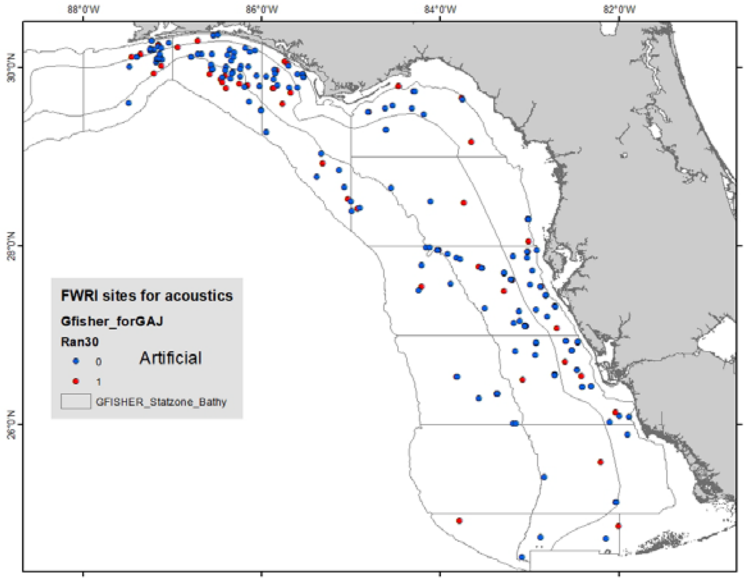
- Eastern GoM
  - West Florida
  - Mississippi/Alabama
- Western GoM
- South Atlantic

- Unifying gears
  - EK80 Echosounder (areal density)
  - Camera gears (relative/absolute abundance, species identification, size distribution)

Sample design: West Florida artificial and natural reefs

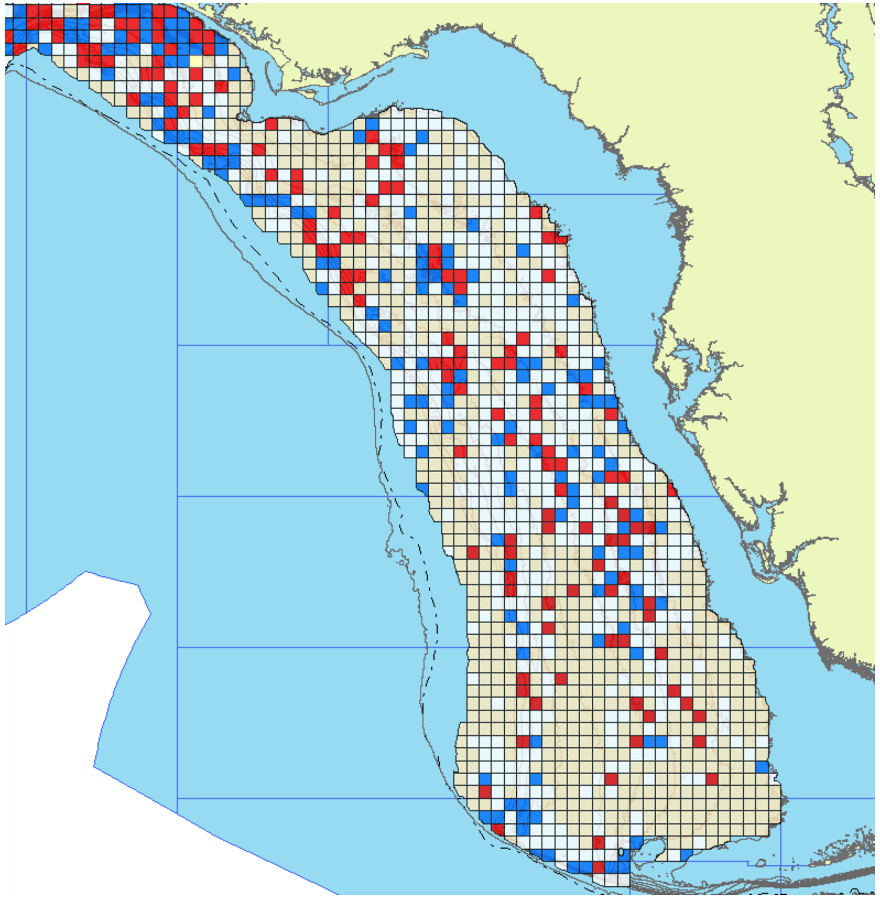
- Leverage existing G-FISHER survey
  - S-BRUV: baitied 360° cameras
  - Known natural and artificial reefs
  - Existing design: two-stage cluster sampling stratified by region [three levels], depth [three levels], habitat type [natural vs artificial], size [three levels], and relief [three levels]
- Supplemental S-BRUV sampling to increase overall coverage
- Addition of echosounder surveys to subset of sites
- Addition of repeat baited/un-baited drops (calibration)





