# Proposal Narrative

## A. Rationale

Management of reef fish in the southeastern U.S. is an extremely contentious issue with substantial disagreement regarding stock status and catch level recommendations among various stakeholder groups. The disagreement between the perceptions of some stakeholders and current management advice has caused many in the public to question the effectiveness and scientific basis for management decisions. Stakeholder trust is critical to effective management because compliance to fisheries regulation is largely voluntary with few actual enforcement agents available in the large area of southeastern U.S. While most of the attention has been focused on the management of Red Snapper, the status and recommended catch levels of other reef fish stocks (Greater Amberjack [GAJ] and Gray Triggerfish) have also been questioned by many stakeholders and scientists. In response to the public concern, the U.S. Congress has funded two independent studies to try to determine an absolute abundance to help guide future management and build stakeholder confidence in the underlying science. The first of these studies, currently concluding, focused on Red Snapper in the Gulf of Mexico (GoM). The second (this competition) focuses on GAJ through the southeastern U.S. (GoM and and South Atlantic {SA]). The innovative approach we propose to estimate an absolute abundance of -- and expand our biological knowledge of -- GAJ builds on the success of, and lessons learned from the Great Red Snapper Count project (GRSC). Many of the scientists included in this proposal were critical to the success of the GRSC.

Estimating an absolute abundance through fisheries independent sampling has been a "Holy Grail" of fisheries scientists for quite some time. While advanced technologies have greatly improved our ability to estimate local abundance, combining site specific counts within the larger geographic frame of this study to estimate absolute abundance is a daunting task. The results of the GRSC do provide confidence that a reasonable lower bounds estimate can be made. Although our experience with the absolute abundance estimate for Red Snapper will be helpful, in many ways estimating GAJ abundance will be even more challenging

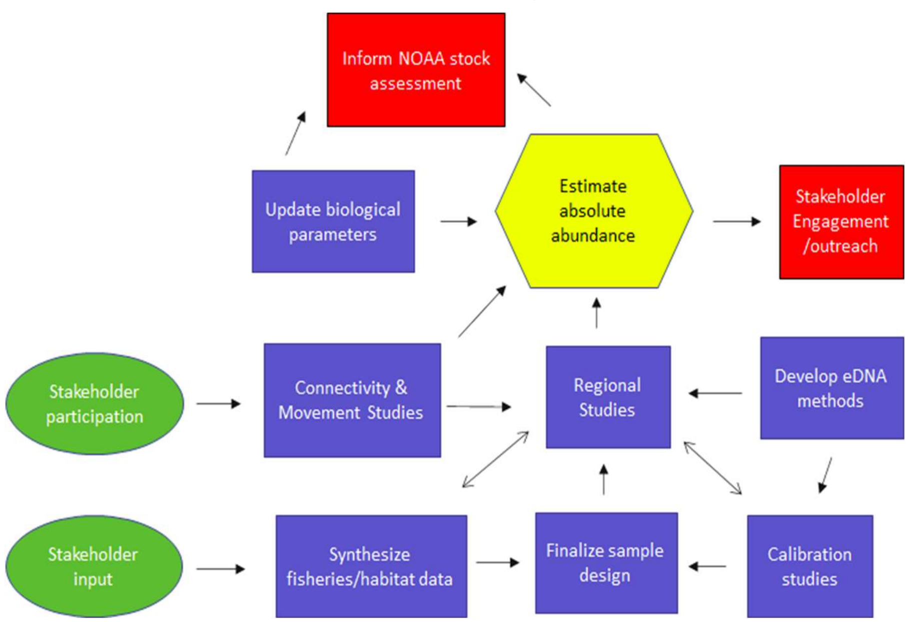


*Figure 1. Schematic diagram of major components and outputs of the proposed study*

mainly because our knowledge of the ecology of GAJ pales in comparison to Red Snapper. A recent search on Google Scholar illustrates this point with 12 times the number of publications on Red Snapper than GAJ in the southeastern U.S. region. Other challenges (like the GRSC) also persist, principally the lack of detailed knowledge of bottom habitats in the regions. Most notable is the lack of detailed mapping for the GoM and SA continental shelf. We address these challenges for estimating absolute abundance by developing a rigorous phased approach. First, we will evaluate and develop methodologies where necessary, refine calibration techniques, and estimate habitat-specific variance estimates where they are currently unavailable to meet the requirements of the funding request. Together these will allow us to determine the most effective methods suitable for making accurate and precise abundance estimates. Second, we will then proceed with a more broadly scaled-up sampling approach using these calibrated techniques and refinement of our design. We couple these two phases with expansive studies of the spatial ecology, connectivity and movement of Greater Amberjack as well as an update of key biological parameters of the species. This latter element is critical to addressing key assumptions of our absolute abundance estimate and improving the current NMFS stock assessment. In the final phase, we estimate an overall and region/habitat specific abundance estimate and communicate those results with the stakeholders. The key feature of our design is that it is adaptable, thus it can account for the habitat nuances in each Gulf region or subregion identified here, as well as account for marginal costs and sampling effort required for these regions and habitat types. This adaptable and scalable approach will be accomplished through sampling technology and design tools that we have refined in the GRSC.

## B. Scientific and Professional Merit

### 1. Hypotheses

Two overall hypotheses will be tested in the proposed study are ($H_A1$) GAJ abundance varies among habitats (artificial, natural, and unknown/unconsolidated bottom [UCB]) and regions and ($H_A2$) GAJ show limited connectivity between SA and GoM regions with a mixing zone near the Florida Keys. To test these hypotheses and formulate a robust estimate within these strata, several supporting objectives must be addressed that will address assumptions on gear and sampling efficiency as well as movement of GAJ.

### 2. Objectives

The overarching goal of the proposed research initiative is to provide an independent estimate of GAJ abundance in the US Gulf GoM and SA in waters out to 150 m in depth. The independent estimate of abundance derived from the proposed research will be compared with the estimates derived from the stock assessment models used by NOAA Fisheries (Stock Synthesis, Beaufort Assessment Model), allowing validation, calibration, and further refinement of the model. To accomplish this ambitious task, we have assembled a well-integrated multidisciplinary team that includes leading fisheries and statistical experts from across the GoM and SA. These scientists have extensive experience with reef fish research along with some of the most robust datasets, ongoing research programs/teams, sampling expertise, and analytical skills available.

To accomplish this goal, we propose an expansive sampling program focused on providing a rigorous estimate of Age 1+ GAJ that can be separated into length bins. The estimate will be stratified by region and habitat type (Fig. 2). The sampling design will be informed by a comprehensive data synthesis (fisheries-dependent and independent data, previous habitat mapping and traditional fishermen knowledge). Sampling approaches will be refined through intensive calibration studies. Key assumptions of our sampling design and approaches as well as supportive information will be collected through a series of companion studies. These supportive projects include studies that are designed to examine unresolved issues associated with our understanding of movement and connectivity of GAJ in the southeastern U.S.

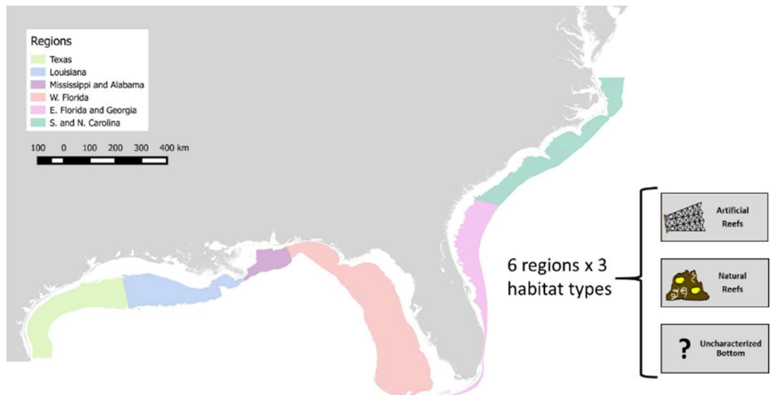


*Figure 2. Map of project subregions. Sampling area delimited by 20 m and 150 m isobaths.*

Our specific objectives are: (1) to synthesize bottom habitat observations and construct a spatially explicit habitat model throughout the study area (SA and GoM), (2) to synthesize existing fisheries data and stakeholder knowledge regarding regional, habitat-specific abundance of GAJ across the study area, (3) to design and conduct a comprehensive study to estimate, within a reasonable margin of uncertainty, the regional, habitat-specific absolute abundance of GAJ using a combination of video observations (towed, ROV mounted, and stationary) and hydroacoustics, (4) to determine movement behavior and connectivity of GAJ at local and regional scales using a combination of acoustic telemetry, conventional tagging and genetic markers, (5) to assess the efficacy of environmental DNA (eDNA) methods in conjunction with visual and acoustic approaches to determine presence/absence and/or relative abundance of GAJ as well as closely related species, (6) to update biological information for GAJ across the study region (age-length) and (7) to engage with stakeholder groups and collaborate with existing outreach teams to facilitate stakeholder input and to communicate the results of the project.

## 3. Approach

The approach we propose is highly adaptable and responsive to the results of our synthesis, calibration, and connectivity studies. In a perfect system, we would have a complete understanding of our sampling universe and strata and be able to lay out a detailed *a priori* design. Unfortunately, comprehensive and high-resolution habitat maps are largely lacking and our knowledge of GAJ pales in comparison to other fisheries species (e.g. Red Snapper and Gag). Although we lay out the best-informed sampling program (design and approach), we recognize that this plan *will* be refined based on the results of our three-phased approach. Phase I proposed for Fall of 2021 and Spring of 2022 will include the comprehensive data synthesis (Objective 1 & 2), calibration studies (component of Objective 3) and the development and implementation of novel eDNA approaches (Objective 5). Phase II (late Spring 2022 and continue through 2022) will involve synoptic data collection using underwater video and hydroacoustics (Objective 3). The final phase (III), 2023, includes data analysis and stakeholder engagement (Objective 7). Work under objectives 4 (connectivity and movement) and 6 (biological information) will occur across phase I and II.

