

SEDAR

Southeast Data, Assessment, and Review

SEDAR 94

Florida Hogfish

SECTION III: Assessment Report

June 2026

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1 Introduction

A benchmark assessment was conducted for Florida Hogfish which effectively served as two independent stock assessments within Florida waters: the Florida Keys/East Florida stock and the West Florida Shelf stock. Assessment models were constructed within the Stock Synthesis integrated modeling framework in version 3.30.24.1 (Methot and Wetzel 2013). This assessment renewed all available data streams from SEDAR 37 (2014) and the SEDAR 37U (2018) update assessment for the West Florida Shelf, provided and recommended measures of stock status according to each stock's management jurisdiction, and provided projections of spawning stock biomass, recruitment, and retained yield to inform the Acceptable Biological Catch (ABC) and the Annual Catch Limit (ACL) for each stock.

1.1 Workshop Times and Places

SEDAR 94 addressed two stock assessments for Hogfish in Florida waters, the Florida Keys/East Florida stock and the West Florida Shelf stock, and was provided by the State of Florida's Fish and Wildlife Research Institute (FWRI) with assistance from numerous state and federal collaborators. A series of four Assessment Workshop webinars were convened by SEDAR between December 2025 and April 2026.

1.2 Terms of Reference

- 1) Review any changes in data and data sources following the data workshop and any analyses suggested by the data workshop. Summarize data as used in each assessment model. Provide justification for any deviations from Data Workshop recommendations.
- 2) Develop population assessment models that are compatible with available data and document input data, model assumptions and configuration, and equations for each model considered.
 - a) Fully document and describe the impacts (on population parameters and management benchmarks) of any changes to the model structure, methods, application or fitting procedures made between this assessment and both the prior benchmark (SEDAR 37) and update (SEDAR 37U) assessments.
 - b) Provide a continuity model consistent with the prior benchmark (SEDAR 37) and update (SEDAR 37U) assessment configurations, if one exists, updated to include the most recent observations. Alternative approaches to a strict continuity run that distinguish between model, population, and input data influences on findings, may be considered. Provide additional continuity models which update these prior assessment's configurations and terminal years with MRIP-FES landings and discards.
- 3) Provide estimates of stock population parameters, if feasible:
 - a) Include fishing mortality, abundance, biomass, selectivity, stock-recruitment relationship (if applicable), and other parameters as necessary to describe the population.
 - b) Include appropriate and representative measures of precision for parameter estimates.
 - c) Compare and contrast population parameters and time series estimated in this assessment with values from the previous benchmark (SEDAR 37) and update (SEDAR 37U) assessments, and comment on the impacts of changes in data, assumptions or assessment methods on estimated population conditions.
- 4) Characterize uncertainty in the assessment and estimated values.
 - a) Consider uncertainty in input data, modeling approach, and model configuration.
 - b) Consider and include other sources as appropriate for this assessment.
 - c) Provide appropriate measures of model performance, reliability, and 'goodness of fit'.
 - d) Provide measures of uncertainty for estimated parameters.
- 5) Provide estimates of yield and productivity.
 - a) Include yield-per-recruit, spawner-per-recruit, and stock-recruitment models.
- 6) Provide estimates of population benchmarks or management criteria consistent with available data, applicable FMPs, proposed FMPs and Amendments, other ongoing or proposed management

- programs, and National Standards. Include values for fishing mortality (including assumed discard mortality if appropriate), spawning stock biomass, fishery yield, SPR and recruitment for potential population benchmarks.
- a) Evaluate existing or proposed management criteria as specified in the management summary.
 - b) Review and provide recommendations for proxy values (e.g. MSY) when necessary, and provide appropriate justifications.
 - c) Compare and contrast reference values (e.g. equilibrium yield at $F_{MSYProxy}$) estimated in this assessment with values from the previous benchmark (SEDAR 37) and update (SEDAR 37U) assessments, and comment on the impacts of changes in data, assumptions or assessment methods on reference point differences.
 - d) Define recent fishing mortality rates ($F_{Current}$) and recent spawning stock biomass ($SSB_{Current}$) that will be compared to management benchmarks to determine management benchmarks as the geometric mean of the most recent three years and the terminal data year, respectively.
- 7) Incorporate known applicable environmental covariates into the selected model, and provide justification for why any of those covariates cannot be included at the time of the assessment.
 - 8) Provide declarations of stock status relative to management benchmarks or alternative data poor approaches if necessary.
 - 9) Provide uncertainty distributions of proposed reference points, stock status, and yield.
 - a) Provide the probability of overfishing at various harvest or exploitation levels.
 - b) Provide a probability density function for biological reference point estimates.
 - c) If the stock is overfished, provide the probability of rebuilding within mandated time periods as described in the management summary or applicable federal regulations.
 - d) Characterize the differences in fishing mortality, virgin biomass, terminal total biomass, terminal spawning stock biomass, and equilibrium yield at $F_{MSYProxy}$ as a result of updating recreational catch and effort data from MRIP-CHTS to MRIP-FES by comparing SEDAR 37U to a continuity model with MRIP-FES landings and discards and SEDAR 37U configuration and terminal year.
 - 10) Project future stock conditions (biomass, abundance, and exploitation) and develop rebuilding schedules if warranted; include estimated generation time.
 - a) Request estimates of retained landings in numbers and biomass from data providers for interim years between the terminal year and first year of the projections, if available, to be used to project future stock conditions. If estimates of retained landings are unavailable, use the average of the previous three years.
 - b) Follow SAFMC Catch Level Projections Recommendations for Florida Keys-East Florida Stock.
 - c) Recommend levels of recruitment to be used in the projections.
 - d) Stock projections (including yields) shall be developed in accordance with the following ($F_{Current}$ is the geometric mean of the most recent three years of data):
 - i) If stock is overfished:
 $F=0$, $F_{Current}$, $F=F_{MSY}$, F at 75% of F_{MSY} , F_{OY}
 $F=F_{Rebuild}$ (per Magnuson-Stevens Act)
 - ii) If overfishing is occurring:
 $F=F_{Current}$, $F=F_{MSY}$, F at 75% of F_{MSY} , F_{OY}
 - iii) If stock is neither overfished nor undergoing overfishing:
 $F=F_{Current}$, $F=F_{MSY}$, F at 75% of F_{MSY} , F_{OY}
 - iv) If data limitations preclude classic projections (i.e. A, B, C above), explore alternative models to provide management advice.
 - v) If an alternative proxy for F_{MSY} is recommended, provide outputs for both the current and recommended proxies.
 - 11) Provide recommendations for future research and data collection.
 - a) Be as specific as practicable in describing sampling design and sampling intensity.
 - b) Emphasize items that will improve future assessment capabilities and reliability.
 - c) Consider data, monitoring, and assessment needs.

- 12) Review, evaluate, and report on the status and progress of all research recommendations listed in the last assessment, peer review reports, and SSC report concerning this stock.
- 13) Complete the Assessment Workshop Report in accordance with project schedule deadlines (Section III of the SEDAR Stock Assessment Report).

1.3 List of Participants

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1.4 List of Working Papers and Reference Documents

Document #	Title	Authors	Date Submitted
Documents Prepared for the Assessment Process			
SEDAR94-AP-01	A Unified Reef Visual Census (RVC) and REEF Citizen Science Index	Brice X. Semmens and Dan A. Greenberg	26 March 2026
SEDAR94-AP-02	Weighted Length Compositions for Recreational FL Keys-EFL Hogfish Landings Using MRIP, Biscayne National Park Creel Survey, and Headboat Data	Shanae D. Allen	15 May 2026

2 Stock Synthesis Model Configurations

2.1 Overview

The base models for the SEDAR 94 Florida Hogfish stock assessment of the Florida Keys/East Florida stock (hereafter, ‘KEYS base model’) and the West Florida Shelf stock (hereafter, ‘WFS base model’) were developed in Stock Synthesis (SS) version 3.30.24.1. Stock Synthesis is an age- and size-structured assessment model in the integrated analysis class of models. It has 1) a population sub-model that simulates growth, maturity, fecundity, recruitment, movement, and mortality processes, 2) an observation sub-model which predicts values for the input data, 3) a statistical sub-model which characterizes goodness of fit and obtains best-fitting parameters and their associated variance, and 4) a forecast sub-model which projects various user-determined management quantities (Methot et al. 2026). Further descriptions of SS options, equations, and algorithms can be found in the SS user’s manual (Methot et al. 2026), the NOAA Fisheries Toolbox website (<http://nft.nfsc.noaa.gov/>), and Methot and Wetzel (2013).

The KEYS base model was of moderate complexity and informed by two fishing fleets (including landings, discards, compositional landings-at-length, and compositional discards-at-length where available), three fishery-independent indices of relative abundance (including length compositions), and two fishery-independent CAAL data that were not associated with any fleet or survey. The data sources and their corresponding temporal scale are presented in Figure 3.1. The KEYS base model estimated 165 out of 272 parameters including, but not limited to, growth parameters (asymptotic length [L_{inf}], von Bertalanffy growth coefficient [k], and the reference length for the start of von Bertalanffy growth [L_{min}]), virgin recruitment ($\ln(R0)$), steepness, variability in recruitment (σR), time-varying stock-recruit deviations, fishing mortality rates for each fleet and year that it was operational, and length-based selectivity parameters for fleets, landings, discards, retention and indices with length composition data. Model-derived estimates include maximum sustainable yield (MSY), MSY-proxy reference points (e.g., $F_{30\%SPR}$ and $F_{40\%SPR}$), and a full time series of population abundance-at-age (units: 1,000s of fish) and biomass (female plus male spawning stock biomass, total, and exploitable in metric tons). The ‘r4ss’ (Taylor et al. 2021) and ‘ss3diags’ (Carvalho et al. 2021) R software packages were utilized extensively to summarize and plot model outputs and perform diagnostic tests.

The WFS base model was of fair to moderate complexity and informed by three fishing fleets (including landings, discards, compositional landings-at-length, and compositional discards-at-length where available), three fishery-independent indices of relative abundance (including length and age compositions where available), and two fishery-independent CAAL data that were not associated with any fleet or survey. The data sources and their corresponding temporal scale are presented in Figure 4.1. The WFS base model estimated 87 out of 124 parameters including, but not limited to, growth parameters (asymptotic length [L_{inf}], von Bertalanffy growth coefficient [k], and the reference length for the start of von Bertalanffy growth [L_{min}]), virgin recruitment ($\ln(R0)$), variability in recruitment (σ_{MR}), time-varying stock-recruit deviations, and length-based selectivity parameters for fleets, landings, discards, retention and indices with length composition data. Model-derived estimates include MSY-proxy reference points (e.g., $F_{30\%SPR}$) and a full time series of population abundance-at-age (units: 1,000s of fish), biomass (female plus male spawning stock biomass, total, and exploitable in metric tons), and fishing mortality rates for each fleet and year that it was operational.

2.2 Life History

Growth was estimated within SS according to the von Bertalanffy growth function where initial values for the asymptotic length (L_{inf}), the von Bertalanffy growth coefficient (k), and the CV as a function of length-at-age were based on the results of the external size-truncated model conducted during the Data Workshop (see Section 2.6.5 in the Data Workshop Report). The L_{max} parameter in SS was specified as equivalent to L_{inf} . The CV parameter was used in SS to describe the variability in length-at-age for the minimum (CV_{young}) and the maximum (CV_{old}) observed ages. Growth was initially configured such that fish grew according to the von Bertalanffy growth model immediately upon ‘settlement’ at age-0 (A_{min}) beginning at a length of 2 cm (L_{min}), but L_{min} was freely estimated.

The platoons feature within SS was also utilized to help account for “Lee’s phenomenon” (Rosa Lee 1912), where the removal of faster growing individuals at a higher rate than slower growing ones leaves behind a population cumulatively comprised of slower growing individuals in the cohorts (McBride and Richardson 2007, Kraak et al. 2019). For the KEYS base model, total recruitment was divided into 5 platoons where the distribution among platoons approximated a normal distribution (0.031, 0.237, 0.464, 0.237, 0.031). In the WFS base model, total recruitment was divided into 3 growth platoons where the distribution among platoons also approximated a normal distribution (0.15, 0.70, 0.15). In both models, the parameter controlling the within/between standard deviation ratio was estimated. As a ‘rule of thumb’, ratio values below 0.5 were considered to have produced unrealistic distributions of mean size-at-age while ratios above 2.0 indicated no meaningful shift in mean size-at-age (R. Methot, *pers. comm.*).

In the KEYS base model, natural mortality followed the Lorenzen (1996) formulation (see Section 2.7.2 in Data Workshop Report) and the natural mortality-at-age vector was treated as a fixed input. The WFS base model utilized the Lorenzen option within SS where the Hamel and Cope (2022) longevity-based estimate of constant M (0.235 yr^{-1} ; see Section 2.7.2 in Data Workshop Report) was treated as a fixed input for the natural mortality parameter across ages 3 – 23. Both models assumed natural mortality-at-age was constant over time.

Both models were configured with two genders to account for the reproductive biology of Hogfish as protogynous hermaphrodites (female at birth, then a portion of the population transitions to male). Thus, it was assumed that the sex-ratio at birth was 100% female. Immature females transitioned to mature females based on fixed stock-specific logistic functions of age (see section 2.8.2 in Data Workshop Report), and mature females transitioned to mature males based on fixed stock-specific cumulative normal distribution functions of length (see section 2.8.3 in Data Workshop Report). Given the

uncertainty of sperm limitation for this species, spawning stock biomass was modeled using the mature biomass of both females and males (Brooks et al. 2008). A fixed length-weight relationship ($w = a * L^b$) was used to convert body length (cm) to body weight (kg) with parameters $a = 2.55e^{-5}$; $b = 2.9273$ for both stocks as analyses conducted during the Data Workshop revealed no stock-specific differences for this relationship. Fecundity was configured as eggs/kg on body weight ($eggs = a * wt^b$) and parameterized such that the number of eggs was equivalent to spawning biomass by fixing $a = 1$ and $b = 1$ (see Section 2.8.4 in Data Workshop Report).

2.3 Fleet and Survey Configuration

The fleet configurations within each base model were informed by the amount of available length and age composition data, observed differences in sampled lengths and ages, uncertainty in the landings and discards, workgroup recommendations from the Data Workshop, and AW panel discussions.

2.3.1 Commercial

Commercial landings of Florida Hogfish from 1927 – 2024 were obtained from Florida’s Marine Fisheries Trip Ticket and NOAA Fisheries’ Accumulated Landings System (ALS) and were reviewed by the Data Workshop and recommended for use within each stock’s assessment model. Although historical estimates (1927 – 1985) were considered highly uncertain, their lowest estimated precision (CV = 0.25 for 1927 – 1961) was still more precise than most annual recreational landings estimates (CV > 0.3; see Section 4.3 of the Data Workshop Report). Commercial landings were predominantly from spear, hook-and-line, and trap gears (see Section 3.3 of the Data Workshop Report) and are presented in Tables 3.1 – 4 and Figures 3.2 – 3 for years 1950 – 2024 for the Florida Keys/East Florida stock and Tables 4.1 – 4 and Figures 4.2 – 3 for years 1950 – 2024 for the West Florida Shelf stock.

Annual sample sizes for length and CAAL composition data by commercial gear type were also limited and highly variable. Given the relatively small contribution of the commercial sector and the sparse, noisy sampling data, the AW panel determined that, for each stock, aggregating all commercial gears into a single fleet was the most parsimonious modeling approach. This differed from SEDAR 37, which modeled spear, hook-and-line, and trap gears as separate commercial fleets for each stock.

No commercial discards were available for model inclusion in either stock (see Section 3.4 in the Data Workshop Report).

2.3.2 Recreational

Estimates of recreational landings and discards of Hogfish from 1981 – 2024 by anglers using private, rental boats, or charter boats came from the Marine Recreational Information Program (MRIP) and Florida’s State Reef Fish Survey (SRFS). The ‘Full SRFS’ estimates, which were comprised of SRFS (2021 – 2024) and the SRFS ratio-calibrated private mode (1981 – 2020), MRIP charter mode, and MRIP shore mode (see Sections 4.3 and 4.4 in the Data Workshop Report) were reviewed by the Data Workshop and determined for use rather than the MRIP estimates. Estimates from the Southeast Region Headboat Survey (SRHS) were also available and recommended for use by the Data Workshop from 1981 – 2024 for the Florida Keys/East Florida stock and from 1986 – 2024 for the West Florida Shelf stock.

Recreational fishermen predominantly landed Hogfish in both stocks using spear and hook-and-line gears, but estimates were highly uncertain and often above CV thresholds of 30% and 50% (see Section 4.3 of the Data Workshop Report). In the SRHS, fishermen landed and discarded Hogfish using hook-and-line gears only and were often <1% of the SRFS landings and discards estimates. Therefore, in both stocks, the SRHS landings and discards estimates were respectively combined with the SRFS hook-and-line gear

estimates. Recreational landings and discard estimates by gear from the ‘Full SRFS’ and SRHS timeseries were compiled for each base model and are presented in Tables 3.5 – 6 and Figures 3.4 – 5 for the Florida Keys/East Florida stock and in Tables 4.5 – 6 and Figures 4.4 – 5 for the West Florida Shelf stock.

In the Florida Keys/East Florida stock, annual input sample sizes of recreational length and CAAL composition data by gear and mode were also low (combined across gears and modes: average 65 positive trips per year and 12 fish aged per year). Consequently, the AW panel determined to aggregate the recreational fisheries by gear and mode into a single combined recreational fleet (Tables 3.5 – 6). This differed from that in SEDAR 37 (2014), which despite having also combined the SRHS with the old MRFSS/MRIP hook-and-line estimates, defined two recreational fleets by gear (spear, hook-and-line). Lastly, for the KEYS base model, the landings estimates for 1981 (1.285 million fish) and 1984 (6.644 million fish), which were flagged by the Data Workshop, were each replaced with more ‘reasonable’ estimates by using the geometric mean of their respective six surrounding years (i.e., 3 years before and 3 years after) to become 295,197 fish in 1981 and 239,962 fish in 1984.

This trend in low data availability was also true for the West Florida Shelf stock where annual input sample sizes of recreational length and CAAL composition data by gear were very low (average 13 positive trips per year and 27 fish aged per year). Initially, the AW panel also wanted to aggregate the recreational fisheries by and gear and mode into a single combined recreational fleet, but determined that since the recreational hook-and-line fishery was continuing to develop and expand and had overtaken the spear fishery in landings in recent years, it should be tracked separately. Therefore, the recreational two-fleet structure by gear (spear, hook-and-line) was retained (Tables 4.5 – 6) as was done in SEDAR 37U (2018).

2.3.2.1 Historical Reconstruction of Recreational Landings

Historical recreational landings were extrapolated back to 1950 using available harvest data (i.e., the full SRFS timeseries plus SRHS landings) and were based on a combination of data related to possible changes in recreational anglers. This extrapolation was done to estimate the potential magnitude of recreational landings that would have occurred leading up to the initiation of the MRIP data in 1981, particularly since license data suggested a peak in recreational effort occurred in the mid-1970s. This data would help provide contrast in information as the fishery developed through time predominantly in the Florida Keys/East Florida region. Contrast in the data is helpful when estimating stock-recruitment parameters within an assessment model, particularly the *steepness* parameter which can be informed if the stock experienced a reduction in biomass and recruitment due to heavier fishing mortality and then recovery if that fishing mortality significantly decreases.

Previous estimates of historic recreational catch have been based on human population from the U.S. Census (Florida spotted seatrout, Murphy et al. 2011) or coastwide estimates of saltwater anglers and days spent saltwater fishing from the National Survey of Fishing, Hunting, and Wildlife-Associated Recreation (FHWAR) (South Atlantic Spanish mackerel, Brennan and Fitzpatrick 2012). The human population method assumes that the number of anglers is proportional to the total coastal population and does not account for periods when recreational fishing expanded faster (or slower) than human population. The FHWAR method applied to Spanish mackerel uses coastwide estimates of saltwater fishing effort and assumes that the rate of expansion in saltwater angling was the same across the entire region. Here, information from the FHWAR survey was combined with historical fishing license data to estimate historical recreational catch in each year from 1950 – 1980.

Historic fishing license data were available in the USFWS National Fishing License Reports from 1958 – 2013; for Florida, no data were available in 1959 and 1960. These reports provide values for the number

of certified paid fishing license holders (participants) in each state, where a license holder is one individual regardless of the number of licenses purchased. The reports do not differentiate between saltwater and freshwater anglers. The National Survey of Fishing, Hunting, and Wildlife-Associated Recreation (FHWAR) provides data about the state in which these activities occurred; number of trips taken; days of participation; and expenditures for food, lodging, transportation, and equipment. The survey was conducted 1991, 1996, 2001, 2006, and 2011 by the Census Bureau for the U.S. Fish and Wildlife Service. An estimate of the percentage of anglers in each state that fish in saltwater is provided in these reports (“%saltwater”). This percentage was extrapolated linearly between years when the survey was not conducted. Prior to 1991, the “%saltwater” was only available nationally and only every five years from 1955 – 1985. These national percentages were used to extrapolate back the statewide estimates. The total number of license holders from the USFWS Historic Fishing License data was then adjusted by the percent estimates from the FHWAR surveys to get the total number of saltwater participants by year and state. Lastly, CPUE was calculated for each year and state by dividing the recreational landings estimates by the total number of saltwater participants. The number of saltwater participants was then multiplied by the average CPUE to estimate historical harvest since 1950. These historical estimates were also available during SEDAR 37 (2014). An update to this method was recently applied to south Atlantic Red Snapper (SEDAR98-DW-08) but showed negligible differences ($\leq 1\%$) in estimates between the two methods. Thus, the original SEDAR 37 methodology was retained here.

In the Florida Keys/East Florida region, recreational landings estimates from the Full SRFS plus SRHS averaged 97.6% (geometric mean) of the total Florida-wide landings between 1981 – 1985. Therefore, the annual numbers of saltwater angler participants in Florida were multiplied by 0.976097 to estimate the annual numbers of participants for the Florida Keys/East Florida region (Table 3.7). CPUE was calculated only using years 1982, 1983, and 1985 (CPUE = 0.263904) as landings estimates for 1981 and 1984 were flagged by the Data Workshop and, when incorporated, egregiously inflated CPUE values (CPUE >2.6). Thus, historical recreational landings estimates were reconstructed for the Florida Keys/East Florida region for the assessment model and are presented in Table 3.7. A comparison of these reconstructed landings alongside the historic commercial landings estimates (in numbers) for years 1950 – 2024 is provided in Figure 3.6. Commercial landings were generally low relative to recreational landings and averaged 5.75% of total landings in numbers across the entire timeseries. The reconstructed recreational landings provided a ramp-up into higher landings estimated to have occurred during the 1970s at a similar magnitude to those of the 1980s through early-1990s (Figure 3.6).

Historic recreational landings estimates were also reconstructed for the West Florida Shelf. First, the annual number of saltwater angler participants in Florida was multiplied by 0.023903 so that what wasn't apportioned to the Florida Keys/East Florida above went to the West Florida Shelf (i.e., $1 - 0.976097$). The CPUE was calculated using years 1981 – 1983 (CPUE = 0.929120; no landings estimates for years 1984 – 1985) which was then multiplied by the number of saltwater angler participants to reconstruct the number of landings (Table 4.7). A comparison of these reconstructed landings alongside the historic commercial landings estimates (in numbers) for years 1950 – 2024 is provided in Figure 4.6. Commercial landings were a little higher, averaging 21.53% of the total landings in numbers across the entire timeseries. The reconstructed recreational landings were not found to add any further contrast to the data but rather portrayed a ramp-up into a landings trend that was already gradually increasing through time thereby extending that trend (Figure 4.6).

2.3.3 Indices

For the KEYS base model, three fishery-independent surveys were modeled: the Reef Visual Census Florida Keys (RVC KEYS), the Reef Visual Census Dry Tortugas (RVC DRTO), and a combined video

survey (combined video; Table 3.8, Figure 3.7). Although the Reef Visual Census Southeast Florida (RVC SEFL) index was submitted for use by the Data Workshop, discussions from the AW panel ultimately led to its removal given frequent duplication with the RVC KEYS index (e.g., overlapping length composition data, 8 years of data with 5 years of overlap) and model parsimony. While there is no individual young-of-year (YOY) survey, the length composition data from the RVC KEYS survey indicates the presence of age-0 fish which have recruited to the reefs and could be used to help inform recruitment within the KEYS base model.

Three fishery-independent surveys were used within the WFS base model: the FWRI FIM polyhaline seagrass survey (seagrass trawl), the SEAMAP-FWRI trawl survey (SEAMAP trawl), and a combined video survey (combined video; Table 4.8, Figure 4.7). The seagrass trawl survey was configured within the WFS base model as an age-0 recruitment index. The fishery-dependent MRIP hook-and-line CPUE, which was submitted for use by the Data Workshop, was ultimately not recommended for inclusion following AW panel discussions and the presence of three fishery-independent indices tracking young-of-year, subadult, and adult life stages.

2.3.4 Length Composition Data

Weighted length compositions for the SEDAR 94 base models were compiled for catch (landings and releases) of Hogfish by fishery and primary gear type. Raw length composition data from fishery-dependent sources may be a biased reflection of the length composition of the catch due to uneven sampling in space and time. Therefore, when calculating landings- and releases-at-length (fish landed or released per length bin in numbers), it is recommended to weight the sampled lengths of landed or released fish at the finest possible scale by the inverse of sampling proportion (Maunder et al. 2020).

Weighted length compositions of the landings and releases are described in detail in SEDAR94-AP-01. In brief, length compositions of landings and releases were catch-weighted according to scales that generally satisfied a minimum level of sampling and captured key differences in sampled lengths. Input sample sizes for length compositions were set equal to the number of trips with at least one measured Hogfish. They were then internally re-weighted using fleet-specific Dirichlet-Multinomial parameters or Francis multipliers to estimate effective sample sizes (for additional details refer below to Section 2.11).

Catch-weighted length compositions of landed and released alive Hogfish are summarized by fleet in Figures 3.8 – 9 for the KEYS base model and in Figure 4.8 for the WFS base model. Length samples were assigned to have occurred mid-year (July) and were binned into 2 cm fork length intervals from 2 – 86 cm (KEYS base model) or 2 – 90 cm (WFS base model).

2.3.5 Conditional Age-at-Length Data

Conditional age-at-length inputs by fleet are presented in Figures 3.10 – 13 for the KEYS base model and Figures 4.9 – 10 for the WFS base model. This input allows the integrated models to use the information from sparse age-length data without assuming that the data was representative of ages across the full range of sizes. Input sample sizes for the number of ages sampled in a given length bin by year were set equal to the number of aged fish and were assigned to have occurred mid-year (July).

Conditional age-at-length data is particularly useful when internally estimating growth and is conditioned on the selectivity associated with the data.

Conditional age-at-length inputs are presented in Figures 3.10 – 13 for the KEYS base model and Figures 4.9 – 10 for the WFS base model and were available from the retained landings of the fishery fleets as well as from the various fishery-independent life history research parsed by gear. Conditional age-at-length data is particularly useful when internally estimating growth. It allows the integrated models to use

the information from sparse age-length data, without assuming that the data was representative of ages across the full range of sizes, and is conditioned on the selectivity associated with the data. For the WFS base model, only the CAAL data from the SEAMAP trawl survey and the fishery-independent spear data collected from various life history research were retained. During the model development process, it was found that inclusion of the sparse commercial and recreational CAAL data resulted in conflict with the length data and prohibited reasonable estimates of L_{inf} (e.g., chasing the upper bound of 130 cm FL). The AW panel was concerned that growth could not be reasonably estimated internally opted to retain only the CAAL data which were considered most informative to growth.

2.4 Initial Conditions

The KEYS base model used 1950 as the starting year and did not assume the stock was at equilibrium because Hogfish removals are known to have occurred in the southeastern U.S. since the late 1930s, primarily in the Florida Keys region. Available estimates of historical commercial and recreational landings were not considered stable over time; instead, they were characterized as a ramp-up to peak catch levels observed during the 1970s through the early-1990s. Although the precision of these historical catch estimates was low, their inclusion allowed for fleet- and year-specific estimation of fishing mortality rates and was considered preferable to assuming unknown fleet-specific equilibrium catch and initial fishing mortality rates. The model also assumed that removals prior to 1950 remained below MSY and that the population had not declined below B_{MSY} .

The start year of the WFS base model was 1986 and the stock was also not assumed to be at equilibrium. As mentioned above, the historic commercial and reconstructed recreational catch suggested a low level of landings which gradually increased through time. The inclusion of this data was explored during the model development process; however, the use of the reconstructed data did not further inform model parameters in a more significant way compared to if the model only had data available from 1986. The trade-off of additional uncertainty for no difference in model results led to the AW panel's decision of starting the model in 1986. Therefore, an $\ln(R0)$ offset parameter was configured for 1985 which estimated an initial depletion of the stock before the model began in 1986.

2.5 Spatio-Temporal Structure

The SEDAR 94 base models were configured as single area models within their respective stock boundaries as defined by the 25° 9' N latitudinal line off Cape Sable, Florida (see Section 2.3 in Data Workshop Report). The West Florida Shelf encompassed the eastern Gulf waters north of this boundary while the Florida Keys/East Florida stock comprised waters south of this boundary, around the Florida peninsula, and north to the Florida/Georgia border. Fishing fleets were separated by sector (e.g., commercial and recreational), each having a distinct selectivity, with low sample sizes across data components at finer regional spatial scales precluding further spatial separation of fleets within stock boundaries.

Hogfish in the Florida Keys/East Florida stock were modeled from age-0 through age-16 years (maximum age observed in this stock), while Hogfish in the West Florida Shelf stock were modeled from age-0 through age-23 (maximum age observed in this stock). Recruits for both stocks were defined as fish which recruited to the biological population at calendar age-0. Each model was configured with one season (i.e., annual) from January through December where fishing was treated to have occurred throughout the whole season. Hogfish are protracted spawners with a core spawning season in winter months. Therefore, spawning was configured to occur on January 1 and, given a pelagic larval duration of ~34 days (see Section 2.4 in Data Workshop Report), settlement of recruits was configured to occur in February. Surveys, length composition data, and CAAL data were configured to occur mid-year (July 1).

2.6 Recruitment Dynamics

Each SEDAR 94 base model assumed the Beverton-Holt stock-recruitment relationship. In SS, this stock-recruitment function uses three parameters which were simultaneously estimated: 1) *steepness* (the initial slope of the ascending limb), 2) the virgin recruitment estimated in log-space ($\ln(R0)$), and 3) the standard deviation of the natural log of recruitment (*sigmaR*). *SigmaR* penalizes deviations from the spawner-recruitment curve (calculated from $\ln(R0)$ and *steepness*), and it defines the difference between the arithmetic mean spawner-recruitment curve and the expected geometric mean (Methot et al. 2026).

All three stock-recruitment parameters were estimated within the KEYS base model. However, only the $\ln(R0)$ and *sigmaR* parameters were estimated within the WFS base model. The total landings time series for the West Florida Shelf showed little contrast as it generally increased over time, with the highest removals occurring near the end of the series. Because the data did not provide enough information to estimate the *steepness* parameter, the model consistently converged on a value of 0.99. As a result, *steepness* was fixed at this value, effectively assuming average recruitment rather than estimating a stock-recruitment relationship. This issue was also encountered in SEDAR 37 and SEDAR 37U, where the same approach was adopted.

Simple annual deviations from the stock-recruitment function, which were constrained to sum to zero, were estimated assuming a lognormal error structure. Main recruitment deviations were estimated for years of greater data-richness (1981 – 2021, KEYS; 1986 – 2024, WFS) and corresponded to when the length and age composition data for the fleets began to become available. Recruitment for years 1950 – 1980 in the KEYS base model followed the stock-recruitment curve. No early recruitment deviations were estimated in both models. In SS, expected recruitments need to be bias-adjusted because of its assumed lognormal error structure. The adjustment is accomplished by applying a full-bias correction to the recruitment deviations which have enough data to inform the model about the range of recruitment variability (Methot et al. 2026). Following the recommendation from Methot and Taylor (2011) to use the full bias adjustment on data-rich years, the KEYS base model used full bias adjustment between 1991 – 2022 and the WFS base model used full bias adjustment between 1995 – 2022, after which both models phased out to no bias adjustment through 2024.

Earlier in the KEYS base model development process, main recruitment deviations were configured to extend to the terminal year, 2024, and deviations were not constrained to sum to zero. Estimated recruitment in the last three years (2022 – 2024) was highly elevated, following the index of abundance trends and corresponded to the stock continuing to recover after management intervention beginning in 2017. However, this configuration also produced a retrospective pattern due to the model's inability to predict that recovery trend as the terminal years of the model withdraw. The AW panel felt the increasing trend in recruitment was likely realistic given the data; however, introducing process error by removing the deviations for years 2022 – 2024 (i.e., recruitment followed the stock-recruitment curve instead) still allowed recruitment to increase, but eliminated the retrospective pattern.

2.7 Fishing Mortality

Fishing mortality (F) can be estimated with two approaches in SS: a mid-season harvest rate using Pope's approximation or a season-long fishing mortality rate using the Baranov catch equation (Methot et al. 2026). When estimated as a season-long rate, F can be a parameter for each year and fleet (F_{Par}) or can be a tuned factor using Pope's and Baranov catch equations sequentially (i.e., a hybrid, F_{Hybrid}). As a parameter, F_{Par} is influenced most by both types of catch data (retained and discards) and associated standard errors; whereas the tuning of F_{Hybrid} is influenced by only the retained catch and can result in the near exact match to the observed retained catch but poorer fits to the discard data.

In the KEYS base model, fishing mortality for the commercial fleet was configured using F_{hybrid} because the standard errors for the landings were generally small (~ 0.05) and there were no available discard estimates; whereas the recreational fleet was configured using F_{par} because discards were available and the standard errors associated with the landings were often >0.4 . While the same was true for the West Florida Shelf data, the WFS base model did not show significant improvement to model fit of the indices, length compositions, or CAAL data when configured with F_{par} . Therefore, rather than unnecessarily add annual fleet-specific fishing mortality parameters to the model (i.e., overparameterize), all three fleets were configured using F_{hybrid} .

For tracking and reporting purposes, both base models utilized the annual exploitation rate (biomass), calculated as the ratio of the total annual catch in biomass to the age-1+ biomass at the beginning of the year, to characterize the fishing mortality rates of Hogfish. This was chosen to account for the differing spear and hook-and-line selectivities, to track both female and male portions of the population (not just one or the other), and to be consistent and comparable with both SEDAR 37 (2014) and SEDAR 37U (2018) assessments.

2.8 Catchability

For each of the three respective fishery-independent surveys within each SEDAR 94 base model, constant catchability was assumed. In the SEDAR 37 FLK/EFL base model, time varying catchability was applied to an earlier-starting RVC KEYS index to account for a change in survey design, and which resulted in a doubling of estimated survey catchability. For the SEDAR 94 KEYS base model, the RVC KEYS index started in 1999 and thereby circumvented the need to estimate changes in survey catchability.

2.9 Selectivity

Selectivity patterns describe the probability of capture-at-length or -age by a given fishery or gear. Selectivity can be used to model different gear types, targeting, and fish availability according to the spatial utilization of fish and/or fishery. When configuring length-based selectivity, SS will also estimate a derived age-based selectivity.

The KEYS base model was configured using length-based selectivity for all fleets and indices where selectivity for the commercial fleet and retention for the recreational fleet followed major changes in size limits and bag/trip limits in the south Atlantic regulation of Hogfish in the Florida Keys/East Florida. Selectivity of both the commercial and recreational fleets were configured using the six-parameter double normal function to best accommodate each fleet's differences in gear's selectivity patterns. Five of the six parameters were freely estimated and the fixed parameter (p_5 – initial selectivity at start bin) was configured such as to extend the logistic decay of small fish selectivity down to the start bin. Without any estimated discards, commercial selectivity was configured to change following major changes in South Atlantic regulations of Hogfish. Time-varying selectivity was applied for years 1950 – 1994 (no size or bag limit regulations), 1995 – 2017 (minimum size limit of 12" fork length), and 2018 – 2024 (minimum size limit of 16" fork length and 25lb ww bag limit per boat/day).

Both RVC indices (Florida Keys and Dry Tortugas) were configured with dome-shaped selectivity using the six-parameter double normal function based on the survey area, length composition data, as well as the survey design being constrained to depths less than 30 m. For both indices, five of the six parameters were freely estimated where p_5 (initial selectivity at start bin) was fixed as above. Selectivity for both indices was also held constant over time.

Selectivity for the combined video survey in the KEYS base model was configured using a single-logistic function (flat-topped) based on the gear (stereo-imaging cameras), survey area and design where sampled

depths occurred greater than 30 m, and length composition data. Both parameters were freely estimated and held constant over time.

The WFS base model was configured using length-based selectivity for all fleets and indices except for the FWRI FIM polyhaline seagrass survey which was specified as an age-0 recruitment index (i.e., selectivity = 1 only on age-0 fish). All three fishing fleets were configured using the six-parameter double normal function for flexibility and were based on fishermen input on where the fisheries largely operate and their respective observed composition data. Selectivity of all three fishing fleets varied through time following eastern Gulf regulatory changes in minimum size limits of Hogfish for years 1986 – 1999 (no size or bag limit regulations), 2000 – 2017 (minimum size limit of 12” fork length), and 2018 – 2024 (minimum size limit of 14” fork length). For the commercial fleet, 5 of the 6 parameters were freely estimated and allowed for selection of larger and older fish through the final length bin. However, for both recreational fleets, the length composition data were heavily domed and showed very little selectivity of fish into the larger length bins. Following model parsimony, only 4 of the 6 parameters were estimated where p5 and p6 (final selectivity at last bin) was also fixed to decay the large fish selectivity down to the final bin.

The SEAMAP-FWRI trawl survey in the WFS was configured with dome-shaped selectivity using the six-parameter double normal function and based on gear design (i.e., a trawl), survey area where Hogfish were primarily collected, and the length composition data. Five of six parameters were freely estimated and held constant through time.

The combined video survey in the WFS was configured using a single-logistic function (flat-topped) based on the gear (stereo-imaging cameras), survey area, sampling depths, and length composition data. Both parameters were freely estimated and held constant over time.

2.9.1 Retention

Size regulations for Hogfish are in the form of a minimum size limit; therefore, retention was modeled as an asymptotic function of size using a four-parameter logistic function.

In the KEYS base model, time varying asymptotic retention was applied to the recreational fleet to account for changes in size and bag limits. The first three retention parameters were freely estimated but varied for years 1950 – 1994 (no size or bag limit regulations), 1995 – 2017 (minimum size limit of 12” fork length and bag limit of 5 fish/person), and 2018 – 2024 (minimum size limit of 16” fork length and bag limit of 1 fish/person). The fourth parameter (male offset) was not applicable and was fixed at zero.

For the WFS base model, asymptotic retention was applied only to the recreational hook-and-line fleet where the first three retention parameters were freely estimated and the first two varied for years 1986 – 1999 (no size or bag limit regulations), 2000 – 2017 (minimum size limit of 12” fork length), and 2018 – 2024 (minimum size limit of 14” fork length) to account for changes in size limits. The fourth parameter (male offset) was not applicable and was fixed at zero. Discard estimates were unavailable for the commercial fleet and were insufficient (i.e., only two observations) for the recreational spear fleet (i.e., only two years of highly uncertain observations); therefore, retention was not modeled separately.

2.9.2 Discards

Live and dead discards were calculated and fit for the recreational fleet within the KEYS base model and for the recreational hook-and-line fleet within the WFS base model. Live discards were estimated by applying the converse of the retention function to the total catch, while dead discards were the result of assumed discard mortality rates (Methot and Wetzel 2013). The recreational discard mortality rate was treated as a fixed input (41.4 %, see section 4.7 in the Data Workshop Report) for each base model.

Discard mortality rates are a logistic function of size such that mortality may decline from 1.0 to an asymptotic level as fish get larger. However, the discard mortality rate was treated as constant across size by setting both the ascending slope (p1) and descending slope (p2) parameters to 0.1 and the parameter producing the discard mortality rate (p3) to the specified value (i.e., 0.414). Discard mortality rates were also assumed to be constant through time.

2.10 Maximum Likelihood and Error Structure

A maximum likelihood approach is used in SS to evaluate the overall goodness of fit to each data source (i.e., landings, discards, indices, length compositions, and CAAL). Datasets contained an assumed error distribution (e.g. lognormal) and an associated likelihood determined by the difference between observed and predicted values and the variance of the error distribution. The total likelihood is the sum of the individual components' likelihoods. The global best fit to all the data was determined using a nonlinear iterative search algorithm to minimize the total negative loglikelihood across the multidimensional parameter space.

The error structure for landings, discards, and indices was assumed to be lognormal, except where noted. For most data sources, the variance of the observations was available only as a coefficient of variation (CV). In SS, if lognormal error structures were required, CVs were converted to a standard error (SE) in log-space using $SE = \sqrt{\ln(1 + CV^2)}$. Within the landings data, commercial landings contained little uncertainty (see Section 3.3 of the Data Workshop Report) because the programs which collect those data consider it a census (assumed to be complete or nearly so) rather than a survey (which is from a sample). Limitations of the SRHS design prevented variance estimates from being developed for the headboat landings and discard estimates, and while proxy CV values were available for this assessment, the CVs for the SRFS estimates were used since they were combined into one recreational fleet. Uncertainty in the index observations was estimated through the standardization techniques used therein to determine final observed index CV values (see Section 5.4 of the Data Workshop Report).

Multinomial distributions were assumed for the length composition data of the landings, discards, and indices as well as the CAAL data of the landings and fishery-independent datasets, which have variances estimated by the input sample sizes. The variance of the multinomial distribution is a function of true probability and sample size; thus, an increase in sample size represents lower variance and vice versa. The effective sample size is meant to represent the number of independent and random samples each year to determine the length or age composition. The assumption of independent sampling is typically violated because fish caught in the same tow or set tend to be more similar to each other in length or age than are fish from different catches, and this can extend to fish caught by the same vessel. In addition, the assumption of random sampling can be violated (e.g. by sampling vessels non-randomly or by under-sampling nighttime trips or fishing areas).

The variance associated with each data source can be highly influential, especially when there are conflicts among data sources. Because true effective sample sizes are unknown, input sample sizes were initially set equal to the number of trips with at least one measured Hogfish for length composition data to avoid over-weighting observations of lengths in the likelihoods. The input sample sizes for CAAL data were set to the number of Hogfish sampled because there are fewer fish aged at a given length bin.

2.11 Super-Periods and Data Weighting

In both SEDAR 94 base models, the length composition data for the respective commercial and recreational fleets were characterized by low annual sample sizes, often well below 30 or 50, which produced very coarse and angular distributions for selectivity functions to fit. To help reduce noise and

increase input sample sizes, the super-period approach within SS was utilized which allowed the data to be representative blend across a set of time steps and cause the model to create an expected value for this observation using the same set of time steps (Methot et al. 2026). For the respective fishery fleets within each base model, the super-periods followed when the data became available and when the regulatory time blocks occurred to align with the changes in selectivity and/or retention. In the KEYS base model, super-periods were not applied to the size composition data of either RVC index, but a single super-period was applied across the whole timeseries for the combined video survey due to similar annual sample size issues. In the WFS base model, no super-periods were applied to the SEAMAP survey or the combined video survey composition data.

In the KEYS base model, the Dirichlet-Multinomial distribution, which estimates a parameter (*theta*, θ) that internally scales the input sample size for composition data, was implemented on all length composition data (Thorson et al. 2017; Methot et al. 2026). All *theta* parameters were also given a normal prior $N(0, 1.813)$ as recommended by Ian Taylor (Methot et al. 2026). For the CAAL data (i.e., commercial landings, recreational landings, fishery-independent spear, and fishery-independent trawl), *theta* parameters were generally estimated greater than 4 and nearly 5 (i.e., they were associated with 99 – 100% weight with little information in the likelihood about the parameter value) and the *theta* ratios ($\theta/(1+\theta)$) were close to 1.0, indicating that the model was attempting to tune the input sample sizes as high as possible (Methot et al. 2026). Since the CAAL input sample sizes were based on the number of fish aged within each length bin, manually changing them to a higher input sample size seemed unachievable apart from aggregating them into larger age-at-length bins. Therefore, the CAAL data were left unweighted.

For the WFS base model, Francis weighting was applied to the length composition data as well as to the CAAL data (TA1.8 in Francis 2011). Francis (2011) and Punt (2017) developed re-weighting procedures to adjust the effective sample sizes of length and age data iteratively until the multipliers reached a stable value. Multipliers are calculated so that variability of model inputs is consistent with the model fits to mean length or mean age (Francis 2011). Iterations of the WFS base model were sequentially conducted until the decrease in total likelihood of the model resulted in a difference of two units or less and subjective intervention by the analyst was minimized.

Both Francis and Dirichlet-multinomial weighting methods were explored within each respective base model and final weighting methods were chosen based on individual model performance, diagnostics, and AW panel discussions.

2.12 Model Diagnostics

Model diagnostics of the SEDAR 96 base models were performed in R using the ‘r4ss’ and ‘ss3diags’ (github.com/JABBAmodel/ss3diags) packages and largely followed the recommendations put forth in the Carvalho et al. (2021) “cookbook” for integrated stock assessment models. While each diagnostic is briefly summarized below, further descriptions can be found in Carvalho et al. (2021) and references therein.

2.12.1 Convergence

Convergence of the base model was initially assessed by determining that there were no parameters estimated at a bound, the final gradient was 0.0001 or less, and that the Hessian matrix was positive definite.

2.12.1.1 Correlation Analysis

High correlation among parameters was assessed as it can lead to poor model stability along with flat likelihood response surfaces. While some parameters will always be correlated due to their structural nature (e.g., growth and stock-recruitment parameters), many highly correlated parameters may warrant reconsideration of modeling assumptions and parameterization. Therefore, correlation among parameters was examined and any correlations with an absolute value greater than 0.7 were reported. Parameters correlated due to their structural nature were estimated in different phases of the base model to reduce their direct influence on one another.

2.12.1.2 Jitter Analysis

Once individual model convergence was established, a jitter analysis varied the parameter's starting values to gauge whether the base model had converged on a global solution instead of a local minimum. For this analysis, initial values were jittered by 20% and 100 iterations were performed.

2.12.2 Goodness of fit

Fits and patterns in residuals were assessed in a variety of ways to identify potential model misspecification. First, model fits to landings, discards, indices, length compositions, and CAAL data were evaluated via visual inspection of residuals. Overall residual patterns for each model component (indices, length compositions, and CAAL) were identified through joint residual plots (Winker et al. 2018; Carvalho et al. 2021). These plots include a Loess smoother to detect auto-correlation of residual patterns and data conflicts, as well as indicate outliers that were beyond the 3-sigma limit. Then, a non-parametric runs test (Wald and Wolfowitz 1940) was performed on the indices, length compositions, and CAAL data to test for randomness and the presence of temporal autocorrelation in residuals. Combined root mean square error (RMSE) values were also calculated for the indices and length composition data to evaluate goodness-of-fit. Generally, undesirably high RMSEs exceed 30%.

2.12.3 Model Consistency

2.12.3.1 Likelihood Profiles

Consistency within the base model was evaluated by identifying how the sources of information influence various model estimates. This was done first through likelihood component profiles on two important stock-recruitment parameters where applicable: the virgin recruitment parameter, $\ln(R0)$, and the *steepness* parameter. The $\ln(R0)$ parameter, largely regarded as an ideal global scaling parameter, was sequentially fixed to plausible values ranging in log-space from 7.0 – 9.0 by 0.1 (KEYS base model) or from 6.5 – 8.5 by 0.1 (WFS base model) and the change in total and data-component likelihoods were examined. In the KEYS base model, the *steepness* parameter was fixed to values ranging from 0.3 – 0.99 by 0.05. Ideally, the plotted relationship between negative marginal likelihood values and the range of parameter values yields a well-defined minimum that aligns with that estimated by the base model. If a given parameter is not well estimated, the profile plot may show conflicting signals across data sources and/or a flat marginal likelihood surface. This indicates that multiple parameter values are equally likely given the data. In such instances, the parameter may not be influential in the model, or the model shows instability and model assumptions may need to be reconsidered.

2.12.3.2 Age-structured Production Models

An age-structured production model (ASPM) and an ASPM with estimated recruitment deviations (ASPMdev) were also developed in SS to investigate which processes were influencing the shape of the production function and whether composition data were influencing the variability in recruitment. For the ASPM, this was completed first by fixing all parameters to those values estimated by the base model, except for the $\ln(R0)$ parameter and the initial fishing mortality parameters. Next, the likelihood

components (i.e., lambdas) for the length composition and CAAL data were set to zero along with the recruitment deviations for both the early and main periods, such that only the catch and indices of abundance were fit by the model. For the ASPMdev, the recruitment deviations of the ASPM were configured back to the values in the base model and the bias-correction factor was re-adjusted following Methot and Taylor (2011). Trends in both spawning stock biomass and fishing mortality were compared between the base model, the ASPM, and the ASPMdev.

2.12.3.3 Retrospective Analysis

Each base model was subjected to a retrospective analysis which removed six successive years of data from the terminal year of the model (i.e., years 2018 – 2024) corresponding to the most recent regulatory time blocks beginning in 2018. Iteratively removing data associated with the model's terminal year elucidates the effect of the final year on model results. If results of this analysis show a retrospective bias (consistent patterns of increasing or decreasing model estimates and related derived quantities with each retrospective peel), it can be an indication of model misspecification of temporal dynamics. It is preferable for estimates associated with each retrospective peel to be randomly distributed around the base model results. Model performance was evaluated through visual inspection of retrospective patterns and the Mohn's Rho (ρ) metric (Mohn 1999, Hurtado-Ferro et al. 2015). Here, the 'rule of thumb' ρ values (-0.15 to 0.20) as proposed by Hurtado-Ferro et al. (2015) for longer-lived species were used to characterize retrospective bias.