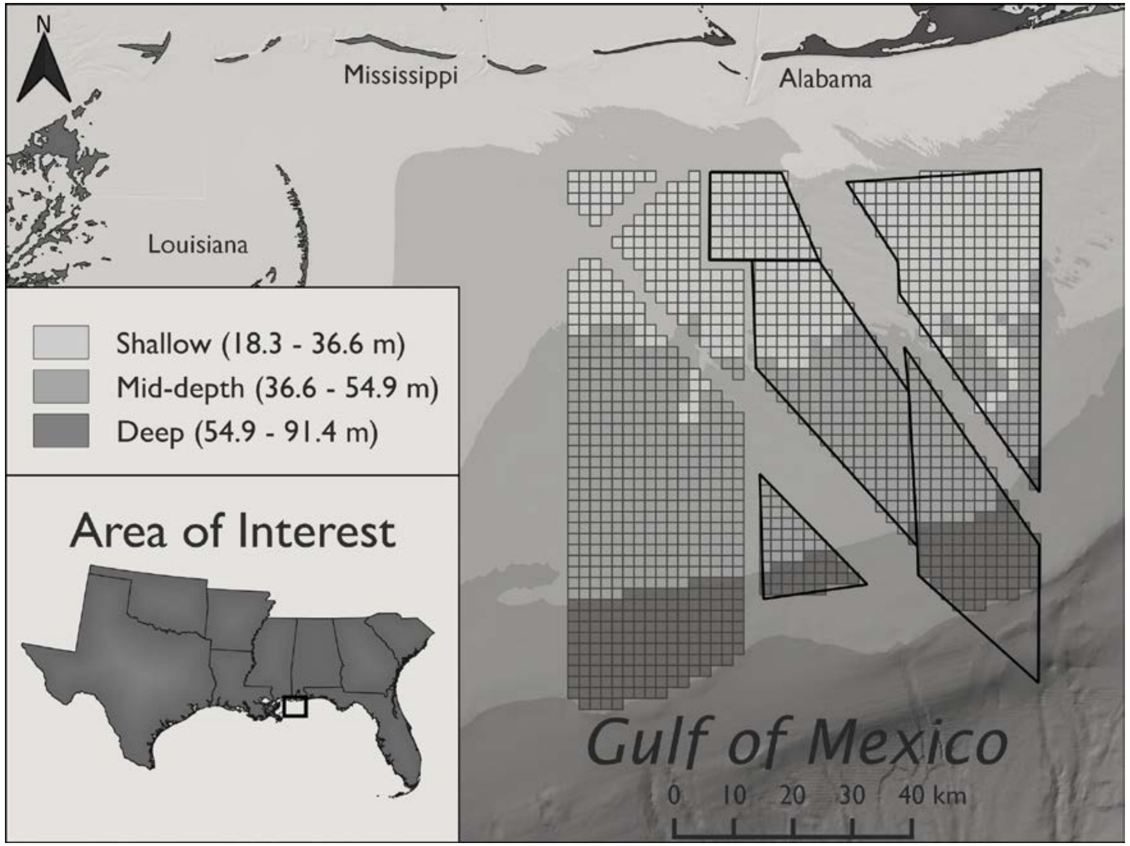
Sample design: West Florida uncharacterized

- C-BASS + echosounder
- Unconsolidated/unknown habitat
- Stratified by existing abundance data (G-FISHER)
  - Red – High Catch
  - Blue – Moderate Catch
  - White – No Catch
  - Tan – Zero Effort
- Largest allocations on 'Zero Effort' and 'High Catch' grid cells
- Incidental multibeam mapping provides independent estimate of unknown natural and artificial reefs