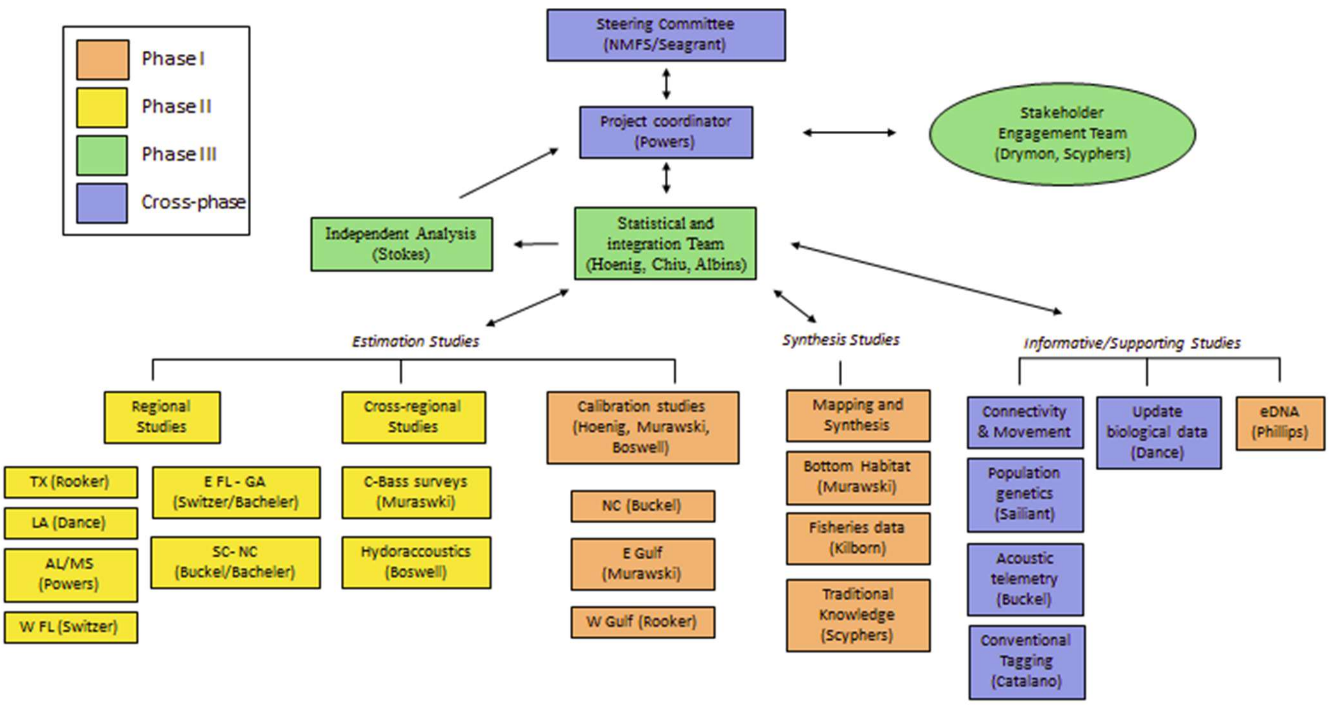


*Figure 3. Schematic illustration of major components and project leads for studies that support the projects seven objectives. Different colors represent different planned phases of the 2-year project. Lead PIs for each study component are also identified.*

## 3.1. (Objective 1) Synthesize existing habitat data

While no comprehensive bathymetry and habitat maps exist for the entire region under study, there are resources which have compiled partial coverage of multibeam bathymetric data (https://maps.ngdc.noaa.gov/ viewers/bathymetry/ ) and a number of the PIs have extensive experience with and have surveyed portions of the region using bathymetric sonars and side-scan sonars (i.e., University of South Florida, Florida Fish and Wildlife Research Institute, NOAA, University of South Alabama). For example, the State of FL has collected extensive habitat mapping data (Fig. 4). In this case, data were collected following a randomized site selection approach whereby standardized (~2 $km^2$) surveys were conducted throughout the eastern GoM to locate and classify natural and artificial reef features. Similar randomized habitat surveys have occurred in other states (e.g., AL and MS). To date these have not been synthesized across the region.

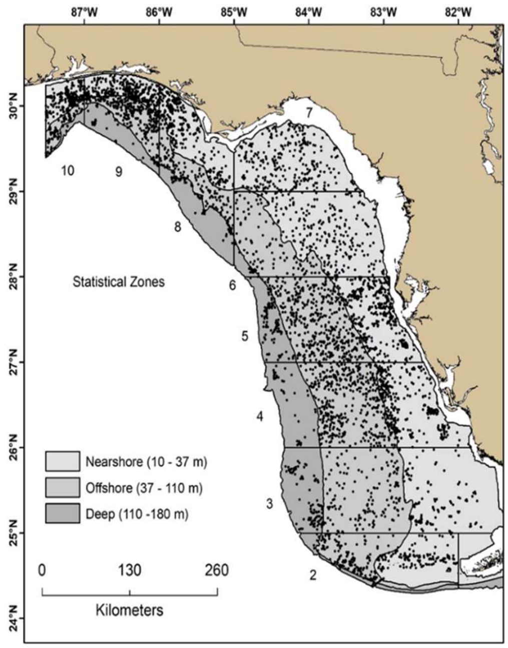


*Figure 4. Centroid locations of randomized habitat mapping surveys conducted by the state of Florida from 2010 – present.*

To facilitate habitat stratification of the study region, Objective 1 will be to compile such existing habitat mapping data into a comprehensive GIS mapping product across the entire GoM-SA region. The GIS layers will include multibeam bathymetry and derivative metrics including steepness and indices of rugosity. Other layers will include side-scan imagery, ground truth habitat characteristics (e.g., CMECS- Coastal and Marine Ecological Characterization Standard classification of substrate types https://iocm.noaa.gov/standards/cmecs-home.html) and ancillary information. These data, along with abundance data from Objective 2, will feed into spatially explicit Bayesian models of GAJ abundance in relation to environmental variables that unify the entire GoM-SA region and will inform the sampling design of the proposed study (see section 3.3.1 below).

## 3.2. (Objective 2) Synthesize existing occurrence/abundance data

### 3.2.1. Existing fishery dependent and independent data

The Gulf of Mexico and South Atlantic continental shelves are routinely surveyed by state and federal agencies to provide fishery-independent data on abundance and distribution in support of stock assessments for many reef fishes, including GAJ. Surveys include the SEAMAP groundfish, ichthyoplankton, longline and baited camera or camera/trap surveys conducted by NMFS and various state partners. Additionally, the PIs have conducted ROV, acoustic and towed camera surveys associated with the GRSC in the GoM, which also contain GAJ observations that can be utilized. In addition, fishery-dependent data on GAJ catch will be sourced from observer coverage of reef fish fisheries, as well as logbook (lower resolution) and VMS data (very high precision).

Together the fishery-dependent and fishery-independent data will be combined with habitat information (Objective 1) to develop spatially explicit Bayesian models of GAJ occurrence and abundance. These will be used to refine sampling strata for field-activities to be conducted under this program.

### 3.2.2. Incorporating traditional fishermen knowledge

Collecting the local ecological knowledge (LEK) of recreational and commercial anglers offers a powerful tool for simultaneously engaging stakeholders, assessing the distribution of fish populations, and optimizing the efficiency of field studies (Powers et al. 2012, Scyphers et al. 2014, Aminpour et al. 2021). We will document the local ecological knowledge (LEK) of recreational and commercial fishers using interviews and online surveys to identify regional geographic areas and habitats of perceived higher GAJ abundance. This LEK will be used as Bayesian prior information in the spatially explicit models of GAJ occurrence and abundance in Phases I and III (see Section 3.3.1). Importantly, the Phase I models will guide the sampling designs in Phase II. The overarching goal of the interviews and online survey will be to measure participants' LEK of GAJ abundance via map-based questions of temporal and spatial dimensions (i.e., participatory mapping). For instance, a core series of questions will directly ask participants to select areas on a map where they would expect to find the highest abundances of GAJ. To achieve broad representation of LEK, participants will be recruited through multiple pathways, including incorporation of stakeholder LEK obtained from the visioning phase of this project. Sea Grant Fisheries Extension networks and purposive sampling will also be used to recruit interviewees representing recreational, commercial, and for-hire sectors (n=50). Third, Qualtrics Research Panels will be used to recruit a larger sample of individuals who saltwater fish in the GoM and SA (n=1000). Panel samples have rapidly gained popularity over the past decade as a quick, cost-effective, and robust approach to online surveys (Boas et al. 2020). Results of these analyses will be used to inform spatial models of GAJ abundance that will serve to refine our overall sampling design (see section 3.3.1).

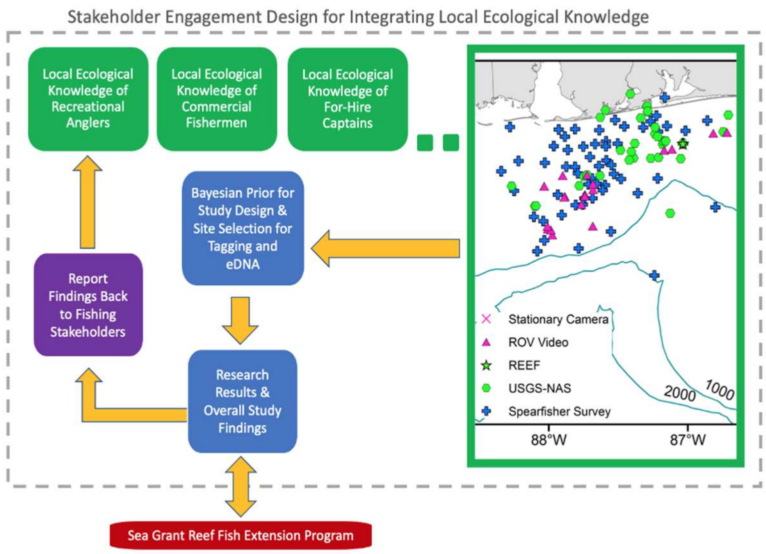


*Figure 5. Flow chart showing our study design for engaging stakeholders and directly integrating their local ecological knowledge (LEK) in the study design.*

## 3.3. (Objective 3) Estimate absolute abundance of Greater Amberjack

In this proposal narrative we devote substantial attention to this objective as it is the main intent of the congressional appropriations. While the PI's have learned many lessons from the GRSC, which will improve the proposed project's sampling efficiency, estimating GAJ is likely more challenging than Red Snapper for several reasons. First, the overall abundance of the stock is substantially smaller based on our current understanding (100's of thousands vs. 10's of millions for Red Snapper), which will result in a higher prevalence of 0's in our data set. Second, our understanding of GAJ movement is rudimentary, hence the need to focus most of our abundance sampling effort into the smallest possible temporal window and to include a component which will explicitly examine GAJ movement and connectivity (Objective 4). Third, at smaller sizes it is often difficult to separate GAJ from congeners: Lesser Amberjack (*Seriola fasciata*), Almaco Jack (*S. rivoliana*), Banded Rudderfish (*S. zonata*) using video and/or acoustic methods.  This latter issue will be addressed through extensive inter-lab calibration for the video-based counts, calibration experiments for hydroacoustic methods, and the application of eDNA approaches to a subset of field sites.

### 3.3.1. Sampling design and framework

Our sampling design leverages existing region wide surveys conducted by NMFS and partner States along the SA (NC-FL) and GoM (FL-TX) with additional sampling conducted by a set of regional and cross-regional teams. Along the SA, the Southeast Reef Fish Survey (SERFS) is a collaborative survey consisting of three fishery-independent programs that use identical methodologies to sample reef fishes: (1) the Southeast Fishery-Independent Survey, (2) the Marine Resources Monitoring, Assessment, and Prediction Program of the South Carolina Department of Natural Resources, and (3) the Southeast Monitoring and Assessment Program. The SERFS survey follows a simple random sampling design where ~1,500 – 2000 sampling stations (out of a total sampling frame of ~4,000 known natural reef stations) are selected for sampling each year. Within the GoM, the Gulf Fishery Independent Survey of Habitat and Ecosystem Resources (G-FISHER) uses a similar overall design and methodology (stationary cameras). This survey, which extends from 10 – 180 m, employs a stratified-random design whereby sampling effort on natural and artificial reef features is allocated among various spatial and habitat strata. One of the co-PI's (Switzer) is an integral part of the planning and execution of these studies on both coast (also see supporting letters from Drs. Nate Bacheler and Matt Campbell, NMFS SEFSC). Although, the overall sampling design of these surveys is fixed by NMFS and its partners each year, supplemented sampling both in terms of number of stations and in survey methods will be funded by the proposed study (see regional workplans). In addition to these planned surveys, region and cross-region studies conducted by our project investigators will collect additional samples from all three habitat types in regions throughout the study area.

