# Optimizing Fishery Independent Surveys in the Gulf of Mexico Project Report

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## Acronyms and Abbreviations

| | |
|---|---|
| AUV | Autonomous underwater vehicle |
| BOEM | Bureau of Ocean and Energy Management |
| Commission | Gulf States Marine Fisheries Commission |
| CKMR | Close-kin mark-recapture |
| COI | Mitochondrial encoded cytochrome c oxidase subunit I |
| CTD | Conductivity, temperature and depth |
| CUFES | Continuous Underway Fish Egg Sampler |
| CV | Coefficient of variation |
| DNA | Deoxyribonucleic acid |
| EBFM | Ecosystem-Based Fisheries Management |
| eDNA | Environmental DNA |
| GenBank | National Institute of Health genetic sequence database |
| G-FISHER | Gulf Fishery Independent Survey of Habitat and Ecosystem Resources |
| HRMA | High Resolution Melting Analysis |
| ICCAT | International Commission for the Conservation of Atlantic Tunas |
| km | Kilometer |
| m | Meter |
| MOCNESS | Multiple Opening and Closing Net Environmental Sensing System |
| mtDNA | Mitochondrial DNA |
| NOAA | National Oceanic and Atmospheric Administration |
| ROV | Remotely operated vehicle |
| pH | Potential of hydrogen |
| SEAMAP | Gulf of Mexico Southeast Area Monitoring and Assessment Program |
| SEFSC | NOAA Southeast Fisheries Science Center |
| SOM | Survey optimization model |
| VIAME | Video Image Analytics for the Marine Environment |

# Executive Summary

NOAA Fisheries Southeast Fisheries Science Center (SEFSC) and the Gulf of Mexico's Southeast Area Monitoring and Assessment Program (SEAMAP) have a long-term focus on collecting fishery independent data for stock assessments and ecosystem-based fisheries management (EBFM). In order to collect data for next generation stock assessments and EBFM, the SEFSC tasked the Gulf States Marine Fisheries Commission (Commission) with reimagining the fishery independent survey enterprise in the Gulf of Mexico by considering new approaches to fishery independent surveys, optimizing the sampling design of current SEFSC and SEAMAP fishery independent surveys, and incorporating advanced sampling technologies into existing or new surveys.

The Commission formed a Steering Committee composed of experts from the fields of fisheries independent survey design, stock assessments, ecosystem modeling, climate change, and advanced technologies to oversee the project and develop new fishery independent surveys. The Steering Committee's goal for the project was to identify an idealized sampling approach—through a balanced portfolio of actions that is robust to uncertainty, including future climate scenarios—to gain a holistic understanding of the status and trends of the Gulf of Mexico ecosystem. The Steering Committee felt that the project should explore ways to optimize current surveys, augment current fishery independent surveys where there are gaps, and consider novel sampling approaches to incorporate into existing or new surveys.

The Steering Committee recognized that there are many improvements that could be made to existing surveys and new surveys that could be implemented to fill primary data gaps. However, the primary need is to maintain or improve existing surveys that provide the necessary data used across many stock assessments. Two major long-term priorities emerged from the group discussions and prioritization exercise: 1) increasing the number of bottom longline stations in the NOAA Fisheries Bottom Longline Survey and 2) securing long-term funding for the SEAMAP Reef Fish Survey. Securing the resources to fund these priorities in a level-funding environment could be accomplished by reprioritizing other SEFSC activities, eliminating or altering other surveys (e.g., discontinuing the SEAMAP Spring or Fall Plankton Survey or discontinuing the SEAMAP Fall Plankton Survey and collecting plankton during the SEAMAP Summer or Fall Shrimp/Groundfish Survey) or by conducting some surveys every other year.

Furthermore, the Steering Committee recognized additional investments that, while initially costly, would ultimately create efficiencies and reduce costs in the long-term. Genetic approaches have such potential. The application of close-kin mark-recapture (CKMR) to larval and adult Atlantic Bluefin Tuna (*Thunnus thynnus*) has already produced an estimate of absolute population size, and continued application would result in a time series of relative/absolute abundance estimates. CKMR could also be evaluated for other species, and instituted when feasible. The use of genetic methods to more fully elucidate the species composition of plankton samples would increase the utility of the plankton surveys for stock assessments and EBFM. The use of environmental DNA could also produce useful information for stock assessment at low cost. Advanced technologies such as artificial intelligence and machine learning also have great potential to reduce costs in the long-term. Continued investment in video-reading automation would likely yield high returns on investment with staff time, particularly if the video survey were expanded. Finally, the use of acoustics to measure relative abundance, and the development of epigenetic clocks to age fish inexpensively could also create efficiencies; however, these are larger investments with an unknown probability of success.

Relatively minor adjustments to surveys that could improve information value include: collecting additional samples to augment life history data (e.g., age, reproduction, diet), installing supplementary probes on CTDs to collect a wider variety of environmental data, and using CTD altimeters to make better use of environmental data. Additionally, adding acoustic echosounders and net monitoring systems to trawl surveys would increase the precision of data collected in those surveys.

Ultimately, the optimal survey design and recommendations will depend on available funding, which could be summarized in terms of three possible scenarios:

- Scenario 1 – level or potentially reduced funding: The primary recommendation under this scenario would be to increase the number of bottom longline stations in the NOAA Fisheries Bottom Longline Survey and secure long-term funding for the SEAMAP Reef Fish Survey, at the expense of discontinuing some lower-priority surveys or conducting them every other year. Additional cuts could fund research investments that would likely yield cost-savings in the long-run.
- Scenario 2 – short-term funding increase (e.g., Inflation Reduction Act funding) followed by long-term decrease in funding: The primary recommendation under this scenario would be to immediately invest in research initiatives that would be highly likely to yield significant cost savings in the long-term (e.g. automation of video reading, CKMR).
- Scenario 3 – long-term sustained increase in funding: In this scenario, a larger suite of priority recommendations outlined in the report could be implemented into the foreseeable future. This includes implementation of new surveys to cover gaps that are not easily filled by the current configuration, including habitat mapping, a forage fish survey, a marine mammal, seabird, and sea turtle abundance survey, and pelagic fish surveys.

The recommendations in this report represent the culmination of a multiyear project to optimize fishery independent sampling in the Gulf of Mexico. The recommendations are intended to improve efficiencies and strengthen the overall effectiveness of the current survey enterprise. An optimization tool is also included to demonstrate the potential tradeoffs between current sampling efforts and hypothetical alternatives that are informed by specific management goals or priorities. The dynamic tool can be used to weight management objectives to reflect high level prioritization. To aid decision makers in evaluating potential benefits and tradeoffs, the Steering Committee prioritized recommendations to address current needs at level cost, as well as innovative advancements that require initial investment, but are likely to produce long-term efficiencies. The Steering Committee recognizes that survey priorities change, but expects that the information contained in this report, as well as supplementary information, will be useful to decision makers as priorities emerge and evolve.

# 1. Introduction

In an effort to improve the management of the nation's fisheries, NOAA Fisheries is implementing its Next Generation Stock Assessment framework that will address the demands and challenges of maximizing yield while ensuring that overfishing does not occur and stocks do not become overfished. Lynch et al. (2018) describe next generation stock assessments as assessments to support harvest policies that are more holistic and ecosystem-linked following a strategic approach that makes best use of available resources; use innovative science and technological advancements to improve the data used in stock assessments and projection; and create a more timely, efficient, and effective stock assessment process that prioritizes stock-specific goals and objectives.

NOAA Fisheries Southeast Fisheries Science Center (SEFSC) and the Gulf of Mexico's Southeast Area Monitoring and Assessment Program (SEAMAP) have a long-term focus on collecting fishery independent data for stock assessments and ecosystem-based fisheries management (EBFM). To collect data for current and next generation stock assessments and EBFM, the SEFSC tasked the Gulf States Marine Fisheries Commission (Commission) with reimagining the fishery independent survey enterprise in the Gulf of Mexico by optimizing the sampling design of SEFSC and SEAMAP fishery independent surveys and incorporating advanced sampling technologies into existing or new surveys. The Commission also would develop an implementation plan for transitioning current fishery independent surveys to any new surveys in order to not lose the historical aspect of previous fishery independent surveys.

The Commission formed a Steering Committee composed of experts from the fields of fisheries independent survey design, stock assessments, ecosystem-based management, climate change, and advanced technologies to oversee the project and develop new fishery independent surveys. The Steering Committee's goal for the project was to identify an idealized sampling approach—through a balanced portfolio of actions that is robust to uncertainty, including future climate scenarios—to gain a holistic understanding of the status and trends of the Gulf of Mexico ecosystem. The Steering Committee felt that the project should explore ways to optimize current surveys, augment current fishery independent surveys where there are gaps, and consider novel sampling approaches for new surveys.

The Steering Committee proposed six action steps to meet the project goal. These were to:

1. Develop a list of data needs for managing fisheries in the Gulf of Mexico using previous work in order to review and determine needed changes to the survey enterprise;
2. Develop a plan for improving coverage, precision and calibration of surveys for key assessed species that currently have some survey coverage;
3. Develop surveys that can provide monitoring of the Gulf of Mexico ecosystem, especially considering new technologies and piggybacking technology on other surveys;
4. Design and conduct a survey valuation process;
5. Prepare optimal survey designs; and
6. Develop an implementation plan to transition existing surveys to more optimal designs.

The Steering Committee envisioned using new technologies to develop new surveys that would replace current fishery independent surveys when the six action steps were first developed. While some of these new technologies show promise, these new technologies are not fully developed enough at this time to gather the data needed to replace existing surveys. Analysis showed that current surveys are fairly robust at collecting fishery independent data and could be strengthened by collecting additional data. Therefore, after analysis, effort was not expended trying to address action step 6.

This report details a comprehensive study of the available fishery independent data along with fisheries science and management data needs for the Gulf of Mexico. Similar to previous studies dating back over a decade (SEFSC 2008, Suprenand et al. 2015, Grüss et al. 2018, SEFSC 2018), this analysis provides numerous recommendations and suggestions to improve fishery independent sampling in the Gulf of Mexico. Recommendations range from minor improvements in data collection to the development of entirely new surveys that will collect data to fill current data gaps, help manage fisheries, and move towards EBFM.

## 1.1 Organizational Structure

The Steering Committee formed three subcommittees to garner additional expert opinion. The Data and Surveys Subcommittee was composed of experts who have done recent assessments for species utilizing data collected from trawls, plankton, cameras, longlines, and hook surveys. The Data and Surveys Subcommittee helped identify which species were collected by the surveys, which species each survey did a good job of collecting data on, which species were collected by the surveys but the surveys did not provide data for stock assessments, and what were some potential cost-effective improvements that could be made to each survey. The Data and Surveys Subcommittee also helped identify the data gaps from current fishery independent surveys.

The Ecosystem-Based Fisheries Management Subcommittee developed data needs to institute ecosystem-based fisheries management and how to monitor and manage for climate change impacts on the ecosystem. Areas of research with respect to data gaps included trophic interactions and trophic connectivity, providing data to support multi-species reference points, the impacts of invasive species, forage fish dynamics, benthic invertebrates and benthic community, habitat relationships and habitat preferences, and the connection between habitat and fisheries productivity.

The Novel Sampling Approaches Subcommittee explored advanced sampling technologies that could be utilized to improve and expand current fishery independent data collection. The subcommittee reviewed the sampling methods from the Great Red Snapper Count to see how sampling gears and technologies could be used to develop new fishery independent surveys for other species. The Novel Sampling Approaches Subcommittee also examined the potential role of advanced technologies like environmental deoxyribonucleic acid (eDNA), acoustics, remotely operated vehicles (ROVs), autonomous underwater vehicles (AUVs), and other emerging or available technology to help fill data gaps.

The Commission provided a project coordinator to coordinate and oversee all project activities. The Commission has a history of working cooperatively with state and federal agencies, academic institutions, and non-governmental organizations on a range of marine fishery related issues. The project coordinator supervised the project, hired and managed the project analyst and facilitator, and convened meetings of the Steering Committee and its associated subcommittees.

The project analyst helped analyze data, developed appropriate models of existing data, and determined gaps in current sampling strategies and data collection procedures. The goal and eventual outcome of this analysis was to develop recommendations for a sampling regime that will provide needed improvements for fishery independent surveys in the Gulf of Mexico as recommended by the technical subcommittees and Steering Committee.

The facilitator ensured an open and inclusive process where all interests and perspectives were heard and thoughtfully considered. He coordinated with the project coordinator and the project analyst and, as needed, Steering Committee and subcommittee members, to develop meeting agendas, provide facilitation support, and ensure accurate, impartial documentation of meetings, workshops and associated agreements (e.g., action items, meeting summaries/workshop reports, and recommendations).

# 2. Data Needs for Stock Assessment

The main purpose of fishery independent surveys is to provide biological and abundance data for stock assessments. Fishery independent surveys provide relative abundance trends where data are assumed to reflect proportional changes in stock size. Several studies (Suprenand et al. 2015, Grüss et al. 2018, SEFSC 2018, Berenshtein et al. 2021) have examined stock assessment and EBFM data needs for the Gulf of Mexico and made recommendations based on data gaps. NOAA Fisheries recently performed a data gap analysis for Gulf of Mexico fish stocks that identified assessment gaps. This project also held multiple Steering Committee and subcommittee meetings to discuss current and future data needs. The project held meetings with stock assessment and EBFM experts to ask detailed questions on the types of data these experts felt were lacking for their assessments and models. Throughout these meetings and discussions, participants generally agreed that current Gulf of Mexico fishery independent surveys provide good data for some species, but not for all species and life stages.

## 2.1 Analysis of Survey Data

The Steering Committee initially recommended an examination of six species groups including amberjack, tuna, grouper, menhaden/baitfish, tilefish/deepwater grouper, and small pelagics. These groups were expanded to a species-specific list by including those species that comprised the top 95% of the total commercial catch in 2020 (Table 1). These 94 species were combined into 12 functional groups. Coastal sharks were included based on high exploitation rates in both commercial and recreational catches.

The project analyst conducted an analysis of the frequency of occurrence of the species of interest in the surveys based on data compiled for the surveys between 2016 and 2019 (pelagic trawl was from 2011-2016). The average percent positive frequency of occurrence by species group (Figure 1), shows from a broad perspective the relative ability of a survey to gather data on a species group. An analysis by species was also completed. Note that this represents the raw percent positive over each survey and values based on a species core habitat sampled may differ based on the degree of survey and species habitat.

Survey and species overlap were estimated by comparing predicted ranges by species or species group and comparing the distribution of the survey, and then calculating the overlap (Figure 2). Additional distribution maps are located online at the following link. Although there are caveats with respect to this work (i.e., the overlap calculations use model predicted distribution), distributions may shift over time or seasonally and this overlap analysis indicates the degree to which the stock is expected to be sampled by a specific survey and gear. It could be expected that for greater overlap between the survey and gear the more useful the survey is for that species, as long as the gear selects for the species. In reality, some species are patchily distributed and even with high overlap the variability (CV) is quite high.

The project investigated the relationship between the survey and specific species variability within that survey with a bootstrap analysis of the species caught by the SEAMAP Summer and Fall Shrimp/Groundfish Surveys and NOAA Fisheries Bottom Longline Survey. This analysis calculated the CV at varying sample sizes, above and below the recent median number of stations per year. This work indicated that for some species, moderately increasing the number of stations sampled could improve the precision of the survey (lower CV), but for other species with low occurrences, the chances of increased precision remain low (Figures 3-5 and Tables 2-4).

Length frequency analysis, both by species and survey (i.e., Red Snapper and SEAMAP Summer and Fall Shrimp/Groundfish Surveys, Figure 6) and combined over all surveys (Figure 7) indicated where sampling was consistent over time for a given species or where the survey selectivity has changed. The analysis of species by survey (Figure 7) indicates the overlap and potential redundancy of surveys by species. Individual analyses are available online at this link.

### 2.2 Data Gaps

After compiling the data gaps reported in other studies, the NOAA Fisheries' data gap analysis, and the above analyses, several data gaps were apparent. Table 5 details the species-specific data gaps. Note that some species like Almaco Jack and Banded Rudderfish are not regularly targeted by commercial or recreational fisheries and are therefore a lower priority.

## 3. EBFM Data Needs

Priority EBFM data needs in the Gulf of Mexico were identified based on previous reports (Chagaris et al. 2019, Berenshtein et al. 2021) and several meetings with Steering Committee members, the EBFM Subcommittee, and other ecosystem experts. Monitoring of the Gulf of Mexico ecosystem may require a number of specialized ongoing studies. The EBFM Subcommittee framed its discussions on data needs around key ecosystem questions, but also acknowledged that any enhancements to single species data will also inform ecosystem models and EBFM. Several general needs from previous reports and the meetings are listed below.

- Diet studies, including stomach content and stable isotope analysis, to quantify trophic interactions and trophic connectivity. DNA barcoding and eDNA should be used to identify prey items to species, especially when attempting to quantify predation on key species or life stages.
- Mapping of the seafloor, reef, and biogenic habitat to improve our ability to accurately predict species distributions, especially for reef fishes.
- Conduct targeted surveys to better understand species habitat relationships and habitat preferences, such as multi-gear sampling and sampling across environmental gradients and oceanographic fronts.
- Collect benthic samples to provide baseline information on the benthic community, quantify biomass of benthic invertebrates, and understand how benthic biomass production varies with environmental conditions and its coupling to the pelagic component.
- Establish or expand ocean observation systems to monitor the bio-physical environment and provide a better understanding of transport mechanisms and upwelling dynamics.
- Improve estimates of bycatch, over time and space, especially in menhaden and shrimp fisheries that use indiscriminate gear types.
- Conduct marine mammal surveys to provide data on abundance, trends, mortality, trophic level, and diet composition.
- Conduct surveys of seabirds to provide data on abundance, trends, mortality, trophic level, and diet composition.
- Increase the spatial and temporal sampling for harmful algal blooms to determine their spatial extent throughout the water column, and paired with fish and invertebrate sampling to assess impacts on the ecosystem.
- Initiate a network for synthesis and collection of water quality data across the entire Gulf of Mexico, including sampling for nutrient concentrations, dissolved oxygen, organic and inorganic carbon concentrations, pH, chlorophyll, temperature, salinity, microplastics, and other contaminants.

## 4. Current Surveys and Recommended Changes to Current Surveys

Current Gulf of Mexico fishery independent surveys include a spring and fall plankton survey, summer and fall trawl survey, video camera reef fish survey and habitat mapping, and inshore bottom longline survey as part of SEAMAP and an offshore bottom longline survey as part of NOAA Fisheries sampling. All surveys use standardized gears and protocols for data collection. The SEAMAP Spring Plankton Survey began in 1982 while the SEAMAP Fall Plankton Survey began in 1984. The SEAMAP Summer Shrimp/Groundfish Survey began in 1982 while the SEAMAP Fall Shrimp/Groundfish Survey began in 1985. The SEAMAP Reef Fish Survey began in 1992. The SEAMAP Bottom Longline Survey began in 2008 while the NOAA Fisheries Bottom Longline Survey began in 1995. These surveys have undergone minor modifications over the years, but the historical fishery independent time series from these surveys represent the foundation for

Gulf of Mexico stock assessments. Data from these surveys have been used in stock assessments for 39 species or species groups.

In examining data gaps, it became apparent that some gaps could be addressed with a dedicated annual survey, some possibly could be addressed with a short-term dedicated effort, and that other gaps could probably not be addressed with current technology. Data gaps were classified according to their addressability and the type of survey that could address the data gap. Some data gaps potentially could be addressed by increasing sampling effort in current surveys. Other data gaps, such as coastal pelagic diet or life history data, could be addressed by targeted or limited efforts to gather the data. Filling some data gaps would not be possible with current or even new technology since the species is not easily captured or is generally low in abundance. Some identified data gaps such as bycatch cannot be addressed by fishery independent surveys.

Funding levels currently prevent additional data collection on current surveys. Current fishery independent surveys are described below. If funding increases were available, additional data could be collected on current surveys to help fill identified data gaps. Additional information such as diet and genetic sampling could be acquired with additional support for sampling and processing.

## 4.1 SEAMAP Spring Plankton Survey

The SEAMAP Spring Plankton Survey began in 1982 and targets 97 stations every year in April and May. The stations are in a systematic grid approximately 56 km apart (Figure 8). The objectives of the survey are to assess the occurrence, abundance and geographical distribution of the early life stages of spring spawning fishes, especially Atlantic Bluefin Tuna, from mid-continental shelf to deep Gulf of Mexico waters using a bongo frame fitted with 335-micron nets, a neuston frame fitted with a 950-micron net; describe the pelagic habitat of fish larvae through measurements of various physical and biological parameters; collect detailed observations (i.e. identification, number, volume, bell diameter) of captured jellyfish and ctenophores; and collect volumetric measurements of net caught *Sargassum*.

The bongo nets consist of two conical 61-cm nets with 335-micron mesh. Bongo tows are oblique, surface to near bottom (or 200 m) and back to surface. A SBE19 SEACAT Profiler is attached on the towing wire above the frame to provide real time depth readings along with temperature and salinity. A mechanical flowmeter is mounted off-center in the mouth of each bongo net to record the volume of water filtered. A single or double 2x1 m pipe frame neuston net fitted with 950-micron mesh netting is towed at the surface with the frame half-submerged for 10 minutes. Samples are taken upon arrival on station, regardless of time of day. A Continuous Underway Fish Egg Sampler (CUFES) is used to collect surface (~3 m) zooplankton and egg samples along track lines between stations. A 1 $m^2$ Multiple Opening and Closing Net Environmental Sensing System (MOCNESS) is used to collect plankton samples from discrete depths to assess the vertical distributions of invertebrates, fish eggs and larvae. The MOCNESS is fitted with nine 505-micron mesh nets. In addition, hydrographic data (surface chlorophylls, salinity, temperature, and dissolved oxygen) are collected at all stations.

Data from the SEAMAP Spring Plankton Survey have been used in stock assessments for Atlantic Bluefin Tuna and Skipjack Tuna.

**Recommendation: Use close-kin mark-recapture on larval Atlantic Bluefin Tuna captured in plankton tows and adult Atlantic Bluefin Tuna to develop a time series of absolute abundance**
The SEAMAP Spring Plankton Survey provides the only fishery independent data included in the International Commission for the Conservation of Atlantic Tunas (ICCAT) stock assessment of Atlantic Bluefin Tuna and is used to tune the adult stock assessment. Over the last several years, researchers have begun to use genetic markers to examine parent–offspring pairs in marine fish in a technique known as close-kin mark-recapture (CKMR) (Bravington et al. 2016). Larval or juvenile fish are genotyped at a number of independent loci and then compared to genotypes obtained by adult fish for close-kin pairs (i.e., parent offspring). Adult abundance can then be inferred from the number of close relatives given sampling. Recaptures can also provide information on adult survival rate. McDowell et al. (2022) used larval Atlantic Bluefin Tuna (*Thunnus thynnus*) to demonstrate the utility of CKMR using larval fish while Bravington et al. (2016) demonstrated CKMR's utility with juvenile Southern Bluefin Tuna (*Thunnus maccoyii*).

Current standardized plankton sampling may not capture enough Atlantic Bluefin Tuna larvae to conduct CKMR. McDowell et al. (2022) used paired bongo nets with 505-micron mesh that were towed in an undulating pattern between the surface and 25 m for ten minutes to intensively sample Atlantic Bluefin Tuna larvae at targeted survey locations. These samples using non-standard SEAMAP bongo nets could be collected during standard SEAMAP Spring Plankton Survey sampling. The total approximate cost for conducting a plankton station and sorting and identification of the larval fish is $7,300. It costs approximately $30 per fish for the DNA extraction and genotyping based upon genotyping 3,500 fish per year. Approximately 1,000 larvae are needed for an unbiassed coefficient of variation when using CKMR to calculate an adult abundance.

Genetic material from adult Atlantic Bluefin Tuna could be obtained from recreational or commercial sampling. Otoliths or a DNA sample for epigenetic aging would also need to be obtained for aging purposes.

The following bullet points summarize the main considerations for this recommendation.

- **Benefits:** Better estimates of population size and other demographic parameters for Atlantic Bluefin Tuna leading to better management for the species.
- **Challenges:** Current standardized plankton sampling may not capture enough Atlantic Bluefin Tuna larvae to conduct CKMR. Changes to sampling protocol and/or intensive sampling along fronts may be needed. Obtaining adequate larval sample sizes and adult genetic samples could be challenging.
- **Steps to implementation:** Cost and logistical challenges are surmountable. Bravington et al. (2016) and McDowell et al. (2022) proved the concept of using CKMR on tuna and aside from financial investment, the main need would be logistical and personnel investment for fieldwork, plankton sorting, genetic analysis, and data processing.

- **Anticipated cost:** The total approximate cost for conducting a plankton station and sorting and identification of the larval fish is $7,300. It costs approximately $30 per fish for the DNA extraction and genotyping based upon genotyping 3,500 fish per year. Approximately 1,000 larvae are needed for an unbiassed coefficient of variation when using CKMR to calculate an adult abundance. Approximately $1.5 - 2.7 million would cover the costs for sampling 200 stations and collecting the approximately 1,000 larvae needed along with collecting samples from 3,500 adults.
- **Links to other elements of the fishery independent survey enterprise:** Directed sampling for Atlantic Bluefin Tuna will collect other larvae and could provide information on other species also.
- **Timeline:** Immediate

**Recommendation: Evaluate CKMR for other species and then institute it for those species where it is advantageous**

Skipjack Tuna (*Katsuwonus pelamis*), Swordfish (*Xiphias gladius*), Longbill Spearfish (*Tetrapturus pfluegeri*), White Marlin (*Tetrapturus albidus*), several smaller tuna species (*Thunnus* spp.), and Sailfish (*Istiophorus platypterus*) all spawn during April and May when the SEAMAP Spring Plankton Survey is conducted. Routine or directed sampling could potentially provide samples on these species for CKMR analysis. The costs to analyze the samples would depend on the number of individuals needed to estimate census size with the required allowance for error. Because each species has different biological characteristics and population size, running simulation studies prior to engaging in CKMR studies is required for proper experimental design. Adult samples are also needed for the analysis.