2.12.4 Model Validation (Prediction Skill)

Having established model consistency and structural stability, the predictive skill of the base model was evaluated to check whether the model's predictive capacity is consistent with the future reality. This was done in two ways. First, a retrospective forecast was performed by adding model-based hindcasts to each of the seven-year peels of the retrospective analysis. Then, a forecast bias, which is an average relative error corresponding to the retrospective bias (i.e., Mohn's Rho (ρ) metric), was computed to gauge model performance and consistency when adding data.

The second method was through the hindcast cross-validation approach (Kell et al. 2021), which compares observations to their predicted future values, and was applied to both the indices and length composition data. Predictive skill was evaluated based on the mean absolute scaled error (MASE), which scales the mean absolute error of the forecasted value to the mean absolute error of the naïve in-sampled value and indicates whether the average model forecasts are better or worse than a random walk. For example, MASE scores >1 indicate average model forecasts are worse than a random walk (i.e., no predictive skill). However, a MASE score of 0.5 would indicate that the model forecasts twice as accurately as a naïve baseline prediction, thereby containing predictive skill.

2.12.5 Sensitivity Runs

2.12.5.1 Florida Keys/East Florida: Start Year

During the model development process, a preliminary base model for the KEYS was constructed to explore the start year of 1986. This configuration followed the SEDAR 37 base model as well as discussions at the Data Workshop concerning when catch or effort data start becoming more available with less uncertainty (e.g., see Sections 3.7 and 4.9.2 in the Data Workshop Report). In addition to a start year sensitivity, this model was unable to adequately estimate any stock-recruitment relationship ($h = 0.99$), indicating that it contained insufficient contrast in the data (e.g., the stock experienced a reduction in SSB and recruitment due to periods of heavier fishing followed by periods of less intense fishing pressure where the SSB and recruitment were able to begin recovering again). However, profiling the *steepness* parameter for this model revealed an improved model fit if *steepness* was <0.99 . When

including the historical catch data, the model was able to estimate a *steepness* value, which ultimately led AW panel discussions to determine this configuration would become the new base model. Therefore, this preliminary model was retained as a sensitivity to these differing assumptions.

2.12.5.2 Florida Keys/East Florida and West Florida Shelf: Discard Mortality

In accordance with Data Workshop (see Data Workshop Report Section 4.7), model runs examining sensitivity to discard mortality rates for the fishing fleets were recommended. Since discards from the commercial fleets in both base models and the recreational spear fleet in the WFS base model were unavailable and/or assumed negligible, sensitivity runs were conducted only for the recreational fleet (KEYS base model) or the recreational hook-and-line fleet (WFS base model). This was completed by configuring the fixed parameter inputs in the discard mortality equation to produce the respective discard mortality rates for each scenario. For the recreational fleet, the upper bound sensitivity was set at 59% while the lower bound was set at 23.8%.

2.12.5.3 Florida Keys/East Florida and West Florida Shelf: Natural Mortality

Sensitivity runs exploring alternative assumptions on natural mortality were conducted based on recommendations from the Data Workshop (see Section 2.7.4 in the Data Workshop Report). While several were explored during the model development process, only three per stock will be presented here. All scenarios continued to assume natural mortality was inversely related to length.

For the KEYS base model, the first sensitivity explored the assumption of using the longevity-based estimator from Hamel and Cope (2022), where $M = 5.4/t_{\max}$ (as was performed for the WFS base model) and fixed as the reference value for age-3 fish. For the Florida Keys/East Florida stock, the maximum age observed has been 16 years, thus $M = 0.338 \text{ yr}^{-1}$. The second scenario sought to explore further recommendations of Maunder et al. (2023) and Hamel and Cope (2022) by internally estimating natural mortality within the KEYS base model and using the standard deviation = 0.31 (in log-space) as a prior. Lastly, the third scenario continued to internally estimate natural mortality, but removed the standard deviation prior in effort to understand where the model would internally absorb mortality if given free reign. This was done to help provide potential insight into how the model felt natural mortality was needed to occur in order to better fit the data.

The first sensitivity run for the WFS base model utilized the mortality-at-weight formulation of Lorenzen (1996) as a fixed input (as was performed for the KEYS base model) and explored the effects of reducing the base model's natural mortality-at-age. A second sensitivity run applied the longevity-based estimator from Hamel and Cope (2022; i.e., $M = 0.235 \text{ yr}^{-1}$) as the reference age for age-3 fish; this configuration similarly reduced natural mortality at younger ages but was found to have increased it across older ages when compared to the prior Lorenzen (1996) method. The third sensitivity run reported here also followed as in the KEYS base model where internal estimation of natural mortality was explored across ages 3 – 23 without the use of the standard deviation prior in log-space. The use of the standard deviation prior was explored but will not be reported here as the freely estimated sensitivity run resulted in a comparatively better fit to the data.

2.13 Per-recruit Analyses

The expected results of a yield-per-recruit (YPR) analysis are to obtain targets of fishing mortality and age at first capture in effort to evaluate regulations regarding gear types (e.g. hook/mesh sizes and minimum sizes), fishing seasons, or fishing effort (e.g. harvest strategies; Haddon 2001). Overall, the assumed goal is to identify the maximum yield from the fishery and then to adjust that target based on risk aversion and uncertainty. Inherent in YPR analyses is the inconsideration of whether the target fishing effort is sustainable, and it assumes that the fishery has reached an equilibrium with the fishing

mortality it exerts. It also assumes characteristics of natural mortality, growth, and recruitment are constant with stock size (Haddon 2001).

2.14 Uncertainty in Parameters and Derived Quantities

A total of 165 out of 272 parameters were estimated within the KEYS base model for Hogfish in the Florida Keys/East Florida. Of the 272 total parameters, 24 were used to describe life history components (6 estimated), 5 were related to the stock-recruitment relationship (3 estimated), 41 estimated annual recruitment deviations, 150 described annual fleet-specific fishing mortality rates for years 1950 – 2024 (75 estimated), 3 were related to index catchabilities, 5 estimated the Dirichlet-Multinomial theta parameters for length composition data, and 44 described selectivity, retention and discard mortality for the 2 fleets and 3 indices (35 estimated).

Within the WFS base model, a total of 87 out of 124 parameters were estimated. Of the 87 total parameters, 26 were used to describe life history components (5 estimated), 6 were related to the stock-recruitment relationship (3 estimated), 40 estimated annual recruitment deviations, 3 were related to index catchabilities, and 50 described selectivity, retention and discard mortality for the 3 fleets and 3 indices (39 estimated).

Parameter input for SS includes an initial starting value, the range of values a parameter could take (min/max), an associated standard deviation, the prior type and standard deviation (where applicable), and the phase which the parameter will be estimated (positive value) or fixed (negative value). Both base models also used the soft bounds option which moves parameters away from the bounds with a weak penalty (Methot et al. 2026).

Derived quantities include annual numbers- and biomass-at-age, spawning stock biomass, fishing mortality rates-at-age, and internally calculated reference points (e.g., F_{MSY} , $F_{30\%SPR}$, SSB_{MSY} , $SSB_{F30\%SPR}$). Also, recent fishing mortality rates ($F_{Current}$) and recent spawning stock biomass ($SSB_{Current}$) as the geometric mean of the most recent three years were compared to management benchmarks to determine stock status.

Approximate uncertainty estimates for estimated and derived quantities were calculated after model fitting based on the asymptotic standard errors from the covariance matrix determined by inverting the Hessian matrix (i.e., the matrix of second derivatives was used to determine the level of curvature in the parameter phase space and to calculate parameter correlations; Methot and Wetzel 2013). Asymptotic standard errors provided a minimum estimate of uncertainty in parameter values.

2.14.1 MCMC

Monte Carlo Markov Chain (MCMC) analyses provided posterior distributions of model parameters and selected derived quantities. MCMC allows probabilistic reporting of the uncertainty associated with the estimated values. Estimates of population values in the terminal year of the stock assessment are often the most uncertain. Assuming the MCMC posterior distributions provide reliable estimates of model uncertainty, the probability that the estimated terminal year value is above or below the overfished/overfishing reference points can be calculated. In this way, a level of risk associated with failing to reach the reference points can be quantitatively specified. Posterior distributions of current spawning stock biomass ($SSB_{Current}$) and fishing mortality rates ($F_{Current}$) as the geometric mean of the most recent three years (2022 – 2024) were compared to associated reference points (i.e., MSST, MFMT).

Convergence of single chains was assessed by Geweke's diagnostic to determine whether the mean of the first 10% of the chain was not significantly different from the last 50% of the chain, while convergence of

the combined chains was assessed using Gelman and Rubin's (1992) potential reduction scale factor implemented in the 'coda' package (Plummer et al. 2006) in R.

2.14.1.1 Florida Keys/East Florida

Two configurations of the KEYS base model precluded a conventional approach to the MCMC analysis: 1) the need for constraining the recruitment deviations to sum to zero, and 2) the use of F as an annual fleet-specific estimable parameter (i.e., F_{par}). In MCMC, recruitment deviations cannot sum to zero as the constraint prevents the algorithm from exploring the space efficiently, leading to illogical patterns in the posteriors and slow convergence; conversely, F as a freely estimable parameter allows too much space for the algorithm to explore and also leads to poor mixing and slow convergence. To explore this issue, an MCMC 'proxy' model was developed which took the KEYS base model and removed the sum to zero constraint on the recruitment deviations and allowed deviations to continue through 2024 (ending main recruitment deviations in 2021 led to a negatively summed total deviation, which was resolved by extending to 2024). Next, the expected recreational landings estimated by the KEYS base model, which accounted for the observation error in the catch as well as the discards, was used as the data input for recreational landings in the MCMC 'proxy' model and the F_{hybrid} configuration was utilized to produce an exact fit to that catch. Since the F_{hybrid} configuration was already being utilized for the commercial fleet, it precluded the need to apply this approach in the MCMC 'proxy' model, and the commercial catch was left unchanged. During the model development process, the results between the KEYS base model and this MCMC 'proxy' model were found to be similar and differences were driven predominantly by changes to the recruitment deviation configuration. While unconventional, the goal of this alternative ensemble approach was to help provide further measures of potential uncertainty within the KEYS base model.

In total, eight MCMC chains were produced based on the MCMC 'proxy' model. For each chain, a total of 2,000,000 iterations were performed but only one out of every 500 iterations were saved, resulting in 4,000 potential iterations used to generate estimates of uncertainty in fishing mortality and spawning stock biomass. Visual inspection of trace plots to adjust appropriate levels of burn-in and thinning as well as to address any autocorrelation in the iterations led to a burn-in of 800 with further thinning of every 8, resulting in 400 samples per chain.

2.14.1.2 West Florida Shelf

Eight MCMC chains were produced from the WFS base model. In each chain, 1,000,000 iterations were performed with every 500 iterations saved, resulting in 2,000 potential iterations used to generate posterior distributions. Visual inspection of trace plots to adjust appropriate levels of burn-in and thinning as well as to address any autocorrelation in the iterations led to a burn-in of 500, resulting in 1,500 samples per chain.

2.14.2 Parametric Bootstrap

Parametric bootstrap resampling methods were used to analyze the uncertainty associated with the data and to detect possible model misspecification. One thousand bootstrapped datasets were produced by randomly drawing datasets according to assumed error distributions centered on fitted values. By fitting the model to each of the bootstrapped datasets, base model parameter estimates and derived quantities were compared to the distribution of parameter estimates and derived quantities from the bootstraps. Large discrepancies between the base model estimates and the median of the distribution produced by bootstrap analysis may indicate model misspecification of error distributions, data conflicts, or considerable autocorrelation within datasets (Methot and Wetzel 2013).

2.15 Bridge Building

The second TOR (2a) specifies the development of continuity models consistent with the prior benchmark assessment's configuration. Unfortunately, as is frequent with models developed over a decade ago, a strict continuity model was largely unreproducible due to significant changes occurring with several data streams. For example, the recreational landings and discard data estimates were no longer based on the older MRFSS and MRIP ad-hoc survey combination method, there were no commercial discard estimates available here, the combined video survey design is not the same from 2012, and all fishery-dependent indices developed during SEDAR 37 (2014) were not recommended for use or utilized in either the KEYS or WFS base models.

Thus, a bridge building exercise was performed for each stock which compared the estimates of spawning stock biomass, fishing mortality rates, and recruitment from 1) the SEDAR 37 base model, 2) a SEDAR 37 base model re-formed using the original data put into the respective SEDAR 94 configuration, and 3) the SEDAR 94 KEYS or WFS base model. Notable changes to the SEDAR 37 FLK/EFL base model to bring it into the SEDAR 94 KEYS base model configuration include: adding the regulatory time blocks starting in 1995, condensing the three commercial fleets and their respective length and age composition data into one commercial fleet, condensing the two recreational fleets and their respective length and age composition data into one fleet, removing the fishery-dependent indices, correct a misspecified input to the hermaphroditism function, match super-period application to the length composition data, match application of Dirichlet-multinomial weighting, estimate growth, and apply the platoon function. Similarly, bringing the SEDAR 37U WFS base model into the SEDAR 94 WFS base model configuration included: adding the regulatory time blocks starting in 2000, condensing the three commercial fleets and their respective length and age composition data into one commercial fleet, removing the fishery-dependent indices, correct a misspecified input to the hermaphroditism function, match super-period application to the length composition data, match application of Francis weighting, estimate growth, and apply the platoon function.

This TOR (2b) also requested development of additional models which replaced the MRFSS/MRIP recreational landings plus dead discards in the SEDAR 37 base models with the Full SRFS landings plus dead discards timeseries. In the SEDAR 37 base model, discards were not modeled separately; rather, dead discards were incorporated into the landings by applying a discard mortality rate of 100% for spear and 10% for hook-and-line gears. While the TOR actually specified using the MRIP-FES timeseries, the AW panel resolved that since the Full SRFS timeseries was recommended for use over the MRIP-FES by the Data Workshop panel and the TORs were written well beforehand, the Full SRFS timeseries should be used to satisfy this TOR.

3 FL KEYS/EFL Stock Synthesis Model Results

3.1 Life History

The KEYS base model internally estimated growth where asymptotic length (L_{inf}) was estimated at 51.2 cm FL and the growth coefficient (k) was estimated at 0.177. Using the platoons feature within SS, this corresponded to the 3rd platoon (of the 5 total platoons) which was apportioned 46.4% of annual recruitment. The estimated mean length-at-age was found similar to the results of the external growth model developed during the Data Workshop (Figure 3.14; see Section 2.3.5 in the Data Workshop Report) and the additional platoons allowed fish to grow faster (i.e., larger) and slower (i.e., smaller). For example, in the fourth platoon, where 23.7% of annual recruitment was apportioned, mean fish size was as large as 63.1 cm FL; but in the second platoon, also receiving 23.7% of recruitment, mean fish size was

as large as 33.9 cm FL. These faster growing fish became vulnerable to the fisheries sooner whereas the slower growing fish encountered the fisheries much less, helping to mimic the “Lee phenomenon” hypothesized to be occurring in this stock. Furthermore, the platoon within/between standard deviation ratio parameter was estimated at 0.73, suggesting a shift to lower mean size-at-age has been occurring for this population.

3.2 Landings and Discards

Fits to the landings data for the commercial and recreational fleets are presented in Figures 3.15 – 16. The fits to the commercial landings were nearly exact (total negative log-likelihood = 3.500e-05) while the recreational landings were allowed more flexibility given their higher observation error (total negative log-likelihood = 17.053). The KEYS base model generally fit the observed recreational landings well except in 1988, which expected much higher landings, and in years 2008, 2012, and 2015, which expected lower landings. Figures 3.17 – 18 compare model estimated landings across fleets in biomass and numbers of fish, respectively.

Fits to the recreational discard data were well (total negative log-likelihood = -1.544) as most estimates were close to the observed values and within the 95% confidence intervals (Figure 3.19) except for year 2009 which estimated higher numbers of fish discarded.

3.3 Indices

The KEYS base model fits to the three fishery-independent indices (RVC Florida Keys, RVC Dry Tortugas, and combined video) are presented in Figures 3.20 – 22. Model fits to the indices were overall well (total negative log-likelihood = 7.023) and seemed to follow a similar common trend.

Model fits to the RVC Florida Keys index were fair (RMSE = 0.2527), but misfit in certain years contributed the most to the model’s overall total negative log-likelihood for the index component. The observed trend started very low and gradually increased through time until the series high in 2024. But the model expected higher abundances in those first two years before becoming more aligned through 2018. Fits to years 2022 and 2024 were an average between the two as the model balanced fitting the other two indices (Figure 3.20).

Fits to the RVC Dry Tortugas index were closest (RMSE = 0.1646) and the observed trend was similar to the RVC Florida Keys index. The fitted values followed the observed stable but variable trend through the 2000s and then increased from 2018 – 2024 (Figure 3.21).

Lastly, model fits to the combined video index were the worst of the three (RMSE = 0.3804), but this index also contained the greatest amount of observed error. The fitted values generally followed the observed trend which began as an initial high in 1993 and gradually decreased though 1997, became stable but variable through 2017, then began gradually increasing again (Figure 3.22).

3.4 Length and Age Composition

3.4.1 Data Weighting

Weighting of the length composition data using the Dirichlet-multinomial distribution resulted in $\ln(\theta)$ parameters < 5 with most close to 0 (commercial landings: $\theta = 2.093$, recreational discards: $\theta = 0.987$, recreational landings: $\theta = -0.764$, combined video: $\theta = 0.442$, RVC indices: $\theta = -0.347$; Table 3.9). Thus, theta ratios were all below 1.0 (commercial landings: 0.890, recreational discards: 0.728, recreational landings: 0.318, combined video: 0.609, RVC indices: 0.414). Fits to all three indices also improved (via RMSE) when compared to an unweighted model. The RVC Dry Tortugas index decreased from RMSE =

0.201 to 0.165, the RVC Florida Keys decreased from $RMSE = 0.276$ to 0.253 , and the combined video decreased from $RMSE = 0.400$ to 0.380 .

3.4.2 Length Composition

The KEYS base model fits to the length composition data along with the Pearson residuals associated with the landings, discards, and indices are presented in Figures 3.23 – 27. The quality of the fit varied among fleets and indices and fits aggregated across time were reasonable (total negative log-likelihood = 582.548). The model's predicted distributions were able to match the observed overall distributions but partially underestimated the peak for the recreational discards (Figure 3.23).

The retained length composition data for the commercial fleet were weighted annually by the commercial landings and were aggregated into three super-periods: 1989 – 1994 ($n_{input} = 48$), 1995 – 2017 ($n_{input} = 457$), and 2018 – 2023 ($n_{input} = 24$); no length data were available for year 2024. Fits to these data largely agreed with the observed distributions (Figures 3.24a and 3.27a), matched the changes in minimum size limits, and smoothed through jagged-looking length bins in earlier and later periods characterized by low input sample sizes. For both the 1989 and 2018 super-periods, under-sampling in years 1991 and 2021 influenced atypically larger proportions of fish calculated for the largest length bins (Figure 3.24a). The commercial fleet's length composition data also reflected larger individuals were more regularly targeted when compared to the recreational fishery, especially during the second super-period (1995 – 2017; Figure 3.24a – b).

The recreational retained length composition data were weighted annually by the recreational landings, were characterized by comparatively larger sample sizes, and were aggregated into five super-periods: 1981 – 1985 ($n_{input} = 230$), 1986 – 1994 ($n_{input} = 555$), 1995 – 2004 ($n_{input} = 749$), 2005 – 2017 ($n_{input} = 1,247$), and 2018 – 2024 ($n_{input} = 119$; Figures 3.24b and 3.27a). The first two super-periods (1981 – 1994) characterize the first time block (no size limits) and were split to accommodate alternative models developed during the AW process which started in 1986. While there is no minimum size limit during this time, length composition data show similar patterns to the second time block containing a 12" FL (30.5 cm) minimum size limit. The third and fourth super-periods (1995 – 2017; second time block) were split to align with the recreational discards which became available in 2005 (Figure 3.24c). The fifth super-period (2018 – 2024) reflected a shift in mode to the new 16" FL (40.6 cm), however smaller fish were still shown to be retained (Figure 3.24b). Fits to the recreational discard length composition data were split into two super-periods: 2005 – 2017 and 2018 – 2024. Distributions show discards are predominantly individuals smaller than the respective minimum size limits; while there were some fish above the minimum size limit discarded from 2005 – 2017, there were no fish discarded above 16" FL (40.6 cm) in the 2018 - 2024 time block when the daily bag limit reduced to 1 fish/person (Figure 3.24c).

The observed length distributions for both RVC indices utilized 5 cm bin widths to resolve the digit bias observed in 2 cm bin widths where model fits to the overall distributions appeared well (Figure 3.23). Annual fits to the RVC Florida Keys length compositions were reasonable (Figures 3.25 and 3.27b; total $n_{input} = 5,194$); modal lengths were generally around 20 cm FL, but annual variability led to some years being underestimated at the mode with overestimation at adjacent sizes or vice-versa. While Hogfish in the Florida Keys were observed by this survey up to the 85 cm FL bin, individuals were predominantly less than 40 cm FL (Figure 3.25). Fits to the annual observed length compositions for the RVC Dry Tortugas index were also fair but exhibited comparatively more annual variability and noise across length bins (Figures 3.26 and 3.27c; total $n_{input} = 2,974$). Fish were generally larger in the Dry Tortugas, with modal lengths around 35 – 40 cm FL and more frequently observed individuals up to the largest length bin compared to the RVC Florida Keys survey.

The observed length composition data of the combined video survey were generally more uniform in distribution, rather than having a stronger dome-shape as seen in the other length compositions (Figure 3.23). Annual sample sizes for this survey were very low (commonly less than 20) leading to noisy compositions; without any changes in catchability or regulatory time blocks to consider for this index, a single super-period was applied for years 2002 – 2024 ($n_{\text{input}} = 184$). Models fits to these aggregated data became reasonable and were able to smooth through the coarse and irregular length bins (Figures 3.23 and 3.27a).

3.4.3 Conditional Age-at-Length

The KEYS base model fits to the CAAL data associated with the landings as well as fishery-independent spear and trawl data are presented in Figures 3.28 – 32. The quality of the fit varied among data sources and fits to their aggregated mean ages were generally acceptable (total negative log-likelihood = 618.568; Figure 3.28). Ages sampled from the fleets were infrequent and the average number of ages available annually per length bin was 2 – 3; therefore, to reduce noise and help the model’s internal estimation of growth, years where only one or two age-at-length observations were available were removed.

The fits to the annual mean ages for the commercial fleet followed the trends of the observations generally well and mean age occurred between ages 4 – 7 (Figure 3.28). The model did not fit year 2015 by expecting a slightly lower mean age and year 2016 had the greatest uncertainty due to single observations for each age-at-length bin. No ages were sampled from 2017 – 2024 (except for one otolith sampled in 2022 which was removed). The annual fits to the observed ages were reasonable and the model was able to track the observed ages across length bins (Figure 3.29). Between 1998 – 2011, sampled ages-at-length contained larger individuals (~28 – 54 cm FL) predominantly collected from the spear gear but were more length-truncated (~30 – 40 cm FL) across 2012 – 2015 from additional hook-and-line and trap gear samples.

Model fits to the annual mean ages for the recreational landings were largely within the bounds of uncertainty with mean age stable but variable around age 5 (Figure 3.28). Annual fits to the observed ages-at-length were adequate; the combined age data were comprised of both spear and hook-and-line gears, were more consistently sampled across years compared to the commercial fishery, and were normally within 30 – 50 cm FL (Figure 3.30). Ages-at-length above 50 cm FL were more commonly sampled from the spear gear.

The fishery-independent CAAL data were constructed from the life-history research of McBride and Richardson (2007), Faletti and Stallings (2021), Towne et al. (2021), and from unpublished FWRI research (see Section 2.6 in Data Workshop Report). The data were parsed by gear into two fleets: a spear fleet and a trawl fleet, and they were not linked to any other fleet or index. Their main purpose of inclusion was to inform the internal estimation of growth. The fits to the annual mean ages for the fishery-independent spear fleet were suitable and followed the observed trends, largely between ages 3 – 6 (Figure 3.28). Annual fits to the observed ages-at-length were well and were considered the most informative data source for the internal estimation of growth, encompassing annually the widest range of ages-at-length (~6 – 62 cm FL; Figure 3.31). Contrastly, the fishery-independent trawl fleet were predominantly smaller individuals (<30 cm FL) and were helpful with informing growth of the younger individuals. Fits to the annual mean ages were well with observations variable around ages 1 – 3 (Figure 3.28); fits to the annual observed ages-at-length were also consistent (Figure 3.32).

3.5 Estimated Parameters and Derived Quantities

The SEDAR 94 KEYS base model estimated most parameters reasonably well (i.e., $|CV| < 1$; Table 3.10). Of the 165 active parameters, 37 exhibited poor estimation (i.e., $|CV| > 1$); including 26 recruitment

deviations, 2 years estimating the annual recreational fishing mortality rates, and 9 parameters describing selectivity (mostly commonly the top logit and/or end logit parameters). No parameters were estimated near bounds.

3.5.1 Stock Biomass (Total and Spawning)

The predicted total biomass and spawning stock (mature female plus male) biomass are summarized in Table 3.11 and Figures 3.33 – 34. Both trends in biomasses gradually decreased through time from 1950 until about the year 2000, then became stable but variable through 2017, then began increasing again through 2024 (Figures 3.33 – 34).

The unfished spawning stock biomass (SSB_0) was estimated at 5,462.14 mt (Table 3.11, Figure 3.34a) where the estimated female spawning biomass was 1,391 mt and the male biomass as 4,071 mt (Figure 3.34b). In 1986, the depletion ratio (SSB/SSB_0) was 0.446 and decreased to an average 0.223 from 1995 – 2017; it was lowest from 2006 – 2010 (avg. ratio = 0.189) but since 2018 has increased in trend from 0.246 to 0.382 in 2024 (Table 3.11). Temporal trends in spawning biomass appeared to be influenced predominantly by changes in male spawning biomass, whereas female spawning biomass showed greater stability through time (Figure 3.34b), consistent with the historical tendency of males being targeted more heavily than females.

3.5.2 Recruitment

The relationship between spawning biomass and age-0 fish as parameterized by the Beverton-Holt stock-recruitment model is presented in Figure 3.35. The *steepness* parameter was estimated at 0.472, the *sigmaR* parameter was estimated at 0.449, and the $\ln(R0)$ parameter was estimated at 8.000 (Table 3.10), which equates to 2,981,882 age-0 Hogfish.

The estimated annual recruitment of age-0 Hogfish to the biological population in the Florida Keys/East Florida is summarized in Table 3.11 and Figure 3.36a-b. From 1950 – 1980, age-0 recruitment followed the stock-recruitment curve, declining gradually as the population declined through time (Figure 3.36a). Recruitment was stable but variable from 1981 – 1992 (avg. 2.257 million fish), diminished considerably from 1993 – 1998 (avg. 0.942 million fish), then began gradually increasing in trend again with variation through 2024 to 2.052 million fish (Figure 3.36a). Recent notably high years of recruitment were estimated to be in 2007 (2.523 million fish), 2012 (2.486 million fish), 2013 (2.032 million fish), and 2015 (2.830 million fish). Higher recruitment may also likely have occurred for years 2022 – 2024 based on the trend in both RVC indices as well as additional models developed during this process which estimated annual deviations in recruitment through 2024 (e.g., see the MCMC ‘proxy’ model description above in Section 2.13.1). Uncertainty in the estimated recruitment was highest during the 1980s when only catch and sparse fishery length composition data were available.

Annual deviations of estimated recruitment from the stock-recruitment curve were configured from 1981 – 2021 and followed the annual trend of the estimated recruitment above (Figure 3.36b). Values deviated around the stock-recruitment curve, except between 1993 and 1998 where they were negatively deviated, and from 2016 – 2021 where they were slightly but continually positively deviated (Figure 3.36b). The estimated (and applied) recruitment bias adjustment ramp as recommended by Methot and Taylor (2011) is shown in Figure 3.37.

3.5.3 Fishing Mortality

The annual exploitation fishing mortality rates on Florida Keys/East Florida Hogfish are presented in Table 3.12 and Figure 3.38. Exploitation rates generally followed the trend in catch; between 1981 and 1994 exploitation averaged 0.102 yr^{-1} with a high in 1988 (0.217 yr^{-1}). From 1995 – 2017, exploitation

rates were variable with notable highs in 2005 ($F = 0.262 \text{ yr}^{-1}$), 2009 ($F = 0.216 \text{ yr}^{-1}$), and 2015 ($F = 0.179 \text{ yr}^{-1}$; Table 3.12, Figure 3.38). After new regulations (SAFMC Snapper Grouper Amendment 37) were implemented near the end of 2017, exploitation averaged 0.022 yr^{-1} for years 2018 – 2024.

Fleet-specific fishing mortality rates (i.e., instantaneous apical rates representing the fishing mortality level on the most vulnerable age class) are also provided in Table 3.12 and Figure 3.39. Apical fishing mortality rates were considerably higher for the recreational fleet and, like the exploitation rates above, followed the trend in annual catch. In contrast, commercial fishing mortality rates were very low but were highest between 1986 – 2005 (Table 3.12, Figure 3.39).

3.5.4 Selectivity and Retention

Selectivity for all fleets and indices was estimated using length-based selectivity functions which the KEYS base model used to further derive age-based selectivity (Figures 3.40 – 44). Fishing fleet-specific length-based selectivity and/or retention patterns, as well as assumed discard mortality rates, are illustrated in Figures 3.40 – 41.

Selectivity of Hogfish for the commercial fleet was time-varying to follow changes in minimum size regulations; without discard estimates (which must be assumed negligible) or discard length composition data, selectivity here functions as retention. Selectivity was dome-shaped generally between 27 – 41 cm FL from 1950 – 1994, 29 – 41 cm FL from 1995 – 2017, and 39 – 53 cm FL from 2018 – 2024; an asymptote of 60% was reached in all three time blocks (Figure 3.40). In the first two time blocks, fish became vulnerable beginning at age-2 before becoming more fully selected by ages 5 and 6; age-derived selectivity of fish in the 2018 – 2024 time block was more gradual due to the increase in minimum size, beginning around age-3 and continuing to age-16 (Figure 3.43).

Dome-shaped selectivity of Hogfish by the recreational fleet was generally between 23 – 54 cm FL, reaching an asymptote of 9% by 55 cm FL (Figure 3.41). Age-derived selectivity was primarily across ages 2+ with fuller selectivity occurring between ages 4 – 6 (Figure 3.44). Retention was time-varying and fish were fully retained by 9 cm FL from 1950 – 1994 (Figure 3.41a), 33 cm FL from 1995 – 2017 (Figure 3.41b), and 55 cm from 2018 – 2024 (Figure 3.41c). Note that where retention was estimated to occur well below 23 cm FL from 1950 – 1994, it meant fish vulnerability still followed the estimated selectivity curve and that, given the absence of minimum size limits, whatever negligible number of fish were encountered were retained. Furthermore, this time period contained no discard length composition data; thus, discards-at-length from 1950 – 1994 followed selectivity and the additive inverse of retention. From 1995 – 2017, Hogfish were discarded largely between 21 – 33 cm FL (Figure 3.41b), whereas fish from 2018 – 2024 were discarded in greater proportion across a wider range from 21 – 51 cm FL due to the increased minimum size limit and reduction in daily bag limit (Figure 3.41c).

The selectivity (vulnerability to observations by divers) of Hogfish by the RVC Florida Keys index was dome-shaped, occurring mostly between 11 – 53 cm FL and reached an asymptote of 12% by 55 cm FL (Figure 3.42). Juvenile fish started to become vulnerable at about 9 cm and individuals became fully selected between 21 – 29 cm FL (Figure 3.42). Age-derived selectivity occurred across all ages with fish becoming more fully selected at ages 2 – 3 (Figure 3.44). In the RVC Dry Tortugas index, selectivity was dome-shaped and primarily occurred on larger individuals between 29 – 87 cm FL (Figure 3.42). As a result, age-derived selectivity appeared more flat-topped by gradually increasing from age 1 to the maximum age (Figure 3.44). Fish observed by the combined video index, which operated near and north of the Dry Tortugas but sampled deeper waters, began to be selected around 11 cm FL and became fully selected by 41 cm FL (Figure 3.42). Age-derived selectivity of this index started at age-1 and became more fully selected by ages 10+ (Figure 3.44).

3.6 Model Diagnostics

3.6.1 Convergence

The SEDAR 94 KEYS base model converged with a total objective function of 2314.27. The model contained no parameters on the bounds, had a small final gradient <0.0001 , and had a positive definite Hessian matrix. Highly correlated parameters were inspected, but all were found to be structurally correlated and therefore left as-is estimated in their different model phases.

The results of the jitter analysis found that no jittered runs contained a total likelihood lower than the base model, suggesting that the base model had converged on a global solution (Figure 3.45). From the 100 jittered runs, 70% had a low gradient (<0.0001) but the maximum gradient was 0.3174.

3.6.2 Goodness of fit

The joint residual plots for the indices (Figure 3.46a), mean length composition data (Figure 3.46b), the conditional age-at-length data (Figure 3.46c), and the mean general size composition data (Figure 3.46d) indicated reasonable fits to the data as combined RMSE values were 0.302, 0.023, 0.316, and 0.105 respectively. As illustrated by the loess-smoother and size of the boxplots, residual variability of the indices was more positively biased at the beginning of the timeseries due to the more poorly fit combined video index (RMSE = 0.38). When the RVC indices became available in 1999, the overall trend centered around zero through 2009 then became more negatively deviated until reaching near zero again in the terminal years (Figure 3.46a). Due to the application of super-periods, the frequency of mean length residuals was only during the start of those periods; residuals and interquartile ranges of these data were small and consistent across time, indicating general agreement with the fisheries and index data (Figure 3.46b). In the conditional age-at-length data, residuals were more negatively biased in the beginning and end of the timeseries as influenced by the poorer-fitting fishery-independent trawl ages (RMSE = 0.657) and, to a lesser extent, the recreational ages (RMSE = 0.234; Figure 3.46c). Lastly, the fits to the mean size data for the RVC indices were well and mostly centered around zero across the timeseries (Figure 3.46d).

The residual series of all three indices passed the runs test, indicating residuals were sufficiently random and without significant autocorrelation (Figure 3.47). The RVC Florida Keys index had a residual in 1999 larger than three standard deviations and this misfit in the KEYS base model was likely balancing with the trends of the other two indices that suggested abundance in prior years was more elevated. It's unclear if this low relative abundance reflects more localized depletion in the Florida Keys or reflects the survey design change in the sampling of available habitat. Earlier index values available during the Data Workshop (i.e., 1997 – 1998) also indicated low abundances; but rather than estimate time-varying catchability (as was done with this index in SEDAR 37 [2014]), the AW panel determined to further curtail the index to 1999 to account for the change in survey.

Only the recreational length composition data had sufficient observations for the runs test and passed (Figure 3.48a). The other length composition data had too few observations due to the application of the super-periods. For the RVC size composition data, both indices failed due to each having two years of residuals greater than three standard deviations with some possible temporal autocorrelation (Figure 3.48b). The KEYS base model estimated for each RVC index a more consistent mean size across time, however, the data showed greater annual variability in mean sizes causing some misfit as described above in Section 3.3.2. While the fits to the annual distributions would not change, these residual patterns may likely be improved if Francis data weighting was utilized since the changes to effective sample sizes would extend the confidence intervals for these annual mean lengths. The conditional age-at-length residuals for the commercial landings and both fishery independent fleets passed the runs test (Figure

3.49). The fishery independent spear ages had one residual greater than three standard deviations and, as noted above, the fishery independent trawl data showed large residuals. The residuals for the recreational landings failed the runs test and showed some positive temporal autocorrelation from 2009 – 2016 as well as a residual in 2004 greater than three standard deviations (Figure 3.49).

3.6.3 Model Consistency

3.6.3.1 Likelihood Profiles

The profile likelihood on the $\ln(R0)$ parameter revealed that the parameter was largely influenced by the recruitment and RVC size data components but conflicted with the index data component (Figure 3.50). The profile minimum agreed with the KEYS base model estimate of 8.0, but also indicated a parameter estimate between $\sim 7.8 - 8.2$ would not produce a significantly worse fit to the data (i.e., change in log-likelihood < 2 units). Agreement from the RVC size data component was primarily influenced by the RVC Dry Tortugas size data while the RVC Florida Keys size data preferred an $\ln(R0)$ estimate greater than 8.3. The length, discard, and conditional age-at-length data were largely non-informative to the $\ln(R0)$ parameter but showed some indication that the estimate should be > 7.2 and < 8.4 .

Similarly, the profile of the *steepness* parameter indicated influence from the recruitment component, but conflict with the index component. The profile minimum agreed with the KEYS base model estimate of 0.472 but showed a parameter estimate between 0.4 – 0.6 would not produce a significantly worse fit to the data (Figure 3.51). The recruitment component favored a *steepness* estimate between 0.35 – 0.5 while the index component suggested a much weaker stock-recruitment relationship (*steepness* > 0.75). The remaining length, size, discard, and conditional age-at-length data components were largely non-informative but indicated the parameter estimate should be > 0.35 .

3.6.3.2 Age-structured Production Models

The results from the ASPM indicate that for most of the timeseries there is enough information in both the catch and index data for the production function to largely drive the stock dynamics and for the model to be adequately informed about scale (Figures 3.52 – 53). The ASPM also greatly benefited from the F as a parameter configuration (process error) which allowed the model to access the observational error of the catch in order to compensate for the lack of recruitment deviations. In other words, rather than being able to adjust how many recruits will be needed to fit the upcoming data (bottom-up), the ASPM was able to tune fishing mortality to adjust the numbers in the population and fit the data (top-down). This resulted in the ASPM artificially estimating a significantly high exploitation rate in 1984 in order to reduce the spawning biomass low enough so that estimated recruitment (based on the stock-recruitment curve) would be low enough to fit the data through the mid-1990s (Figure 3.52a-c). After year 2000 when all three indices were available, the ASPM had a close enough estimate of absolute scale in which to adequately fit the indices (Figure 3.53b-d) and continued to follow the population trends of the KEYS base model.

The estimate of $\ln(R0)$ by all three models generally overlapped in distribution (Figure 3.53a) and corroborated the results of the $\ln(R0)$ profile. The ASPM with recruitment deviations (ASPMdev) estimated a slightly smaller population scale with larger exploitation rates but followed the same trend as the KEYS base model (and to a lesser extent the ASPM), indicating the inclusion of length and age composition data in the KEYS base model is still informative to estimates of population scale (Figure 3.52a-b). The trend in age-0 recruitment and recruitment deviations of the ASPMdev was also very similar to the KEYS base model, suggesting the model needed that process error in order to better fit the trends in the indices (Figure 3.52c-d). Indeed, without the influence of the composition data, fits to all three indices by the ASPMdev were improved.

Fits to the RVC Dry Tortugas index ($RMSE_{ASPMdev} = 0.109$; $RMSE_{ASPM} = 0.202$; Figure 3.53c; Table 3.13) were the best, followed by the RVC Florida Keys index ($RMSE_{ASPMdev} = 0.205$; $RMSE_{ASPM} = 0.310$; Figure 3.53a; Table 3.13). The combined video survey was the worse fitting of the three indices ($RMSE_{ASPMdev} = 0.352$; $RMSE_{ASPM} = 0.493$; Figure 3.53d; Table 3.13) with the ASPM largely underestimating the first 5 years of the survey.

3.6.3.3 Retrospective Analysis

The retrospective analysis showed a slight pattern in estimates of spawning stock biomass and exploitation after removing successive terminal years. Spawning stock biomass tended to decrease in trend while exploitation tended to increase in trend; thus, estimates of the population became more favorable with the addition of each successive year of data (Figure 3.54a-b). All runs were within the 95% confidence interval of the KEYS base model, converged, and contained no parameters on the bounds. Furthermore, the calculated values for Mohn's rho for SSB ($\rho_M = -0.112$; Table 3.14) and exploitation ($\rho_M = 0.112$; Table 3.14) were within the "acceptable" range for longer-lived species according to Hurtado-Ferro et al. (2015).

As mentioned earlier in Section 2.6, the KEYS base model's inclusion of process error in the form of recruitment deviations ending in 2021 and the sum-to-zero constraint eliminated the stronger retrospective pattern observed in earlier models. Also mentioned earlier in section 2.13.1 was the use of an MCMC 'proxy' model to aid in estimates of uncertainty in model parameters and derived quantities. Since this model had to remove the sum-to-zero constraint and extend recruitment deviations through 2024, we report a retrospective pattern could still be seen in that model. The calculated Mohn's rho value for SSB was -0.222 and 0.230 for exploitation; hence, we continued to treat this model as supplementary in providing further measures of uncertainty rather than a replacement to the KEYS base model.

3.6.4 Model Validation (Prediction Skill)

Retrospective forecasting showed that the one year forward projections were largely consistent with the overall estimated trend in the reference model and were similar in trend to the results of the retrospective analysis (Figure 3.54a-b). All retrospective forecasts fell within the 95% confidence interval of the KEYS base model. The forecast rho value for spawning stock biomass increased slightly to $\rho_F = -0.099$ and exploitation decreased to $\rho_F = -0.095$ (Table 3.14), suggesting model stability as well as consistency when successive data became available.

A hindcast with cross-validation of the terminal seven years of data was performed to gauge predictive capacity of the KEYS base model. From the indices, eleven total observations were available, and a joint MASE score of 0.657 indicated the KEYS base model predicted these indices almost twice as accurately as a naïve forecast (Table 3.15). All three indices scored similar MASE values; the combined video survey was lowest (MASE = 0.63, Table 3.15), followed by the RVC Dry Tortugas index (MASE = 0.67, Table 3.15), and the Florida Keys index (MASE = 0.69, Table 3.15). Only the RVC Dry Tortugas mean size data indicated predictive capacity (MASE = 0.597, Table 3.15) while the number of super-period observations for commercial, recreational, and combined video mean length data precluded computing of prediction residuals. The MASE values for the conditional age-at-length (CAAL) data demonstrated low mean absolute errors and all CAAL data sources were better predicted by the KEYS base model than a naïve baseline prediction (joint MASE = 0.167; Table 3.15).

3.6.5 Sensitivity Runs

3.6.5.1 Start Year

The results from the sensitivity model using 1986 as a start year exhibited substantial consistency with the KEYS base model (Figure 3.55a – f). Estimates of exploitation (Figure 3.55a), spawning stock biomass

(Figure 3.55b), and recruitment (Figure 3.55e), were all on average <10% difference from the KEYS base model estimates. However, the differences between the two models came down to estimated differences in stock productivity and subsequent SPR-based reference points for biomass.

Since the data in the ‘StYr_1986’ model were insufficient to estimate a stock-recruitment relationship, *steepness* was fixed at 0.99. This meant that, although estimates of SSB and recruitment were similar between the two models, recruitment would be centered around the same average at lower stock sizes as it would be at larger and unfisher stock sizes (Figure 3.55f). This difference becomes significant primarily when considering reference points for the stock. For example, the estimates of exploitation at 30% and 40% SPR were largely consistent between the two models (KEYS base model = 0.190 and 0.128, ‘StYr_1986’ model = 0.186 and 0.133, respectively). However, the $SSB_{F40\%SPR}$ value estimated by the ‘StYr_1986’ model was 1,321.570 mt (compared to 912 mt by the KEYS base model) and the $SSB_{F30\%SPR}$ value was 989.077 mt (compared to 154.312 mt by the KEYS base model). Furthermore, the $SSB_{F30\%SPR}$ value estimated by the KEYS base model was in close proximity to equilibrium yield values nearing zero (see below Section 3.7) and contained high uncertainty (CV = 2.54). MSY-based reference points were also not possible for the ‘StYr_1986’ model given the absence of a stock-recruitment relationship.

Interestingly, profiling the *steepness* parameter in the ‘StYr_1986’ model indicated a significantly better model fit to the data (via total log-likelihood) when set well below 0.99 (Figure 3.55g) and was influenced most by both the recruitment component and the RVC size composition component.

3.6.5.2 Discard Mortality

The KEYS base model was rather insensitive to changes in discard mortality estimates. Higher (59%) discard mortality rates corresponded to higher exploitation rates, and vice-versa, but produced on average a 5% difference in annual exploitation from the KEYS base model (Figure 3.56a). Increases in exploitation corresponded to decreases in spawning stock biomass which overall only exhibited an average 2% change (Figure 3.56b). Age-0 recruitment was nearly unchanged with <1% average difference (Figure 3.56c).

3.6.5.3 Natural Mortality

The differing assumptions on natural mortality primarily resulted in mortality-at-age values which were higher than those input to the KEYS base model, especially at the youngest ages (Figure 3.57a). In the KEYS base model, age-3 fish experienced $M = 0.279 \text{ yr}^{-1}$ based on the Lorenzen (1996) mortality-at-weight equation (see Section 2.7 in the Data Workshop Report). The three sensitivity runs, ‘HamelCope_age3’, ‘est_HamelCope_age3’, and ‘est_HamelCope_age3_noprior’ resulted in age-3 M values of 0.338 yr^{-1} , 0.435 yr^{-1} , and 0.312 yr^{-1} , respectively. Estimates of exploitation rate (Figure 3.57b) and spawning stock biomass (Figure 3.57c) were consistent and were within the uncertainty provided by the KEYS base model. However, a scalar pattern that emerged was that as M increased across scenarios, so did estimates of age-0 recruitment (Figure 3.57d). This makes sense because the greatest increases to *M-at-age* occurred on age-0 individuals; therefore, the model needed to generate more age-0 fish to ensure enough adult fish were available in the population.

From a likelihood perspective, both the ‘HamelCope_age3’ and ‘est_HamelCope_age3_noprior’ scenarios fit the data similarly to the KEYS base model (i.e., within 2 LL units) and produced comparable estimates of life history and stock-recruitment parameters. For example, estimated (L_{inf}) values were 54.0 and 52.5 cm FL, respectively, while *steepness* estimates were 0.44 and 0.46. These results were particularly informative because when the model was allowed to freely estimate natural mortality internally without a prior (i.e., ‘est_HamelCope_age3_noprior’), the outputs closely aligned with those of the KEYS base model.

Surprisingly, when M was estimated internally using the standard deviation prior in log-space, it resulted in a significantly higher M and poorer model fits to the data (via LL). In response, the model adjusted several life history and stock-recruitment parameters to compensate for the elevated mortality. Virgin recruitment (R_0) and annual recruitment, on average, was nearly four times greater than the KEYS base model and L_{inf} increased to 64.2 cm FL. With this larger asymptotic length, the model consistently underestimated mean lengths for fish ages 1–11 as the growth coefficient (k) was reduced to 53% ($k = 0.095$) the value estimated by the KEYS base model.

3.7 Per-recruit Analyses

The yield-per-recruit (YPR), spawner-per-recruit (SSB/R), static spawning potential ratio (SPR), and total equilibrium yield analyses were computed as a function of the instantaneous exploitation rate on Florida Keys/East Florida Hogfish and are presented in Table 3.16 and Figures 3.58 – 59a. Presented with these values is also their relation to various MSY- and SPR-based reference points. The SPR values by year were calculated and are presented in Figure 3.59b. The retained yield at F_{MSY} for Florida Keys/East Florida Hogfish was estimated to be 94.552 mt (208,451 lbs.; Figure 3.58d) while the total yield (retained yield plus dead discards) at F_{MSY} was 165.068 mt (363,913 lbs.; Figure 3.58c). The retained yield associated with $F_{40\%SPR}$ was estimated at 71.100 mt (156,749 lbs.; Figure 3.58d) but at $F_{30\%SPR}$ was estimated to be 17.249 mt (38,027 lbs.; Figure 3.58d) with high uncertainty ($CV = 2.54$).

3.8 Uncertainty in Parameters and Derived Quantities

3.8.1 MCMC Analysis

Of the eight chains produced, only six were found to have converged based on Geweke’s diagnostic; thus, a total of 2,400 iterations remained. The six chains were combined, and convergence was evaluated using trace plots (Figure 3.60) and the Gelman and Rubin’s (1992) potential scale reduction factor (PSRF) for selected model parameters ($\ln(R_0)$, SSB_0 , and *steepness*) and derived quantities (exploitation in 2024, SSB in 2024, F_{MSY} , SSB at F_{MSY} , and the retained yield at F_{MSY}). PSRF values for all selected parameters and stock status criteria were close to 1 and since none of the PSRF upper confidence intervals exceeded the ‘rule of thumb’ value of 1.1, it was concluded that the MCMC converged (Table 3.17).

Posterior distributions from the MCMC ‘proxy’ model were produced for stock-recruitment parameters (Figure 3.61) as well as the derived quantities of $F_{current}$ (Figure 3.62a), F_{MSY} (Figure 3.62b), the retained yield associated with F_{MSY} (Figure 3.62c), $SSB_{current}$ (Figure 3.62d), SSB at F_{MSY} (Figure 3.62e), 75% of the SSB at F_{MSY} (Figure 3.62f), $F_{40\%SPR}$ (Figure 3.63a), and SSB at $F_{40\%SPR}$ (Figure 3.63b). Estimated values of the KEYS base model were generally found to fall within the interquartile ranges of these posterior distributions (Figures 3.61 – 63) which further evidenced the MLE values were not “captured in a strange neighborhood”. Given the high uncertainty of 30% SPR-based reference points estimated by the KEYS base model, posterior distributions were not attempted.

3.8.2 Parametric Bootstrap

Results of the bootstrap analysis indicated that the model exhibited a measure of instability when fitting to the randomly generated data sets. From the 1,000 bootstrapped data sets, 669 runs had a gradient >0.0001 yet the maximum gradient observed was still relatively low at 0.707. A total of 746 runs had at least one parameter on the bounds. However, distributions of selected parameter estimates and derived quantities were largely consistent with those observed in the posterior distributions from the MCMC ‘proxy’ model and the KEYS base model estimates generally fell within the interquartile ranges (Figure 3.64).

