NOAA FISHERIES

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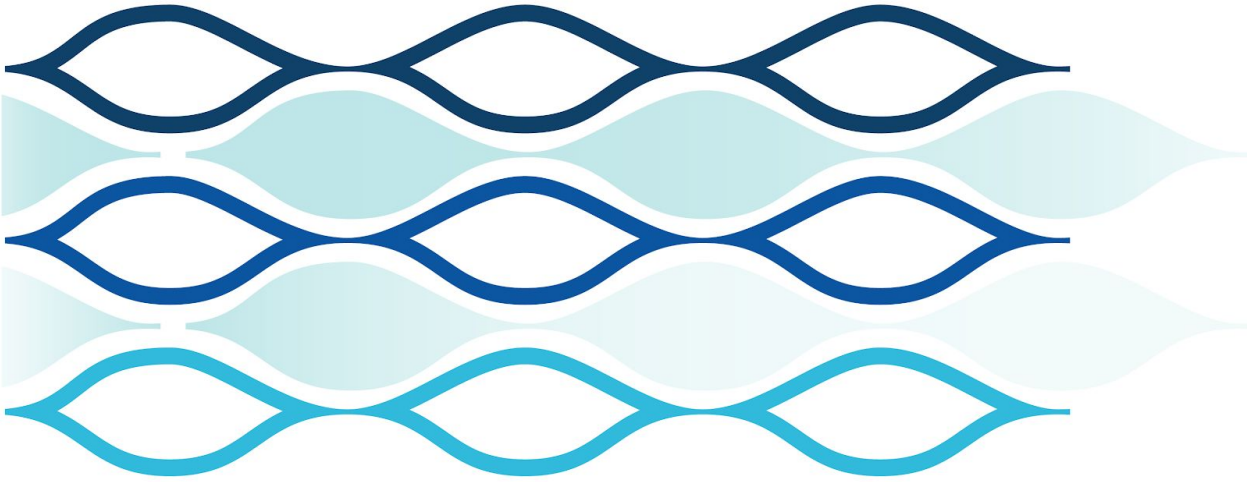
Recommended Use of the Current Gulf of Mexico Surveys of Marine Recreational Fishing in Stock Assessments



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Executive Summary

Background: The NOAA Fisheries Marine Recreational Information Program (MRIP) works closely with the Gulf States Marine Fisheries Commission, Mississippi Department of Marine Resources, Alabama Department of Conservation and Natural Resources, Florida Fish and Wildlife Conservation Commission, and Louisiana Department of Wildlife and Fisheries to improve monitoring of recreational catches of red snapper and other species in the Gulf of Mexico. The various survey designs conducted by the MRIP partners are classified as "general" or "supplemental" based on how they are used. The general surveys conducted in each state are designed to provide accurate annual statistical estimates of the catch of all finfish species for one or more specific modes of fishing (shore, private boat, charter boat, and/or headboat), including both catch that is harvested and catch that is released alive. The MRIP general survey approach for charter boat fishing combines the For-Hire Survey (FHS) of charter boat fishing effort with the Access Point Angler Intercept Survey (APAIS) of charter boat angler catch rates. The MRIP general survey approach for shore and private/rental boat fishing combines the Fishing Effort Survey (FES) of fishing effort with the APAIS. In Louisiana, LA Creel provides the general surveys of charter boat and private angler fishing. The supplemental surveys conducted in Mississippi (Tails n' Scales, or MS-TNS) and Alabama (Snapper Check, or AL-SC) are specialized to provide more precise and timely statistical estimates of private boat and charter boat red snapper landings during the short federal and state seasons. The supplemental surveys conducted in Florida (Gulf Reef Fish Survey, or FL-GRFS) are specialized to provide more precise private boat catch statistics for red snapper and other reef fish species. The intent is to use data from both the specialized and general surveys to produce one set of catch estimates for the species, catch types, and fishing modes covered by both.

Understanding Differences: Key Survey Design Assumptions and Potential for Bias: Through the MRIP peer review process, NOAA Fisheries has certified the various state survey designs as statistically valid with some critical assumptions. However, the validity of some of these assumptions has not been fully established and the resulting estimates may be biased. Accordingly, different certified survey designs, with different critical assumptions, can produce consistently different catch estimates.

It is difficult to know which surveys provide the best estimates of catch because the true catch is unknown. Therefore, the MRIP partners are working together to evaluate the critical assumptions made by each survey and the potential for bias due to what are called "nonsampling errors." For example, all of the on-site access point intercept surveys described in this paper fail to sample fishing trips that end at private access sites and assume that such "private access trips" are similar on average to the sampled "public access trips." If this key assumption cannot be validated, there is potential for estimates to be biased due to a coverage error in the on-site survey. This paper describes these and other kinds of nonsampling errors that may exist in each of the current surveys.

Choice of Recreational Statistics for Stock Assessments and Management: Given that some of the different survey designs currently used in the Gulf States have produced very different estimates in years when two or more surveys were conducted side by side, questions have arisen about how the data should be used. For stock assessments, it is important for the catch estimates to be measured in the same ''currency'' through time and corrected for any known biases; otherwise, the estimates of stock status will be biased. If the survey design used in a given state has been changed at any point during the historical time series, and the new survey

design produces catch estimates consistently higher or lower than the survey design it replaced, then a calibration will be needed to convert estimates throughout the time series into one common currency. Likewise, if the survey designs used in different states are not identical, then the catch estimates may not be comparable among states and multiple state-specific calibrations would be needed. If a different survey is used for quota monitoring (e.g., a specialized state survey such as AL-SC) than is used in the assessment, then it will also be necessary to convert the catch advice from the assessment into the currency used for quota monitoring in any given year.

At least four different options have been proposed for the assessment and management of Gulf fish:

- **Option 1:** Use a time series of catch estimates fully calibrated to ensure comparability across years and among states.
    - Option 1a: Use the current fully calibrated MRIP time series (1981-2017) of catch estimates for MS, AL, and FL for charter boat fishing and private boat fishing. This approach employs the peer-reviewed FES mail survey for effort estimates and adjusts past Coastal Household Telephone Survey (CHTS) estimates to account for temporal changes in telephone usage. Convert LA Creel estimates to the MRIP currency using simple ratio calibrations based on side-by-side comparisons of LA Creel and MRIP surveys in 2015-2017. Use these for assessment and management purposes.
    - Option 1b: Use the common currency in Option 1a for assessment purposes, but for management purposes convert assessment-based annual catch limits (ACLs) into the currencies used by the alternative general survey (LA Creel in LA) and supplemental surveys (Tails n' Scales in MS, Snapper Check in AL, or Gulf Reef Fish Survey in FL). An ACL set for a particular stock such as Gulf red snapper could be partitioned among states in support of regional management. This approach will not be available until early 2020, when peer-reviewed calibration methods are expected to be available for each state.
    - Option 1c: Integrate the supplemental and general surveys in MS, AL, and FL to produce one set of estimates for species covered by both. Use this series for assessment purposes. For management, either use the integrated series, or convert the assessment-based ACLs into the currencies used by the alternative general survey (LA Creel in LA) and supplemental surveys (Tails n' Scales in MS, Snapper Check in AL, or Gulf Reef Fish Survey in FL). This approach will not be possible until final decisions are made on integrated estimation methods (in 2021) and calibrations are approved for use in MS, AL, and FL.

- **Option 2:** Rescale MRIP time series estimates (1981-2018) to better match estimates based solely on LA Creel and the new supplemental surveys in MS, AL, and FL. This approach would assume estimates produced by the general MRIP surveys are known to be biased and all of the other new surveys are known to be unbiased. It would also be based on an assumption that all of the new survey designs in LA, MS, AL, and FL would produce similar estimates if conducted side-by-side in the same state. As there is no clear evidence that any of these assumptions are valid, this approach would be very difficult to defend on statistical grounds. For example, it is quite possible that the LA Creel surveys would produce different estimates of private boat reef fish catches than those produced by the Gulf Reef Fish Survey if they were conducted side-by-side in FL. It is also quite possible that the methods used for the MS Tails

n' Scales surveys would produce estimates of red snapper landings in AL that are different from those produced by the Snapper Check surveys.

- **Option 3:** Use LA Creel catch estimates for all species in LA, Gulf Reef Fish Survey catch estimates for reef fish species in FL, supplemental survey landings estimates for red snapper in MS and AL, and the general MRIP survey estimates of catch for all state, mode, species, and catch type domains not covered by the supplemental surveys. This approach would assume that all survey approaches produce unbiased estimates and would produce similar estimates if conducted side-by-side. However, recent side-by-side comparisons have demonstrated that the different survey designs do not produce comparable estimates for private boat fishing, and there is no evidence that any of the current surveys are immune to nonsampling errors. Accordingly, this approach would also be very difficult to defend on statistical grounds.

- **Option 4:** Use general MRIP survey estimates of private boat and shore catches based on the CHTS-APAIS design, rather than those based on the new FES-APAIS design. This approach presupposes that CHTS estimates of effort are less prone to potential bias than FES estimates. However, this supposition is known to be invalid, especially for the years since 2000 when the coverage of the CHTS declined dramatically with the increasing use of wireless phones (the CHTS only contacted households with landline phones). The segment of the recreational fishing population reached by the CHTS in recent years is a much smaller proportion of the total reached in years prior to 2000 and is demographically very different (generally older) from that covered by the FES. The FES has also collected data showing that the average fishing effort of households with a landline phone is now significantly lower than that of households using only a wireless phone. The FES has a much lower nonresponse rate (~60%) than the CHTS (~92%), indicating it is much less susceptible to potential nonresponse error, and a non-respondent follow-up study showed that there was no evidence of a significant nonresponse error in the FES. Hence, the CHTS-based estimates since 2000 are not comparable to CHTS-based estimates prior to 2000, and have become increasingly less so with time. For this reason, MRIP has discontinued the CHTS and any attempt to convert FES-based estimates for 2018 and later years into estimates comparable to CHTS-based estimates prior to 2000 will be difficult to accomplish with any reasonable degree of certainty. Therefore, Option 4 is indefensible on statistical grounds, and use of CHTS-based estimates will not be feasible moving forward.