The following bullet points summarize the main considerations for this recommendation.

- **Benefits:** Improved understanding of population dynamics and demographic parameters for these harder to sample pelagic species. Calculating an index of abundance for these pelagic species is difficult since usually only part of the population is sampled. The use of genetic methods could vastly improve the understanding of the stocks.
- **Challenges:** CKMR may not work for these species since it may be difficult to collect enough larval samples for the analysis. Collecting adult tissue samples may prove expensive and problematic, but partnering with commercial and recreational fishery participants may lower costs.
- **Steps to implementation:** Simulated population models with current population parameters are needed for each species to estimate the number of larval samples required for proper experimental design. Adult samples are needed also. A method of adult tissue collection needs to be developed for each species.
- **Anticipated cost:** It is not possible to provide accurate costs for a CKMR study at this stage. The costs to analyze the samples would depend on the number of larval samples needed to estimate census size with the required allowance of error. Approximately $500,000 would enable the initial research.
- **Links to other elements of the fishery independent survey enterprise:** All of the genetic work is linked to using new and emerging technology for data generation and processing.
- **Timeline:** Immediate

**Recommendation: Use genetic methods to identify species that currently cannot be identified to the species level**

The value of ichthyoplankton surveys as fishery independent data for stock assessments has been limited by the inability to identify larvae to the species level for many managed species. In the Gulf of Mexico, only 30% of the ichthyoplankton can be identified down to the species level with the rest being undescribed or inadequately described due to incomplete descriptions or poor diagnostic characteristics. Stock assessments and EBFM are hindered when managers lack species level ichthyoplankton identification.

Over the past 30 years, molecular techniques have been developed that have aided larval fish identification. High-resolution melting analysis (HRMA) provides a fast, cheap genotyping tool that can be used to identify larval fish (Smith et al. 2009, Brechon et al. 2013). By isolating DNA from a small piece of tissue, the sample is processed to allow a comparison of the sample's fluorescence as a function of temperature. HRMA is nondestructive allowing researchers to perform diet and aging studies as well as allowing a morphometric description once the larvae has been identified. Alleles produce distinct melting curves that can be compared with reference samples to identify the larval fish. For species that have not been characterized in an HRMA context, sequencing larvae at the mitochondrial encoded cytochrome c oxidase subunit I (COI) or 12s (barcoding) genes is a good approach. Because of mass sequencing technologies, metabarcoding can be used to produce sequence data for thousands of samples at once in an inexpensive and efficient manner. Building a database of sequence data associated with voucher specimens for all Gulf fishes will make either of the techniques above more efficient and accurate. Ichthyoplankton genetic identifications will result in a substantial advance on species distributions and abundance estimates. Species captured during the SEAMAP Spring Plankton Survey that would benefit from larval genetic identification are the *Thunnus* species, *Seriola* species, and billfish. The finer scale resolution of the taxonomic identifications of species in the SEAMAP ichthyoplankton database will allow for the calculation of larval abundance indices for species with little or no fishery independent data available for assessment as well as ecologically important species.

Approximately $65,000 would be needed annually to identify approximately 6,000 ichthyoplankton specimens. SEAMAP ichthyoplankton samples going back to 2009 would be available for HRMA analysis.

The following bullet points summarize the main considerations for this recommendation.

- **Benefits:** Improved understanding of the population dynamics and levels of some tuna (*Thunnus*) species, amberjack (*Seriola*) species, and billfish. This would increase the information content derived from the plankton survey which currently identifies only about 30% of the larvae collected.
- **Challenges:** Few challenges are associated with this recommendation. The samples are available and the genetic identification methods have been developed. Additional analytical studies to calibrate the relationship between larval abundance and adult biomass would need to be developed.

- **Steps to implementation:** Develop HRMA characteristics for species and sequence larvae at the mitochondrial encoded COI or 12s (barcoding) genes. Verify data and contribute to a database of sequence data associated with voucher specimens.
- **Anticipated cost:** Approximately $65,000 would be needed annually to identify 6,000 samples.
- **Links to other elements of the fishery independent survey enterprise:** Advancing genetic methods in the Gulf will benefit both single species stock assessment as well as EBFM.
- **Timeline:** Immediate

**Recommendation: Reinstitute the April portion of the SEAMAP Spring Plankton Survey**
The SEAMAP Spring Plankton Survey samples a core group of 97 fixed location stations. The primary objective of the SEAMAP Spring Plankton Survey is to assess the occurrence, abundance, and geographic distribution of the early life stages of spring spawning fishes, especially Atlantic Bluefin Tuna. Before 2007, some of these stations were sampled in April and then resampled in May to make sure that Atlantic Bluefin Tuna spawning was not missed if water temperatures rose above 24°C, the lower limit of spawning activity, before May sampling began. Sampling stations in April and then resampling them in May ceased in 2007 due to budget constraints.

Increased water temperatures associated with climate change are projected to lead to shifts in Atlantic Bluefin Tuna spawning times and spawning areas (Muhling et al. 2011). If Atlantic Bluefin Tuna begin spawning earlier than May, the SEAMAP Spring Plankton Survey would potentially miss sampling these critical spawning events. Reinstituting the April sampling would allow researchers to determine if Atlantic Bluefin Tuna are beginning to spawn earlier in the year and ensure sampling spans the entire Atlantic Bluefin Tuna spawning season in the Gulf of Mexico if spawning starts to occur earlier in the year. The cost to reinstitute April sampling would be approximately $7,300 to conduct each plankton station and the associated sorting and identification of the larval fish.

The following bullet points summarize the main considerations for this recommendation.

- **Benefits:** April sampling would allow researchers to determine if Atlantic Blue Tuna are beginning to spawn earlier in the year as Gulf of Mexico waters warm due to climate change. This would provide additional confidence in annual abundance estimates in years where increased water temperatures could lead to earlier Atlantic Bluefin Tuna spawning times that would be missed if only sampling during May.
- **Challenges:** Ship time to sample during April may be challenging to obtain. Additional analytical studies to calibrate the relationship between larval abundance in April and May and adult biomass would need to be conducted.
- **Steps to implementation:** Ship time and personnel would need to be secured to conduct April sampling.
- **Anticipated cost:** Approximately $710,000 is needed to conduct an additional 97 stations and sort and identify the captured ichthyoplankton.
- **Links to other elements of the fishery independent survey enterprise:** Increased plankton sampling could provide information on biodiversity, species distribution, and

environmental data. Samples could be used in other Gulf genetic studies such as HMRA, CKMR, and building a DNA voucher library.
- **Timeline:** Immediate

**Recommendation: Install additional probes on the CTD or collect additional water samples to measure nutrient loads, carbon concentration, dissolved organic carbon, and pH**

Many different water quality measurements need to be taken beyond the standard environmental data (salinity, temperature, dissolved oxygen, transmissivity) that are currently collected. Additional information on nutrient loads, carbon concentration, dissolved organic carbon, and pH are needed to support EBFM. A pH sensor to add to a CTD array would cost approximately $6,000. Water samples would cost approximately $25 per sample to analyze for inorganic nutrients such as ammonium, nitrite, nitrate, soluble reactive phosphorous and silicate. Particulate organic carbon and nitrogen analysis would be approximately $12 per sample. Dissolved organic carbon and total dissolved nitrogen would cost $15 per sample. With the total dissolved nitrogen measurements, you can subtract out the inorganic nitrogen species concentrations (ammonium + nitrate + nitrite) to calculate dissolved organic nitrogen concentrations which complements the dissolved organic carbon measurements.

The following bullet points summarize the main considerations for this recommendation.
- **Benefits:** Additional information on nutrient loads, carbon concentration, dissolved organic carbon, and pH are needed to support EBFM and examine the impacts of climate change.
- **Challenges:** This is a feasible recommendation with the main hurdle being time on station to collect the water samples and the funding needed to analyze the samples.
- **Steps to implementation:** Installation and calibration of the probes and collection of water samples during the survey and analysis of the data are the necessary steps.
- **Anticipated cost:** It would cost approximately $6,000 to add a pH sensor to the CTD array. Water samples would cost approximately $25 per sample to analyze for inorganic nutrients such as ammonium, nitrite, nitrate, soluble reactive phosphorous and silicate. Particulate organic carbon and nitrogen analysis would be approximately $12 per sample. Dissolved organic carbon and total dissolved nitrogen would cost $15 per sample.
- **Links to other elements of the fishery independent survey enterprise:** Improved data on nutrient loads, carbon concentration, dissolved organic carbon, and pH would strengthen our understanding of climate change impacts on biodiversity, species distribution, and environmental data in general and could link to indices of abundance or factors that influence the index variability.
- **Timeline:** Immediate

## 4.2 SEAMAP Reef Fish Survey

The SEAMAP Reef Fish Survey began in 1992 as a Gulf wide survey targeting shelf-edge natural reef areas. In 2005, the NOAA Fisheries Panama City Laboratory began a survey that sampled shallow natural reef areas in the northeastern Gulf of Mexico. The Florida Fish and Wildlife Research Institute initiated a reef fish survey in 2008 on natural reef habitats on the west Florida Shelf that expanded in 2014 to include natural and artificial reef habitats throughout Florida. All three surveys used stereo video cameras to quantify reef fish relative abundance. The primary objective of the surveys was to provide reef fish indices of relative abundance and size composition data to support stock assessments. Seeing the benefit of a single standardized reef fish survey, researchers used over $6 million in funding from the NOAA RESTORE Science Program in 2019 to increase survey efforts and unify these surveys as the Gulf Fishery Independent Survey of Habitat and Ecosystem Resources (G-FISHER) beginning in 2020. As part of the survey redesign, researchers analyzed historical data to delineate biologically relevant spatial and habitat strata, define optimal allocation of sampling effort based on a combination of habitat availability and managed species richness, and assess the relative performance of the final optimized survey design for several key reef fish taxa.

The objectives of the survey are to assess the relative abundance of reef fish on the continental shelf edge-banks of the northern Gulf of Mexico, reef fish associated with oil and gas platforms, and reef fish associated with artificial reefs; map areas using a side scan sonar system; collect water samples for eDNA analysis; and collect environmental data.

The current SEAMAP Reef Fish Survey (Figure 9) uses a habitat-based survey design with proportional station allocation based upon six spatial strata and six habitat strata that is optimized to sample managed species. Stations are sampled with camera arrays baited with Atlantic Mackerel and squid prior to deployment. Each camera array is allowed to soak at the bottom for a minimum of thirty-five minutes to assure that twenty minutes of continuous video and stereo images are recorded. Camera arrays are only deployed during the day and habitat mapping is conducted at night. Vertical line sampling is also conducted to collect biological samples for life history information. Water samples are taken at approximately 100 stations per year for eDNA analysis. In addition, water temperature, salinity, dissolved oxygen, and transmissivity are collected at all stations.

Data from the SEAMAP Reef Fish Survey have been used in stock assessments for Gray Triggerfish, Gag Grouper, Red Grouper, Mutton Snapper, Hogfish, Red Snapper, Greater Amberjack, Almaco Jack, Lesser Amberjack, Snowy Grouper, Speckled Hind, Yellowmouth Grouper, Vermilion Snapper, Gray Snapper, Yellowtail Snapper, and Scamp.

Since the survey went through a lengthy redesign and optimization process in 2019, this project did not consider optimization or changes to the survey. Even though the survey underwent an optimization process, there are several recommendations that would ensure sustainability and improve the timeliness and utility of data provided by this survey.

**Recommendation: Secure long-term funding**

Improvements to the SEAMAP Reef Fish Survey have only been possible through the availability of dedicated, short-term funding ($6 million over five years) from the NOAA RESTORE Science Program. Funding is set to end in 2024. It is likely that the NOAA RESTORE Science Program will provide an additional five years of funding to continue the current level of reef fish sampling, but there are no guarantees though that the funding will be extended. Regardless, long-term funding will need to be secured to sustain the SEAMAP Reef Fish Survey in the future. Estimated costs are $2.4 million annually to sustain the current sampling level.

The following bullet points summarize the main considerations for this recommendation.

- **Benefits:** Additional funding would allow continuation of the current level of reef fish monitoring once NOAA RESTORE Science Program funding runs out to allow continued collection of data on economically important reef fish communities.
- **Challenges:** None
- **Steps to implementation:** None
- **Anticipated cost:** Estimated costs are $2.4 million annually to sustain the current level of sampling.
- **Links to other elements of the fishery independent survey enterprise:** Strengthen our understanding of reef fish communities, biodiversity, species distribution, and environmental data in general and could link to indices of abundance or factors that influence the index variability.
- **Timeline:** Immediate

**Recommendation: Enhance survey-specific habitat mapping efforts**

Optimization of the SEAMAP Reef Fish Survey design in the eastern Gulf of Mexico was facilitated by the availability of randomized habitat mapping data, collected primarily through side scan sonar. The randomized nature of these habitat mapping surveys provided representative estimates of habitat quantity and quality that could be used to estimate total habitat availability, a key component in the optimal allocation of sampling effort. In the western Gulf of Mexico, most historical habitat mapping data have been collected using multibeam sonar, and were focused on the shelf break in regions with presumed high-relief habitats. Since habitat classification is critical to the survey design and station allocation, there is a need for randomized habitat mapping in the western Gulf of Mexico, especially on the shelf where habitat data are limited. Periodic remapping, especially after disturbances such as hurricanes, is also needed at some level to assess the temporal stability of habitat mapping data. Additional efforts are also required to calibrate habitat classification between side scan and multibeam sonar at the scale of habitat classes used in the survey. These objectives can be accomplished through dedicated mapping surveys conducted using either research vessels or automated vehicles to ensure that the full range of reef habitats are sampled sufficiently. Habitat mapping efforts are estimated to cost $1.25 million annually, although these efforts can be reduced after several years of successful data collection.

The following bullet points summarize the main considerations for this recommendation.

- **Benefits:** Develop representative estimates of habitat quantity and quality that could be used to estimate total habitat availability, a key component in the optimal allocation of sampling effort, understanding of species distribution, habitat utilization and environmental monitoring.
- **Challenges:** Data processing is the main challenge associated with this recommendation.

- **Steps to implementation:** Reef fish sampling is conducted only during the day so habitat mapping currently is done at night. Additional funding would allow calibration of habitat classification between side scan and multibeam sonar at the scale of habitat classes used in the SEAMAP Reef Fish Survey.
- **Anticipated cost:** Habitat mapping efforts are estimated to cost $1.25 million annually, although these efforts can be reduced after several years of successful data collection.
- **Links to other elements of the fishery independent survey enterprise:** Strengthen our understanding of reef fish species distribution as it relates to habitat type.
- **Timeline:** Immediate

**Recommendation: Develop acoustic camera sampling protocols**

While visibility is rarely limiting to video camera sampling in the eastern Gulf of Mexico, the turbid waters and nepheloid layer of the western Gulf of Mexico make video camera sampling impossible in some regions. Dedicated efforts to test and calibrate alternative sampling approaches, including the use of acoustic cameras or active acoustics surveys, is necessary to provide reef fish abundance data in these regions. Dedicated gear testing and calibration studies should be conducted to compare data provided by paired acoustic and optical instruments from which sampling protocols can be developed for use in the turbid waters of the western Gulf of Mexico. Estimated costs to develop, test, calibrate, and implement acoustic sampling approaches is approximately $3 million.

The following bullet points summarize the main considerations for this recommendation.

- **Benefits:** Provide estimates of reef fish abundance data in regions that are impossible to sample with current video techniques due to low visibility.
- **Challenges:** This is a research recommendation that will need to undergo significant development. Dedicated gear testing and calibration studies should be conducted to compare data provided by acoustic cameras and paired optical instruments from which sampling protocols can be developed.
- **Steps to implementation:** Ship time and project staff need to be allocated and an implementation plan developed.
- **Anticipated cost:** Estimated costs to develop, test, calibrate, and implement acoustic sampling approaches is approximately $3 million.
- **Links to other elements of the fishery independent survey enterprise:** Strengthen our understanding of reef fish communities, biodiversity, species distribution, and collect environmental data that could link to indices of abundance or factors that influence the index variability.
- **Timeline:** Protocol development can start immediately. Approximately 2-3 years are needed to conduct calibrated sampling approaches with acoustic and video cameras.

**Recommendation: Improve timeliness in processing of video data**

Processing the video data from each station takes a tremendous amount of time, and video data are not available for at least one year following completion of sampling for a particular year. Automated video analysis using artificial intelligence through Video Image Analytics for the

Marine Environment (VIAME) is promising.  At present, VIAME does a reasonable job of identifying some of the more common species encountered, but has difficulty identifying others. Continued efforts to refine and improve the VIAME detector, test the detector with Gulf wide videos, and evaluate comparability of VIAME results with those from manual video reads should be explored to evaluate whether VIAME can improve the timeliness of data completion for all species in all environments encountered across the Gulf of Mexico.  It would cost approximately $600,000 to operationalize VIAME.

The following bullet points summarize the main considerations for this recommendation.

- **Benefits:** Quicker review of all video data collected during the SEAMAP Reef Fish Survey saving both time and money.
- **Challenges:** The main challenge would be improving detection and identification of species that are not commonly encountered during sampling.
- **Steps to implementation:** Additional staff time is needed to compare the identification and enumeration of species from VIAME and manual video reads.  Staff time is needed to train VIAME with videos from across the Gulf of Mexico so VIAME can learn to identify all species that will be encountered by the SEAMAP Reef Fish Survey.
- **Anticipated cost:** Approximately $600,000 is needed to operationalize VIAME.
- **Links to other elements of the fishery independent survey enterprise:** Strengthen our understanding of reef fish communities, biodiversity, species distribution, and environmental data and could link to indices of abundance or factors that influence the index variability.
- **Timeline:** Approximately 12-18 months are needed to train VIAME before it is ready to process videos from all sampling areas throughout the Gulf of Mexico.

## 4.3 SEAMAP Summer and Fall Shrimp/Groundfish Survey

The SEAMAP Summer Shrimp/Groundfish Survey began in 1982 and currently targets approximately 350 stations during June and July every year.  The SEAMAP Fall Shrimp/Groundfish Survey began in 1985 and currently targets approximately 300 stations during October and November every year.  Both surveys sample waters from 9 – 110 m in depth (Figure 10) across statistical zones 2 – 21.  The statistical zones are divided into two depth zones (9 – 37 m and 38 – 110 m).  Stations are proportionally allocated based upon the area contained within each statistical zone and water depth with stations being randomly selected.

The objectives of the SEAMAP Summer Shrimp/Groundfish Survey are to monitor the size and distribution of penaeid shrimp during or prior to migration of Brown Shrimp from bays to the open Gulf of Mexico; aid in evaluating the “Texas Closure” management measure of the Gulf Council's Shrimp Fishery Management Plan; and provide information on shrimp and groundfish stocks across the northern Gulf of Mexico from inshore waters to 110 m.  The objectives of the SEAMAP Fall Shrimp/Groundfish Survey are to sample the northern Gulf of Mexico to determine abundance and distribution of demersal organisms from inshore waters to 110 m; obtain length-frequency measurements for major finfish and shrimp species to determine population size structures; and collect environmental data to investigate potential relationships between abundance and distribution of organisms and environmental parameters.

Both surveys use a 12.8 m semi-balloon trawl with 8'x40" chain doors. The trawl is towed at 2.5 knots for 30 minutes to sample each station. All specimens collected in the trawl during the survey are identified, weighed, enumerated, and measured. In addition, water temperature, salinity, dissolved oxygen, and transmissivity or Secchi disc depth are collected at all stations.

Data from the SEAMAP Summer and Fall Shrimp/Groundfish Surveys have been used in stock assessments for White Shrimp, Brown Shrimp, Pink Shrimp, Hogfish, Spanish Mackerel, King Mackerel, Gray Triggerfish, Wenchman, Red Snapper, Vermilion Snapper, Lane Snapper, Gray Snapper, Red Grouper, small coastal sharks, smoothhound sharks, Atlantic Sharpnose Shark, Bonnethead, and Blacknose Shark.

**Recommendation: Collect samples for improved life history data for age, reproduction, and diet**

Otolith Processing – Age and growth data are invaluable when conducting stock assessments for managed fish, especially those data collected from fishery independent surveys that target a much broader size-range than fishery dependent surveys. In addition, the emerging field of otolith microchemistry has exhibited increasing utility in recent years to examine connectivity among various life history stages as well as discern the relative contribution of presumed estuarine and nearshore nurseries to the fishery. Most fishery independent surveys have the ability to provide a large quantity of material for the examination of age/growth and otolith microchemistry. However, any substantial increase in the amount of material collected would rapidly exceed processing capabilities of existing age and growth facilities. Approximately $500,000 are needed annually to support expansion of one or two otolith processing laboratories in the Gulf of Mexico. This will ensure that collected otoliths and spines are sectioned and aged in a timely manner, as well as foster the application of otolith microchemistry techniques in assessing recruitment dynamics and connectivity of spatially explicit life history stages for managed fish. The utility of epigenetic aging should be evaluated in concert with commencement of otolith processing efforts.

Reproductive Histology – Reproductive data (e.g., fecundity, size/age at maturity, spawning frequency, and periodicity) are essential when conducting stock assessments for managed fish. As with age, growth, and dietary analyses, biological material can be readily obtained from fishery independent surveys. Reproductive analyses, which include the preparation and interpretation of histology slides, require specialized skills so approximately $350,000 annually is needed for the establishment of a reproductive biology lab in the Gulf of Mexico.

Dietary Analysis – As fisheries management moves toward an ecosystem-based approach, understanding of ecosystem dynamics has been compromised by the lack of sufficient trophodynamic data. To better understand predator/prey dynamics, trophic interactions, and to support the development of ecosystem-based fisheries management, gut contents analysis is essential. As with age and growth samples, gut contents can readily be collected from existing fishery independent surveys at little to no additional cost. Identifying and quantifying gut contents is a time intensive process that requires specialized skills so approximately $1 million annually is needed to establish a diet analysis lab in the Gulf of Mexico. This lab would focus on integration of traditional gut content analyses with genetic barcode identification of unidentifiable prey items to the lowest possible taxonomic level, as well as the addition of stable isotope analyses to more broadly define predator-prey relationships. Inclusion of genetic barcoding techniques for more discrete prey identification allows for finer resolution of specific trophic interactions, thereby enhancing the utility for ecosystem-based models. Stable isotope analysis offers an alternative to gut content analysis and involves using a mass spectrophotometer to identify the isotopic signature from fish tissue. Variations in isotopic concentrations can be applied to the food web to draw direct inferences regarding diet and trophic level.

The following bullet points summarize the main considerations for this recommendation.

- **Benefits:** Improved understanding of age and growth, recruitment dynamics, and connectivity of spatially explicit life history stages for managed fish. This recommendation would benefit not only stock assessments, but ecosystem modeling also.
- **Challenges:** This is a field research recommendation with considerable post survey laboratory analysis time. Identifying and quantifying gut contents is a time intensive process and genetic barcode identification of unidentifiable prey items may yield variable levels of information. Otolith and fin spine collection and sectioning have well developed protocols. The few logistical challenges are the time it takes to collect and process the samples along with data processing and warehousing.
- **Steps to implementation:** Staff need to be allocated and a plan of implementation developed. Before beginning the otolith work, alternative aging techniques such as epigenetic aging should be explored. Even with epigenetic aging, there would be a need for otolith analysis, but not on the scale of this recommendation.
- **Anticipated cost:** Approximately $500,000 are needed annually to support expansion of one or two otolith processing laboratories in the Gulf of Mexico. Approximately $350,000 is needed annually for the establishment of a reproductive biology lab in the Gulf of Mexico while approximately $1 million is needed annually to establish a diet analysis lab in the Gulf of Mexico.
- **Links to other elements of the fishery independent survey enterprise:** Strengthen our understanding of the trophic dynamics of fish communities, species distribution, and age and growth in general and could link to indices of abundance or factors that influence the index variability. This is a cross cutting recommendation that would provide laboratory services for multiple surveys.
- **Timeline:** Collection of biological samples could begin immediately, but it would take approximately 6-9 months after the allocation of funds to expand laboratory facilities to support otolith, reproductive biology, and diet studies.

**Recommendation: Take samples for epigenetic aging**

Aging fish by examining growth rings in otoliths, vertebrae, scales, and fin rays is costly and time intensive. New studies (Weber et al. 2021) have shown that changes in DNA methylation levels correlate with chronological age allowing researchers to develop epigenetic clocks which are age predictive models based on DNA methylation. Given the importance of age data for fisheries assessments and the ability to collect a fin clip or muscle sample for epigenetic aging without killing the fish, the development of epigenetic clocks would save time and money over traditional aging methods. Epigenetic aging has the potential to provide more timely data and a greater quantity of age data than traditional aging methods. Epigenetic clocks would need to be developed at a per species cost of $10,000 to $20,000 if a species was within a genus with a preexisting epigenetic clock. If new loci needed to be mapped, then the cost per species would rise to $50,000 to $100,000. Otolith readings would still need to be validated periodically against the epigenetic clocks. Once epigenetic clocks were developed, it would cost approximately $10 to age a fish. Current costs to age a fish via otoliths is approximately $40. In addition to the cost savings, approximately 10,000 fish could be aged within a single lab equipped for this type of work within a month, allowing for more timely data for assessments.