3.9 Stock Status Determination Criteria

A summary of the Florida Keys/East Florida Hogfish stock status determination criteria and their values as presented in the TORs and according to the SAFMC from the SEDAR 94 KEYS base model is presented in Table 3.18. Stock status of Florida Keys/East Florida Hogfish was considered in SEDAR 37 (2014) according to both MSY and MSY_{proxy} based reference points (e.g., SPR 30%) and *steepness* was estimated to be 0.83 using a full beta prior ($h = 0.748$, $sd = 0.146$) based on Shertzer and Conn (2002). Subsequently, the SAFMC Snapper Grouper Amendment 37 set MSY to $F_{30\%SPR}$. The KEYS base model also estimated the *steepness* parameter with the assumption of a stock-recruitment relationship and we continue by presenting both MSY- and SPR-based reference points for consideration (Figures 3.65 – 66). However, while SPR-based reference points are characterized here, it should be noted that due to the lower value of the *steepness* parameter estimated by the KEYS base model ($h = 0.47$), most 30% SPR reference points were estimated with high uncertainty (i.e., $CV > 2$).

The Maximum Fishing Mortality Threshold (MFMT) for Florida Keys/East Florida Hogfish is currently defined as $F_{30\%SPR}$ and overfishing is occurring if the recent average of fishing mortality rates ($F_{current}$) exceeds the MFMT. $F_{current}$ is calculated as the geometric mean of exploitation rates for 2022 – 2024. Based on this, the MFMT was estimated by the KEYS base model to be 0.190 yr^{-1} , $F_{current}$ was estimated to be 0.020 yr^{-1} , and F_{2024} was estimated to be 0.016 yr^{-1} (Figure 3.66a). The F_{MSY} was estimated to be 0.077 yr^{-1} (Figure 3.65a) and $F_{40\%SPR}$ was estimated to be 0.128 yr^{-1} (Figure 3.66a). Using either of these reference points, the Florida Keys/East Florida Hogfish stock was not found to be experiencing overfishing ($F_{current}/F_{30\%SPR} = 0.105$; $F_{current}/F_{MSY} = 0.258$; $F_{current}/F_{40\%SPR} = 0.156$).

The minimum stock size threshold (MSST) for Florida Keys/East Florida Hogfish is currently defined as 75 percent of the spawning stock biomass associated with $F_{30\%SPR}$ (i.e., $0.75 * SSB_{F_{30\%SPR}}$). The stock is overfished if the recent average spawning stock biomass ($SSB_{current}$) is less than MSST. The $SSB_{current}$ is calculated as the geometric mean of the spawning stock biomass for 2022 – 2024 and was estimated to be 1,964.579 mt (2,204.623 lbs.) with SSB_{2024} estimated to be 2,084.69 mt (4,595,955 lbs.). The $SSB_{F_{30\%SPR}}$ was estimated by the KEYS base model with high uncertainty ($CV = 2.54$) at 154.312 mt (340,200 lbs.) and MSST was therefore defined as 115.734 mt (255,150 lbs.; Figure 3.66b). The SSB_{MSY} was estimated at 1,952.400 mt (4,304,305 lbs.; Figure 3.65b) and the $SSB_{F_{40\%SPR}}$ was estimated at 912.573 mt (2,011,879 lbs.; Figure 3.66b). Based on these results, the Florida Keys/East Florida Hogfish stock was not found to be overfished ($SSB_{current}/SSB_{F_{30\%SPR}} = 16.975$; $SSB_{current}/SSB_{MSY} = 1.342$; $SSB_{current}/SSB_{F_{40\%SPR}} = 2.870$).

From the posterior distributions of the MCMC ‘proxy’ model, the median value for F_{MSY} was estimated to be 0.099 yr^{-1} (Figure 3.62b), $F_{current}$ was estimated to be 0.019 yr^{-1} (Figure 3.62a), SSB_{MSY} was estimated to be 1,650.74 mt (3,639,259 lbs.; Figure 3.62e), $MSST_{MSY}$ was 1,238.055 mt (2,729,444 lbs.; Figure 3.62f), and $SSB_{current}$ was estimated to be 2,084.086 mt (4,594,623 lbs.; Figure 3.62d). Median values of $F_{40\%SPR}$ and $SSB_{F_{40\%SPR}}$ were 0.133 yr^{-1} (Figure 3.63a) and 1,124.165 mt (2,478,360 lbs.; Figure 3.63b), respectively. The MCMC distribution of the retained yield at F_{MSY} had a median value of 97.388 mt (214,704 lbs.; Figure 3.62c). Additional posterior distributions of the MSY-based F_{ratio} ($F_{current}/F_{MSY}$) and SSB_{ratio} ($SSB_{current}/MSST_{MSY}$) are presented in Figure 3.67 where median values were 0.193 and 1.685, respectively. The estimates for these reference points as derived by the KEYS base model were just outside the interquartile ranges of these posterior distributions; however, the uncertainty indicated a more favorable stock condition, namely that the F_{ratio} was lower (Figure 3.67a) and the SSB_{ratio} was higher (Figure 3.67b). The distribution of the F_{ratio} was entirely below one, indicating a high probability that overfishing is not occurring while 99% of the distribution for the SSB_{ratio} was above one, indicating a high probability that the stock is not overfished.

3.10 Bridge Building

The SEDAR 37 base model characterized a stock that was heavily depleted in the start year and remained depleted through the terminal year. This was very different in comparison to the SEDAR 94 KEYS base model which estimated around double or more the spawning stock size for most overlapping years and the bridge building model which estimated more of a middle ground between the two (Figure 3.68a).

Typically, this display of model behavior in SS would be identified with some temporal or configuration misspecification and addressed. Unfortunately, however, at the time of the SEDAR 37 assessment the diagnostic capabilities of SS were not as developed as we have available today and misspecifications were missed in that model development process. For example, by applying the ‘cookbook’ diagnostics to the SEDAR 37 base model, the ASPM model immediately crashed the population without access to the composition data or recruitment deviations while the ASPMdev model was near exact to the base model; this suggests the base model sustained the population almost entirely on the process error of recruitment deviations. Corresponding to the trend in SSB, estimates of exploitation rate in the SEDAR 37 base model were higher than reported here but tended to follow the same trend. Exploitation rates from the bridge building model were closer in scale to the KEYS base model and typically fell within the 95% confidence intervals (Figure 3.68b). Age-0 recruitment of the bridge building model was more often similar to the KEYS base model while the SEDAR 37 base model was closer in magnitude to the lower 95% confidence interval (Figure 3.68c).

However, stock-recruitment dynamics were quite different between all three models (Figure 3.68d) due to differences in available data and configuration. For example, *steepness* was estimated in both the KEYS base model and the SEDAR 37 base model, but at very different values (S94: $h = 0.472$; S37: $h = 0.829$). In SEDAR 37, the *steepness* parameter was not configured for use in the initial equilibrium recruitment which meant any decline in SSB between SSB_0 and the start year did not correspond with any decline in recruitment (i.e., $h = 0.99$). Depletion in the 1986 start year was significant (~90%) and since the SSB_0 estimate was similar to the KEYS base model estimate, the absence of any reduction in recruitment was influential to the *steepness* parameter and resulted in a comparatively higher value. The KEYS base model also had access to the historic catch data which greatly informed the *steepness* parameter. In contrast, the bridge building model, without the historic catch data or a prior, had a difficult time estimating *steepness* and needed to be fixed at 0.99. This resulted in similar SSB and recruitment magnitudes (Figure 3.68a,c) but also higher recruitment estimates during the 1990s when stock size was much lower.

Lastly, a continuity model which aimed at exploring the impact of updating the recreational landings timeseries from the old MRFSS/MRIP to the SRFS back-calculated historical timeseries within the SEDAR 37 base model was developed (i.e., “SEDAR 37 SRFS”). For each gear, spear (Figure 3.69a) and hook-and-line (Figure 3.69b), the differences in catch magnitude between the two survey methods were minimal and higher SRFS estimates became more consistent starting in 2004 (Figure 3.69c). This was not too surprising as the SRFS estimates for these years (1986 – 2012) behave more like a scalar reduction to the MRIP estimates. Consequently, differences in model estimated population dynamics were minimal as trends in spawning stock biomass (Figure 3.70a), recruitment (Figure 3.70b), and exploitation rate (Figure 3.70c) were often within the uncertainty estimated by the SEDAR 37 base model in the first half of the timeseries before becoming higher through 2012.

3.11 FL KEYS/EFL Discussion

The SEDAR 94 Florida Keys/East Florida Benchmark Assessment incorporated fourteen years of new data since the previous assessment (SEDAR 37; terminal year = 2012); changes to the data took place in nearly every component and all historical data were procured and recompiled following SEDAR Data

Best Practices as closely as possible. This assessment utilized stock-specific characterizations of life history data, reanalyzed older reproduction data according to recent recommendations (Lowerre-Barbieri et al. 2022), and applied recent methods to estimate natural mortality (Hamel and Cope 2022; Lorenzen 2022). It made use of revised estimates of recreational landings and discards (via SRFS and SRFS-calibrated data for the Florida private mode and MRIP-FES data for charter and shore modes), incorporated historic commercial landings and reconstructed recreational landings, and revised recreational discard mortality rates based on recent data collections. Lastly, this assessment incorporated additional fishery-independent age-at-length data and updated original fishery-independent surveys but removed several fishery-dependent CPUE timeseries.

Data used in the KEYS base model were often characterized by high uncertainty and limited availability, necessitating several configuration changes to maintain model parsimony. One of the most important changes involved the treatment of fishing fleets. Recreational landings, discards, and composition data separated by spear and hook-and-line gears were highly uncertain, with annual CVs frequently exceeding 0.5 and sample sizes often being low. To address these limitations, the gears were combined into a single recreational fleet, resulting in modest improvements in the precision of landings and discard estimates. However, annual CVs still commonly exceeded 0.3 – 0.5, and length-composition data remained noisy, requiring the use of super-periods to increase effective sample sizes. Similar challenges existed for the commercial fishery. Although commercial landings estimates were relatively precise, annual sample sizes for composition data were low, discard estimates were unavailable, and commercial landings represented only a small proportion of total landings (on average, less than 5%). As a result, commercial gears were also aggregated into a single fleet, and super-periods were applied to the length-composition data. These data limitations underscore the importance of improving more targeted and consistent biological sampling in both the recreational and commercial fisheries to reduce uncertainty in model estimates and strengthen future Hogfish stock assessments.

By configuring recreational fishing mortality as an annual parameter within the KEYS base model, uncertainty in the recreational landings and discard data could be better accommodated. The model generally reproduced the observed trend and magnitude of recreational landings, although it estimated higher landings in 1988 and lower landings in 2008, 2012, and 2015. These deviations were linked to the model's interpretation of population dynamics. Specifically, the model estimated a decline in female numbers-at-age during the late 1990s and early 2000s, a signal that was likely informed by the co-occurring period of low recreational landings. To generate this reduction in females, the model first estimated a decline in mean male numbers-at-age beginning in 1988, which reduced reproductive output. Because sex transition in the model is governed by the cumulative hermaphroditism function, the initial decline in males subsequently propagated through the population and contributed to further reductions in female numbers, which in turn led to continued reductions in mean male numbers-at-age through approximately 2009. As spawning biomass declined, the model was unable to produce enough fish to support the unusually high recreational landings estimates observed in several later years. Consequently, the model favored lower landings estimates in those years to remain consistent with the broader population dynamics implied by the full dataset. The configuration of recreational fishing mortality to annual parameters was supported by a runs test of the recreational landing's residuals from 1981 – 2024, which indicated the residuals were sufficiently random and lacked significant temporal autocorrelation ($p = 0.36$). Additional support came from a sensitivity analysis conducted during the model development process in which recreational landings were fit exactly (i.e., F_{hybrid}). Although that configuration improved agreement with the recreational landings data, it produced poorer fits to other data sources, particularly the abundance indices, discards, and length composition data. Together, these results suggest that

allowing the model flexibility to deviate from the input recreational landings estimates resulted in a more internally consistent fit across all available datasets.

Historically, the recreational private mode catch time series has been the largest contributor to recreational landings and discards for the Florida Keys/East Florida Hogfish stock. In recent stock assessments, incorporation of Florida's SRFS data effectively acted as a scalar reduction to the pre-2021 private mode catch series, resulting in reductions to estimates of spawning stock biomass and productivity when comparing to models utilizing the MRIP-FES calibration. This pattern was observed in the SEDAR 79 (2024) Mutton Snapper benchmark assessment and the SEDAR 96 (2024) Yellowtail Snapper operational assessment. For Hogfish, however, the ad-hoc calibrated MRFSS-MRIP estimates used in SEDAR 37 were already similar in magnitude to the "Full SRFS" estimates evaluated here and the MRIP-FES calibration estimates were never used in a Florida Keys/East Florida Hogfish assessment. As a result, incorporating SRFS produced only minor changes in estimated stock size and exploitation rates, as demonstrated by the "SEDAR 37 SRFS" continuity model. In contrast, results from the "S37data_S94config" continuity model indicated that the larger difference in biomass estimates between the KEYS base model and the SEDAR 37 base model were driven primarily by the configuration changes implemented for SEDAR 94. These findings suggest that model structural and configuration changes, rather than the adoption of SRFS catch estimates, were the primary source of the observed differences in estimated biomass.

In SEDAR 37, all three Hogfish stocks in the southeastern U.S. were assumed to exhibit the same life history characteristics where knowledge on growth, mortality, reproduction, and hermaphroditism was predominantly informed by West Florida Shelf data. Thus, a key modification to the KEYS base model in the current assessment was the incorporation of stock-specific life-history information for the Florida Keys/East Florida stock. Central to this effort was the availability and inclusion of fishery-independent CAAL data from multiple life-history studies, which allowed growth to be estimated directly within the assessment model. Although some of these data were available during SEDAR 37 (e.g., the McBride dataset), they were not incorporated as direct model inputs. Without these fishery-independent data, the SEDAR 37 model could not reliably estimate growth, as reported therein by a sensitivity run which estimated an asymptotic length of 42.6 cm FL. In contrast, growth parameter estimates from the KEYS base model were consistent with those from the external growth model developed during the Data Workshop and the estimated plateau parameter (0.73) indicated evidence of age truncation and Lee's phenomenon within the Florida Keys/East Florida stock (McBride and Richardson 2007). Estimates of mean length-at-age for platoon 4 (63.1 cm FL at age 16) and platoon 5 (77.8 cm FL at age 16) were further supported by observations of larger Hogfish within the commercial length composition data (i.e., commercial TIP data from northeast Florida that were not aged) and anecdotally by fish observed but not measured during dives in the Dry Tortugas (D. Morley, *pers. comm.*). Similarly, mean length-at-age estimates for platoons 3 and 4 were consistent with growth parameter estimates reported by Drake (2021) for Hogfish sampled in Puerto Rico and the U.S. Virgin Islands ($L_{inf} = 62.4$ cm FL), where habitat conditions are more comparable to the Florida Keys reef tract than to those of the West Florida Shelf or northeast Florida regions (see also section 2.9.4 of the Data Workshop report for comparative discussion on the growth estimates from Cuba). Lastly, incorporating stock-specific hermaphroditism transition rates allowed the KEYS base model to better represent the earlier female-to-male transition observed in the Florida Keys/East Florida stock. Overall, this assessment has benefited substantially from the incorporation of targeted life-history research and the use of stock-specific biological information.

The development and application of the MCMC "proxy" model in this assessment was an uncommon approach but may provide a useful pathway for future Stock Synthesis assessments that benefit from the

flexibility of the F as parameter configuration. This may be particularly valuable when catch data contain considerable observation error and there is a desire to characterize uncertainty beyond model-based standard errors or self-testing bootstrap analyses. Stock Synthesis models configured with the F_{hybrid} approach typically fit landings almost exactly, effectively ignoring observation error and assuming that catches are known without uncertainty. In the southeastern U.S., this assumption is often reasonable for commercial fisheries because monitoring programs function more like a census than a statistical survey and observation error is low ($CV = 0.05$). However, as demonstrated in this assessment, recreational landings estimates from private, shore, and charter modes are survey-based and can contain considerable uncertainty that should be accounted for within the assessment framework. Estimating F as a parameter allows uncertainty in landings to be integrated with other data sources, enabling the model to estimate catches that differ slightly from the survey estimates while remaining within the bounds of the reported observation error. The MCMC “proxy” model therefore retained the same underlying assumption of a “known” catch used in other F_{hybrid} configurations but treated the KEYS base model’s expected catch values as the reference truth rather than the original survey estimates (e.g., SRFS or MRIP). But when including annual fleet-specific F values in an MCMC routine, it greatly expands the parameter space and often causes simulants to explore regions far from the MLE estimates. The MCMC “proxy” model therefore provided a practical configuration workaround for the KEYS base model, capturing uncertainty in parameters and derived quantities while relying on the landings estimates generated by the KEYS base model.

The results of the model diagnostics suggest the SEDAR 94 KEYS base model may be suitable for use in the management of Florida Keys/East Florida Hogfish. The KEYS base model demonstrated adequate fits to the various data components while the jitter analysis and low gradient (<0.0001) lent support that the KEYS base model converged to a global solution. The KEYS base model also exhibited model consistency as the removal of successive years of data back to the 2018 (first model year of new regulations) showed no discernable retrospective patterns in estimates of exploitation rates and spawning stock biomass. The results of the $\ln(R0)$ profiling, as well as the ASPM and ASPMdev, suggested that the estimates of absolute abundance and trend were consistent and primarily influenced by both the catch information and the variability in recruitment. Retrospective forecasting and the hindcast cross-validation techniques also suggested the KEYS base model exhibited more predictive skill than a random-walk for several data sources.

The MSY-based reference values for Florida Keys/East Florida Hogfish as estimated by the SEDAR 94 KEYS base model moderately supported the historical stock status paradigm of the prior assessments by indicating that the stock experienced intermittent overfishing over a 36-year period and remained overfished for 22 years. Exploitation rates oscillated above and below the candidate F_{MSY} largely between 1981 – 2017; from 1950 – 1980 and from 2017 – 2024 they were estimated below F_{MSY} . The estimated spawning stock biomass dropped below the candidate SSB_{MSY} target in 1993 but rose above it again in the terminal year 2024; the stock was below the candidate MSST_{MSY} from 1996 – 2018. Using these reference point values, the current stock would not be undergoing overfishing ($F_{\text{current}}/F_{\text{MSY}} = 0.258$), nor would it be considered overfished ($\text{SSB}_{\text{current}}/\text{MSST}_{\text{MSY}} = 1.342$). However, estimates of stock condition based on SPR reference values by the KEYS base model differed substantially from this historical perspective. Using the candidate $F_{40\% \text{SPR}}$ proxy, exploitation rates were mainly below $F_{40\% \text{SPR}}$ with only eight years above it. The spawning stock biomass has remained above both a candidate $\text{SSB}_{F40\% \text{SPR}}$ target (reaching it in 2006) and $\text{MSST}_{F40\% \text{SPR}}$ for the duration of the timeseries. From these reference point values, the current stock would also be considered not overfished ($\text{SSB}_{\text{current}}/\text{MSST}_{F40\% \text{SPR}} = 2.870$), nor undergoing overfishing ($F_{\text{current}}/F_{40\% \text{SPR}} = 0.156$). For either of these candidate reference values, the uncertainty in derived quantities was well captured by both the MCMC and bootstrapping analyses with

distributions inclining towards even more favorable stock conditions. In addition, the Florida Keys/East Florida Hogfish stock has shown signs of recovery since 2018, both in observed measures (e.g., RVC indices) and in model-based estimates, likely due in part to the regulatory changes implemented in late 2017.

The SAFMC Snapper Grouper Amendment 37 defines MSY as $F_{30\%SPR}$ and the MSST as 75% of $SSB_{F_{30\%SPR}}$. Under these reference values, the SEDAR 94 KEYS base model indicates that the current Florida Keys/East Florida Hogfish stock is also neither overfished ($SSB_{current}/MSST > 1.0$) nor undergoing overfishing ($F_{current}/MFMT < 1.0$). However, these reference values provide the least protection for the stock as the stock would need to undergo considerable decline to trigger any management intervention moving forward. Current biomass was estimated to be nearly 17 times the MSST, with no evidence of an overfished condition since 1950. The assessment identified only a few years of overfishing having occurred – 1988, 2005, and 2009. The per-recruit analysis conducted in this assessment indicated that $F_{30\%SPR}$ maximizes yield-per-recruit, but it led to very low long-term yields and was estimated to be highly uncertain. Furthermore, projection analyses suggested yields at this exploitation rate were not sustainable. By comparison, F_{MSY} reduced yield-per-recruit by 32% but increased equilibrium total yield by 486% (74,902 to 363,913 lbs.), while $F_{40\%SPR}$ yielded a 13% reduction in yield-per-recruit but a 387% increase in total yield (to 289,974 lbs.). Overall, F_{MSY} (0.077 yr^{-1}) was more conservative than $F_{40\%SPR}$ (0.128 yr^{-1}) but produced higher equilibrium yields, supporting consideration of alternative candidate reference points to $F_{30\%SPR}$ for this stock.

The disparity in $F_{30\%SPR}$ values between the SEDAR 37 FLK/EFL base model and the SEDAR 94 KEYS base model was primarily driven by differences in model configuration, life-history assumptions, and estimates of stock productivity. Notably, the *steepness* parameter was estimated at $h = 0.83$ in the SEDAR 37 FLK/EFL base model, compared with $h = 0.47$ in the current assessment. As demonstrated by the per-recruit analysis, these differences in stock-recruitment dynamics resulted in substantially different $F_{30\%SPR}$ estimates and corresponding positions on the equilibrium yield curve. Additional insight was provided by the “S37data_S94config” continuity model. Using $F_{30\%SPR}$ reference points and the geometric mean $F_{current}$ (2010 – 2012), this model suggested that applying configuration changes similar to those used in the current assessment to the SEDAR 37 FLK/EFL base model could have produced a more favorable terminal stock condition (e.g., $SSB_{ratio} = 1.24$ and $F_{ratio} = 0.70$). Consequently, the stock may have been perceived as being in better condition than indicated by the original assessment. Furthermore, evidence of undiagnosed model misspecification in the SEDAR 37 FLK/EFL base model, as indicated by the ASPM diagnostic described in Section 3.10, adds uncertainty regarding the validity of that model's conclusions. Taken together, the differences in model assumptions, configuration, and apparent misspecification led to substantially different perceptions of stock status and highlight the uncertainty associated with the SEDAR 37 FLK/EFL base model. These findings suggest that the contrasting stock status outcomes between the two assessments were driven more by differences in assessment methodology and underlying assumptions than by changes in the underlying population dynamics themselves.

3.12 FL KEYS/EFL Projections

Short- and long-term deterministic projections were conducted to estimate Florida Keys/East Florida Hogfish spawning stock biomass and yield under a range of harvest scenarios. These were performed under several assumed conditions: growth, and stock-recruitment parameters were kept constant (at values estimated by the SEDAR 94 KEYS base model) while relative apical F , selectivity, and discarding and retention associated with the terminal three years (2022 – 2024) would remain the same into the future. The average relative apical F values from 2022 – 2024 as estimated by the base model were used to determine the fleet allocations in the projection scenarios. These were 1.43% for the commercial fleet

and 98.57% for the recreational fleet. The method to project the assessment results was developed in the R statistical computing environment by SEFSC assessment scientists (<https://github.com/SEFSC/SFD-AllocationForecasting>).

Although the Florida Keys/East Florida Hogfish stock is currently managed using the $F_{30\%SPR}$ proxy reference point, projections from the KEYS base model (as well as the per-recruit analysis in Section 3.6) suggested this F value (0.189 yr^{-1}) was of much higher risk. In long-term equilibrium projections using the stock-recruitment curve, $F_{30\%SPR}$ held constant depleted the population to <20% within the first 7 years (by 2032) and was <5% in the terminal 10 years of the projections. By assuming recruitment to be constant at the whole timeseries average (1950 – 2024), the population declined until being 21% depleted in the final 10 years of the projections; however, results from the KEYS base model indicate it is unlikely recruitment could be sustained at that average given the degree of depletion. Furthermore, estimates of exploitation rate by the KEYS base model only exceeded this value in 3 years (1988, 2005, and 2009). Therefore, we discuss projections using the F_{MSY} and $F_{40\%SPR}$ proxy reference values but tabulate the $F_{30\%SPR}$ proxy reference value scenarios in Tables 3.19 – 20 to satisfy the TOR.

First, long-term deterministic projections were conducted to determine the equilibrium fishing mortality rate that achieves F_{MSY} or 40%SPR ($F_{40\%SPR}$), as well as the associated spawning stock biomass (SSB_{MSY} or $SSB_{40\%SPR}$), by using an iterative process to set exploitation rates each year that ensures 1) MSY or the MSY_{proxy} (i.e. SPR 40%) is achieved at equilibrium, and 2) annual relative apical fishing mortality between fleets is maintained at the average of the base model's terminal three years (2022 – 2024). This iterative process to achieve equilibrium F_{MSY} or $F_{40\%SPR}$ is different than the Newton-Raphson method utilized by the base model, thus results will be near-exact rather than identical to base model reference point values (Methot et al. 2026). Projections were for 100 years (2025 – 2124) where recruitment either followed the Beverton-Holt stock-recruitment relationship, as parameterized by the KEYS base model, or was held constant at the long-term (1950 – 2024) average; equilibrium was assumed to have been obtained in the final 10 years of the projection (i.e., 2115 – 2124) as recommended by Van Beveren et al. (2021). Please note, however, that due to the configuration of the KEYS base model where main recruitment deviations ended in 2021, projected recruitment within all scenarios *not* relying on the stock-recruitment curve began in 2022. This was a limitation imposed by the structural framework of SS and could not be changed.

Next, short-term deterministic projections, which used a similar iterative process as the long-term projections, were conducted under a range of harvest scenarios and assumed age-0 recruitment remained constant at the recent 5-year average (2020 – 2024) estimated by the KEYS base model (Schueller et al. 2022; Van Beveren et al. 2021). Per the TORs, short-term projections explored the effects of holding fishing mortality rates constant at the equilibrium F_{MSY} or $F_{40\%SPR}$ (as determined via the long-term projection above), at 75% of that equilibrium F_{MSY} or $F_{40\%SPR}$, and at $F_{current}$ (from section 3.8) in order to produce annual yield values. While only the first 5 years of the short-term projection are recommended for use, reported projections were extended until 2034.

3.12.1 Results

The projection results for the constant F scenarios including the associated fishing mortality rates, retained landings (in pounds and numbers), spawning stock biomass (mt), and age-0 recruitment (in numbers) as estimated for assessment years (1950 – 2024) and forecast years (2025 – 2044) are presented in Figures 3.71 – 78 and Tables 3.21 – 25. The equilibrium fishing mortality rate that achieved 40% SPR ($F_{40\%SPR}$) in the long-term projections was 0.129 yr^{-1} (Figure 3.71, Table 3.21) and was near exact to the KEYS base model estimate (0.128 yr^{-1}). Likewise, the equilibrium F_{MSY} in the long-term projection was 0.073 yr^{-1} (Figure 3.75, Table 3.24) compared to 0.077 yr^{-1} by the KEYS base model.

Retained landings from the long-term constant $F_{40\%SPR}$ projection scenario initially increased to values similar to yields prior to 2018, then quickly declined through the 5-yr projection period from 395,330 lbs. in 2025 to 315,678 lbs. in 2029 (Table 3.21, Figure 3.72). Spawning stock biomass declined in response to the higher exploitation rates but became similar to recent years since 2020 (Table 3.21, Figure 3.73); when following the stock-recruitment curve, SSB declined further until becoming more like the mid-2000s years (Table 3.21, Figure 3.73) as recruitment continued to decline through the projection period (Table 3.21, Figure 3.74).

Resulting trends from the short-term $F_{40\%SPR}$ scenario presented as a middle ground between the two long-term projection scenarios given the differing assumptions on recruitment (Table 3.22, Figures 3.71 – 74). $F_{40\%SPR}$ is higher than most exploitation rates estimated throughout the model timeseries and was nearly six-and-a-half times higher than recent exploitation rates ($F_{40\%SPR}/F_{current} = 6.43$). When exploitation rates were held at 75% $F_{40\%SPR}$ (0.097 yr^{-1} ; Table 3.22, Figure 3.71), they were a little higher than the whole timeseries (1950 – 2024) average of 0.065 yr^{-1} and were nearly five times higher than recent exploitation rates ($75\% F_{40\%SPR}/F_{current} = 4.82$). In the short-term $F_{40\%SPR}$ scenario, retained landings were 387,977 lbs. (114,417 fish) in 2025 and 295,513 lbs. (88,248 fish) in 2029 (Table 3.22, Figure 3.72). In the 75% $F_{40\%SPR}$ scenario, retained landings were 290,920 lbs. (85,881 fish) in 2025 and 254,188 lbs. (74,818 fish) in 2029 (Table 3.22, Figure 3.72). In both scenarios, projected SSB immediately declined (Table 3.22, Figure 3.73) but stabilized near recent year values due to the assumptions on recruitment (Table 3.22, Figure 3.74).

Results from both the long- and short-term constant F_{MSY} projection scenarios were comparatively more stable across time. The exploitation rate at F_{MSY} was nearly four times greater than the current exploitation rate ($F_{MSY}/F_{current} = 3.88$) and 75% F_{MSY} (0.054 yr^{-1} ; Table 3.25, Figure 3.75) was nearly three times greater ($75\% F_{MSY}/F_{current} = 2.91$). Unlike the $F_{30\%SPR}$ or $F_{40\%SPR}$ scenarios, whose initial spike in retained landings led to immediate declines in SSB and subsequent further declines in yield, the retained landings from the long- and short-term constant F_{MSY} scenarios (Tables 3.24 – 25, Figure 3.76) shaped more steady projections of the SSB (Tables 3.24 – 25, Figure 3.77) given the constant recruitment (Tables 3.24 – 25, Figure 3.78). Retained landings from the short-term constant F_{MSY} scenario were 217,900 lbs. (64,372 fish) in 2025 and 207,928 lbs. (60,588 fish) in 2029 (Table 3.25, Figure 3.76). In the 75% F_{MSY} scenario, retained landings were 163,401 lbs. (48,298 fish) in 2025 and 169,282 lbs. (48,986 fish) in 2029 (Table 3.25, Figure 3.76). Since recruitment in the short-term is held constant at values lower than the long-term or stock-recruit curve estimate (Table 3.25, Figure 3.78), SSB under the constant F_{MSY} scenario declined slightly; however, SSB under the constant 75% F_{MSY} scenario was steadier with a slight increase over time (Table 3.25, Figure 3.77).

Short-term projections for the $F_{current}$ scenario estimated comparatively lower F values (i.e., 0.020 yr^{-1} ; Table 3.23, Figure 3.71) and resulted in retained landings increasing to 59,990 lbs. (17,750 fish) in 2025 and 71,199 lbs. (20,355 fish) in 2029 (Table 3.23, Figure 3.72). Projected SSB continued to increase to values estimated similar to the 1980s, reaching 2,517.76 metric tons in 2029 (Table 3.23, Figure 3.73).

3.12.2 Discussion

The various constant F scenarios reflect progressing degrees of risk and management. As for many projection exercises, there were numerous caveats to the methods, including unchanging fleet selectivity and fleet allocations, growth, natural mortality, stock-recruitment parameters, other fixed quantities in the base model, process error in recruitment for the terminal three years, and assumptions of recruitment in future years. Projection results should, therefore, be interpreted carefully.

The estimates of retained yield from the first five years of the short-term $F_{30\%SPR}$ projection decreased from 570,132 to 339,973 lbs. and were similar in magnitude to the average retained landings across earlier parts of the timeseries (e.g., 1950 – 1994: avg. 365,791 lbs.; 1986 – 1994: avg. 562,018 lbs.) when the stock was experiencing its fastest decline. This scenario, and the 75% $F_{30\%SPR}$ scenario, present the highest risk given the greater landings and the underlying assumption that recruitment will not diminish with a depleting stock size, which occurred in the long-term equilibrium scenario when recruitment followed the stock-recruitment curve.

In the short-term constant $F_{40\%SPR}$ and 75% $F_{40\%SPR}$ scenarios, the estimated retained yield from the first five years were similar to the average yield from 1995 – 2017 (287,855 lbs.). During this period, spawning biomass remained above $SSB_{F_{40\%SPR}}$ and followed a more stable but variable trend, while exploitation rates fluctuated between levels that approached or exceeded $F_{40\%SPR}$. Furthermore, as the population's biomass began to increase again in 2018, projections under the constant $F_{40\%SPR}$ scenario suggest that, depending on recruitment assumptions, this increasing trend may be overturned.

The results from the short-term F_{MSY} projections were slightly more conservative than $F_{40\%SPR}$ and indicated a level of harvest that either would not significantly decrease the population from where it has recovered or allow much further recovery, thereby acting as an in-between of more recent (2018+) and prior (1995 – 2017) average yields.

The most conservative constant F scenario representing the least amount of risk was $F_{current}$ and was the only constant F projection where the SSB continued to recover (increase) though time. Results under this scenario represent a status-quo where projected yields were like the average landings from 2018 – 2024 (52,415 lbs.) with both SSB and exploitation rates projected to continue well within any MSY or SPR -based thresholds.

3.13 FL KEYS/EFL Tables

Table 3.1. Historic commercial landings (metric tons) and annual CVs of Florida Keys/East Florida Hogfish by gear for years 1950 – 1985.

Year	Landings (mt)				CV
	Spear	Hook-and-line	Trap	Combined	
1950	0.000	6.305	0.000	6.305	0.25
1951	0.000	11.340	0.000	11.793	0.25
1952	0.000	12.292	0.000	12.292	0.25
1953	0.000	11.294	0.000	11.294	0.25
1954	0.000	12.338	0.000	12.338	0.25
1955	0.000	11.022	0.000	11.068	0.25
1956	0.000	9.163	0.000	9.163	0.25
1957	0.000	4.128	0.000	4.128	0.25
1958	0.000	2.087	0.000	2.087	0.25
1959	0.000	2.449	0.000	2.449	0.25
1960	0.000	1.678	0.000	1.678	0.25
1961	0.454	0.726	0.000	0.726	0.25
1962	0.000	1.225	0.000	1.225	0.2
1963	0.000	3.629	0.000	3.629	0.2
1964	0.000	6.123	0.000	6.123	0.2
1965	0.045	3.719	0.000	3.719	0.2
1966	0.000	4.808	0.000	4.808	0.2
1967	0.000	5.534	0.000	5.534	0.2
1968	0.000	5.488	0.000	5.488	0.2
1969	0.000	3.946	0.000	3.946	0.2
1970	0.000	4.853	0.000	4.853	0.2
1971	0.000	4.264	0.000	4.264	0.2
1972	0.000	4.672	0.000	4.672	0.2
1973	0.000	3.266	0.000	3.266	0.2
1974	0.000	3.447	0.000	3.447	0.2
1975	0.000	3.447	0.000	3.447	0.2
1976	0.000	1.860	0.000	1.860	0.2
1977	0.000	5.162	0.000	5.162	0.2
1978	0.000	1.025	0.000	1.025	0.1
1979	0.000	0.918	0.000	0.918	0.1
1980	0.000	8.917	0.000	8.917	0.1
1981	0.000	8.187	0.000	8.187	0.1
1982	0.000	1.028	0.000	1.028	0.1
1983	0.000	2.097	0.000	2.097	0.1
1984	0.000	1.051	0.000	1.051	0.1
1985	0.000	2.013	0.000	2.013	0.1

Table 3.2. Historic commercial landings (numbers) and annual CVs of Florida Keys/East Florida Hogfish by gear for years 1950 – 1985.

Year	Landings (numbers)				CV
	Spear	Hook-and-line	Trap	Combined	
1950	0	4,894	0	4,894	0.25
1951	352	8,803	0	9,155	0.25
1952	0	9,542	0	9,542	0.25
1953	0	8,768	0	8,768	0.25
1954	0	9,577	0	9,577	0.25
1955	35	8,556	0	8,592	0.25
1956	0	7,113	0	7,113	0.25
1957	0	3,204	0	3,204	0.25
1958	0	1,620	0	1,620	0.25
1959	0	1,901	0	1,901	0.25
1960	0	1,303	0	1,303	0.25
1961	0	563	0	563	0.25
1962	0	951	0	951	0.2
1963	0	2,817	0	2,817	0.2
1964	0	4,754	0	4,754	0.2
1965	0	2,887	0	2,887	0.2
1966	0	3,732	0	3,732	0.2
1967	0	4,296	0	4,296	0.2
1968	0	4,261	0	4,261	0.2
1969	0	3,063	0	3,063	0.2
1970	0	3,768	0	3,768	0.2
1971	0	3,310	0	3,310	0.2
1972	0	3,627	0	3,627	0.2
1973	0	2,535	0	2,535	0.2
1974	0	2,676	0	2,676	0.2
1975	0	2,676	0	2,676	0.2
1976	0	1,444	0	1,444	0.2
1977	0	4,007	0	4,007	0.2
1978	0	796	0	796	0.1
1979	0	713	0	713	0.1
1980	0	6,922	0	6,922	0.1
1981	0	6,356	0	6,356	0.1
1982	0	798	0	798	0.1
1983	0	1,628	0	1,628	0.1
1984	0	816	0	816	0.1
1985	0	1,562	0	1,562	0.1

Table 3.3. Commercial landings (metric tons) and annual CVs of Florida Keys/East Florida Hogfish by gear for years 1986 – 2024.

Year	Landings (mt)				CV
	Spear	Hook-and-line	Trap	Combined	
1986		21.740		21.740	0.05
1987		29.068		29.068	0.05
1988		29.238		29.238	0.05
1989		35.769		35.769	0.05
1990		34.682		34.682	0.05
1991	6.859	11.537	13.412	31.808	0.05
1992	11.284	21.296	9.599	42.180	0.05
1993	11.272	22.035	9.730	43.037	0.05
1994	10.632	14.830	3.123	28.585	0.05
1995	8.042	10.800	2.887	21.729	0.05
1996	7.909	9.224	2.677	19.809	0.05
1997	6.954	10.664	3.834	21.452	0.05
1998	7.065	5.283	3.340	15.688	0.05
1999	4.374	4.151	7.153	15.678	0.05
2000	5.292	3.680	5.088	14.060	0.05
2001	5.481	4.261	1.030	10.772	0.05
2002	5.878	4.135	0.857	10.870	0.05
2003	3.888	6.730	1.219	11.837	0.05
2004	5.617	6.185	1.091	12.892	0.05
2005	3.987	3.056	0.606	7.650	0.05
2006	3.722	1.865	0.858	6.444	0.05
2007	3.387	2.603	0.596	6.586	0.05
2008	3.398	1.965	0.634	5.997	0.05
2009	3.336	2.412	0.750	6.498	0.05
2010	2.441	2.423	0.451	5.315	0.05
2011	2.854	2.257	0.578	5.689	0.05
2012	3.732	1.738	0.969	6.438	0.05
2013	4.936	2.012	0.828	7.775	0.05
2014	6.046	2.340	1.391	9.777	0.05
2015	6.442	2.042	1.525	10.008	0.05
2016	5.311	1.812	0.880	8.003	0.05
2017	3.659	0.852	0.314	4.825	0.05
2018	1.610	0.374	0.077	2.060	0.05
2019	0.814	0.124	0.119	1.057	0.05
2020	1.190	0.107	0.043	1.341	0.05
2021	1.348	0.151	0.035	1.534	0.05
2022	1.188	0.159	0.037	1.383	0.05
2023	1.032	0.061	0.043	1.137	0.05
2024	1.007	0.087	0.025	1.118	0.05

Table 3.4. Commercial landings (numbers) and annual CVs of Florida Keys/East Florida Hogfish by gear for years 1986 – 2024.

Year	Landings (numbers)				CV
	Spear	Hook-and-line	Trap	Combined	
1986	0	16,876	0	16,876	0.05
1987	0	22,565	0	22,565	0.05
1988	0	22,696	0	22,696	0.05
1989	0	27,767	0	27,767	0.05
1990	0	26,923	0	26,923	0.05
1991	5,324	8,956	10,411	24,692	0.05
1992	8,760	16,532	7,452	32,743	0.05
1993	8,751	17,106	7,553	33,409	0.05
1994	8,253	11,512	2,425	22,190	0.05
1995	6,243	8,383	2,241	16,867	0.05
1996	6,139	7,160	2,078	15,377	0.05
1997	5,398	8,279	2,976	16,653	0.05
1998	5,485	4,101	2,592	12,178	0.05
1999	3,396	3,222	5,553	12,170	0.05
2000	4,108	2,857	3,950	10,914	0.05
2001	4,255	3,308	800	8,362	0.05
2002	4,563	3,210	666	8,438	0.05
2003	3,018	5,224	946	9,189	0.05
2004	4,360	4,801	847	10,008	0.05
2005	3,095	2,373	471	5,939	0.05
2006	2,889	1,447	666	5,003	0.05
2007	2,629	2,021	463	5,113	0.05
2008	2,638	1,526	492	4,655	0.05
2009	2,590	1,872	582	5,044	0.05
2010	1,895	1,881	350	4,126	0.05
2011	2,215	1,752	448	4,416	0.05
2012	2,897	1,349	752	4,998	0.05
2013	3,832	1,562	642	6,036	0.05
2014	4,693	1,817	1,080	7,589	0.05
2015	5,000	1,585	1,183	7,769	0.05
2016	4,123	1,407	683	6,213	0.05
2017	1,910	445	164	2,519	0.05
2018	840	195	40	1,076	0.05
2019	425	65	62	552	0.05
2020	621	56	23	700	0.05
2021	704	79	18	801	0.05
2022	620	83	19	722	0.05
2023	539	32	23	594	0.05
2024	526	45	13	584	0.05

Table 3.5. Recreational landings (numbers) of Florida Keys/East Florida Hogfish by gear for years 1981 – 2024 and annual CVs. The ‘Full SRFS’ estimates are comprised of ‘SRFS & SRFS-calibrated Private’ mode, MRIP charter mode, and MRIP shore mode landings estimates. ‘SRFS & SRFS-calibrated Private’ estimates are comprised of SRFS private mode (2021 – 2024) and SRFS ratio-calibrated MRIP private mode (1981 – 2020). The ‘Full SRFS Combined’ is comprised of the ‘Full SRFS’ estimates plus the SRHS estimates.

Year	Full SRFS		Landings (thousands)			Full SRFS		
	Spears	CV	HL	CV	SRHS HL	CV	Combined	CV
1981	1,261.618	0.64	22.688	0.62	1.063	0.05	1,285.369	0.77
1982	49.56	0.58	-	-	0.105	0.05	106.740	0.76
1983	182.971	0.80	10.475	0.93	0.314	0.05	193.760	0.77
1984	374.61	0.65	6,269.688	1.04	0.567	0.05	6,644.906	1.01
1985	-	-	176.795	0.97	0.273	0.05	177.068	1.07
1986	95.631	0.74	44.713	0.64	0.589	0.05	140.933	0.62
1987	175.257	0.52	115.874	0.41	0.562	0.05	287.793	0.50
1988	2.391	1.07	66.048	0.81	0.512	0.05	207.630	0.60
1989	61.153	0.96	107.177	0.55	0.392	0.05	168.651	0.58
1990	151.498	0.67	94.21	0.66	0.226	0.05	245.934	0.56
1991	28.131	0.87	59.774	0.80	0.239	0.05	88.144	0.79
1992	126.627	0.49	80.219	0.61	0.383	0.05	244.231	0.50
1993	89.084	0.54	182.23	0.50	0.251	0.05	271.565	0.52
1994	131.068	0.51	66.587	0.49	0.188	0.05	197.843	0.54
1995	64.259	0.64	93.467	0.53	0.414	0.05	158.139	0.63
1996	47.283	0.55	61.529	0.56	0.23	0.05	109.042	0.54
1997	38.643	0.65	27.429	0.50	0.226	0.05	66.140	0.59
1998	31.882	0.54	15.534	0.51	0.236	0.05	47.623	0.61
1999	78.313	0.54	20.54	0.50	0.207	0.05	99.008	0.71
2000	23.817	0.67	12.236	0.69	0.166	0.05	36.220	0.82
2001	21.254	0.51	48.929	0.56	0.2	0.05	70.384	0.79
2002	57.898	0.56	23.566	0.55	0.152	0.05	81.615	0.81
2003	87.332	0.50	48.728	0.62	0.146	0.05	136.206	0.58
2004	62.844	0.52	105.71	0.70	0.467	0.05	169.022	0.69
2005	138.33	0.74	25.447	0.51	0.543	0.05	164.319	0.77
2006	77.115	0.61	50.908	0.48	0.608	0.05	128.631	0.57
2007	115.967	0.48	63.299	0.61	0.336	0.05	179.602	0.52
2008	330.684	0.64	27.319	0.59	0.203	0.05	358.206	0.65
2009	150.09	0.53	95.188	0.76	0.134	0.05	245.412	0.56
2010	163.503	0.68	28.789	0.89	0.071	0.05	192.364	0.74
2011	46.612	0.59	36.482	0.71	0.095	0.05	83.188	0.68
2012	343.894	0.79	42.228	0.58	0.106	0.05	386.226	0.79
2013	76.11	0.46	62.8	0.57	0.124	0.05	139.034	0.53
2014	235.219	0.48	49.699	0.41	0.181	0.05	285.100	0.51
2015	389.797	0.62	122.587	0.27	0.283	0.05	512.667	0.49
2016	176.357	0.44	62.756	0.45	0.167	0.05	239.280	0.48
2017	61.083	0.53	17.219	0.56	0.078	0.05	78.379	0.57
2018	17.155	0.80	1.345	0.90	0.012	0.05	18.512	0.74
2019	-	-	5.689	1.07	0	0.05	5.689	0.39
2020	0.01	1.00	8.975	0.66	0.015	0.05	9.000	0.82
2021	27.456	0.23	5.756	0.54	0.007	0.05	37.713	0.25
2022	6.861	0.28	13.481	0.59	0.006	0.05	18.421	0.28
2023	11.236	0.24	3.976	0.50	0.043	0.05	10.158	0.29
2024	8.971	0.30	4.325	0.48	0.012	0.05	13.308	0.28

Table 3.6. Recreational discards (numbers) of Florida Keys/East Florida Hogfish by gear for years 1981 – 2024 and annual CVs. The ‘Full SRFS’ estimates are comprised of ‘SRFS & SRFS-calibrated Private’ mode, MRIP charter mode, and MRIP shore mode landings estimates. ‘SRFS & SRFS-calibrated Private’ estimates are comprised of SRFS private mode (2021 – 2024) and SRFS ratio-calibrated MRIP private mode (1981 – 2020). The ‘Full SRFS Combined’ is comprised of the ‘Full SRFS’ estimates plus the SRHS estimates.

Year	Discards (thousands)							
	Full SRFS Spear	CV	Full SRFS HL	CV	SRHS HL	CV	Full SRFS Combined	CV
1981	-	-	-	-	-	-	-	-
1982	-	-	-	-	-	-	-	-
1983	-	-	-	-	-	-	-	-
1984	-	-	-	-	-	-	-	-
1985	-	-	-	-	-	-	-	-
1986	-	-	-	-	-	-	-	-
1987	-	-	2.714	1.09	-	-	2.714	1.09
1988	-	-	228.086	1.09	-	-	230.511	1.08
1989	-	-	5.37	1.09	-	-	5.370	1.09
1990	1.677	1.09	14.419	0.86	-	-	16.095	0.80
1991	-	-	-	-	-	-	-	-
1992	2.996	1.09	14.775	0.71	-	-	34.489	0.62
1993	-	-	5.31	1.09	-	-	5.310	1.09
1994	-	-	21.894	0.76	-	-	21.894	0.78
1995	2.072	1.09	66.178	0.70	-	-	68.249	0.70
1996	2.062	1.09	23.835	0.64	-	-	25.897	0.79
1997	-	-	11.35	0.67	-	-	11.350	0.67
1998	-	-	30.742	0.54	-	-	30.723	0.62
1999	0.643	1.09	31.21	0.49	-	-	31.863	0.53
2000	1.363	1.09	12.994	0.72	-	-	14.357	0.91
2001	-	-	9.715	0.92	-	-	9.715	1.08
2002	3.148	0.97	-	-	-	-	3.148	1.09
2003	-	-	25.348	0.60	-	-	25.348	0.74
2004	0.466	1.09	70.534	0.83	0.023	0.5	71.023	0.84
2005	-	-	147.51	0.80	0.099	0.5	147.609	0.80
2006	2.132	1.09	33.235	0.84	0.178	0.5	35.545	0.81
2007	7.263	1.09	48.359	0.85	0.115	0.5	55.737	0.82
2008	-	-	35.794	0.62	0.175	0.5	35.969	0.63
2009	-	-	10.026	1.08	0.073	0.5	10.099	1.08
2010	-	-	8.871	0.81	0.039	0.5	8.910	0.76
2011	-	-	3.643	0.77	0.032	0.5	3.675	1.06
2012	-	-	51.392	0.80	0.086	0.5	51.478	0.82
2013	2.483	1.09	51.632	0.52	0.11	0.5	54.225	0.55
2014	4.141	0.84	87.451	0.36	0.109	0.5	91.701	0.42
2015	-	-	60.743	0.55	0.155	0.5	60.898	0.69
2016	1.953	1.09	35.694	0.69	0.112	0.5	37.759	0.72
2017	-	-	55.895	0.86	0.149	0.5	56.044	0.88
2018	-	-	42.916	0.57	0.118	0.5	43.034	0.70
2019	-	-	43.62	0.76	0.066	0.5	43.686	0.78
2020	-	-	43.522	0.62	0.099	0.5	43.621	0.68
2021	6.089	0.78	69.36	0.29	0.258	0.5	80.429	0.29
2022	-	-	67.396	0.36	0.132	0.5	75.619	0.38
2023	0.165	0.90	95.582	0.31	0.213	0.5	122.053	0.40
2024	0.928	1.26	44.626	0.32	0.13	0.5	45.971	0.35

Table 3.7. Historical reconstruction of recreational landings (Full SRFS Combined) of Florida Keys/East Florida Hogfish from 1950 – 1980. The estimated number of saltwater angler participants in Florida was multiplied by the ratio 0.976097 to obtain the estimated number of participants within the Florida Keys/East Florida region. The number of participants was then multiplied by the average catch/number of participants from years 1982, 1983, and 1985 (CPUE = 0.263904) to reconstruct the number of landings.