Recommendations: NOAA Fisheries has determined that Option 1—using a time series of catch estimates fully calibrated to ensure comparability across years and among states—is the best approach to use for stock assessments at this time. Option 1a is preferred until Options 1b or 1c are possible. Options 2 and 3 would be very difficult to defend without a considerable amount of further study. Options 1a and 4 are the only possibilities for the South Atlantic region, as there are no competing state surveys, but Option 4 is statistically indefensible. Having catch estimates that are comparable both across states and throughout the historical time series should be the top priority.

As we learn more about the possible causes of differences in estimates produced by the different survey designs, we will further improve the sampling and estimation methods of the surveys and reduce the potential for biases due to non-sampling errors. As these improvements are made, we may need to develop and apply

new calibrations to produce a more accurate comparable time series of catch estimates for use in stock assessments and management decision-making.

Introduction

Historical Context

Since 2013, the Marine Recreational Information Program (MRIP) has supported collaborative state-federal development of supplemental surveys in Mississippi (MS), Alabama (AL), and Florida (FL) to improve monitoring of recreational charter boat and private boat landings in the short-season red snapper fishery. NOAA Fisheries has worked closely with the Gulf States Marine Fisheries Commission (GSMFC), Mississippi Department of Marine Resources (MDMR), Alabama Department of Conservation and Natural Resources (DCNR), and Florida Fish and Wildlife Conservation Commission (FWC) in this effort. To help with this work, MRIP has supported the participation of five consultants with expertise in survey design, survey statistics, and survey operations. Three workshops held in 2013-2015 focused on development, testing, and evaluation of several alternative methodological approaches. The intent was to develop and implement specialized red snapper surveys in each of the three states that could supplement the general MRIP surveys used to monitor marine recreational catches of all finfish species. The supplemental and general surveys are appropriately described as MRIP surveys that are addressing the data needs of state-federal partners in the Gulf of Mexico.

Louisiana Department of Wildlife and Fisheries (LDWF) developed and implemented the LA Creel survey program in 2014 as a new general survey approach that would better address state priorities for monitoring catches of both state and federally managed species. LDWF subsequently accepted an offer from MRIP to provide expert statistical support for a peer review of the LA Creel survey designs. In 2014, LDWF and NOAA Fisheries cooperated to plan 2015 side-by-side conduct of the LA Creel surveys with the general MRIP surveys previously conducted in LA. LDWF actually conducted both the LA Creel Intercept Survey (LA-IS) and the MRIP Access Point Angler Intercept Survey (APAIS) in 2015. The peer review conducted by five MRIP consultants in 2015 recommended some methodological improvements that LDWF subsequently made. In addition, both the MRIP Coastal Household Telephone Survey (CHTS) and the new MRIP Fishing Effort Survey (FES) were conducted side-by-side with the LA Creel License Frame Telephone Survey (LA-LFTS) of private angler fishing effort in 2016 and 2017. The benchmarking of the LA Creel surveys against the general MRIP surveys has allowed measurement of differences in estimates of fishing effort and catch rates. LDWF and NOAA Fisheries have been working together since 2016 to evaluate differences in the survey estimates and identify possible causes of the differences. In consultation with NOAA Fisheries and the MRIP consultants, LDWF has been using data obtained during the benchmarking periods to develop simple ratio calibration methods that could be used to convert LA Creel estimates into estimates more comparable to those produced by the general MRIP surveys or vice versa.

Certification and Transition Planning

What qualifies a survey design to be declared as statistically valid through the MRIP certification process? To be certified by NOAA Fisheries, the survey design must be statistically valid given critical assumptions made regarding the absence of potential sources of bias. In addition, the assumptions made must be considered to have a reasonable chance of being validated. If all critical assumptions are valid, the certified survey design should produce unbiased estimates. If one or more critical assumptions of a certified survey design are not valid, the survey estimates may be biased. Therefore, it is possible that two different certified survey designs

will produce estimates of the same population parameters that are consistently different. You may have one certified survey design consistently producing higher, or lower, estimates than another certified design. This can happen to the extent that critical design assumptions made by one or both survey designs are not valid. In other words, the differences in survey estimates may be attributable to unknown biases in one or both surveys. Without known population totals, it is very difficult to know which survey estimates are closer to the true population value.

NOAA Fisheries is continuing to work with GSMFC, MDMR, DCNR, FWC, LDWF, and MRIP consultants to evaluate critical design assumptions of the surveys and the potential for non-sampling errors. Studies designed to test assumptions and measure any bias resulting from making invalid assumptions could help explain estimation differences and allow for development of any needed bias corrections. For MS, AL, and FL, the state-federal partners are currently evaluating how best to use supplemental and general survey data and estimates to produce one set of estimates for red snapper landings in MS and AL, as well as one set of estimates for catches of red snapper and other reef fish species off the Gulf coast of Florida. An integrated approach that uses information from both the supplemental and general surveys may be the most statistically sound. In addition, collaborative work is ongoing to determine how estimates produced by different survey designs in different states can be calibrated to ensure comparability of catch statistics across years and among states.

Description of the Gulf of Mexico Surveys

Current Gulf of Mexico Survey Designs

The MRIP partners currently conduct a number of different marine recreational fishery surveys in the Gulf States from Louisiana to Florida. The different survey designs are classified as “general” or “supplemental” based on how they are used. The general surveys conducted in each state are designed to provide accurate annual statistical estimates of catch of all finfish species for one or more specific modes of fishing (shore, private boat, charter boat, and/or headboat), including both catch that is harvested and catch that is released alive. The supplemental surveys conducted in Mississippi and Alabama are specialized to provide more precise and timely statistical estimates of private boat and charter boat red snapper landings during the short federal and state seasons. The supplemental surveys conducted in Florida are specialized to provide more precise private boat catch statistics for red snapper and other reef fish species. As implied by the word “supplemental,” the specialized surveys were developed to supplement the general surveys. The intent is to use data from both the specialized and general surveys to produce one set of estimates for the species, catch types, and fishing modes covered by both.

General Survey Designs

The general survey designs consist of two or more complementary surveys. One component survey is designed primarily to produce estimates of total fishing effort, and another independent survey is designed primarily to produce estimates of mean catch per unit effort. Estimates from the two surveys are combined to estimate total catch.

The general survey designs for charter boat fishing are as follows:

1. For-Hire Survey (FHS)-Access Point Angler Intercept Survey (APAIS): The FHS is a weekly telephone survey of the operators of registered charter boats that is used to estimate the total number of angler

fishing trips in MS, AL, and FL by three different primary areas of fishing – federal waters (Exclusive Economic Zone), state ocean waters (ocean component of state territorial sea), or state inland waters (inland component of state territorial sea). The FHS sampling frame for each state includes all charter boats listed in the MRIP for-hire vessel registry with a valid phone number. The MRIP vessel registry for each state is based on an updated list of state registered vessels, as well as an updated list of federally permitted vessels. A dockside pre-validation survey is used to estimate and correct for potential FHS reporting errors. Boats selected in advance for the FHS weekly sample are checked on an opportunistic sample of days during the week for which their operators are asked to report trips, and comparisons of on-site data and report data are used to estimate any needed corrections. The APAIS is an on-site survey of anglers who have finished fishing for the day, and it is used primarily to estimate the mean numbers of fish harvested and released of different species per angler trip (mean harvest and release rates) by primary area of fishing (federal waters, state ocean waters, and state inland waters). A secondary objective of the APAIS is to estimate the proportion of angler trips made on charter boats in the FHS sampling frame. The inverse of that estimated proportion is used to expand the FHS effort estimate to account for the trips on boats not in the FHS frame. The FHS and APAIS estimates are combined to estimate total numbers of fish harvested and released by area fished. The FHS/APAIS estimates are produced bimonthly, and bimonthly estimates are aggregated to provide annual estimates.

2. LA Creel For-Hire Survey-Intercept Survey (LA FHS-IS): The LA Creel For-Hire Survey (LA-FHS) conducted by LDWF is a weekly telephone survey very similar to the FHS that is used to estimate the total number of charter boat trips by primary area of fishing (offshore or inshore) in LA. The LA-FHS samples from a list of registered charter boat captains (instead of registered boats), but the questionnaire is almost identical to that of the MRIP FHS that was implemented in LA prior to 2014. There is no attempt to pre-validate trip reports provided in the weekly telephone survey sample, so there is no method in place to measure and account for possible reporting errors in the self-reported effort estimates. The LA Creel Intercept Survey is an on-site access point survey of charter boat captains who have finished a fishing trip, and the collected data are used to estimate the mean numbers of fish harvested and released of different species per charter boat trip by primary area of fishing. A secondary objective of the Intercept Survey is to estimate the proportion of charter boat trips made by licensed captains. The inverse of this estimated proportion is used to expand the Telephone Survey effort estimate to account for charter boat trips by unlicensed captains. Estimates from the two surveys are combined to estimate total numbers of fish landed and released by area fished. These estimates are produced weekly, and weekly estimates are aggregated to provide annual estimates.

The general survey designs for private boat and shore fishing are as follows:

3. Fishing Effort Survey (FES)-Access Point Angler Intercept Survey (APAIS): The FES is a mail survey of residential households used to estimate the total number of private boat and shore angler fishing trips by state residents in MS, AL, and FL. Saltwater license information provided by the states is used to improve sampling efficiency and more appropriately weight information gathered from angling households. The FES replaced the legacy Coastal Household Telephone Survey (CHTS) in 2018. As described above, the APAIS is an on-site survey of anglers who have finished fishing for the day, and it is used to partition angler trips by primary area of fishing and estimate the mean harvest and release rates

by primary area of fishing. A secondary objective of the APAIS for private boat and shore fishing is to estimate the proportion of angler trips made by the state residents covered by the FES. The inverse of that estimated proportion is used to expand the FES effort estimate to account for trips by out-of-state residents. The FES and APAIS estimates are combined to estimate total numbers of fish harvested and released by area fished separately for private boat and shore modes of fishing. Cumulative FES-APAIS estimates are produced bimonthly, with cumulative annual estimates obtained at the end of the year.