The following bullet points summarize the main considerations for this recommendation.

- **Benefits:** Improved timeliness and the quantity of age data in comparison to traditional aging methods.
- **Challenges:** This is a research recommendation with considerable time for laboratory analysis, with some field sampling expected. Developing epigenetic clocks by calibrating changes in DNA methylation levels with traditional otoliths and spine-based collection, sectioning, reading and validation will take time and funding.
- **Steps to implementation:** Projects funds and staff need to be allocated and a plan of implementation developed.
- **Anticipated cost:** Initially $500,000 are needed annually to support the development of epigenetic clocks and to begin aging fish. Once epigenetic clocks have been developed for the more common species, costs would depend on how many samples were processed. Current costs are approximately $10 to age a fish.
- **Links to other elements of the fishery independent survey enterprise:** Strengthen our understanding of age and growth in various species. This is a crosscutting recommendation that would help build the capacity for genetic analysis in the Gulf of Mexico.
- **Timeline:** Samples could begin to be collected immediately. Some species already have epigenetic clocks, so aging could begin on these species within 6-9 months after the allocation of funds. Development of epigenetic clocks for other species could begin within 6-9 months.

**Recommendation: Add acoustic echosounders to trawl surveys**

Reliability of fishery independent survey abundance estimates are compromised when the survey or gear does not cover the entire extent of the fish stock in the water column (Kotwicki et al. 2017). Bottom trawl surveys provide relative trends in biomass for demersal species, but underestimate biomass for fish species higher in the water column because the gear does not effectively capture fish above the fishing height of the trawl (Monnahan et al. 2021). The

SEAMAP Summer and Fall Shrimp/Groundfish Surveys capture many pelagic and semi-pelagic species, but even though their percent positive capture can be high (Table 1), the survey data cannot be used for assessment purposes since it does not accurately reflect the stock's true biomass trends. Hypoxia is frequently encountered while conducting the trawl surveys in the northern Gulf of Mexico and demersal species will often move off the bottom and up into the water column to avoid the hypoxia (Hazen at al. 2009, Zhang et al. 2009, Roman et al. 2019). Changes in catch due to gear availability in hypoxic areas are concerning because a change in catch rate due to hypoxia will be reflected as a change in abundance, which can have negative consequences for management.

In order to accurately assess species' biomass throughout the water column, bottom trawl surveys should incorporate acoustics to ensure that sampling encompasses both midwater and demersal components of the population. Trawls and acoustics used together cover the entire water column and allow a more accurate estimation of the biomass present at the sampling location. It would cost approximately $200,000 to purchase a fisheries acoustic system with three transducers to sample at different frequencies. Software licensing for data interpretation would be approximately $30,000 per year.

The following bullet points summarize the main considerations for this recommendation.

- **Benefits:** Improved estimates of abundance due to sampling that encompasses both midwater and demersal components of the population.
- **Challenges:** Acoustics have not been used extensively in the Gulf of Mexico so acoustic species identification initially may be problematic.
- **Steps to implementation:** Significant preliminary acoustic work would need to be done to acoustically identify species encountered across the entire Gulf of Mexico during the SEAMAP Shrimp/Groundfish Surveys. While the NOAA vessels already have fisheries acoustic systems, at least two additional systems would need to be purchased and installed. Extensive training is needed before starting sampling.
- **Anticipated cost:** Approximately $500,000 is needed to collect baseline acoustic information on Gulf of Mexico species to lay the groundwork for acoustic sampling. In addition, two fisheries acoustic systems would need to be purchased and installed at an approximate cost of $450,000. Staff training both in operation of equipment and post processing would cost approximately $100,000. Approximately $500,000 is needed to collect baseline acoustic information on Gulf of Mexico species to lay the groundwork for acoustic sampling. Annual software costs for data analysis would be approximately $30,000.
- **Links to other elements of the fishery independent survey enterprise:** This would increase the reliability of fishery independent survey abundance estimates by sampling the entire extent of the fish stock in the water column.
- **Timeline:** While acoustics can be added to vessels immediately, the preliminary acoustic work to acoustically identify Gulf of Mexico species would take two years.

**Recommendation: Investigate whether piggybacking plankton samples during the surveys would provide better plankton information for managed species**

Historically, SEAMAP conducted ichthyoplankton sampling during the SEAMAP Summer and Fall Shrimp/Groundfish Surveys. Ichthyoplankton sampling during the SEAMAP Fall Shrimp/Groundfish Survey was discontinued in 2015 while it was discontinued in 2017 in the SEAMAP Summer Shrimp/Groundfish Survey. The lack of gulf wide spatial coverage was the primary reason that ichthyoplankton data from the SEAMAP Summer and Fall Shrimp/Groundfish Surveys have not been used in stock assessments for Gray Triggerfish, Red Snapper, Vermilion Snapper, and King Mackerel. Indices based on piggybacked SEAMAP Summer and Fall Shrimp/Groundfish Surveys in the western Gulf of Mexico have been explored (Hanisko et al. 2007). However, spatial coverage was often curtailed if weather or mechanical issues delayed the SEAMAP Summer and Fall Shrimp/Groundfish Surveys and impacted the trawling effort. A limited number of years of ichthyoplankton data with appropriate spatial coverage in the western Gulf of Mexico from the SEAMAP Summer Shrimp/Groundfish Survey have shown higher Red Snapper larval abundances than data from the SEAMAP Fall Plankton Survey (Hanisko et al. 2007), but current staffing limitations and duties have not allowed a re-analysis utilizing data from 2004 through 2016. Additional resources would allow a reexamination of the ichthyoplankton data from the shrimp/groundfish surveys to determine if more informative data for stock assessments and EBFM could be collected by piggybacking ichthyoplankton sampling on the shrimp/groundfish surveys.

The following bullet points summarize the main considerations for this recommendation.

- **Benefits:** Reexamination of historical ichthyoplankton data from the SEAMAP Summer and Fall Shrimp/Groundfish Surveys would determine if more informative data for stock assessments and EBFM could be collected by piggybacking plankton sampling on the SEAMAP Summer and Fall Shrimp/Groundfish Surveys than continuing a standalone SEAMAP Fall Plankton Survey.
- **Challenges:** The only challenge associated with this recommendation would be the staff time needed to complete the analysis.
- **Steps to implementation:** Approximately six months of staff time are needed to run the analysis.
- **Anticipated cost:** Approximately $50,000 are needed to support the analysis.
- **Links to other elements of the fishery independent survey enterprise:** This recommendation could provide information on the best time to sample plankton to maximize the data's benefit to fisheries management. Ship time for other surveys would be available if the SEAMAP Fall Plankton Survey was discontinued.
- **Timeline:** Immediate

**Recommendation: Install net monitoring systems to monitor how the trawl operates throughout the tow**

A net monitoring system is a wireless system that allows researchers to assess the accuracy of the trawl's deployment, as it is being towed, and during its retrieval. The NOAA vessels already use net monitoring systems. Net monitoring systems on all SEAMAP vessels will allow comparisons amongst the vessels to see if there are differences between vessels in how the net fishes. With sensors attached to the doors and footrope, the system calculates how far the doors are spread and monitors the trawl's position in reference to the seafloor using an inclinometer.

Sensors and a hydrophone communicate to a command center that collects and displays all of the appropriate data. A dissolved oxygen sensor can also be attached to the headrope and one of the trawl doors to monitor dissolved oxygen levels and temperature at bottom depth during the tow. A net monitoring system costs approximately $65,000.

The following bullet points summarize the main considerations for this recommendation.

- **Benefits:** Bringing all SEAMAP vessels used in the SEAMAP Shrimp/Groundfish Surveys in line with the NOAA vessels and allow for cross calibration and assessment of the accuracy of the trawl's deployment, as it is being towed, and during its retrieval.
- **Challenges:** Funding for installation is the only challenge.
- **Steps to implementation:** Purchase and install the net monitoring system.
- **Anticipated cost:** NOAA vessels already have net monitoring systems. Approximately $130,000 is needed to purchase and install the net monitoring systems on the other two vessels involved with the SEAMAP Shrimp/Groundfish Surveys.
- **Links to other elements of the fishery independent survey enterprise:** This could provide more informative data for stock assessments and EBFM.
- **Timeline:** Immediate

**Recommendation: Install additional probes on the CTD or collect additional water samples to measure nutrient loads, carbon concentration, dissolved organic carbon, and pH**

The benefits and costs of this recommendation are presented in section 4.1.

**Recommendation: Install an altimeter on the CTD with real time depth capabilities to make sure the CTD is taking environmental data readings as close to the bottom as possible**

SEAMAP protocol for the SEAMAP Shrimp/Groundfish Surveys requires a full CTD cast to obtain environmental data at every trawling station. NOAA vessels have altimeters on their CTDs, but not all SEAMAP partners currently have altimeters on their CTDs so they therefore are risk averse when lowering the CTD to the bottom with bottom measurements being collected between 1 and 2 m off the bottom. Environmental data collection, especially dissolved oxygen, needs to be taken as close to the bottom as possible. In order to collect data as close to the bottom as possible without losing or damaging the CTD, real time altimeters should be installed on the CTDs to allow real time depth monitoring. Accurate depth monitoring will allow data collection as close to the bottom as possible without damaging the CTD. An altimeter and real time conducting cable would cost approximately $7,500 per CTD.

The following bullet points summarize the main considerations for this recommendation.

- **Benefits:** Collecting environmental data as close to the sea floor as possible.
- **Challenges:** The only challenge is purchasing and installing the equipment.
- **Steps to implementation:** Purchase the altimeter and install the real time conducting cable and altimeter on the CTD.
- **Anticipated cost:** Approximately $22,500 are needed to purchase and install an altimeter and real time conducting cable on the three CTDs that are currently used in the SEAMAP Shrimp/Groundfish Surveys.

- **Links to other elements of the fishery independent survey enterprise:** This could provide more informative data for environmental analysis since each partner would now sample as close to the bottom as possible.
- **Timeline:** Immediate

**Recommendation: Take benthic samples that would allow analysis of sediment characterization as well as meiofauna and macrofauna assessments in relation to fish density**
In order to understand the benthic ecology of the Gulf of Mexico, researchers must have knowledge of the marine substrates that compose the seabed, and fauna that inhabit them. Substrate complexity and sediment type are important factors that can affect the distribution of benthic organisms. Sediment and benthic invertebrate data are needed to provide a better understanding of seabed conditions and the role they play in the distribution, abundance, and production of demersal fish. Meiofauna (< 1mm) and macrofauna (> 1mm) provide important links in the marine benthic food web and biogeochemical cycles. Macrofauna are important prey items for many small demersal and juvenile fish (Camp et al. 2019), as well as macroinvertebrates, but little data exist for this major component of the ecosystem. Benthic fauna are also good indicators for pollution, disturbance, and climate change and serve as an important bioindicator of human-induced alterations of the marine environment (Rabalais et al. 2007, Levin et al. 2009, Desrosiers et al. 2013, Santibañez-Aguascalientes et al. 2023). Sediment samples need to be collected and analyzed and benthic invertebrate biomass should be quantified across the entire Gulf of Mexico, and then monitored at routine intervals. Benthic sampling can be conducted at all stations or selected stations during current fishery independent sampling. A box core is approximately $7,500, but sediment, meiofauna, and macrofauna analyses are time consuming, labor intensive, and thus expensive. Grain size analysis would be approximately $60 per sample. Meiofauna and macrofauna analysis would be approximately $1,500 per sample, but analyses are highly dependent on sample size and the depths where the samples are collected.

The following bullet points summarize the main considerations for this recommendation.

- **Benefits:** Improved knowledge of the marine substrates that compose the seabed and the fauna that inhabit them.
- **Challenges:** The extra time involved in collecting samples could be a challenge. The total amount of time taken over a survey would depend on the number of samples collected and the amount of time it takes to collect each sample. This challenge could be overcome if additional days at sea were supplied for each survey.
- **Steps to implementation:** Researchers need to decide how many samples are needed throughout the Gulf. Plans could then be developed to acquire these samples from the various fishery independent surveys that are already out collecting data. A contract with a laboratory to analyze the collected would also need to be secured.
- **Anticipated cost:** Approximately $350,000 would be needed to purchase three box cores, collect 200 samples, and analyze the 200 samples for grain size, meiofauna, and macrofauna. Annual costs after the first year would be approximately $325,000 to collect and analyze 200 samples annually.

- **Links to other elements of the fishery independent survey enterprise:** Sediment grain size information could help in habitat mapping while benthic fauna analysis would help in ecosystem modeling and EBFM.
- **Timeline:** Immediate

## 4.4 SEAMAP Fall Plankton Survey

The SEAMAP Fall Plankton Survey began in 1984 and targets 138 stations every year in August and September. The stations are in a systematic grid approximately 56 km apart (Figure 11). The objectives of the survey are to assess the occurrence, abundance and geographical distribution of the early life stages of fall spawning fishes, especially King and Spanish Mackerel, Red Drum, Red Snapper, and other snappers, on U.S. continental shelf waters using a bongo frame fitted with 335-micron nets, a neuston frame fitted with a 950-micron net; describe the pelagic habitat of fish larvae through measurements of various physical and biological parameters; collect detailed observations (i.e. identification, number, volume, bell diameter) of captured jellyfish and ctenophores; and collect volumetric measurements of net caught *Sargassum*.

The bongo nets consist of two conical 61-cm nets with 335-micron mesh. Bongo tows are oblique, surface to near bottom (or 200 m) and back to surface. A SBE19 SEACAT Profiler is attached on the towing wire above the frame to provide real time depth readings along with temperature and salinity. A mechanical flowmeter is mounted off-center in the mouth of each bongo net to record the volume of water filtered. A single or double 2x1 m pipe frame neuston net fitted with 950-micron mesh netting is towed at the surface with the frame half-submerged for 10 minutes. Samples are taken upon arrival on station, regardless of time of day. A CUFES is used to collect surface (~3 m) zooplankton and egg samples along track lines between stations. A 1 $m^2$ MOCNESS is used to collect plankton samples from discrete depths to assess the vertical distributions of invertebrates, fish eggs and larvae. The MOCNESS is fitted with nine 505-micron mesh nets. In addition, hydrographic data (surface chlorophylls, salinity, temperature, and dissolved oxygen) are collected at all stations.

Data from the SEAMAP Fall Plankton Survey have been used in stock assessments for Red Snapper, Vermilion Snapper, King Mackerel, and Gray Triggerfish.

**Recommendation: Use genetic methods to identify species that currently cannot be identified to the species level**

The benefits and costs associated with this recommendation are presented in Section 4.1. Species captured during the SEAMAP Fall Plankton Survey that would benefit from larval genetic identification are species in the snapper family Lutjanidae.

**Recommendation: Use CKMR for managed species captured in plankton tows to develop a time series of absolute abundance**

The benefits and costs of this recommendation are presented in section 4.1.

**Recommendation: Install additional probes on the CTD or collect additional water samples to measure nutrient loads, carbon concentration, dissolved organic carbon, and pH**

The benefits and costs of this recommendation are presented in section 4.1.

**Recommendation: Install an altimeter on the CTD with real time depth capabilities to make sure the CTD is taking environmental data readings as close to the bottom as possible**
The benefits and costs of this recommendation are presented in section 4.3 and would only apply to vessels that currently do not have a CTD with real time depth capability.

## 4.5 SEAMAP Bottom Longline Survey

The SEAMAP Bottom Longline Survey began in 2008. In 2015, the sampling area was standardized to include the 3 – 10 m depth contour in statistical zones 10 through 21 (Figure 12). The SEAMAP Bottom Longline Survey samples during three seasons Spring (April-May), Summer (June-July), and Fall (August-September). Sampling is conducted in waters defined by the 3 – 10 m depth contour. Approximately 57 stations are targeted each season (171 stations yearly) for sampling. Stations are proportionally allocated and randomly distributed within the 3 – 10 m depth contour in each statistical zone based on the proportion of those depths present. Since the 3 – 10 m depth strata are smaller in some statistical zones relative to other statistical zones, each statistical zone is allocated at least two stations during each season in order to ensure adequate sampling coverage.

The objectives of the survey are to collect information on shark and finfish abundances and distribution with a 1.842 km longline and to collect environmental data. All specimens collected on the longline are identified, weighed, enumerated, and measured. In addition, water temperature, salinity, dissolved oxygen, and transmissivity or Secchi disc depth are collected at all stations.

The longline gear consists of a 1.842 km (426 kg test monofilament) mainline with 100 gangions (3.66 m, 332 kg test monofilament) containing #15/0 circle hooks and baited with Atlantic Mackerel, *Scomber scombrus*. The longline is fished for one hour from the time of last high-flier deployment to the time of first high-flier retrieval.

Data from the SEAMAP Bottom Longline Survey have been used in stock assessments for Blacktip Shark, Atlantic Sharpnose Shark, Great Hammerhead Shark, and Red Drum.

**Recommendation: Expand the SEAMAP Bottom Longline Survey to cover the 3 – 10 m survey area off Florida**
The SEAMAP Bottom Longline Survey is currently conducted in water depths of 3 – 10 m from statistical zone 10 in northern Florida to statistical zone 21 at the U.S./Mexican border where it targets coastal shark and finfish species within the shallow waters of the Gulf of Mexico. Expanding the survey to sample Florida would provide a wealth of data that could be used for current fisheries management, understanding predator/prey interactions, and support the development of EBFM. Funding limitations do not allow sampling in statistical zones 1-9 off Florida. An additional $250,000 annually would allow the survey to sample the entire Gulf of Mexico during the Spring, Summer, and Fall time periods.

The following bullet points summarize the main considerations for this recommendation.

- **Benefits:** Better data collection throughout the entire northern Gulf of Mexico that could be used for fisheries management, understanding predator/prey interactions, and support the development of EBFM.
- **Challenges:** Several small boats would be needed to conduct the survey across all of Florida's west coast. Personnel also would be needed to conduct the surveys.
- **Steps to implementation:** Obtain the necessary gear and outfit 4-5 smaller vessels with winches that can handle the bottom longline and sample across the entire coast.
- **Anticipated cost:** Approximately $250,000 annually would be needed to allow Florida to sample the entire west Florida coastline during the Spring, Summer, and Fall time periods.
- **Links to other elements of the fishery independent survey enterprise:** This could provide more informative data for stock assessments and EBFM
- **Timeline:** Immediate

**Recommendation: Collect samples for improved life history data for age, reproduction, and diet**

The benefits and costs of this recommendation are presented in section 4.3. Multiple aspects of this recommendation relating to lab work and personnel overlap with those presented in section 4.3, however onboard sampling is necessary.

**Recommendation: Take samples for epigenetic aging**

The benefits and costs of this recommendation are presented in section 4.3.

**Recommendation: Expand the survey out to 20 m Gulf wide to allow additional data collection on Red Drum and also have more overlap with the NOAA Fisheries Bottom Longline Survey**

In 1987, a recreational and commercial harvest moratorium was established for Red Drum (*Sciaenops ocellatus*) in Gulf of Mexico federal waters. The current Red Drum stock status is unknown. Red Drum are routinely caught in the current SEAMAP Bottom Longline Survey and the Louisiana Department of Wildlife Fisheries used the bottom longline catch data in their 2022 Red Drum Stock Assessment (West et al. 2022). Before SEAMAP standardized their sampling area in 2015, state partners sampled areas deeper than the current 3 – 10 m sampling universe where they frequently encountered Red Drum in areas between 10 – 20 m. Expanding the SEAMAP Bottom Longline Survey out to 20 m and expanding the survey to sample off Florida, as recommended above, will allow the survey to sample adult Red Drum across the entire Gulf of Mexico in offshore areas where Red Drum catches are currently prohibited. These catches will allow the collection of biological samples for age and growth, reproduction, and dietary analysis.

Expansion of the SEAMAP Bottom Longline Survey into deeper waters, would also allow more overlap with the NOAA Fisheries Bottom Longline Survey. The NOAA Fisheries Bottom Longline Survey samples from 9 – 366 m. Expanding the SEAMAP Bottom Longline Survey would provide more data for comparing catches between the two surveys that utilize the same gear and protocols to possibly combine these datasets for assessment purposes. The cost associated with expanding the SEAMAP Bottom Longline Survey out to 20 m would be $400,000.

The following bullet points summarize the main considerations for this recommendation.

- **Benefits:** Better data collection for species such as Red Drum that could be used for current fisheries management and calibrating the relative differences in the NOAA Fisheries Bottom Longline Survey and the SEAMAP Bottom Longline Survey.
- **Challenges:** Survey expansion would require an analysis to determine the appropriate number of stations to cover the entire Gulf of Mexico out to 20 m. State SEAMAP partners are currently conducting the SEAMAP Bottom Longline Survey out to 10 m, so an expansion to 20 m would possibly require additional vessels and personnel to cover a larger area within the three sampling seasons.
- **Steps to implementation:** An analysis to determine the appropriate number of stations would be required. Outfitting vessels with appropriate gear and winches would be required.
- **Anticipated cost:** Approximate costs are $400,000.
- **Links to other elements of the fishery independent survey enterprise:** This could provide more informative data for stock assessments and EBFM
- **Timeline:** Depending on when funding was provided, it would take 6-12 months to begin sampling during the start (April-May) of the SEAMAP Bottom Longline Survey sampling season.

**Recommendation: Take benthic samples that would allow analysis of sediment characterization as well as meiofauna and macrofauna assessments in relation to fish density**
The benefits and costs of this recommendation are presented in section 4.3.

**Recommendation: Install additional probes on the CTD or collect additional water samples to measure nutrient loads, carbon concentration, dissolved organic carbon, and pH**
The benefits and costs of this recommendation are presented in section 4.1.

**Recommendation: Install an altimeter on the CTD with real time depth capabilities to make sure the CTD is taking environmental data readings as close to the bottom as possible**
The benefits and costs of this recommendation are presented in section 4.3.

## 4.6 NOAA Fisheries Bottom Longline Survey

The NOAA Fisheries Bottom Longline Survey began in 1995 and samples water depths of 9 – 366 m in August and September each year. The objectives are to collect data on shark and Red Snapper abundances and distributions; collect morphological measurements and biological samples to facilitate life history studies; tag coastal teleosts and sharks to assess their residency and movement patterns; and collect water temperature, salinity, dissolved oxygen, and transmissivity at all stations.

Approximately 150 stations in the Gulf of Mexico are proportionally allocated each year based on the surface area of the continental shelf (Figure 13) width within the statistical zones and depth zones (50% allocation 9 m - 55 m, 40% allocation 55 m - 183 m, 10% allocation 183 m - 366 m). The longline gear consists of a 1.842 km mainline (4 mm diameter), 100 gangions constructed of a snap, 3.7 m monofilament leader (3 mm diameter) and a #15/0 circle hook baited with

Atlantic Mackerel. The survey initially fished J-hooks when the survey began in 1995. A mixture of J-hooks and 15/0 circle hooks were utilized between 1999 and 2000 and 15/0 circle hooks have been used exclusively since 2001. The longline is fished for one hour from the time of last high-flier deployment to the time of first high-flier retrieval. All specimens collected on the longline are identified, weighed, enumerated, and measured. Biological samples are collected on most species.

Data from the NOAA Fisheries Bottom Longline Survey have been used in stock assessments for Atlantic Sharpnose Shark, Blacknose Shark, Blacktip Shark, smoothhound sharks, large coastal shark complex, Red Grouper, Red Snapper, Sandbar Shark, Great Hammerhead, Scalloped Hammerhead, small coastal shark complex, tilefish, and Yellowedge Grouper.

**Recommendation: Increase the number of stations in the Gulf of Mexico in order to reduce CVs**
The NOAA Fisheries Bottom Longline Survey has been used in stock assessments for a variety of shark species as well as Red Grouper, Red Snapper, Yellowedge Grouper, Golden Tilefish, and Blueline Tilefish. While the survey data have been used in the stock assessments, CVs could be reduced and abundance indices improved by increasing the number of stations that the survey samples (Figure 3). The NOAA Fisheries Bottom Longline Survey only samples 150 stations within the Gulf of Mexico with 50% of the stations allocated in the 9 – 55 m depth strata, 40% in the 55 – 183 m depth strata, and 10% in the 183 – 366 m depth strata.

During the project, data gaps for Yellowedge Grouper, Golden Tilefish, and Blueline Tilefish were identified. If effort is increased across the entire survey, the CV for these species is not predicted to change drastically as only 10% of the total increased effort would go towards the deepwater areas that these species inhabit. If an additional 50 stations were added to the deepwater depth strata of the survey, CVs are predicted to drop dramatically for these three species (Figure 14). The current effort allocation in the shallow and midwater depth strata would not change. Approximately 10 additional sampling days would be needed to sample an additional 50 longline stations. Bottom longline stations cost approximately $4,000 per station.

The following bullet points summarize the main considerations for this recommendation.

- **Benefits:** Better data collection that could be used for fisheries management for Yellowedge Grouper, Golden Tilefish, and Blueline Tilefish as well as other deepwater species.
- **Challenges:** Funding and securing an additional 10 days of ship time are the major challenges associated with this recommendation.
- **Steps to implementation:** Projects funds and staff need to be allocated and a plan of implementation and analysis developed.
- **Anticipated cost:** Approximate costs are $200,000 to collect an additional 50 longline stations.
- **Links to other elements of the fishery independent survey enterprise:** This would provide more informative data for stock assessments and EBFM.
- **Timeline:** Immediate

**Recommendation: Take samples for epigenetic aging**
The benefits and costs of this recommendation are presented in section 4.3.

**Recommendation: Take benthic samples that would allow analysis of sediment characterization as well as meiofauna and macrofauna assessments in relation to fish density**
The benefits and costs of this recommendation are presented in section 4.3.