Year	Number of Saltwater Anglers		Reconstructed Landings (numbers)
	Florida	Florida Keys/East Florida	Florida Keys/East Florida
1950	265,900	259,544	68,495
1951	274,187	267,633	70,629
1952	282,475	275,723	72,764
1953	290,762	283,812	74,899
1954	299,049	291,901	77,034
1955	307,337	299,990	79,169
1956	315,624	308,080	81,303
1957	323,911	316,169	83,438
1958	332,199	324,258	85,573
1959	365,676	356,935	94,197
1960	374,577	365,623	96,489
1961	414,720	404,807	106,830
1962	391,199	381,848	100,771
1963	399,699	390,145	102,961
1964	418,956	408,941	107,921
1965	442,416	431,840	113,964
1966	453,819	442,972	116,902
1967	493,510	481,714	127,126
1968	496,090	484,232	127,791
1969	521,289	508,828	134,282
1970	562,752	549,301	144,963
1971	705,592	688,726	181,758
1972	731,204	713,726	188,355
1973	772,865	754,391	199,087
1974	834,392	814,448	214,936
1975	870,670	849,858	224,281
1976	821,995	802,346	211,742
1977	739,438	721,764	190,476
1978	667,847	651,884	172,035
1979	716,261	699,140	184,506
1980	588,882	574,806	151,694

Table 3.8. Indices of relative biomass or abundance values and associated CVs for Florida Keys/East Florida Hogfish from years 1993 – 2024.

Year	RVC Florida Keys		RVC Dry Tortugas		Combined Video	
	Index	CV	Index	CV	Index	CV
1993	-	-	-	-	1.852	0.34
1994	-	-	-	-	1.441	0.49
1995	-	-	-	-	1.552	0.38
1996	-	-	-	-	1.009	0.38
1997	-	-	-	-	0.930	0.32
1998	-	-	-	-	-	-
1999	0.300	0.13	1.133	0.08	-	-
2000	0.592	0.09	0.834	0.09	-	-
2001	0.652	0.08	-	-	-	-
2002	0.806	0.08	-	-	1.536	0.52
2003	0.948	0.08	-	-	0.686	0.44
2004	1.063	0.09	0.855	0.07	0.945	0.36
2005	0.938	0.07	-	-	0.768	0.35
2006	0.815	0.07	0.577	0.08	0.635	0.34
2007	0.907	0.06	-	-	0.346	0.54
2008	1.402	0.05	0.791	0.07	0.407	0.43
2009	1.004	0.05	-	-	0.660	0.35
2010	0.797	0.07	0.834	0.06	1.427	0.25
2011	0.865	0.06	-	-	0.782	0.31
2012	1.059	0.05	1.133	0.05	0.752	0.40
2013	-	-	-	-	0.705	0.23
2014	1.324	0.05	0.813	0.06	0.492	0.28
2015	-	-	-	-	0.760	0.21
2016	1.543	0.05	0.791	0.07	0.923	0.16
2017	-	-	-	-	1.214	0.15
2018	1.158	0.05	1.112	0.05	1.262	0.16
2019	-	-	-	-	1.175	0.17
2020	-	-	-	-	1.648	0.16
2021	-	-	1.390	0.08	1.094	0.19
2022	0.943	0.10	-	-	1.536	0.52
2023	-	-	1.518	0.07	0.686	0.44
2024	1.882	0.07	1.219	0.09	0.945	0.36

Table 3.9. Dirichlet-multinomial weights applied to length and size composition data of the SEDAR 94 KEYS base model. Theta ratios are calculated as $\theta/(1+\theta)$.

Data Type	Fleet/Index	$\ln(\theta)$	θ	θ ratio
Length Composition	Commercial landings	2.093	8.11	0.89
	Recreational discards	0.987	2.68	0.73
	Recreational landings	-0.764	0.47	0.32
	Combined video index	0.442	1.56	0.61
Size Composition	RVC Florida Keys and RVC Dry Tortugas indices	-0.347	0.71	0.41

Table 3.10. List of Stock Synthesis parameters for the SEDAR 94 KEYS base model. The list includes expected parameter values (Value), lower (Min) and upper (Max) bounds of the parameters, associated standard deviation (Std Dev) and coefficients of variation (CV), prior type (Prior), prior standard deviation (Prior Std Dev), and the phase (Phase) of estimation. Parameters designated as fixed were held at their initial values and have no associated range or SE.

	Parameter Label	Value	Min	Max	Std Dev	CV	Prior	Prior Std Dev	Phase
1	L_at_Amin_Fem_GP_1	6.649	2	20	0.754	0.113			3
2	L_at_Amax_Fem_GP_1	51.170	30	80	3.391	0.066			3
3	VonBert_K_Fem_GP_1	0.177	0.05	0.4	0.024	0.138			4
4	CV_young_Fem_GP_1	0.479	0.05	0.9	0.051	0.107			7
5	CV_old_Fem_GP_1	0.367	0.05	0.9	0.045	0.122			7
6	Wtlen_1_Fem_GP_1	2.55E-05	-3	3					Fixed
7	Wtlen_2_Fem_GP_1	2.927	-3	4					Fixed
8	Mat50%_Fem_GP_1	2.080	1	4					Fixed
9	Mat_slope_Fem_GP_1	-3.034	-4	-0.1					Fixed
10	Eggs_scalar_Fem_GP_1	1.000	-3	3					Fixed
11	Eggs_exp_wt_Fem_GP_1	1.000	-3	3					Fixed
12	L_at_Amin_Mal_GP_1	0.000	-1	1					Fixed
13	L_at_Amax_Mal_GP_1	0.000	-1	1					Fixed
14	VonBert_K_Mal_GP_1	0.000	-1	1					Fixed
15	CV_young_Mal_GP_1	0.000	-1	1					Fixed
16	CV_old_Mal_GP_1	0.000	-1	1					Fixed
17	Wtlen_1_Mal_GP_1	2.55E-05	-3	3					Fixed
18	Wtlen_2_Mal_GP_1	2.927	-3	4					Fixed
19	Herm Infl_age	6.080	1	11					Fixed
20	Herm_stdev	2.330	1	5					Fixed
21	Herm_asymptote	0.999	0.01	1					Fixed
22	CohortGrowDev	1.000	0	1					Fixed
23	Platoon_SD_Ratio	0.730	0.1	3	0.253	0.346			1
24	FracFemale_GP_1	1.000	0	1					Fixed
25	SR_LN(R0)	8.000	6	14	0.150	0.019			1
26	SR_BH_steep	0.472	0.2	0.99	0.049	0.103			2
27	SR_sigmaR	0.449	0.1	2	0.101	0.226			7
28	SR_regime	0.000	-5	5					Fixed
29	SR_autocorr	0.000	0	0					Fixed
30	Main_RecrDev_1981	-0.012	-4	4	0.404	33.109			3
31	Main_RecrDev_1982	-0.042	-4	4	0.400	9.532			3
32	Main_RecrDev_1983	-0.088	-4	4	0.396	4.503			3
33	Main_RecrDev_1984	-0.083	-4	4	0.398	4.807			3
34	Main_RecrDev_1985	0.234	-4	4	0.391	1.676			3
35	Main_RecrDev_1986	-0.037	-4	4	0.374	10.120			3
36	Main_RecrDev_1987	0.222	-4	4	0.341	1.537			3
37	Main_RecrDev_1988	0.168	-4	4	0.315	1.873			3
38	Main_RecrDev_1989	0.016	-4	4	0.300	18.933			3
39	Main_RecrDev_1990	0.349	-4	4	0.230	0.659			3
40	Main_RecrDev_1991	-0.045	-4	4	0.226	5.040			3
41	Main_RecrDev_1992	0.112	-4	4	0.183	1.636			3
42	Main_RecrDev_1993	-0.595	-4	4	0.221	0.372			3
43	Main_RecrDev_1994	-0.159	-4	4	0.174	1.092			3
44	Main_RecrDev_1995	-0.644	-4	4	0.206	0.320			3
45	Main_RecrDev_1996	-0.757	-4	4	0.211	0.279			3
46	Main_RecrDev_1997	-0.320	-4	4	0.174	0.545			3
47	Main_RecrDev_1998	-1.010	-4	4	0.264	0.261			3
48	Main_RecrDev_1999	0.091	-4	4	0.162	1.767			3
49	Main_RecrDev_2000	-0.334	-4	4	0.247	0.740			3
50	Main_RecrDev_2001	-0.177	-4	4	0.242	1.363			3
51	Main_RecrDev_2002	0.238	-4	4	0.211	0.888			3
52	Main_RecrDev_2003	0.151	-4	4	0.232	1.534			3
53	Main_RecrDev_2004	0.163	-4	4	0.210	1.286			3
54	Main_RecrDev_2005	-0.147	-4	4	0.243	1.659			3
55	Main_RecrDev_2006	0.189	-4	4	0.193	1.025			3
56	Main_RecrDev_2007	0.722	-4	4	0.132	0.183			3
57	Main_RecrDev_2008	-0.053	-4	4	0.176	3.346			3
58	Main_RecrDev_2009	0.286	-4	4	0.139	0.485			3
59	Main_RecrDev_2010	-0.334	-4	4	0.194	0.581			3
60	Main_RecrDev_2011	0.029	-4	4	0.151	5.192			3

61	Main_RecrDev_2012	0.547	-4	4	0.107	0.196	3
62	Main_RecrDev_2013	0.335	-4	4	0.116	0.345	3
63	Main_RecrDev_2014	-0.203	-4	4	0.158	0.780	3
64	Main_RecrDev_2015	0.659	-4	4	0.125	0.190	3
65	Main_RecrDev_2016	0.166	-4	4	0.201	1.212	3
66	Main_RecrDev_2017	0.032	-4	4	0.207	6.477	3
67	Main_RecrDev_2018	0.129	-4	4	0.208	1.609	3
68	Main_RecrDev_2019	0.010	-4	4	0.234	22.484	3
69	Main_RecrDev_2020	0.081	-4	4	0.234	2.891	3
70	Main_RecrDev_2021	0.109	-4	4	0.229	2.098	3
71	F_fleet_1_YR_1950_s_1	0.010					-
72	F_fleet_1_YR_1951_s_1	0.010					-
73	F_fleet_1_YR_1952_s_1	0.010					-
74	F_fleet_1_YR_1953_s_1	0.010					-
75	F_fleet_1_YR_1954_s_1	0.010					-
76	F_fleet_1_YR_1955_s_1	0.010					-
77	F_fleet_1_YR_1956_s_1	0.010					-
78	F_fleet_1_YR_1957_s_1	0.010					-
79	F_fleet_1_YR_1958_s_1	0.010					-
80	F_fleet_1_YR_1959_s_1	0.010					-
81	F_fleet_1_YR_1960_s_1	0.010					-
82	F_fleet_1_YR_1961_s_1	0.010					-
83	F_fleet_1_YR_1962_s_1	0.010					-
84	F_fleet_1_YR_1963_s_1	0.010					-
85	F_fleet_1_YR_1964_s_1	0.010					-
86	F_fleet_1_YR_1965_s_1	0.010					-
87	F_fleet_1_YR_1966_s_1	0.010					-
88	F_fleet_1_YR_1967_s_1	0.010					-
89	F_fleet_1_YR_1968_s_1	0.010					-
90	F_fleet_1_YR_1969_s_1	0.010					-
91	F_fleet_1_YR_1970_s_1	0.010					-
92	F_fleet_1_YR_1971_s_1	0.010					-
93	F_fleet_1_YR_1972_s_1	0.010					-
94	F_fleet_1_YR_1973_s_1	0.010					-
95	F_fleet_1_YR_1974_s_1	0.010					-
96	F_fleet_1_YR_1975_s_1	0.010					-
97	F_fleet_1_YR_1976_s_1	0.010					-
98	F_fleet_1_YR_1977_s_1	0.010					-
99	F_fleet_1_YR_1978_s_1	0.010					-
100	F_fleet_1_YR_1979_s_1	0.010					-
101	F_fleet_1_YR_1980_s_1	0.010					-
102	F_fleet_1_YR_1981_s_1	0.010					-
103	F_fleet_1_YR_1982_s_1	0.010					-
104	F_fleet_1_YR_1983_s_1	0.010					-
105	F_fleet_1_YR_1984_s_1	0.010					-
106	F_fleet_1_YR_1985_s_1	0.010					-
107	F_fleet_1_YR_1986_s_1	0.010					-
108	F_fleet_1_YR_1987_s_1	0.010					-
109	F_fleet_1_YR_1988_s_1	0.010					-
110	F_fleet_1_YR_1989_s_1	0.010					-
111	F_fleet_1_YR_1990_s_1	0.010					-
112	F_fleet_1_YR_1991_s_1	0.010					-
113	F_fleet_1_YR_1992_s_1	0.010					-
114	F_fleet_1_YR_1993_s_1	0.010					-
115	F_fleet_1_YR_1994_s_1	0.010					-
116	F_fleet_1_YR_1995_s_1	0.010					-
117	F_fleet_1_YR_1996_s_1	0.010					-
118	F_fleet_1_YR_1997_s_1	0.010					-
119	F_fleet_1_YR_1998_s_1	0.010					-
120	F_fleet_1_YR_1999_s_1	0.010					-
121	F_fleet_1_YR_2000_s_1	0.010					-
122	F_fleet_1_YR_2001_s_1	0.010					-
123	F_fleet_1_YR_2002_s_1	0.010					-
124	F_fleet_1_YR_2003_s_1	0.010					-
125	F_fleet_1_YR_2004_s_1	0.010					-
126	F_fleet_1_YR_2005_s_1	0.010					-
127	F_fleet_1_YR_2006_s_1	0.010					-
128	F_fleet_1_YR_2007_s_1	0.010					-
129	F_fleet_1_YR_2008_s_1	0.010					-
130	F_fleet_1_YR_2009_s_1	0.010					-

201	F_fleet_2_YR_2005_s_1	0.834	0	3	0.254	0.304			2
202	F_fleet_2_YR_2006_s_1	0.244	0	3	0.101	0.414			2
203	F_fleet_2_YR_2007_s_1	0.230	0	3	0.083	0.363			2
204	F_fleet_2_YR_2008_s_1	0.223	0	3	0.093	0.414			2
205	F_fleet_2_YR_2009_s_1	0.594	0	3	0.198	0.333			2
206	F_fleet_2_YR_2010_s_1	0.097	0	3	0.055	0.570			2
207	F_fleet_2_YR_2011_s_1	0.053	0	3	0.029	0.539			2
208	F_fleet_2_YR_2012_s_1	0.177	0	3	0.074	0.420			2
209	F_fleet_2_YR_2013_s_1	0.269	0	3	0.094	0.349			2
210	F_fleet_2_YR_2014_s_1	0.407	0	3	0.121	0.297			2
211	F_fleet_2_YR_2015_s_1	0.491	0	3	0.142	0.290			2
212	F_fleet_2_YR_2016_s_1	0.345	0	3	0.131	0.378			2
213	F_fleet_2_YR_2017_s_1	0.254	0	3	0.127	0.499			2
214	F_fleet_2_YR_2018_s_1	0.093	0	3	0.051	0.546			2
215	F_fleet_2_YR_2019_s_1	0.041	0	3	0.017	0.415			2
216	F_fleet_2_YR_2020_s_1	0.059	0	3	0.031	0.522			2
217	F_fleet_2_YR_2021_s_1	0.158	0	3	0.047	0.294			2
218	F_fleet_2_YR_2022_s_1	0.107	0	3	0.039	0.363			2
219	F_fleet_2_YR_2023_s_1	0.077	0	3	0.024	0.315			2
220	F_fleet_2_YR_2024_s_1	0.063	0	3	0.018	0.295			2
221	LnQ_base_RVC_KEYS(3)	-7.207	-18	5					Fixed
222	LnQ_base_RVC_DRTO(4)	-6.377	-18	5					Fixed
223	LnQ_base_COMB_VIDEO(5)	-6.928	-18	5					Fixed
224	Size_DblN_peak_COM(1)	29.896	15	60	2.796	0.094			3
225	Size_DblN_top_logit_COM(1)	-9.531	-15	15	74.964	7.865			4
226	Size_DblN_ascend_se_COM(1)	3.161	0.01	15	0.879	0.278			5
227	Size_DblN_descend_se_COM(1)	3.046	0.01	5	0.711	0.233			5
228	Size_DblN_start_logit_COM(1)	-999.000	-15	15					Fixed
229	Size_DblN_end_logit_COM(1)	0.387	-15	15	0.415	1.073			3
230	Size_DblN_peak_REC(2)	32.770	15	50	0.607	0.019			3
231	Size_DblN_top_logit_REC(2)	-12.290	-15	15	46.133	3.754			4
232	Size_DblN_ascend_se_REC(2)	3.812	0.1	15	0.146	0.038			5
233	Size_DblN_descend_se_REC(2)	4.601	0.1	15	0.229	0.050			5
234	Size_DblN_start_logit_REC(2)	-999.000	-15	7					Fixed
235	Size_DblN_end_logit_REC(2)	-2.351	-15	15	0.329	0.140			3
236	Retain_L_infl_REC(2)	6.443	4	50	50.294	7.806			3
237	Retain_L_width_REC(2)	0.683	0.01	10	12.928	18.920			4
238	Retain_L_asymptote_logit_REC(2)	2.723	-15	15	0.356	0.131			5
239	Retain_L_maleoffset_REC(2)	0.000	-1	1					Fixed
240	DiscMort_L_infl_REC(2)	0.100	0	1					Fixed
241	DiscMort_L_width_REC(2)	0.100	0	1					Fixed
242	DiscMort_L_level_old_REC(2)	0.414	0.01	1					Fixed
243	DiscMort_L_male_offset_REC(2)	0.000	-1	2					Fixed
244	Size_DblN_peak_RVC_KEYS(3)	22.080	5	50	0.673	0.030			3
245	Size_DblN_top_logit_RVC_KEYS(3)	-2.735	-15	15	0.589	0.215			4
246	Size_DblN_ascend_se_RVC_KEYS(3)	3.796	0.1	15	0.130	0.034			3
247	Size_DblN_descend_se_RVC_KEYS(3)	4.924	0.1	15	0.363	0.074			5
248	Size_DblN_start_logit_RVC_KEYS(3)	-999.000	-15	15					Fixed
249	Size_DblN_end_logit_RVC_KEYS(3)	-2.014	-15	15	0.337	0.167			3
250	Size_DblN_peak_RVC_DRTO(4)	55.507	30	70	3.188	0.057			3
251	Size_DblN_top_logit_RVC_DRTO(4)	-2.166	-15	15	2.980	1.376			4
252	Size_DblN_ascend_se_RVC_DRTO(4)	6.188	0.1	15	0.116	0.019			3
253	Size_DblN_descend_se_RVC_DRTO(4)	6.900	0.1	15	5.596	0.811			5
254	Size_DblN_start_logit_RVC_DRTO(4)	-999.000	-5	5					Fixed
255	Size_DblN_end_logit_RVC_DRTO(4)	-0.979	-15	15	1.661	1.696			3
256	Size_inflection_COMB_VIDEO(5)	27.744	15	40	3.062	0.110			3
257	Size_95%width_COMB_VIDEO(5)	11.501	0.1	15	2.864	0.249			4
258	ln(DM_theta)_Len_P1	2.093	-5	20	0.807	0.385	0	1.813	2
259	ln(DM_theta)_Len_P2	0.987	-5	20	0.895	0.907	0	1.813	2
260	ln(DM_theta)_Len_P3	-0.764	-5	20	0.195	0.255	0	1.813	2
261	ln(DM_theta)_Len_P4	0.442	-5	20	0.613	1.387	0	1.813	2
262	ln(DM_theta)_Sz_P5	-0.347	-5	20	0.141	0.406	0	1.813	2
263	Size_DblN_peak_COM(1)_BLK1repl_1995	31.034	15	60	0.437	0.014			3
264	Size_DblN_peak_COM(1)_BLK1repl_2018	41.809	15	60	1.193	0.029			3
265	Size_DblN_ascend_se_COM(1)_BLK1repl_1995	1.883	0.01	15	0.286	0.152			5
266	Size_DblN_ascend_se_COM(1)_BLK1repl_2018	1.473	0.01	6	0.777	0.528			5
267	Retain_L_infl_REC(2)_BLK1repl_1995	28.543	6	50	0.317	0.011			3
268	Retain_L_infl_REC(2)_BLK1repl_2018	42.700	6	50	2.200	0.052			3
269	Retain_L_width_REC(2)_BLK1repl_1995	1.332	0.1	10	0.200	0.150			4
270	Retain_L_width_REC(2)_BLK1repl_2018	5.030	0.1	10	1.342	0.267			4

271	Retain_L_asymptote_logit_REC(2)_BLK1repl_1995	3.081	-15	15	0.560	0.182	5
272	Retain_L_asymptote_logit_REC(2)_BLK1repl_2018	9.293	-15	15	77.497	8.339	5

Table 3.11. Predicted total biomass (metric tons, pounds), spawning stock biomass (SSB; metric tons, pounds), age 1+ abundance (1000s of fish), age-0 recruits (1000s of fish), and depletion (SSB/SSB0) for Florida Keys/East Florida Hogfish. Virgin is the estimated unfished condition while Initial is the estimated initial conditions of the stock before the model start year.

Year	Biomass (mt)	Biomass (lbs.)	SSB (mt)	SSB (lbs.)	Age 1+ Abundance (000s)	Age-0 Recruits (000s)	B/B0	SSB/SSB0
Virgin	5,768	12,716,770	5,462	12,041,957	6,588	2,982	1.000	1.000
Initial	5,768	12,716,770	5,462	12,041,957	6,588	2,982	1.000	1.000
1950	5,768	12,716,770	5,462	12,041,957	6,588	2,982	1.000	1.000
1951	5,685	12,532,288	5,380	11,860,561	6,522	2,969	0.985	0.985
1952	5,596	12,336,870	5,292	11,667,216	6,457	2,955	0.970	0.969
1953	5,508	12,142,841	5,206	11,476,229	6,396	2,941	0.955	0.953
1954	5,423	11,956,506	5,122	11,293,113	6,338	2,928	0.940	0.938
1955	5,341	11,774,625	5,041	11,114,517	6,282	2,914	0.926	0.923
1956	5,263	11,602,686	4,965	10,945,753	6,229	2,901	0.912	0.909
1957	5,190	11,441,727	4,893	10,787,924	6,180	2,888	0.900	0.896
1958	5,125	11,297,963	4,829	10,647,049	6,136	2,877	0.888	0.884
1959	5,064	11,164,209	4,770	10,516,072	6,094	2,866	0.878	0.873
1960	4,998	11,018,770	4,705	10,373,587	6,047	2,854	0.866	0.861
1961	4,935	10,879,394	4,643	10,236,945	6,002	2,842	0.856	0.850
1962	4,865	10,726,437	4,575	10,087,163	5,951	2,829	0.843	0.838
1963	4,807	10,597,180	4,518	9,960,529	5,910	2,817	0.833	0.827
1964	4,748	10,467,107	4,460	9,833,366	5,867	2,806	0.823	0.817
1965	4,685	10,328,966	4,399	9,698,201	5,822	2,793	0.812	0.805
1966	4,622	10,190,207	4,337	9,562,440	5,775	2,780	0.801	0.794
1967	4,559	10,050,786	4,276	9,426,084	5,728	2,767	0.790	0.783
1968	4,488	9,893,553	4,206	9,272,356	5,674	2,752	0.778	0.770
1969	4,420	9,743,727	4,139	9,125,881	5,623	2,737	0.766	0.758
1970	4,350	9,590,241	4,071	8,976,055	5,570	2,722	0.754	0.745
1971	4,272	9,417,486	3,995	8,807,335	5,510	2,704	0.741	0.731
1972	4,157	9,163,955	3,883	8,559,602	5,418	2,677	0.721	0.711
1973	4,039	8,903,898	3,767	8,305,320	5,324	2,649	0.700	0.690
1974	3,916	8,632,575	3,647	8,040,898	5,225	2,618	0.679	0.668
1975	3,781	8,334,752	3,516	7,750,924	5,116	2,582	0.655	0.644
1976	3,641	8,028,023	3,380	7,452,528	5,001	2,544	0.631	0.619
1977	3,525	7,771,118	3,267	7,203,362	4,905	2,510	0.611	0.598
1978	3,436	7,574,268	3,181	7,013,456	4,831	2,484	0.596	0.582
1979	3,376	7,443,357	3,124	6,888,013	4,781	2,466	0.585	0.572
1980	3,307	7,290,797	3,058	6,741,163	4,720	2,444	0.573	0.560
1981	3,269	7,207,485	3,022	6,662,105	4,689	2,383	0.567	0.553
1982	3,040	6,702,009	2,802	6,177,286	4,460	2,226	0.527	0.513
1983	3,054	6,733,843	2,822	6,222,173	4,414	2,119	0.530	0.517
1984	2,963	6,531,239	2,744	6,049,110	4,239	2,091	0.514	0.502
1985	2,778	6,124,816	2,561	5,646,237	4,015	2,765	0.482	0.469
1986	2,675	5,896,858	2,438	5,374,583	4,286	2,050	0.464	0.446

Table 3.11 continued. Predicted total biomass (metric tons, pounds), spawning stock biomass (SSB; metric tons, pounds), age 1+ abundance (1000s of fish), age-0 recruits (1000s of fish), and depletion (SSB/SSB0) for Florida Keys/East Florida Hogfish. Virgin is the estimated unfished condition while Initial is the estimated initial conditions of the stock before the model start year.

Year	Biomass (mt)	Biomass (lbs.)	SSB (mt)	SSB (lbs.)	Age 1+ Abundance (000s)	Age-0 Recruits (000s)	B/B0	SSB/SSB0
1987	2,655	5,852,347	2,412	5,317,440	4,097	2,624	0.460	0.442
1988	2,606	5,744,299	2,368	5,220,172	4,278	2,451	0.452	0.433
1989	2,198	4,846,797	1,964	4,328,953	3,938	1,906	0.381	0.359
1990	2,212	4,876,537	1,987	4,380,519	3,755	2,659	0.383	0.364
1991	2,135	4,707,156	1,913	4,217,575	3,981	1,747	0.370	0.350
1992	2,201	4,853,344	1,982	4,369,672	3,733	2,069	0.382	0.363
1993	2,006	4,421,635	1,824	4,022,003	3,545	975	0.348	0.334
1994	1,893	4,174,210	1,743	3,841,621	2,885	1,470	0.328	0.319
1995	1,702	3,753,282	1,582	3,487,250	2,694	857	0.295	0.290
1996	1,531	3,375,564	1,422	3,134,092	2,241	720	0.265	0.260
1997	1,461	3,221,130	1,375	3,031,224	1,963	1,092	0.253	0.252
1998	1,431	3,155,256	1,343	2,961,778	2,026	540	0.248	0.246
1999	1,378	3,037,176	1,287	2,838,209	1,721	1,582	0.239	0.236
2000	1,255	2,765,787	1,149	2,533,927	2,045	962	0.217	0.210
2001	1,254	2,764,861	1,131	2,493,274	1,958	1,113	0.217	0.207
2002	1,272	2,803,993	1,156	2,549,624	2,006	1,711	0.220	0.212
2003	1,332	2,936,227	1,189	2,620,745	2,394	1,596	0.231	0.218
2004	1,348	2,970,971	1,184	2,611,133	2,519	1,612	0.234	0.217
2005	1,308	2,883,183	1,152	2,539,946	2,558	1,162	0.227	0.211
2006	1,102	2,429,384	967	2,131,500	2,168	1,445	0.191	0.177
2007	1,146	2,526,938	1,001	2,206,761	2,287	2,523	0.199	0.183
2008	1,218	2,684,613	1,031	2,272,988	2,973	1,186	0.211	0.189
2009	1,293	2,849,938	1,109	2,445,919	2,648	1,747	0.224	0.203
2010	1,197	2,638,051	1,053	2,321,490	2,637	908	0.207	0.193
2011	1,295	2,855,956	1,160	2,558,178	2,349	1,391	0.225	0.212
2012	1,416	3,121,635	1,281	2,824,166	2,483	2,486	0.245	0.235
2013	1,493	3,290,995	1,301	2,869,206	3,124	2,032	0.259	0.238
2014	1,530	3,372,367	1,319	2,908,118	3,220	1,196	0.265	0.241
2015	1,494	3,293,420	1,316	2,902,342	2,758	2,830	0.259	0.241
2016	1,437	3,167,888	1,241	2,734,901	3,364	1,665	0.249	0.227
2017	1,459	3,217,559	1,249	2,754,500	3,129	1,463	0.253	0.229
2018	1,511	3,331,185	1,346	2,967,620	2,936	1,689	0.262	0.246
2019	1,654	3,646,049	1,492	3,289,760	3,054	1,595	0.287	0.273
2020	1,809	3,989,000	1,641	3,616,728	3,104	1,807	0.314	0.300
2021	1,952	4,304,107	1,776	3,914,903	3,264	1,956	0.338	0.325
2022	2,045	4,508,299	1,855	4,088,583	3,418	1,931	0.355	0.340
2023	2,159	4,760,067	1,961	4,323,772	3,528	1,989	0.374	0.359
2024	2,286	5,039,547	2,085	4,595,955	3,657	2,052	0.396	0.382

Table 3.12. Annual exploitation rates on Florida Keys/East Florida Hogfish combined across all fleets as well as annual estimates of instantaneous apical fishing mortality rates by fleet. Apical fishing mortality rates represent the instantaneous fishing mortality level on the most vulnerable age class for each fleet.

Year	Exploitation (Biomass)	Commercial	Recreational	Year	Exploitation (Biomass)	Commercial	Recreational
1950	0.0132	0.0018	0.0393	1988	0.2168	0.0206	0.6724
1951	0.0146	0.0033	0.0412	1989	0.0722	0.0275	0.1658
1952	0.0154	0.0037	0.0431	1990	0.1185	0.0269	0.2991
1953	0.0158	0.0034	0.0449	1991	0.0537	0.0246	0.1072
1954	0.0167	0.0038	0.0468	1992	0.1642	0.0334	0.4182
1955	0.0171	0.0034	0.0486	1993	0.1210	0.0365	0.2842
1956	0.0173	0.0029	0.0504	1994	0.1546	0.0262	0.4079
1957	0.0170	0.0013	0.0522	1995	0.1445	0.0235	0.4163
1958	0.0172	0.0007	0.0540	1996	0.0826	0.0229	0.2134
1959	0.0192	0.0008	0.0601	1997	0.0519	0.0256	0.1123
1960	0.0197	0.0006	0.0622	1998	0.0650	0.0193	0.1685
1961	0.0219	0.0002	0.0697	1999	0.1247	0.0208	0.3710
1962	0.0210	0.0004	0.0664	2000	0.0497	0.0200	0.1241
1963	0.0222	0.0013	0.0685	2001	0.0477	0.0152	0.1205
1964	0.0241	0.0021	0.0725	2002	0.0328	0.0150	0.0717
1965	0.0252	0.0013	0.0775	2003	0.0800	0.0161	0.2143
1966	0.0264	0.0017	0.0804	2004	0.1291	0.0177	0.3622
1967	0.0292	0.0020	0.0887	2005	0.2620	0.0117	0.8339
1968	0.0298	0.0020	0.0903	2006	0.0908	0.0106	0.2439
1969	0.0314	0.0015	0.0963	2007	0.0885	0.0105	0.2298
1970	0.0346	0.0019	0.1057	2008	0.0861	0.0090	0.2233
1971	0.0440	0.0017	0.1363	2009	0.2162	0.0096	0.5936
1972	0.0469	0.0019	0.1454	2010	0.0422	0.0078	0.0971
1973	0.0506	0.0014	0.1582	2011	0.0257	0.0075	0.0530
1974	0.0564	0.0015	0.1765	2012	0.0716	0.0080	0.1766
1975	0.0609	0.0015	0.1906	2013	0.1008	0.0095	0.2687
1976	0.0590	0.0009	0.1846	2014	0.1491	0.0119	0.4073
1977	0.0554	0.0025	0.1687	2015	0.1793	0.0126	0.4913
1978	0.0501	0.0005	0.1536	2016	0.1270	0.0104	0.3451
1979	0.0549	0.0005	0.1679	2017	0.0984	0.0060	0.2543
1980	0.0483	0.0045	0.1385	2018	0.0255	0.0033	0.0928
1981	0.1043	0.0043	0.3199	2019	0.0113	0.0015	0.0409
1982	0.0351	0.0006	0.1049	2020	0.0158	0.0016	0.0587
1983	0.0670	0.0012	0.2013	2021	0.0399	0.0017	0.1582
1984	0.0991	0.0006	0.3073	2022	0.0268	0.0015	0.1071
1985	0.0825	0.0012	0.2542	2023	0.0192	0.0011	0.0772
1986	0.0612	0.0137	0.1617	2024	0.0155	0.0011	0.0626
1987	0.0790	0.0185	0.2031				

Table 3.13. Index root mean square error (RMSE) values from the SEDAR 94 KEYS base model (Base), the age-structured production model (ASPM), and the ASPM with estimated recruitment deviations (ASPMdev).

Index	Base	ASPM	ASPMdev
RVC Florida Keys	0.2527	0.3100	0.2055
RVC Dry Tortugas	0.1646	0.2016	0.1085
Combined Video	0.3804	0.4934	0.3524

Table 3.14. Mohn's rho (ρ_M) and forecast Mohn's rho (ρ_F) values calculated from the retrospective and retrospective forecasting analyses, respectively, on estimates of spawning stock biomass (SSB) and exploitation fishing mortality rates (F) from the SEDAR 94 KEYS base model. Analyses were performed across 6 successive years of removal from the terminal year 2024.

Quantity	Year Peel	Mohn's Rho (ρ_M)	Forecast Mohn's Rho (ρ_F)
SSB	2023	-0.059	-0.065
SSB	2022	-0.011	-0.027
SSB	2021	-0.072	-0.048
SSB	2020	-0.143	-0.106
SSB	2019	-0.186	-0.161
SSB	2018	-0.198	-0.188
SSB	Combined	-0.112	-0.099
F	2023	0.065	0.106
F	2022	0.069	-0.392
F	2021	0.040	-0.196
F	2020	0.123	0.278
F	2019	0.096	-0.119
F	2018	0.280	-0.247
F	Combined	0.112	-0.095

Table 3.15. Hindcast cross-validation summary statistics for the KEYS base model. N = number of observations to compute each statistic. MASE = mean absolute scaled error, with values < 1 (in green) indicative of superior prediction skill over a naïve baseline forecast (random walk) and values > 1 (in red) indicative of poor prediction skill. Model MAE = mean absolute error of model prediction residuals. Naïve MAE = mean absolute error of naïve predictions

Model Component	Data Source	MASE	Model MAE	Naïve MAE	N
Index of Abundance	RVC_KEYS	0.693	0.311	0.448	2
	RVC_DRTO	0.672	0.119	0.177	3
	COMB_VIDEO	0.628	0.139	0.221	6
	joint	0.657	0.165	0.250	11
Conditional Age-at-Length	REC	0.305	0.091	0.298	3
	FI_LHR_SP	0.142	0.019	0.134	1
	FI_LHR_TW	0.040	0.038	0.944	1
	joint	0.167	0.066	0.395	5
Size Composition	RVC_KEYS	1.984	0.120	0.060	2
	RVC_DRTO	0.597	0.038	0.064	3
	joint	1.132	0.071	0.063	5

Table 3.16. The yield-per-recruit (YPR), spawner-per-recruit (SSB/R), static spawning potential ratio (SPR), and total equilibrium yield in metric tons computed over a range of exploitation rates on Florida Keys/East Florida Hogfish.

Exploitation	YPR	SSB/R	SPR	Total Yield (mt)
0.000	0.000	1.831	1.000	0.123
0.005	0.009	1.743	0.951	26.680
0.010	0.018	1.661	0.907	50.138
0.015	0.025	1.584	0.865	70.771
0.020	0.032	1.512	0.825	88.819
0.025	0.039	1.445	0.789	104.498
0.031	0.045	1.382	0.755	117.999
0.036	0.051	1.323	0.722	129.495
0.041	0.056	1.268	0.692	139.138
0.047	0.061	1.216	0.664	147.067
0.052	0.066	1.167	0.637	153.407
0.058	0.070	1.122	0.612	158.270
0.064	0.074	1.078	0.589	161.759
0.069	0.078	1.037	0.566	163.968
0.075	0.082	0.999	0.545	164.980
0.081	0.085	0.962	0.525	164.874
0.087	0.088	0.928	0.506	163.721
0.093	0.091	0.895	0.489	161.585
0.099	0.094	0.864	0.472	158.528
0.105	0.097	0.835	0.456	154.604
0.111	0.099	0.807	0.441	149.863
0.117	0.101	0.781	0.426	144.354
0.123	0.104	0.756	0.412	138.121
0.129	0.106	0.732	0.399	131.203
0.135	0.108	0.709	0.387	123.639
0.141	0.110	0.687	0.375	115.465
0.147	0.111	0.667	0.364	106.712
0.153	0.113	0.647	0.353	97.412
0.160	0.114	0.628	0.343	87.595
0.166	0.116	0.611	0.333	77.286
0.172	0.117	0.593	0.324	66.512
0.178	0.119	0.577	0.315	55.296
0.185	0.120	0.562	0.307	43.662
0.191	0.121	0.547	0.298	31.630
0.197	0.122	0.532	0.291	19.221
0.204	0.123	0.519	0.283	6.453
0.210	0.125		0.276	

Table 3.17. Gelman and Rubin's (1992) potential scale reduction factor (PSRF) values from the combined six MCMC chains for selected model parameters ($\ln(R0)$ and *steepness*) and derived quantities (SSB₀, SSB in 2024, F exploitation in 2024, F_{40%SPR}, F_{MSY}, SSB at F_{MSY}, and the retained yield at F_{MSY}) of the SEDAR 94 KEYS base model.

PSRF	PSRF Upper CI	Parameter or Derived Quantity
1.00	1.01	$\ln(R0)$
1.00	1.01	<i>steepness</i>
1.00	1.01	SSB ₀
1.00	1.00	SSB ₂₀₂₄
1.00	1.00	F ₂₀₂₄
1.03	1.06	F _{40%SPR}
1.02	1.03	F _{MSY}
1.00	1.01	SSB _{MSY}
1.01	1.01	Retained yield at F _{MSY}

Table 3.18. The stock status determination criteria for Florida Keys/East Florida Hogfish according to the South Atlantic Fishery Management Council (SAFMC). All MSY or SPR proxy values of 30%SPR and 40%SPR were derived from the SEDAR 94 KEYS base model.

South Atlantic and Gulf of Mexico Fishery Management Councils

Criteria	Definition	MSY	30% SPR	40% SPR
MSY	The retained yield at F_{MSY} or $F_{SPRproxy}$	94.552 mt (208,451 lbs.)	17.249 mt (38,027 lbs.)	71.100 mt (156,709 lbs.)
F_{MSY} or proxy	The fishing mortality rate associated with MSY or SPR proxy	0.077 yr ⁻¹	0.190 yr ⁻¹	0.128 yr ⁻¹
MFMT (Maximum Fishing Mortality Threshold)	F_{MSY} or SPR proxy	0.077 yr ⁻¹	0.190 yr ⁻¹	0.128 yr ⁻¹
$F_{current}$ (recent average fishing mortality rate)	The geometric mean of F exploitation for 2022 – 2024		0.020 yr ⁻¹	
SSB_{MSY} or SPR_{proxy}	The estimated spawning stock biomass associated with F_{MSY} or $F_{SPRproxy}$	1,952.4 mt (4,304,305 lbs.)	154.312 mt (340,300 lbs.)	912.573 mt (2,011,879 lbs.)
MSST (Minimum Stock Size Threshold)	$0.75 * SSB_{MSY}$ or SPR_{proxy}	1,464.3 mt (3,228,229 lbs.)	115.734 mt (255,150 lbs.)	684.43 mt (1,508,909 lbs.)
$SSB_{current}$ (recent average of SSB)	The geometric mean of SSB for 2022 – 2024		1,964.579 mt (4,331,156 lbs.)	

Table 3.19. Projection results when exploitation rates = $F_{30\%SPR}$ (0.190) for Florida Keys/East Florida Hogfish. Equilibrium projections assume predicted recruitment follows either the spawner-recruit curve (S-R) or the long-term average from 1950 – 2024 (2.145 million fish). Recruitment (Recruits) is in thousands of age-0 fish, F is the exploitation rate, SSB is in metric tons (female plus male SSB), Retained Yield is in pounds (whole weight), and Retained Num is in numbers of fish.

Year	$F_{30\%SPR}$ Equilibrium Long-Term Projections (S-R)					$F_{30\%SPR}$ Equilibrium Long-Term Projections				
	Age-0 Recruits	F	SSB	Retained Yield	Retained Num	Age-0 Recruits	F	SSB	Retained Yield	Retained Num
2025	2,095.40	0.190	2,155.98	570,691	168,223	2,145.97	0.191	2,185.38	580,881	172,753
2026	1,952.30	0.190	1,875.40	497,337	146,197	2,145.97	0.191	1,916.61	510,476	151,453
2027	1,822.94	0.190	1,652.00	433,813	129,071	2,145.97	0.191	1,696.18	447,544	134,281
2028	1,714.14	0.190	1,482.80	383,751	116,153	2,145.97	0.191	1,529.40	398,698	121,997
2029	1,620.17	0.190	1,348.56	344,973	106,122	2,145.97	0.191	1,407.67	363,882	113,866
2030	1,537.71	0.190	1,238.86	314,323	98,017	2,145.97	0.191	1,320.37	339,911	108,658
2031	1,464.66	0.190	1,147.39	289,426	91,271	2,145.97	0.191	1,258.52	323,561	105,358
2032	1,398.92	0.190	1,069.30	268,588	85,490	2,145.97	0.191	1,214.62	312,262	103,220
2033	1,339.71	0.190	1,002.13	250,929	80,478	2,145.97	0.191	1,184.14	304,507	101,837
2034	1,286.12	0.190	943.77	235,761	76,087	2,145.97	0.191	1,163.39	299,210	100,945

Table 3.20. Projection results when exploitation rates = $F_{30\%SPR}$ (0.190) and 75% $F_{30\%SPR}$ (0.142) for Florida Keys/East Florida Hogfish. Short-term projections assume predicted age-0 recruitment is equal to the average from 2022 to 2024 (1.926 million). Recruitment (Recruits) is in thousands of age-0 fish, F is the exploitation rate, SSB is in metric tons (female plus male SSB), Retained Yield is in pounds (whole weight), and Retained Num is in numbers of fish.

Year	$F_{30\%SPR}$ Short-Term Projections					0.75 * $F_{30\%SPR}$ Short-Term Projections				
	Age-0 Recruits	F	SSB	Retained Yield	Retained Num	Age-0 Recruits	F	SSB	Retained Yield	Retained Num
2025	1,926.50	0.190	2,155.77	570,132	167,826	1,926.50	0.142	2,155.77	427,532	126,030
2026	1,926.50	0.190	1,869.46	494,613	144,732	1,926.50	0.142	1,978.62	393,651	115,229
2027	1,926.50	0.190	1,635.39	427,970	126,381	1,926.50	0.142	1,821.10	361,314	106,084
2028	1,926.50	0.190	1,457.90	376,586	113,371	1,926.50	0.142	1,690.87	333,212	98,817
2029	1,926.50	0.190	1,327.66	339,998	104,783	1,926.50	0.142	1,587.27	310,172	93,232
2030	1,926.50	0.190	1,233.56	314,744	99,271	1,926.50	0.142	1,507.44	292,090	89,053
2031	1,926.50	0.190	1,166.21	297,431	95,761	1,926.50	0.142	1,447.68	278,162	85,948
2032	1,926.50	0.190	1,117.87	285,407	93,477	1,926.50	0.142	1,403.57	267,813	83,724
2033	1,926.50	0.190	1,083.77	277,093	91,990	1,926.50	0.141	1,372.19	260,447	82,200
2034	1,926.50	0.190	1,060.06	271,359	91,021	1,926.50	0.141	1,350.48	255,349	81,193

Table 3.21. Projection results when exploitation rates = $F_{40\%SPR}$ (0.129) for Florida Keys/East Florida Hogfish. Equilibrium projections assume predicted recruitment follows either the spawner-recruit curve (S-R) or the long-term average from 1950 – 2024 (2.145 million fish). Recruitment (Recruits) is in thousands of age-0 fish, F is the exploitation rate, SSB is in metric tons (female plus male SSB), Retained Yield is in pounds (whole weight), and Retained Num is in numbers of fish.

Year	$F_{40\%SPR}$ Equilibrium Long-Term Projections (S-R)					$F_{40\%SPR}$ Equilibrium Long-Term Projections				
	Age-0 Recruits	F	SSB	Retained Yield	Retained Num	Age-0 Recruits	F	SSB	Retained Yield	Retained Num
2025	2,095.40	0.129	2,155.98	388,356	114,684	2,145.97	0.130	2,185.38	395,330	117,777
2026	2,026.02	0.129	2,015.12	363,898	106,997	2,145.97	0.130	2,059.46	373,607	110,836
2027	1,962.11	0.129	1,893.44	340,320	100,535	2,145.97	0.130	1,944.46	351,083	104,475
2028	1,907.09	0.129	1,794.33	320,020	95,315	2,145.97	0.130	1,848.36	331,348	99,374
2029	1,858.12	0.129	1,710.20	303,064	91,019	2,145.97	0.130	1,771.09	315,678	95,612
2030	1,814.10	0.129	1,637.66	288,840	87,386	2,145.97	0.130	1,710.44	303,796	92,943
2031	1,774.46	0.129	1,574.65	276,752	84,259	2,145.97	0.130	1,663.73	294,951	91,083
2032	1,738.09	0.129	1,518.71	266,203	81,491	2,145.97	0.130	1,627.52	288,264	89,752
2033	1,705.01	0.129	1,469.29	257,001	79,038	2,145.97	0.130	1,600.22	283,304	88,809
2034	1,674.85	0.129	1,425.40	248,919	76,849	2,145.97	0.130	1,579.99	279,639	88,140

Table 3.22. Projection results when exploitation rates = $F_{40\%SPR}$ (0.129) and 75% $F_{30\%SPR}$ (0.097) for Florida Keys/East Florida Hogfish. Short-term projections assume predicted age-0 recruitment is equal to the average from 2020 to 2024 (1.926 million). Recruitment (Recruits) is in thousands of age-0 fish, F is the exploitation rate, SSB is in metric tons (female plus male SSB), Retained Yield is in pounds (whole weight), and Retained Num is in numbers of fish.

Year	$F_{40\%SPR}$ Short-Term Projections					0.75 * $F_{40\%SPR}$ Short-Term Projections				
	Age-0 Recruits	F	SSB	Retained Yield	Retained Num	Age-0 Recruits	F	SSB	Retained Yield	Retained Num
2025	1,926.50	0.129	2,155.77	387,977	114,417	1,926.50	0.097	2,155.77	290,920	85,881
2026	1,926.50	0.129	2,008.97	361,975	105,975	1,926.50	0.097	2,083.63	282,153	82,639
2027	1,926.50	0.129	1,875.57	335,863	98,479	1,926.50	0.097	2,011.21	272,361	79,612
2028	1,926.50	0.129	1,763.71	313,326	92,573	1,926.50	0.097	1,945.21	262,819	76,996
2029	1,926.50	0.129	1,673.19	295,513	88,248	1,926.50	0.097	1,887.62	254,188	74,818
2030	1,926.50	0.129	1,601.54	281,984	85,181	1,926.50	0.097	1,839.18	246,758	73,048
2031	1,926.50	0.129	1,545.76	271,867	83,037	1,926.50	0.097	1,799.77	240,519	71,627
2032	1,926.50	0.129	1,502.12	264,205	81,501	1,926.50	0.097	1,767.69	236,111	70,717
2033	1,926.50	0.129	1,468.76	258,484	80,410	1,926.50	0.097	1,742.11	232,258	69,913
2034	1,926.50	0.129	1,443.60	254,228	79,632	1,926.50	0.097	1,722.37	229,227	69,295

Table 3.23. Projection results when exploitation rates = $F_{current}$ (0.020) for Florida Keys/East Florida Hogfish. Short-term projections assume predicted age-0 recruitment is equal to the average from 2020 to 2024 (1.926 million). Recruitment (Recruits) is in thousands of age-0 fish, F is the exploitation rate, SSB is in metric tons (female plus male SSB), Retained Yield is in pounds (whole weight), and Retained Num is in numbers of fish.

$F_{current}$ Short-Term Projections					
Year	Age-0 Recruits	F	SSB	Retained Yield	Retained Num
2025	1,926.50	0.020	2,155.77	59,990	17,750
2026	1,926.50	0.020	2,262.18	63,201	18,531
2027	1,926.50	0.020	2,358.30	66,169	19,226
2028	1,926.50	0.020	2,443.60	68,845	19,834
2029	1,926.50	0.020	2,517.76	71,199	20,355
2030	1,926.50	0.020	2,581.60	73,242	20,796
2031	1,926.50	0.020	2,636.39	75,004	21,170
2032	1,926.50	0.020	2,681.80	76,471	21,477
2033	1,926.50	0.020	2,720.02	77,714	21,734
2034	1,926.50	0.020	2,752.18	78,762	21,948

Table 3.24. Projection results when exploitation rates = F_{MSY} (0.073) for Florida Keys/East Florida Hogfish. Equilibrium projections assume predicted recruitment follows either the spawner-recruit curve (S-R) or the long-term average from 1950 – 2024 (2.145 million fish). Recruitment (Recruits) is in thousands of age-0 fish, F is the exploitation rate, SSB is in metric tons (female plus male SSB), Retained Yield is in pounds (whole weight), and Retained Num is in numbers of fish.