Estimating region- and habitat-specific abundance of GAJ will be achieved by employing both design-based (i.e., stratified random sampling or stratified cluster sampling) and model-based (i.e., hierarchical spatial regression) inference in a unified framework. The design-based approach relies solely on the randomization process as the basis for inference, that is, no model is formulated for the distribution of variables or the relationships among environmental variables and fish abundance. In contrast, the model-based approach relies on, and takes advantage of, the formulation of models relating the relevant variables and accounting for spatial autocorrelation. These approaches will be implemented in two steps. First, we will develop a holistic, hierarchical, spatially explicit Bayesian model of GAJ relative abundance in relation to environmental variables that unifies the entire GoM-SA region. The data for this model will come from the Phase I work of this project (Objectives 1 & 2). This preliminary model will be used to set up design-based sampling plans involving simple random sampling or cluster sampling within strata defined by region and habitat and allocate Phase II sampling efforts (per unit area or per bottom feature) according to the predicted GAJ relative abundance. The Phase II design-based sampling will give rise to the Phase III design-based GAJ abundance estimates (with associated variances) by region and habitat. Second, the spatial model will be updated based on the data collected in this project to give a detailed map of modeled GAJ distribution, filling in spatial gaps between *in-situ* abundance estimates while also reducing the variance of *in-situ* estimates. Thus, this updated model takes advantage of spatial autocorrelation among observations and integrates them over GoM-SA to provide a second, improved model-based estimate of GAJ abundance. The schematic in Figure 6 summarizes the unified approach and anticipated output.

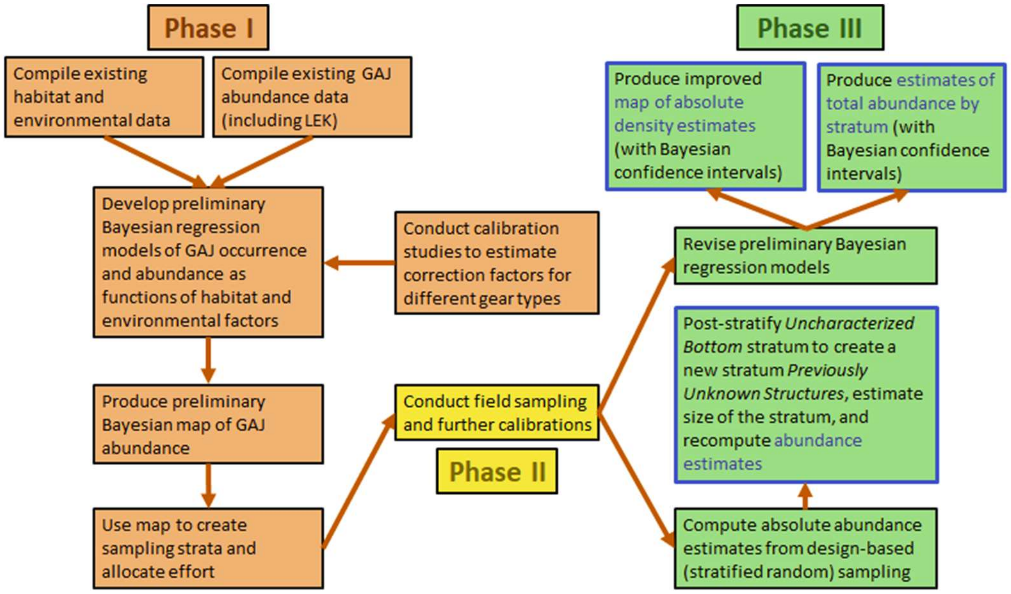


*Figure 6. Flow chart illustrating integration of Phases I–III of the study.*

Preliminary spatially explicit models will be developed, that predict GAJ presence (model A) and GAJ abundance (model B) from environmental data. These models can be used to predict presence or abundance at any point in the GoM-SA study area. Model (A) will be key for designing the sampling plans for each stratum. By itself, it does not provide estimates of abundance, but it will be needed for the model-based estimates of total abundance where it will serve to model the likelihood of structural zeros (Tang et al., 2018). The preliminary spatial models (A) and (B) constructed from the datasets assembled in Phase I of this study will be used to design stratified sampling schemes for the collection of field observations. These surveys will complement existing programs whose sampling designs are fixed, e.g., the simple random sampling within strata used in the SA and GoM. Following field data collection (Phase II), the preliminary models for (A) and (B) will be updated (Phase III) to substantially improve the accuracy and precision of model predictions and model (B) will be used to estimate total abundance by stratum and habitat. At the same time, the results of the design-based sampling (i.e., simple random sampling within strata) will provide a second set of estimates.

We will also attempt to use post-stratification to improve abundance estimates. This is a sensible procedure when a factor is known or suspected *a priori* to affect the magnitude of the response but no sampling frame is available from which to select random samples. In the case of GAJ, there may be bottom anomalies in the large areas of unconsolidated and uncharacterized bottom, such as sunken cargo containers and boats and other debris) that attract fish. Variance may be reduced substantially if areas with previously unknown anomalies are treated as a separate stratum from areas with unconsolidated bottom. In this case, stratum size (the amount of bottom with unknown anomalies) has to be estimated from the data (see Sukhatme et al. 1984). Note that this is very different from the unacceptable procedure of stratifying based on the response variable (i.e., looking at the abundance data and making separate post-strata for areas with high and low numbers of observed fish).

#### *3.3.1.1 Initial site selection procedures*

The initial, default sample design will entail simple random sampling within strata, with the primary stratification by region (TX, LA, MS-AL, West FL, East FL-Georgia, and SC-NC) and habitat type (artificial structure, natural structure, and uncharacterized bottom). Sampling effort targets for each stratum will be determined based on the results of the preliminary models described above and will be tailored to provide the most accurate and precise absolute abundance estimates possible for each stratum under the logistical constraints of the study (see section 3.3.1.3 below for details regarding expected precision). The results of these preliminary models will allow us to concentrate sampling effort (per unit area) in areas where GAJ presence is likely and to do minimal sampling (per unit area) where the species is not likely to be encountered. (In this scheme, large areas of uncharacterized and unconsolidated bottom receive appropriate sampling effort by virtue of the size of the areas and the anticipated variances). In cases where the current project proposes leveraging existing region-wide efforts (e.g., SERFS, G-FISHER), we will conduct supplementary sampling to attain prescribed effort targets.

#### *3.3.1.2 Modeling GAJ abundance*

For the GRSC, the random forest statistical methodology was used to generate maps of the probability of occurrence of red snapper. Although such an approach could be used for GAJ, this approach does not incorporate a parametric model of spatial autocorrelation nor does it take advantage of the Bayesian framework's ability to employ prior elicitation (Albert et al., 2012) that captures existing knowledge of GAJ distribution.

A spatially explicit GAJ abundance regression model developed from the Phase I data, and updated with field survey data collected during Phase II of the proposed study, will provide the means to predict abundance or occurrence of GAJ over a fine scale grid of points covering the entire sampling region. The model regresses abundance/occurrence on environmental covariates including habitat type, bottom type, depth, as well as latitude and longitude. What is left unaccounted for by these explanatory variables may exhibit substantial spatial autocorrelation across sites, as was the case for Chiu et al. (2013). This autocorrelation is a formal component of the regression model. In Chiu et al. (2013), it takes the form of conditional autoregressive (nearest-neighbor) dependence; in Kuh, Chiu & Westveld (2020) it takes the form of an exponential function of inverse-distance. Under the Bayesian hierarchical framework, the spatial dependence structure allows imputation of any missing covariate values and thus allows one to obtain a prediction of abundance or presence (provided latitude and longitude are known for each point for which we desire a prediction). This model assumes and allows for nearness of adjacent observations to influence predictions. To reiterate, it is the spatial structure imposed on the residuals that allows nearby cells to inform each other. Thus, we improve the precision of each site-specific estimate by "borrowing data" from nearby sampling sites. The hierarchical Bayesian modeling approach additionally integrates the expert opinion data compiled in Phase I. Importantly, in Chiu et al. (2013), the spatial resolution of the response variable (analog of GAJ presence or abundance) varies due to different measurement devices; this varying resolution is formally unified by the single model hierarchy while keeping the raw data intact without the need to align the data by brute force prior to modeling, the latter of which would have led to greater uncertainty in the predicted response due to the loss of informational content inherent in the raw data. In this project, our GAJ models (A) for presence/absence and (B) for abundance will be structured similarly to that by Chiu et al. (2013) due to the various sources of GAJ data, namely, the existing Phase I data and prior elicitation data under Objectives 1–2, and the Phase II data under Objective 3.

This approach can also incorporate the field data compiled across multiple independent calibration studies in Phase I and address the uncertainty in the values of the calibration coefficients for converting abundance indices to densities per unit habitat. Specifically, the data are multivariate observations from various sampling gears, only some of which are believed to give absolute measures of abundance per unit area. The abundance index data that require conversion to absolute abundance per unit area, alongside the absolute abundance measures that do not require conversion, will be related through a regression as one of the levels in the Bayesian model hierarchy – this is the calibration level within the overall hierarchical framework. The study-specific calibration coefficients are the regression parameters from this level, and their uncertainty may vary greatly across the independent calibration studies. The hierarchical approach allows the direct inference of this varying uncertainty. In the case that this very complex model imposes an impractical computational burden, the calibration level in the hierarchy can be replaced by a simpler structure, whereby study-specific variance parameters associated with the combined abundance "data" (involving both data that have been calibrated and data that do not require calibration prior to modeling) will be accompanied by informative prior distributions, and a tighter prior distribution for the variance parameter will reflect a more reliable calibration study. It is anticipated that the model developed in Phase I will employ the simpler structure.

Selection of models among possible candidate models will be based on regression diagnostics, information criteria (BIC, WAIC) and cross validation (a measure of how well a model predicts new data which have been left out of the training dataset (Hastie et al., 2009)).

#### *3.3.1.3 Precision and "Power" considerations*

Under the stratified random sampling design to be used in this project, the variance of the estimate for each stratum is determined by the variability of the observations, the size of the sample taken, and the size of the stratum as well as the precision of any calibration factors that need to be applied to convert indices to absolute abundances. Estimates of sampling variance are required to determine the coefficient of variation (CV) and to determine necessary sample sizes.

The GRSC project was fortunate to have a separately funded planning phase in which preliminary data could be analyzed to obtain estimates of variances. The GAJ RFP does not afford an opportunity to amass data in this way. We can, however, compare the proposed sampling efforts for GAJ with those in the GRSC and in existing programs for reef fishes. All other things (e.g., stratum size, sampling effort) being equal, a species with lower abundance is likely to have a lower sampling variance than one with higher abundance. This follows directly from the fact that the variance is a monotonic function of the mean for any of the common distributions of counts. The assumption that this will hold true in the case of GAJ is borne out by a cursory examination of towed camera data from the GRSC:

In 41 transects over pipeline and mud, covering Texas to Alabama, and totaling 20,665 15-second bins, a total of 10,404 red snapper and 203 Amberjack spp. were seen. The RS standard deviation was 766 compared to only 16 for Amberjack. Thus, with sampling effort comparable to that used in the GRSC, the precision of the estimates of abundance of GAJ over unconsolidated and uncharacterized bottom should be much smaller than for Red snapper, which were less than the 30% mandated by that RFP.

Additionally, each estimate produced by the model-based (hierarchical Bayesian regression) approach will utilize a substantially larger volume of data than a more traditional predictive model, comprising historical fishery-dependent and independent data, expert fisherman knowledge, and observations from a dedicated, species-specific, multi-gear, regional survey (to be collected in Phase II of this project). We expect this process to result in the most accurate and precise estimates of GAJ abundance possible.