4. LA Creel License Frame Telephone Survey (LA-LFTS)-Intercept Survey(LA-IS): The LA-LFTS is a weekly survey of saltwater fishing license holders used to estimate the total number of private angler fishing trips (private boat and shore angler trips) taken by licensed anglers by area fished (offshore or inshore) in LA. The LA Creel Intercept Survey is an on-site access point survey of angler fishing parties who have finished fishing for the day, and it is used to estimate mean landing and release rates by primary area of fishing. The Intercept Survey for private angler fishing is very similar in design to the MRIP APAIS for shore and private boat fishing but focuses on intercepting and collecting trip data from angler parties rather than individual anglers. A secondary objective of the Intercept Survey is to estimate the proportion of private trips made by licensed anglers. The inverse of the estimated proportion is used to expand the LA-LFTS effort estimate to account for private trips by unlicensed anglers. Estimates from the two surveys are combined to estimate total numbers of fish landed and released by area fished. Estimates are produced weekly for most species, and weekly estimates are aggregated to provide cumulative annual estimates.

   The general survey design for headboat fishing in all Gulf States (including Texas) is the Southeast Region Headboat Survey (SRHS).

5. The SRHS is a logbook survey paired with a dockside biological sampling survey to estimate total numbers and weights of fish harvested and numbers of fish caught and released by headboat anglers fishing aboard vessels included in the SRHS frame. The SRHS frame in the Gulf of Mexico includes for-hire vessels licensed to carry 15 or more passengers that have a federal permit. Estimates are produced bimonthly and aggregated to provide cumulative annual estimates. Pilot studies funded by MRIP have led to the successful implementation of a mandatory electronic reporting requirement for logbook reports. An additional study funded by MRIP is testing the use of an additional dockside sampling survey to validate self-reported logbook data and account for any unreported trips and catch.

Supplemental Survey Designs

The supplemental survey designs are as follows:

6. Mississippi's Tails n' Scales (MS-TNS) Surveys: This survey program conducted by the Mississippi Department of Marine Resources (MDMR) has two complementary survey designs specialized for estimating red snapper landings and released catch – one for charter boat fishing and one for private boat fishing. The designs of the two are very similar, combining mandatory reporting by state red snapper permit holders with a dockside access-point intercept survey needed to estimate the numbers of unreported red snapper trips, landings, and released catch, as well as validate submitted catch reports. The design used is called a "capture-recapture" design, where the mandatory reporting is the capture phase and the dockside intercept survey is the recapture phase. One design requirement

needed to produce unbiased estimates is that the capture phase must be completely independent of the recapture phase, meaning that the dockside intercept of a trip does not influence the reporting of that trip in any way. Permit holders are required to register each red snapper trip by obtaining a trip number prior to making the trip, and they must submit a report for the trip before they can register another trip. The registration number for each trip is included in each trip report and is also obtained when a trip is intercepted. This facilitates accurate matching of intercepted trips with reported trips. Permit holders are also encouraged to submit the report for each registered trip prior to offloading their landed fish to increase the likelihood that a potential dockside intercept of the same trip will not influence reporting. The dockside survey estimates the proportion of red snapper trips and landings that have been reported based on the proportions of trips and landings observed dockside that are attributable to trips already captured in the reporting phase. The inverse of each of these estimated proportions is used as a multiplier to expand the counts of reported trips and landings to include unreported trips and landings. Comparisons of landings observed for recaptured trips with the landings in the previously captured trip reports are also used to estimate any corrections needed in the reported numbers of red snapper landings. Although counts of reported red snapper landings are available in near real time, the MS-TNS estimates of total landings are only periodically available when there is a sufficient amount of dockside sampling data to produce reasonably stable estimates of the unreported trips and catch. Reporting is only required during state and federal fishing seasons, and the dockside survey is only conducted during those seasons. The MS-TNS surveys do not currently collect data and provide estimates of the catches of other finfish species on red snapper trips.

7. Alabama's Snapper Check (AL-SC) Surveys: This survey program conducted by the Alabama Department of Conservation and Natural Resources (DCNR) also has two complementary survey designs specialized for estimating red snapper landings: one for charter boat fishing and one for private boat fishing. Similar to MS-TNS, both designs combine mandatory reporting by state red snapper permit holders with a dockside access point intercept survey in a capture-recapture methodology used to estimate the total numbers of red snapper trips and landings. Unlike the MS-TNS surveys, permit holders in AL are not required to register each red snapper trip prior to making it, so matching of intercepted trips to reported trips has proved to be more challenging. AL does require permit holders to submit each trip report prior to offloading their landed fish to ensure that the trip report is independent of a potential dockside intercept of the same trip, but the level of compliance with this requirement has been difficult to evaluate. As in the TNS surveys, the capture-recapture estimation methodology is used to account for unreported trips and catch, as well as any needed correction to the reported red snapper landings. Although counts of reported red snapper landings are available in near real time, the AL-SC estimates of total landings are only periodically available when there is a sufficient amount of dockside sampling data to produce reasonably stable estimates of the unreported trips and catch. Reporting is only required during state and federal fishing seasons, and the dockside survey is only conducted during those seasons. The AL-SC surveys do not provide estimates of the number of red snapper caught and released alive, and they do not provide estimates of the catches of other finfish species on red snapper trips.

8. Florida's Gulf Reef Fish Survey (FL-GRFS): This program conducted by the Florida Fish and Wildlife Conservation Commission (FWC) is a complementary surveys design specialized for estimating private boat total catch of red snapper and other reef fish species along the west coast of Florida, excluding the Florida Keys. The design combines two different independent surveys: a mail survey of fishing effort and

an on-site access point intercept survey of completed private boat angler fishing trips. The Mail Survey (FL-GRFS-MS) samples from a list of anglers who have subscribed to participate in the FL-GRFS as part of purchasing their saltwater fishing license. It is used to provide a monthly estimate of the number of private boat fishing trips made by subscribed anglers that targeted red snapper or other reef fish species. The Access Point Intercept Survey (FL-GRFS-IS) samples from a subset of the access points used for APAIS sampling that were determined to be sites with a significant amount of fishing trips targeting reef fish. Only anglers who have finished private boat fishing for the day and targeted reef fish are intercepted for interviews. The survey is used primarily to estimate the mean harvest and release rates for reef fish species by primary area of fishing. To account for any private boat reef fish trips returning to sites covered by the APAIS, and not the FL-GRFS-IS, APAIS data from reef fish trips are included in the estimation of mean harvests and releases. A secondary objective of the FL-GRFS-IS is to estimate the proportion of private boat reef fish trips made by anglers who subscribed for the FL-GRFS-MS. The inverse of that estimated proportion is used to expand the FL-GRFS-MS effort estimate to account for trips by unsubscribed private boat anglers. The effort and catch rate estimates are combined to estimate total numbers of reef fish harvested and released by area fished (federal ocean waters, state ocean waters, and state inland waters). FL-GRFS estimates are produced monthly, and monthly estimates are aggregated to produce cumulative annual estimates.

MRIP Certification of Survey Designs

Most of the survey designs described above have been peer reviewed and certified by MRIP as statistically valid, provided all their critical assumptions are met. Among the general survey designs, the FES, APAIS, LA-LFTS, and LA-IS have all been peer reviewed and certified. The FHS and the LA-FHS are both scheduled to be peer reviewed in 2019 with the expectation that they will ultimately be certified by MRIP with relatively minor modifications. Some enhancements to the design of the SRHS have been tested for potential implementation (see above), and MRIP expects to peer review and ultimately certify an improved SRHS design in 2019. The supplemental survey designs were all peer reviewed and certified after a number of design modifications were made over the last few years. MRIP initiated the peer review of the MS-TNS survey designs in June 2017, and MDMR made several methodological changes before MRIP certified them in June 2018. MRIP initiated a peer review of the AL-SC survey designs in December 2015, and DCNR subsequently made a number of adjustments to the sampling and estimation methods before MRIP conditionally certified them in July 2018. MRIP initiated a peer review of the FL-GRFS designs in February 2018 and certified them in December 2018 after FWC provided a timeline for implementing some recommended methodological improvements.

Comparisons of Survey Estimates

Many people have expressed concern that the estimates produced by the different current surveys are not directly comparable. It is perhaps easy to understand that a new design like the FES-APAIS can consistently produce very different estimates than the legacy CHTS-APAIS that it replaced because the FES was specifically designed to be much less susceptible than the CHTS to undercoverage, nonresponse, and measurement errors. During the 2015-2017 benchmarking of the two survey designs, we could see that the FES-APAIS consistently produced much higher estimates of shore and private boat fishing effort than the CHTS-APAIS. We could also see, in comparison with the CHTS, the FES: (1) provided much more complete coverage of the marine recreational angling households in each state, (2) obtained much higher response rates, and (3) allowed residents of contacted households more time to recall, record, and report recreational fishing trips made during a two-month reference period.

It is more difficult for many to understand how two new survey designs certified as statistically valid can consistently produce very different estimates of the same parameters when conducted side-by-side. However, as mentioned above, this is quite possible if critical assumptions regarding potential sources of bias made by one or both survey designs are not being met. This issue will be discussed further in the next section of this paper where we will focus on key assumptions made by the different survey designs regarding the absence of potential non-sampling errors. This section reviews situations where two different certified survey designs were conducted over the same time period and compares the effort and catch estimates that have been produced. In some cases, the two different designs have produced very similar estimates, while in other cases the two designs have produced very different estimates.

The FES estimates of shore and private boat fishing effort were substantially higher than the CHTS estimates when the two surveys were conducted side-by-side in MS, AL, and FL during the 2015-2017 benchmarking period used to develop a needed calibration. In this case, the differences in the effort estimates and catch estimates based on those effort estimates most likely reflect known differences in the potential for non-sampling errors, such as coverage, nonresponse, and measurement errors. Table 1 (see Appendix A, page 27) compares cumulative 2015-2017 estimates of shore and private boat fishing effort based on the original CHTS-APAIS design with revised estimates in the currency of the FES-APAIS design. The FES-APAIS estimates for Mississippi, Alabama, and West Florida are those produced using the calibration developed to account for differences between CHTS-based and FES-based estimates of effort. The FES-APAIS estimates for Louisiana are based on the actual 2015-2017 FES estimates adjusted for undercoverage using only 2015 APAIS estimates. The total FES-APAIS estimates of shore fishing effort across the three states are 4.0 times higher than the CHTS-FES estimates. The total FES-APAIS estimates of private boat fishing effort across the three states are 2.4 times higher than the CHTS-APAIS estimates.