Year	F_{MSY} Equilibrium Long-Term Projections (S-R)					F_{MSY} Equilibrium Long-Term Projections				
	Age-0 Recruits	F	SSB	Retained Yield	Retained Num	Age-0 Recruits	F	SSB	Retained Yield	Retained Num
2025	2,095.40	0.073	2,155.98	218,112	64,521	2,145.97	0.073	2,185.38	222,050	66,262
2026	2,090.78	0.073	2,146.29	217,779	64,067	2,145.97	0.073	2,193.60	223,641	66,363
2027	2,086.26	0.073	2,136.87	216,692	63,675	2,145.97	0.073	2,194.87	223,564	66,123
2028	2,083.28	0.073	2,130.67	215,583	63,402	2,145.97	0.073	2,193.32	222,748	65,783
2029	2,080.71	0.073	2,125.35	214,639	63,209	2,145.97	0.073	2,190.30	221,783	65,472
2030	2,078.45	0.073	2,120.68	213,883	63,066	2,145.97	0.073	2,186.84	220,926	65,230
2031	2,076.60	0.073	2,116.85	213,294	62,964	2,145.97	0.073	2,183.70	220,251	65,065
2032	2,074.61	0.073	2,112.75	212,729	62,863	2,145.97	0.073	2,180.06	219,635	64,931
2033	2,072.90	0.073	2,109.24	212,265	62,778	2,145.97	0.073	2,176.98	219,162	64,837
2034	2,071.48	0.073	2,106.32	211,893	62,707	2,145.97	0.073	2,174.55	218,815	64,775

Table 3.25. Projection results when exploitation rates = F_{MSY} (0.073) and 75% F_{MSY} (0.054) for Florida Keys/East Florida Hogfish. Short-term projections assume predicted age-0 recruitment is equal to the average from 2020 to 2024 (1.926 million). Recruitment (Recruits) is in thousands of age-0 fish, F is the exploitation rate, SSB is in metric tons (female plus male SSB), Retained Yield is in pounds (whole weight), and Retained Num is in numbers of fish.

Year	F_{MSY} Short-Term Projections					0.75 * F_{MSY} Short-Term Projections				
	Age-0 Recruits	F	SSB	Retained Yield	Retained Num	Age-0 Recruits	F	SSB	Retained Yield	Retained Num
2025	1,926.50	0.073	2,155.77	217,900	64,372	1,926.50	0.054	2,155.77	163,401	48,298
2026	1,926.50	0.073	2,139.95	216,661	63,479	1,926.50	0.054	2,182.07	166,019	48,654
2027	1,926.50	0.073	2,117.77	213,933	62,404	1,926.50	0.054	2,198.84	167,707	48,850
2028	1,926.50	0.073	2,094.41	210,819	61,406	1,926.50	0.054	2,209.31	168,732	48,950
2029	1,926.50	0.073	2,071.79	207,928	60,588	1,926.50	0.054	2,215.04	169,282	48,986
2030	1,926.50	0.073	2,051.14	205,480	59,958	1,926.50	0.054	2,217.67	169,532	48,983
2031	1,926.50	0.073	2,033.16	203,499	59,495	1,926.50	0.054	2,218.60	169,613	48,968
2032	1,926.50	0.073	2,016.90	201,820	59,133	1,926.50	0.054	2,217.49	169,510	48,927
2033	1,926.50	0.073	2,003.19	200,482	58,862	1,926.50	0.054	2,215.90	169,363	48,884
2034	1,926.50	0.073	1,991.89	199,432	58,663	1,926.50	0.054	2,214.27	169,212	48,846

3.14 FL KEYS/EFL Figures

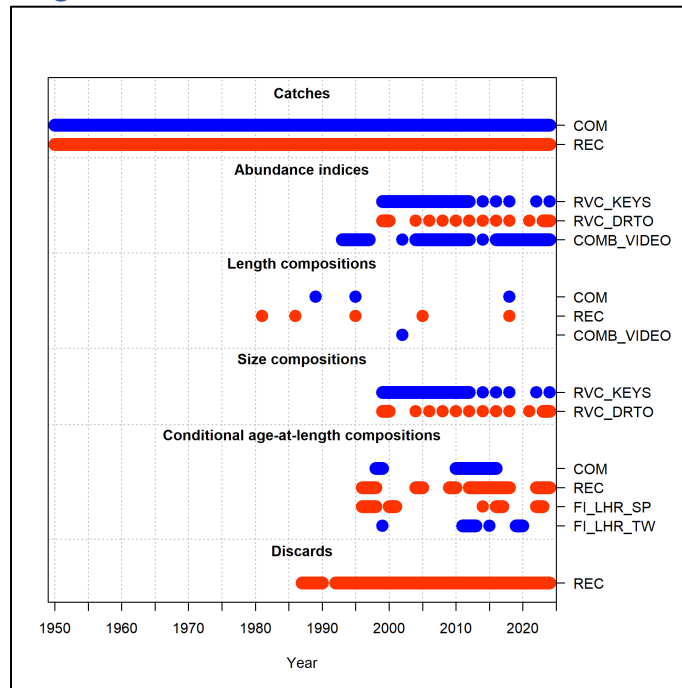


Figure 3.1. Data sources used in the Florida Keys/East Florida Hogfish Stock Synthesis assessment model (KEYS base model).

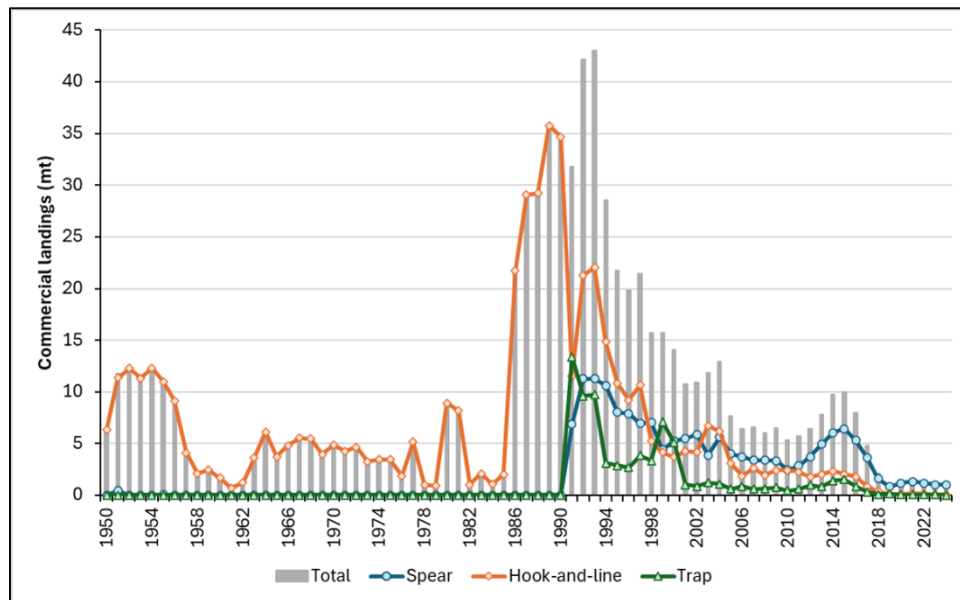


Figure 3.2. Commercial landings (metric tons) of Florida Keys/East Florida Hogfish by gear for years 1950 – 2024.

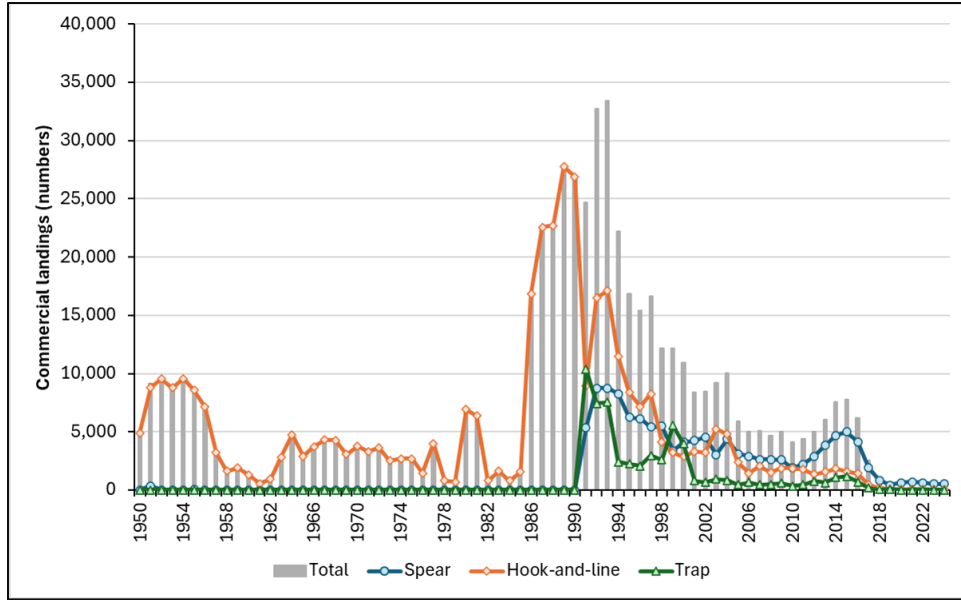


Figure 3.3. Commercial landings (numbers) of Florida Keys/East Florida Hogfish by gear for years 1950 – 2024.

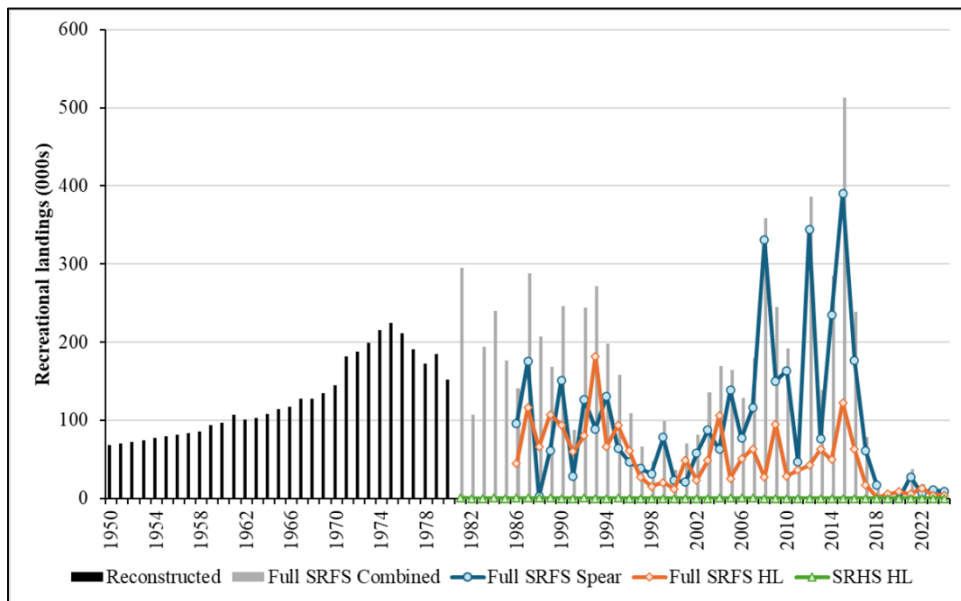


Figure 3.4. Recreational landings (numbers) of Florida Keys/East Florida Hogfish for years 1950 – 2024. The reconstructed historic landings are from 1950 – 1980 (black bars). The ‘Full SRFS’ estimates are from 1981 – 2024 (grey bars) and are comprised of ‘SRFS & SRFS-calibrated Private’ mode, MRIP charter mode, and MRIP shore mode landings estimates. ‘SRFS & SRFS-calibrated Private’ estimates are comprised of SRFS private mode (2021 – 2024) and SRFS ratio-calibrated MRIP private mode (1981 – 2020). The ‘Full SRFS Combined’ is comprised of the ‘Full SRFS’ estimates plus the SRHS estimates where the flagged estimates for 1981 and 1984 were replaced with the geometric mean of their six respective surrounding years. Landings by gear are presented beginning in 1986.

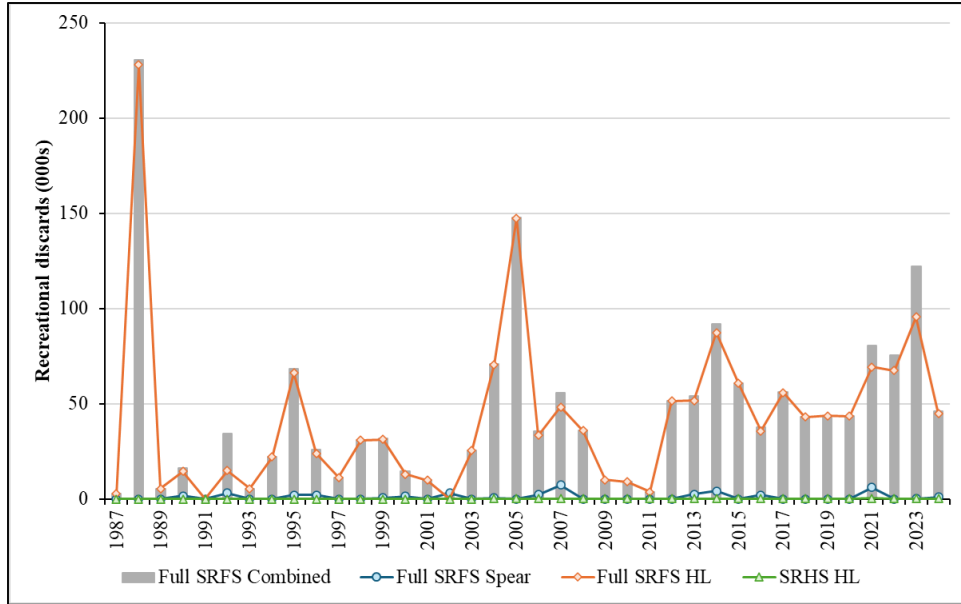


Figure 3.5. Recreational discards (numbers) of Florida Keys/East Florida Hogfish by gear for years 1987 – 2024. The ‘Full SRFS’ estimates are comprised of ‘SRFS & SRFS-calibrated Private’ mode, MRIP charter mode, and MRIP shore mode landings estimates. ‘SRFS & SRFS-calibrated Private’ estimates are comprised of SRFS private mode (2021 – 2024) and SRFS ratio-calibrated MRIP private mode (1981 – 2020). The ‘Full SRFS Combined’ is comprised of the ‘Full SRFS’ estimates plus the SRHS estimates.

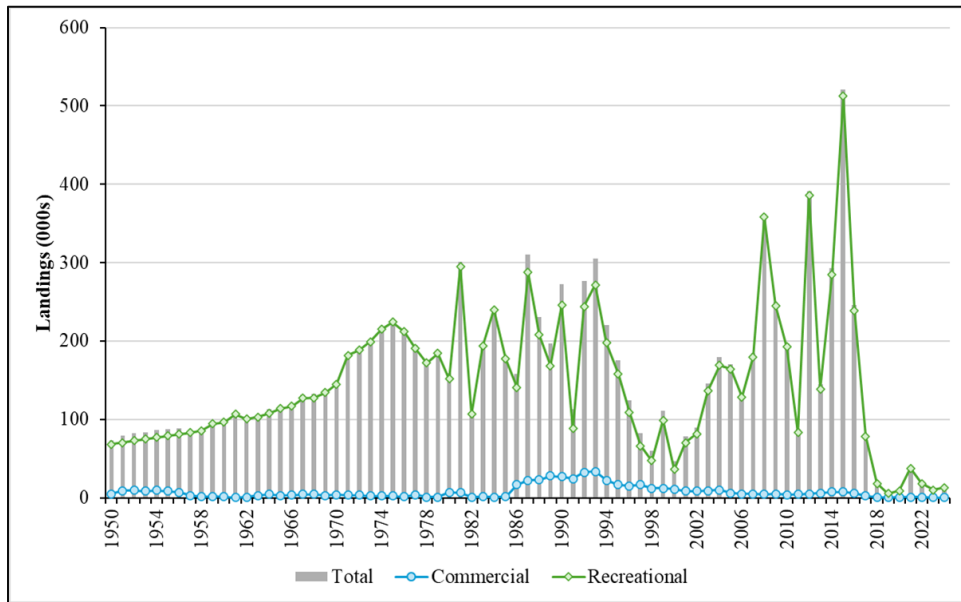


Figure 3.6. A comparison of the commercial landings (numbers; blue dots) with the recreational landings (numbers; green diamonds) of Florida Keys/East Florida Hogfish from 1950 – 2024.

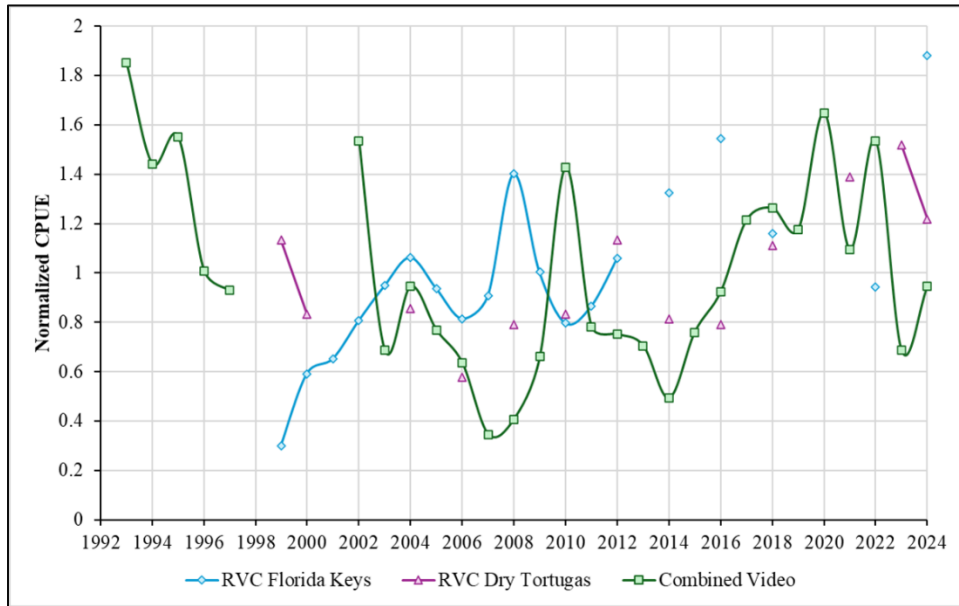


Figure 3.7. Normalized indices of relative abundance for Florida Keys/East Florida Hogfish from 1993 – 2024 from the Reef Fish Visual Census (RVC) and combined video surveys. The RVC Florida Keys was from 1999 – 2012, 2014, 2016, 2018, 2022, and 2024 while the RVC Dry Tortugas was from 1999 – 2000, biennially from 2004 – 2018, 2021, 2023, and 2024. The combined video was from 1993 – 1997 then 2002 – 2024.

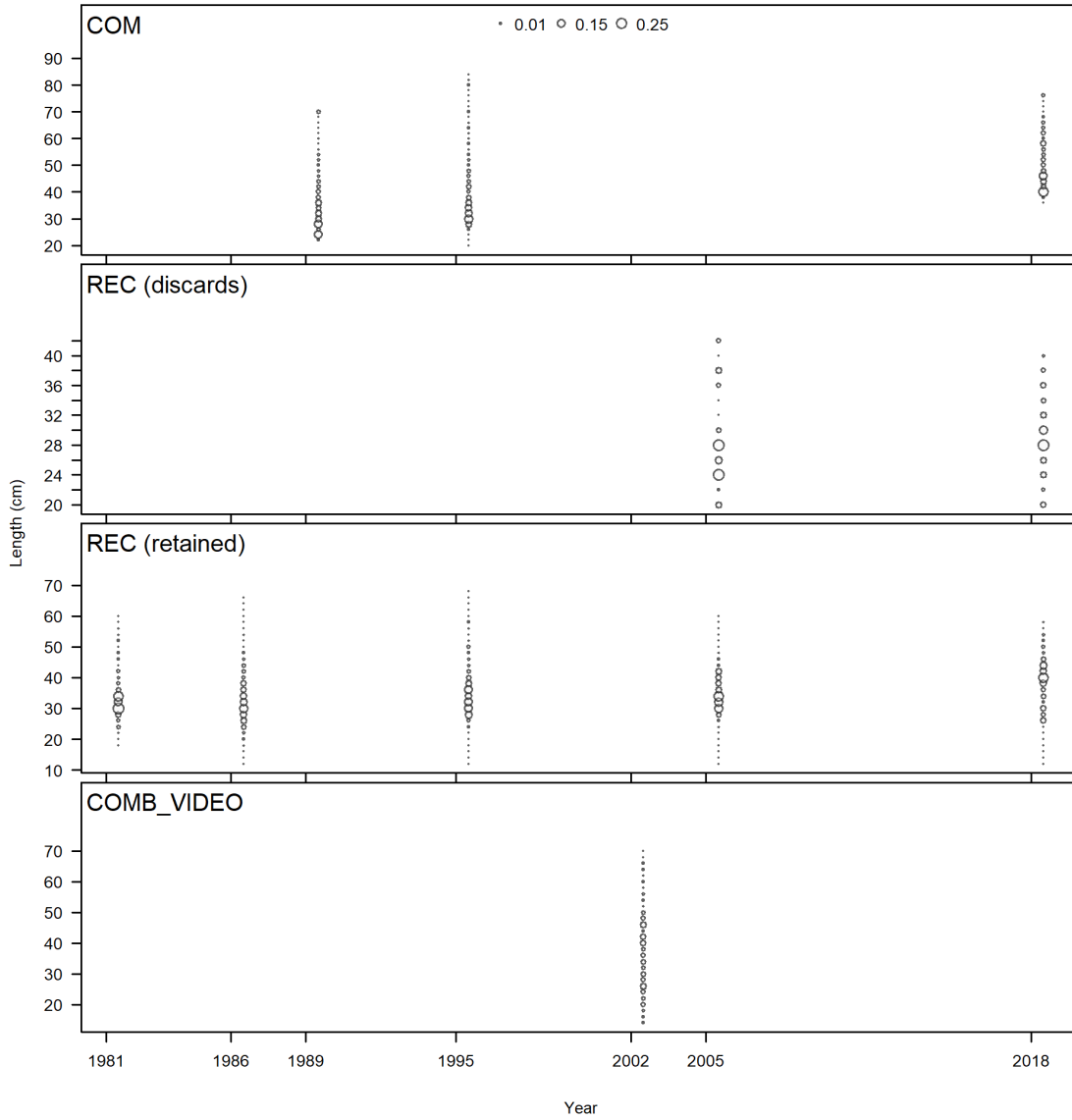


Figure 3.8. Catch-weighted length compositions (2 cm FL bins) of Florida Keys/East Florida Hogfish landings (retained) and discards by fishery for years 1981 – 2024. Commercial = COM, Full SRFS plus SRHS = REC, and combined video Index = COMB_VIDEO.

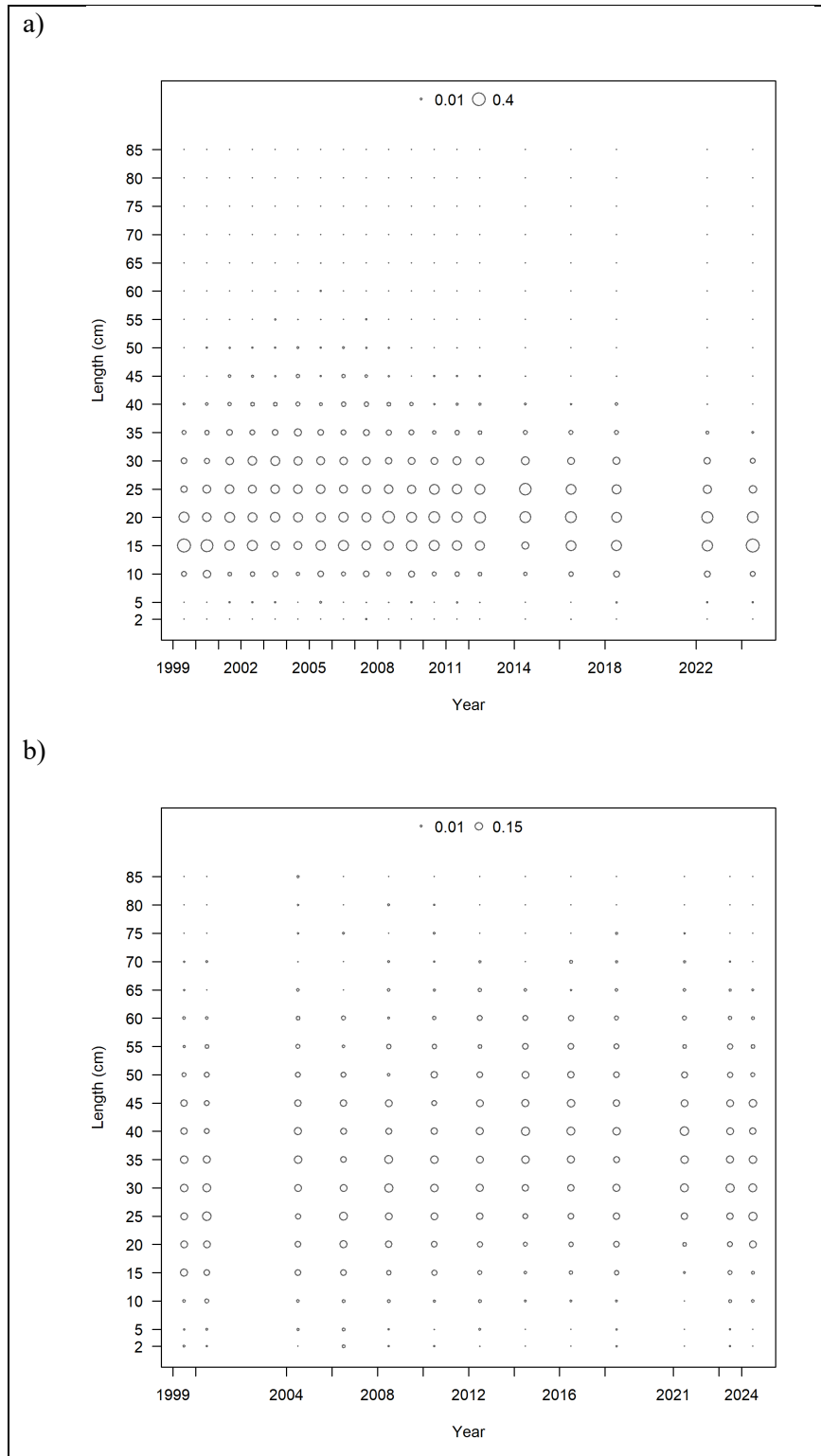


Figure 3.9. Generalized size compositions (5 cm FL bins) of Florida Keys/East Florida Hogfish from a) the RVC Florida Keys index and b) the RVC Dry Tortugas index for years 1999 – 2024.

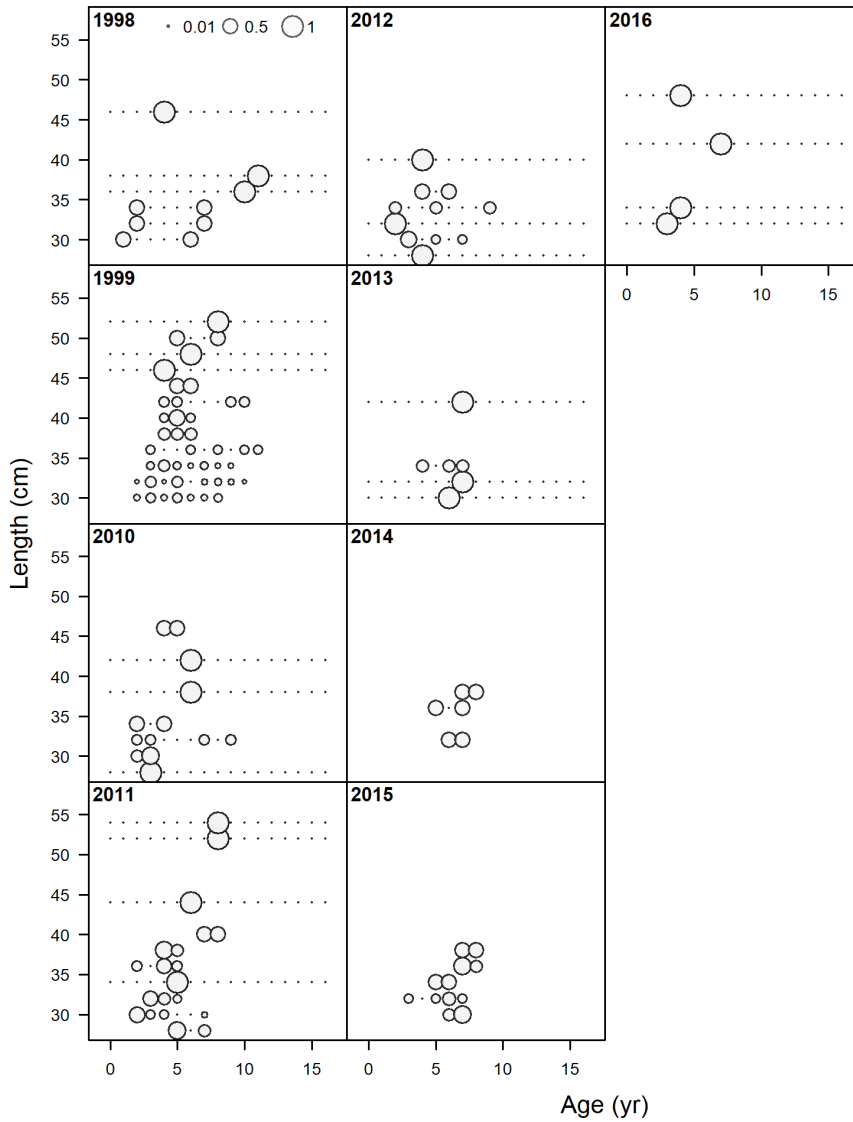


Figure 3.10. Observed conditional age-at-length in 2 cm FL bins of Florida Keys/East Florida Hogfish for the commercial fleet during years 1998 – 2016.

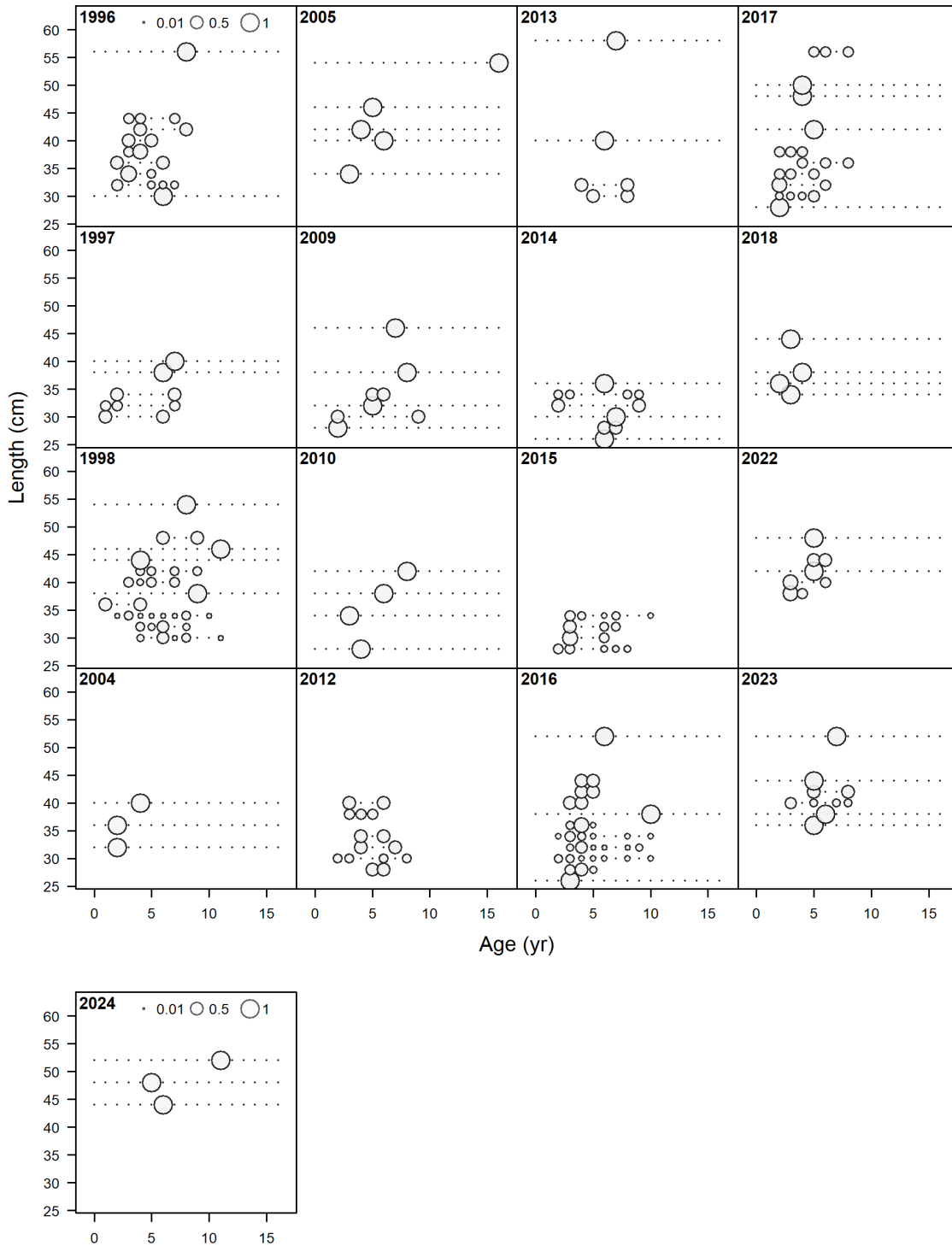


Figure 3.11. Observed conditional age-at-length in 2 cm FL bins of Florida Keys/East Florida Hogfish for the recreational fleet during years 1996 – 2024.

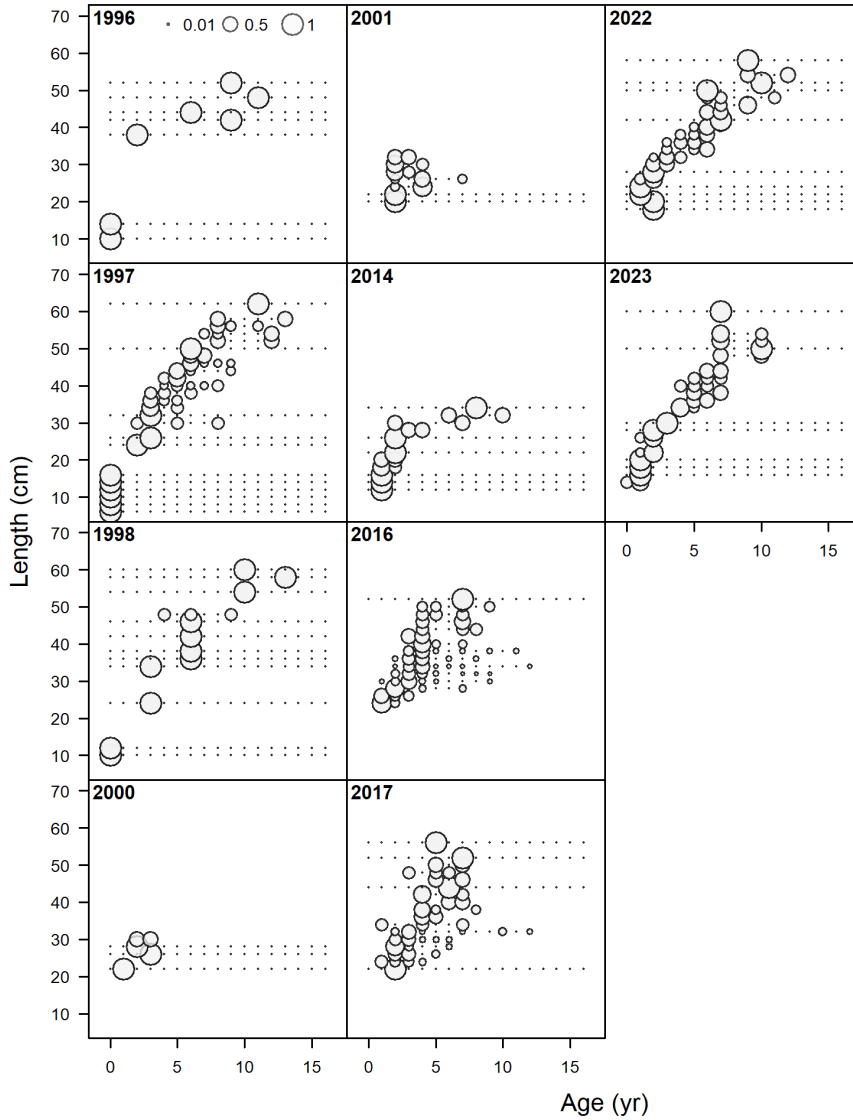


Figure 3.12. Observed conditional age-at-length in 2 cm FL bins of Florida Keys/East Florida Hogfish collected by the spear gear from fishery-independent data sources during years 1996 – 2023.

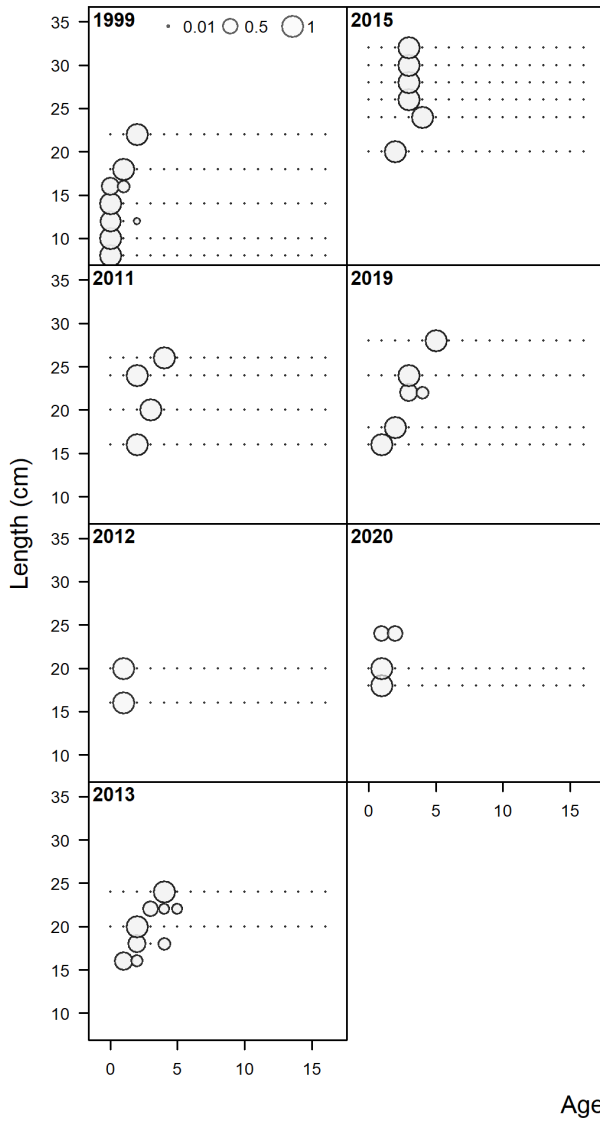


Figure 3.13. Observed conditional age-at-length in 2 cm FL bins of Florida Keys/East Florida Hogfish collected by the trawl gear from fishery-independent data sources during years 1999 – 2020.

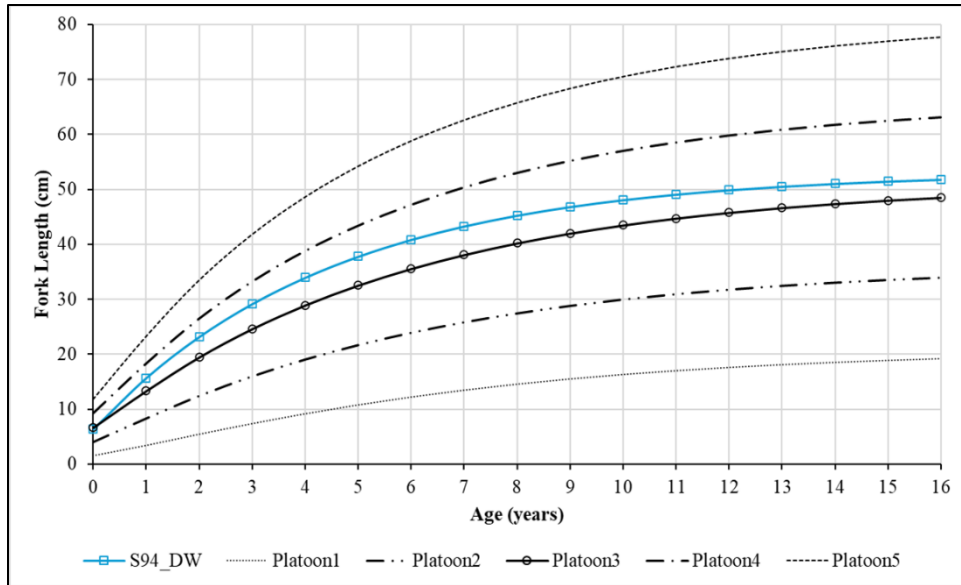


Figure 3.14. Mean size-at-age across 5 platoons for Florida Keys/East Florida Hogfish as estimated by the SEDAR 94 KEYS base model. Distribution of recruitment among platoons approximated a normal distribution (0.031, 0.237, 0.464, 0.237, 0.031) and the 3rd platoon (black circles) followed the L_{inf} (51.2 cm FL) and k (0.177) parameters estimated by the SEDAR 94 KEYS base model. A comparison with the external growth model developed during the Data Workshop is shown by the blue squares.

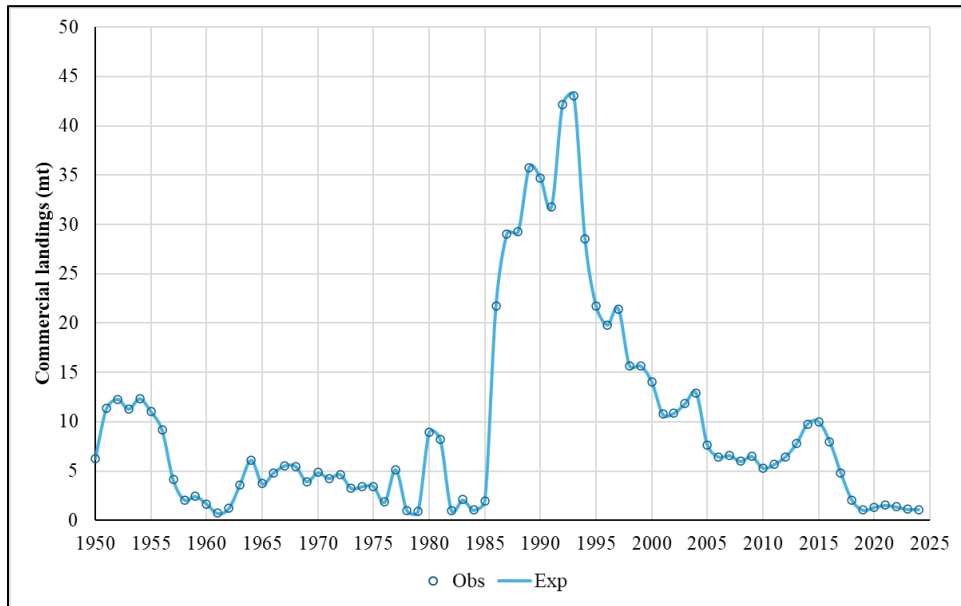


Figure 3.15. Florida Keys/East Florida Hogfish observed (dots) and expected (solid line) landings by the commercial fleet (in metric tons) from the SEDAR 94 KEYS base model.

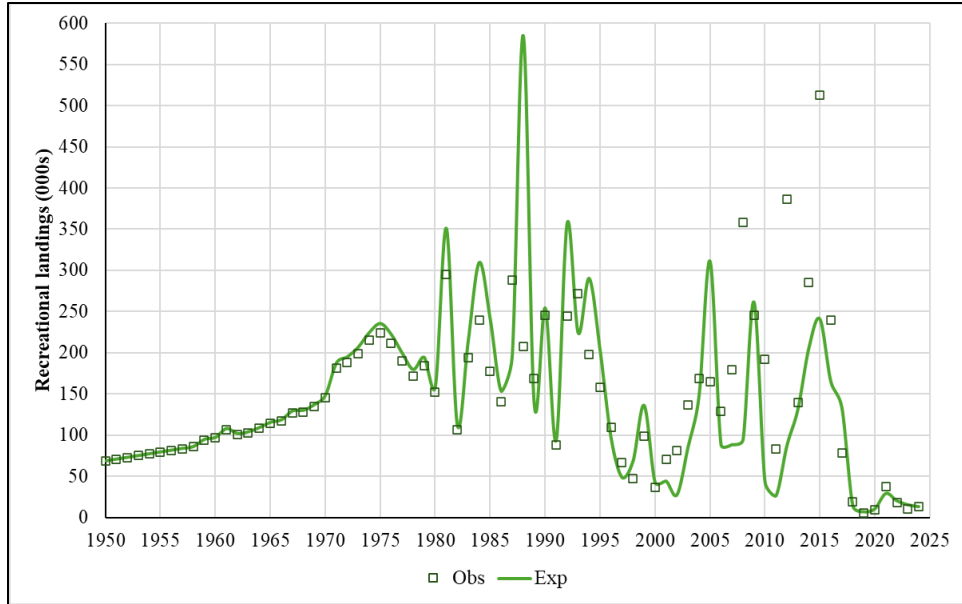


Figure 3.16. Florida Keys/East Florida Hogfish observed (squares) and expected (solid line) landings by the recreational fleet (in thousands of fish) from the SEDAR 94 KEYS base model.

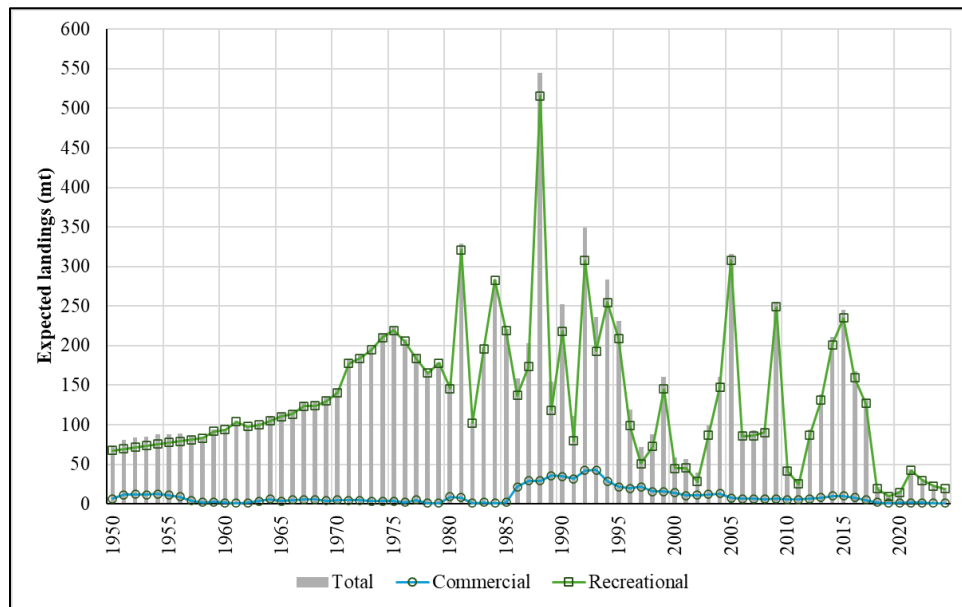


Figure 3.17. Expected landings of Florida Keys/East Florida Hogfish by fleet (in metric tons) as estimated from the SEDAR 94 KEYS base model.

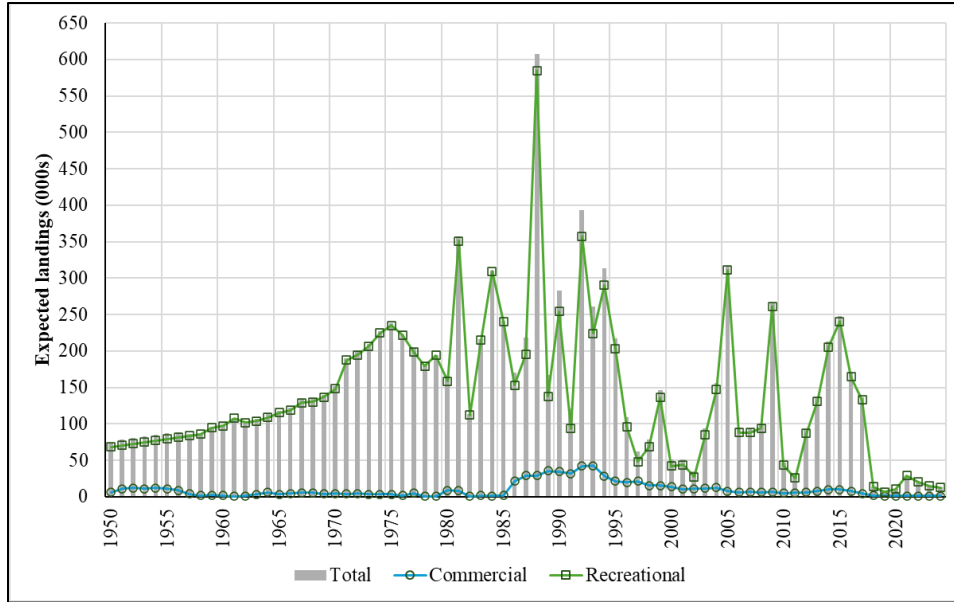


Figure 3.18. Expected landings of Florida Keys/East Florida Hogfish by fleet (in thousands of fish) as estimated from the SEDAR 94 KEYS base model.