### 3.3.2. Abundance Sampling Methods

The general field sampling approach for GAJ absolute abundance estimates will be to use a combination of video (stationary, ROV-based, and towed) and hydroacoustics to measure density. The specific type of video sampling will be habitat and region specific due to logistical constraints (e.g., towed cameras are effective for sampling large swathes of low-relief habitat, but not effective for sampling high-relief artificial habitat). Additionally, we will assess the efficacy of emerging eDNA technologies to assess the presence and relative abundances of GAJ in conjunction with video and hydroacoustic approaches. The PIs have extensive experience using these sampling tools in their respective regions and will conduct several calibration studies designed to integrate abundance data from the different video sampling gears used in the project. Critical to the success of this project is the calibration of the various gears and methods that will be employed- lesson learned from the review stage of the GRSC results.

#### *3.3.2.1. Hydroacoustics*

A multi-frequency scientific echosounder system (Simrad EK80) will be used to permit quantitative density estimation of GAJ among all regions. Application of hydroacoustics as a cross-regional sampling approach will assist in creating an integrated estimate that is additive across regions to create a final estimate. To ensure consistency in data collection and analysis, Dr. Boswell's lab at FIU will train regional field crews at the onset of the project and his lab will perform all data analysis regardless of collection region. Calibrated split beam transducers will be deployed from either ship mounted or stabilized towfish platforms. Calibration procedures will be performed with the EK80 software following guidance in Demer et al. (2015). Each survey will use 70 and 120kHz echosounders, and survey and transect design will be based on habitat type and configured appropriately to ensure as unbiased as estimate as possible within each region. Raw data files collected from the echosounder will be reviewed and processed in Echoview v. 12. Prior to processing, data will be calibrated for sound speed, transducer gain and system performance to account for any variance in operation of the echosounders and variation in water column structure on sound speed and sound absorption through the water column. By applying the calibration information, backscatter data collected across surveys can be quantitatively compared (Simmonds and MacLennan 2005).

Processing acoustic data requires several steps to maintain quality control and manage noise and interference (e.g., boat wakes, waves, bottom echo, electrical interference) and echoes generated by sources other than fish. Echograms will be bounded with surface and bottom lines to analyze backscatter from potential targets of interest within the water column. Surface lines will exclude data from the upper part of the water column affected by vessel noise, bubbles, turbulence and near field conditions (area close to the transducer where the beam pattern is not predictable). We will employ a hierarchical approach to distinguish among fish echo traces, with emphasis on identifying GAJ among other fishes. Three different methods will be applied to determine the composition of scatterers: multifrequency volume backscatter summation approach, target strength thresholding and a broadband classification process. All detected fish (individuals and aggregations) in the echogram will be isolated from fluid-like targets or microzooplankton based on a backscatter summation algorithm (Fernandes 2009, D'Elia et al., 2014). The algorithm sums volume backscatter (Sv; dB re 1 $m^{-1}$) samples across multiple discrete frequencies (e.g., 70, 120, 200 kHz) and applies a threshold over the summed echograms. This threshold will be determined during the calibration study and tuned to produce the cleanest Sv echogram (Fernandes 2009, D'Elia et al., 2014). Summing and thresholding the echogram allows for the removal of organisms with Rayleigh or resonant properties (e.g., zooplankton) and retains only organisms for which the backscatter is persistent across frequencies (e.g., fish schools or aggregations) (Lavery et al. 2007; Fernandes 2009).

Fish schools and targets will be classified as GAJ by using a target strength (TS; dB re 1 $m^2$) threshold. Target strength relates the cross-sectional backscatter to fish size and fish morphology (Jech and Horne 2002) and can aid in length estimation and species identification. The best TS threshold to discern AJ from other species will be derived from the calibration study using both modeled (from CT scans) and in situ target strength measurement from direct observations.

Finally, recent progress in the use of broadband methods offers potential to discriminate among targets based on their morphological and backscattering properties across a continuous spectrum of frequencies (Jech et al., 2017; Boswell et al., 2020). Broadband backscatter models will be derived as part of the calibration effort to ascertain which frequencies contain the greatest discriminatory power for separating AJ from other targets (Verma et al., 2017; Setiawan et al., 2020; Khodabandeloo et al., 2021; Roa and Boswell, unpublished).

Since GAJ can occur in both single targets and in aggregations, the total abundance will be estimated by using both echo-integration and echo-counting methods. Narrowband data will be used to quantify density through echo-integration and echo-counting methods and broadband data will be used for classification. Aggregations and schools will be detected and isolated in Echoview (Barange 1994). Aggregation regions will be partitioned into 5 x 5-m cells and their volume backscattering coefficient ($Sv,_{RBC}$; $m^2\ m^{-3}$) will be exported for density analysis. To obtain the density of individuals within each cell of the aggregation, Sv will be divided by the mean backscattering cross section (linear form of target strength; TS of a single individual, yielding to an estimate of total number of fish per volume of water (fish $m^{-3}$; Eqn1). In instances when single targets are not detected, an algorithm will be applied to detect targets around the periphery of the aggregation region where fish density is lower, and fish echoes are less likely to overlap, evaluated with the Nv parameter described by Sawada et al. (1993). We will assume that the single targets outside the aggregation border and within 5 m of distance from the aggregation depth are representative of the targets inside the aggregation (Scoulding et al. 2015). This assumption will be verified during the calibration study. Only cells with low density, specifically with Nv<0.01 individual per $m^3$ will be used for TS estimation. All TS values will be converted to backscattering cross section ($\sigma_{bs}$, $m^2$), according to $\sigma_{bs} = 10^{(TS/10)}$. A mean target strength ($\sigma_{bs}$,mean) will be derived by averaging together the backscattering cross section of all the single targets associated with the school. Finally, the volume density (ρv) estimate of the echo integration (EI) will be calculated according to:

(1) $\rho v_{cell\text{-}EI} = Sv_{,RBC}/\sigma_{bs},mean$

where RBC is region by cell and $\sigma_{bs}$,mean is the mean of the targets in the border.

The volume density, ρv (fish $m^{-3}$) per cell of the echo-counting (EC) will be estimated by simply dividing the number of targets for the beam volume sum (Kieser and Mulligan 1984):

(2) $\rho v_{cell\text{-}EC}$ = #single-targetscell/beam-volume-sumcell

The volume density of the echo-integration and the echo-counting will be converted to areal density (fish $m^{-2}$ re cell height) by multiplication with the mean thickness of the cell. The two density estimators will then be summed to obtain the total areal density per cell (fish $m^{-2}$):

(3) $\rho a_{cell\text{-}EC} = \rho v_{cell\text{-}EC}$ x Thickness_meancell

(4) $\rho a_{cell\text{-}EI} = \rho v_{cell\text{-}EI}$ x Thickness_meancell

(5) $\rho a_{cell} = \rho a_{cell\text{-}EC} + \rho a_{cell\text{-}EI}$.

A geostatistical approach will be applied to account for spatial autocorrelation inherent in mobile continuous data collection. Site specific variograms will model the spatial continuity of the data collected at each site through an automated procedure (White and Boswell, unpublished). Ordinary kriging will interpolate spatially weighted estimates of area density over a projected survey grid from the predicted variogram resulting in acoustic based fish density estimates for 5 x 5-m cells over the area bounded by the ends of the transects. Per cell fish abundance will be derived by multiplying the density estimated by 25 (the area of the cell).

#### *3.3.2.2. Video: Stationary, ROV and towed camera-based systems*

Reef fishes, including Amberjacks (*Seriola* spp.) are difficult to sample due to the complexity of the habitats they occupy as well as their demersal nature, high species diversity, and mobility. Additionally, the cryptic nature and behavioral differences among species further compounds problems of estimating reef fish abundance. Although historical surveys of reef fishes relied primarily on traditional capture gears, with the advent and improvement in underwater optical instrumentation, surveys of reef fishes have increasingly employed visual techniques including SCUBA (Smith et al. 2011), stationary camera arrays (Keenan et al. 2018; Campbell et al. 2019), trap-mounted cameras (Bacheler and Shertzer 2020), remotely operated vehicles (ROVs; Powers et al. 2018; Lewis et al. 2020; Garner et al. 2021), and towed video (Lembke et al. 2017). Video has become the most used method to quantify trends in abundance of reef-associated fish species around the world (Mallet and Pelletier 2014), and various video survey methods are used extensively in the GoM and SA.

There are many examples worldwide of video being used successfully to determine trends in reef fish abundance over time; nevertheless, the utility of video data to estimate absolute reef fish abundance has been limited due to an incomplete understanding of the behavior of reef fishes around cameras as well as factors contributing to the probability of detection across the range of habitats and physical conditions encountered during survey activities. With a primary objective of estimating absolute abundance of GAJ, dedicated efforts are needed to understand potential biases of video survey methodologies being employed (i.e., attraction/avoidance, influence of bait, enumeration methods, identification difficulties) and how they may influence probability of detection or sighting functions. Regardless, pairing video surveys with other sampling methods such as active acoustics is often necessary in such instances. Baited camera systems will be used throughout all study regions for artificial and natural bottom structures. Additional video surveys in these habitat types will also use ROV based camera systems. Finally, a towed video system paired with hydroacoustics will be used throughout the entire geographic area (Murawski MS-NC and Rooker TX-LA).

### *3.3.3 Calibration of sampling gears and methods*

This proposal incorporates several optical and acoustic observation technologies to determine the density of GAJ occupying various habitats. These technologies include water column active acoustics (WCAA), baited and un-baited drop cameras (DC), towed video (TV) and remotely operated vehicles (ROV). Each of these technologies can provide fish density estimates but all are subject to assumptions regarding the volume and area surveyed relative to fish counts. Recent experiences with independent estimates of Red Snapper densities from coincident WCAA and ROV indicate higher densities for ROV over the same habitats. The source of these differences is not known but may relate to underestimates of acoustic densities due to the near bottom “dead zone” (acoustic shadow), where ROVs were able to document abundant Red Snapper densities. Additionally, differences might have been due to differential attraction to ROVs or artifacts of methods to derive comparable abundance estimates, although limited calibration studies did not indicate this as a substantial effect.

It is highly unlikely that a single calibration coefficient will be sufficient to adjust the densities calculated by each technology owing to the effects of habitat differences, environmental conditions, spawning periods, and other extrinsic and intrinsic factors. Therefore, we will conduct a series of such experiments in the SA, Eastern, and western GoM in the Fall of 2021 and early Spring 2022 to develop a range of calibration coefficients to bound the likely range of these adjustment factors. In consultation with state and federal fishery scientists, we will select several experimental locations that will allow the simultaneous deployment of two or more observing technologies. Locations may include, in the SA, locations off North Carolina and/or off Cape Canaveral, in the Eastern Gulf, off the FL

Panhandle, and in the Western Gulf off TX/LA. An important consideration in site location selection for calibration studies is sufficient water clarity to allow optimal observation and species identification from optical technologies. Additional calibration trials will be conducted in conjunction with ongoing survey activities to assess the transferability of results of focused calibration experiments to the broad study area.