In 2015, LDWF and NOAA Fisheries collaborated to conduct the CHTS-APAIS and FES-APAIS designs alongside the LA Creel surveys of private recreational fishing, and the estimates of total shore and private boat angler fishing effort were quite different. In general, the LA Creel surveys produced lower estimates of private fishing effort than the FES-APAIS, as shown in Table 2 (see Appendix A, page 28). When LA DWF partitioned the LA Creel private effort estimates into shore and private boat components, a collaborative evaluation showed that the estimation differences between the two designs was greater for shore fishing than for private boat fishing. The annual mean catch rate estimates produced by the APAIS and the LA Creel Intercept Survey for several common species were very similar for both private fishing trips and charter boat fishing trips. The LA Creel catch rate estimates were more precise largely because the sample sizes for the LA Creel Intercept Survey were roughly three times greater than those used for the APAIS in the benchmarking study. The total private recreational fishing catch estimates differed primarily due to the differences noted in the estimates of private (shore and private boat) fishing effort. The LA Creel For-Hire Survey and the FHS were not conducted side by side in 2015 to avoid potential confusion charter boat operators would have experienced if contacted by two different surveys asking the same questions over the same time period.

The Tails n' Scales (MS-TNS) surveys were conducted in 2015-2018 to monitor red snapper landings in Mississippi, and the general MRIP surveys for charter boat fishing (FHS-APAIS) and private boat fishing (CHTS-APAIS and/or FES-APAIS) were conducted over the same years. A number of improvements were made in the design of the MS-TNS surveys between 2015 and 2016, so the 2015 TNS estimates may not be directly

comparable to those produced for 2016-2018. In Table 3 (see Appendix A, page 29), the 2016-2017 MS-TNS estimates of total red snapper landings are compared with the harvest estimates produced by the general MRIP surveys for the same years. In general, the more specialized MS-TNS survey estimates are more precise for all years. The TNS estimates of charter boat landings are lower than the FHS-APAIS charter boat harvest estimates, and the ratio of total two-year FHS-APAIS estimates to TNS estimates is 1.6. The MS-TNS estimates of private boat landings are much lower than the general survey harvest estimates, and the ratio of FES-APAIS to TNS estimates is 5.6 over the two years.

The Snapper Check (AL-SC) surveys were conducted in 2014-2018 to monitor red snapper landings in Alabama, and the general MRIP surveys for charter boat fishing (FHS-APAIS) and private boat fishing (CHTS-APAIS and/or FES-APAIS) were conducted over the same years. In Table 4 (see Appendix A, page 30), 2015-2017 AL-SC charter boat and private boat estimates of total red snapper landings are compared with the harvest estimates produced by the general surveys for the same years. In general, the more specialized SC survey estimates have usually been more precise (i.e., with lower Percent Standard Errors or PSEs). The AL-SC estimates of charter boat landings are very similar to the FHS-APAIS charter boat harvest estimates. The AL-SC estimates of private boat landings are much lower than the FES-APAIS private boat harvest estimates over the three years.

The GRFS surveys were conducted in 2016-2018 to monitor private boat catches of red snapper and other reef fish species off the West Coast of Florida, and the general MRIP surveys for private boat fishing (CHTS-APAIS and/or FES-APAIS) were conducted over the same years. In Table 5 (see Appendix A, page 31), GRFS estimates of harvest and released catch for red snapper, red grouper, and gag are compared to the general survey estimates for 2017-2018. GRFS estimates are lower for all three species in both years. Lower estimates are to be expected for at least some reef fish species because GRFS estimates for West Florida do not include fishing in the Florida Keys like the FES-APAIS estimates do. However, the omission of the Keys does not appear to be enough to fully explain differences between GRFS and general survey estimates for most reef fish species.

Understanding Differences

Key Survey Design Assumptions and Potential for Bias

Two survey designs considered to be statistically valid can consistently produce very different estimates of the same parameters when conducted side by side if critical assumptions made by one or both survey designs are not being met. Each of the survey designs currently in use make critical assumptions regarding the absence of potential sources of bias. Although most of the survey designs attempt to measure and account for possible biases due to coverage, nonresponse, or measurement errors, some potential sources of bias are very difficult to evaluate. For example, all of the access point intercept surveys described in this paper fail to cover fishing trips that end at private access sites, and they assume that such “private access trips” are similar on average to the sampled “public access trips” when estimating various parameters of the population of recreational fishing trips, such as:

- Mean species-specific angler catch rates;
- The proportion of trips made by out-of-state residents (not covered by the FES);
- The proportion of trips made by unlicensed anglers or unregistered charter boat operators (not covered by the LA Creel telephone surveys);

- The proportion of reef fish trips made by unsubscribed anglers (not covered by the GRFS Mail Survey); and
- The proportion of unreported red snapper trips (not accounted for in the mandatory reporting components of the TNS and SC surveys).

To the extent that this key assumption regarding the absence of the potential coverage error is not met in each case, the estimates produced by the on-site survey will be biased.

Potential for Errors in Survey Estimates

In general, surveys are designed to maximize the accuracy of their statistical estimates by minimizing both the "sampling error" and a number of possible "non-sampling errors" (Biemer and Lyberg, 2003; Dillman, Smyth, and Christian, 2009; Groves, 1989; Lohr, 1999; Särndal, Swensson, and Wretman, 1992). In survey statistics, sampling error is the error caused by observing a sample instead of the whole population. Estimates derived from a sample survey will likely differ from the values that would have been obtained if the entire population had been included in the survey, as well as from values that would have been obtained had a different set of sample units been selected for the survey. Sampling error is also variable, meaning that it does not result in a systematic difference between a true population parameter and the estimate of that parameter produced from a survey. In theory, the sampling error is the difference between a sample statistic used to estimate a population parameter and the actual but unknown value of the parameter. A survey estimate of a quantity of interest, such as a total, average, or percentage, will generally be subject to sample-to-sample variation. These variations in the possible sample values of a statistic can theoretically be expressed as sampling errors, although in practice the exact sampling error is typically unknown. If observations are collected from a random sample, statistical theory provides probabilistic estimates of the likely size of the sampling error often expressed in terms of the standard error of the statistic. The standard error is used as a measure of statistical "precision," and it may be presented as a proportional or PSE to show how it compares to the estimated statistic. In general, precision reflects how close the estimates from different samples of the same size are to each other. The standard error is small when estimates from different samples are close in value. Therefore, precision is inversely related to standard error. In general, one can decrease sampling error and increase statistical precision by drawing a larger random sample from the population and optimizing the distribution of sample across the study population.

Surveys are also subject to a wide variety of non-sampling errors. Non-sampling errors are errors arising during the course of all survey activities other than sampling. Unlike sampling errors, they can be present in both sampling and census surveys. Also unlike sampling error, non-sampling errors can create variable or systematic differences between true population parameters and the survey or census estimates of those parameters. When the non-sampling errors produce systematic differences, they are referred to as biases. These kinds of errors can be extremely difficult, if not impossible, to measure. They can occur because of problems in coverage, non-response, measurement, data processing, estimation and analysis.

Potential for Bias Due to Coverage Errors

A coverage error is an error that results from gaps between the sampling frame and the target population for which estimates are needed. Undercoverage can cause an error in the estimation of a population total for a given parameter when the number of elements in the population is unknown. Typically, the undercoverage error will produce a negative bias (underestimate) in estimates of population totals. Undercoverage can also cause an error in the estimation of a population mean for a particular parameter if the uncovered elements of

the population differ on average from the covered elements with respect to that parameter. In contrast to estimates of totals, the effects of undercoverage on estimates of means can vary resulting in variable errors, negative biases, or positive biases. As the example provided above indicates, all of the current Gulf shoreside intercept survey designs are potentially susceptible to errors caused by undercoverage of the target population of marine recreational fishing trips. The sample frames for all of these surveys do not include all possible fishing access sites used by recreational saltwater anglers (e.g., private access sites), and we don't really know if the parameters we are trying to estimate differ between fishing trips ending at access sites on the survey frame and fishing trips ending at off-frame sites.

In general, none of the current surveys designed to estimate total fishing effort provide full coverage of the target population of fishing participants. The pairing of each of these surveys with an independent shoreside intercept survey allows a way to collect data on population elements not covered by the effort survey, estimate the corresponding coverage error in the effort survey, and include a correction for it in the calculation of effort estimates produced from the two surveys. The following describes coverage errors in each of the current effort surveys and how the corresponding shoreside survey is used to estimate the coverage error in each case:

- FHS: The sampling frame of charter boats in each state is updated monthly to minimize undercoverage of participating charter boats, but coverage is not always complete. The FHS estimates a mean number of angler trips per boat each week based on data obtained from a random sample of boats in the FHS frame. To produce an estimate of the total trips made in that week, the estimated mean is multiplied by the total number of boats in the frame. If some participating boats are not included in the frame, then the FHS estimates of total trips would be biased low due to the coverage error. The APAIS samplers identify the charter boat used for each intercepted angler trip and check to see if the boat was included in the FHS frame. If not, the trip is identified as an "out-of-frame boat trip" with respect to the FHS. This allows estimation of a proportion of angler trips made on boats in the FHS frame, and the inverse of that estimated proportion is used to correct the coverage error in the FHS estimate. However, as stated above, the APAIS does not cover angler trips that end at off-frame sites. This means that the FHS coverage error correction may be biased due to coverage error in the APAIS. The fact that a large majority of charter boat trips return to publicly accessible sites suggests that the APAIS coverage error will be very small in this case.