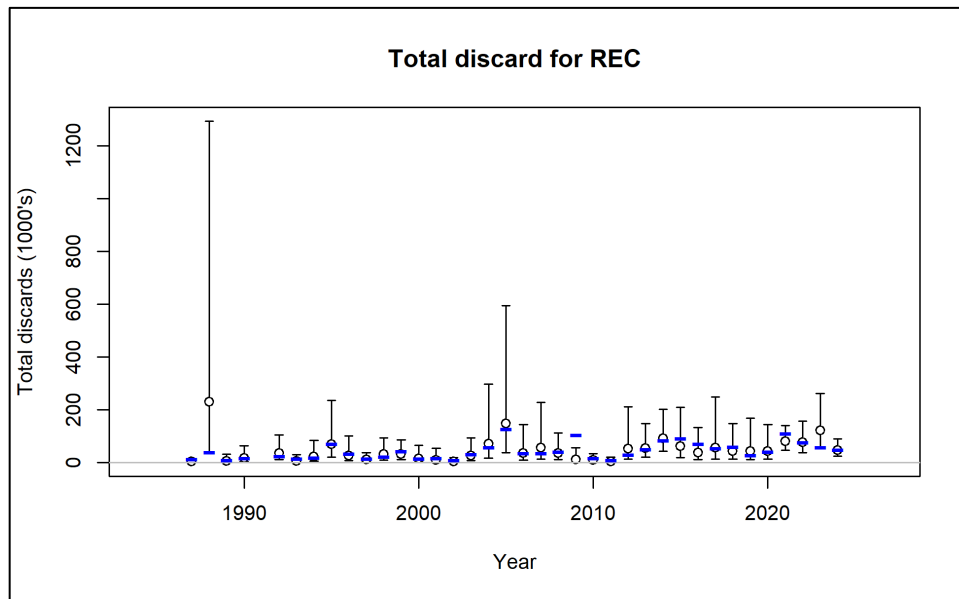


Figure 3.19. Florida Keys/East Florida Hogfish observed (dots with 95% confidence intervals) and expected (blue dashes) discards (i.e., before applying the discard mortality rate for each fleet) by the recreational fleet (in thousands of fish) from the SEDAR 94 KEYS base model.

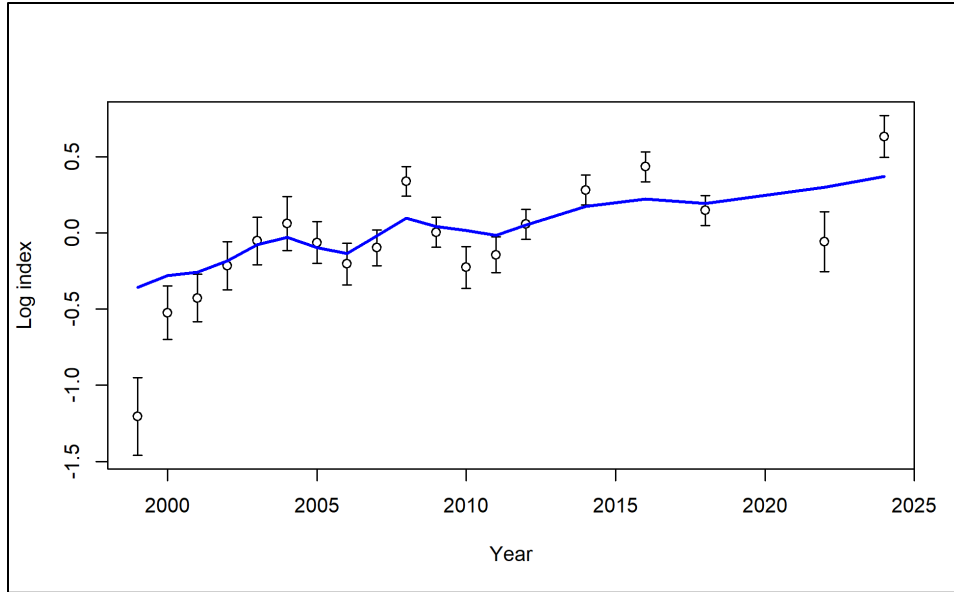


Figure 3.20. The Florida Keys/East Florida Hogfish observed (dots with 95% confidence intervals) and predicted (blue line) RVC Florida Keys index of relative abundance (log-transformed) from the SEDAR 94 KEYS base model.

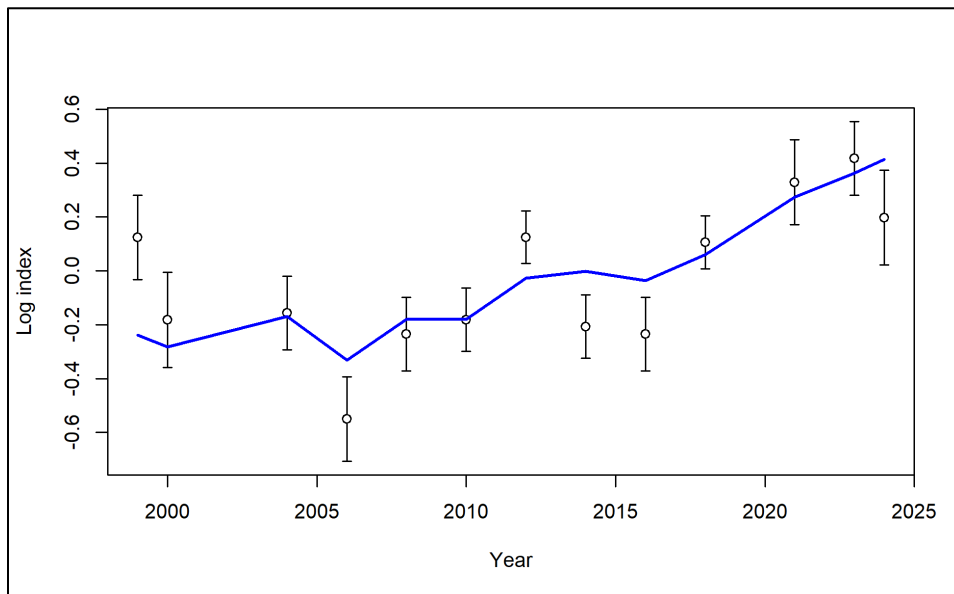


Figure 3.21. The Florida Keys/East Florida Hogfish observed (dots with 95% confidence intervals) and predicted (blue line) RVC Dry Tortugas index of relative abundance (log-transformed) from the SEDAR 94 KEYS base model.

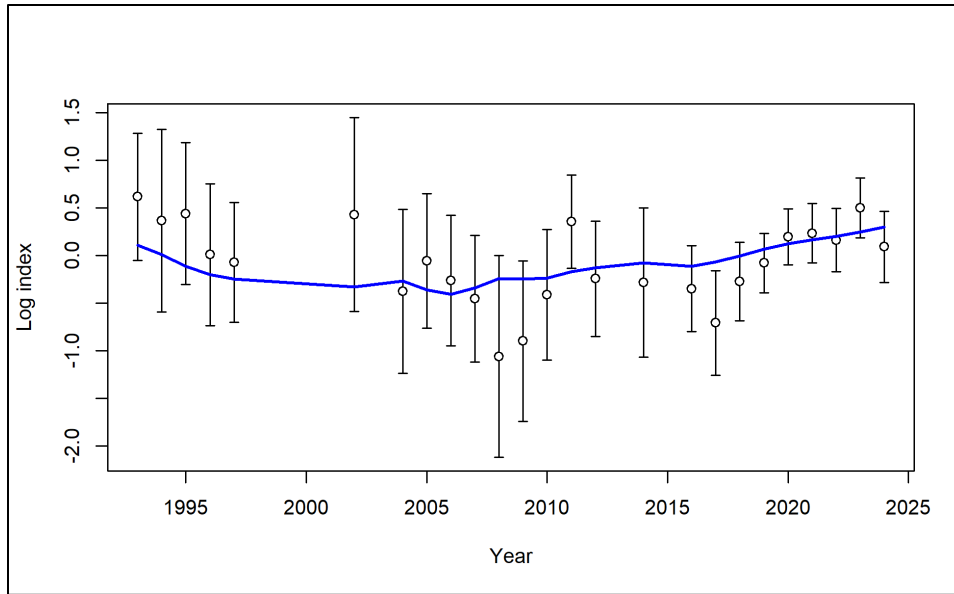


Figure 3.22. The Florida Keys/East Florida Hogfish observed (dots with 95% confidence intervals) and predicted (blue line) combined video index of relative abundance (log-transformed) from the SEDAR 94 KEYS base model.

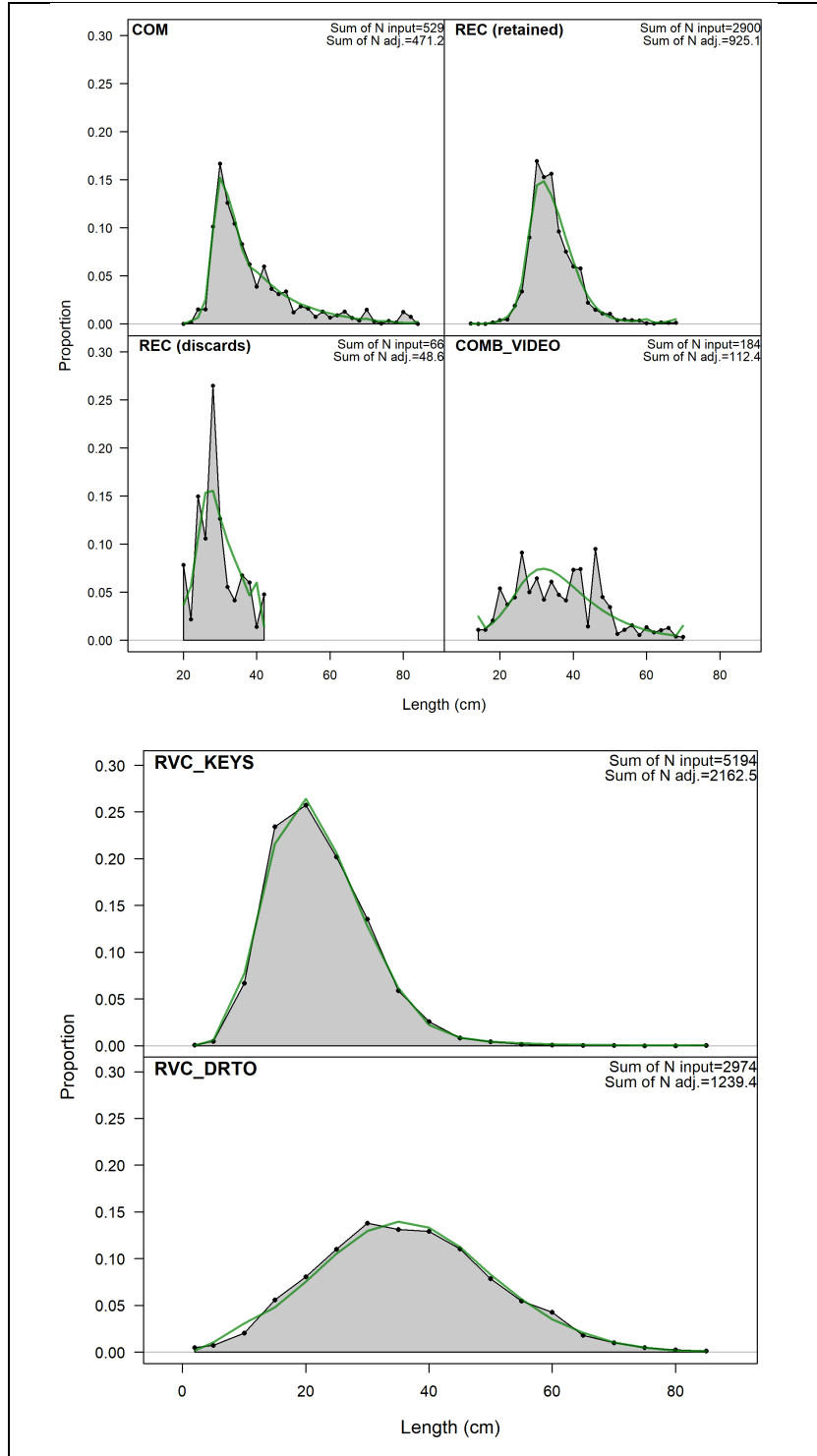


Figure 3.23. Model fits to the length composition of retained and discarded catch within a given fleet or survey aggregated across years for Florida Keys/East Florida Hogfish. Green lines represent predicted length compositions, while grey shaded regions represent observed length compositions. In the upper right hand corners, 'N input.' is the input sample size while 'N adj.' is the effective sample size calculated using the Dirichlet-Multinomial data-weighting adjustment.

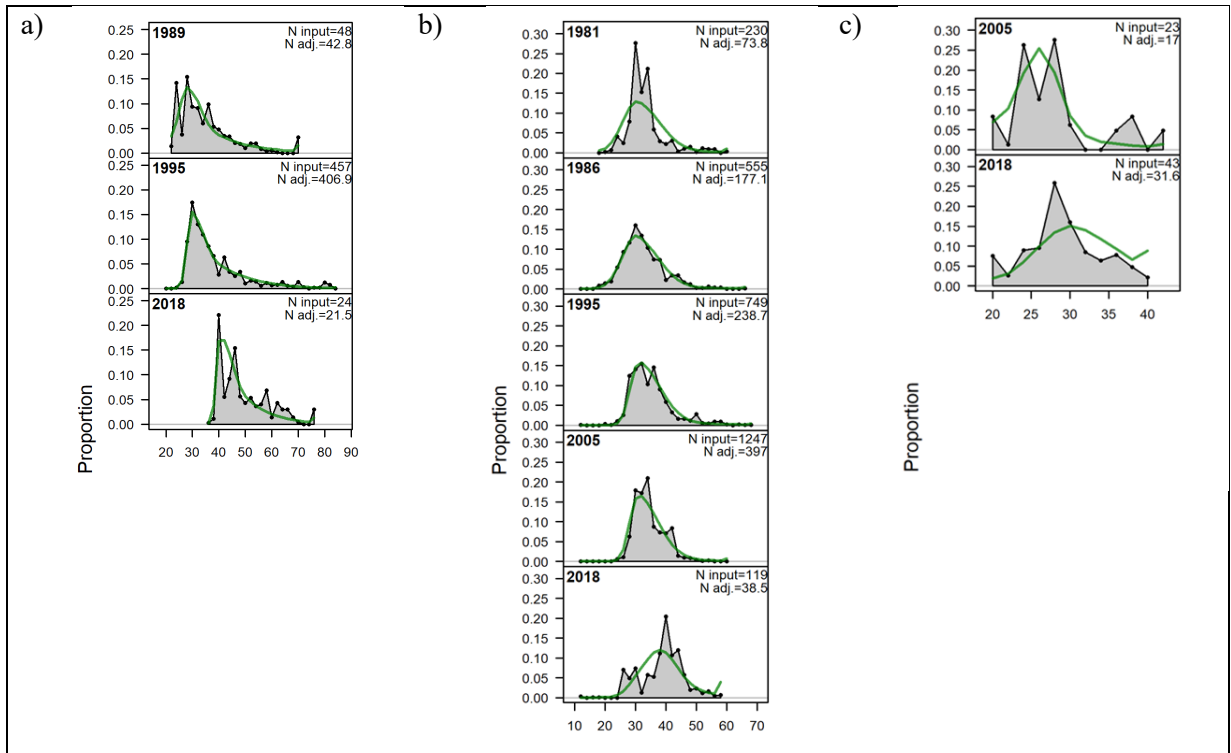


Figure 3.24. Model fits to the length composition of a) retained catch by the commercial fleet, b) retained catch by the recreational fleet, and c) discards for the recreational fleet by super-period for Florida Keys/East Florida Hogfish. Green lines represent predicted length compositions, while grey shaded regions represent observed length compositions. In the upper right hand corners, 'N input.' is the input sample size while 'N adj.' is the effective sample size calculated using the Dirichlet-Multinomial data-weighting adjustment. Data are in 2 cm fork length bins.

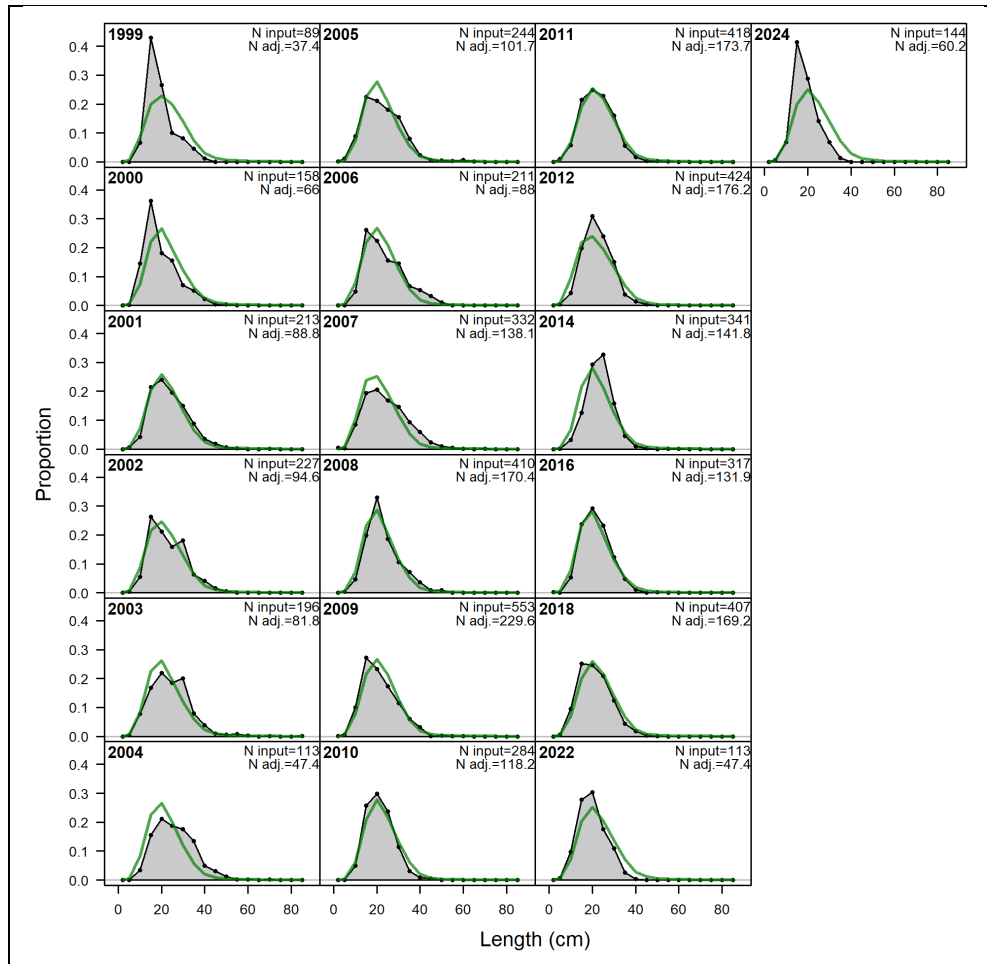


Figure 3.25. Model fits to the length composition data by the RVC Florida Keys index for Florida Keys/East Florida Hogfish. Green lines represent predicted length compositions, while grey shaded regions represent observed length compositions. In the upper right hand corners, 'N input.' is the input sample size while 'N adj.' is the effective sample size calculated using the Dirichlet-Multinomial data-weighting adjustment. Data are in 5 cm fork length bins.

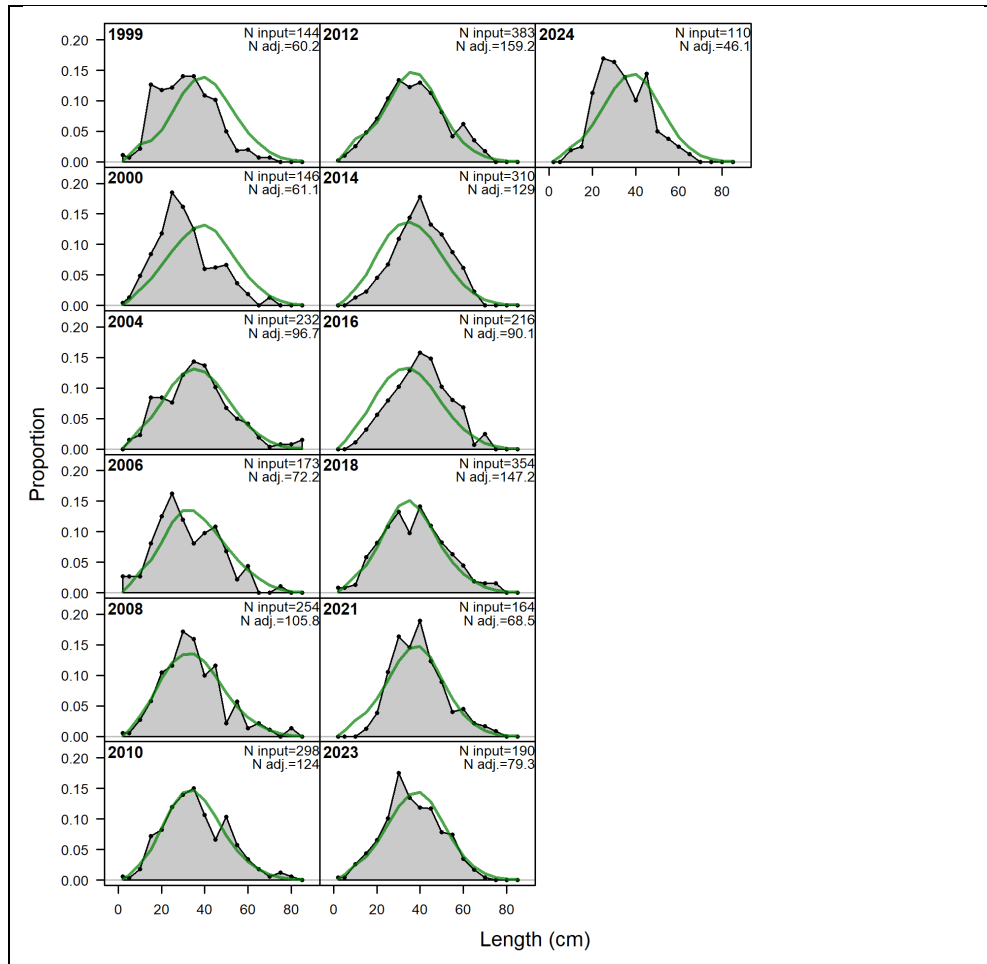


Figure 3.26. Model fits to the length composition data by the RVC Dry Tortugas index Florida Keys/East Florida Hogfish. Green lines represent predicted length compositions, while grey shaded regions represent observed length compositions. In the upper right hand corners, 'N input.' is the input sample size while 'N adj.' is the effective sample size calculated using the Dirichlet-Multinomial data-weighting adjustment. Data are in 5 cm fork length bins.

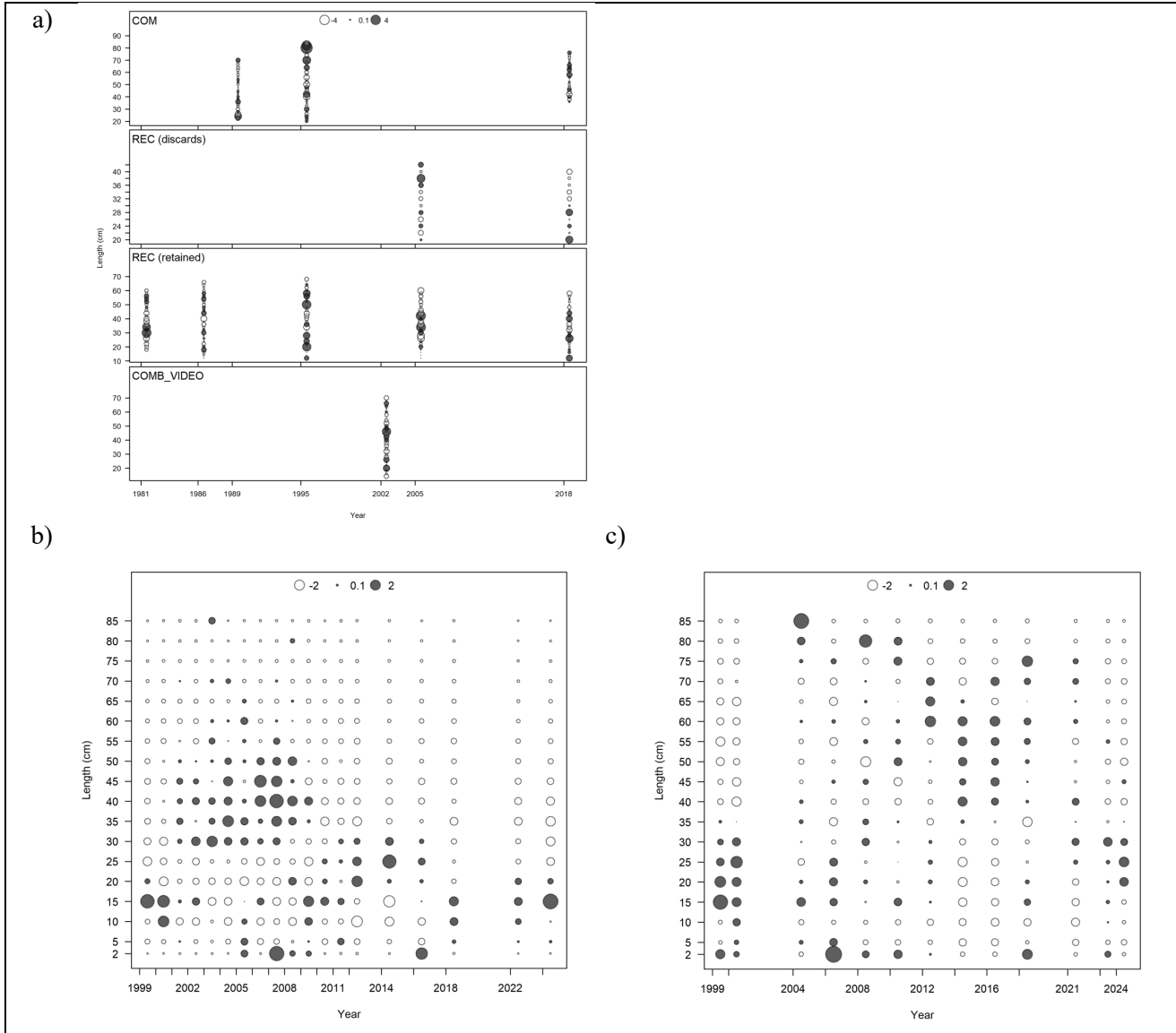


Figure 3.27. Pearson residuals for length composition data for a) the commercial and recreational fleets as well as the combined video index by super-period, b) the RVC Florida Keys index by year, and c) the RVC Dry Tortugas index by year for Florida Keys/East Florida Hogfish. Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected).

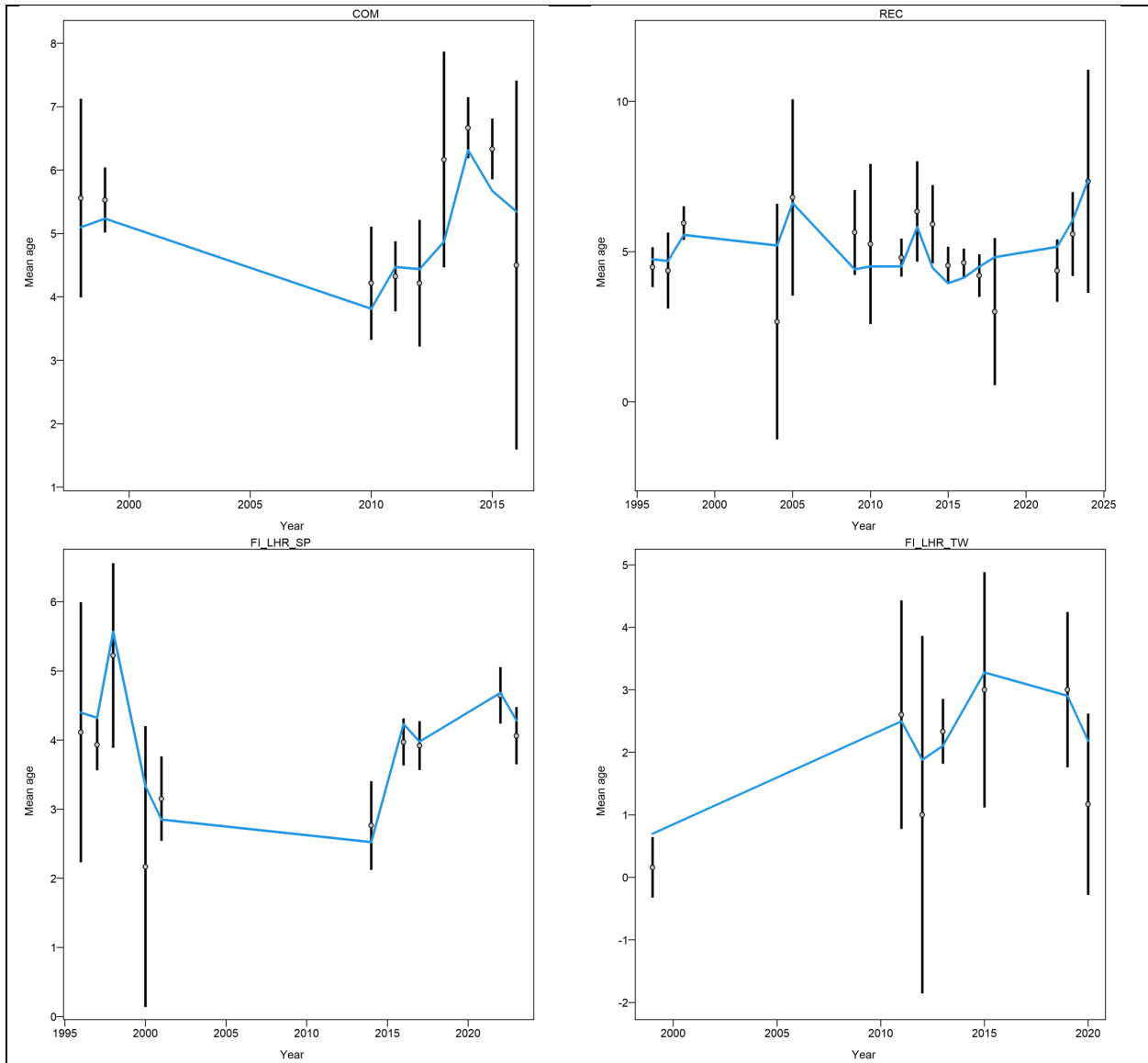


Figure 3.28. Mean ages of Florida Keys/East Florida Hogfish from conditional age-at-length data (commercial retained catch, recreational retained catch, fishery-independent spear, and fishery-independent trawl) aggregated across length bins. Observed values are dots with 95% confidence intervals and predicted values are the blue lines).

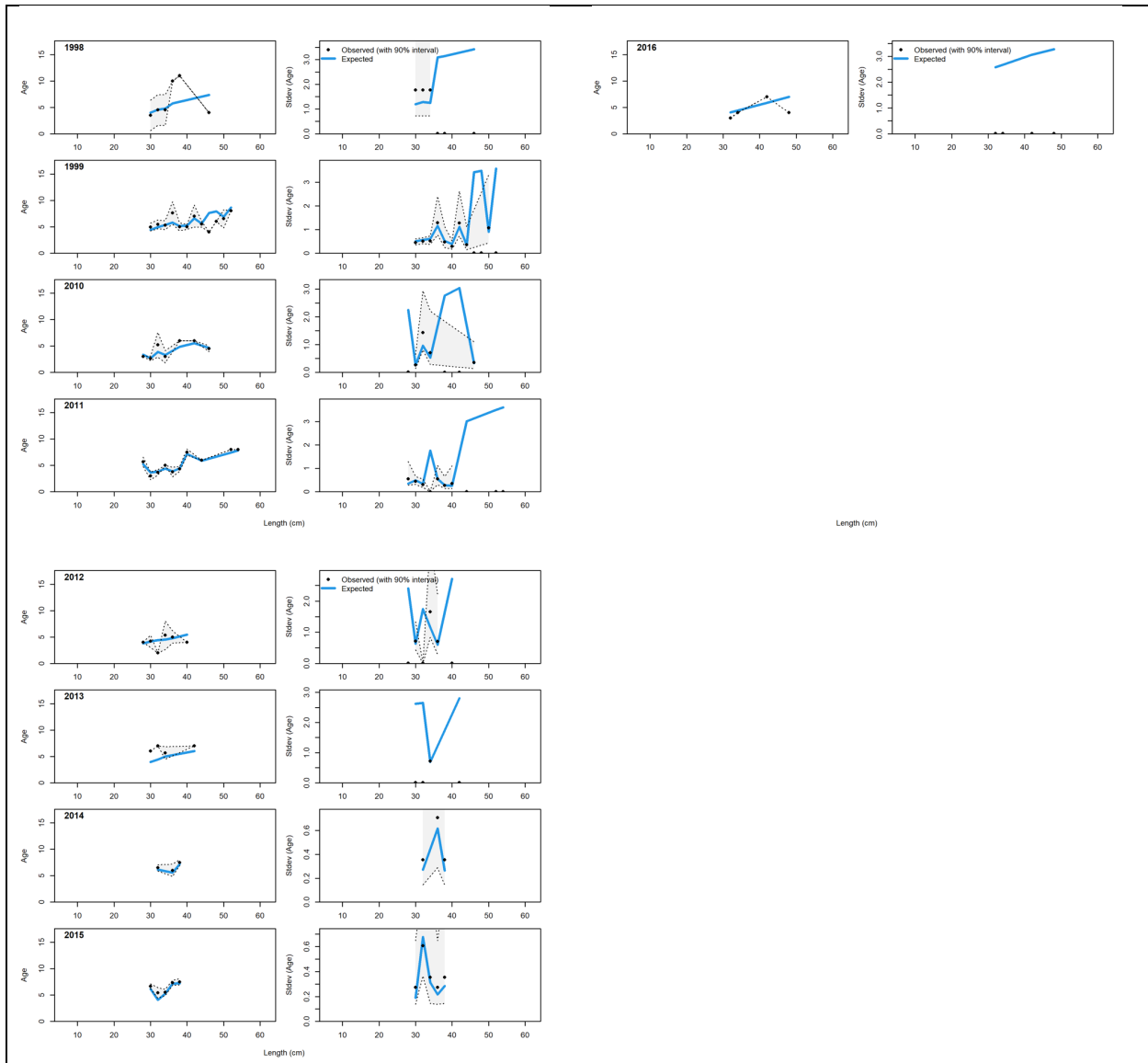


Figure 3.29. Model fits to the annual conditional age-at-length data from retained catch by the commercial fleet for Florida Keys/East Florida Hogfish. In the left plots, the blue lines represent predicted mean age-at-length by size class while the black dots and grey shaded regions represent the observed mean age-at-length by size class with 90% confidence intervals. In the right plots, the blue lines represent predicted standard error of mean age-at-length by size class while the black dots and grey shaded regions represent the observed standard error of mean age-at-length by size class with 90% confidence intervals.

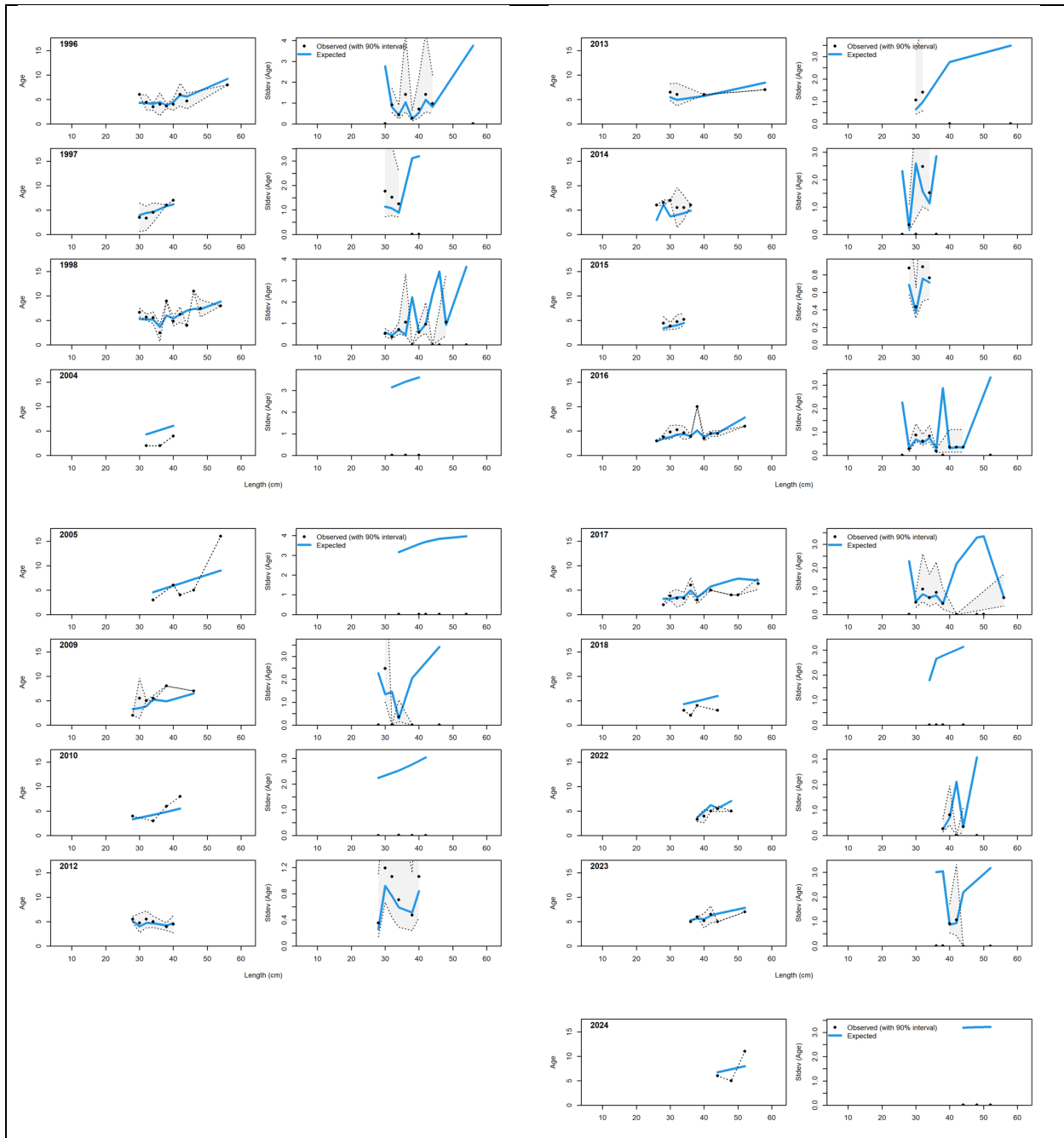


Figure 3.30. Model fits to the annual conditional age-at-length data from retained catch by the recreational fleet for Florida Keys/East Florida Hogfish. In the left plots, the blue lines represent predicted mean age-at-length by size class while the black dots and grey shaded regions represent the observed mean age-at-length by size class with 90% confidence intervals. In the right plots, the blue lines represent predicted standard error of mean age-at-length by size class while the black dots and grey shaded regions represent the observed standard error of mean age-at-length by size class with 90% confidence intervals.

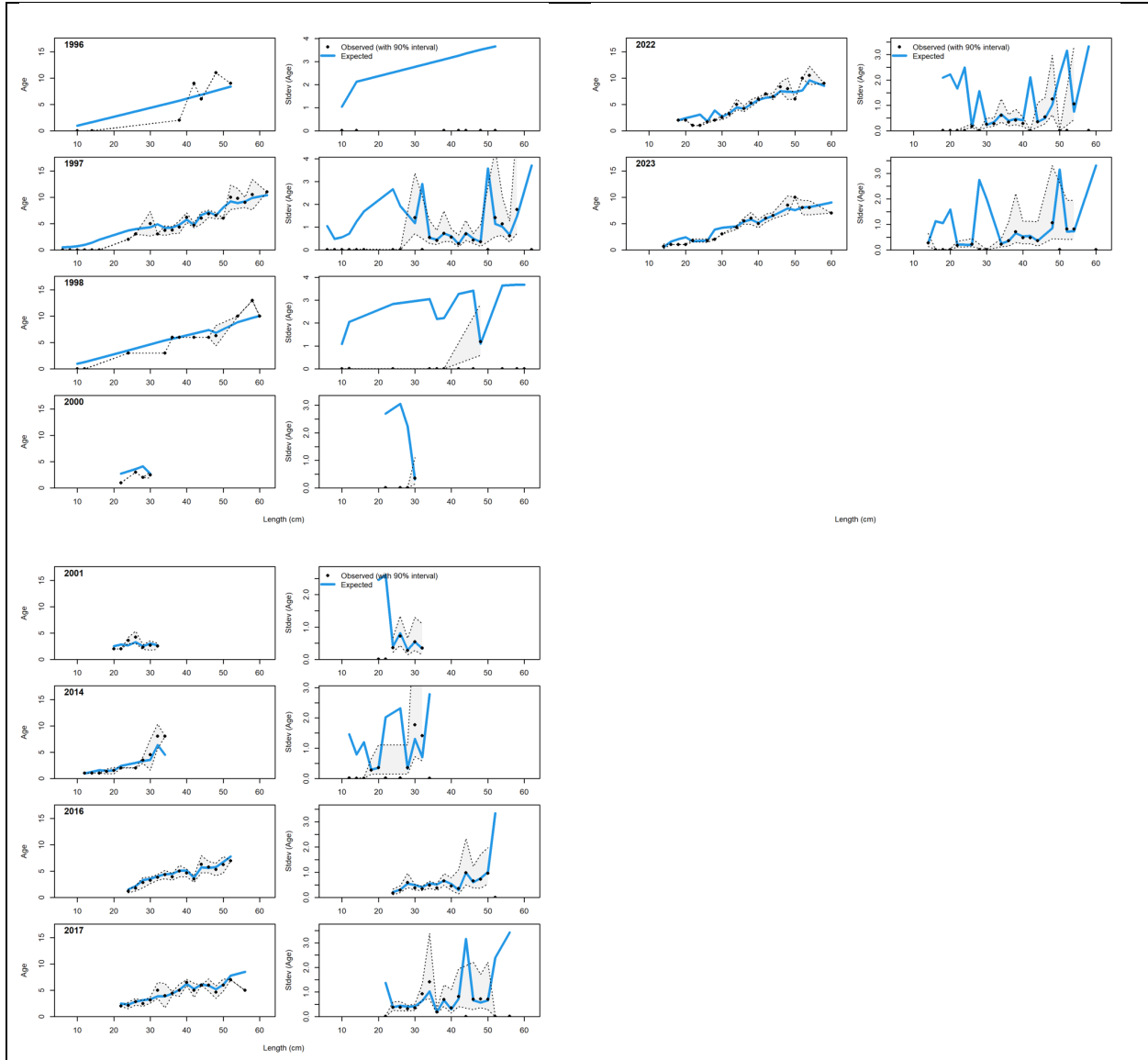


Figure 3.31. Model fits to the annual conditional age-at-length data from fishery-independent spear data sources for Florida Keys/East Florida Hogfish. In the left plots, the blue lines represent predicted mean age-at-length by size class while the black dots and grey shaded regions represent the observed mean age-at-length by size class with 90% confidence intervals. In the right plots, the blue lines represent predicted standard error of mean age-at-length by size class while the black dots and grey shaded regions represent the observed standard error of mean age-at-length by size class with 90% confidence intervals.

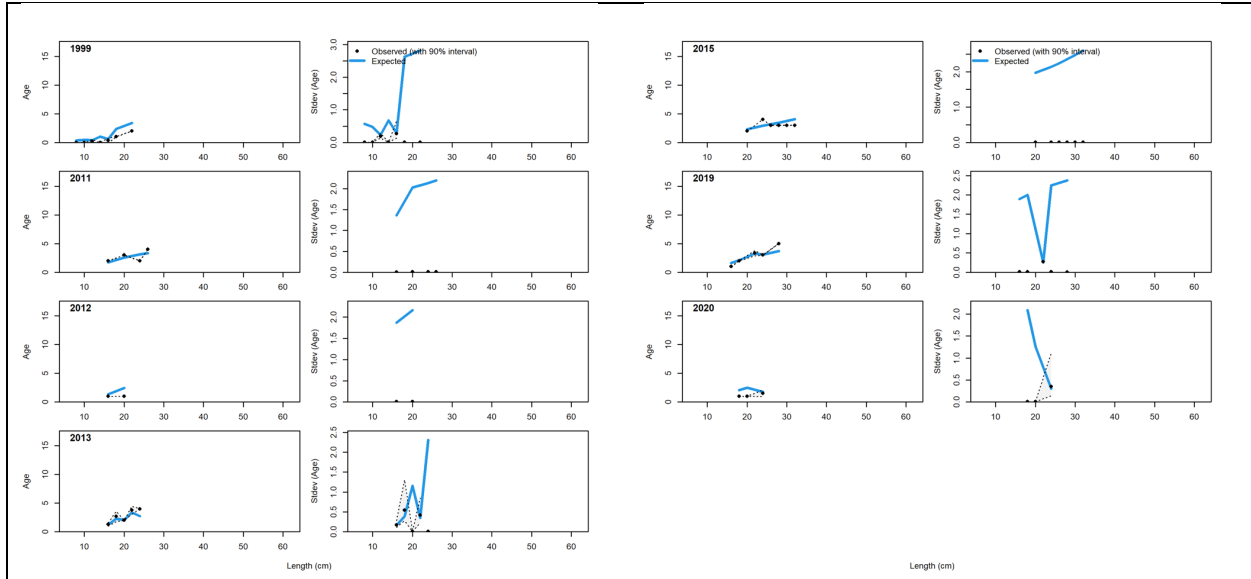


Figure 3.32. Model fits to the annual conditional age-at-length data from fishery-independent trawl data sources for Florida Keys/East Florida Hogfish. In the left plots, the blue lines represent predicted mean age-at-length by size class while the black dots and grey shaded regions represent the observed mean age-at-length by size class with 90% confidence intervals. In the right plots, the blue lines represent predicted standard error of mean age-at-length by size class while the black dots and grey shaded regions represent the observed standard error of mean age-at-length by size class with 90% confidence intervals.

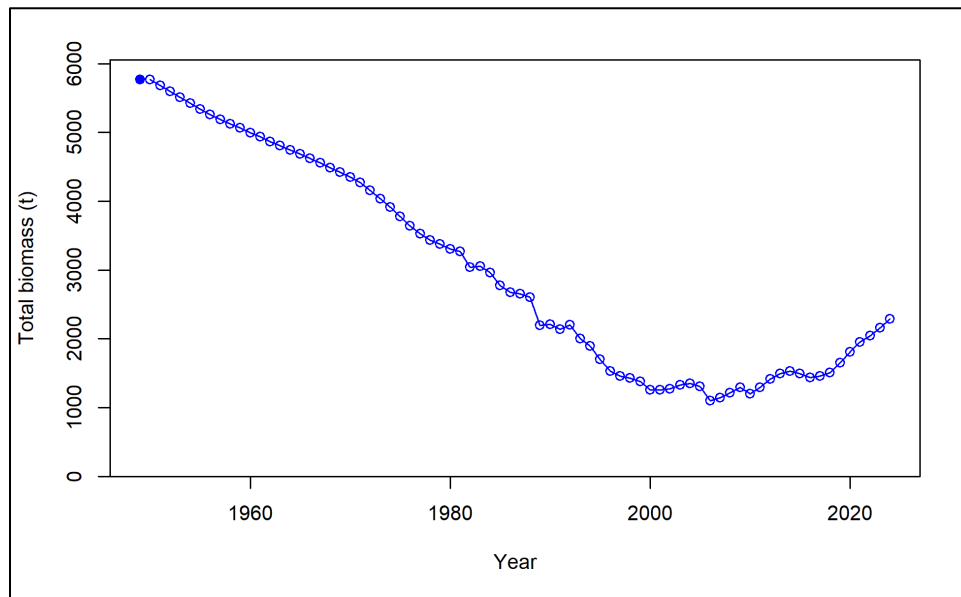


Figure 3.33. Estimates of total biomass (in metric tons) of Florida Keys/East Florida Hogfish (open circles) from 1950 – 2024. The solid blue circle is the estimated unfished total biomass.