**Recommendation: Install additional probes on the CTD or collect additional water samples to measure nutrient loads, carbon concentration, dissolved organic carbon, and pH**
The benefits and costs of this recommendation are presented in section 4.1.

## 4.7 NOAA Fisheries Pelagic Acoustic Trawl Survey

The NOAA Fisheries Pelagic Acoustic Trawl Survey began in October 2002 as an outer shelf and upper slope survey sampling depths between 110 – 500 m. In 2004, the survey became a mid to outer shelf and upper slope survey sampling depths between 50 – 500 m (Figure 15). This survey last sampled in 2016 and was discontinued in 2017. The objectives of the survey were to sample the northern Gulf of Mexico to determine distribution and abundance of benthopelagic fauna to aid in stock assessments; collect morphological measurements and biological samples to facilitate life history studies; collect environmental data; and collect acoustic data with an EK60 acoustic echosounder.

Approximately 150 stations were proportionally allocated based on stratum area with 30% effort between 50 and 110 m, 60% effort between 110 and 200 m and 10% effort between 200 and 500 m. Trawl sampling was conducted using a 27.4 m high-opening fish trawl towed for 30 minutes. All specimens collected in the trawl during the survey were identified, weighed, enumerated, and measured. In addition, water temperature, salinity, dissolved oxygen, and transmissivity were collected at all stations.

Data from the NOAA Fisheries Pelagic Acoustic Trawl Survey have been used in stock assessments for Wenchman, although the ending of this survey prevented the Gulf Council from using the assessment results for management advice. Data were considered for other assessments, but the data time series was not long enough at the time of assessment.

**Recommendation: Reinstitute this survey to provide data primarily on forage species that inhabit shelf edge habitats for EBFM**
The Pelagic Acoustic Trawl Survey began surveying the entire Gulf of Mexico between the depths of 110 – 500 m in 2002. The survey changed in 2004 to sample waters from 50 – 500 m. Its goal was to investigate if the distributional range of species collected in the SEAMAP Shrimp/Groundfish Surveys extended beyond 110 m in depth. Data collected from the NOAA Fisheries Pelagic Acoustic Trawl Survey were used in a stock assessment for Wenchman (*Pristipomoides aquilonaris*) and were considered for other species but not used due to the short duration of the survey that ended in 2016. Reinstituting this survey could potentially provide an important source of fisheries independent information on many commercially, recreationally, and ecologically important species throughout the northern Gulf of Mexico.

The NOAA Fisheries Pelagic Acoustic Trawl Survey had high catch rates of Wenchman throughout the Gulf of Mexico and captured Wenchman in deeper waters that were not sampled by the Reef Fish or Shrimp/Groundfish Surveys. Concerns about Wenchman catches have recently been raised to the Gulf of Mexico Fishery Management Council.

The NOAA Fisheries Pelagic Acoustic Trawl Survey also collects data on potential prey items (lanternfish, pearlsides, driftfish, and squid) for endangered Rice's whale (*Balaenoptera ricei*). Understanding the prey requirements for these endangered whales is vital to protecting the habitat they need to survive. Potential prey occur throughout the Gulf of Mexico, but the Rice's whale core distribution area is only in the northeast Gulf of Mexico. Additional shelf edge sampling could provide insights as to why Rice's whales are mainly in the northeastern Gulf of Mexico.

The Pelagic Acoustic Trawl Survey targeted approximately 150 stations each year that were sampled in October and November. The survey was originally designed to sample water depths of 110 – 500 m, but changed in 2004 to allow more overlap with the SEAMAP Summer and Fall Shrimp/Groundfish Surveys. Since this survey would primarily target deeper water habitats not sampled by current surveys, the survey should target water depths of 110 – 500 m as originally designed. The cost per station in 2016 was $4,172 per station. Therefore, approximately $750,000 would be needed to reinstitute this survey.

The following bullet points summarize the main considerations for this recommendation.

- **Benefits:** Would provide important data on commercially, recreationally, and ecologically important species throughout the northern Gulf of Mexico as well as off shelf data for ecosystem modeling.
- **Challenges:** The only challenge would be funding for the survey.
- **Steps to implementation:** This survey has been conducted in the past, so protocols and sampling methodology have already been developed.
- **Anticipated cost:** The approximate cost would $750,000 annually.
- **Links to other elements of the fishery independent survey enterprise:** This could provide more informative data for stock assessments and ecosystem modeling.
- **Timeline:** This survey could be restarted immediately.

**Recommendation: Collect samples for improved life history data for age, reproduction, and diet**

The benefits and costs of this recommendation are presented in section 4.3.

**Recommendation: Take samples for epigenetic aging**

The benefits and costs of this recommendation are presented in section 4.3.

**Recommendation: Take benthic samples that would allow analysis of sediment characterization as well as meiofauna and macrofauna assessments in relation to fish density**

The benefits and costs of this recommendation are presented in section 4.3.

**Recommendation: Install additional probes on the CTD or collect additional water samples to measure nutrient loads, carbon concentration, dissolved organic carbon, and pH**
The benefits and costs of this recommendation are presented in section 4.1.

**Recommendation: Install an altimeter on the CTD with real time depth capabilities to make sure the CTD is taking environmental data readings as close to the bottom as possible**
The benefits and costs of this recommendation are presented in section 4.1.

# 5. Recommended New Surveys

## 5.1 Habitat Mapping

Habitat mapping will greatly improve the design and efficiency of fishery independent surveys. Improved habitat data will allow for improved estimates of habitat quantity and composition that, combined with the estimation of species abundances on specific habitat types, will improve ecosystem models and EBFM. Better habitat maps will allow scientists to determine the efficiency with which a survey samples the available stock. With better habitat maps, fishery independent surveys can be calibrated across habitats to measure species catchability and selectivity. Being able to calculate catchability and selectivity would improve stock assessments by facilitating estimation of absolute abundance rather than relative abundance. Mapping used in conjunction with fishery independent surveys will allow ecosystem models to describe the interactions of species or multi-species complexes with a variety of habitats or bottom types. Mapping is best accomplished with use of side-scan in shallower depths or multi-beam sonar systems in deeper waters. The SEAMAP Reef Fish Survey currently conducts habitat mapping at night, so habitat mapping could be conducted during existing surveys or could be conducted as a stand-alone effort. It would cost approximately $1 million annually to map approximately 700 $km^2$.

The following bullet points summarize the main considerations for this recommendation.

- **Benefits:** Develop representative estimates of habitat quantity and quality that could be used to estimate total habitat availability, a key component in the optimal allocation of sampling effort, understanding of species distribution, habitat utilization and environmental monitoring.
- **Challenges:** Data processing is the main challenge associated with this recommendation.
- **Steps to implementation:** Habitat mapping protocols have been developed and mapping has been done extensively as part of the SEAMAP Reef Fish Survey. Therefore, the only steps needed would be funding for ship time.
- **Anticipated cost:** Habitat mapping efforts are estimated to cost $1 million annually, although these efforts can be reduced after several years of successful data collection.
- **Links to other elements of the fishery independent survey enterprise:** Strengthen our understanding of reef fish species distribution as it relates to habitat type.
- **Timeline:** Immediate

## 5.2 Forage Fish Acoustics Trawl Survey

Fisheries acoustics has tremendous potential to be incorporated into a forage fish survey with a concurrent mid-water or high opening bottom trawl. Acoustic surveys are cost effective because large areas can be surveyed relatively quickly with minimal staff, but often need to be paired with trawls to provide species and length composition data. The trawl would provide data on the catch rate of forage fish species while the acoustics would provide biomass estimates. Environmental data collection would measure oceanographic factors and their potential influences on forage fish distribution and biomass. Data provided by these surveys would be extremely useful in support of ecosystem modeling efforts by providing estimates of forage fish biomass and overall system productivity, in addition to informing catchability estimates for target species. Equipment would cost approximately $200,000 and approximately $850,000 would be needed annually to sample 300 stations around the Gulf of Mexico.

The following bullet points summarize the main considerations for this recommendation.

- **Benefits:** Would provide valuable data on forage fish for ecosystem modelling and EBFM.
- **Challenges:** While an acoustic trawl forage fish survey was conducted off Florida from 1994-2018, one has not been conducted across the entire Gulf. Acoustics have not been extensively used in the Gulf of Mexico, so considerable research would need to be done in order to acoustically identify the species encountered.
- **Steps to implementation:** Research to acoustically identify species needs to be done before implementing the survey. Catches from a mid-water trawl would need to be compared to a high opening bottom trawl to see which trawl does a better job of capturing target species.
- **Anticipated cost:** Approximate costs for the survey would be $200,000 to purchase equipment and $850,000 annually to conduct the survey.
- **Links to other elements of the fishery independent survey enterprise:** Strengthen our understanding of forage fish distribution and biomass. This survey also might be able to provide data on top level predators such as coastal pelagics.
- **Timeline:** Approximately 1-2 years would be needed to conduct research to acoustically identify the numerous forage fish in the Gulf of Mexico.

## 5.3 Synoptic Life History Surveys

For some species, accurate fisheries assessments often require life history data that cannot be obtained from current fishery independent surveys. Of particular importance are size- or age-specific estimates of fecundity and fraction of the population capable of spawning through time, which can be used to improve the accuracy of estimated annual stock reproductive potential, and sex ratios of hermaphroditic species such as groupers. These life history data require targeted monthly synoptic sampling covering the full spatial distribution and spawning season of the species of interest. Species vary with respect to both spawning season and susceptibility to various fishing techniques. However, because estimated life history parameters are unlikely to change quickly, only periodic (e.g., every 5 – 10 years) sampling would be required. Target species or guilds would be determined based on upcoming stock assessment schedules and most critical life history data needs. Approximately $1 million would be need annually to conduct these targeted surveys.

The following bullet points summarize the main considerations for this recommendation.

- **Benefits:** Synoptic surveys would target species coming up for assessment and provide missing data needed for robust assessments. Of particular importance are size or age-specific estimates of fecundity and fraction of the population capable of spawning through time.
- **Challenges:** Directed sampling would be different for each species targeted.
- **Steps to implementation:** Priority species need to be identified and then a sampling plan would need to be developed for each species.
- **Anticipated cost:** Approximate costs are $1 million for each species targeted for the collection and analysis of the data.
- **Links to other elements of the fishery independent survey enterprise:** Strengthen our understanding of size or age-specific estimates of fecundity and fraction of the population capable of spawning through time.
- **Timeline:** Since the data collection does not need to be standardized, these surveys could be implemented immediately.

## 5.4 Marine Mammal, Seabird, and Sea Turtle Survey

Researchers need biomass estimates, diet composition, and abundance information on coastal and offshore dolphins, small and large whales, seabirds, and sea turtles. The first marine mammal and seabird surveys in the 1990s were piggybacked on the SEAMAP Spring Plankton Survey. Visual transect surveys for marine mammals were conducted during daylight hours and also recorded seabird observations. Marine mammal surveys received their own stand-alone surveys in the early 2000s. Money from the Bureau of Ocean and Energy Management (BOEM) and Deepwater Horizon oil spill settlement have paid for several years of survey work since 2010, but dedicated funding for marine mammal, seabird, and sea turtle surveys has been lacking. Visual transect surveys with supplementary towed hydrophones and acoustics have provided data for current marine mammal stock assessments.

An ideal marine mammal, seabird, and sea turtle survey would consist of a mixture of vessel and aerial surveys across the entire Gulf of Mexico. Aerial transect surveys would be needed to cover coastal waters out to 200 m for marine mammals and sea turtles while vessel surveys would be needed to cover Gulf of Mexico waters greater than 200 m for marine mammals and seabirds. Two vessels would be needed during a 60 to 90-day survey window. One vessel would conduct the visual line-transect surveys while conducting passive acoustic sampling with towed arrays and sonobuoys. The accompanying partner vessel would collect biopsy samples, conduct plankton and prey sampling, along with collecting oceanographic and environmental data. Autonomous vehicles and eDNA have potential to help in data collection and species identification, but further research and development is needed before these tools can be incorporated into routine sampling. This survey would cost approximately $5 million annually.

The following bullet points summarize the main considerations for this recommendation.

- **Benefits:** Reliable information on biomass estimates, diet composition, and abundance information on coastal and offshore dolphins, small and large whales, seabirds, and sea turtles that would help manage these species as well as help fill EBFM data needs.
- **Challenges:** Ship time aboard two vessels simultaneously would be the largest challenge associated with this recommendation.
- **Steps to implementation:** Similar survey methods have been used in the past. Using autonomous vehicles and collecting water samples for eDNA analysis and species identification would require research and development before implementation.
- **Anticipated cost:** This survey would cost approximately $5 million annually, but the survey would only need to be conducted two out of every three years.
- **Links to other elements of the fishery independent survey enterprise:** Strengthen our understanding of marine mammals, seabirds, and sea turtles and provide data for EBFM.
- **Timeline:** This survey could be implemented immediately, but the use of autonomous vehicles and eDNA would require further development.

## 5.5 Pelagic Fish Survey

Stocks of Cobia, Dolphin, King and Spanish Mackerel are important both economically and ecologically. Ichthyoplankton data from the SEAMAP Fall Plankton Survey and data from the SEAMAP Fall Shrimp/Groundfish Survey have been used in the King Mackerel stock assessment. The relative abundance of larvae from the SEAMAP Fall Plankton Survey was used as a proxy for the abundance of spawners in the Gulf of Mexico stock unit. The SEAMAP Fall Shrimp/Groundfish Survey index is assumed to represent the relative abundance of age-0 King Mackerel in the western Gulf of Mexico. SEAMAP Summer and Fall Shrimp/Groundfish Survey data were the only fishery independent data used in the Spanish Mackerel stock assessment. Applications of advanced technology (e.g., CKMR or acoustic surveys) may be the only solution for monitoring the population of these species, while fishery-cooperative sampling could address data needs for estimating biological characteristics and ecosystem interactions.

CKMR could prove useful for developing abundance estimates for these pelagic species. It would require dedicated or piggybacked plankton surveys for larval capture since current plankton survey techniques do not capture enough of these species for CKMR analysis. Each species has different biological characteristics and population size. Therefore, simulation studies will need to be run prior to engaging in CKMR studies to ensure proper experimental design. Gear and techniques used by McDowell et al. (2022) to capture Atlantic Bluefin Tuna larvae could be employed during the summer months to capture Cobia, Dolphin, King and Spanish Mackerel larvae. All four species have a protracted spawning season from April to September peaking in June and July (Finucane et al. 1986, Finucane and Collins 1986, Ditty and Shaw 1992, Brown-Peterson et al. 2001). Opportunistic plankton sampling using undulating bongo nets for 10 minutes during the SEAMAP Summer Shrimp/Groundfish Survey across the entire spawning area could provide enough larvae for CKMR analysis. In previous SEAMAP plankton sampling, Cobia were more than nine time more abundant in neuston catches than bongo catches (Hanisko et al. 2018) and King Mackerel catches were 1.7 times greater at night than during the day in bongo nets (Hanisko and Lyczkowski-Shultz 2013). This suggests that gear avoidance may play a factor in larval capture of these species. Therefore, plankton sampling should probably be conducted at night. Genetic samples from adults, necessary for CKMR analyses, could be obtained through directed sampling of tournaments and fish markets.

Acoustic sampling of adults also should be investigated. Cobia, Dolphin, King Mackerel, and Spanish Mackerel do not have swim bladders, so detecting these species acoustically could be problematic. A dedicated survey may not be needed if a Forage Fish Acoustics Trawl Survey is instituted. The Forage Fish Acoustics Trawl Survey would cover the same areas of distribution as these pelagic species and these top-level predators would potentially be feeding on the forage fish as the acoustic sampling would be conducted.

The cost associated with CKMR sampling would be approximately $7,300 for conducting each plankton station and sorting and identification of the larval fish. It costs approximately $30 per fish for the DNA extraction and genotyping based upon genotyping 3,500 fish per year.

Genetic material from adult pelagics could be obtained from recreational or commercial sampling. Otoliths or a DNA sample for epigenetic aging would also need to be obtained for aging purposes.

The costs associated with acoustically sampling adult pelagics would be the preliminary work needed to determine the target strength of these species. Once the target strength is determined, the costs to sample these species would be same as the costs ($850,000) to conduct the Forage Fish Acoustics Trawl Survey.

The following bullet points summarize the main considerations for this recommendation.

- **Benefits:** Would supply much needed information on Cobia, Dolphin, King and Spanish Mackerel stocks for both stock assessment as well as information on top level predators for EBFM and ecosystem modeling.
- **Challenges:** CKMR has not been explored for these species. Historic plankton sampling has not done a good job of collecting these species in large quantities, so collection of enough larval specimens for CKMR could be problematic. Acoustic sampling could also be problematic since these species do not have swim bladders.
- **Steps to implementation:** Simulated population models with current population parameters are needed for each species to estimate the number of larval samples required for proper experimental design. Summer plankton sampling needs to be conducted to determine if enough larval specimens can be collected for the CKMR analysis. If enough specimens can be collected, then adult samples have to be collected also. Experimental acoustic work needs to be done to help develop target strengths for these species. Once completed, the feasibility of an acoustic survey for these species can be determined.
- **Anticipated cost:** It is not possible to provide accurate costs for a CKMR study at this stage. The costs to analyze the samples would depend on the number of larval samples needed to estimate census size with the required allowance of error. Approximately $500,000 would enable the initial research. A stand-alone acoustic survey for these

species would cost approximately $850,000, but this cost would be significantly lower if the sampling could be conducted in conjunction with a forage fish acoustics trawl survey.

- **Links to other elements of the fishery independent survey enterprise:** Plankton sampling could be conducted during the SEAMAP Summer Shrimp/Groundfish Survey. Acoustic sampling could be combined with a forage fish acoustics trawl survey.
- **Timeline:** Developing population models to estimate the number of larval samples needed for CKMR and plankton sampling could be started immediately. Approximately 1-2 years would be needed to develop target strength for these species and determine the feasibility of an acoustic survey.

# 6. Prioritization

Balancing priorities to ensure that survey goals are met while making the best use of available resources is challenging. In fisheries management there is often a general consensus or legal basis that identifies the need to prioritize certain objectives, such as the conservation of endangered species or the sustainability of fish stocks. This report's recommendations have a wide range of scope. For example, the recommendations range from collecting additional data on existing surveys that would aid in the basic science of monitoring the marine environment (e.g., benthic sampling and habitat mapping), to ensuring high quality data are collected (e.g., net monitoring systems and altimeters on CTDs), to recommending new surveys (e.g., coastal pelagics or forage fish surveys), to developing the capability to integrate new technology and novel methods for data collection (e.g., epigenetic aging or CKMR). Some recommendations are crosscutting and would benefit multiple species across multiple surveys or gears (e.g., diet studies). Others are crucial for a single survey (e.g., secure long-term funding for the SEAMAP Reef Fish Survey).

The Steering Committee prioritized the current fishery independent survey improvement and new survey recommendations in an effort to aid decision makers in analyzing the recommendations' potential benefits and tradeoffs. When prioritizing recommendations, the Steering Committee noted that there may be inherent biases due to the background and interests of the group. The recommendations were scored in a qualitative manner, and it is recognized that any decision to accept certain recommendations would consider the trade-offs between different objectives, some of which are outside the scope of this report (e.g., socio-economic concerns). It is important to recognize that objectives and priorities may change over time and likely may differ among stakeholders. Consequently, there may not be a single portfolio of fisheries independent surveys that satisfies all objectives given logistical and budgetary constraints.

The Steering Committee's prioritization of the survey improvement and new survey recommendations, outlined in Sections 4 and 5, was based upon a qualitative ranking scale of Not Applicable, Low, Medium, High and Very High. Eleven of the sixteen Steering Committee members responded to the request to prioritize the recommendations. For presentation and aggregation purposes, these ranking levels were given a quantitative value of 0-4 respectively, which was then used to compute a weighted score (sum) for each recommendation with average scores also being tabulated (Table 6). Recommendations were evaluated on their overall priority, importance or priority for fisheries management and stock assessment, importance for marine mammals, seabirds and sea turtles, and EBFM.

In addition to the qualitative ranking of survey improvement recommendations, Steering Committee members were asked to complete an additional question that functioned as a resource allocation exercise. Qualitative rankings help elucidate the relative importance of recommendations, but sometimes qualitative rankings can hide the true magnitude of difference between priority recommendations. Another method to examine these differences is to allocate points to each participant and allow them to spend the points on their priority recommendations. Therefore, members were asked to distribute 100 points to indicate the recommendations they felt were the most important overall. The goal of this exercise was to gather insights on how individuals might allocate limited resources or prioritize different recommendations. The only constraint of this exercise was that participants had to allocate all of their points. However, they could choose to allocate all of their points on one recommendation, spread the points out equally among the recommendations, or anywhere in between. Table 6 shows the results of the point allocation rankings in the final two columns.

There were slight priority differences between the two methods, likely reflecting the diverse composition of the respondents. The top five priorities based upon qualitative rankings of their overall priority were:

1) Secure long-term funding for the SEAMAP Reef Fish Survey,
2) Increase the number of bottom longline stations in the NOAA Fisheries Bottom Longline Survey,
3) Develop a new pelagic fish survey,
4) Install net monitoring systems for trawls used in the SEAMAP Summer and Fall Shrimp/Groundfish Surveys, and
5) Use CKMR on larval Atlantic Bluefin Tuna in SEAMAP Spring Plankton Survey.

The top five priorities based upon the point allocation rankings were:

1) Increase the number of bottom longline stations in the NOAA Fisheries Bottom Longline Survey,
2) Secure long-term funding for the SEAMAP Reef Fish Survey,
3) Improve the timeliness in processing of video data from the SEAMAP Reef Fish Survey,
4) Develop a new pelagic fish survey, and
5) Develop a forage fish acoustic trawl survey.

Other avenues of prioritizing the project recommendations exist. Recommendations could also be based on the impact on species of high importance, survey coverage, survey gaps, methodological improvements, and long-term funding availability. For example:

1) Importance of species – Species that are commercially important or have conservation concerns may require higher coverage and more resources. Therefore, recommendations that target these species may have a higher priority (e.g., using CKMR on larval Atlantic Bluefin Tuna from the SEAMAP Spring Plankton Survey and adults to estimate Atlantic Bluefin Tuna absolute abundance).

2) Survey coverage – Surveys that have limited coverage in terms of geographic area or depth range may require more attention to increase their coverage. It is recommended that the SEAMAP Bottom Longline Survey be expanded to cover the 3 – 10 m survey area off Florida and expand the survey out to 20 m to allow additional data collection on Red Drum and also have more overlap with the NOAA Fisheries Bottom Longline Survey.
3) Survey gaps and timing – Surveys that have gaps in their data collection may require more attention to fill in these gaps. It is recommended that the April portion of the SEAMAP Spring Plankton Survey be reinstituted after April sampling was discontinued due to funding constraints.
4) Methodological improvements – Recommendations that involve improvements to survey methods or technology may be prioritized to enhance data quality and accuracy. It is recommended that the SEAMAP Reef Fish Survey develop acoustic camera sampling protocols that will benefit sampling in the western Gulf of Mexico and fully develop VIAME processing of video data to save time and money in video analysis.
5) Funding availability – Recommendations that require long-term funding may need to be prioritized based on funding availability. For example, securing long-term funding for the SEAMAP Reef Fish Survey.

# 7. Additional Needs

Genomic sampling shows promise, but is dependent on accurate genetic reference libraries. GenBank is the National Institute of Health's genetic sequence database and is the largest and most widely used genetic database. While GenBank contains a wealth of DNA sequences, it does not contain information for all fish species in the Gulf of Mexico and surrounding areas. GenBank also does not have voucher specimens available for taxonomic review and there are problems with misidentification. Approximately $225,000 is needed annually to collect and identify specimens, sequence species, manage the database, and curate the collection. Approximately five to ten species could have their entire genomes sequenced each year as part of this cost, while other species could have mtDNA sequence data collected. Additional species could be sequenced each year if more funding were provided. This work would provide genetic resources for future eDNA identification, epigenetic aging, genetic sex identification, and CKMR.

Acoustic sampling has not been extensively conducted in the Gulf of Mexico as in other regions, largely due to faunal diversity. Research must be undertaken on the target strength for common species to assign backscatter data to the correct species or species group. The fish target strength of individual fish and volume backscattering strength from fish schools are essential requirements for estimating abundance from surveys. The target strength is dependent on each species' swim bladder size and also on the swim bladder's shape and compression, the fish's state of maturity, and the fish's fat content. Target strength also is affected by fish's orientation to the transducer beam. Therefore, significant work needs to be conducted to build a feature library before acoustic surveys begin or before using acoustics in conjunction with existing surveys. Acoustic identification of a particular species depends on visual interpretation of the data along with biological sampling in order to reliably distinguish one species from another by acoustic means. Similarities in morphology and behavior make it hard to differentiate fish species with similar acoustic properties. Approximately $500,000 is needed to collect baseline acoustic information on Gulf of Mexico species to lay the groundwork for acoustic sampling.

## 8. Other Survey Considerations

The relative need for balance among fishery independent surveys depends on the specific goals and objectives of the surveys. In general, it is important to ensure that the surveys cover a broad range of habitats and species to provide a comprehensive understanding of the ecosystem. In addition to producing information on relative abundance, fishery independent surveys are tasked with gradually addressing and filling in critical knowledge gaps or addressing specific research questions that are essential for informed decision-making.

Current SEAMAP and NOAA Fisheries fishery independent surveys are collecting data at as many stations as possible. While current surveys have the ability to collect additional data, any new data collection (collecting water samples, deploying additional gear, collecting biological samples, etc.) that slows current data collection will reduce the number of stations that can be collected during the survey. A 30-minute delay at each station to collect additional data during the SEAMAP Summer Shrimp/Groundfish Survey will require an additional 7.5 days at sea to collect the current data as well as the additional data at the survey's 350 stations. Therefore, additional days at sea for all current surveys need to be factored into any budget if additional data will be collected.