- FES: The address-based sampling frame covers all residents of households to which the U.S. Post Office delivers mail, but it does not cover out-of-state residents who may have fished in the state. Due to this undercoverage, the FES estimates of total fishing trips by shore and private boat anglers will be biased low. The APAIS samplers identify the state and county of residence of each intercepted shore or private boat angler, and trips made by residents of other states are considered to be "out-of-frame" with respect to the FES. This allows estimation of a proportion of angler trips made by state residents in each fishing mode, and the inverse of that estimated proportion is used to correct the coverage error in the FES estimate of total trips in that mode. However, as stated above, the APAIS does not cover angler trips that end at private access sites. This means that the FES coverage error correction may be biased due to coverage error in the APAIS. Any resulting bias in the estimated FES undercoverage correction factor would likely be positive if out-of-state anglers are more likely to end their fishing trips at publicly accessible sites than at off-frame sites. However, the potential effects on MRIP private boat and shore

angler effort estimates are limited as state resident anglers typically account for a very high percentage (often 90% or more) of trips intercepted during APAIS sampling.

- LA Creel telephone surveys: The sample frames for the LA-FHS and LA-LFTS are updated weekly to maximize coverage of registered charter boat captains and licensed private anglers, but they do not include unregistered captains or unlicensed anglers. The effort estimates produced by these surveys will be biased low due to the potential coverage errors. The LA-IS samplers ask a question to determine if each intercepted charter boat captain is registered, and they ask anglers in each intercepted private fishing party if they have a LA saltwater fishing license. Unregistered charter boat captains and unlicensed anglers are considered to be "out-of-frame" with respect to the telephone surveys. For charter boats this allows estimation of a proportion of boat trips made by registered captains, and the inverse of that estimated proportion is used as a correction for the coverage error in the LA-FHS estimate of total charter boat trips. For private anglers, the LA-IS data are used to estimate the proportion of boat trips made by licensed anglers, and the inverse of that estimated proportion is used as a correction for the coverage error in the LA-LFTS estimate of total private angler trips. However, as stated above, the LA-IS does not cover angler trips that end at private access sites, and, in addition, it does not cover trips that end during the night at public access sites. This means that the coverage error corrections for the LA-FHS and LA-LFTS may be biased due to coverage error in the LA-IS. If a large majority of charter boat trips return to public access sites, the LA-IS coverage error is likely to be small. If as many as 30-40% of shore and/or private boat trips end at private access sites, the magnitude of the APAIS coverage error could be significant. Any resulting bias in the estimated LA-LFTS undercoverage correction factor for private trips would likely be negative if anglers fishing at night or at private access sites are more likely to be unlicensed than those fishing at public sites during daylight hours.

- GRFS Mail Survey: The sample frame only includes anglers who have subscribed to participate in the survey as part of purchasing their recreational saltwater fishing license. Therefore, it cannot account for reef fish trips made by unsubscribed anglers (including anglers who do not have a license), and the survey estimates of reef fish trips will be biased low due to the coverage error. The GRFS-IS samplers ask a question to determine if each intercepted angler is on the list of subscribers for the Mail Survey. The GRFS-IS data are used to estimate the proportion of private boat reef fish trips made by subscribed anglers, and the inverse of that estimated proportion is used as a correction for the coverage error in the GRFS-MS estimate of total private boat angler reef fish trips. However, GRFS-IS does not cover angler trips that end at private access sites, trips that end at public access sites not in the GRFS-IS site frame, or trips that end during the night at publicly accessible sites in the GRF-IS site frame. If as many as 30-40% of private boat anglers fishing for reef fish are ending their trips at private access sites, as many as 20-30% of the public access daytime trips end at uncovered sites, and as many as 10% of public access trips end at night, the GRFS-IS coverage error could be a very significant source of bias. Any resulting bias in the estimated GRFS-MS undercoverage correction factor would likely be negative if unsubscribed anglers were more likely to end their fishing trips at private access sites than at public access sites or if they were more likely to return to public sites not covered by the GRFS-IS sample frame.

- MS-TNS and AL-SC: These mandatory reporting programs require reports from charter boat captains and private boat owners who have obtained a red snapper permit (i.e., the permit holders constitute the

frame), but they cannot guarantee coverage of all red snapper trips if at least some individuals are fishing for red snapper without a permit. Therefore, an estimate of the total number of red snapper trips based on reports submitted by permit holders alone would likely be biased low due, in part, to a coverage error. The dockside surveys are essential to allow a means for estimating the number of red snapper trips made illegally by any charter boat captains or private boat anglers who do not have a permit. Additionally, these programs are not conducted outside of the state and federal red snapper fishing seasons. As such, there is no coverage for out of season trips with illegal landings of red snapper. However, effects of this temporal undercoverage may be very minimal.

Potential for Bias Due to Nonresponse Error

Nonresponse occurs when the survey obtains no observations, or responses, for one or more sample frame units selected for the survey sample. Nonresponse can occur in a household telephone or mail survey because the survey failed to contact one or more households in the sample or because residents of one or more contacted households chose not to participate in the survey. In a telephone or mail survey directed at registered, licensed, or subscribed individuals, nonresponse may occur because the survey failed to contact one or more selected individuals or one or more contacted individuals chose not to participate. If a significant number of households, or individuals, do not respond to a survey, then the results will be biased if the characteristics of the non-respondents differ from those of the respondents.

In a shoreside access point intercept survey, nonresponse error can occur if some randomly selected site-time-shift assignments are not completed or if samplers were unable to obtain data on one or more fishing trips that ended within the selected site-time-shift assignments that comprise the survey sample. Failure to complete one or more assignments in this case translates into lost observations of fishing trips that could have been included in the shoreside sample of completed fishing trips. If no observations are obtained for a significant number of randomly selected shoreside survey assignments, then the results will be biased if the characteristics of fishing trips missed differ from those observed on the completed shoreside site-time-shift assignments. Nonresponse can also occur in completed assignments when anglers refuse to participate in the intercept survey or are otherwise unable to do so (e.g., do not speak the same language(s) as the sampler). The potential for nonresponse bias will depend on both the proportion of non-responding anglers and the extent to which they differ in systematic ways from the responding anglers.

Although it is very difficult to prevent nonresponse, the potential impacts can be greatly minimized by achieving high survey response rates. Therefore, it is very important to design surveys that can achieve high response rates, and it is equally imperative to monitor survey response rates once the survey is implemented. There are a number of ways surveys can be designed to maximize response rates. In general, high response rates can be achieved by (1) keeping the survey instrument as short as possible, (2) designing it to be equally salient to all potential sample members, (3) providing a brief but persuasive explanation of the survey's purpose and the intended use of requested information, (4) providing periodic reminders to sample members, and (5) providing incentives.

Nonresponse errors can be minimized by using "nonresponse weighting" techniques. One method used is to partition the respondent data into different weighting cells, commonly defined by demographic categories or other auxiliary information, and then adjusting respondent sample weights within cells to represent nonrespondents. This approach, which ensures that weighted respondent distributions for the auxiliary

variables conform to total sample distributions, assumes that any differences between respondents and nonrespondents within each weighting cell are random and not systematic.

The magnitude of potential nonresponse errors may be partly evaluated by conducting comparisons of early and late responders, or it can be directly estimated by conducting a "nonresponse follow-up survey." This type of survey could be conducted with a random sample of the nonrespondents to the initial survey that uses additional measures, such as increased incentives, to increase the likelihood of obtaining a response. The responses of the nonrespondents are compared with the responses of the initial respondents to see if there is any evidence of a significant difference in the average values for the variables used in survey estimates.

In general, all of the current surveys are susceptible to nonresponse errors. Levels of nonresponse are being closely monitored in all surveys, but nonresponse weighting and nonresponse follow-up surveys have only been used to minimize and/or measure nonresponse bias in some of them. The following describes nonresponse in each of the current effort surveys, provides measures of recent nonresponse rates, describes any nonresponse weighting used, and provides results of any nonresponse follow-up surveys:

- FHS and LA-FHS: It is often not possible to make a successful contact with an owner or operator of every charter boat selected in each weekly sample, even though a pre-contact letter is sent a week ahead of time and a number of dialing attempts are made within a 7-day (FHS) or 6-day (LA-FHS) calling period. FHS nonresponse rates are monitored and vary both among states and across weeks within each state. Nonresponse weighting is not currently used, and nonresponse follow-up surveys have not been conducted in any of the Gulf States. FHS response rates vary across states, but are about 61% on average. FHS response rates in 2016-2018 have been 74-88% in MS, 64-74% in AL, and 57-59% in FL. LA-FHS response rates in 2014-2018 are about 71% on average, ranging between 70% and 73%.

- FES: It is very difficult to get a response for every mailing address selected for the bimonthly FES samples. Response rates have varied among states and across sampling waves within each state, but the average in 2018 was 35-40%. Nonresponse weighting is used for the FES to minimize potential nonresponse bias. The FES sample of mailing addresses for each county is stratified into those that are "matched" to an address in the National Saltwater Angler Registry (NSAR) and those that are "unmatched." In addition, FES samples are matched to state boater registration lists to identify addresses with and without a registered boat. Nonresponse weighting adjustment cells are defined by state, sub-state (coastal or non-coastal counties), license match, and boat registration match. Respondent sample weights within each cell are adjusted to represent nonrespondents. This approach ensures that weighted response distributions for the auxiliary variables (license match and boat registration match) conform to total sample distributions for these variables. In other words, households with licensed anglers and/or registered boats are appropriately represented in the responding sample. Significant differences in the mean number of trips reported between early and late-responding households were not observed in the 2013-2014 FES pilot study, and they have not been observed in the ongoing FES. In addition, a nonresponse follow-up survey conducted as part of the FES pilot study showed no evidence of a nonresponse bias in FL, NC, NY, and MA. A second nonresponse follow-up survey is currently being planned for 2020.

- LA-LFTS: It has not been possible to make successful contacts with all license holders selected for the weekly samples even though repeated attempts are made throughout a 5-day dialing period. An initial sample is drawn each week, but more sample is added as needed to ensure a specified number of interviews are completed by the end of the dialing period. This "quota-based sampling" approach can potentially lead to a nonresponse bias if "easy to reach" and "hard to reach" license holders differ in the mean number of trips they take per week. The nonresponse rates in 2014-2018 were about 51% on average. A preliminary analysis indicates that license holders contacted late during the sampling week did not report more or fewer trips on average than those contacted early in the dialing period. However, no nonresponse follow-up survey has been conducted.