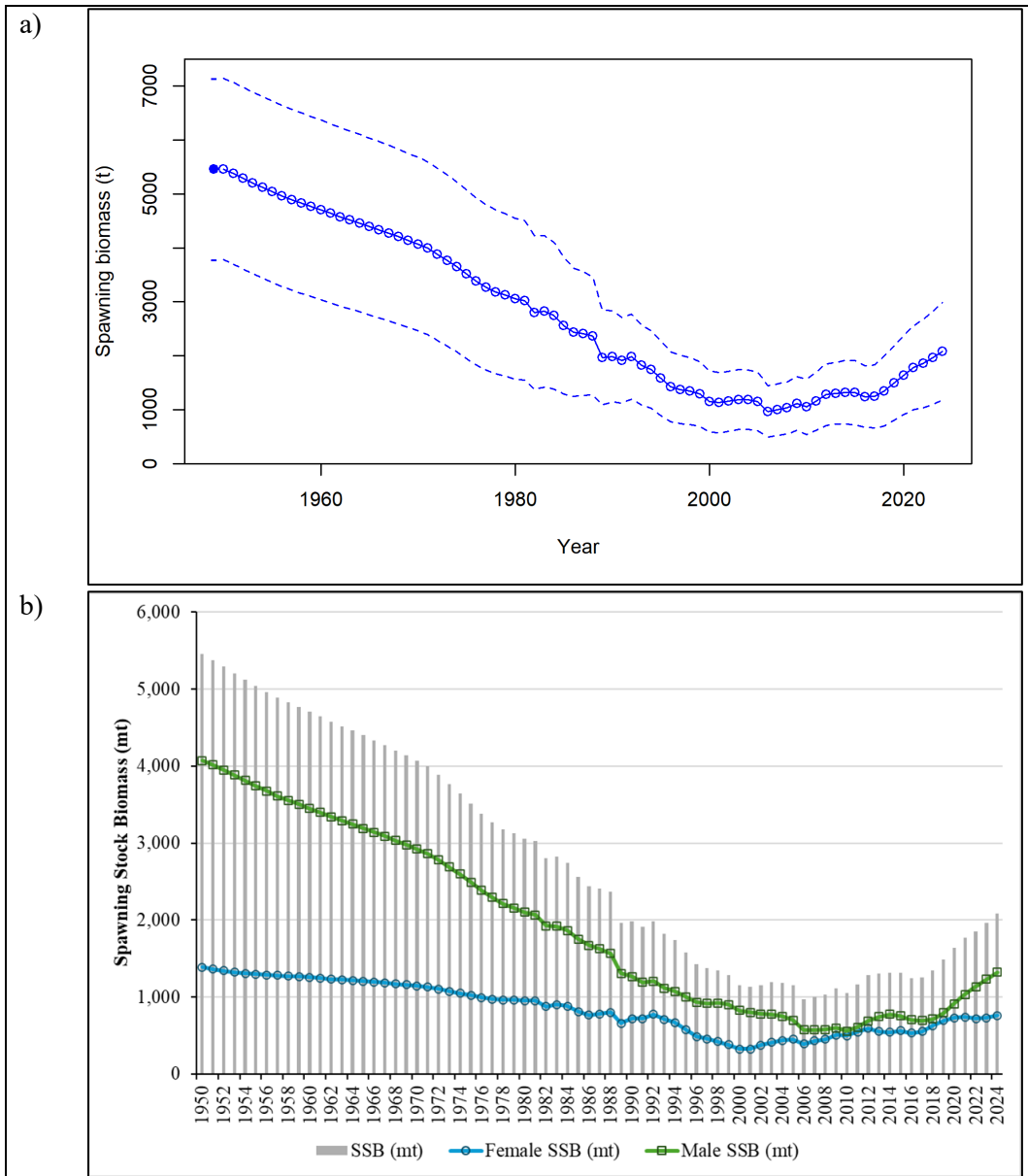


Figure 3.34. Estimates of mature female and male spawning stock biomass a) combined (in metric tons, open circles) with approximate 95% confidence intervals (dashed lines) where the solid blue circle is the estimated unfished spawning stock biomass, and b) separated by sex (female = blue circles, male = green squares, combined = grey bars) for Florida Keys/East Florida Hogfish from 1950 – 2024.

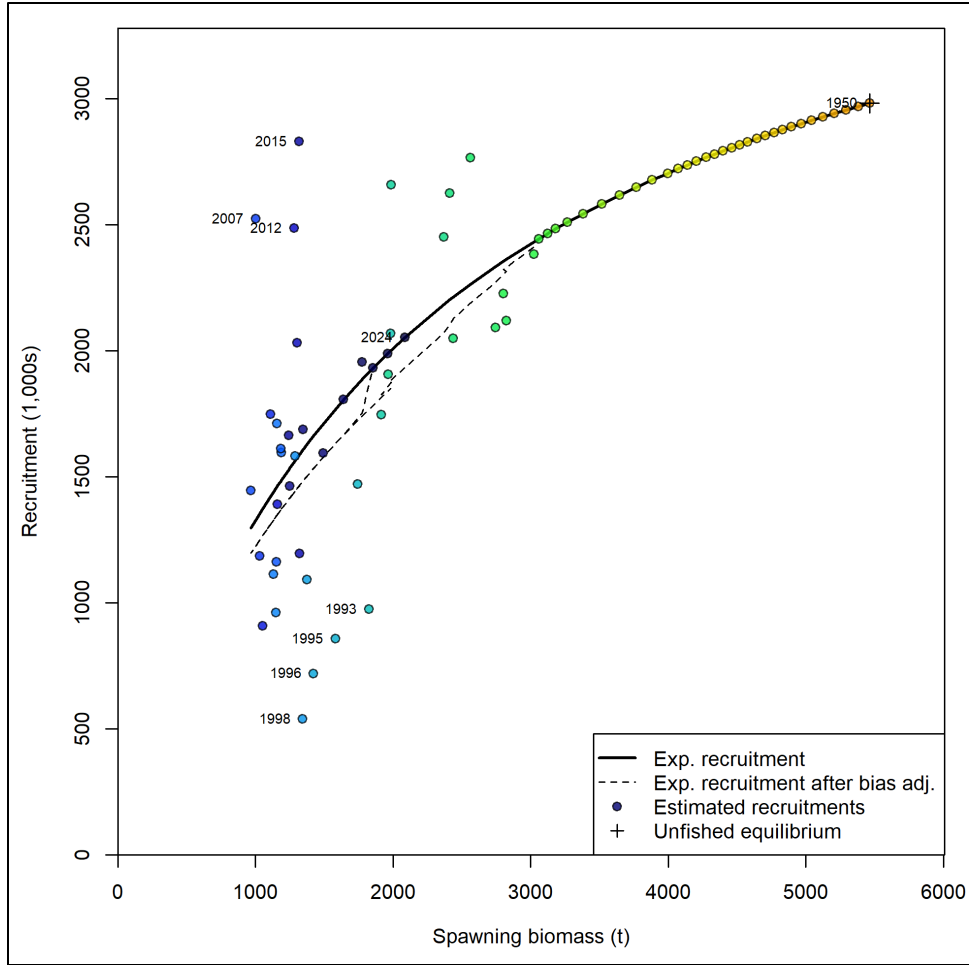


Figure 3.35. Expected stock-recruitment relationship for Florida Keys/East Florida Hogfish. Steepness was estimated at 0.472 and σ_R was estimated at 0.449. Plotted are expected annual recruitments from the SEDAR 94 KEYS base model (circles), expected recruitment from the stock-recruitment relationship (black line), and bias adjusted recruitment from the stock-recruit relationship (dashed line). Point colors indicate year, with warmer colors indicating earlier years and cooler colors showing later years.

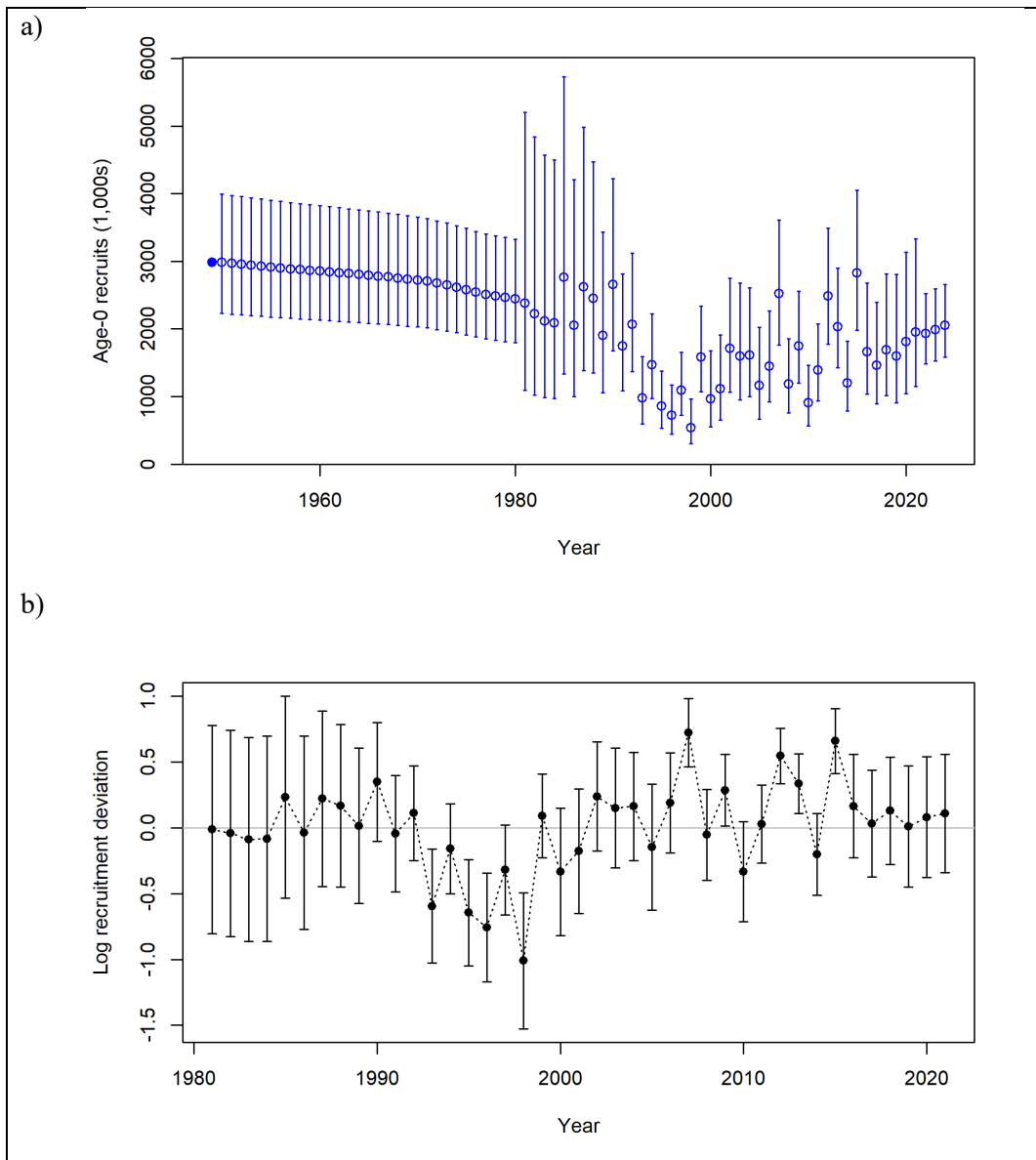


Figure 3.36. Estimated recruitment for Florida Keys/East Florida Hogfish. a) Annual estimated age-0 recruitment (open circles) with 95% confidence intervals (lines) as well as estimated initial equilibrium recruitment (blue dot). b) Log-scaled main recruitment deviations (dots) with 95% confidence intervals (lines) from 1981 – 2021. Recruitment for years 1950 – 1980 and 2022 – 2024 was estimated following the expected stock-recruitment curve.

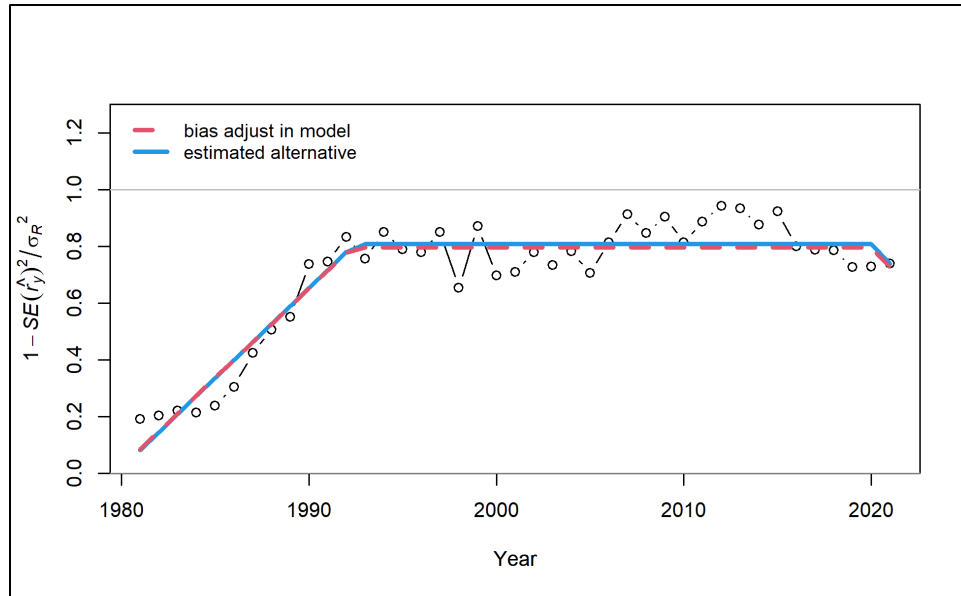


Figure 3.37. Points are transformed variances. Red line shows current settings for bias adjustment specified for the SEDAR 94 KEYS base model, which coincides with the least squares estimate of alternative bias adjustment relationship for recruitment deviations (dashed red line). For more information, see Methot and Taylor (2011).

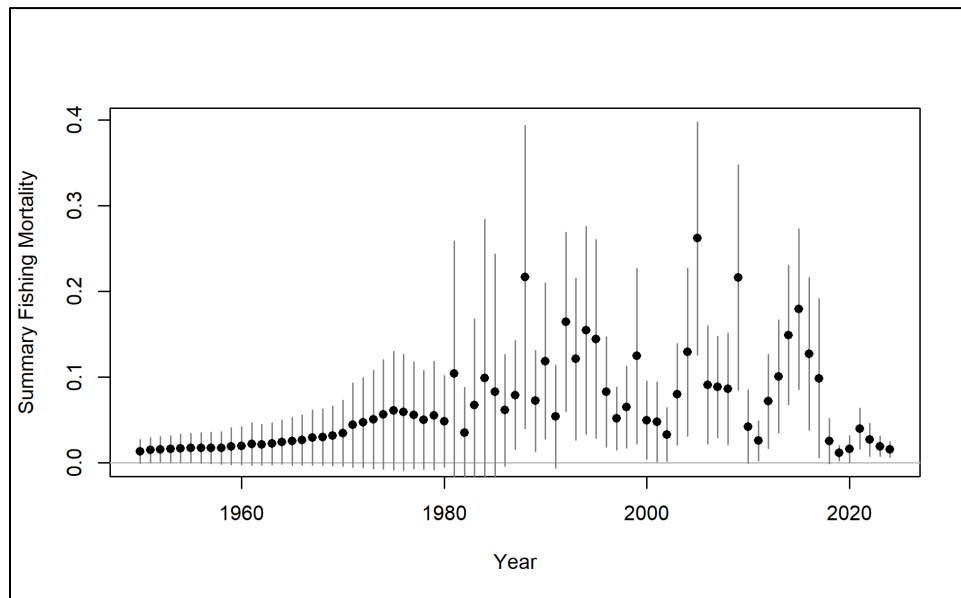


Figure 3.38. Annual exploitation fishing mortality rates, calculated as the ratio of the total annual catch in biomass to the age-1+ biomass at the beginning of the year, for Florida Keys/East Florida Hogfish with 95% confidence intervals from the SEDAR 94 KEYS base model.

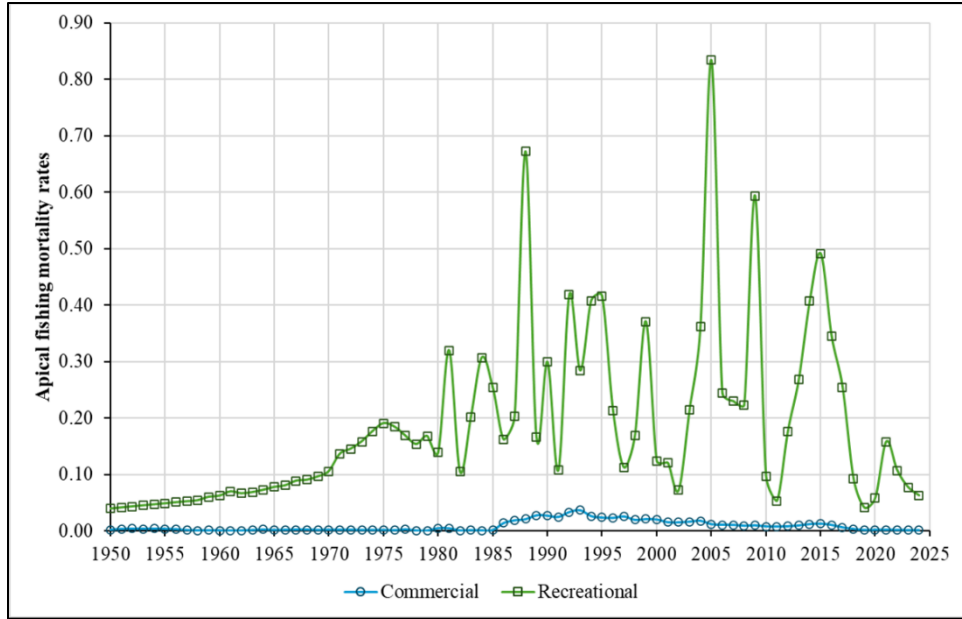


Figure 3.39. Annual fleet-specific instantaneous apical fishing mortality rates for Florida Keys/East Florida Hogfish from the SEDAR 94 KEYS base model. This represents the instantaneous fishing mortality level on the most vulnerable (i.e., selectivity = 1) age class for each fleet.

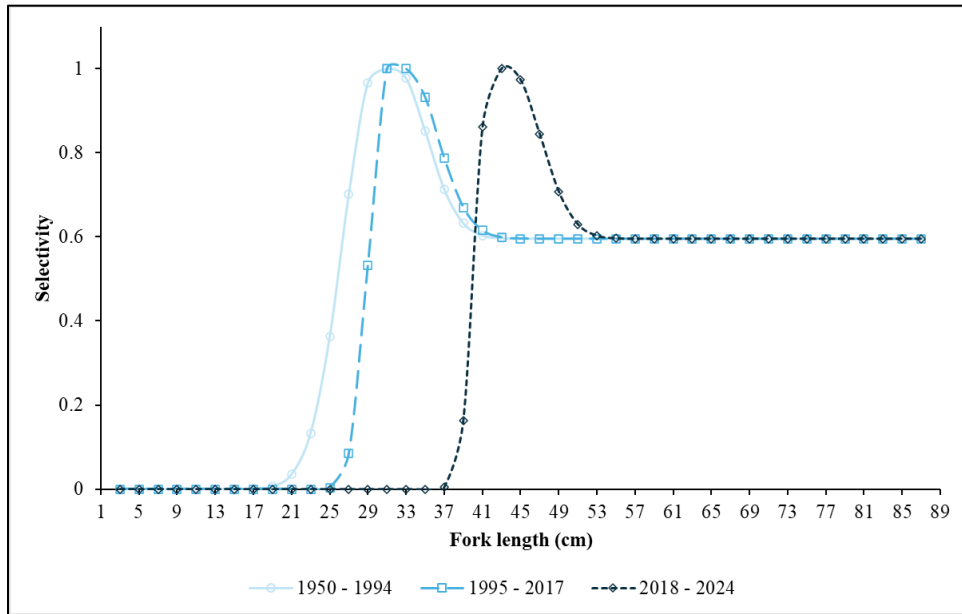


Figure 3.40. Length-based selectivity of the commercial fleet by time block for Florida Keys/East Florida Hogfish from the SEDAR 94 KEYS base model.

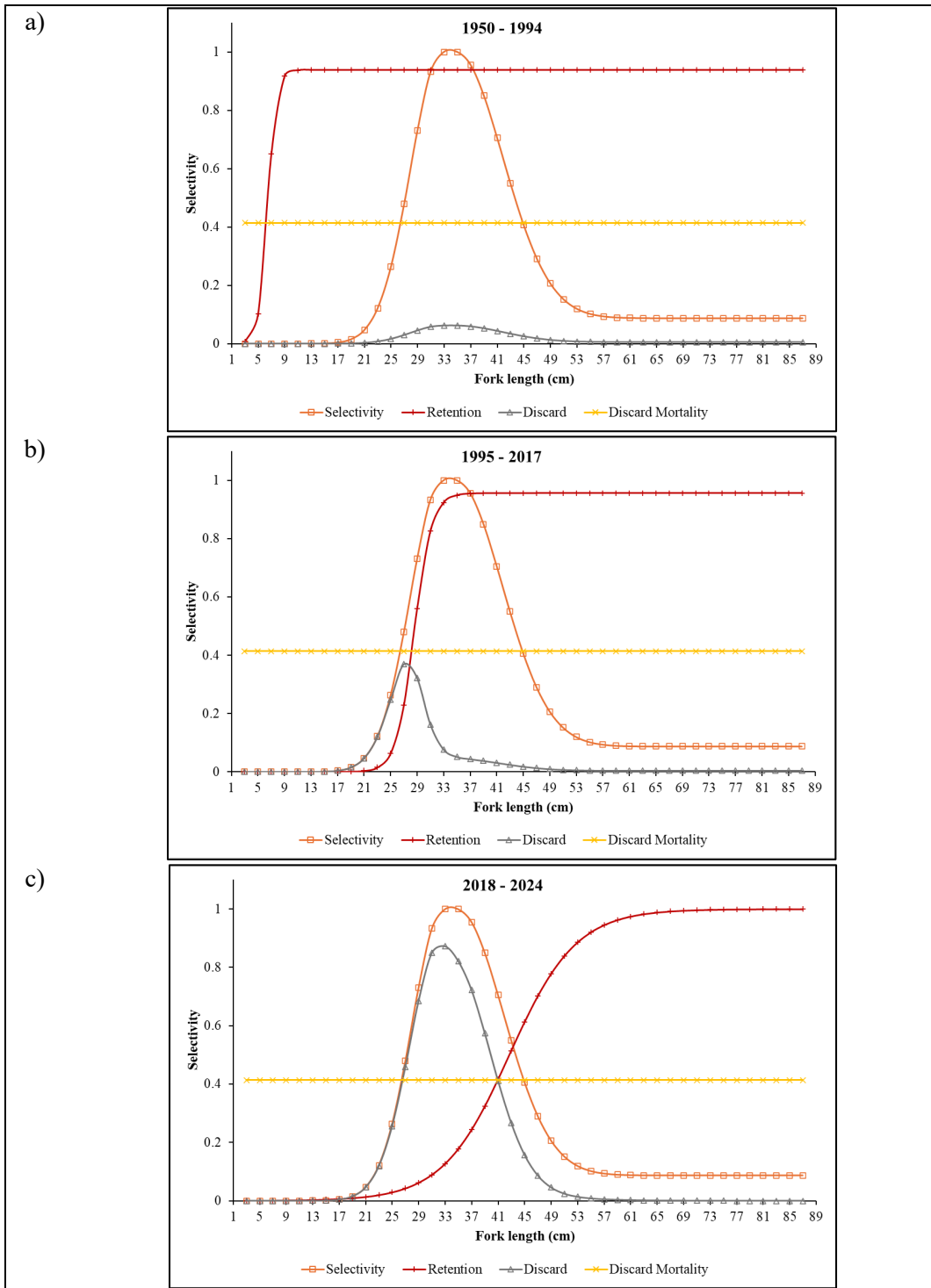


Figure 3.41. Length-based selectivity, retention, discard, and discard mortality (41.4%) patterns of the recreational fleet by time block a) 1950 – 1994, b) 1995 – 2017, and c) 2018 – 2024 for Florida Keys/East Florida Hogfish from the SEDAR 94 KEYS base model.

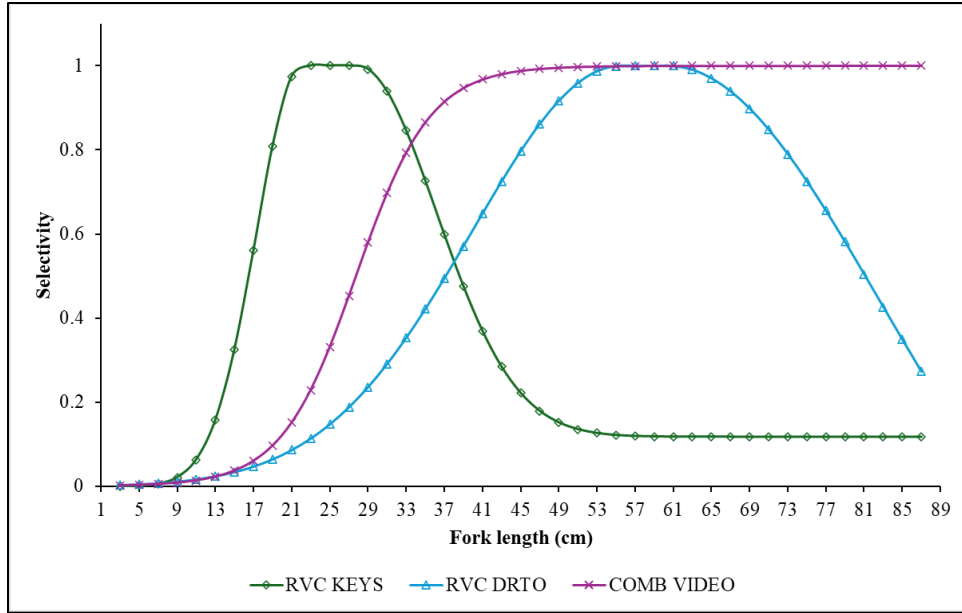


Figure 3.42. Length-based selectivity of the RVC Florida Keys index (green diamonds), RVC Dry Tortugas index (blue triangles), and combined video index (purple x's) for Florida Keys/East Florida Hogfish from the SEDAR 94 KEYS base model.

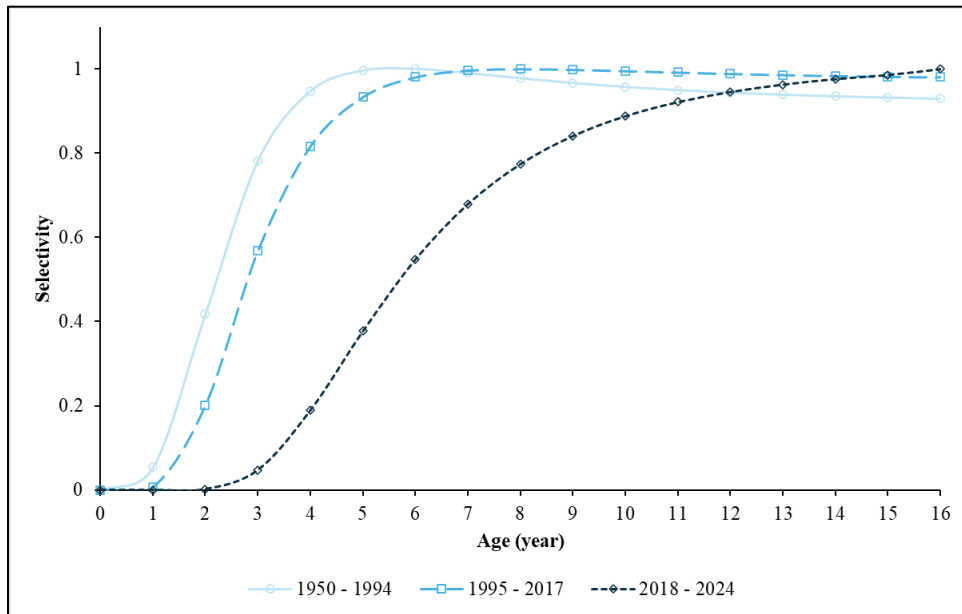


Figure 3.43. Age-derived selectivity of the commercial fleet by time block for Florida Keys/East Florida Hogfish from the SEDAR 94 KEYS base model.

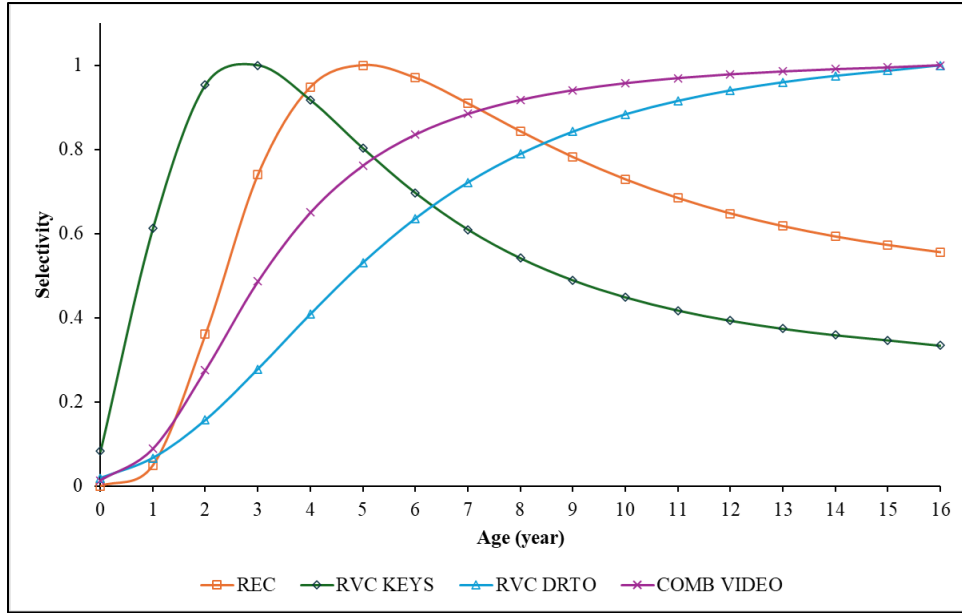


Figure 3.44. Age-derived selectivity of the recreational fleet (orange square), RVC Florida Keys index (green diamonds), RVC Dry Tortugas index (blue triangles), and combined video index (purple x's) for Florida Keys/East Florida Hogfish from the SEDAR 94 KEYS base model.

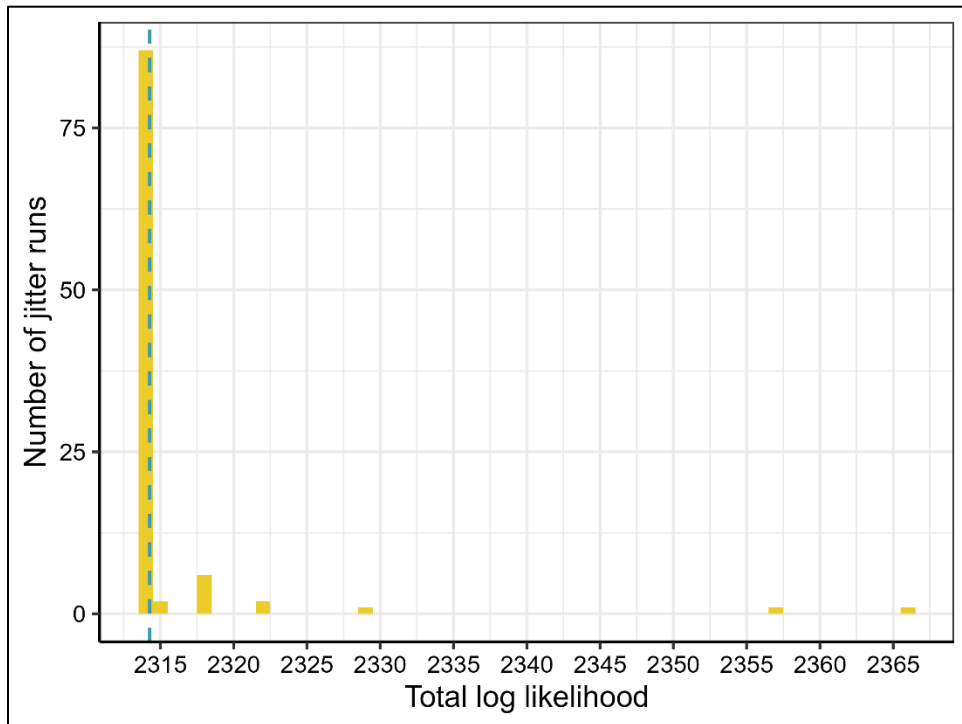


Figure 3.45. Total log-likelihood values of model runs performed by the jitter analysis (yellow bars) and the SEDAR 94 KEYS base model (blue dashed line).

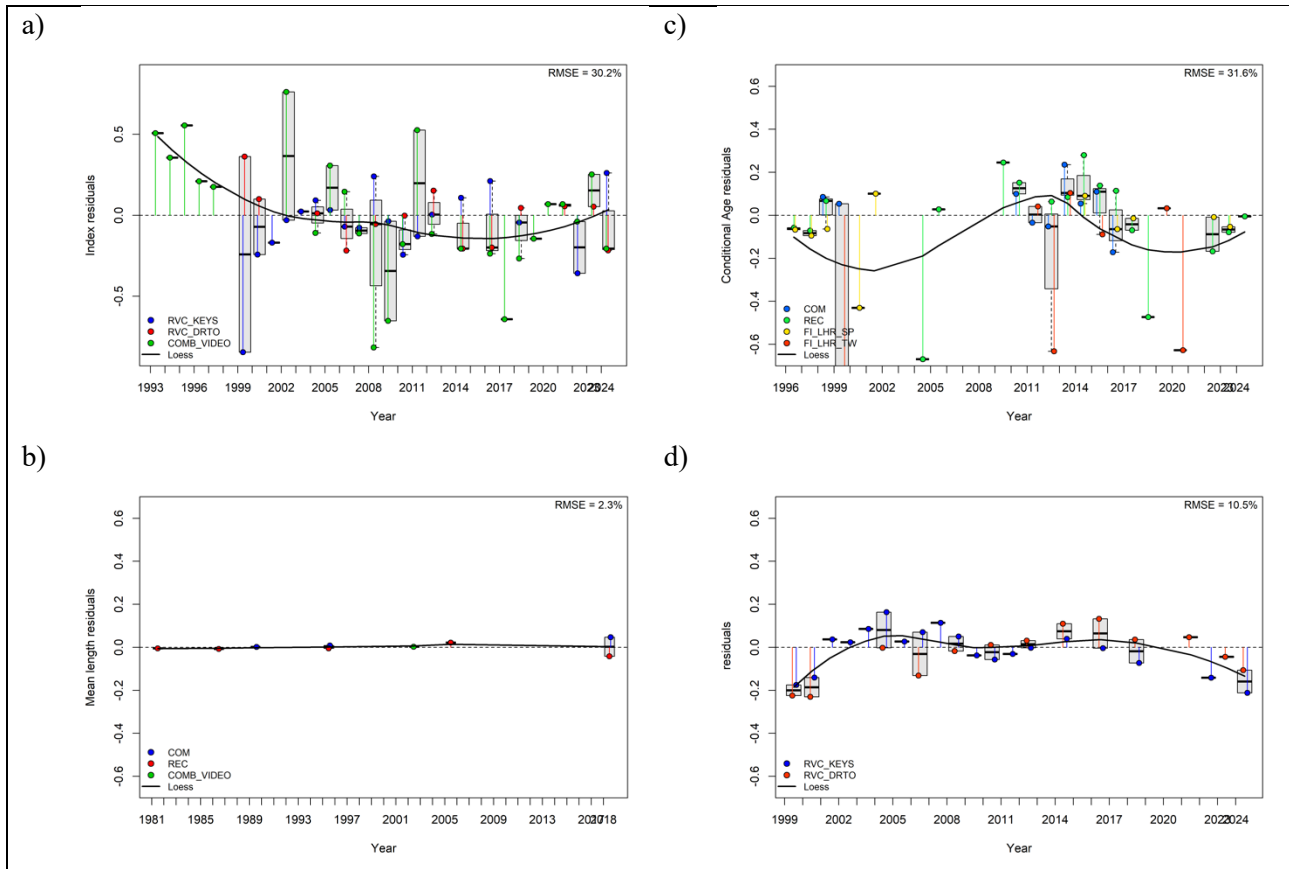


Figure 3.46. Joint residual plots for a) the indices of abundance, b) the annual mean length estimates, and c) the annual conditional age-at-length estimates, and d) the annual mean general size composition (i.e., RVC lengths) of available fleets and indices from the SEDAR 94 KEYS base model. Vertical lines with points show the residuals, boxplots show residual medians and quantiles, and solid black lines are a loess smoother. Root-mean squared errors (RMSE) are included in the upper right-hand corner of each plot.

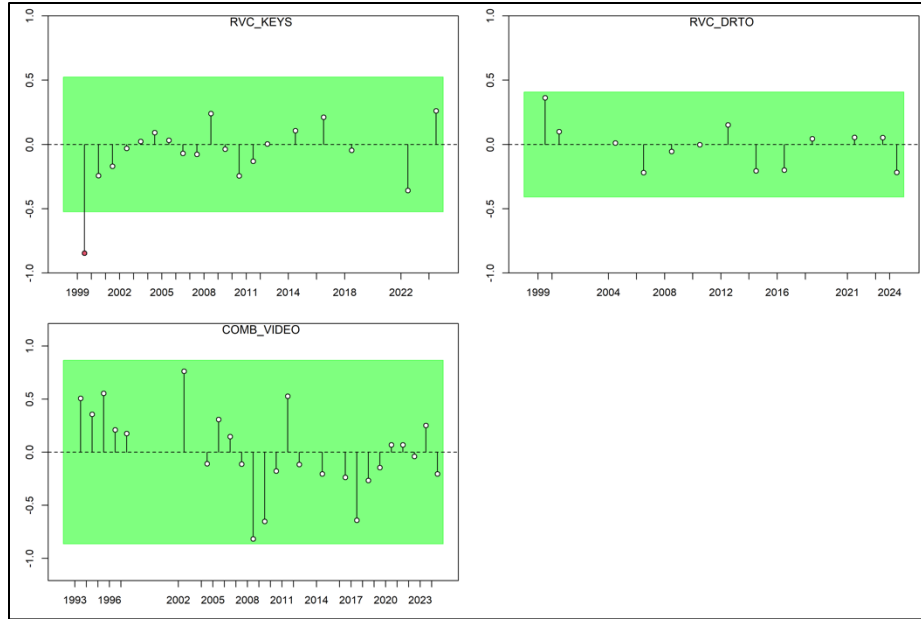


Figure 3.47. Runs tests results for the indices of abundance from the SEDAR 94 KEYS base model. Green shading indicates no evidence ($p \geq 0.05$) and red shading evidence ($p < 0.05$) to reject the hypothesis of a randomly distributed time-series of residuals, respectively. Shaded regions span three residual standard deviations to either side from zero and red points outside of the shading indicate a violation of that ‘three-sigma limit’.

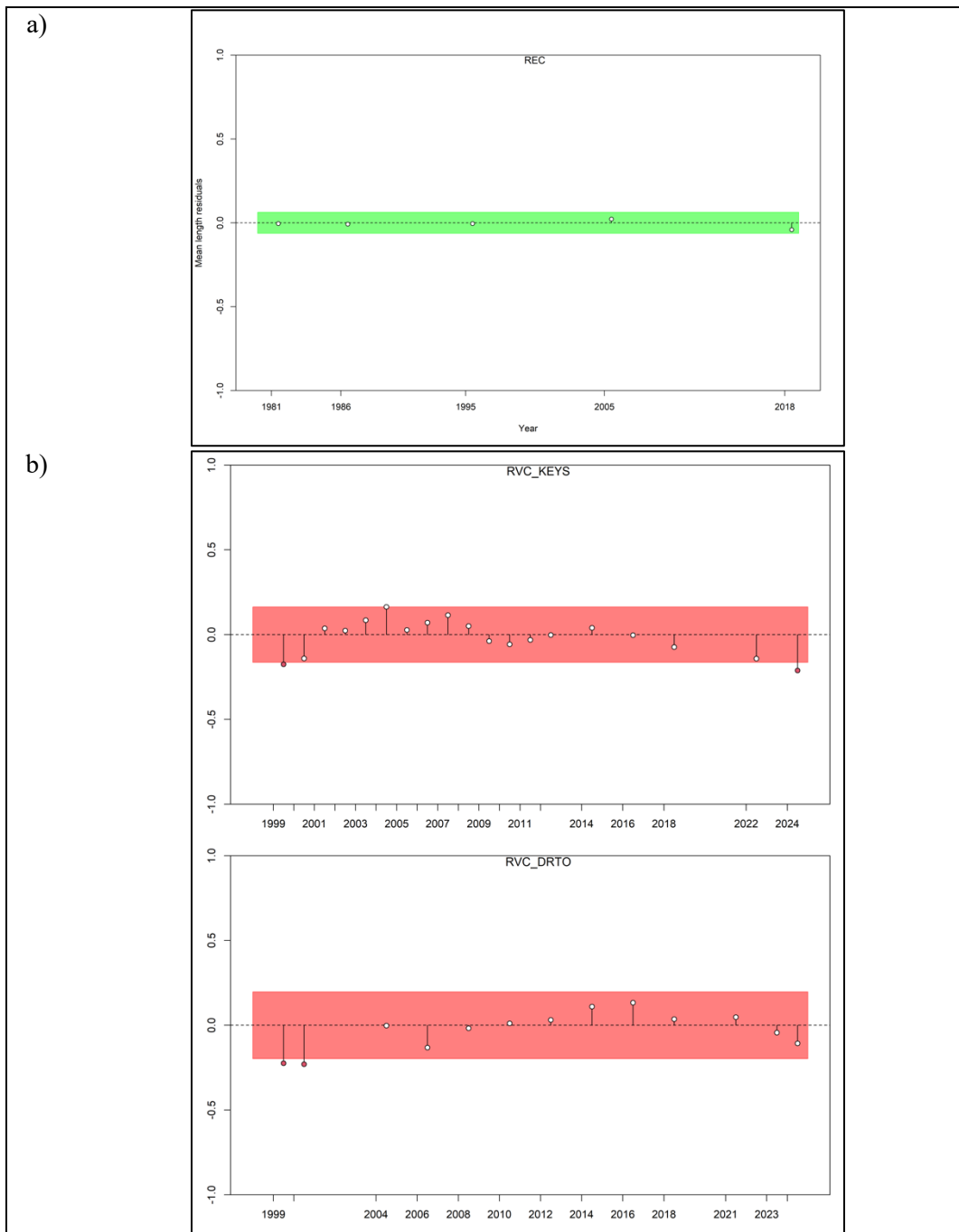


Figure 3.48. Run tests results for a) the annual mean length estimates of the recreational fleet and b) the annual mean general size composition (i.e., RVC lengths) from the SEDAR 94 KEYS base model. Green shading indicates no evidence ($p \geq 0.05$) and red shading evidence ($p < 0.05$) to reject the hypothesis of a randomly distributed time-series of residuals, respectively. Shaded regions span three residual standard deviations to either side from zero and red points outside of the shading indicate a violation of that ‘three-sigma limit’.

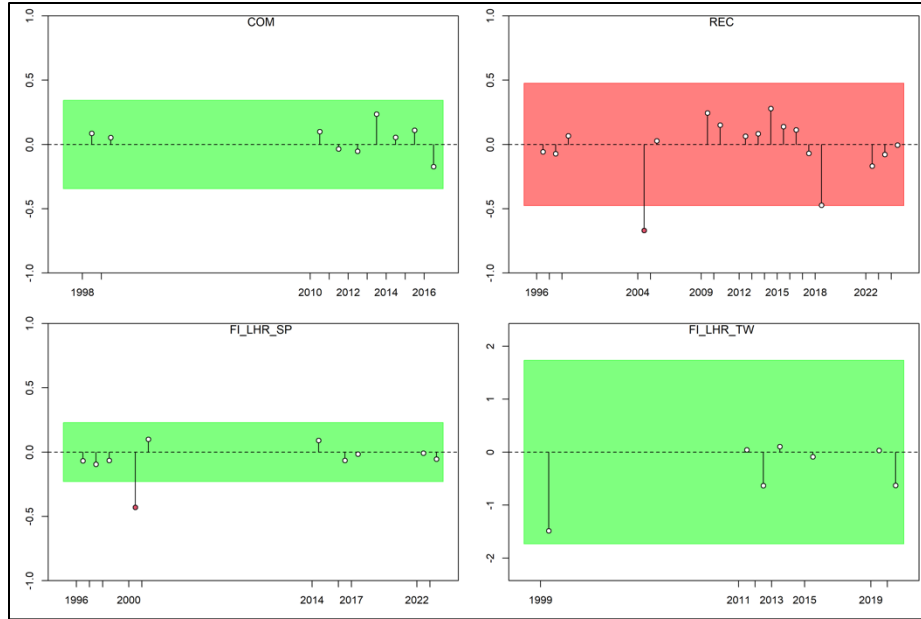


Figure 3.49. Runs tests results for the conditional age-at-length estimates from the SEDAR 94 KEYS base model. Green shading indicates no evidence ($p \geq 0.05$) and red shading evidence ($p < 0.05$) to reject the hypothesis of a randomly distributed time-series of residuals, respectively. Shaded regions span three residual standard deviations to either side from zero and red points outside of the shading indicate a violation of that ‘three-sigma limit’.

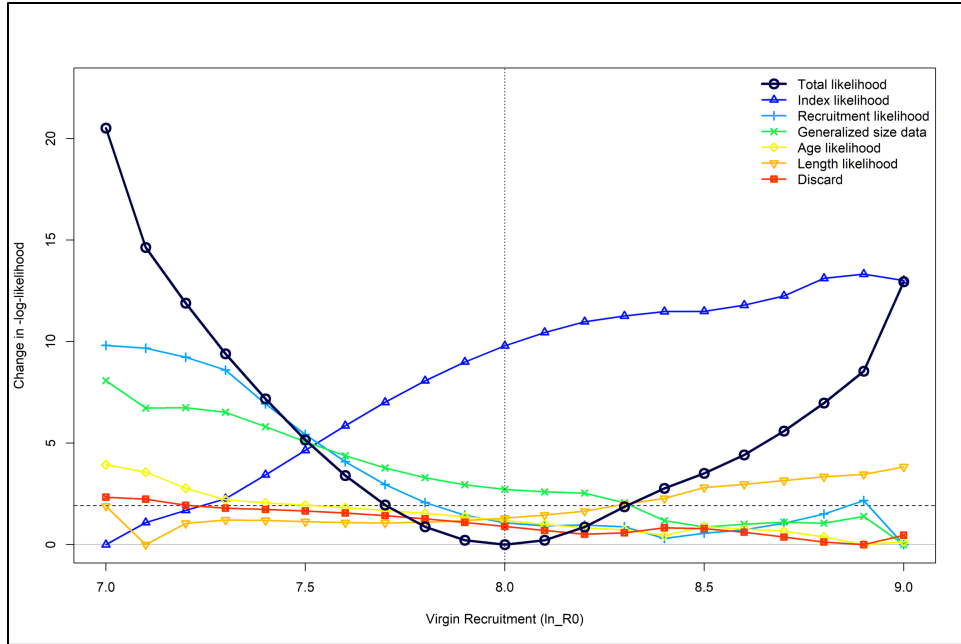


Figure 3.50. Log-likelihood profiles of the unfished (i.e., virgin) recruitment ($\ln(R_0)$) parameter for various data components in the SEDAR 94 KEYS base model. The horizontal dashed line indicates a 2 unit difference in log-likelihood while the vertical dotted line is the estimate from the SEDAR 94 KEYS base model.

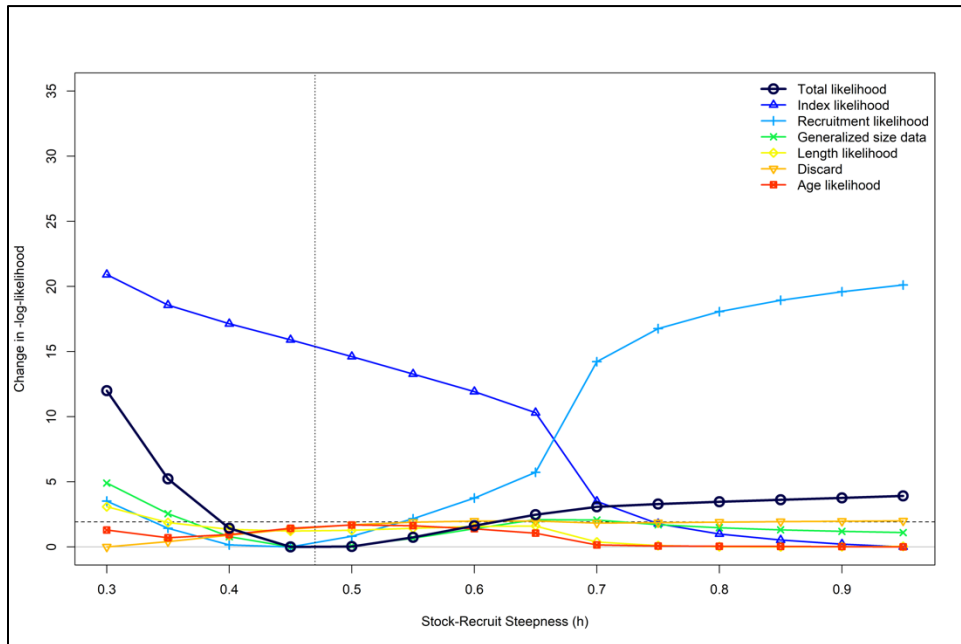


Figure 3.51. Log-likelihood profiles of the *steepness* (h) parameter for various data components in the SEDAR 94 KEYS base model. The horizontal dashed line indicates a 2 unit difference in log-likelihood while the vertical dotted line is the estimate from the SEDAR 94 KEYS base model.