One way to adjust the survey enterprise is to consider whether the SEAMAP Summer or Fall Shrimp/Groundfish Survey could be discontinued without impacting data for stock assessments. Abundance data from both surveys have been used in stock assessments for White Shrimp, Brown Shrimp, Pink Shrimp, Hogfish, Spanish Mackerel, King Mackerel, Gray Triggerfish, Red Snapper, Vermilion Snapper, Gray Snapper, Red Grouper, small coastal sharks, smoothhound sharks, Atlantic Sharpnose Shark, Bonnethead, and Blacknose Shark. While both surveys catch these species, some species are more frequently encountered in one survey over the other.

Which survey provides the best data for assessments depends on the species of interest. Table 7 provides the fork length and sample size from 2016-2019 for the most commonly caught species of interest in the trawl surveys. Red Snapper are more frequently encountered in the SEAMAP Fall Shrimp/Groundfish Survey where the data form the basis for the age-0 Red Snapper index. In 2020, the Gulf of Mexico Fishery Management Council tasked the SEAMAP Trawl Shrimp Data and Index Estimation Work Group (Work Group) with examining shrimp data processing and estimation methods to assess adequacy and appropriateness of data to inform stock assessments for Brown, White, and Pink Shrimp. The Work Group reviewed the history of the SEAMAP Summer and Fall Shrimp/Groundfish Surveys including survey design changes, survey expansion, timing of the survey in relation to shrimp migration patterns, and data collection methods. The Work Group also provided best practice recommendations for developing shrimp abundance indices from the SEAMAP Summer and Fall Shrimp/Groundfish Surveys. The Work Group recommended that data from the SEAMAP Summer and Fall Shrimp/Groundfish Surveys both be used in the Brown Shrimp and White Shrimp stock assessments due to the surveys sampling different life stages. The Work Group recommended that data from the SEAMAP Summer

Shrimp/Groundfish Survey be used for the Pink Shrimp stock assessment. It appeared that both surveys sample the same portion of the Pink Shrimp population, but the SEAMAP Fall Shrimp/Groundfish Survey has a shorter time series on the west Florida shelf.

Environmental data from the SEAMAP Summer Shrimp/Groundfish Survey have been used as part of NOAA's National Centers for Environmental Information Gulf of Mexico Hypoxia Watch that maps near real-time bottom dissolved oxygen data to monitor hypoxic conditions in the Gulf of Mexico. Even though sampling occurs a few weeks before the Louisiana Universities Marine Consortium (LUMCON) annual shelf wide hypoxia survey, bottom dissolved oxygen data from the SEAMAP Summer Shrimp/Groundfish Survey have served as surrogates in years when the LUMCON survey was not conducted.

Another consideration is the elimination of either the SEAMAP Spring or Fall Plankton Survey to free up additional sea days for other surveys. While it may seem that these plankton surveys are redundant, they sample different areas and different species. For example, the SEAMAP Spring Plankton Survey samples further offshore than the SEAMAP Fall Plankton Survey. Different species spawn during different months so even sampling more inshore during the spring or offshore during the fall will not provide data on species that do not spawn when sampling. Table 8 shows this in the percent positive catch rate for several species of interest that can be identified in larval form. Using genetics to identify larval fish may vastly increase these survey's data utility, so managers should consider future data value when making decisions on the value of plankton surveys versus other fishery independent surveys.

## 9. Survey Valuation and Optimization

Based on initial work by Steering Committee members, the project developed a survey optimization model (SOM) to address Action Step 4. The purpose of the SOM is to objectively allocate sampling effort across multiple surveys in order to maximize the information gained by the entire survey enterprise and meet stated management objectives. The current SOM includes eight surveys (NOAA Fisheries Bottom Longline Survey, SEAMAP Summer and Fall Shrimp/Groundfish Surveys, SEAMAP Bottom Longline Survey, SEAMAP Reef Fish Survey, SEAMAP Spring and Fall Plankton Surveys, and the NOAA Fisheries Pelagic Acoustic Trawl Survey) and 94 species that make up 95% of commercial and recreational landings. The model includes four management objectives, representing commercial value, recreational value, ecosystem value, and management importance. The objectives can be assigned a weight to reflect high-level prioritization for example to allocate sampling effort that maximizes informational value for recreationally caught species or alternatively to maximize information for ecosystem monitoring or some balanced approach. Each species included in the SOM is given a valuation for each management objective, where commercial value is based on dockside value of landings, recreational value is represented by the number of landed fish, ecosystem value is derived from energy throughput metrics generated by an ecosystem model, and management importance is based on expert opinion and frequency of stock assessments. The species valuations are then factored into the survey valuation, where species-survey values are discounted by frequency of occurrence and the CV in each fleet, which is related to sample size using a simple power function.  This allows changes in sample size to affect the CV, and therefore factors into the species and survey valuation and optimization.

Values are summed across species and fleets for a combined enterprise value or score which can be optimized.  Optimization is done by adjusting survey sample sizes to maximize the enterprise score, subject to logistic constraints (ship days available), and financial constraints (costs).  The SOM highlights the tradeoffs associated with achieving different management goals, namely commercial, recreational, ecosystem, management importance and uniqueness (of the species-specific data) criteria.  An online version of the SOM that allows users to input their weights based upon their priorities can be accessed at this link.

The objective criteria, which determine the importance placed on various categories can be set based on user preference.  To show the results of the SOM under an array of values, an initial portfolio (Table 9) of scenarios that capture the range of uncertainty and/or plausible options for objective weights was run.  Weights are the relative importance of each objective, and can be greater or equal to 0.  Figures 16-19 show the results of these initial runs.

The SOM is a tool developed to show the potential tradeoffs between current configurations and hypothetical alternatives that are informed by specific management goals or priorities.  Under equal weights, the optimal solution is to put more effort into the trawl and bottom longline surveys because they have lower costs per station, lower CVs, and higher power parameters (in this configuration), and have the highest species richness.  This highlights the tradeoff in what can be somewhat conflicting management objectives such as single species vs ecosystem.

# 10. Evaluating Tradeoffs and Impacts of Budget Reductions

This report, along with the survey optimization model, offers a valuable foundation for evaluating tradeoffs to fishery independent surveys associated with changes to fisheries management priorities or budget reductions.  An informed understanding of the potential consequences of shifting, reducing, or cutting fishery independent surveys is essential before managers decide how to balance budgetary constraints with the need for reliable data collection.

The report contains information on the species-specific survey interactions (e.g., frequency of occurrence, CV, life stage caught), along with information on the use of individual surveys in stock assessments.  This information can be useful in evaluating potential budget cuts on fishery independent surveys by showing overlap, redundancies, and important differences in the data collected by each survey.  Additionally, the SOM can be utilized to simulate and analyze different budget allocation scenarios, allowing for an assessment of the potential impacts on survey efforts.  By adjusting the sampling effort and associated costs in the SOM, managers can observe the corresponding effects on the information gained and the achievement of management objectives.  This enables managers to assess the tradeoffs between budget reductions and the resulting reduction in data quality, potential gaps in knowledge, and impacts on fisheries management decisions.  Importantly, this requires decisions about what the overall balance of monitoring priorities are.  For example, prioritization could be focused on collecting data for EBFM, a group of commercially important species, recreationally important species, data poor species, or some mix of these groups. With the SOM, managers can make informed choices, ensuring that any budget cuts are carefully balanced to minimize adverse effects on fishery independent surveys while maximizing the efficient utilization of available resources.

Additionally, the report highlights the challenges associated with implementing each recommendation. Managers can use this information to assess the tradeoffs between cost reductions and potential drawbacks, such as decreased data accuracy or increased uncertainty in assessments. Further, each recommendation's approximate cost is outlined in the report allowing managers to evaluate the financial implications of any survey improvement recommendations alongside potential scale downs of survey work elsewhere. By carefully examining the costs associated with different recommendations, managers can weigh the potential savings against the potential impact on data quality and fisheries management outcomes.

## 11. Short Term vs. Long Term Recommendations

The survey improvement recommendations note the links that exist between surveys because some recommendations will have cross cutting effects, essentially enhancing data collection across more than a single survey. Importantly there are recommendations that would benefit the overall survey enterprise if implemented sooner, as well as recommendations that may take significant time and money to come to fruition. For example, the following topics would greatly improve data quality and quantity in the near term.

- Fully implementing Video Image Analytics for the Marine Environment (VIAME) to read video from the SEAMAP Reef Fish Survey would allow quicker and cheaper review of all video data collected saving both time and money.
- Using close kin mark recapture (CKMR) on multiple species to provide better estimates of population size and other demographic parameters leading to more sustainable harvests.
- Increasing habitat mapping to develop representative estimates of habitat quantity and quality that could be used to estimate total habitat availability, a key component in the optimal allocation of sampling effort, understanding of species distribution, habitat utilization, and environmental monitoring.
- Using epigenetic aging to improve timeliness and the quantity of age data in comparison to traditional aging methods as well as significant cost savings over traditional aging methods.

Other survey improvement recommendations have the potential to vastly improve Gulf of Mexico fisheries management. The following topics would require dedicated research before implementation.

- Developing a forage fish acoustic survey would provide valuable data on forage fish for ecosystem modelling and EBFM. However, considerable research would need to be done first in order to acoustically identify the species commonly encountered in the Gulf of Mexico. Multiple species school together and possess similar acoustic signatures so accurate estimation of each species' biomass is not currently possible. Despite these complexities, such a survey holds immense value in assessing and managing forage fish populations. Acoustic surveys provide a non-invasive and cost-effective means of estimating abundance, distribution, and behavior of these crucial forage species. Approximately 1-2 years of dedicated research would be needed to acoustically identify the numerous forage fish in the Gulf of Mexico.

- Collecting and analyzing eDNA holds considerable promise for use in oceanic environments. Presently, eDNA is utilized as a non-invasive tool to detect the presence and identify species in marine ecosystems. There is a possibility that eDNA could revolutionize biomass quantification by offering a cost-effective and efficient alternative to traditional fishery independent sampling methods (i.e., trawl, video, or longline surveys). However, interpretation of eDNA data requires careful consideration of factors such as temporal variability, species behavior, and DNA persistence in the environment. Development of the techniques to include eDNA supplementation on existing surveys should be particularly valuable for understanding future changes in distribution or oceanographic changes. Fundamental research and associated resources are needed, although it may be some time before the full utility of eDNA is achieved.

## 12. Conclusion

Historically, fishery independent surveys were oriented at addressing the most pressing issues related to fisheries management, monitoring commercial stocks, preventing overfishing, or the conservation of endangered species. Because no single survey can fulfill all data needs, a portfolio of approaches has been in use in the Gulf of Mexico for decades. Integrating multiple priorities for fishery independent surveys within logistical and budgetary limits can be a challenge. The information generated during this project will aid managers in maximizing data collection with limited fishery independent sampling budgets.

The survey improvement and new survey recommendations in this report represent the culmination of a multiyear effort to optimize fishery independent sampling in the Gulf of Mexico. This report provides the information necessary for managers to improve and further the collection of fishery independent data for stock assessments and ecosystem-based fisheries management. The project identified areas in which data collection is most needed through a data gap analysis and review of the current surveys and how well current fishery independent data met stock assessment objectives, climate change analysis, and ecosystem analysis. Ideally there would be few constraints on the ability to collect data across life history stages, habitat use, and spatial temporal domains. In reality, data collection is constrained by current budgets, personnel, and days at sea.

This project has made recommendations that can improve efficiencies and strengthen the overall effectiveness of the current survey enterprise. While future data needs are unknown, application of these recommendations will improve survey coverage, precision and survey calibration for fish, crustaceans, marine mammals, seabirds, and sea turtles as well as for EBFM. Many of these recommendations are add on recommendations for current surveys. New and emerging technologies, such as CKMR and genetic identification of larval fish, can be incorporated into current surveys and greatly enhance the utility of the data collected. Significant work needs to be done before using acoustics in conjunction with existing surveys. Incorporating acoustics into current trawl surveys will expand the utility of the data especially for species higher in the water column that are encountered, but not adequately sampled currently. Acoustics can also be used to sample reef fish in the turbid waters of the western Gulf of Mexico, but dedicated gear testing and calibration studies need to be completed before a standardized survey can begin. The utility of new technology in stock assessments and fisheries management is expected to grow and any investment in these technologies is expected to return benefits in the future.

All of the recommendations in the report will collect data to fill current data gaps, help manage fisheries, and move towards EBFM. Without significant funding increases, all of the recommendations cannot be implemented. Therefore, managers will need to prioritize implementing the recommendations. As described previously, the Steering Committee ranked their priorities (Table 6) based upon the need that the recommendation addresses, the benefit of implementing the recommendation, and the cost associated with implementing the recommendation. Increasing the number of bottom longline stations in the NOAA Fisheries Bottom Longline Survey and securing long-term funding for the SEAMAP Reef Fish Survey were the top two priorities across both prioritization methodologies.

The Survey Optimization Model allows managers to explore the allocation of resources based on different objective priorities (e.g., commercial fishing, recreational fishing, environmental monitoring). The SOM tool can show the relative distribution of effort and funds based on determination of the objective criteria and species of interest or functional group. This requires a clear statement of the relative importance of multiple objective criteria and species or functional groups needing management. The SOM can be updated and adapted as survey improvement and new survey recommendations are implemented and new data are collected.

Priorities change over time, but the information contained within this report as well as supplementary information should allow managers to address current and future data needs as they see fit and as priorities change. Technology continues to advance. Several technologies show promise for use in fishery independent surveys, but are not currently ready to be fully implemented yet. Managers should stay abreast of these changes and explore new technologies in the future to aid in collection of fishery independent data.

## 13. Acknowledgements

This report would not have been possible without the help and support of the project's Steering Committee, Data and Surveys Subcommittee, Ecosystem-Based Fisheries Management Subcommittee, and Novel Sampling Approaches Subcommittee. The members of these groups are listed in Appendix A. These fisheries management leaders and subject matter experts answered a myriad of questions, provided invaluable insight into the status of current fishery independent surveys and current and future data needs of the Gulf of Mexico, and supplied guidance throughout the project. Funding for this project was provided by NOAA Award NA19NMF4720042.

## Tables

Table 1. Species used in the assessment.

| Common Name | Scientific Name | Group |
|---|---|---|
| Almaco Jack | *Seriola rivoliana* | Amberjack |
| Banded Rudderfish | *Seriola zonata* | Amberjack |
| Greater Amberjack | *Seriola dumerili* | Amberjacks |
| Lesser Amberjack | *Seriola fasciata* | Amberjacks |
| Cobia | *Rachycentron canadum* | CoastalPelagic |
| Florida Pompano | *Trachinotus carolinus* | CoastalPelagic |
| King Mackerel | *Scomberomorus cavalla* | CoastalPelagic |
| Striped Mullet | *Mugil cephalus* | CoastalPelagic |
| Spanish Mackerel | *Scomberomorus maculatus* | CoastalPelagic |
| Wahoo | *Acanthocybium solandri* | CoastalPelagic |
| Cubera Snapper | *Lutjanus cyanopterus* | Deepwater snapper |
| Queen Snapper | *Etelis oculatus* | Deepwater snapper |
| Silk Snapper | *Lutjanus vivanus* | Deepwater snapper |
| Wenchman | *Pristipomoides aquilonaris* | Deepwater snapper |
| Atlantic Croaker | *Micropogonias undulatus* | Groundfish |
| Black Drum | *Pofonias cromis* | Groundfish |
| Gafftopsail catfish | *Bagre marinus* | Groundfish |
| Gulf Butterfish | *Peprilus burti* | Groundfish |
| Gulf Flounder | *Paralichthys albigutta* | Groundfish |
| Red Drum | *Sciaenops ocellatus* | Groundfish |
| Sand Sea Trout | *Cynoscion arenarius* | Groundfish |
| Sheepshead | *Archosargus probatocephalus* | Groundfish |
| Southern Flounder | *Paralichthys lethostigma* | Groundfish |
| Spot | *Leiostomus xanthurus* | Groundfish |
| Spotted Sea Trout | *Cynoscion nebulosus* | Groundfish |
| Black Grouper | *Mycteroperca bonaci* | Grouper_ShallowReef_fish |
| Black Sea Bass | *Centropristis striata* | Grouper_ShallowReef_fish |
| Gag Grouper | *Mycteroperca microlepis* | Grouper_ShallowReef_Fish |
| Atlantic Goliath Grouper | *Epinephelus itajara* | Grouper_ShallowReef_Fish |
| Gray Snapper | *Lutjanus griseus* | Grouper_ShallowReef_Fish |
| Gray Triggerfish | *Balistes capriscus* | Grouper_ShallowReef_Fish |
| Hogfish | *Lachnolaimus maximus* | Grouper_ShallowReef_Fish |
| Lane Snapper | *Lutjanus synagris* | Grouper_ShallowReef_Fish |
| Mutton Snapper | *Lutjanus analis* | Grouper_ShallowReef_Fish |
| Nassau Grouper | *Epinephelus striatus* | Grouper_ShallowReef_Fish |
| Red Grouper | *Epinephelus morio* | Grouper_ShallowReef_Fish |
| Red Hind | *Epinephelus guttatus* | Grouper_ShallowReef_Fish |
| Red Porgy | *Pagrus pagrus* | Grouper_ShallowReef_Fish |
| Red Snapper | *Lutjanus campechanus* | Grouper_ShallowReef_Fish |
| Rock Hind | *Epinephelus adscensionis* | Grouper_ShallowReef_Fish |

| Common Name | Scientific Name | Group |
|---|---|---|
| Scamp | *Mycteroperca phenax* | Grouper_ShallowReef_Fish |
| Vermilion Snapper | *Rhomboplites aurorubens* | Grouper_ShallowReef_Fish |
| White Grunt | *Haemulon plumierii* | Grouper_ShallowReef_Fish |
| Yellowmouth Grouper | *Mycteroperca interstitialis* | Grouper_ShallowReef_Fish |
| Yellowfin Grouper | *Mycteroperca venenosa* | Grouper_ShallowReef_Fish |
| Yellowtail Snapper | *Ocyurus chrysurus* | Grouper_ShallowReef_Fish |
| Blacktip Shark | *Carcharhinus limbatus* | LarageCoastalSharks |
| Bull Shark | *Carcharhinus leucas* | LarageCoastalSharks |
| Lemon Shark | *Negaprion brevirostris* | LarageCoastalSharks |
| Nurse Shark | *Ginglymostoma cirratum* | LarageCoastalSharks |
| Sandbar Shark | *Carcharhinus plumbeus* | LarageCoastalSharks |
| Spinner Shark | *Carcharhinus brevipinna* | LarageCoastalSharks |
| Tiger Shark | *Galeocerdo cuvier* | LarageCoastalSharks |
| Pinfish | *Lagodon rhomboides* | Menhaden_baitfish |
| Bay Anchovy | *Anchoa mitchilli* | Menhaden_baitfish |
| Atlantic Thread Herring | *Opisthonema oglinum* | Menhaden_baitfish |
| Flyingfish | *Exocoetidae* | Menhaden_baitfish |
| Halfbeak | *Hemiramphidae* | Menhaden_baitfish |
| Gulf Killifish | *Fundulus grandis* | Menhaden_baitfish |
| Gulf Menhaden | *Brevoortia patronus* | Menhaden_baitfish |
| Round Herring | *Etrumeus teres* | Menhaden_baitfish |
| Scad | *Decapterus punctatus* | Menhaden_baitfish |
| Scaled Sardine | *Harengula jaguana* | Menhaden_baitfish |
| Silverside | *Menidia beryllina* | Menhaden_baitfish |
| Spanish Sardine | *Sardinella aurita* | Menhaden_baitfish |
| Blue Crab | *Callinectes sapidus* | Shrimp_Crabs |
| Brown Shrimp | *Farfantepenaeus aztecus* | Shrimp_Crabs |
| Pink Shrimp | *Farfantepenaeus duorarum* | Shrimp_Crabs |
| White Shrimp | *Litopenaeus setiferus* | Shrimp_Crabs |
| Blue Runner | *Caranx crysos* | Small Pelagics |
| Bluefish | *Pomatomus saltatrix* | Small Pelagics |
| Bonito | *Sarda sarda* | Small Pelagics |
| Crevalle Jack | *Caranx hippos* | Small Pelagics |
| Dolphinfish | *Coryphaena hippurus* | Small Pelagics |
| Little Tunny | *Euthynnus alletteratus* | Small Pelagics |
| Pompano Dolphinfish | *Coryphaena equiselis* | Small Pelagics |
| Rainbow Runner | *Elagatis bipinnulata* | Small Pelagics |
| Blacknose Shark | *Carcharhinus acronotus* | SmallcoastalSharks |
| Bonnethead | *Sphyrna tiburo* | SmallcoastalSharks |
| Finetooth Shark | *Carcharhinus isodon* | SmallcoastalSharks |
| Atlantic Sharpnose Shark | *Rhizoprionodon terraenovae* | SmallcoastalSharks |

| **Common Name** | **Scientific Name** | **Group** |
|---|---|---|
| Blueline Tilefish | *Caulolatilus microps* | Tilefish_Deepwater_Grouper |
| Speckled Hind | *Epinephelus drummondhayi* | Tilefish_Deepwater_Grouper |
| Golden Tilefish | *Lopholatilus chamaeleonticeps* | Tilefish_Deepwater_Grouper |
| Goldface Tilefish | *Caulolatilus chrysops* | Tilefish_Deepwater_Grouper |
| Misty Grouper | *Epinephelus mystacinus* | Tilefish_Deepwater_Grouper |
| Snowy Grouper | *Hyporthodus niveatus* | Tilefish_Deepwater_Grouper |
| Warsaw Grouper | *Hyporthodus nigritus* | Tilefish_Deepwater_Grouper |
| Yellowedge Grouper | *Hyporthodus flavolimbatus* | Tilefish_Deepwater_Grouper |
| Bigeye Tuna | *Thunnus obesus* | Tuna |
| Blackfin Tuna | *Thunnus atlanticus* | Tuna |
| Atlantic Bluefin Tuna | *Thunnus thynnus* | Tuna |
| Skipjack Tuna | *Katsuwonus pelamis* | Tuna |
| Yellowfin Tuna | *Thunnus albacares* | Tuna |

Table 2. Estimated CV for species of interest caught in the SEAMAP Summer Shrimp/Groundfish Survey if the number of stations is increased from approximately 300 per year to 400 per year.

CV when the number of stations is increased from 300 to 400

| >70% | 70-50% | 50-40% | <40% |
|---|---|---|---|
| Bluefish | Yellow Edge Grouper | Scamp | Red Snapper |
| Snowy Grouper | King Mackerel | Blacknose Shark | Lane Snapper |
| Crevalle Jack | Banded Rudderfish | Greater Amberjack | Red Grouper |
| Cobia | Spanish Mackerel | Scad | Gray Snapper |
| Almaco Jack | Bonnethead | Bigeye Scad | Gray Triggerfish |
| Lesser Amberjack | Gulf Menhaden | | Rough Scad |
| Atlantic Goliath Grouper | Bay Anchovy | | Atlantic Sharpnose Shark |
| Blacktip Shark | Gag grouper | | Vermilion Snapper |
| Dolphinfish | Nurse Shark | | Striped Anchovy |
| Rock Hind | | | Spanish Sardine |
| Sandbar Shark | | | Blue Runner |
| Goldface Tilefish | | | Pink Shrimp |
| Red Hind | | | White Shrimp |
| Blueline Tilefish | | | Brown Shrimp |
| Speckled Hind | | | |
| Tiger Shark | | | |
| Warsaw Grouper | | | |
| Yellowfin Grouper | | | |

Table 3. Estimated CV for species of interest caught in the SEAMAP Fall Shrimp/Groundfish Survey if the number of stations is increased from approximately 300 per year to 400 per year.

| CV when the number of stations is increased from 300 to 400 | | | |
|---|---|---|---|
| >70% | 70-50% | 50-40% | <40% |
| Atlantic Thread Herring | Bay Anchovy | Gulf Menhaden | Spanish Sardine |
| Little Tunny | Gag Grouper | Spanish Mackerel | Scad |
| Warsaw Grouper | Yellowedge Grouper | King Mackerel | Vermilion Snapper |
| Lesser Amberjack | Bluefish | Bigeye Scad | Atlantic Sharpnose Shark |
| Blacktip Shark | Greater Amberjack | | Striped Anchovy |
| Spinner Shark | Blacknose Shark | | Bonnethead |
| Red Hind | Scamp | | Rough Scad |
| Golden Tilefish | Cobia | | Gray Snapper |
| Goldface Tilefish | | | Blue Runner |
| Nurse Shark | | | Gray Triggerfish |
| Yellowmouth Grouper | | | Red Grouper |
| Atlantic Goliath Grouper | | | Lane Snapper |
| Almaco Jack | | | Red Snapper |
| Snowy Grouper | | | Pink Shrimp |
| Crevalle Jack | | | White Shrimp |

Table 4. Estimated CV (by the bootstrap analysis) for species of interest caught in the NOAA Fisheries Bottom Longline Survey if the number of stations is increased from 150 to 300 sets per year.