- GRFS Mail Survey: It has not been possible to get responses from all of the prescribed anglers selected for each monthly sample. Response rates have varied across sampling, but the average in 2017-2018 was about 18%. In 2019, FWRI has made some changes to the survey to increase the response rates, so the 82% nonresponse rate will likely come down a bit. Nonresponse weighting has not been used so far, but some form of it has been recommended and is being considered for future implementation. A nonresponse follow-up survey has not yet been conducted.

- MS-TNS and AL-SC: The mandatory reporting programs for MS-TNS and AL-SC receive data from permitted charter boat captains and private boat owners who comply with the reporting requirement (responders), but without their dockside sampling surveys there is no way to account for trips and catch not reported due to noncompliance (nonresponse). The levels of compliance to the MS-TNS mandatory reporting requirements have been estimated at 80% for charter boat permit holders and 70% for private boat permit holders. The levels of compliance to the AL-SC mandatory reporting requirements have been estimated at 50% for charter boat permit holders and 30% for private boat permit holders.

- APAIS: The new version of this survey that was first implemented in 2013 is designed to maximize completion rates (thereby minimizing nonresponse) for monthly stratified samples of site-time-shift assignments. The prior version of the APAIS allowed for a considerable amount of rescheduling and cancellation of assignments. The "controlled selection" process used to select the monthly samples of assignments takes the number of available samplers into account and ensures that all drawn assignments can be matched to an available sampler. This has greatly reduced the number of drawn assignments not completed.

- LA-IS: The LA-IS is an access point survey for which a stratified sample of site-time-shift assignments are drawn each week. There is a dedicated effort to complete all assignments that can be covered with the existing staff of samplers, but some assignments drawn at random cannot be completed.

- GRFS-IS: The GFS-IS monthly sample of site-time-shift assignments is drawn with the same controlled selection program used for the current version of the APAIS. Therefore, the potential for any nonresponse bias caused by non-random cancellations or other failed attempts to complete assignments is greatly minimized.

- MS-TNS and AL-SC Dockside Surveys: The samples of site-time-shift assignments made for these access point surveys are drawn monthly for MS-TNS and AL-SC, and there is a dedicated effort to complete all assignments that can be covered with the existing staff of samplers.

Potential for Bias Due to Measurement Errors

Measurement errors result in surveys when data is incorrectly requested, provided, received, or recorded. Measurement error is the difference between the value of a characteristic provided by the respondent, or observed by an interviewer, and the true (but unknown) value of that characteristic. As such, measurement error is related to the observation of the variable through the survey data collection process and, consequently, is sometimes referred to as an "observation error." Such errors may occur because of inefficiencies with the survey questionnaire, the data collection method, the interviewer, the respondent, or other parts of the survey process. Measurement error can give rise to both bias and variable errors in a survey estimate over repeated trials of the survey. Measurement bias or response bias occurs as a systematic pattern or direction in the difference between the respondents' answers to a question and the true values.

There are four primary sources of measurement error in surveys:

- Questionnaire: The questionnaire, or survey instrument, may be an important source of measurement error. Its design, its visual layout, the topics it covers, and the wording of the questions can all affect how individuals respond to the survey. Important factors include wording of questions, length of questions, length of the questionnaire, order of questions, the response categories provided, and use of open or closed questions.

- Data Collection Method: The way the survey instrument is administered (by phone, by mail, by web or other electronic means, or in person) can affect how individuals respond. Respondents may answer questions differently in the presence of an interviewer than they would by themselves. With face-to-face interviewing, complex interviews may be conducted, visual aids may be used to help respondents answer questions, and skillful, well-trained interviewers can build rapport and probe for more complete and accurate responses. However, through a combination of personality, appearance, or behavioral traits, the interviewers may inadvertently influence respondents' answers to questions, thereby producing a bias in the survey estimates. A particular concern relates to socially undesirable traits or acts. Respondents may be more reluctant to report such traits or acts to an interviewer than they would if they were responding by themselves. In addition, if they are being interviewed in the presence of others, they may be more likely to respond differently to questions viewed as sensitive. Self-administered surveys are less prone to such "social desirability" effects, but they may suffer from systematic bias if the target population includes a non-negligible proportion of individuals that cannot complete the survey for some reason (e.g., language barrier, literacy issue, other impairment or comprehension issues). Generally, response rates tend to be lower in self-administered surveys, but when responses are provided, the data can potentially be of higher quality.

- Interviewer Effects: In many sampling surveys, interviewers play a critical role in the data collection process, and their performance can influence the quality of the survey data. However, survey managers can attempt to control the performance of interviewers through strategic recruitment, training, and monitoring aimed at minimizing any errors potentially associated with the role of the interviewer.

Because of individual differences, each interviewer will handle the survey situation in a different way. They may not ask questions exactly as worded, and they may not follow skip patterns correctly or probe for answers in an appropriate manner. They may not follow survey protocols exactly, either purposefully or because those directions have not been made clear.

- Respondent Effects: Respondents may contribute to error in measurement by failing to provide accurate responses. Some factors that can influence respondent effects are respondent rules, questions, interviewers, recall period, and telescoping. These are briefly described below:

    - Respondent Rules: Rules that define eligibility criteria used for identifying the person to respond to the survey play an important role. If a survey collects information about households, knowledge of the answers to the questions may vary among different eligible residents of the household.
    - Questions: The wording and complexity of the questions and design of the questionnaire may influence how and whether the respondent understands the questions. Also, the respondent's willingness to respond or provide correct answers may be affected by the types of questions asked, the difficulty of determining answers, and by the respondent's view of the social desirability of the responses.
    - Interviewers: The interviewer's visual cues (e.g., age, gender, dress, facial expressions) as well as audio cues (e.g., tone of voice, pace, inflection) may affect the respondent's comprehension of the questions.
    - Recall Period: Time generally reduces ability to recall facts or events, and respondents generally have more difficulty recalling an activity if there is a long time period between the event and the survey.
    - Telescoping: Telescoping occurs when respondents report an event as being within the reference period when it actually occurred outside that period.

Because setting up procedures to quantify measurement error can be expensive and often difficult to implement, survey managers usually place more emphasis on attempting to control the sources of measurement error through good planning and good survey implementation practices. Such practices include pre-testing of survey materials, questionnaires, and procedures; developing and testing well-defined, operationally feasible survey concepts; implementing high standards for the recruitment of qualified field staff; and developing and implementing intensive training programs with clearly written instructions for the field staff.

All of the current Gulf surveys are potentially susceptible to a variety of measurement errors like the ones described above. The following points to some of the ways that potential measurement errors have been addressed and highlights a few cases where such errors could potentially be causing some bias in survey estimates.

- FHS: The survey instrument for the weekly FHS is designed to collect the minimum data need for estimating the mean number of vessel trips per week and mean number of anglers per vessel trip for boats included in the sampling frame. A pre-contact letter is sent to operators of vessels selected for each week of sampling, so they know to expect a call. Phone interviews are conducted by well-trained state personnel who have established a cooperative relationship with the vessel operators over the

years. The one-week recall period was chosen to minimize potential recall errors, and interviewers provide clear clarification on the Monday-Sunday reference period to minimize any potential telescoping errors.

- FES: The survey instrument for the FES is designed to be short and easily understandable for collecting the minimum data needed for estimating the numbers of private boat and shore angler trips for residential households included in the state address-based sampling frame. The mail contact method and self-administered response mechanism allow household residents more time than an interviewer-mediated telephone survey would to provide a well-thought-out complete accounting of all fishing trips made within the two-month recall period. The two-month recall period was chosen to achieve a balance between potential recall errors and potential telescoping errors, while minimizing total survey costs. Experimental studies comparing 1-month and 2-month recall periods resulted in modestly higher estimates of shore and private boat fishing effort for the 1-month recall period. We suspect that the shorter recall period is more susceptible to telescoping error than the standard 2-month recall period used by the FES.

- LA Telephone Surveys: The survey instruments for the weekly LA-FHS and weekly LA-LFT are designed to collect the minimum data needed for estimating the mean number of boat and/or angler trips per week for registered charter boat captains or licensed private anglers. A pre-contact letter is sent to the charter boat captains selected for each week of sampling, so they know to expect a call, but no pre-contact letter is used for the LA-LFTS. Phone interviews for the LA-FHS are conducted by well-trained state personnel who have established a cooperative relationship with the captains. The one-week recall period was chosen to minimize potential recall errors, and interviewers provide clear clarification on the Monday-Sunday reference period to minimize any potential telescoping errors.

- GRFS Mail Survey: The original survey instrument for the GRFS-MS (2016-2017) was a bit more detailed than the one used in 2018. In response to recommendations obtained from a peer review of the methods, FL-FWRI reduced the number of questions and streamlined the instrument in an attempt to increase response rates and reduce the potential for measurement errors due to potential misunderstandings of questions by respondents. The survey now asks for the minimum amount of data needed to estimate the mean numbers of private boat reef fish trips by the subscribed anglers in the address-based sampling frame. The mail contact method and self-administered response mechanism allow participants more time than an interviewer-mediated telephone survey would to provide a well-thought-out complete accounting of all fishing trips made within the 1-month recall period.