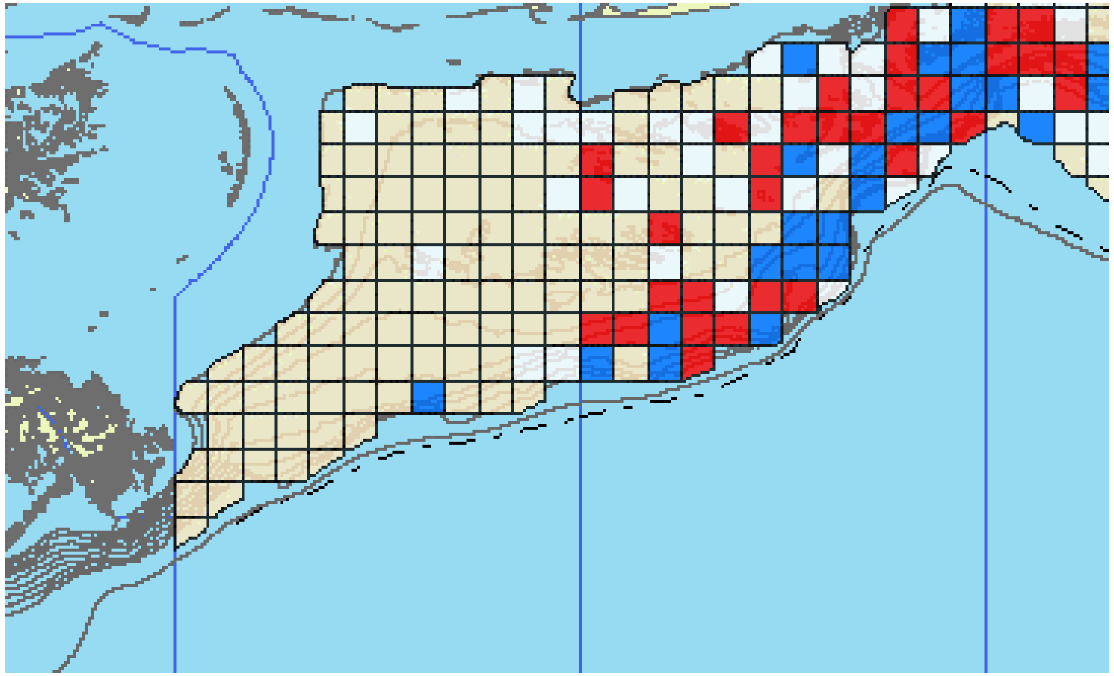
Sample design: Mississippi/Alabama artificial and natural reefs

- Leverage existing USA Fishery-Independent sampling
  - ROV mounted cameras
  - Known natural and artificial reefs
  - Existing design: two-stage cluster sampling stratified by region [two levels], depth [three levels], habitat type [natural vs. artificial], and relief [high vs. low]
- Supplemental ROV sampling to increase sample size, spatial coverage (Mississippi), and high-relief habitats
- Addition of echosounder to most sites
- Addition of S-BRUV to subset of sites
- Addition of eDNA to subset of sites