There are several key experiments to be tested in these calibration studies, including the following:

(1) The use of both baited and un-baited DCs that will be deployed sequentially to understand the relative densities with and without bait attraction.
(2) WCAA will be deployed over both un-baited and baited DC experiments to both estimate the relative density per volume of water sampled and to eventually compare absolute densities between platforms. The use of the camera deployments is critical in determining from "ground truth" the species being ensonified by the WCAA. Issues of numbers per volume of water observed vs. numbers per area observed will be resolved using such experiments.
(3) Similar to the DC experiments, simultaneous use of TV and ROV vs. WCAA will be used both to compare differences in relative and absolute densities and to provide ground truth of species identification to aid in discerning the acoustic signatures (frequency dependent target strength) of GAJ relative to other species encountered.
(4) Similar to (3) intercalibration of ROV and WCAA will be evaluated on both natural habitats and on standing and toppled oil rigs and other infrastructure (particularly in the Western GoM) and on artificial reefs (especially in the Northern GoM).
(5) A subset of DC sites will be sampled repetitively (end of one day and beginning of the next) to assess site occupancy by GAJ to provide insight into structural zeroes within the dataset of GAJ observations.
(6) At least 10 GAJ and other *Seriola spp*., as available, will be collected and transported to the Computed Tomography facility (University of South Alabama Health University Hospital). These will be used to develop acoustic scattering models to determine the species- specific acoustic signatures to be used for identification in the field.
(7) For eDNA technology to become an established tool in marine fisheries management, ground-truthing studies are needed. We will investigate the efficacy of eDNA approaches to assess the presence/absence and relative abundances (via DNA concentrations) of GAJ, as well as three superficially similar species (Lesser Amberjack, Almaco Jack, and Banded Rudderfish) in combination with other methodologies during calibration trials.

These experiments are intended to more fully evaluate potential biases associated with any one technology and to calculate adjustment factors (calibration coefficients) from these studies. Analytically, the relative catchability (to a standard gear) can be calculated using General Linear Models (GLMs) and analyses of proportions among the gears.

### 3.3.4. Cross-regional work plans - Towed video (C-BASS)

While ROV and stationary cameras surveys can be used to derive counts of reef fishes, they are best used for point estimates of features (e.g., artificial reefs, prominent natural relief features). For large expanses of bottom areas where reef fish are not concentrated around particular sites, stationary and ROV-based cameras simply do not cover enough area to be efficient in finding the relatively rare event of occurrence of GAJ. Consequently, in areas suspected to be primarily unconsolidated sediments or large expanses of natural hard bottom, we will utilize towed camera/acoustic sleds to increase sampling efficiency. The towed systems employing video and acoustics represent a cross-regional survey method that will enhance our ability to have additive estimates across regions. Paring both the point count camera-based methods (ROV, stationary cameras) and transect count survey methods (towed camera arrays) with hydroacoustics will increase the robustness of our counts and serve to facilitate cross regions comparisons.

The Camera-Based Assessment Survey System (C-BASS; Grasty 2014; Lembke et al. 2017) consists of a series of six high-definition video cameras used in stereo and individually (Figure 7). The system also has a range of environmental sensors (temperature, depth, salinity, CDOM) and navigation-related sensors. The system has been has used for estimating habitat-stratified population and density estimates (Ilich et al. 2021) in conjunction with simultaneous multibeam sonar habitat characterization, primarily throughout the eastern GoM (2013-2020) with additional work completed in the central and western GoM (2018-2020). Extensive testing of the system has allowed for the evaluation of key assumptions in population estimation from line transect studies using video systems, including a categorical evaluation of the effects of visibility (siting efficiency as a function of water turbidity), attraction/avoidance, species identification, and spatial autocorrelation of observations.

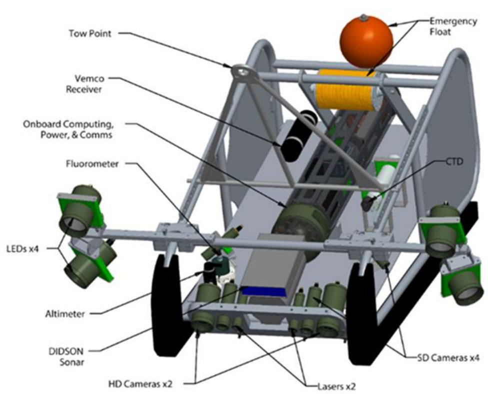



*Figure 7. C-BASS tow sled configuration for near-bottom fish and habitat assessment (Lembke et al. 2017).*

We propose to deploy the C-BASS camera system to assist in the estimation of population size for GAJ in the northern and eastern GoM (MS/AL and FL) and along the SA coast. This part of the project will concentrate on natural hard- and soft-bottom habitats and other low relief human-derived hard structures (e.g. oil and gas pipelines). Within designated habitat or relative density strata we will deploy the C-BASS in a series of 15 nm transects to estimate amberjack densities as imaged via the towed video camera system. Analysis of the imagery collected with the C-BASS system will commence with reading the videos for fish abundance. The average stratified densities of amberjack (and all associated species) will follow methods in Grasty (2014) and Murawski (2020).

Based on the areas to be surveyed and the available surveying time, a preliminary estimate of the total number of 15 km segments to be quantified via C-BASS and simultaneous acoustic water column measurements is ~125 using the FIO R/Vs Weatherbird II and W.T. Hogarth. These transects will be distributed among the GoM and SA regions in proportion to the approximate areas to be surveyed and according to the final sampling design adopted.

### *3.3.5. Regional work plans*

Guided by the overall sampling design refined during Phase I of the study, each regional study will collect observations by habitat type in each of the six regions defined (Table 1). Lessons learned from the calibration study may also result in slight modification or the addition of other gear types. The PI's have all agreed to modify sampling effort and budgetary cost (if needed) to accommodate any shift in effort dictated by the model develop at the end of Phase I.

#### 3.3.5.1 Texas and Louisiana

Benthic habitat in the W-GoM is dominated by large areas of uncharacterized bottom (UCB) that account for most of the seabed on the continental shelf (~140,000 km$^2$ from Texas to Louisiana). Recent acoustic surveys of UCB in this region indicated that fish occurrence and density are patchy across this habitat and concentrated in areas with relief anomalies or areas of the bottom where the seabed is raised forming areas of topographic complexity.

To generate density estimates of GAJ on UCB under the expectation of a persistent nepheloid layer across the Western Gulf of Mexico, we will use three different but complementary survey approaches: EK80 split-beam echo sounder, ARIS HD imaging sonar, and stereo camera array (SCA). Because previous EK80 surveys on UCB in this region clearly indicated that reef-fish biomass was predominantly over relief anomalies, we anticipate that our sampling design will disproportionately sample stations with relief anomalies (subject to revisions in the sampling design at the end of Phase I).

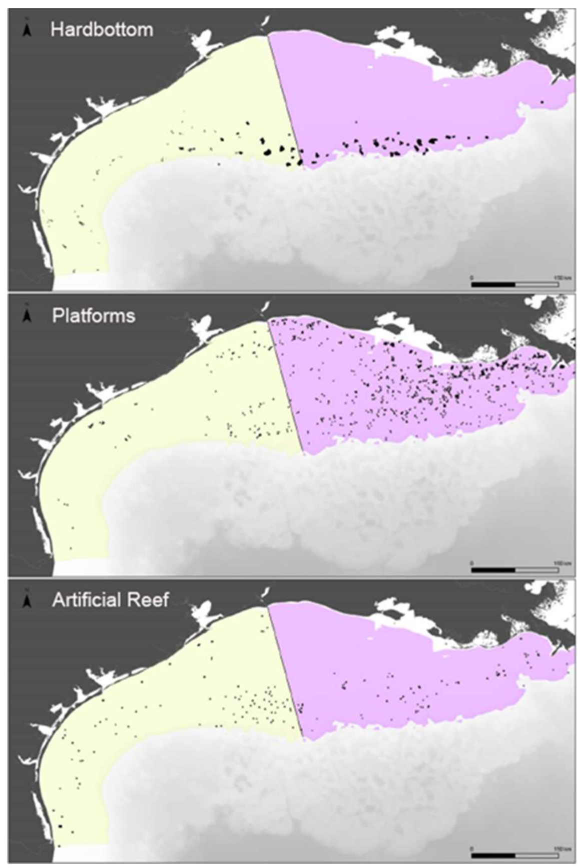


*Figure 8. Distribution of known habitat (natural hardbottom, platforms, and artificial reefs) in Texas and Louisiana*

Interspersed within the UCB is a complex network of natural banks (reefs) extending from south Texas to the Mississippi River delta, including several banks in the Flower Garden Banks National Marine Sanctuary (FGBNMS). These natural banks provide critical hard bottom habitat for a variety of reef-dependent fishes, including GAJ (Campbell et al. 2015, Rooker et al. 2019). Like UCB, estimating GAJ abundance on natural banks of Texas and Louisiana will again rely primarily on stereo camera array (SCA) surveys. We propose to complement SCA surveys with two additional camera/video platforms that have been successfully used in surveys of other reef fishes: towed camera platforms (TCP) and remotely operated vehicle (ROV). All three gear types will be deployed concurrently at sampling stations, with the latter two approaches (TCP, ROV) used to generate density given that both are actively moving across the banks and therefore can be used to estimate the area surveyed during each deployment.

In the Western GoM, the third habitat stratum, artificial structures, consists primarily of standing platforms, Rigs-to-Reefs structures, and ships. These structures provide important habitat for a diverse reef fish community that includes GAJ (Rooker et al. 1997; Ajemian et al. 2015a; Streich et al. 2017; Gallaway et al. 2020). GAJ abundance at artificial habitats will be estimated using EK80 surveys coupled with species composition data derived from DCA and ROV. This approach has been used successfully to estimate reef fish absolute abundance at artificial reefs off TX and LA (Stanley and Wilson 1996, 1997, 2000; Stunz et al. 2021).

#### 3.3.5.2. Mississippi and Alabama

Three primary habitat types occur off the MS/AL coast in the northern GoM: artificial reefs, natural hard bottom and uncharacterized bottom. Randomized side-scan surveys have estimated that the area consists primarily of unstructured sand, mud, and shell with relatively small patches of artificial and natural reef distributed sporadically across the continental shelf. In AL, many of the artificial and natural reefs have been mapped and are in known locations based on the results of randomized surveys of the coastal waters. Sufficient surveys have also been conducted to estimate the total number of artificial reefs and the areal extent of natural reef as well as a variance around that estimate in AL. For MS, there are 200-300 artificial reefs whose location are known. Additionally, there is well mapped (USGS) area of natural reef habitat. We will utilize the data base of 100’s of artificial reefs and thousands of deeper water natural reef contacts to randomly choose sites to survey as prescribed by the sampling plan developed in Phase I. Preliminary estimates (largely based on budgetary constraints) of number of survey sites include 50 for artificial reefs and 70 for natural reefs in the MS/AL region. UCB areas will be surveyed by C-BASS during Murawski’s Gulf-wide cruises. The number of transects to be surveyed will be dictated by the sample design completed at the end of Phase I.

After site selection is completed, ROV video surveys, baited cameras and hydroacoustics surveys will be conducted at each artificial and natural reef chosen. Multiple gears will allow better enumeration of GAJ around the structure and provide further data to compare the methods. Video footage of the fish community will be recorded at the selected stations using high-definition video on a four-thruster ROV. The ROV will be equipped with sonar with a 75-m detection range and 360° viewing capabilities, allowing the operator to safely approach large structures. The ROV will be flown around the perimeter of the structure and a total count will be made. GAJ normally occur in numbers less than 10 allowing for accurate counts without a large probability of double counting. The hydroacoustic surveys of the reefs will allow us to evaluate this assumption. A baited camera system, identical to those used in WFL will also be deployed at the site in a similar manner than the deployment in WFL and the calibration study. When possible, fish measurements will be estimated by using a pair of Digi-Key 5-mW red lasers, aligned in parallel and separated by 3 cm, as a frame of reference. Video imagery from the ROV will be saved to a handheld high-definition recorder for later analysis. In the laboratory, fish visible in the ROV footage will be identified to the lowest possible taxon, enumerated, and measured (when possible). Fish abundance will be estimated using the MaxN (Schobernd et al. 2013) as well as a total count. Baited camera video will be analyzed by the MaxN method. Hydroacoustic surveys will be processed by Boswell group at FIU.