- APAIS, LA-IS, and FL-GRFS-IS: In general, the site-time-shift assignments drawn for these access point surveys are conducted by well-trained state agency personnel who strictly adhere to survey protocols and have expertise in the identification of different finfish species. The interviewers intercept anglers who have just finished a day of fishing and ask them to recall information about their fishing day. The interviewers ask to see landed fish that anglers make available for inspection, identify those fish to the species level, count them, and obtain weight and length measurements on a representative sample of them. They also ask anglers to recall the species and numbers of fish caught and released alive. All of these surveys ask key questions related to the identification of boat trips or angler trips that could not be covered by the corresponding survey of fishing effort. The APAIS asks each intercepted angler to

report their state and county of residence. The LA-IS asks each intercepted captain or angler to report their permit or license status, and the FL-GRFS-IS asks each intercepted reef fish angler to report their subscription status (for participation in the FL-GRFS-MS). It is very likely that anglers will not consider a question about their location of residence as sensitive, and the potential of sensitivity effects for state of residence are limited, as the large majority of intercepted anglers already report being an in-state resident. However, many fishing participants may consider questions about permit, license, or subscription status to be very sensitive, given that they are being interviewed after just having completed a day of fishing. The social desirability/sensitivity construct would suggest that anglers fishing without a license or subscription may be motivated to answer inaccurately or refuse to answer the question for fear of legal reprisal. To the extent that this is occurring, resulting effort estimates will be negatively biased as the coverage adjustments would overestimate the proportions of trips taken by licensed or subscribed anglers. Therefore, it will be important to show that responses to the latter types of questions are free of potential measurement error.

- MS-TNS and AL-SC: The self-reporting of red snapper trips and catch may be susceptible to measurement errors if permit holders are either unaware of the mandatory reporting requirements or aware and choose to deliberately try to promote a given outcome. The pairing of the mandatory reporting with a dockside sampling survey allows for direct measurements of differences between permit holder reports of landed fish and observations of landed fish made by trained dockside survey interviewers. With such measurements made for a probability sample of submitted trip reports, any errors due to under- or over-reporting of trips and/or catch can then be corrected in the estimation process.

Potential for Bias Due to Other Non-Sampling Errors

The capture-recapture design utilized by MS-TNS and AL-SC is susceptible to potential non-sampling errors beyond those categorized above. Implementation of the design to produce unbiased estimates of the numbers of red snapper fishing trips and the numbers (or weights) of red snapper landed depends on two very important assumptions: (1) the mandatory reporting “capture” component and the dockside survey “recapture” component are independent, and (2) dockside recaptures of trips already captured in submitted reports are accurately identified. The estimation approach assumes that the reporting of a red snapper trip by a permit holder is independent of the dockside intercept survey. In other words, it is assumed that a dockside intercept of a trip has no effect on the reporting of that trip. If this “independence assumption” is not met, the capture-recapture estimation approach will be subject to “correlation error” that could lead to biased estimates. To ensure that this assumption will be met, both programs require permit holders to report each red snapper trip before (or immediately after) offloading any fish. That way, a dockside interview to collect data on a reported trip will always occur after a trip report has been submitted and will comprise an independent “recapture” of the trip “captured” in the report. A dockside interview obtained for a trip not reported as required would not comprise a legitimate recapture even if a trip report was submitted after the dockside interview. It is very important to understand that the dockside survey is used to assess the reporting tendencies of permit holders and provide accurate estimates of the proportions of trips and catch that would not be reported in the absence of the dockside survey. Both MS-TNS and AL-SC are potentially vulnerable to correlation errors in their estimation of unreported red snapper trips and landings to the extent that samplers (or advanced knowledge of samplers) being present at access points may influence reporting behavior. This

effect could be investigated by, for example, comparing catch rates for vessels on trips reported versus trips reported and observed during validation sampling.

The capture-recapture design also assumes it will be possible to accurately identify dockside recaptures of trips reported as required by permit holders. Any errors in matching intercepted trips to submitted trip reports represent another kind of non-sampling error that could potentially lead to biased estimates. MS-TNS requires permit holders register each red snapper trip by obtaining a trip number prior to making the trip and requires submission of a report for the trip before a trip number can be obtained for a subsequent trip. The registration number for each trip is included in each trip report and is also obtained when a trip is intercepted. This facilitates accurate matching of intercepted trips with reported trips, thereby greatly reducing the potential for any bias in estimates due to this kind of measurement error. The requirement to "clear" a registered trip with a report before registering for another trip also allows MDMR to follow up with tardy permit holders to get missing trip reports. AL-SC does not currently use this approach and is potentially more vulnerable to errors in trip matching.

Recommended Sources and Uses of Statistics for Stock Assessments

Proposed Options

Given that some of the different survey designs currently used in the Gulf States have produced very different estimates in years when two or more surveys were conducted side-by-side, questions have been raised about how current estimates should be used in stock assessments. For stock assessments, it is important for the catch estimates to be measured in the same ''currency'' through time and corrected for any known biases; otherwise, the estimates of stock status will be biased. If the survey design used in a given state has been changed at any point during the historical time series, and the new survey design produces catch estimates consistently higher or lower than the survey design it replaced, then a calibration will be needed to convert estimates throughout the time series into one common currency. Likewise, if the survey designs used in different states are not identical, then the catch estimates may not be comparable among states and multiple state-specific calibrations would be needed. If a different survey is used for quota monitoring (e.g., a specialized state survey such as AL-SC) than is used in the assessment, then it will also be necessary to convert the catch advice from the assessment into the currency used for quota monitoring in any given year.

At least four different options have been proposed for the assessment and management of Gulf species fisheries:

- Option 1: Use a time series of catch estimates fully calibrated to ensure comparability across years and among states
    - Option 1a: One possible way to provide catch estimates in a common currency for multiple states throughout the historical time series is to use the calibrations available right now. MRIP has already provided a fully calibrated time series (1981-2017) of catch estimates for MS, AL, and FL in the common currency of the current general survey designs for charter boat fishing (FHS-APAIS) and private boat fishing (FES-APAIS). Based on side-by-side conduct of LA Creel

surveys and general MRIP surveys in 2015-2017, LDWF has developed simple ratio calibrations that allow conversion of LA Creel estimates into the same general surveys currencies (FHS-APAIS and FES-APAIS). Therefore, it is possible at this time to produce comparable 1981-2017 charter boat and private boat estimates for LA, MS, AL, and the West coast of FL.

- Option 1b: Another possible way to provide catch estimates that are comparable across states and throughout the 1981-2017 time series would be to wait until calibrations have been developed for each of those states to allow conversion of estimates in the common currency described in Option 1a into estimates that would be comparable to those produced by the alternative general survey (LA Creel in LA) or the supplemental survey (Tails n' Scales in MS, Snapper Check in AL, or Gulf Reef Fish Survey in FL) conducted in each state. The estimates produced in MS and AL for red snapper and in FL for red snapper and other reef fish species would be calibrated against estimates based solely on the MRIP general surveys (FHS-APAIS and FES-APAIS). This would allow comparable 1981-2017 estimates in the currency of the general surveys to be used in stock assessments and the setting of ACLs. An ACL set for a particular stock such as Gulf red snapper could then be partitioned among states in support of the current regional management approach, and the state-specific calibrations could be applied to convert the state-specific ACLs into the currency of the new state-specific survey approach for red snapper landings. This assumes peer-reviewed calibration methods are available for LA, MS, AL, and FL. We don't currently expect that this approach will be possible until 2020 when simple ratio-based calibration methods have been developed and approved for use in MS, AL, and FL.
- Option 1c: A third way to provide catch estimates that are comparable across states and throughout the 1981-2017 time series would be to wait until (a) methods have been finalized for integrating the supplemental and general surveys in MS, AL, and FL to produce one set of estimates for species covered by both, and (b) calibrations have been developed for each of those states to allow conversion of estimates into a common currency. The integrated estimates produced in MS and AL for red snapper and in FL for red snapper and other reef fish species would be calibrated against estimates based solely on the MRIP general surveys (FHS-APAIS and FES-APAIS). This would allow comparable 1981-2017 estimates in the currency of the general surveys to be used in stock assessments and the setting of ACLs. An ACL set for a particular stock such as Gulf red snapper could then be partitioned among states in support of the current regional management approach, and the state-specific calibrations could be applied to convert the state-specific ACLs into the currency of the new state-specific survey approach for red snapper landings. This assumes (1) peer-reviewed integrated estimation methods are available for MS, AL, and FL, and (2) peer-reviewed calibration methods are available for LA, MS, AL, and FL. We don't currently expect that this approach will be possible until 2021, when final decisions have been made on integrated estimation methods.

- Option 2: It has been suggested that it may be possible to rescale 1981-2018 estimates based on the general MRIP surveys (FHS-APAIS and FES-APAIS) to better match estimates based solely on LA Creel and the new supplemental surveys in MS, AL, and FL. This approach would assume estimates produced by the general MRIP surveys are known to be biased and all of the other new surveys are known to be unbiased. It would also be based on an assumption that all of the new survey designs in LA, MS, AL, and FL would produce similar estimates if conducted side-by-side in the same state. We do not have clear evidence at this point in time that any of these assumptions are valid. Therefore, an approach like this

would be very difficult to defend on statistical grounds. For example, it is quite possible that the LA Creel surveys would produce different estimates of private boat reef fish catches than those produced by the GRFS if they were conducted side-by-side in FL. It is also quite possible that the methods used for the MS-TNS surveys would produce estimates of red snapper landings in AL that are different from those produced by the AL-SC surveys. Additionally, it is quite possible implementation of the GRFS survey designs or LA Creel survey designs in either MS or AL would yield very different estimates than those produced by MS-TNS or AL-SC.

- Option 3: It has also been suggested that assessments should just use LA Creel catch estimates for all species in LA, GRFS catch estimates for reef fish species in FL, supplemental survey landings estimates for red snapper in MS and AL, and the general MRIP survey estimates of catch for all other state, mode, species, and catch type domains. This approach would assume that all survey approaches produce unbiased estimates and would produce similar estimates if conducted side-by-side. However, recent side-by-side comparisons have demonstrated that the different survey designs do not produce comparable estimates for private boat fishing, and there is no evidence that any of the current surveys are immune to nonsampling errors. Accordingly, this approach would also be very difficult to defend on statistical grounds.