CV when the number of stations is increased from 150 to 300.

| >70% | 70-50% | 50-40% | <40% |
|---|---|---|---|
| Almaco Jack | Red Drum | Gafftopsail Catfish | Spinner Shark |
| Atlantic Bluefin Tuna | Bonnethead | | Golden Tilefish |
| Lesser Amberjack | Gag Grouper | | Nurse Shark |
| Yellowmouth Grouper | Blueline Tilefish | | Blacktip Shark |
| Yellowfin Tuna | | | Red Grouper |
| Black Grouper | | | Red Snapper |
| Spanish Mackerel | | | Tiger Shark |
| Bonito | | | Sandbar Shark |
| Atlantic Goliath Grouper | | | Blacknose Shark |
| White Grunt | | | Atlantic Sharpnose Shark |
| Red Porgy | | | Yellowedge Grouper |
| Lane Snapper | | | |
| Black Sea Bass | | | |
| Crevalle Jack | | | |
| Bluefish | | | |
| Little Tunny | | | |
| Blackfin Tuna | | | |
| Mutton Snapper | | | |
| Atlantic Croaker | | | |
| Wahoo | | | |
| Queen Snapper | | | |
| Sand Sea Trout | | | |
| Vermilion Snapper | | | |
| Dolphinfish | | | |
| King Mackerel | | | |
| Pinfish | | | |
| Gray Snapper | | | |
| Greater Amberjack | | | |
| Finetooth Shark | | | |
| Scamp | | | |
| Speckled Hind | | | |
| Cobia | | | |
| Snowy Grouper | | | |
| Lemon Shark | | | |
| Warsaw Grouper | | | |

Table 5. Species specific data gaps.

| Species or Species Group | Abundance | Data Gap<br>Age Composition | Life History |
|---|---|---|---|
| Almaco Jack | X | X | X |
| Banded Rudderfish | X | | X |
| Greater Amberjack | | X | X |
| Lesser Amberjack | | X | X |
| Cobia | X | X | X |
| King Mackerel | X | X | X |
| Spanish Mackerel | X | X | X |
| Atlantic Goliath Grouper | X | X | X |
| Black Grouper | X | X | X |
| Gag Grouper | | X | X |
| Gray Snapper | | X | X |
| Gray Triggerfish | | X | |
| Hogfish | | | X |
| Lane Snapper | | X | X |
| Mutton Snapper | X | X | X |
| Nassau Grouper | X | X | X |
| Scamp | | X | X |
| Speckled Hind | X | X | |
| Vermilion Snapper | | X | X |
| Yellowfin Grouper | X | X | X |
| Yellowtail Snapper | X | X | X |
| Red Drum | X | X | |
| Blueline Tilefish | X | | |
| Cubera Snapper | X | X | X |
| Silk Snapper | X | X | X |
| Snowy Grouper | X | | X |
| Tilefish | X | | |
| Yellowedge Grouper | | X | X |
| Warsaw Grouper | X | | |
| Menhaden and Baitfish | X | | |
| Atlantic Bluefin Tuna | X | X | X |
| Yellowfin Tuna | X | | X |
| Brown Shrimp | | X | X |
| Pink Shrimp | | X | X |
| White Shrimp | | X | X |
| Finetooth Shark | | X | |

Table 6. Steering Committee ranking of survey improvement recommendations and new survey recommendations. The table ranks the recommendations based upon the overall priority of their average score. Notice that this ranking may differ from the point allocation method rankings. MMSST = marine mammals, seabirds, and sea turtles

| Recommendation | Sum of Individual Scores | | | | Average Score | | | | Point Allocations | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Overall Priority | Stock Assessment | MMSST | EBFM | Overall Priority | Stock Assessment | MMSST | EBFM | Percent of Total | Total Points |
| R10. Secure long-term funding - SEAMAP Reef Fish Survey | 35 | 34 | 4 | 28 | 7.0 | 6.8 | 0.8 | 5.6 | 0.67 | 101 |
| R19. Increase the number of stations in the Gulf of Mexico in order to reduce CVs - NOAA Fisheries Bottom Longline Survey | 29 | 29 | 4 | 15 | 5.8 | 5.8 | 0.8 | 3.0 | 1.00 | 151 |
| R25. Develop a new Pelagic Fish Survey | 29 | 35 | 4 | 17 | 5.8 | 7.0 | 0.8 | 3.4 | 0.44 | 67 |
| R16. Install net monitoring systems to monitor how the trawl operates throughout the tow - SEAMAP Summer and Fall Shrimp/Groundfish Survey | 27 | 23 | 4 | 17 | 5.4 | 4.6 | 0.8 | 3.4 | 0.21 | 31 |
| R6. Use close-kin mark-recapture on larval Atlantic Bluefin Tuna captured in plankton tows and adult Atlantic Bluefin Tuna to develop a time series of absolute abundance - SEAMAP Spring Plankton Survey | 26 | 29 | 6 | 11 | 5.2 | 5.8 | 1.2 | 2.2 | 0.31 | 47 |
| R7. Evaluate CKMR for other species and then institute it for those species where it is advantageous - SEAMAP Spring Plankton Survey | 26 | 28 | 8 | 14 | 5.2 | 5.6 | 1.6 | 2.8 | 0.34 | 52 |
| R12. Improve timeliness in processing of video data - SEAMAP Reef Fish Survey | 26 | 31 | 4 | 23 | 5.2 | 6.2 | 0.8 | 4.6 | 0.48 | 72 |

| Recommendation | Sum of Individual Scores | | | | Average Score | | | | Point Allocations | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Overall Priority | Stock Assessment | MMSST | EBFM | Overall Priority | Stock Assessment | MMSST | EBFM | Percent of Total | Total Points |
| R11. Enhance survey-specific habitat mapping efforts - SEAMAP Reef Fish Survey | 25 | 24 | 10 | 27 | 5.0 | 4.8 | 2.0 | 5.4 | 0.28 | 43 |
| R21. Develop a Habitat Mapping Survey | 25 | 23 | 19 | 27 | 5.0 | 4.6 | 3.8 | 5.4 | 0.37 | 56 |
| R8. Use genetic methods to identify species that currently cannot be identified to the species level - SEAMAP Spring and Fall Plankton Surveys | 23 | 27 | 6 | 19 | 4.6 | 5.4 | 1.2 | 3.8 | 0.24 | 36 |
| R4. Install an altimeter on the CTD with real time depth capabilities to make sure the CTD is taking environmental data readings as close to the bottom as possible - SEAMAP Summer and Fall Shrimp/Groundfish Survey, SEAMAP Fall Plankton Survey, and SEAMAP Bottom Longline Survey | 22 | 16 | 12 | 21 | 4.4 | 3.2 | 2.4 | 4.4 | 0.20 | 30 |
| R14. Add acoustic echosounders to trawl surveys - SEAMAP Summer and Fall Shrimp/Groundfish Surveys | 22 | 19 | 9 | 20 | 4.4 | 3.8 | 1.8 | 4.0 | 0.11 | 16 |
| R20. Reinstitute this survey to provide data primarily on forage species that inhabit shelf edge habitats for EBFM - NOAA Fisheries Pelagic Acoustic Trawl | 22 | 21 | 6 | 23 | 4.4 | 4.2 | 1.2 | 4.6 | 0.18 | 27 |
| R24. Develop a Marine Mammal, Seabird, and Sea Turtle Survey | 22 | 11 | 36 | 24 | 4.4 | 2.2 | 7.2 | 4.8 | 0.42 | 63 |
| R13. Develop acoustic camera sampling protocols - SEAMAP Reef Fish Survey | 21 | 24 | 3 | 18 | 4.2 | 4.8 | 0.6 | 3.6 | 0.28 | 42 |
| R22. Develop a Forage Fish Acoustics Trawl Survey | 21 | 16 | 17 | 31 | 4.2 | 3.2 | 3.4 | 6.2 | 0.44 | 66 |

| Recommendation | Sum of Individual Scores | | | | Average Score | | | | Point Allocations | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Overall Priority | Stock Assessment | MMSST | EBFM | Overall Priority | Stock Assessment | MMSST | EBFM | Percent of Total | Total Points |
| R2a. Collect samples for improved life history data for age and reproduction | 19 | 25 | 7 | 18 | 3.8 | 5.0 | 1.4 | 3.6 | 0.21 | 31 |
| R2b. Collect samples for improved diet data | 19 | 14 | 6 | 30 | 3.8 | 2.8 | 1.2 | 6.0 | 0.21 | 31 |
| R17. Expand the SEAMAP Bottom Longline Survey to cover the 3-10m survey area off Florida | 19 | 22 | 5 | 18 | 3.8 | 4.4 | 1.0 | 3.6 | 0.17 | 26 |
| R5. Install additional probes on the CTD or collect additional water samples to measure nutrient loads, carbon concentration, dissolved organic carbon, and pH - SEAMAP Bottom Longline Survey, NOAA Fisheries Bottom Longline Survey, SEAMAP Summer and Fall Shrimp/Groundfish Survey, SEAMAP Spring and Fall Plankton Surveys | 18 | 16 | 13 | 25 | 3.6 | 3.2 | 2.6 | 5.0 | 0.17 | 26 |
| R15. Investigate whether piggybacking plankton samples during the SEAMAP Summer and Fall Shrimp/Groundfish Surveys would provide better plankton information for managed species | 18 | 18 | 4 | 12 | 3.6 | 3.6 | 0.8 | 2.4 | 0.13 | 19 |
| R18. Expand the survey out to 20 m Gulf wide to allow additional data collection on Red Drum and also have more overlap with the NOAA Fisheries Bottom Longline Survey - SEAMAP Bottom Longline Survey | 18 | 18 | 4 | 12 | 3.6 | 3.6 | 0.8 | 2.4 | 0.23 | 34 |
| R23. Develop synoptic life history surveys | 18 | 21 | 4 | 16 | 3.6 | 4.2 | 0.8 | 3.2 | 0.03 | 5 |

| Recommendation | Sum of Individual Scores | | | | Average Score | | | | Point Allocations | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Overall Priority | Stock Assessment | MMSST | EBFM | Overall Priority | Stock Assessment | MMSST | EBFM | Percent of Total | Total Points |
| R1. Take samples for epigenetic aging - SEAMAP Summer and Fall Shrimp/Groundfish Surveys, SEAMAP Bottom Longline Survey, NOAA Fisheries Bottom Longline Survey | 17 | 26 | 8 | 11 | 3.4 | 5.2 | 1.6 | 2.2 | 0.19 | 28 |
| R9. Reinstitute April portion of the SEAMAP Spring Plankton Survey | 16 | 18 | 4 | 14 | 3.2 | 3.6 | 0.8 | 2.8 | 0.13 | 19 |
| R3. Take benthic samples that would allow analysis of sediment characterization as well as meiofauna and macrofauna assessments in relation to fish density - SEAMAP Summer and Fall Shrimp/Groundfish Surveys, SEAMAP Bottom Longline, Surveys, NOAA Fisheries Bottom Longline Survey, and NOAA Fisheries Pelagic Acoustic Trawl Survey | 12 | 6 | 5 | 19 | 2.4 | 1.2 | 1.0 | 3.8 | 0.08 | 12 |

Table 7. A comparison of average size (FL with the exception of shrimp that are TL) for the most commonly caught species of interest from the SEAMAP Summer and Fall Shrimp/Groundfish Survey. Sample size represents the number of individuals measured and not the total number caught.

| | | Average Fork Length (mm) | | Sample Size | |
|---|---|---|---|---|---|
| Common Name | Scientific Name | Summer Trawl | Fall Trawl | Summer Trawl | Fall Trawl |
| Atlantic Croaker | *Micropogonias undulatus* | 155 | 166 | 23,396 | 32,359 |
| Atlantic Sharpnose Shark | *Rhizoprionodon terraenovae* | 484 | 608 | 437 | 234 |
| Atlantic Thread Herring | *Opisthonema oglinum* | 172 | 146 | 2,081 | 1,592 |
| Bay Anchovy | *Anchoa mitchilli* | 59 | 49 | 1,167 | 581 |
| Blue Runner | *Caranx crysos* | 170 | 153 | 300 | 2,176 |
| Bonnethead | *Sphyrna tiburo* | 846 | 487 | 103 | 308 |
| Brown Shrimp | *Farfantepenaeus aztecus* | 128 | 139 | 192,470 | 28,911 |
| Gafftopsail Catfish | *Bagre marinus* | 142 | 174 | 208 | 979 |
| Greater Amberjack | *Seriola dumerili* | 195 | 290 | 177 | 38 |
| Gray Snapper | *Lutjanus griseus* | 268 | 264 | 1,395 | 805 |
| Gray Triggerfish | *Balistes capriscus* | 175 | 147 | 992 | 1,711 |
| Gulf Butterfish | *Peprilus burti* | 116 | 138 | 17,876 | 10,804 |
| Gulf Flounder | *Paralichthys albigutta* | 308 | 310 | 326 | 249 |
| Gulf Menhaden | *Brevoortia patronus* | 145 | 167 | 809 | 864 |
| King Mackerel | *Scomberomorus cavalla* | 174 | 265 | 260 | 168 |
| Lane Snapper | *Lutjanus synagris* | 202 | 178 | 10,589 | 8,191 |
| Pinfish | *Lagodon rhomboides* | 151 | 155 | 11,330 | 9,266 |
| Pink Shrimp | *Farfantepenaeus duorarum* | 134 | 142 | 24,998 | 5,334 |
| Red Grouper | *Epinephelus morio* | 313 | 321 | 1,008 | 502 |
| Red Porgy | *Pagrus pagrus* | 140 | 165 | 1,642 | 931 |
| Red Snapper | *Lutjanus campechanus* | 188 | 127 | 8,414 | 19,482 |
| Round Herring | *Etrumeus teres* | 101 | 133 | 558 | 179 |
| Sand Seatrout | *Cynoscion arenarius* | 160 | 207 | 8,041 | 5,608 |
| Scad | *Decapterus punctatus* | 127 | 119 | 2,761 | 2,270 |
| Scaled Sardine | *Harengula jaguana* | 138 | 136 | 3,524 | 3,309 |
| Southern Flounder | *Paralichthys lethostigma* | 288 | 305 | 274 | 277 |
| Spanish Mackerel | *Scomberomorus maculatus* | 191 | 276 | 295 | 202 |
| Spanish Sardine | *Sardinella aurita* | 151 | 143 | 1,616 | 1,087 |
| Spot | *Leiostomus xanthurus* | 165 | 178 | 8,529 | 14,417 |
| Vermilion Snapper | *Rhomboplites aurorubens* | 174 | 161 | 5,001 | 3,746 |
| Wenchman | *Pristipomoides aquilonaris* | 131 | 125 | 8,863 | 4,945 |
| White Grunt | *Haemulon plumierii* | 210 | 211 | 2,797 | 1,698 |
| White Shrimp | *Litopenaeus setiferus* | 175 | 164 | 24,018 | 7,743 |
| Yellowtail Snapper | *Ocyurus chrysurus* | 192 | 178 | 247 | 114 |

Table 8. Species of interest percent positive occurrence in the SEAMAP Spring and Fall Plankton Surveys.

| | Percent Positive Occurrence | | | |
|---|---|---|---|---|
| Species | Spring Plankton Bongo | Spring Plankton Neuston | Fall Plankton Bongo | Fall Plankton Neuston |
| Atlantic Bluefin Tuna | 13.5% | 11.8% | NA | NA |
| Cobia | 0.7% | 0.9% | 0.5% | 3.1% |
| King Mackerel | 1.1% | 1.3% | 26.0% | 14.7% |
| Spanish Mackerel | 0.5% | 1.1% | 14.8% | 10.0% |
| Gray Snapper | NA | NA | 3.6% | 1.6% |
| Red Snapper | NA | NA | 12.2% | 8.7% |
| Triggerfish | 0.3% | 1.4% | 3.0% | 12.9% |
| Little Tunny | 6.9% | 4.5% | 30.5% | 16.9% |
| Bonito | NA | 0.0% | 0.1% | NA |
| Dolphinfish | 4.8% | 27.2% | 1.3% | 10.7% |
| Pompano Dolphinfish | 0.4% | 10.1% | 0.1% | 2.0% |
| Red Drum | NA | 0.0% | 16.4% | 11.0% |

Table 9. An initial portfolio of scenarios that capture the range of uncertainty and/or plausible options for objective weights.

| | Objective Weight | | | | |
|---|---|---|---|---|---|
| Scenario | Commercial | Recreational | Ecosystem | Management/Assessment Importance | Uniqueness |
| A | 1 | 1 | 1 | 1 | 1 |
| B | 1 | 0 | 0 | 0 | 0 |
| C | 0 | 1 | 0 | 0 | 0 |
| D | 0 | 0 | 1 | 0 | 0 |
| E | 0 | 0 | 0 | 1 | 0 |
| F | 0 | 0 | 0 | 0 | 1 |

# Figures

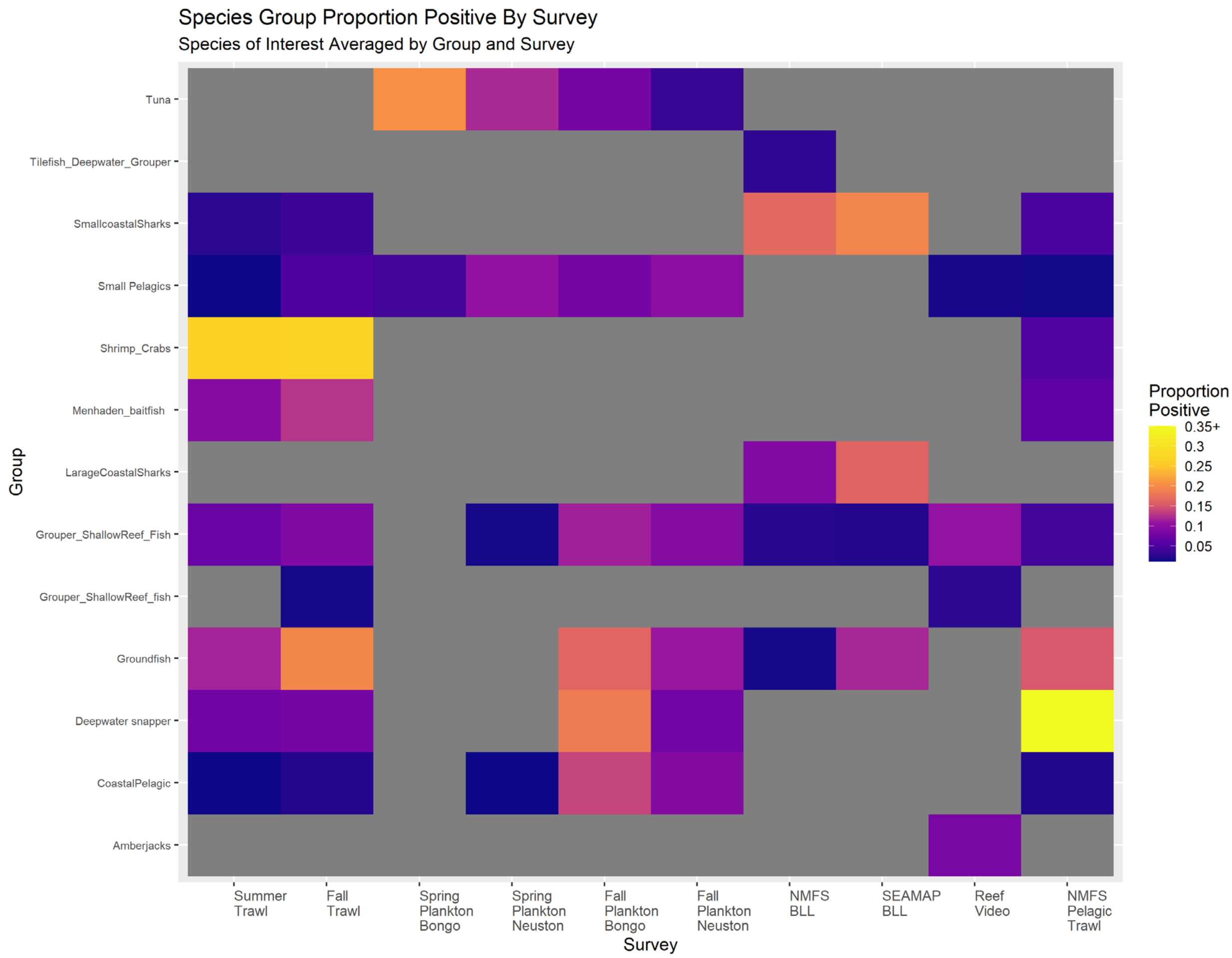


Figure 1. Species of Interest heat maps which show the range of percent positive occurrence for functional groups based on survey (methodology in the case of the plankton tows).

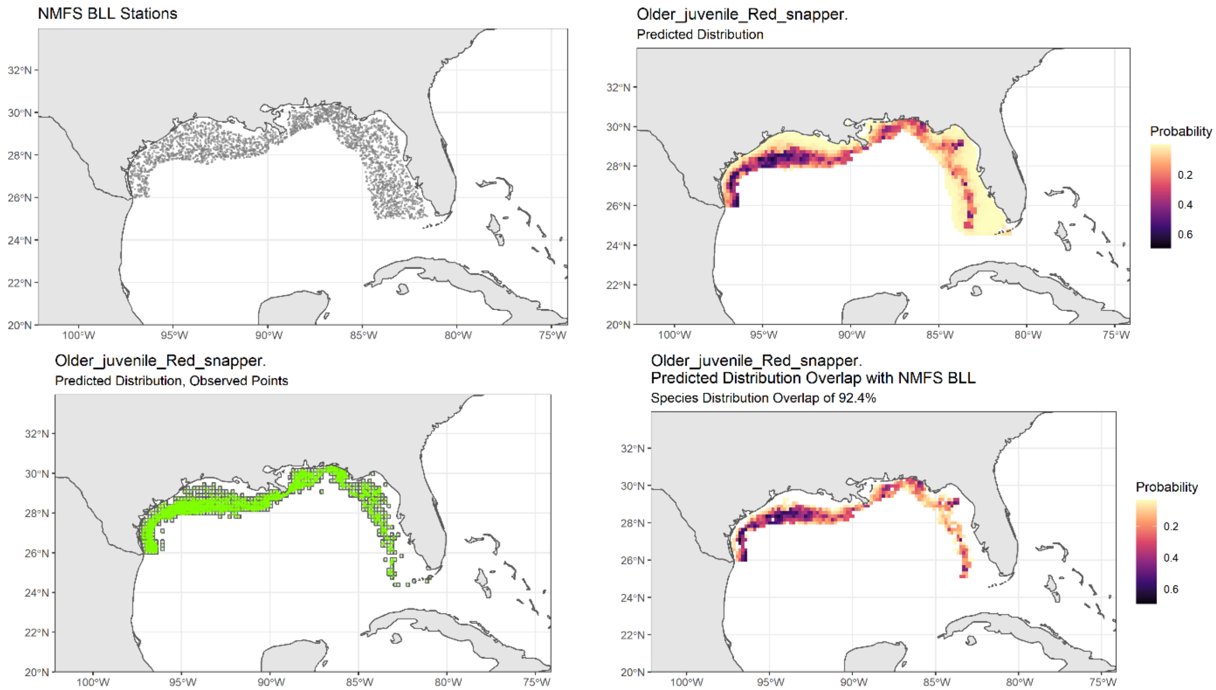


Figure 2. Example of the analysis of the overlap between the NOAA Fisheries Bottom Longline Survey and the predicted distribution of Red Snapper.

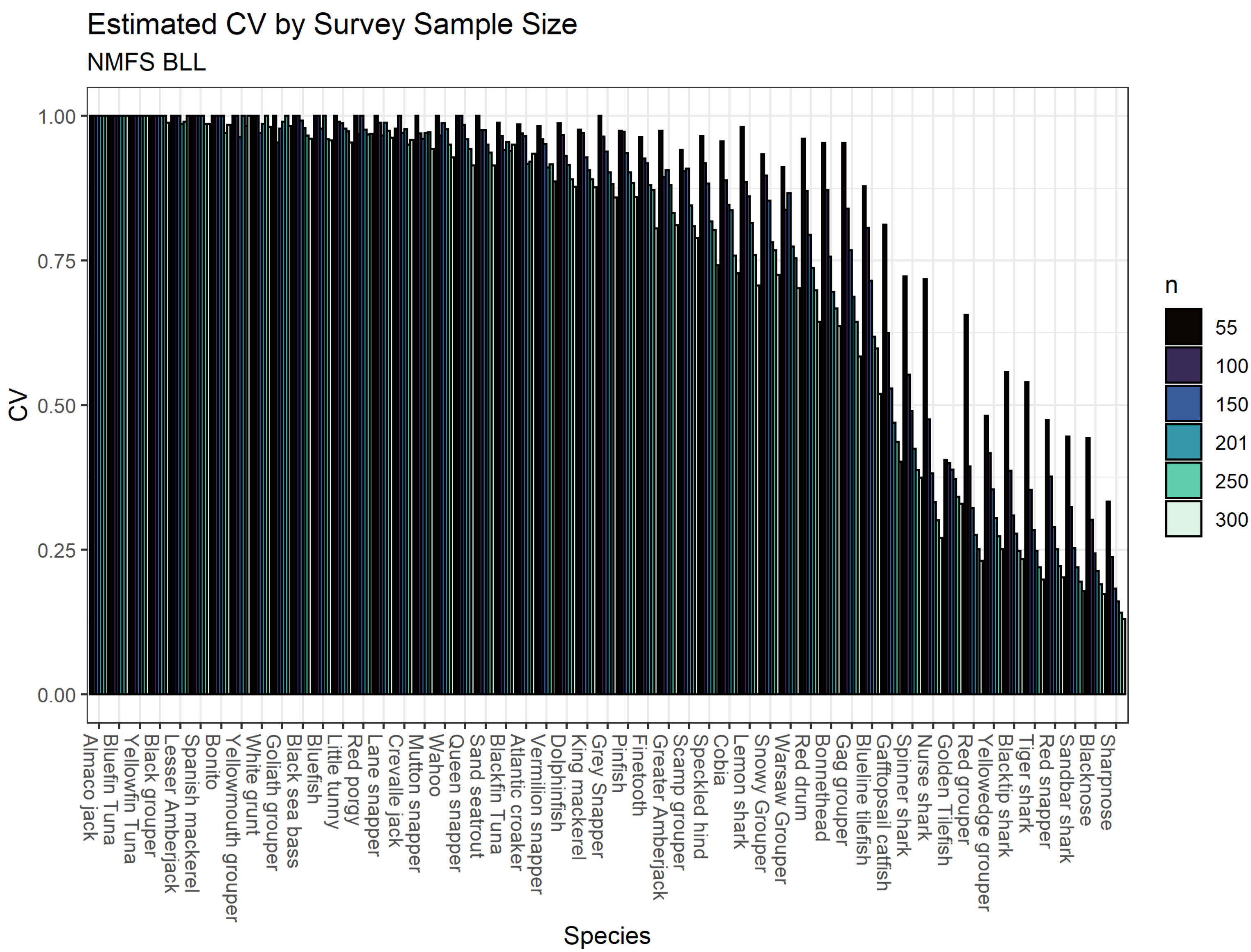


Figure 3. Estimated CV by sample size for the NOAA Fisheries Bottom Longline Survey. The median number of stations from 2016-2019 was 150.