Video and hydroacoustic surveys along the MS/AL coast will be complemented by eDNA surveys (section 3.5). Water samples will be collected, in duplicate, from a subset of the survey stations, across different habitat types (as guided by calibration trials) to assess the presence/absence and relative abundances of GAJ, as well as three superficially similar species to aid in species identifications from video datasets.

#### 3.3.5.3. West Florida

Along the GoM coast of FL, estimates of the abundance of GAJ associated with known natural and artificial reef habitats will largely be derived from data from an ongoing reef fish survey conducted by the state of FL and NMFS. Presently, this survey represents the only fishery-independent source of information on the abundance and size composition used for the assessment of GAJ in the Gulf, with annual CVs ranging from 0.15 – 0.38 since 2010 when all three surveys have been in place (SEDAR 2020; Thompson et al. 2020). Historically conducted as three separate surveys, survey efforts have been unified since 2020 as the Gulf Fishery Independent Survey of Habitat and Ecosystem Resources (G-FISHER). Sampling under G-FISHER will employ a stratified-random design in which annual sampling effort will be allocated among both spatial and habitat strata. Annual effort will be allocated optimally based on a combination of estimated habitat availability (e.g., more effort on strata that are more common) and managed species richness (e.g., more effort on strata where, on average, more managed species are observed). We anticipate that the annual G-FISHER survey effort within Florida waters will consist of approximately 825 natural reef sites and 150 artificial reef sites. As the G-FISHER survey design cannot be modified for this project and was not designed specifically to quantify the abundance of Greater Amberjack, we anticipate allocating approximately 75 – 100 supplemental sites to strata with particularly high variability in Greater Amberjack abundance based on a priori analyses of historical survey data.

Each reef site will be sampled with a stereo-baited remote underwater camera (S-BRUV) array. Most stations will be sampled with full spherical camera systems, although S-BRUV arrays with two orthogonal stereo cameras (Keenan et al. 2018) may be deployed as needed due to gear loss or technical malfunctions. Regardless, all camera systems will utilize identical cameras and lenses to ensure comparability of count data, although conversion factors to transform single-camera abundance data to a full spherical proxy will be developed. All S-BRUV arrays will be baited with a combination of squid and Atlantic mackerel and deployed for approximately 30 minutes prior to retrieval. Twenty minutes of video will be processed, and the relative abundance will be determined as MaxN, or the maximum number of a particular taxon observable on a single video screen shot. Similarly, sizes will be estimated for each taxon at one point during the video where most individuals are measurable using SeaGIS software; to ensure the quality of stereo measurement data, all cameras will be calibrated at the beginning and end of the sampling season. For *Seriola*, both relative abundance and size composition will be determined at both the species and genus level (*Seriola dumerili*, *Seriola fasciata*, *Seriola rivoliana*, *Seriola zonata*, and *Seriola* spp.).

Active acoustics surveys will be conducted concurrent to S-BRUV deployments at a subset of reef monitoring stations throughout the eastern GoM study area (~ 400 – 500 total surveys allocated among spatial and habitat strata). For acoustic surveys conducted by the state of Florida (on the *R/V Gulf Mariner*), a vessel-mounted hydroacoustic array will be used that has been equipped with split-beam 38kHz, 70 kHz, and 120 kHz Simrad EK80 echosounders. For acoustic surveys conducted in conjunction with FIU personnel on larger research vessels, a multifrequency echosounder system (38, 70, 120 and 200 kHz) will be deployed from a stabilized towbody. Surveys will be conducted using either a systematic survey of the entire sampling site or a radial pattern with the S-BRUV at the intersection of each transect; active acoustic survey protocols for S-BRUV stations will be determined based on results of early calibration trials.

### 3.3.5.4. East Florida and Georgia

Along the SA coast of FL and GA, estimates of the abundance of GAJ associated with known natural reef habitats will largely be derived from data from SERFS. The SERFS survey follows a simple random sampling design where ~1,500 – 2000 sampling stations (out of a total sampling frame of ~4,000 known natural reef stations) are selected for sampling each year; approximately 50% of these (750 – 1000 stations) will occur off FL and GA. The SERFS sampling frame includes water depths from 15 – 90 m and extends from 27° N northward to Cape Hatteras. Each randomly selected station will be sampled with a chevron trap (1.7 m x 1.5 m x 0.6 m with a total volume of 0.91 $m^2$) constructed of 2 mm wire mesh (3.4 x 3.4 cm) and a teardrop-shaped mouth approximately 18 cm wide and 45 cm high (Bacheler et al. 2013). Each trap will be baited with 24 menhaden (*Brevortia* spp.) and soak for approximately 90 minutes. Two outward-facing, high-definition (GoPro Hero 3+/4) underwater cameras will be attached to each chevron trap: one over the mouth and one over the nose. Video from the camera facing the trap mouth will be read beginning 10 minutes after the trap lands; snapshots will be read every 30 seconds for a total of 20 minutes (41 total snapshots). The SERFS survey typically utilizes SumCount as the relative abundance metric from video surveys, although a proxy to MaxN can be readily obtained. Active acoustics surveys will be conducted at a subset of stations using a calibrated SIMRAD EK60 echosounder system equipped with a suite of 18kHz, 38 kHz, 120 kHz, and 200 kHz transducers. As the *R/V Pisces* is the only vessel used in the SERFS survey equipped with an acoustic system, all acoustic surveys will be restricted to the area sampled by this vessel.

Because the SERFS survey exclusively samples natural reefs, supplemental survey effort (conducted by the State of FL under PI Switzer) will include conducting surveys at approximately 75 – 100 randomly selected artificial reefs off the coast of GA and FL. In addition, due to the spatial limitations of the SERFS survey, supplemental survey effort will be conducted at approximately 35 – 65 natural reef sites in deep waters off the FL and GA coast (90+ m), and at 75 – 100 natural reef sites off southeast Florida. All supplemental natural and artificial reef sites will be sampled with spherical S-BRUV arrays from which abundance (MaxN) and size composition will be determined at both the species and genus level for *Seriola* (*Seriola dumerili*, *Seriola fasciata*, *Seriola rivoliana*, *Seriola zonata*, and *Seriola* spp.). Active acoustic surveys will be conducted concurrent to S-BRUV sampling at a subset (~ 100 – 150 total surveys) of supplemental artificial and natural reef sites using a vessel-mounted hydroacoustic array equipped with split-beam 38kHz, 70 kHz, and 120 kHz Simrad KE80 transducers.

#### 3.3.5.5. South Carolina and North Carolina

Along the coasts of SC and NC, estimates of the abundance of GAJ associated with known natural reef habitats will largely be derived from data from SERFS as described previously. It is estimated that approximately 50% of annual SERFS effort (750 – 1000 stations) will occur off SC and NC in waters from 15 – 90 m. Each randomly selected station will be sampled with a chevron trap baited with 24 menhaden (*Brevortia* spp.) and allowed to soak for approximately 90 minutes. Two outward-facing, high-definition (GoPro Hero 3+/4) underwater cameras will be attached to each chevron trap: one over the mouth and one over the nose. Video will be processed according to methods described previously for the SERFS survey. Active acoustics surveys will be conducted at a subset of stations sampled by the *R/V Pisces* using a SIMRAD EK60 echosounder system equipped with a suite of 18kHz, 38 kHz, 120 kHz, and 200 kHz transducers.

Off the coasts of SC and NC, SERFS sampling will be supplemented by survey efforts conducted by the state of FL. Supplemental survey effort will be conducted at approximately 35 – 65 natural reef sites in deep waters (90+ m). All supplemental natural and artificial reef sites will be sampled with spherical S-BRUV arrays from which abundance (MaxN) and size composition will be determined at both the species and genus level for *Seriola* (*Seriola dumerili*, *Seriola fasciata*, *Seriola rivoliana*, *Seriola zonata*, and *Seriola* spp.). Active acoustic surveys will be conducted concurrent to S-BRUV sampling at a subset (~ 20 – 40 total surveys) of supplemental natural reef sites using a vessel-mounted hydroacoustic array equipped with split-beam 38kHz, 70 kHz, and 120 kHz Simrad KE80 transducers.

Table 1. Summary of gears used, planned gear-calibration experiments, and approximate number of stations that we anticipate covering across the study region in the three *a priori* habiatat types. Allocation of effort will be modified based on GAJ abundance models formulated in Phase I.

| Region | State | Habitat Type | Gear Used | | | | Gear Calibration | Number of Stations |
|---|---|---|---|---|---|---|---|---|
| | | | EK80 | SCA | ROV | Tow | | |
| Western Gulf of Mexico | TX | Natural Bottom | | | | | Yes | 240 |
| | | Artificial | | | | | No | 170 |
| | | Uncharacterized Bottom | | | | | No | 3000 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | LA | Natural Bottom | | | | | Yes | 165 |
| | | Artificial | | | | | No | 150 |
| | | Uncharacterized Bottom | | | | | No | 3000 |
| Eastern Gulf of Mexico | MS/AL | Natural Bottom | | | | | Yes | 70 |
| | | Artificial | | | | | Yes | 50 |
| | | Uncharacterized Bottom | | | | | No | 1700 |
| | WFL | Natural Bottom | | | | | Yes | 850 |
| | | Artificial | | | | | No | 150 |
| | | Uncharacterized Bottom | | | | | No | 5700 |
| South Atlantic | EFL/GA | Natural Bottom | | | | | Yes | 1000 |
| | | Artificial | | | | | No | 100 |
| | | Uncharacterized Bottom | | | | | No | 5700 |
| | SC/NC | Natural Bottom | | | | | Yes | 1000 |
| | | Artificial | | | | | No | 50 |
| | | Uncharacterized Bottom | | | | | No | 5700 |

Additional Sampling from other Surveys (G-FISHER)

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Western Gulf | TX/LA | Natural Bottom | | | | | Yes | 493 |
| | | Artificial | | | | | Yes | 273 |

## 3.4. (Objective 4) Movement, population connectivity, and mortality

### 3.4.1. Acoustic telemetry and Conventional Tagging

The movement, population connectivity and stock structure of GAJ remains uncertain and the potential for additional sub-regional stock structure has been acknowledged in assessments (SEDAR 33, 59). Like many other coastal fisheries, Greater Amberjack populations in the Gulf of Mexico (GoM) and South Atlantic (SA) are managed as separate non-mixing stocks (SEDAR 70). Relatively little is known about the migratory behavior and population connectivity of contingents within the GoM as well as exchange with SA. Though recent data (otolith shape, genetics, and tagging) suggest substructure within GoM and differences between GoM and SA.

Acoustic telemetry is a powerful approach to assess the movements and population connectivity of coastal marine species (Hussey et al. 2015). The widespread deployment of passive acoustic receivers has led to increasing collaboration among researchers to develop large-scale cooperative networks of receivers in many of the world's coastal waters, including the GoM and SA (iTAG and FACT). Thus, the infrastructure now exists (and continues to expand) for large-scale tracking of coastal reef fishes using acoustic telemetry in both regions. Additional receivers will be deployed in this project to increase coverage of critical habitats where current receiver coverage is lacking. Specifically, receivers will primarily be deployed at areas of increased abundance at the shelf-edge reefs and platforms of the western and central GoM (Gallaway et al. 2019), as well as artificial and natural reefs off the North Carolina coast in the SA. Given the long tag durations, this technology allows researchers to monitor migration patterns of individuals over multiple migration cycles to examine inter-annual variability in migration behavior (Hussey et al. 2015, Hays et al. 2016).