- Option 4: It has been suggested that assessments should continue to use general MRIP survey estimates of private boat and shore catches based on the CHTS-APAIS design rather than those based on the new FES-APAIS design. This approach presupposes that CHTS estimates of effort are less prone to potential bias than FES estimates. However, this assumption is known to be invalid, especially for the years since 2000 when it has been shown that the coverage of the CHTS began to decline rather dramatically with the increasing use of wireless phones (the CHTS only contacted households with landline phones). The segment of the recreational fishing population reached by the CHTS in recent years is a much smaller proportion of the total reached in years prior to 2000, and it is demographically very different (generally older) from that covered by the FES. The FES has also collected data showing that the average fishing effort of households with a landline phone is now significantly lower than that of households using only a wireless phone. The FES has a much lower nonresponse rate (~60%) than the CHTS (~92%), indicating it is much less susceptible to potential nonresponse error, and a non-respondent follow-up study showed that there was no evidence of a significant nonresponse error in the FES. It is clear that CHTS-based estimates since 2000 are not really comparable to CHTS-based estimates prior to 2000, and they have become increasingly less comparable over the more recent years. For these reasons, MRIP stopped conducting the CHTS. Due to the continued decline of coverage and response rates for the CHTS from 2000 to 2017, future conduct of the CHTS cannot be justified. Any attempt to convert FES-based estimates for 2018 and later years into estimates comparable to CHTS-based estimates prior to 2000 will be difficult to accomplish with any reasonable degree of certainty. Therefore, Option 4 cannot be defended on statistical grounds, and use of CHTS-based estimates will not be feasible moving forward.

Factors to Consider

There are several important factors to consider when choosing among the different options provided above. The following questions should be addressed when considering the use of estimates from one or more of the available surveys in stock assessments:

- Validity of Survey Design: Has the survey design been peer reviewed? Were peer review recommendations for improvements adequately addressed? Has the survey design been certified by MRIP?
- Stability of Survey Design: Are methodological changes being made to the survey that could cause changes in survey estimates? At what point did (or will) the survey design stabilize?

- Performance Level and Stability: Is the survey meeting performance expectations? For example, is there satisfactory compliance with mandatory reporting requirements? Are survey response rates being maintained at an acceptable level? At what point did (or will) survey performance stabilize?
- Validity of Key Design Assumptions: Have key assumptions regarding potential non-sampling errors been tested? If there is evidence to suggest non-sampling errors may be causing bias in estimates, have attempts been made to measure the errors and account for them in final estimates?
- Level of Integration among Surveys: If the survey is intended to be supplemental, would integration of supplemental and general survey results increase statistical precision and reduce potential for bias due to potential non-sampling errors in one or both surveys?
- Adequacy of Benchmarking Period: Have new survey estimates been benchmarked against legacy survey estimates for a sufficient period of time to allow development of an appropriate calibration?
- Availability of Calibrations: Are peer-reviewed calibration approaches available that will allow conversion of survey estimates into a currency common across years and among states?

Recommendations

NOAA Fisheries has determined that Option 1—using a time series of catch estimates fully calibrated to ensure comparability across years and among states—is the best approach to use for stock assessments at this time. Option 1a is preferred until Options 1b or 1c are possible. Options 2 and 3 would be very difficult to defend without a considerable amount of further study. Options 1a and 4 are the only possibilities for the South Atlantic region, as there are no competing state surveys, but Option 4 is neither statistically defensible nor feasible. Having catch estimates that are comparable both across states and throughout the historical time series should be the top priority.

As we learn more about the possible causes of differences in estimates produced by the different survey designs, we will further improve the sampling and estimation methods of the surveys and reduce the potential for biases due to non-sampling errors. As these improvements are made, we may need to develop and apply new calibrations to produce a more accurate comparable time series of catch estimates for use in stock assessments and management decision-making.

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Appendix A. Tables

Table 1. Cumulative CHTS-APAIS and FES-APAIS Estimates of Shore and Private Boat Angler Fishing Trips for Louisiana, Mississippi, Alabama, and West Florida in 2015-2017. (PSE = Percent Standard Error of the Estimate; Ratio = FES-APAIS Estimate/CHTS-APAIS Estimate; FES-APAIS estimates for Louisiana in 2016 and 2017 based on 2015 APAIS data; FES estimates for Louisiana based on actual FES data rather than application of a calibration to CHTS estimates)

Shore Fishing Effort					
State	CHTS-APAIS		FES-APAIS		Ratio
	Estimate	PSE	Estimate	PSE	
Louisiana	3,509,373	5.3	16,823,488	7.8	4.8
Mississippi	2,037,142	8.8	9,169,467	8.5	4.5
Alabama	4,144,990	8.4	15,718,321	8.6	3.8
Florida (West)	16,426,891	4.3	61,477,279	4.3	3.7
TOTAL	26,118,396	3.2	103,188,555	3.2	4.0
Private Boat Fishing Effort					
State	CHTS-APAIS		FES-APAIS		Ratio
	Estimate	PSE	Estimate	PSE	
Louisiana	8,110,515	3.1	15,868,033	6.6	2.0
Mississippi	2,000,828	6.6	4,906,918	6.7	2.5
Alabama	2,853,262	5.8	6,630,885	5.7	2.3
Florida (West)	20,867,724	2.4	52,683,305	2.5	2.5
TOTAL	33,832,329	1.8	80,089,141	2.2	2.4

Table 2. Comparison of 2015 LA Creel and FES-APAIS Fishing Effort Estimates for Shore and Private Boat Anglers in Louisiana. (LDWF produced separate LA Creel estimates for shore and private boat angler trips to allow collaborative evaluation of estimation differences between LA Creel and MRIP surveys. PSE= Percent Standard Error of the Estimate; Ratio = FES-APAIS Estimate / LA Creel Estimate)

Fishing Mode	LA Creel		FES-APAIS		Ratio
	Estimate	PSE	Estimate	PSE	
Shore Trips	493,296	8.6	5,163,445	14.5	10.5
Private Boat Trips	1,818,726	3.7	5,493,738	12.3	3.0
Total Private Trips	2,267,121	3.4	10,657,183	9.5	4.7

Table 3. Comparison of 2016-2017 Tails n' Scales and MRIP General Survey Estimates of Mississippi Red Snapper Landings. (PSE= Percent Standard Error of Estimate; Ratio = MRIP General Survey Estimate / Tails n' Scales Estimate)

Charter Boat Landings of Red Snapper in Numbers of Fish					
	Tails n' Scales		FHS-APAIS		
Year	Estimate	PSE	Estimate	PSE	Ratio
2016	2,204	8.5	3,458	41.8	1.2
2017	3,197	4.9	5,374	24.2	1.8
TOTAL	5,401	4.5	8,832	22.0	1.6
Private Boat Landings of Red Snapper in Numbers of Fish					
	Tails n' Scales		FES-APAIS		
Year	Estimate	PSE	Estimate	PSE	Ratio
2016	12,246	12.5	87,820	32.2	7.2
2017	23,992	9.5	116,426	39.0	4.9
TOTAL	36,238	7.6	204,246	26.2	5.6

Table 4. Comparison of 2016-2017 Snapper Check and MRIP General Survey Estimates of Alabama Red Snapper Landings. (PSE= Percent Standard Error of Estimate; Ratio = MRIP General Survey Estimates / Snapper Check Estimate)

Charter Boat Landings of Red Snapper in Numbers of Fish					
	Snapper Check		FHS-APAIS		
Year	Estimate	PSE	Estimate	PSE	Ratio
2015	72,215	11.6	66,960	22.3	0.9
2016	79,636	13.3	95,608	20.4	1.2
2017	104,652	24.0	86,495	19.3	0.8
TOTAL	256,503	11.1	249,063	11.9	1.0
Private Boat Landings of Red Snapper in Numbers of Fish					
	Snapper Check		FES-APAIS		
Year	Estimate	PSE	Estimate	PSE	Ratio
2015	96,102	8.1	562,889	23.8	5.9
2016	99,276	11.8	550,772	20.4	5.5
2017	122,787	15.6	1,162,965	20.7	9.5
TOTAL	318,165	7.5	2,276,626	13.1	7.2

Table 5. Comparisons of 2016-2017 FL-GRFS and FES-APAIS Estimates of Private Boat Harvest and Released Catch for Reef Fish Species in West Florida. (PSE= Percent Standard Error of Estimate; Ratio = FES-APAIS Estimate / FL-GRFS Estimate)

Red Snapper					
Number of Fish Harvested					
	FL-GRFS		**FES-APAIS**		
Year	Estimate	PSE	Estimate	PSE	Ratio
2016	296,519	15.3	669,649	19.1	2.3
2017	485,004	11.9	1,366,132	21.6	2.8
TOTAL	781,523	9.4	2,035,781	15.8	2.6
Number of Fish Caught and Released					
	FL-GRFS		**FES-APAIS**		
Year	Estimate	PSE	Estimate	PSE	Ratio
2016	1,456,776	15.5	3,201,977	21.3	2.2
2017	1,918,313	10.9	5,589,110	17.3	2.9
TOTAL	3,375,089	9.1	8,791,087	13.5	2.6
Red Grouper					
Number of Fish Harvested					
	FL-GRFS		**FES-APAIS**		
Year	Estimate	PSE	Estimate	PSE	Ratio
2016	142,259	14.3	354,634	23.7	2.5
2017	67,247	13.9	214,531	25.4	3.2
TOTAL	209,506	10.7	569,165	17.6	2.7
Number of Fish Caught and Released					
	FL-GRFS		**FES-APAIS**		
Year	Estimate	PSE	Estimate	PSE	Ratio
2016	1,097,822	11.4	2,199,458	16.0	2.0
2017	882,479	11.7	2,269,800	20.7	2.6
TOTAL	1,980,301	8.2	4,469,258	13.1	2.3
Gag					
Number of Fish Harvested					
	FL-GRFS		**FES-APAIS**		
Year	Estimate	PSE	Estimate	PSE	Ratio
2016	80,435	19.0	196,126	29.9	2.4
2017	98,295	16.0	253,921	23.1	2.6
TOTAL	178,730	12.3	450,047	18.4	2.5
Number of Fish Caught and Released					
	FL-GRFS		**FES-APAIS**		
Year	Estimate	PSE	Estimate	PSE	Ratio
2016	787,806	10.4	1,637,015	23.0	2.1
2017	1,092,567	9.6	2,951,718	16.0	2.7
TOTAL	1,880,373	7.1	4,588,733	13.2	2.4