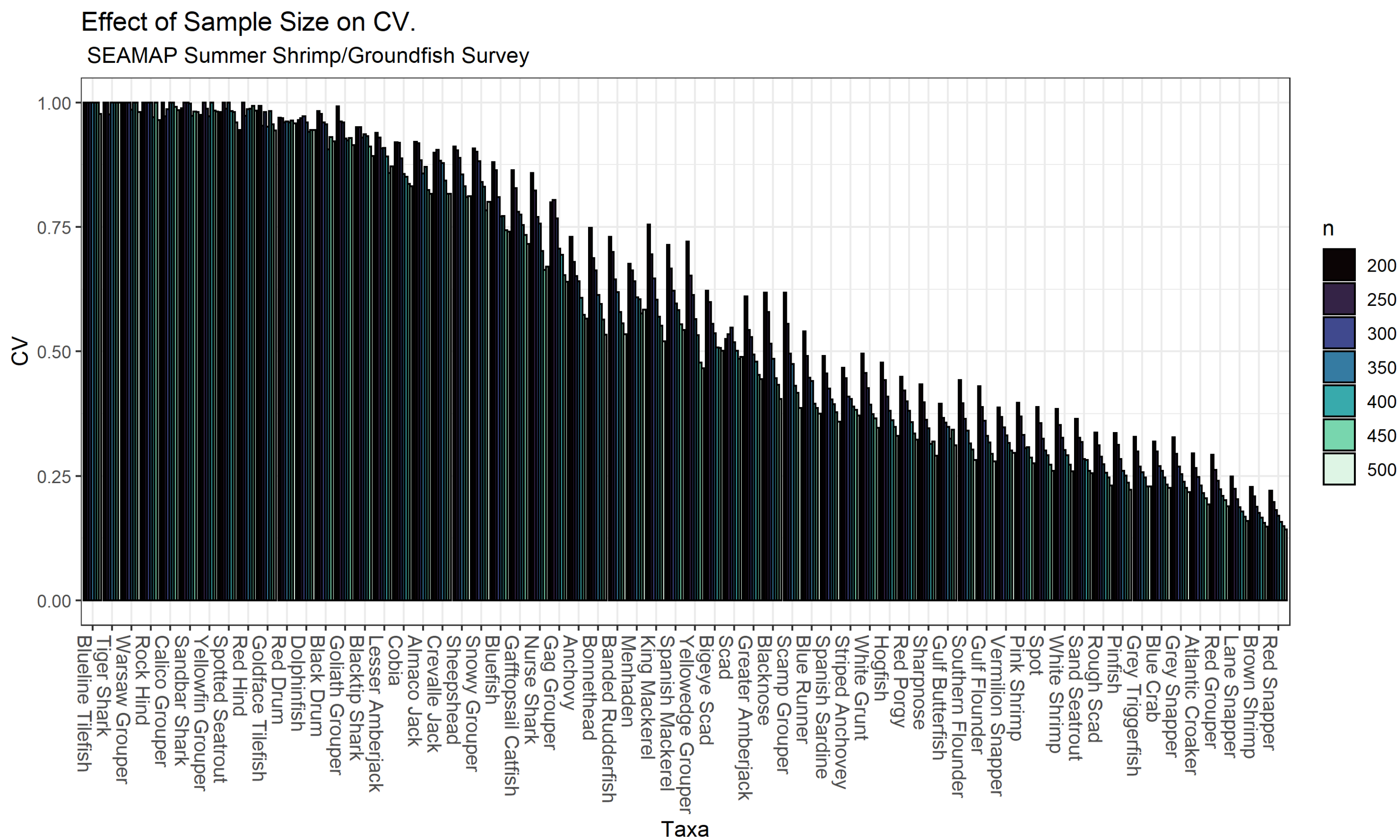


Figure 4. Estimated CV by sample size for the SEAMAP Summer Shrimp/Groundfish Survey. The median number of stations from 2016-2019 was 315.

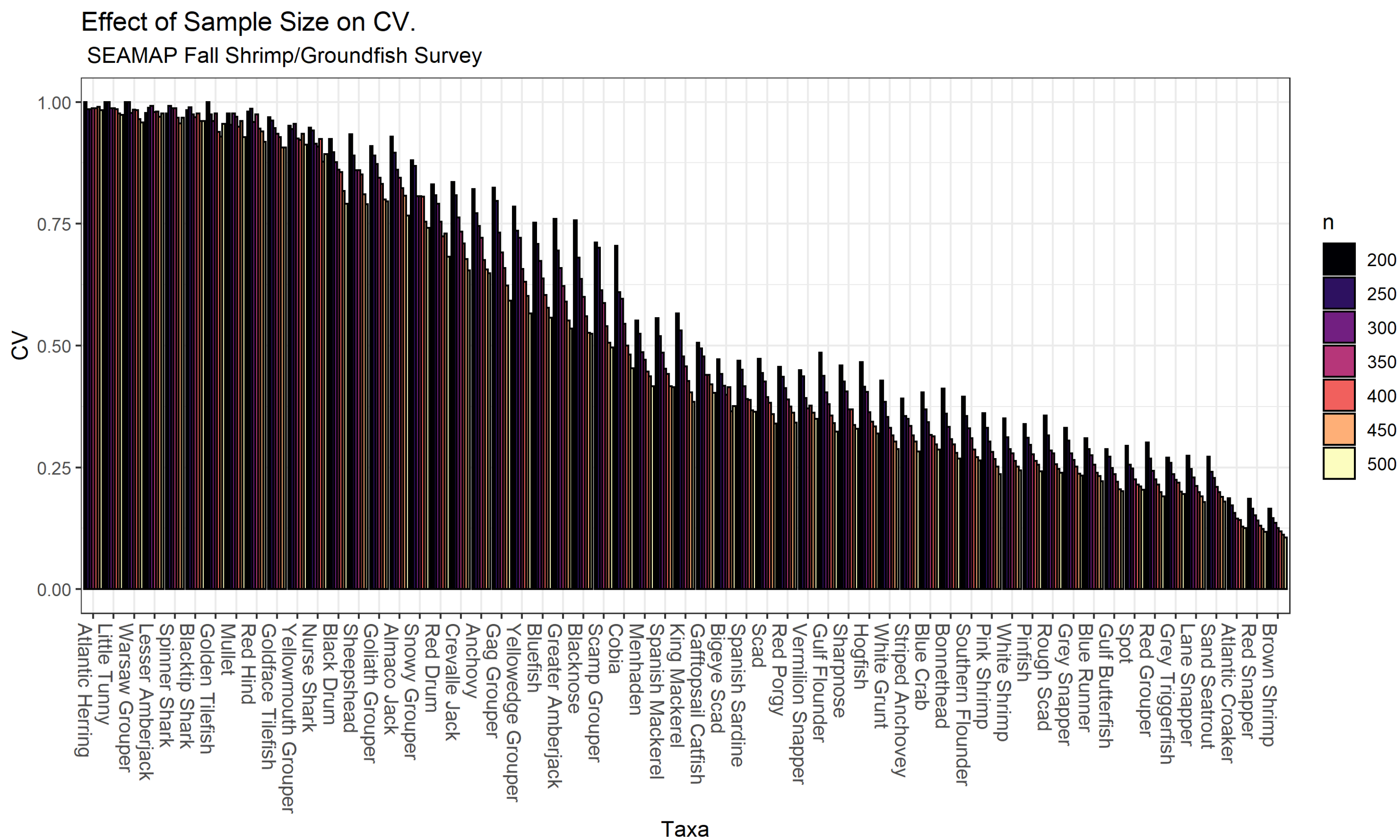


Figure 5. Estimated CV by sample size for the SEAMAP Fall Shrimp/Groundfish Survey. The median number of stations from 2016-2019 was 275.

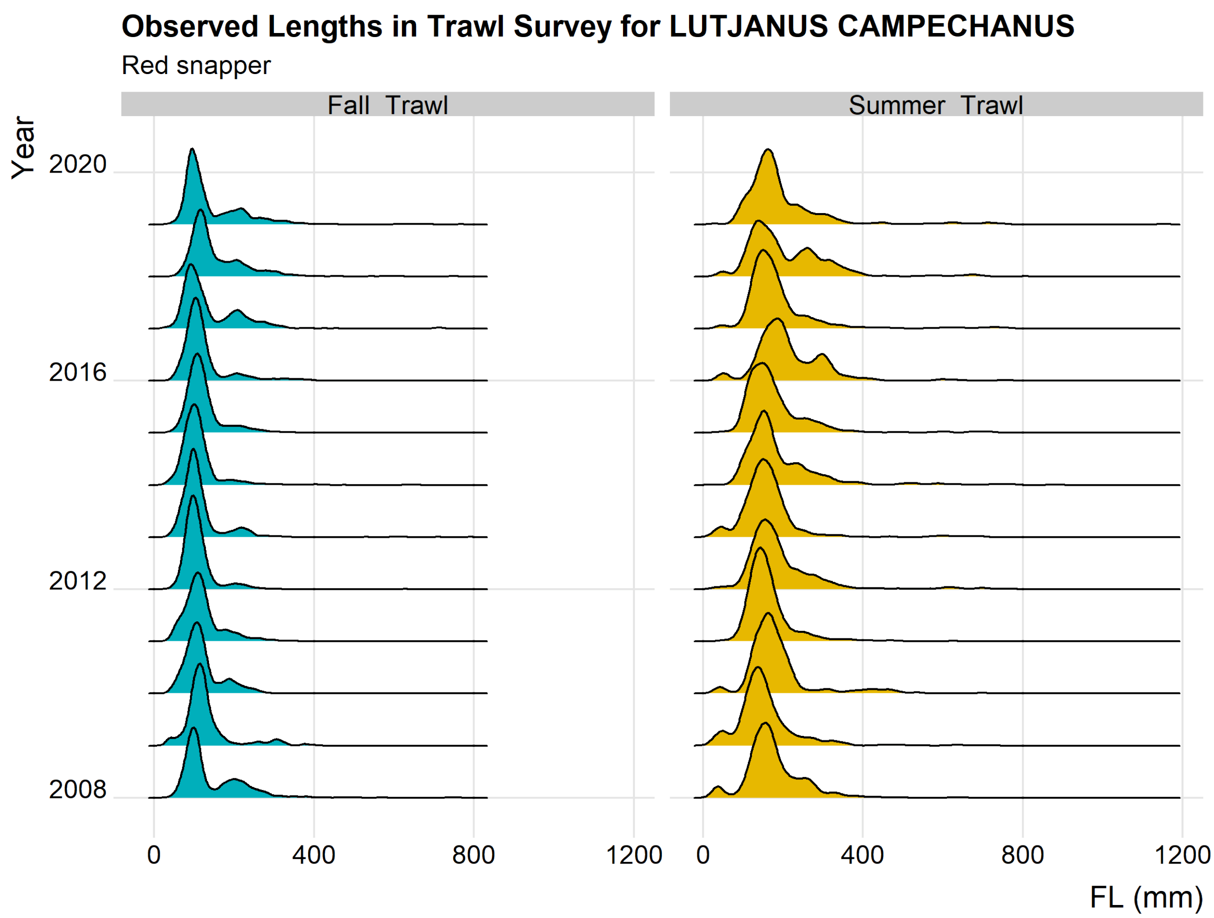


Figure 6. Length composition by year for Red Snapper caught in the SEAMAP Summer and Fall Shrimp/Groundfish Surveys.

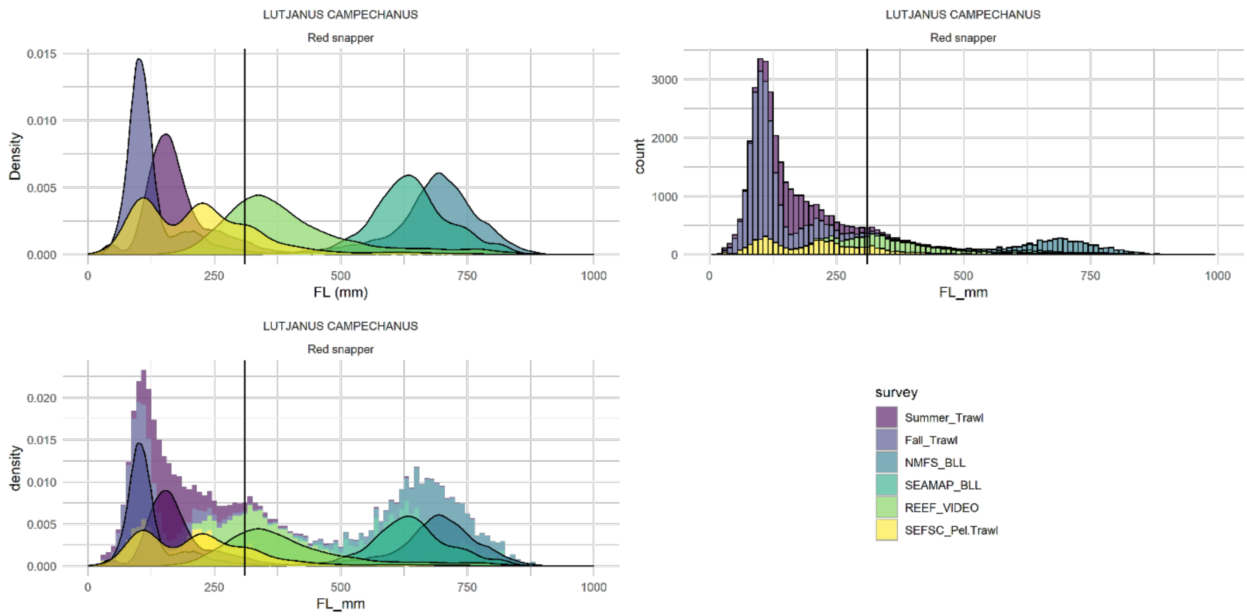


Figure 7. Comparison of the length composition for Red Snapper caught by survey. The vertical black line indicates the estimated length at 50% maturity.

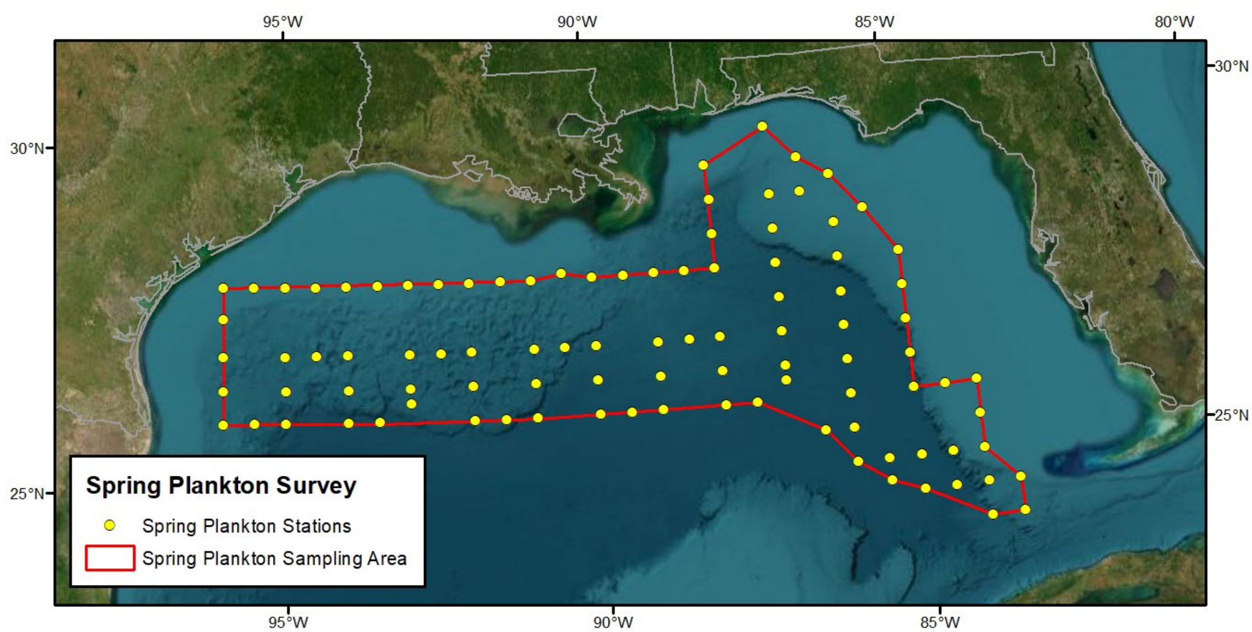


Figure 8. The SEAMAP Spring Plankton Survey sampling area and the 97 standard stations.

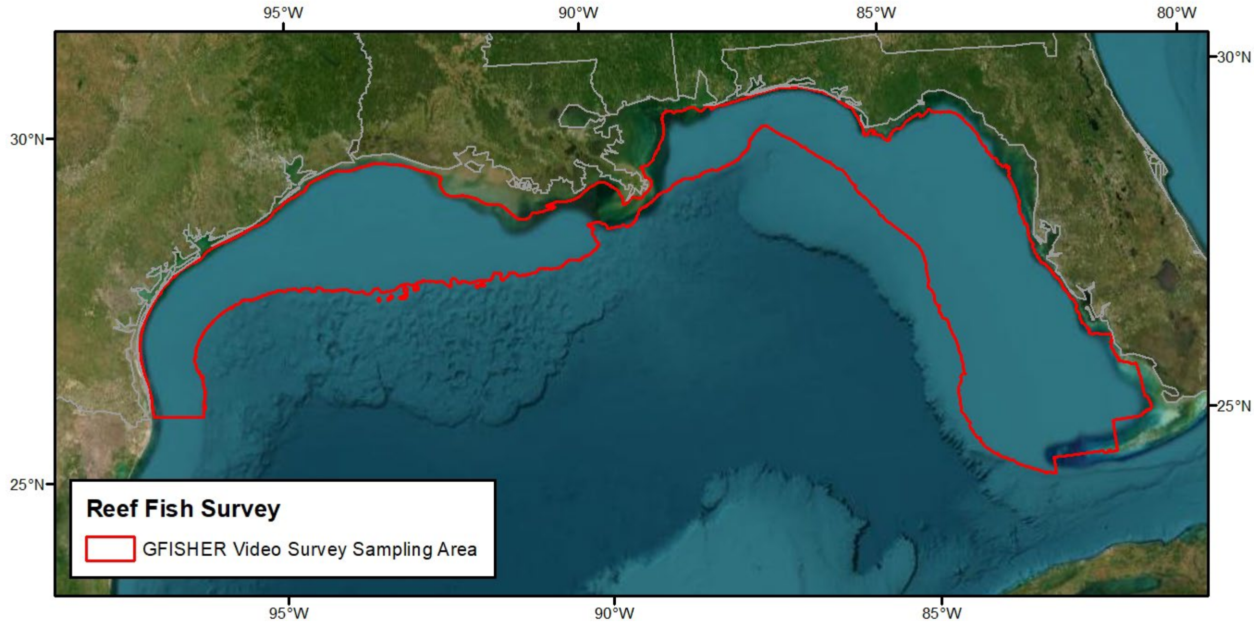

Figure 9. The SEAMAP Reef Fish Survey sampling area encompassing waters from 10 – 180 m in depth.

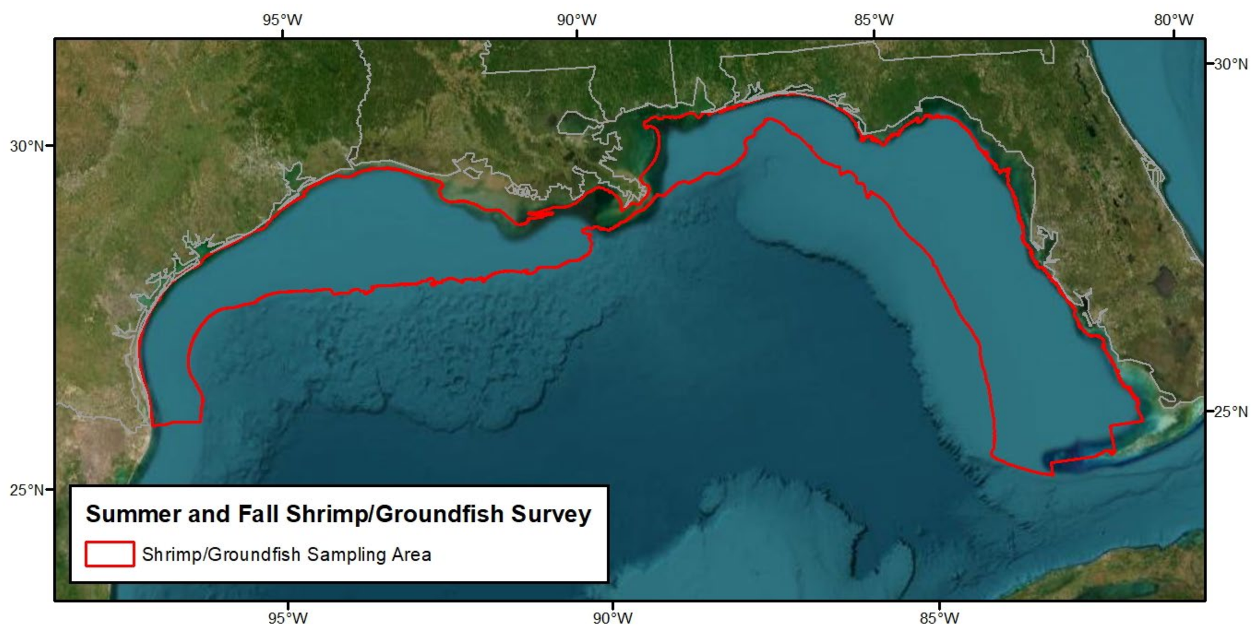

Figure 10. The SEAMAP Summer and Fall Shrimp/Groundfish Surveys sampling area encompassing waters from 9 – 110 m in depth.

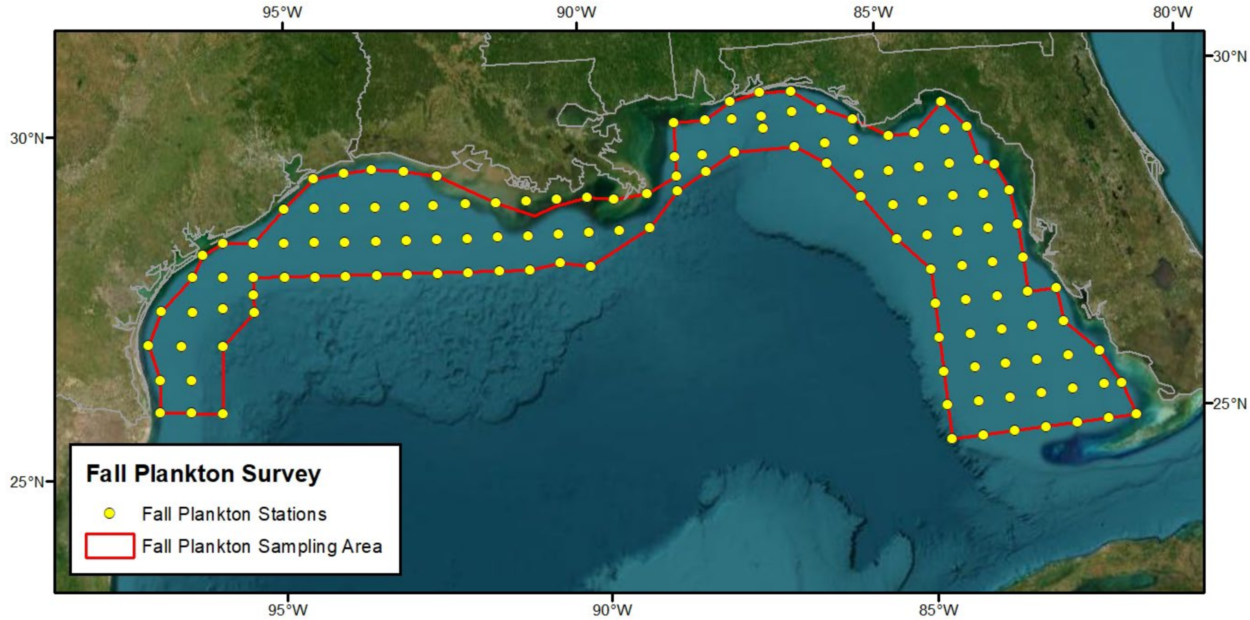


Figure 11.  The SEAMAP Fall Plankton Survey sampling area and the 138 standard stations.