In addition to movement, electronic tags coupled with high-reward external tags provide data that can be used to estimate mortality rates (Hightower and Harris 2017). The use of electronic and conventional tags to estimate mortality was listed as a research recommendation in the most recent SA Greater Amberjack stock assessment (SEDAR 59, 2020) because the status estimates were most sensitive to input values of natural mortality rate (*M*). Estimates of fishing mortality (*F*) from an independent tagging study could be used to corroborate estimates of *F* from stock assessments in the GoM and SA. Most relevant to the RFP, estimates of *F* and landings data can be used to estimate absolute abundance. Tagging-based estimates of mortality are often made on monthly or seasonal time steps (Bacheler et al. 2009, Harris and Hightower 2017) that can improve management decisions. The use of conventional reward tags also provides an opportunity for angler engagement in the management process by paying them for returning tagged fish that they have captured. These angler tag returns are critical for partitioning fishing and natural mortality in the combined telemetry-conventional tagging approach (Hightower and Harris 2017). Finally, we will obtain a tagging-based estimate of abundance by dividing sector and region-specific landings data by our estimates of exploitation rates from the tagging study. This additional estimate of abundance is partially independent from the NMFS stock assessment.

The goal of the proposed tagging study is to provide the first comprehensive characterization of Greater Amberjack habitat use, movement, stock structure, and mortality in the U.S. GoM and SA. The study will focus on four primary objectives: (1) Characterize reef residency and site fidelity of Greater Amberjack at natural and artificial habitats in the GoM and SA, (2) identify seasonal movement patterns and connectivity of Greater Amberjack among habitats within each region, (3) evaluate exchange and mixing between three primary regions (SA, western GoM, and eastern GoM), and (4) Estimate fishing and natural mortality rates of Greater Amberjack in the SA, eastern GoM, and western GoM.

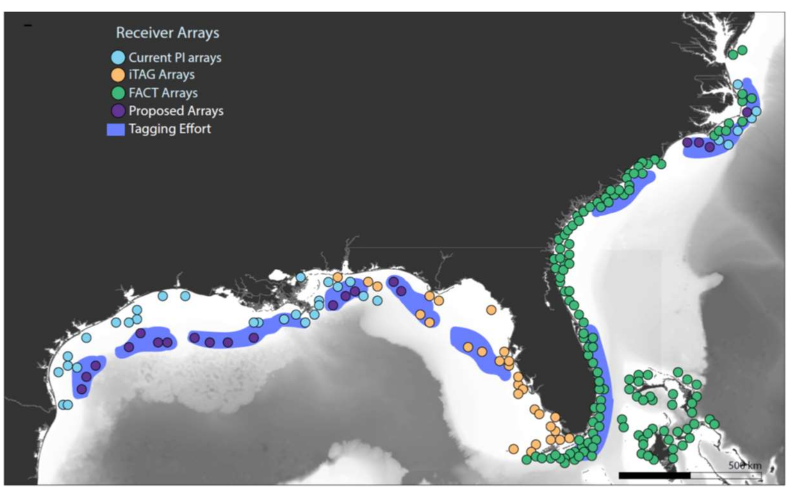


*Figure 9. Distribution of acoustic receiver arrays maintained by the PIs (light blue), existing large receiver networks (iTAG - orange, FACT - green), and arrays to be deployed by the PIs in the proposed study (purple). Note that points represent receiver arrays (1-100s of receivers) rather than locations of individual receivers.*

Acoustic telemetry will be used to investigate movement patterns, habitat use, and residency of Greater Amberjack within and across three primary regions: SA, eastern GoM, and western GoM, with each primary region divided into three sub-regions. Individuals (n = 150 per primary region; n = 50 per sub-region) will be captured via hook and line and internally fitted with acoustic transmitters with a battery life of approximately 6 years.

We will also implement a conventional tagging program, using high-reward external tags, to partition fishing and natural mortality rates. Greater Amberjack tagged with acoustic transmitters (n=150 per primary region) will also be tagged externally with an anchor tag labeled “Cut and return tag for $250 reward”. In addition to the telemetered fish, we will work with our recreational fishing industry partners to capture and conventionally tag up to an additional 250 legal-sized Greater Amberjack in each of the three primary regions. These additional fish will be tagged across the shelf at randomly selected sites known to harbor Greater Amberjack. Tag shedding rates will be estimated by placing two tags in 50% of the externally tagged Greater Amberjack. Each tag will be printed with a toll-free telephone number and email address to facilitate tag returns by anglers. Anglers reporting the capture of a tagged Greater Amberjack will be queried as to the date, location, fishery sector (private, for-hire, commercial), approximate fish size at capture, port of origin, and fate (harvested or released). We will also ask anglers whether they were aware of the tagging program prior to catching the tagged Greater Amberjack and if so, how they became aware of it, to assess the potential for angler non-reporting.

### 3.4.2. Population genetics

In this project component, genome scans generated by the double-digest restriction site-associated DNA (dd-RAD) sequencing method will be used to infer stock structure and connectivity of GAJ in US waters. Current information on population genetic structure in GAJ is limited to a study of mitochondrial DNA variation by Gold and Richardson (1998) and a recent study by Hardgrove et al. (2018) based on 11 microsatellite loci. Divergence among geographic populations was very weak in both studies. Gold and Richardson (1998) found some weak support for divergence between Atlantic and Gulf of Mexico stocks when the Florida Keys samples were grouped with those from the East coast, suggesting that the Atlantic genetic stocks included the Florida Keys. Hardgrove et al. (2018) sampled the Florida Keys spawning population (assumed to represent the Atlantic breeding stock) and three Gulf locations. The distinction between the Gulf and Keys spawning stocks based on analysis of spawning adults was weakly supported. A two stocks model for the sampled range was supported but without clear geographic delineation. It was suggested that GAJ may form a complex metapopulation with extended geographic mixing. These two studies were limited by incomplete geographic sampling (Hardgrove et al. 2018 did not sample the western GoM or SA) and small numbers of markers which prevented assessment of divergence due to natural selection and limited the power of inferences on demographic parameters. This study will address limitations of the two previous studies by using genome scans involving thousands of Single Nucleotide Polymorphism (SNP) markers and a comprehensive sampling from the Carolinas to the Western Gulf of Mexico.

Samples will be collected in conjunction with other project components and existing surveys by NOAA including the Trip Interview Program and state fishery dependent surveys. Fin clips will be preserved from geographic populations (US East coast from the Carolinas and Southeast FL, Southeastern, Northeastern, Southwestern, and Northwestern GoM). The target sample size for the genetic project component will be 600 individuals (50 per year for two years for each geographic area) to allow testing the temporal stability of inferred patterns. In a first task, genomic resources needed to interpret genome scans will be developed. A draft reference genome sequence will be produced by sequencing the genome of one GAJ using the PACBIO Sequel and the Illumina Novaseq platforms and assembling the reads in contigs and scaffolds. A high-density linkage map of the GAJ genome will be developed based on 10,000 or more SNP loci discovered and genotyped using the dd-RAD sequencing method (Peterson et al. 2012) in one male individual and amplified DNA from individual spermatozoa. The map will be used to anchor genome contigs and scaffolds to form the reference genome. Geographic samples will be assayed using the dd-RAD sequencing protocol aiming for 10,000 or more SNPs usable for genetic characterization of populations.

## 3.5. (Objective 5) Environmental DNA

We will investigate the efficacy of eDNA approaches to assess the presence/absence and relative abundance of GAJ, as well as three superficially similar species (Lesser Amberjack, Almaco Jack, and Banded Rudderfish) in conjunction with other approaches. To achieve this, we will develop novel eDNA tools for GAJ and compare their performance to visual and hydroacoustic approaches during calibration trials (section 3.3.3). We will then integrate these 'ground-truthed' eDNA methods into field surveys in MS/AL waters and compare the results to complementary datasets obtained via other methodologies.

All field and lab eDNA methods will scrupulously adhere to eDNA protocols and controls to reduce the likelihood of contamination of exogenous DNA and cross-contamination of samples (Goldberg et al. 2016). Water samples (10 L) will be collected, in duplicate, from at least 20 stations and/or timepoints during calibration trials and field surveys. Water samples will be collected via sterile Niskin bottles attached to a CTD and will immediately be filtered on-site to reduce the likelihood of DNA degradation post-collection. Filters will be rolled and preserved in Longmire's buffer. Environmental data (e.g., temperature, salinity, DO, turbidity) will be collected at each sampling location to approximate the lifespan of DNA in the water column, facilitating the interpretation of eDNA results.

Total eDNA will be extracted from ½ of each filter using the QIAGEN DNeasy Blood and Tissue Kit incorporating QIAshredder spin columns (see Schweiss et al. 2020). DNA extracts will be screened for target DNAs using a custom-designed Droplet Digital PCR (ddPCR) genetic assay. DdPCR technology can detect a single copy of target DNA in a reaction, making it the most sensitive and precise technology available for the quantification of DNA from environmental samples (Doi et al. 2015). The ddPCR assay will be developed to target DNA from Greater Amberjack as well as Lesser Amberjack, Almaco Jack, and Banded Rudderfish. Simultaneously targeting these four species will allow us to assess whether ddPCR eDNA methods can be used to guide species identifications from video datasets, where species presence can be uncertain due to difficulties in distinguishing superficially similar species.

A rigorous three-criteria approach for positive detections of each target species will be implemented to reduce the likelihood of false positive detections: 1) droplets must fall above an assay-specific manual threshold, 2) droplets are within the known positive range for the assay, and 3) the concentration of target DNA is at or greater than the Limit of Quantification for the developed assay. Target DNAs will be quantified using Rare Event Detection and Absolute Quantification analysis methods in the Bio-Rad QuantaSoft software. The frequency of positive detections and the relative concentrations of target DNAs will then be compared to complementary datasets obtained via other approaches. More broadly, this will inform on how eDNA tools can be integrated into multi-disciplinary approaches to study the distribution and abundance of marine fishes.

## 3.6. (Objective 6) Update of basic biological information

Recent stock assessments for GAJ in the GoM have recommended an expanded sampling program to "elucidate regional and sub-regional differences in the demographic of greater amberjack" (SEDAR 33). In particular, age and growth information from the Western GoM has been extremely limited despite the fact that there is some evidence of stock structure between the eastern and western GoM. While more recent studies have been conducted in the SA, there is still a need to update/develop region-specific demographic information. Of relevance to this RFP is the need to develop region-specific age-length keys to characterize distribution and abundance of GAJ by age class across the regions. We will utilize both fisheries dependent and fisheries independent collections of GAJ from each of three regions (SA, Eastern GoM, Western GoM) to update biological information and develop age-length keys that will also allow us to convert length estimates to age in regional surveys. Dockside sampling will be conducted to collect GAJ from for-hire and private recreational angling communities in each region. Several PIs on this proposal (Dance, Powers, FWC) already operate dockside sampling programs in their respective regions and work closely with anglers to collect samples across a suite of fisheries species. Additional fisheries independent sampling will be conducted by the PIs and coordinated with tagging efforts to collect individuals that are not targeted (sublegal fish) or less targeted (shelf-edge reefs) in the recreational fishery. We will target approximately 300 fish per region (n ~ 100 per subregion). Otoliths and fin clips will be collected from all specimens and additional biological tissues (e.g., muscle, gonads, liver) will be harvested and archived when possible. Note that during these collections fin clips will be collected for the population genetic component as well. Additional fin clips will be collected from all fish in the tagging studies.