Sample design: Mississippi/Alabama uncharacterized

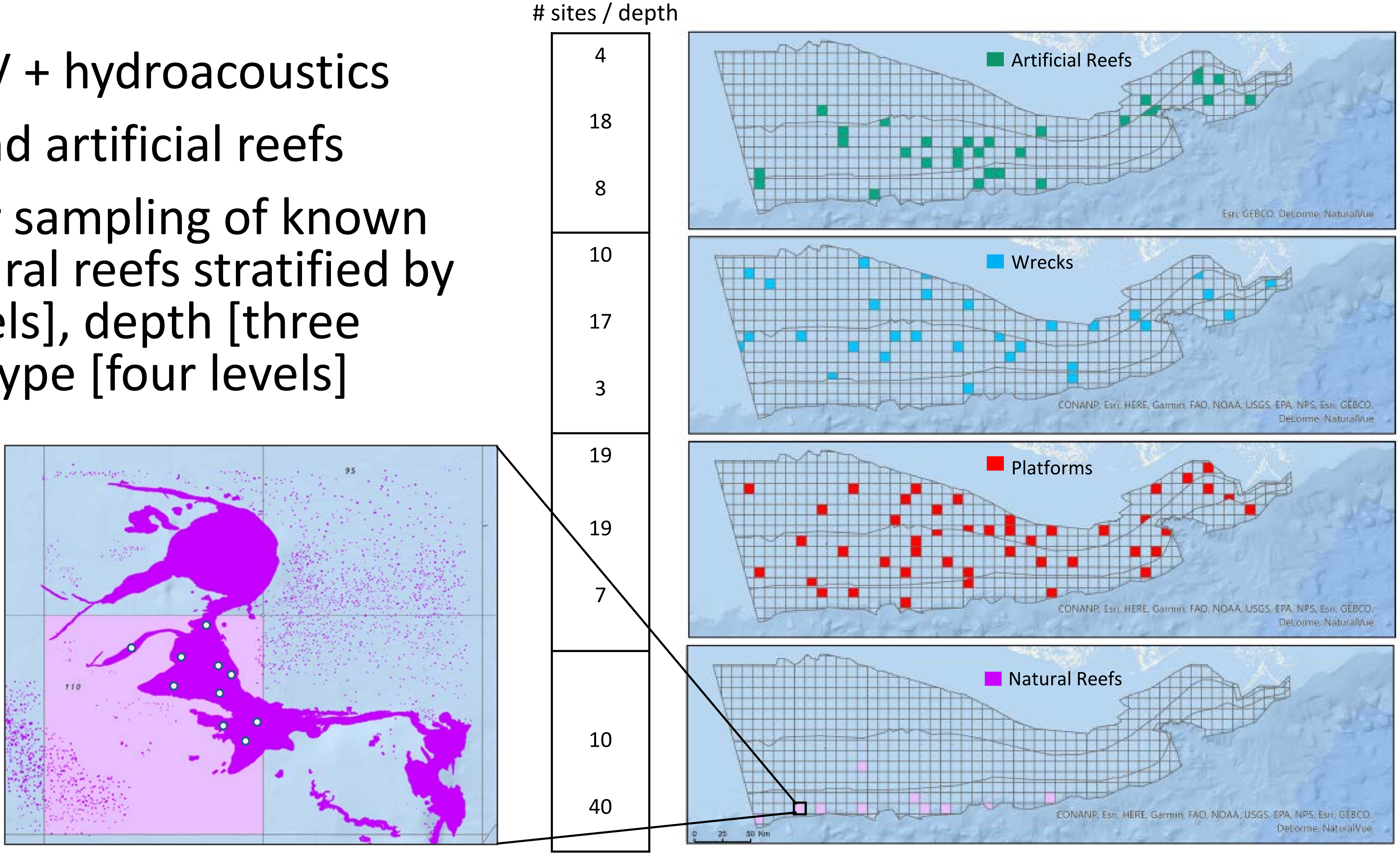
- C-BASS + echosounder
- Unconsolidated/unknown habitat
- Stratified by region [two levels] and existing abundance data (G-FISHER)
    - Red – High Catch
    - Blue – Moderate Catch
    - White – No Catch
    - Tan – Zero Effort
- Largest allocations to 'Zero Effort' and 'High Catch' grid cells
- Incidental multibeam mapping provides independent estimate of unknown natural and artificial reefs (esp. in MS where existing mapping data not available)



Sample design: Western GoM natural and artificial reefs

- BRUV and/or ROV + hydroacoustics
- Known natural and artificial reefs
- Two-stage cluster sampling of known artificial and natural reefs stratified by region [three levels], depth [three levels], and reef type [four levels]

20-40 / 40-80 / 80-150 m

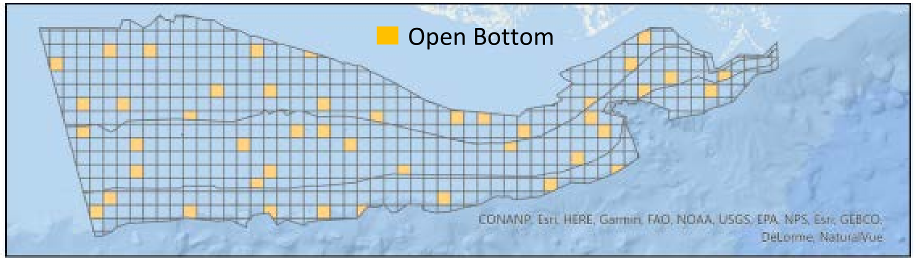


Sample design: Western GoM uncharacterized

- Echosounder + BRUV and/or ROV
- 5 nm transect at each selected cell with vessel echosounder
- Video and scientific echosounder surveys at locations where biomass/structure is detected on vessel echosounder
- Stratified by region [three levels] and depth [three levels]
- Vessel echosounder data will also provide estimate of unknown natural and artificial reefs