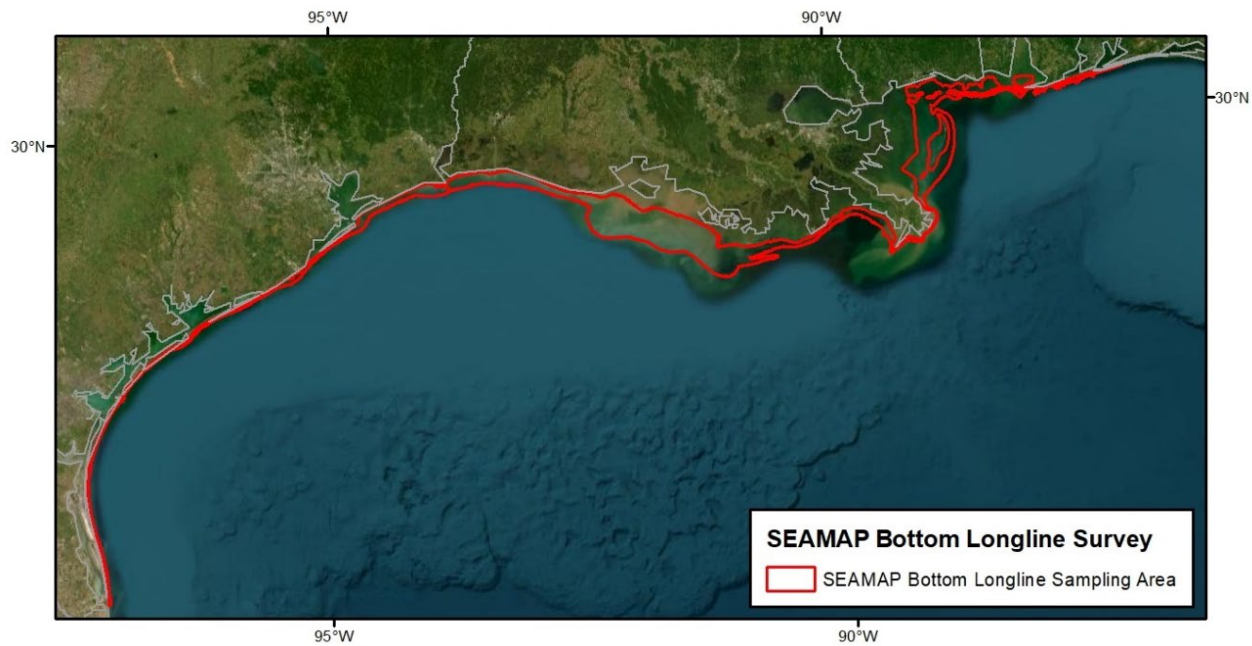


Figure 12.  The SEAMAP Bottom Longline Survey sampling area encompassing waters from 3 – 10 m in depth.

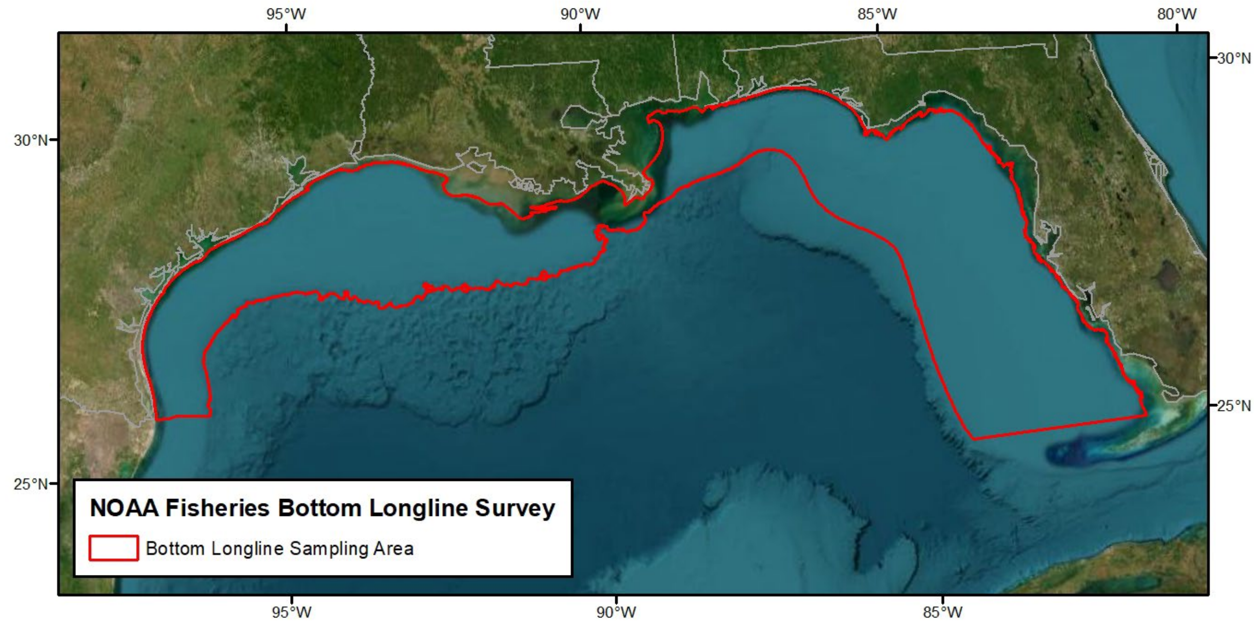


Figure 13. The NOAA Fisheries Bottom Longline Survey sampling area encompassing waters from 9 – 366 m in depth.

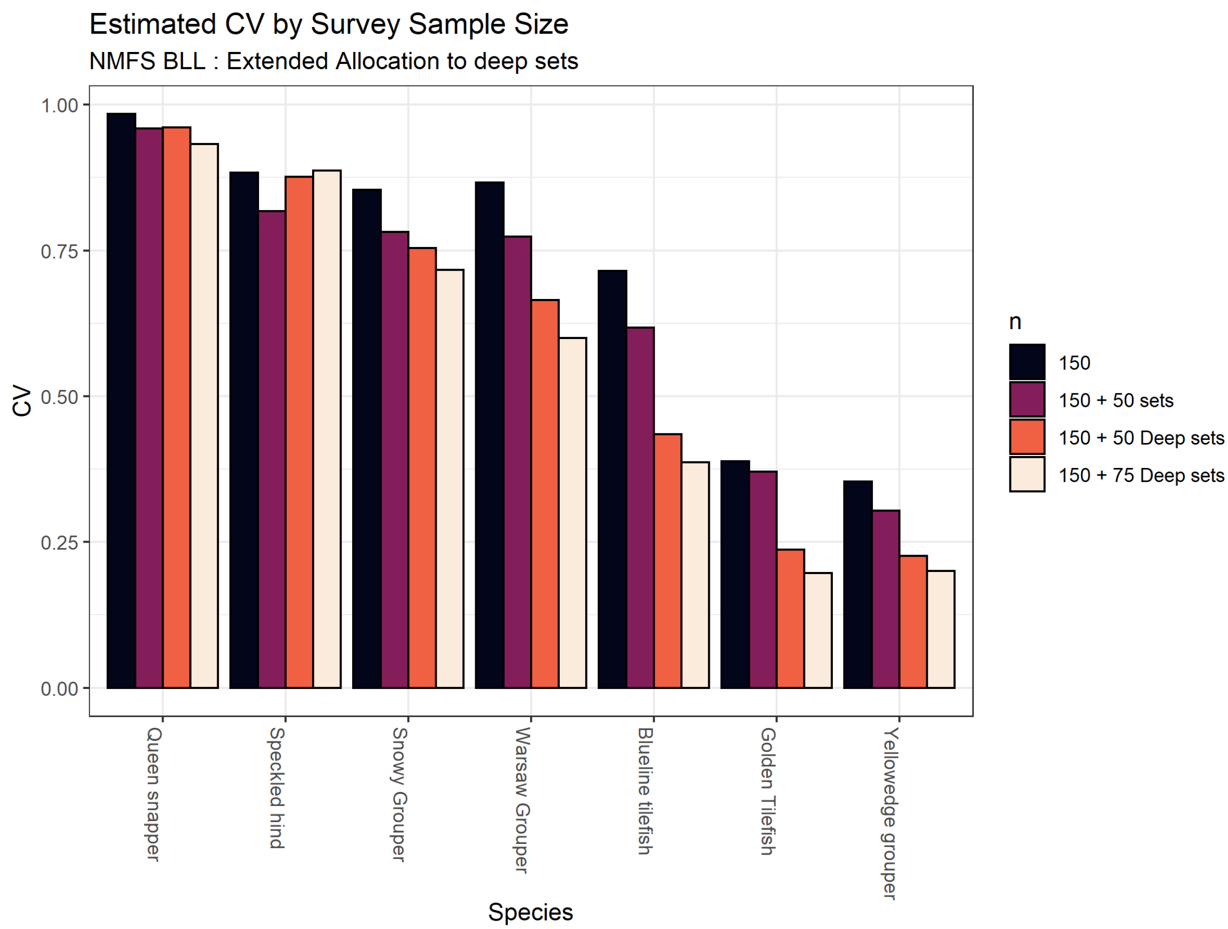


Figure 14. Estimated CV by sample size for the NOAA Fisheries Bottom Longline Survey if additional stations were added to the 183 – 366 m depth strata.

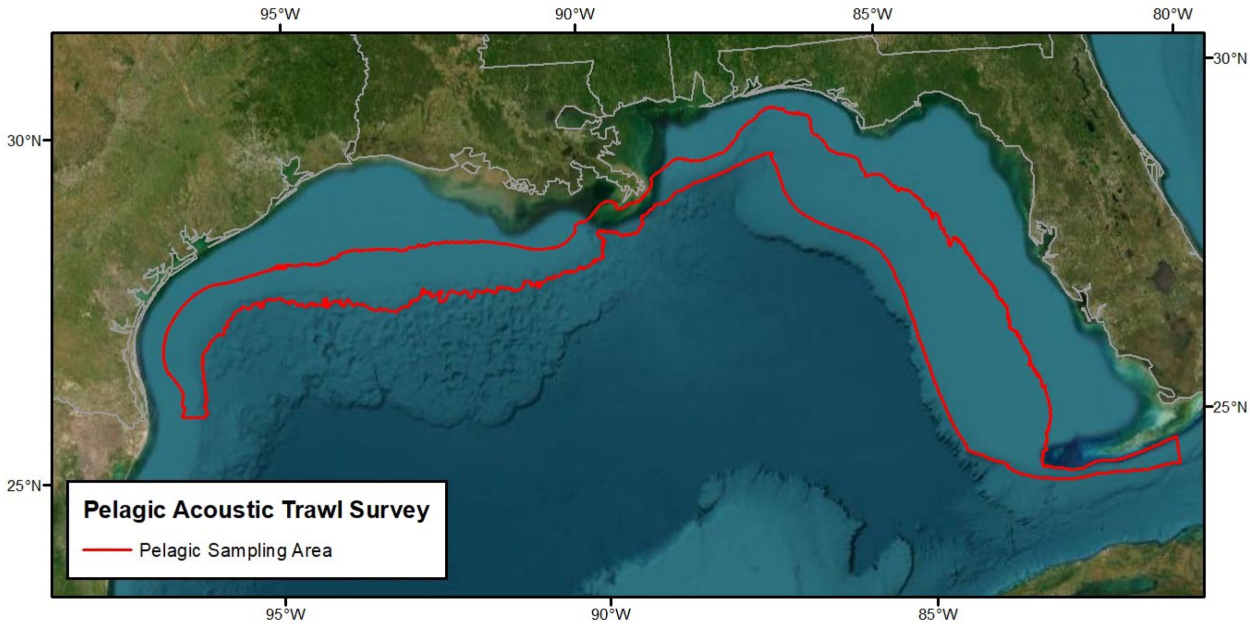


Figure 15. The NOAA Fisheries Pelagic Acoustic Trawl Survey sampling area encompassing waters from 50 – 500 m in depth.

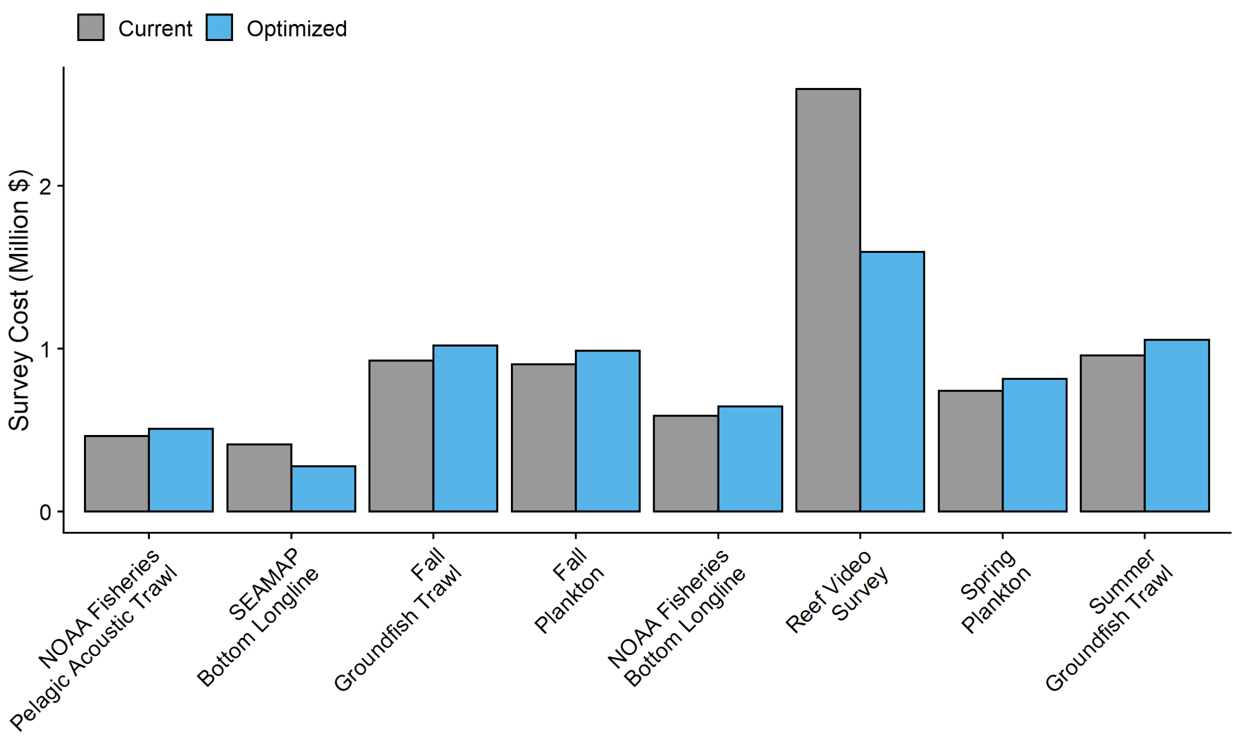


Figure 16. Current and optimized survey costs based on the SOM and equal weights for commercial value, recreational value, ecosystem value, management importance, and uniqueness.

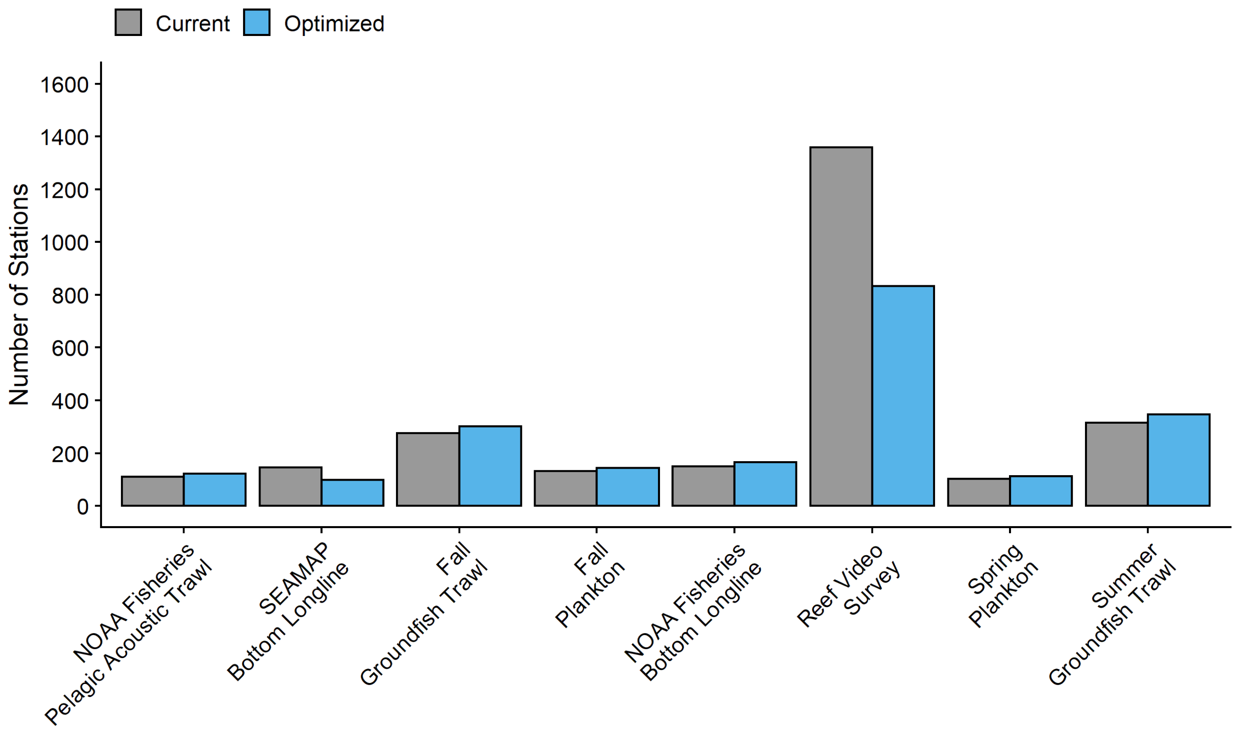


Figure 17. Current and optimized number of stations for the surveys based on the SOM and equal weights for commercial value, recreational value, ecosystem value, management importance, and uniqueness.

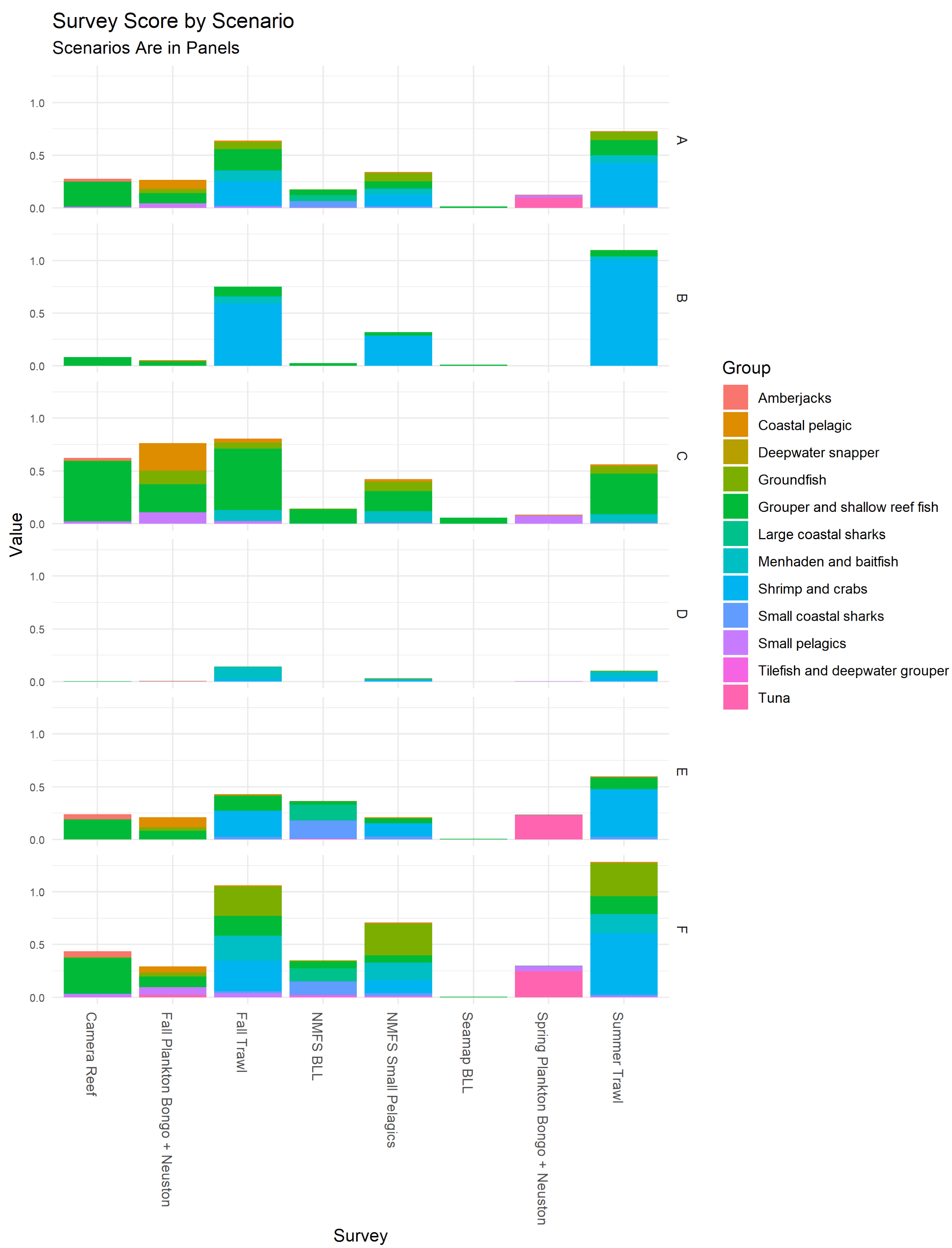


Figure 18. Survey values shown for six scenarios resulting from various objective weights (shown in Table 9).

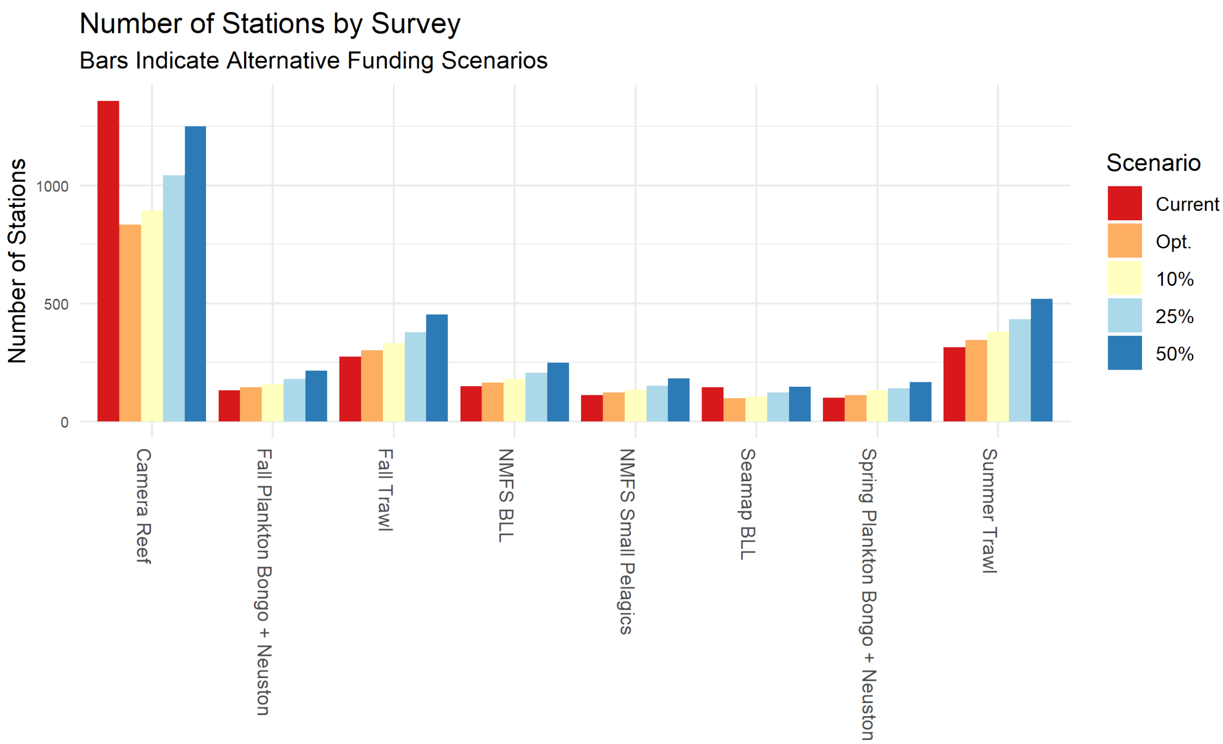


Figure 19. Current and optimal sample sizes for the surveys under equal management criteria weighting with current cost and logistical constraints, along with a 10%, 25% and 50% funding increase.

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# Appendix A. Steering Committee and Subcommittee Membership

Steering Committee

| | |
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| Kevin Boswell | Florida International University |
| Shannon Calay | NOAA Fisheries |
| David Chagaris | University of Florida |
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| Eric Hoffmayer | NOAA Fisheries |
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| Mandy Karnauskas | NOAA Fisheries |
| Todd Kellison | NOAA Fisheries |
| Rick Methot | NOAA Fisheries |
| Keith Mullin | NOAA Fisheries |
| Ted Switzer | Florida Wildlife Research Institute |
| John Walter | NOAA Fisheries |

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| Eric Hoffmayer | NOAA Fisheries |
| Walter Ingram | NOAA Fisheries |
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