GAJ will be aged according to methodology adopted by the Gulf States Marine Fishery Commission (GSMFC). Otolith preparation and aging will be conducted in Pi Powers and Dance labs. Opaque rings will be counted out from the core along a primary and secondary axis as described in Murie and Parkyn (2008), increments will be measured, and margin codes will be assigned based on methods established by the GSMFC. All otoliths will be read by two independent readers based on a standardized aging protocol (Murie and Parkyn 2013). The results will then be compared, and when the readers disagree, they will jointly examine the otolith in question. If a consensus is not reached, the otolith data for that fish will be omitted from further analyses. Inter-lab calibration will also be performed using a reference set that Deb Murie (UFL) recently assembled for Powers.

While our primary goal for objective 6 will be to develop region-specific age-length relationships, we will also archive biological samples that may be used to update region-specific reproductive indices (fecundity, spawning season, etc.) if funding allows or becomes available.

### 3.7. (Objective 7) Stakeholder engagement

Effective management of GAJ requires thoughtful and frequent collaboration not only between resource managers and researchers, but with stakeholders as well. Consequently, the GAJ Research Program was structured to encourage “co-defined and co-developed” research (Ebel et al. 2018). Part of this structure included a visioning phase where stakeholder input was collected. At the conclusion of this research project, members of the visioning team will initiate a documenting phase that will summarize results and transfer knowledge.

We will work with established groups, particularly the existing GAJ Research Program visioning team, to synthesize and summarize project findings for broad dissemination. To accomplish this, we will work with the leadership team, as well as specific regional Sea Grant point of contact for each state in the GoM and the SA. This includes assisting in the preparation and distribution of materials that succinctly convey the information learned from this project. In addition to working directly with the existing GAJ Research Program visioning team, we will work closely with a newly established Sea Grant Reef Fish Extension Collaborative whose goals are to “extend science concerning reef fish, including, but not limited to, data and information produced from the recently concluded “Great Red Snapper Count,” the ongoing Sea Grant Amberjack Research program and…”. Members of the current project team include those who lead the engagement portion of the Great Red Snapper Count and are thus well suited to assist the currently established groups to ensure the broadest possible dissemination of findings from this study.

## C. Project Management and Coordination

This consortium will bring together extensive research capabilities of investigators with many years of experience in studies of reef fish and the interface of management and science. There is a minimal ramp-up phase for this study and given that most of this team is already working in this system on reef fish having completed the GRSC. The team will be led by PI **Powers,** Chair of Marine Sciences at the University of South Alabama and a Senior Marine Scientist at the Dauphin Island Sea Lab (USA-DISL). As the consortium leader, Dr. Powers will be responsible for overall project oversight, coordination among regional/design Co-PIs, field sampling off MS/AL, and dissemination of findings. Powers will be assisted by a full-time science coordinator (Dr. Mark Albins) and a grants administration specialist (TBD), who will also work directly for PI Powers to ensure sub-awardee administrative requirements are met.

A PI coordinating committee will meet quarterly throughout the project. The committee will include all regional (Rooker [TX], Dance [LA], Powers [MS/SL], Switzer [FL-GA], Buckle [SC/NC]) and cross-regional leaders [Murawski, Boswell, and Hoenig] as well as the stakeholder engagement lead [Drymon]. Dr. Powers will chair the committee and Dr. Greg Stunz will serve as the vice-chair. Dr. Stunz recently led the GRSC and his experience in large program leadership will be critical to the project success. Dr. Stunz is also designated as the back-up leader for the project. Project leads for different study components can be found in Figure 3.

Table 2. Project and component leaders* and collaborators.

| **Investigator** | **Institution** | **Duties** | **Coordinating Committee Member** |
|---|---|---|---|
| Sean Powers | USA | Lead PI & Regional Lead AL/S | Yes (Chair) |
| John Hoenig | VIMS | Design/Modeling/Analysis | Yes |
| Grace Chiu | VIMS | Design/Modeling/Analysis | |
| Lynne Stokes | SMU | Statistical Review/Consultant | |
| Steve Murawski | USF | Cross-regional*:* C-BASS | Yes |
| Kevin Boswell | FIU | Cross-regional*: Hydroacoustic Lead* | Yes |
| Eric Saillant | USM | Cross-regional*: Population Genetics Lead* | |
| Matt Catalano | Auburn | Cross-regional*: High reward tagging Lead* | |
| Nicole Phillips | USM | Cross-regional*: eDNA Lead* | |
| Marcus Drymon | MSU | Lead: Stakeholder Input & Comm. | Yes |
| Jay Rooker | TAMUG | Co-Regional Lead: TX | Yes |
| Greg Stunz | TAMU CC | Co-Regional Lead TX | Yes (Vice-chair) |
| Mike Dance | LSU | Regional Lead: LA | Yes |
| Ted Switzer | FWC | Regional Lead: W FL & E FL-GA | Yes |
| Jeff Buckel | NCSU | Regional Lead: NC-SC, Lead Telemetry | Yes |
| Nate Bacheler | NOAA | Collaborator | |
| Matt Campbell | NOAA | Collaborator | |

*Several co-PI's will assist the project leaders: Mark Albins, USA (MS/AL region), Marta D'Elia, FIU (hydroacoustic), Stephen Midway, LSU (LA Region), Steven Scyphers, NEU (stakeholder input), and David Wells, TAMUG, (TX-Region).

While input and exchange with NMFS will occur throughout the project, PI/NMFS/Steering committee meetings will be conducted at major transition points in the phased design. A PI meeting will occur at the outset to ensure all suggested revisions during the proposal review are incorporated. A second PI team/NMFS meeting will occur at the critical Phase I and Phase II transition when the sampling design and framework are finalized. A key lesson learned during the final review of the GRSC was the need for earlier feedback on the sample design and strategy. Clear expectations on the number of sampling sites per strata and close adherence to the design/approach *a priori* (before the sampling in Phase II begins) is critical to the acceptance of the studies abundance and variance estimates. A third meeting between Phase II and III will be conducted to discuss trade-offs in any analysis changes necessitated by study complications and to plan the stakeholder engagement. A final review meeting is anticipated at the end of the project to present the results to the SSC committees (SAFMC and GMFMC) and any independent reviewers. Our outreach and engagement team will communicate on the projects progress and overall design as well as seek input from stakeholders throughout the project; however, to the extent practical the PIs will not finilize the abundance and variance estimates until the completion of a NMFS, SSC, and independent review (another critical lesson learned from the review of the GRSC).

## D. End-User Involvement

A primary end user of the estimates will be stock assessment scientists at the Southeast Fisheries Science Center (SEFSC), the Southeast Regional Office (SERO), the Gulf Fishery Management Council (GMFMC), the South Atlantic Fishery Management Council (SAFMC) and associated Science and Statistical Committees (SSCs) of the Councils. Our research team is uniquely suited to facilitate this type of interaction during the development of this design given our active involvement with the fishery management process. Our design was developed with these outcomes in mind – to produce a usable product for stock assessment and advance the science of fisheries-independent monitoring. For example, several of the PIs participate with the Gulf and South Atlantic fishery management committees. PI Powers and Co-PI Scyphers are members of the Gulf SSC, Co-PI Stunz serves on the GMFMC and is a former SSC member, and Co-PI Buckel serves on the SAFMC and SA SSC. Co-PI Drymon is a member of the Gulf Council's Outreach & Education Technical Committee. Thus, our team is acutely aware of and integrated into the management process and can facilitate the transfer of information to be incorporated into the Greater Amberjack stock assessment.

While not directly involved in the technical aspects of scientific data collection, constituents' participation represents a strategic engagement opportunity between the scientific/management community and Gulf stakeholders. In our opinion, developing these relationships during the implementation phase is critical. Our team of investigators routinely partners with willing and enthusiastic individuals (citizen scientists) to help collect meaningful data that would otherwise be too expensive or time-intensive to obtain. These partnerships are important in not only informing the public about ongoing research in their community but, in many cases, creating a vested interest by the public in understanding and conserving our natural resources. We have several design components that easily facilitate participation for recreational and commercial anglers. The primary component of this design that includes stakeholder engagement is the high reward tagging study that will be performed regionally throughout the GoM and SA. While scientific tagging during the initial fishing effort is imperative, recapture of the fish is not. Thus, we will rely on commercial and recreational anglers to catch and report tagged fish. To ensure high reporting, we will heavily incentivize reporting of these captured fish with high monetary rewards, which has been very successful in other studies. Moreover, we will charter both commercial and for-hire vessels for many aspects of our studies. Certainly, a major benefit from this involvement is the fishing community becomes engaged in the study, and thus the fishery. Comprehensive awareness campaigns that will be developed for the high reward tagging study also offer the opportunity to engage the general and angling public about this study. This involvement will allow citizens and regional consortia to provide key support in obtaining accurate and precise abundance estimates.

## E. Expected Impacts and Application of Results

The primary benefits of this study are to (1) provide an independent absolute abundance estimate of Age-1+ GAJ in the GoM and SA, (2) to shed light on the spatial and habitat-related distribution of the species, and (3) to better understand population and movement dynamics of GAJ in the region. This assessment will reduce uncertainty by providing robust population estimates, lead to maximum fishery access for stakeholders, and increase revenue to coastal communities. This is a large-scale survey using novel, integrated sampling approaches. The scientific approaches to surveying a widespread species occurring in diverse habitats, such as GAJ, will be advanced by the development, implementation and evaluation of results obtained. But the task is daunting.

This complex study addresses one of the most controversial issues currently facing fisheries management in the southeastern US – estimating absolute abundance of GAJ. But this is not a new problem—it existed in the early 1980's. The practical benefit is that an independent estimate of abundance of age-1 and older GAJ will provide valuable information relevant to sustainable management of the GoM and SA GAJ populations. Potential secondary benefits from this work are estimates of GAJ growth, mortality, site fidelity, and population connectivity, as well as habitat specific reef fish community structure across the study region.

## F. Data Management and Sharing Plan

We understand our role in satisfying the directives for sharing environmental data and peer reviewed publications expressed in version 3.0 of the NOAA document *Data and Publication Sharing Directive for NOAA Grants, Cooperative Agreements and Contracts* and will adhere with guidance, definitions, directives, and requirements contained therein. All data collected from this award will be made available to the MS-AL SeaGrant Program. We also have the full intention of sharing and making these data readily available to end-users such as the Gulf of Mexico Fishery Management Council and Science and Statistical Committee in a timely manner. A dedicated data manger will be hired under PI Powers direction. The Data manager will work closely with each regional and cross-regional PI to ensure timely delivery of data to the analytical team at VIMS. The Data manager will also be in close contact with the Harte Research Institute for Gulf of Mexico Studies (HRI) at Texas A&M University-Corpus Christi who will archive all data collected. Dr. Jim Gibeaut, Endowed Chair for Coastal and Marine Geospatial Sciences is an external collaborator on this project and is the PI for the GRIIDC activity. Dr. Gibeaut has worked with PI Powers and co-PI Stunz and with NCEI and other NOAA data-centric groups for decades and are active participants in the data and informatics community.

The Harte Research Institute for Gulf of Mexico Studies (HRI) at Texas A&M University-Corpus Christi has an outstanding history with data management and access and willlead this component under co-PI Stunz's direction. Poject PIs will be assisted with data archiving by the Gulf of Mexico Research Initiative Information and Data Cooperative (GRIIDC, http://data.gulfresearchinitiative.org/) housed at HRI.