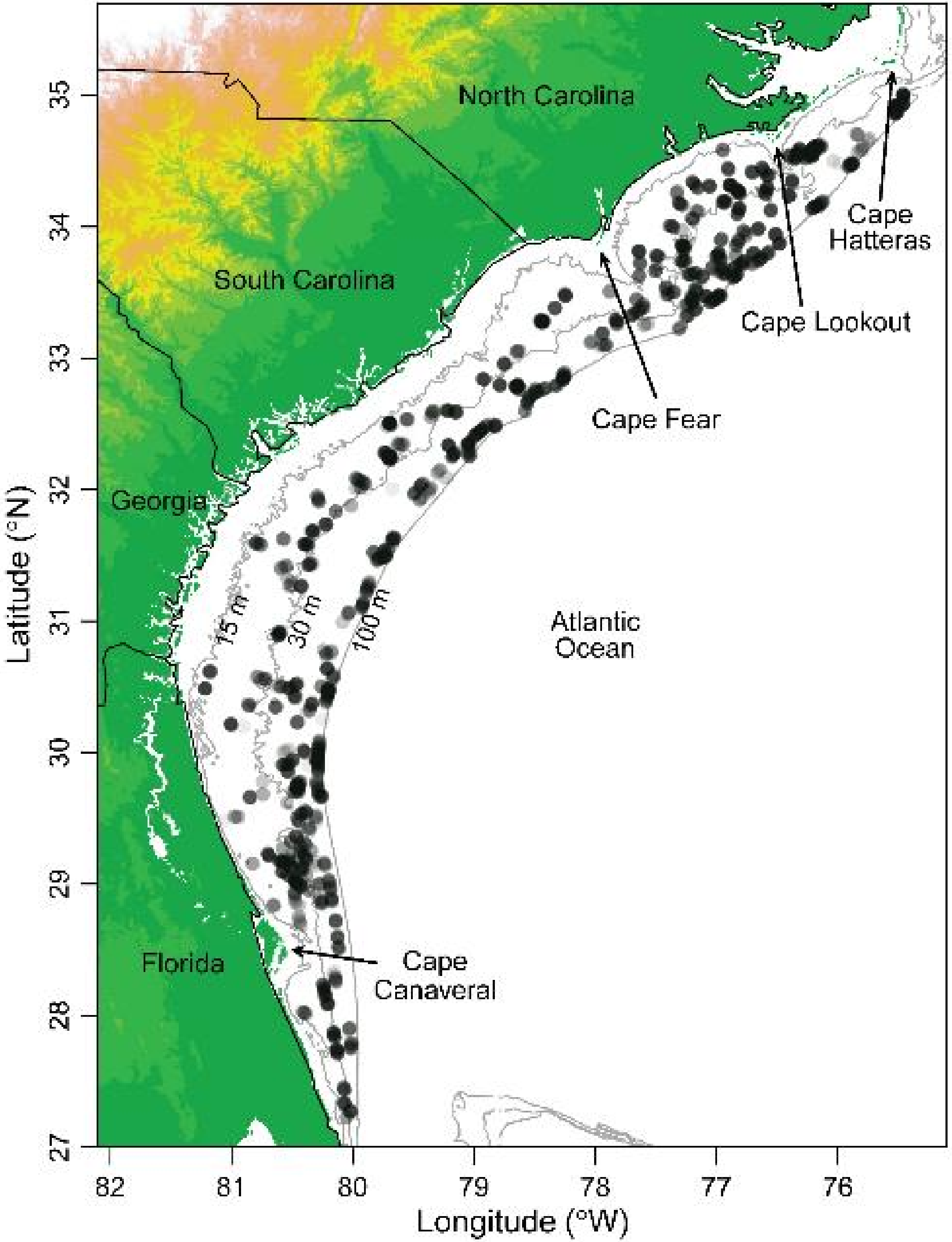
20-40 / 40-80 / 80-150 m

sites / depth
18
17
10



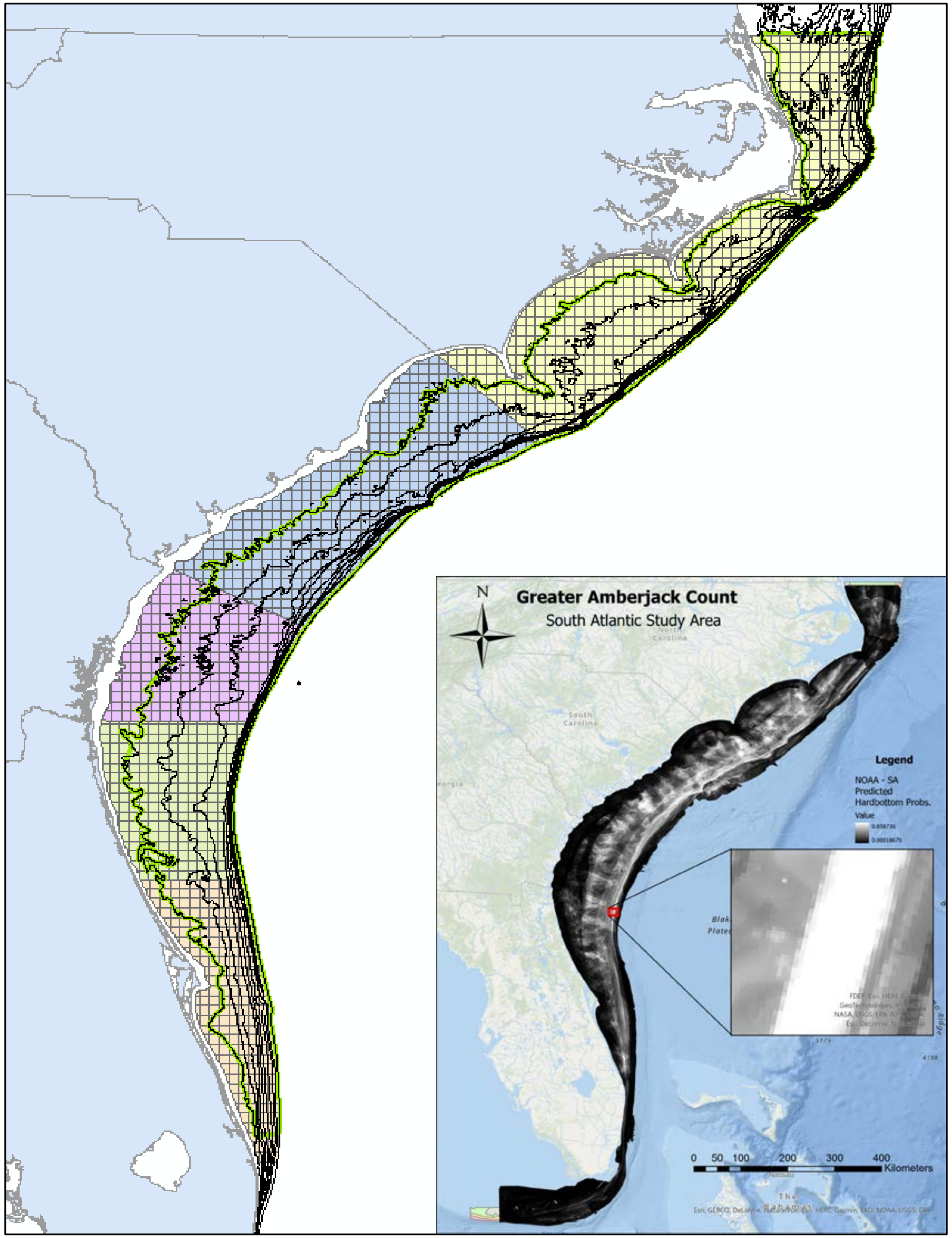
Sample design: South Atlantic artificial and natural reefs

- Leverage SERFS (trap mounted cameras)
  - Known natural reef point-locations
  - Simple random sample from list of known natural reef point-locations
  - Does not cover artificial habitat
  - Cameras are depth limited
  - Does not cover SE FL
- S-BRUV + echosounder
  - Known natural and artificial reefs
  - Two-stage cluster sampling of known artificial and natural reef point-locations stratified by region [four levels] and depth [three levels]
  - Will cover all depths, but extra effort in deeper waters and in SE FL where SERFS coverage is lacking



Sample design: South Atlantic uncharacterized

- C-BASS + echosounder
- Random sampling stratified by region [four levels], depth [three levels], and probability of natural reef based on NCCOS model [high, low, zero]
- Incidental multibeam mapping provides estimate of unknown natural and artificial reefs (potentially validation of NCCOS model)



Questions