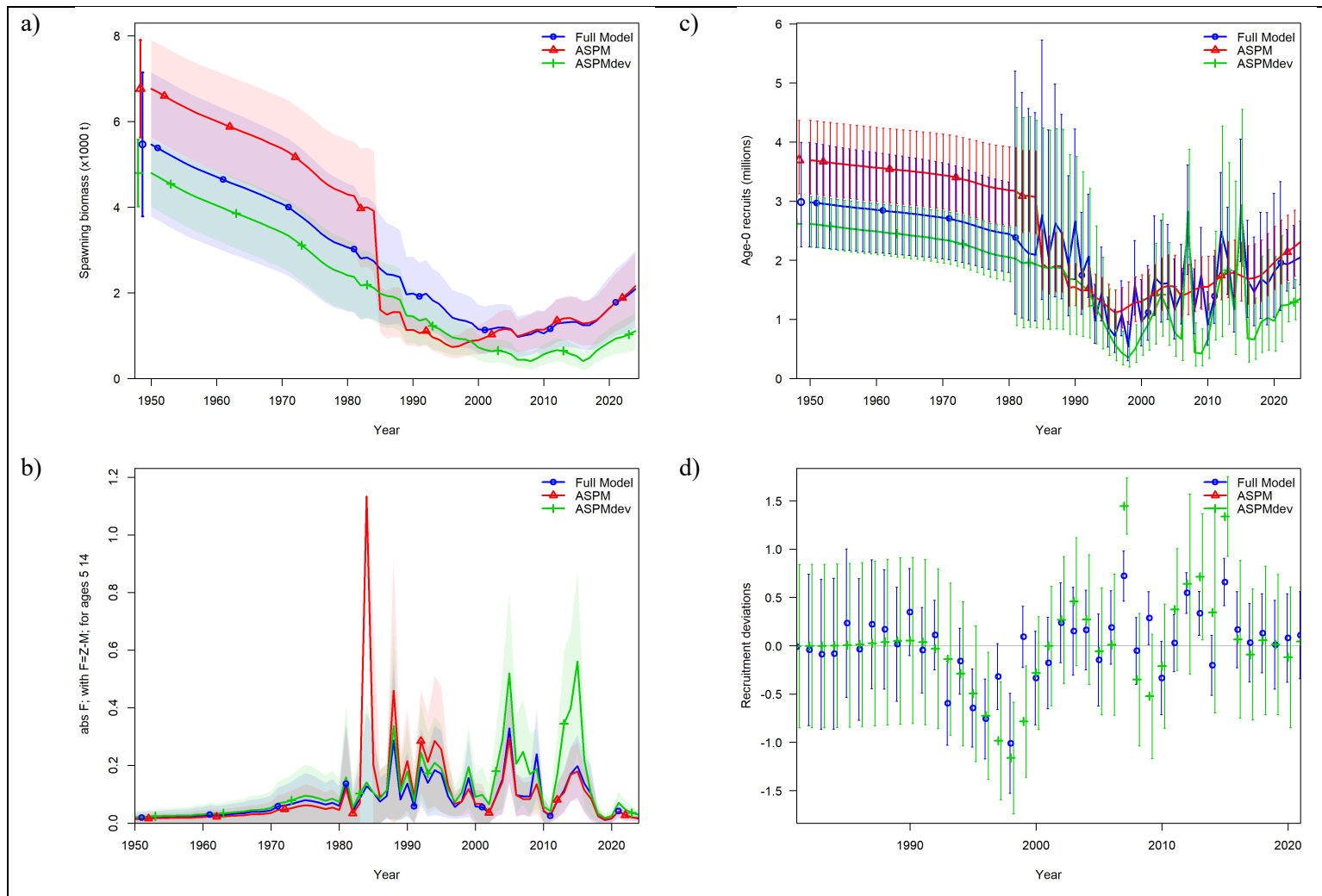


Figure 3.52. Results comparison between the SEDAR 94 KEYS base model (Full Model), the deterministic Age-Structured-Production Model (ASPM), and the ASPM with recruitment deviations (ASPMdev) showing a) spawning stock biomass, b) exploitation rates, c) estimates of age-0 recruitment, and d) estimates of recruitment deviations.

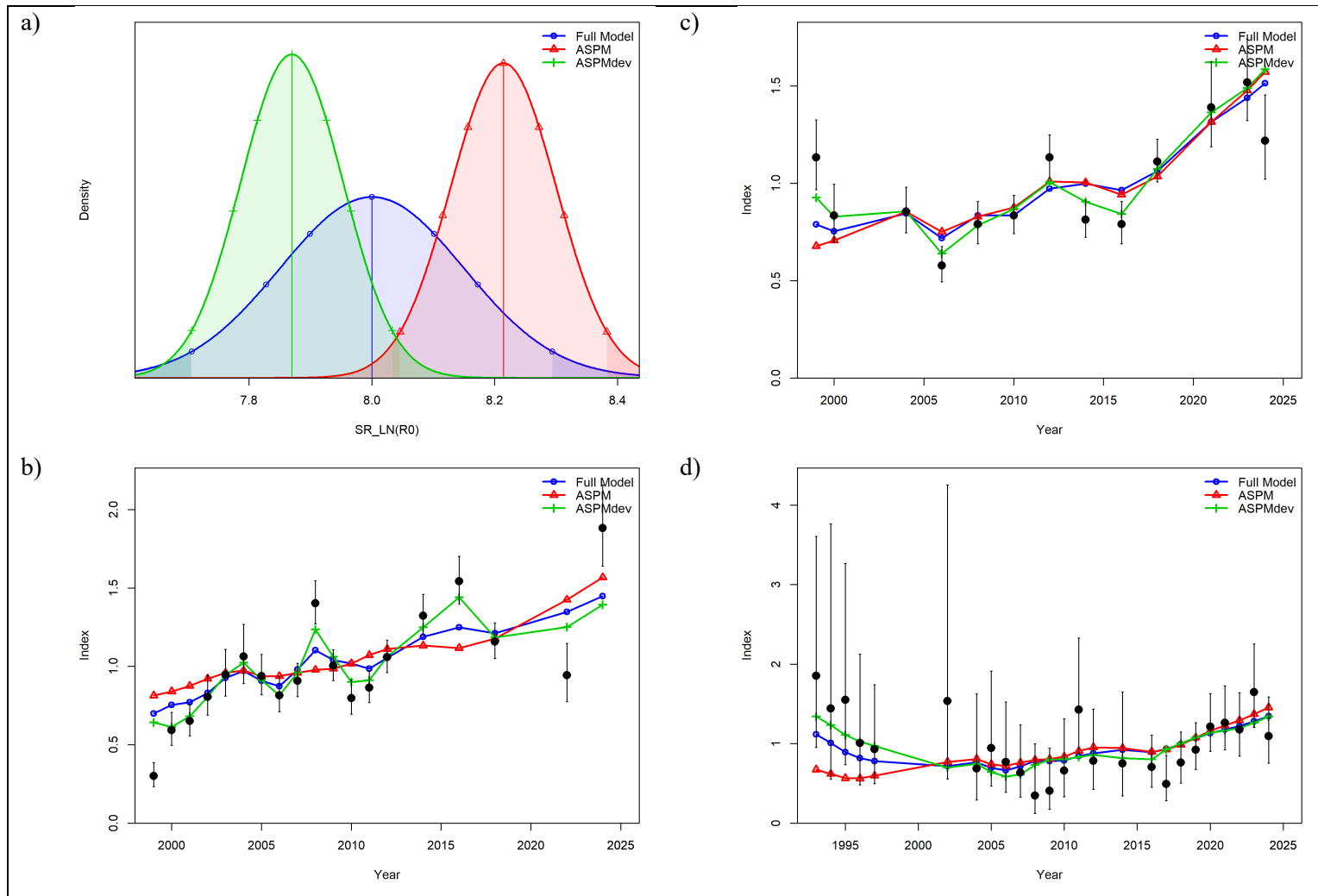


Figure 3.53. Results comparison between the SEDAR 94 KEYS base model (Full Model), the deterministic Age-Structured-Production Model (ASPM), and the ASPM with recruitment deviations (ASPMdev) showing a) estimates of the virgin recruitment parameter in log-space $\ln(R0)$, b) observed and predicted values for the RVC Florida Keys index, c) observed and predicted values for the RVC Dry Tortugas index., and d) observed and predicted values for the combined video index.

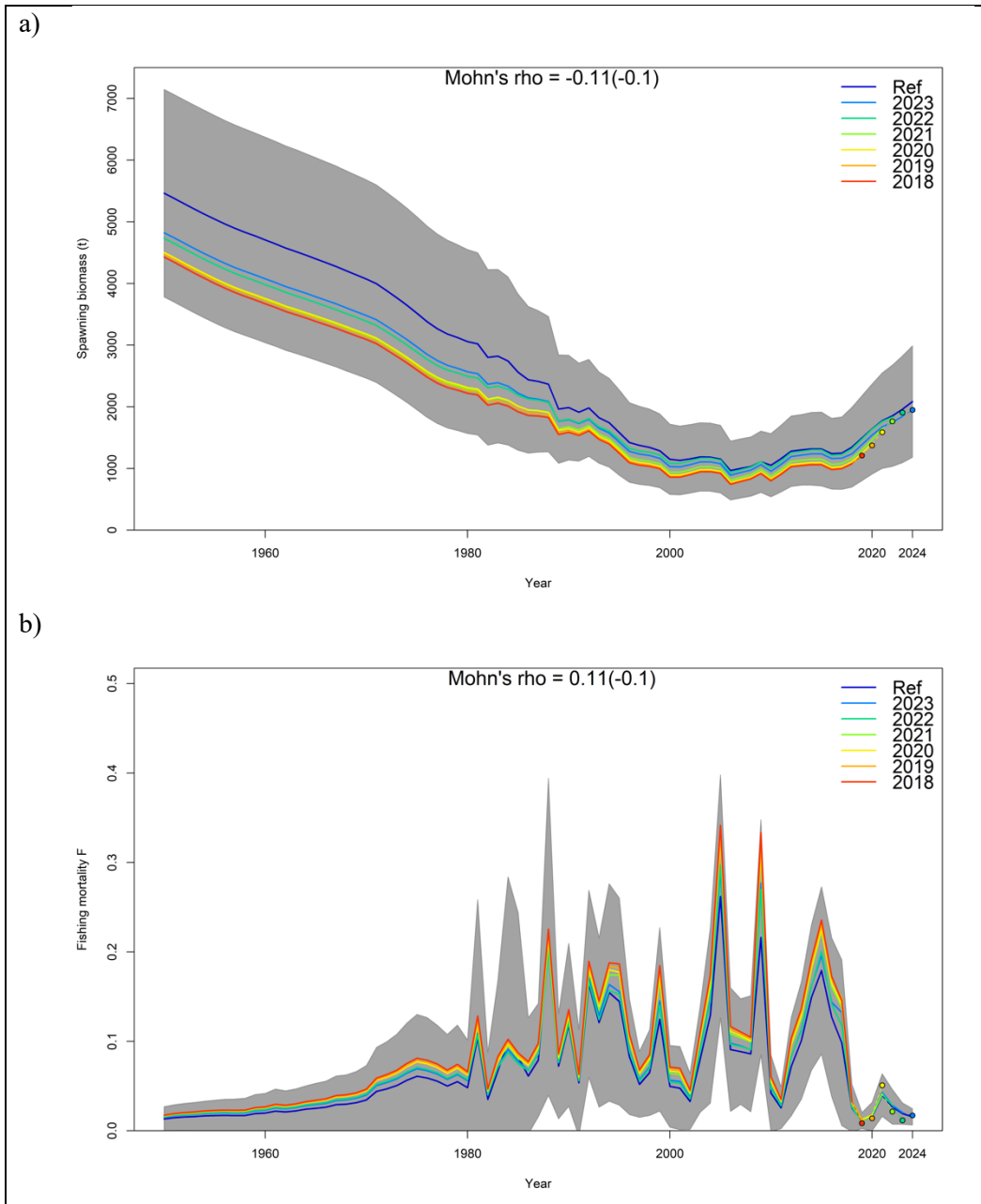


Figure 3.54. Retrospective forecast results of a) spawning stock biomass and b) exploitation rates conducted by re-fitting the SEDAR 94 KEYS base model (Ref) after sequentially removing seven years of observations. The Mohn's rho (ρ_M) statistic and corresponding forecast rho (ρ_F) values (in parenthesis) are provided at the top of each panel. One-year-ahead projections denoted by color-coded dashed lines with terminal points are shown for each peel. Grey shaded areas are the 95 % confidence intervals from the SEDAR 94 KEYS base model.

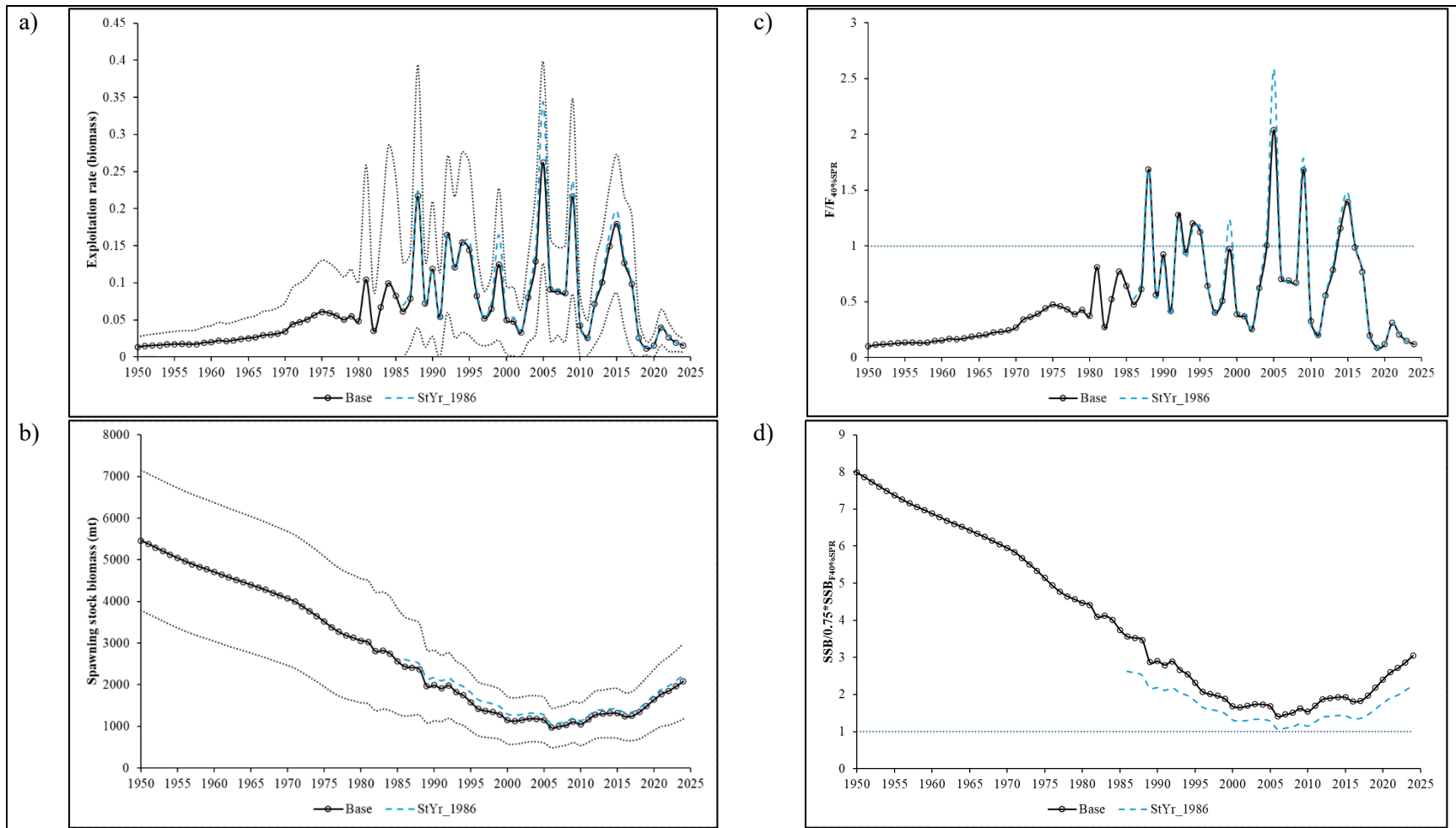


Figure 3.55. The a) exploitation rate, b) spawning stock biomass, c) $F/F_{40\%SPR}$ ratio, and d) $SSB/0.75*SSB_{F40\%SPR}$ ratio from the KEYS base model compared to a sensitivity run with 1986 as the start year and *steepness* = 0.99 for Florida Keys/East Florida Hogfish.

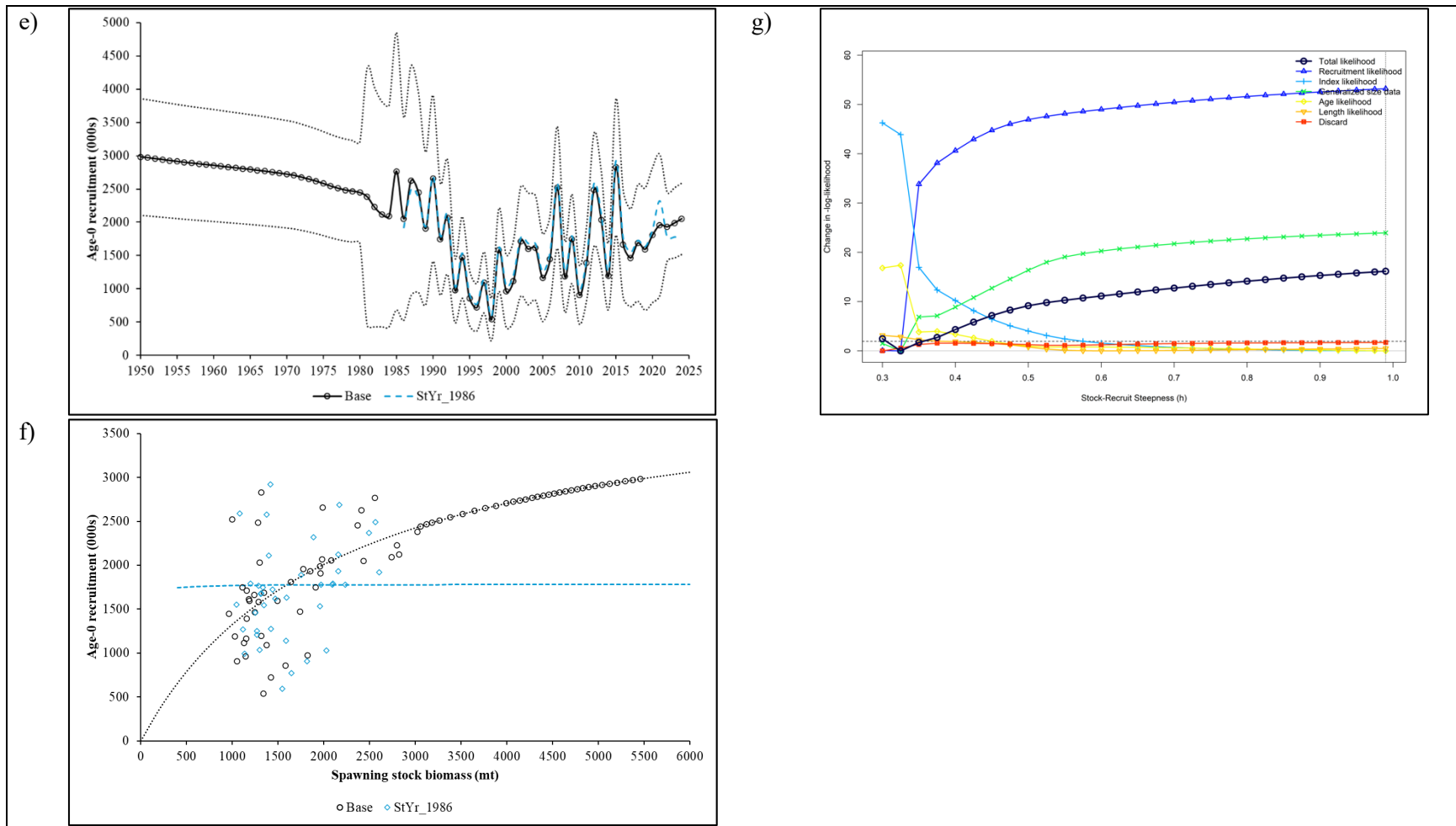


Figure 3.55 cont. The e) age-0 recruitment and f) stock-recruitment relationship from the KEYS base model compared to a sensitivity run with 1986 as the start year and $steepness = 0.99$ for Florida Keys/East Florida Hogfish. Panel (g) shows the $steepness$ parameter profile of the sensitivity model with 1986 as the start year and $steepness = 0.99$.

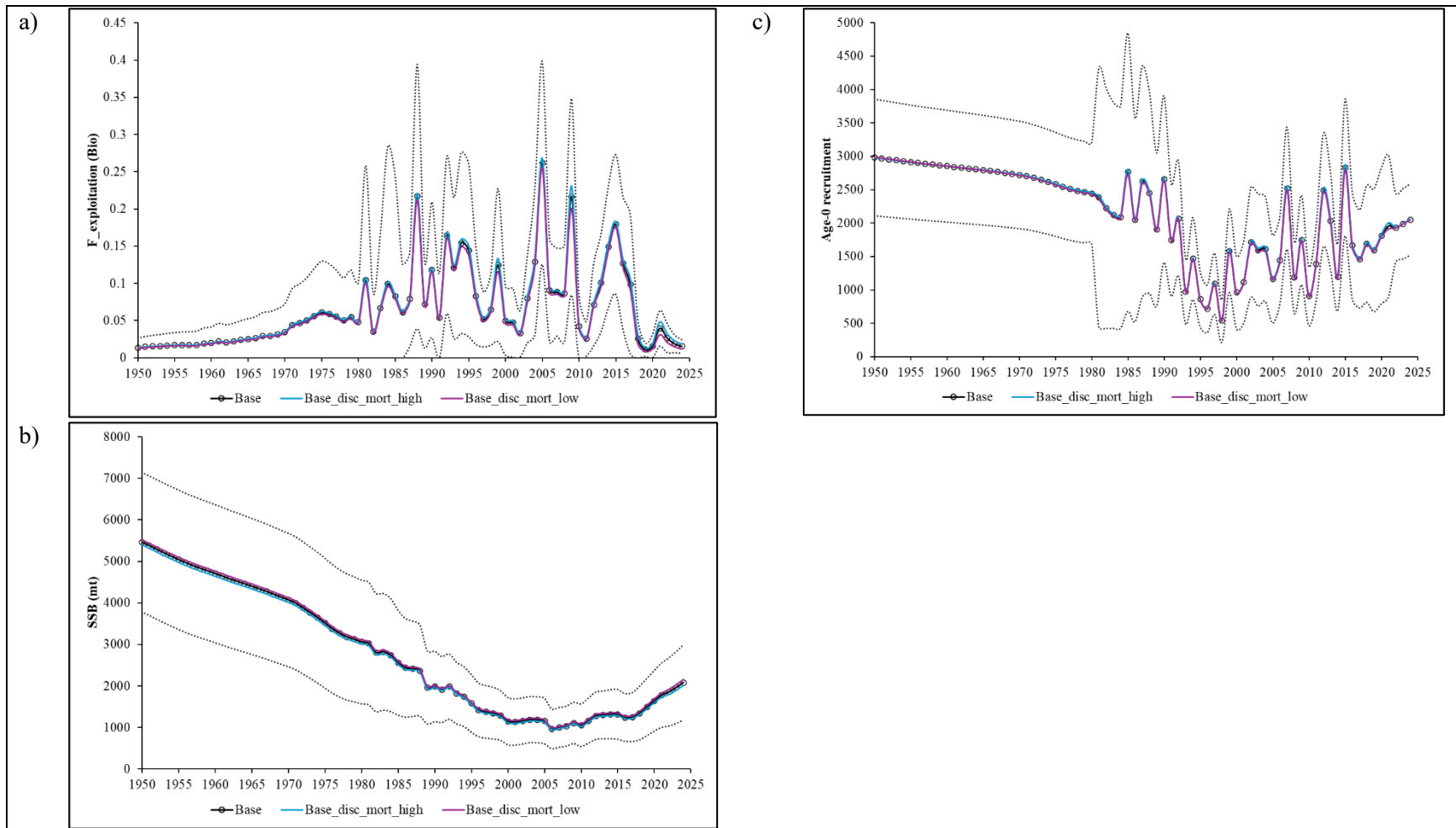


Figure 3.56. The a) exploitation rate, b) spawning stock biomass, and c) age-0 recruitment from the KEYS base model compared to sensitivity runs exploring high (59%) and low (23.8%) discard mortality rates for Florida Keys/East Florida Hogfish.

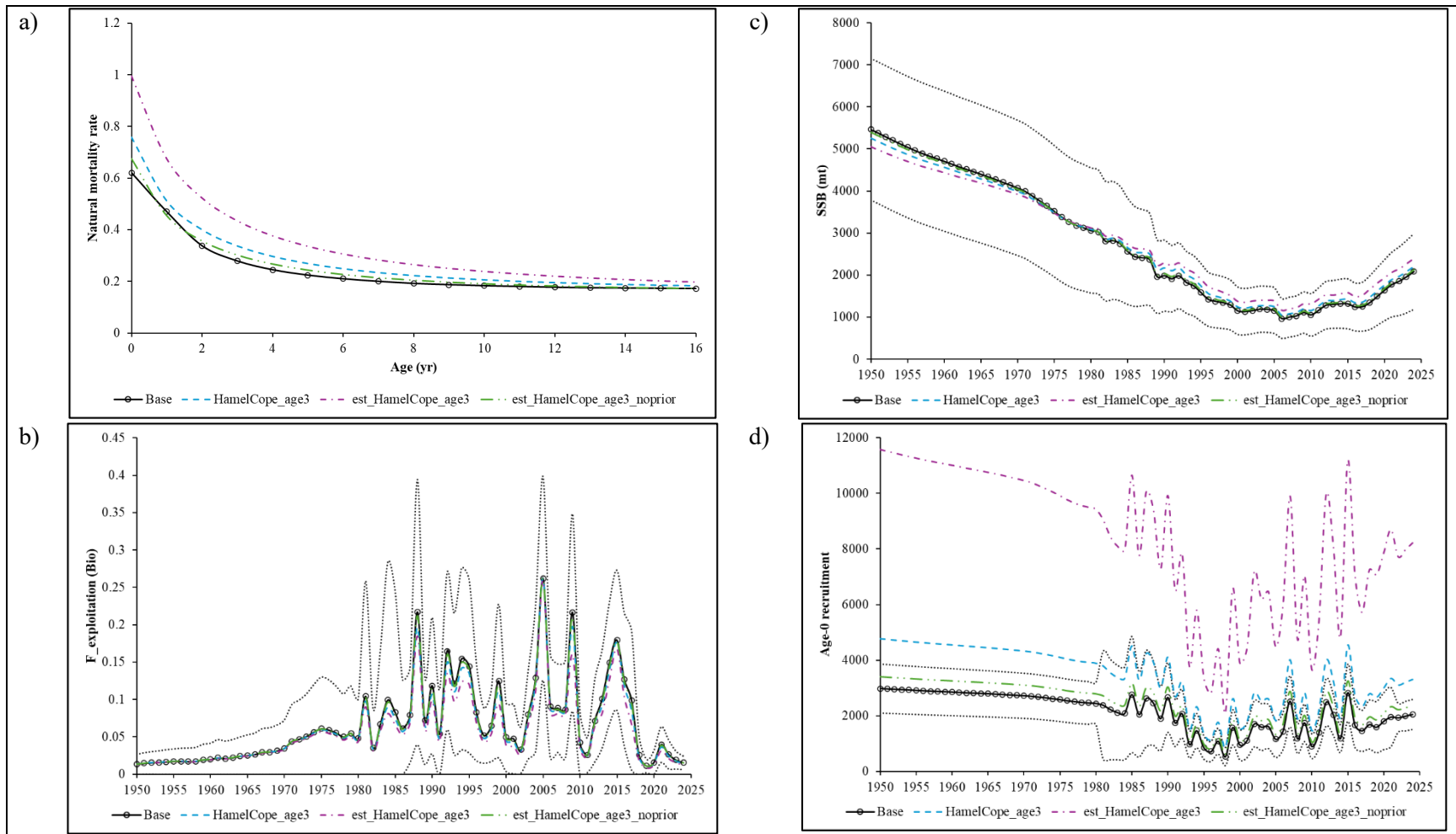


Figure 3.57. The a) natural mortality rate, b) exploitation rate, c) spawning stock biomass, and d) age-0 recruitment from the KEYS base model compared to sensitivity runs exploring assumptions on natural mortality for Florida Keys/East Florida Hogfish. ‘HamelCope_age3’ uses the Hamel and Cope (2022) longevity-based estimate ($M=0.338 \text{ yr}^{-1}$) for age-3 fish, ‘est_HamelCope_age3’ estimates M using the standard deviation (0.31) prior in log-space, and ‘est_HamelCope_age3_noprior’ removes the standard deviation prior to freely estimate.

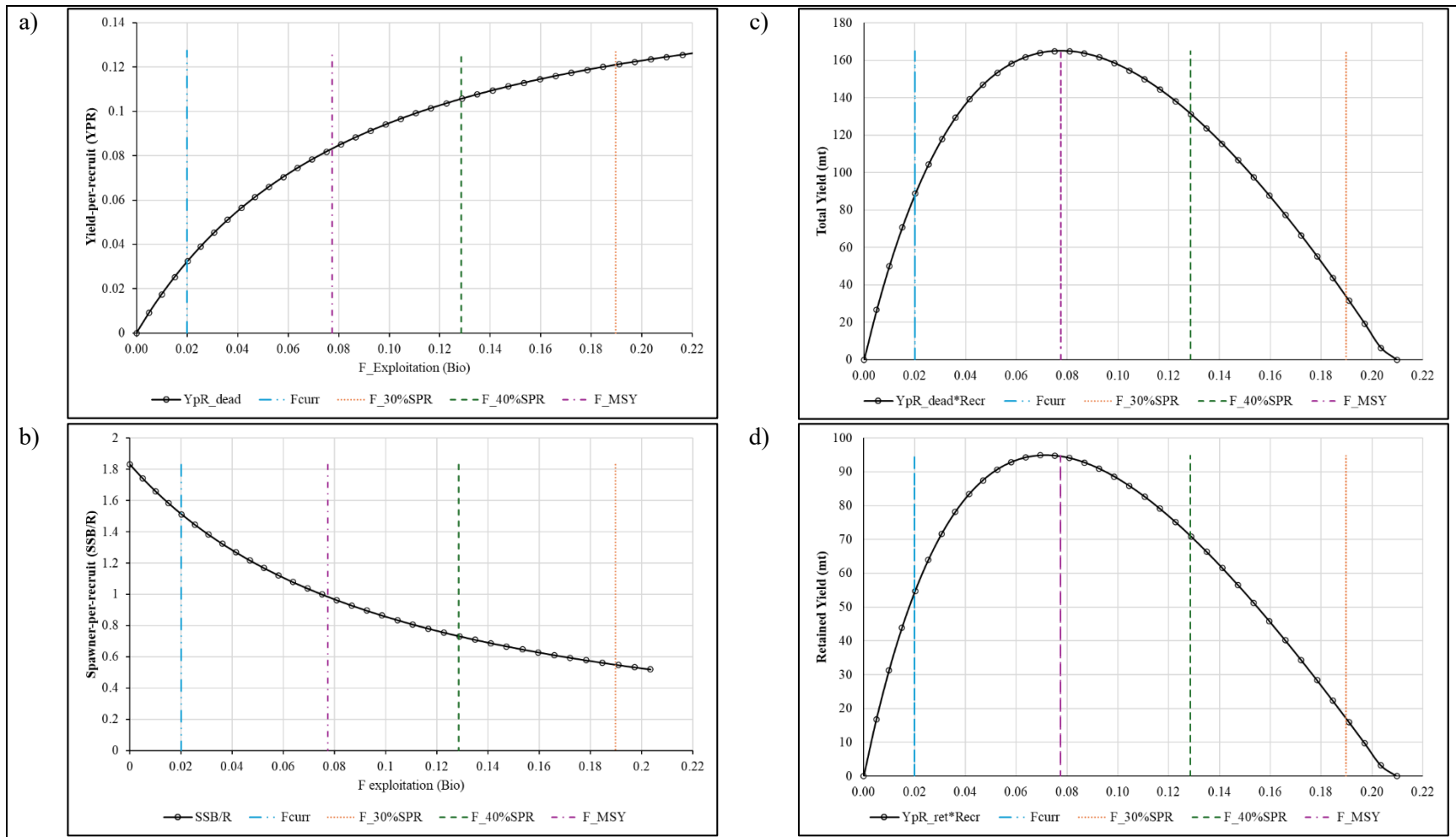


Figure 3.58. The a) yield-per-recruit, b) spawner-per-recruit, c) total equilibrium yield, and d) retained equilibrium yield computed as a function of the instantaneous exploitation rate on Florida Keys/East Florida Hogfish.

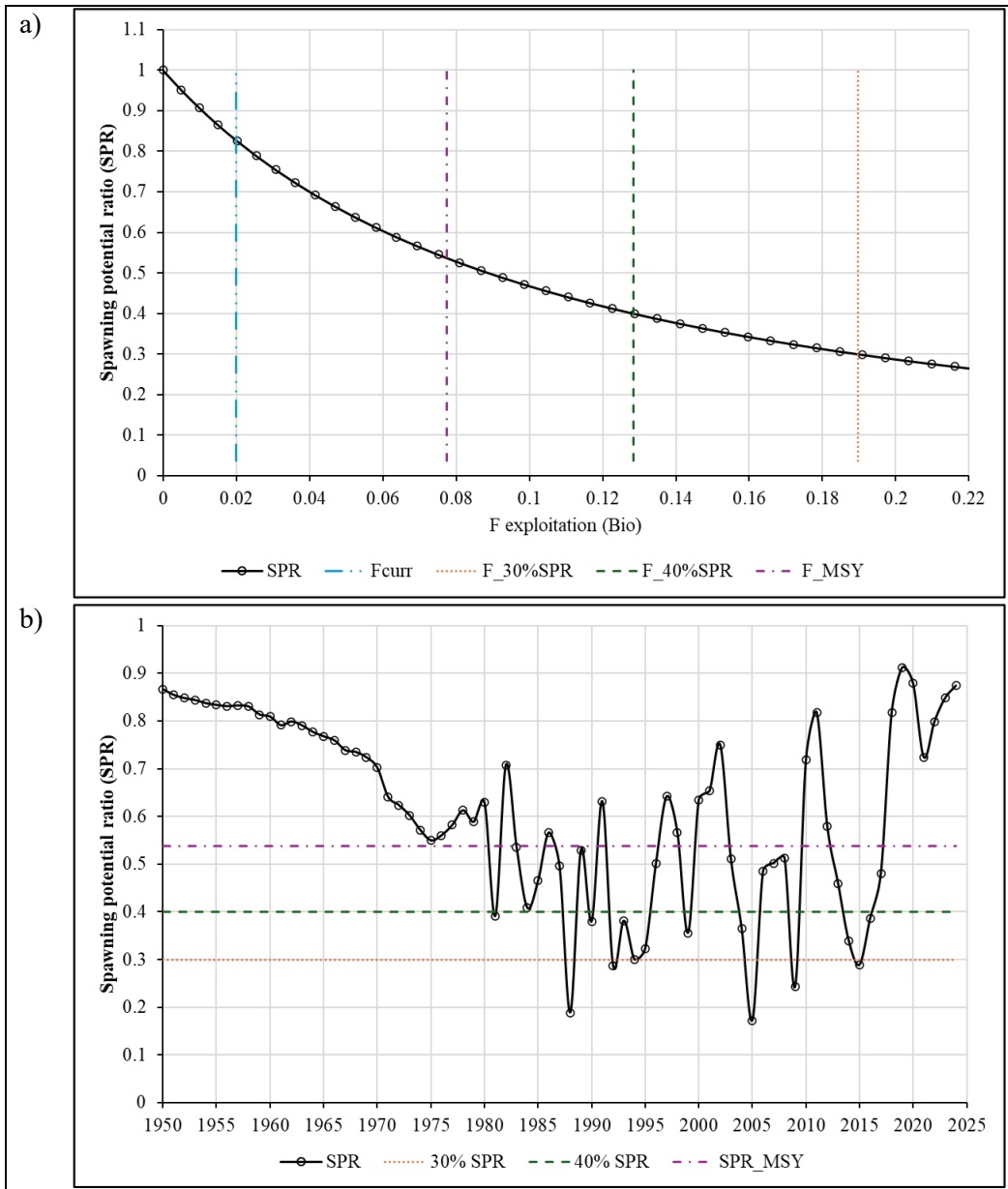


Figure 3.59. The a) static spawning potential ratio (SPR) computed as a function of the instantaneous exploitation rate, and b) static spawning potential ratio (SPR) by year for Florida Keys/East Florida Hogfish.

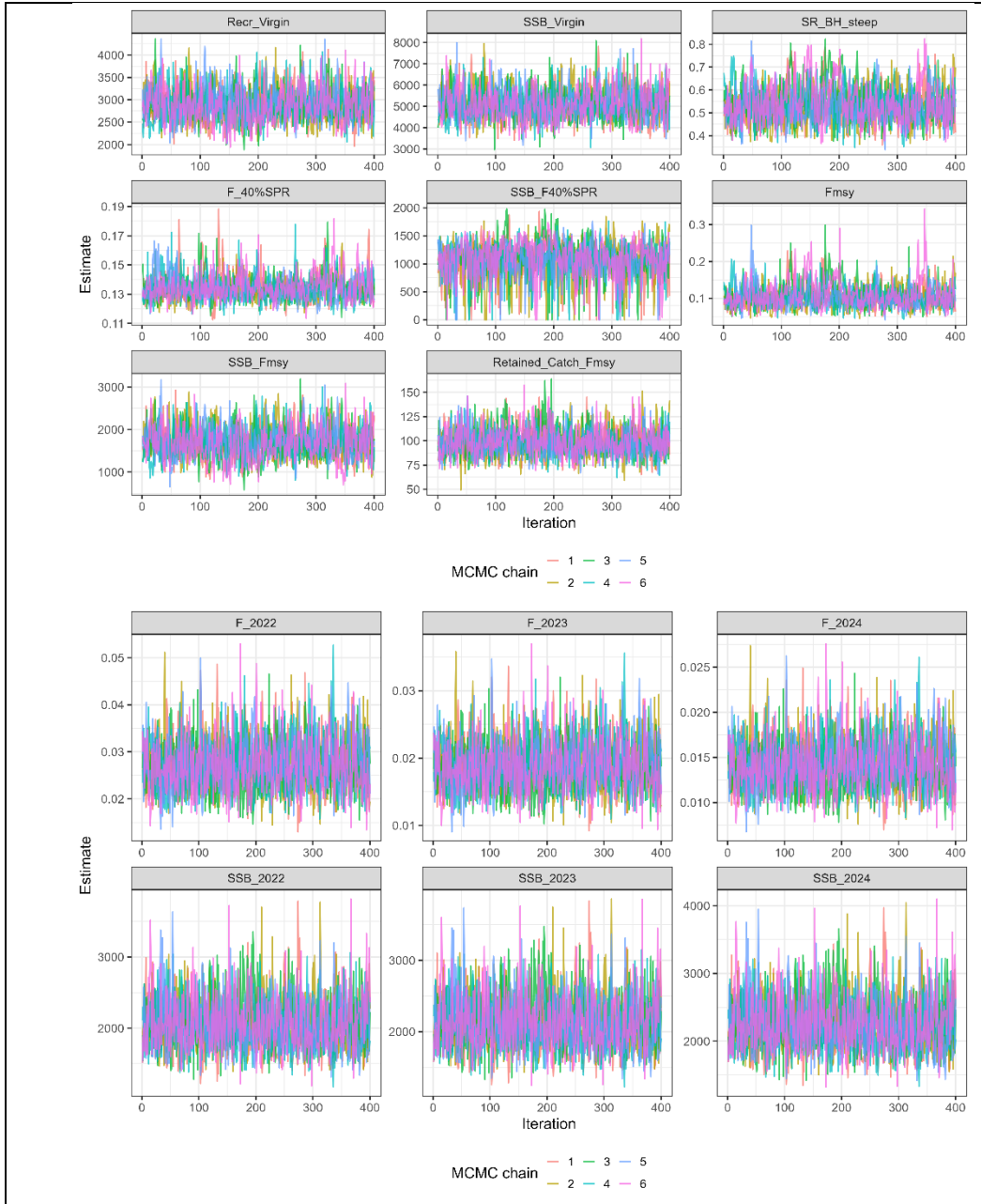


Figure 3.60. Combined trace plots of the six MCMC chains for selected parameters and derived quantities from the MCMC ‘proxy’ model based on the SEDAR 94 KEYS base model.

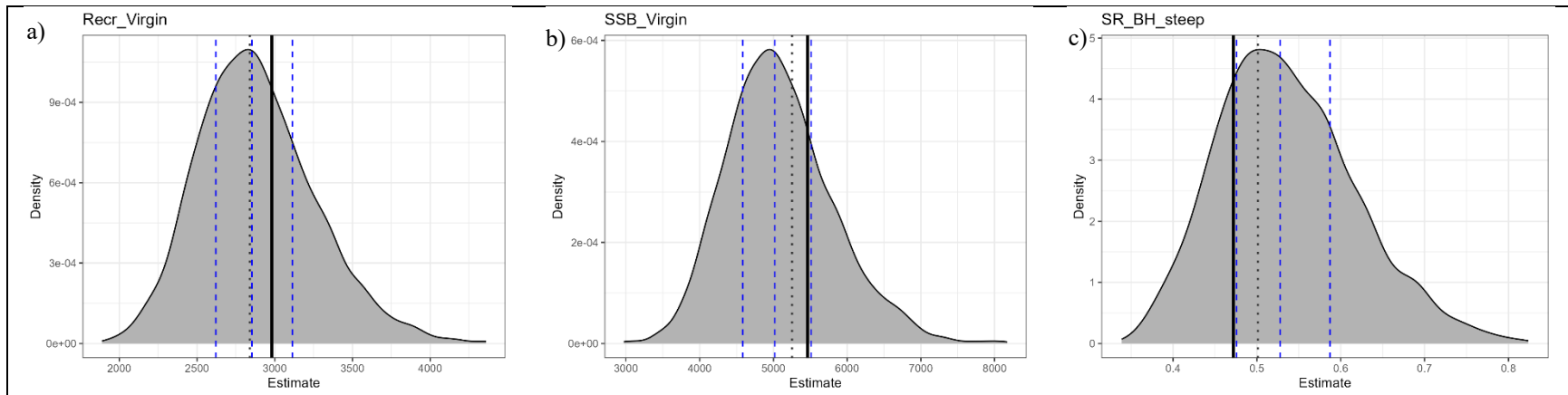


Figure 3.61. The posterior distributions for a) R_0 (i.e., virgin recruitment), b) SSB_0 (i.e., virgin spawning stock biomass), and c) steepness from the combined six-chain MCMC of the MCMC ‘proxy’ model based on the SEDAR 94 KEYS base model. The blue dashed lines indicate the median and interquartile range, the black dotted line is the estimate from the MCMC ‘proxy’ model, and the solid black line is the estimate from the SEDAR 94 KEYS base model.

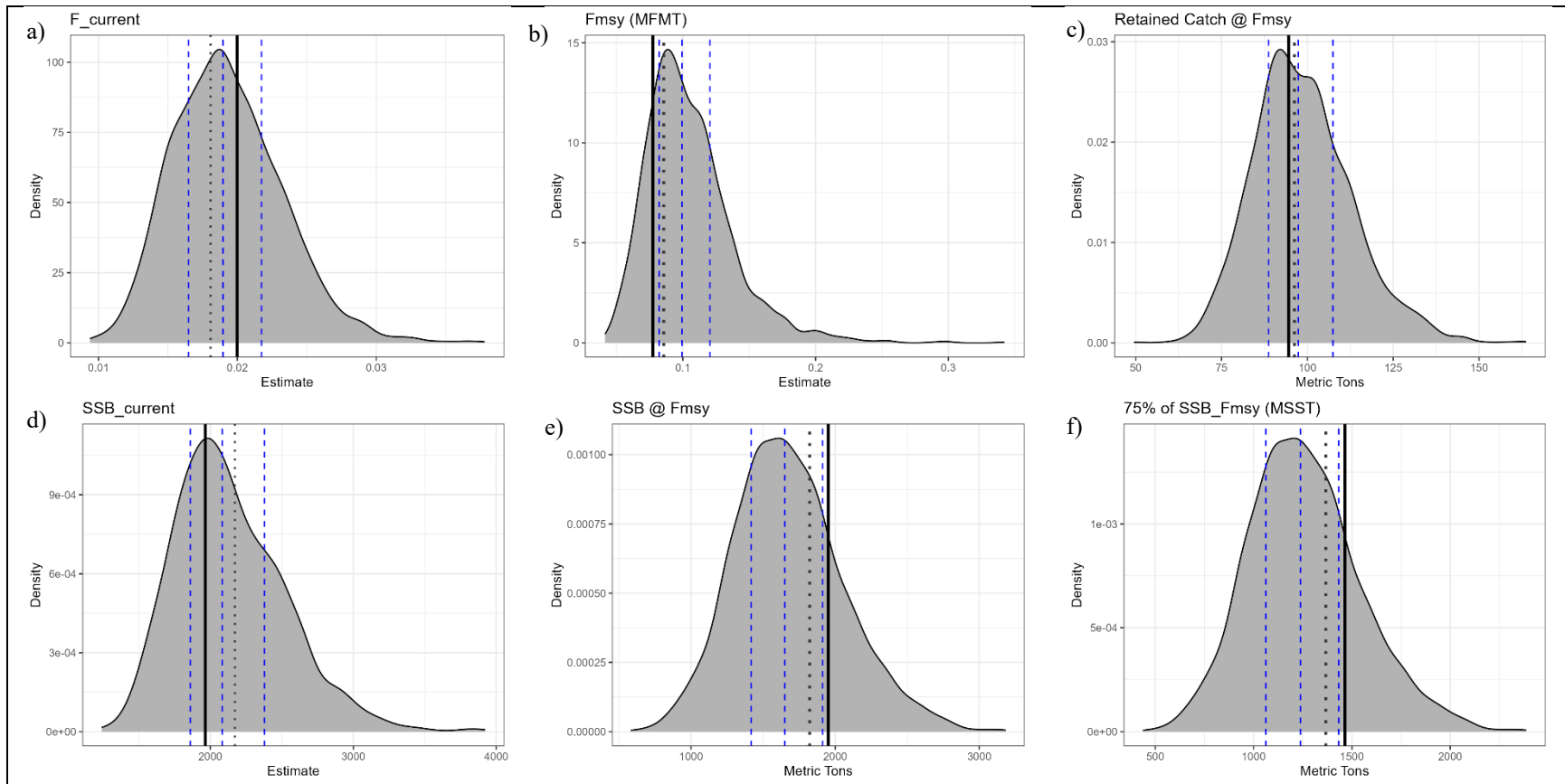


Figure 3.62. The posterior distributions for a) $F_{current}$ (i.e., geometric mean of F for years 2022 – 2024), b) F_{MSY} (i.e., MFMT), and c) the retained yield associated with F_{MSY} , d) $SSB_{current}$ (i.e., geometric mean of SSB for years 2022 – 2024), e) SSB at F_{MSY} , and f) 75% of SSB at F_{MSY} (i.e., MSST) from the combined six-chain MCMC of the MCMC ‘proxy’ model based on the SEDAR 94 KEYS base model. The blue dashed lines indicate the median and interquartile range, the black dotted line is the estimate from the MCMC ‘proxy’ model, and the solid black line is the estimate from the SEDAR 94 KEYS base model.

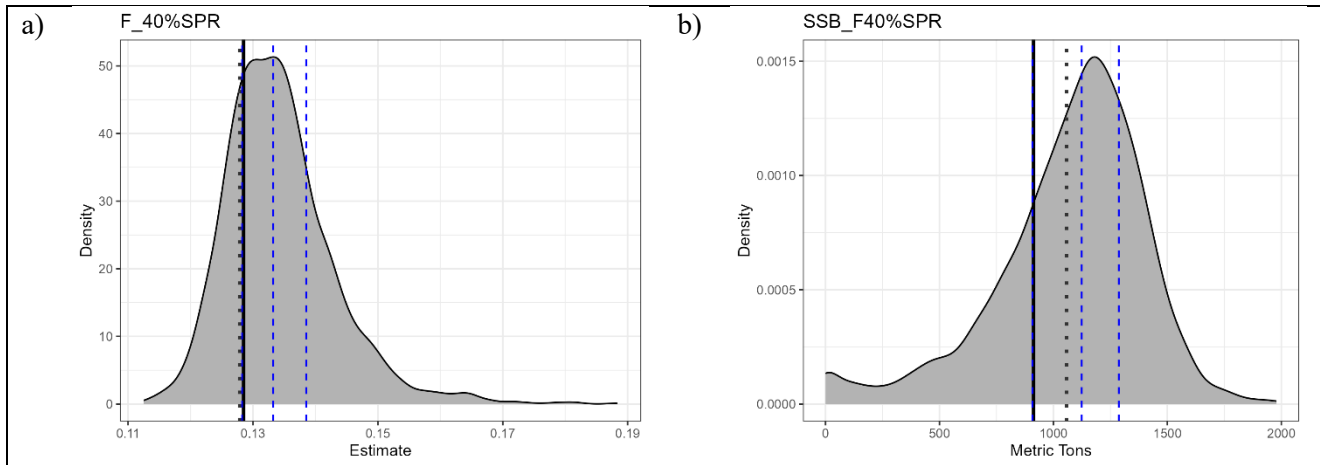


Figure 3.63. The posterior distribution for a) $F_{40\%SPR}$ and b) $SSB_{F40\%SPR}$ values from the combined six-chain MCMC of the MCMC ‘proxy’ model based on the SEDAR 94 KEYS base model. The blue dashed lines indicate the median and interquartile range, the black dotted line is the estimate from the MCMC ‘proxy’ model, and the solid black line is the estimate from the SEDAR 94 KEYS base model.

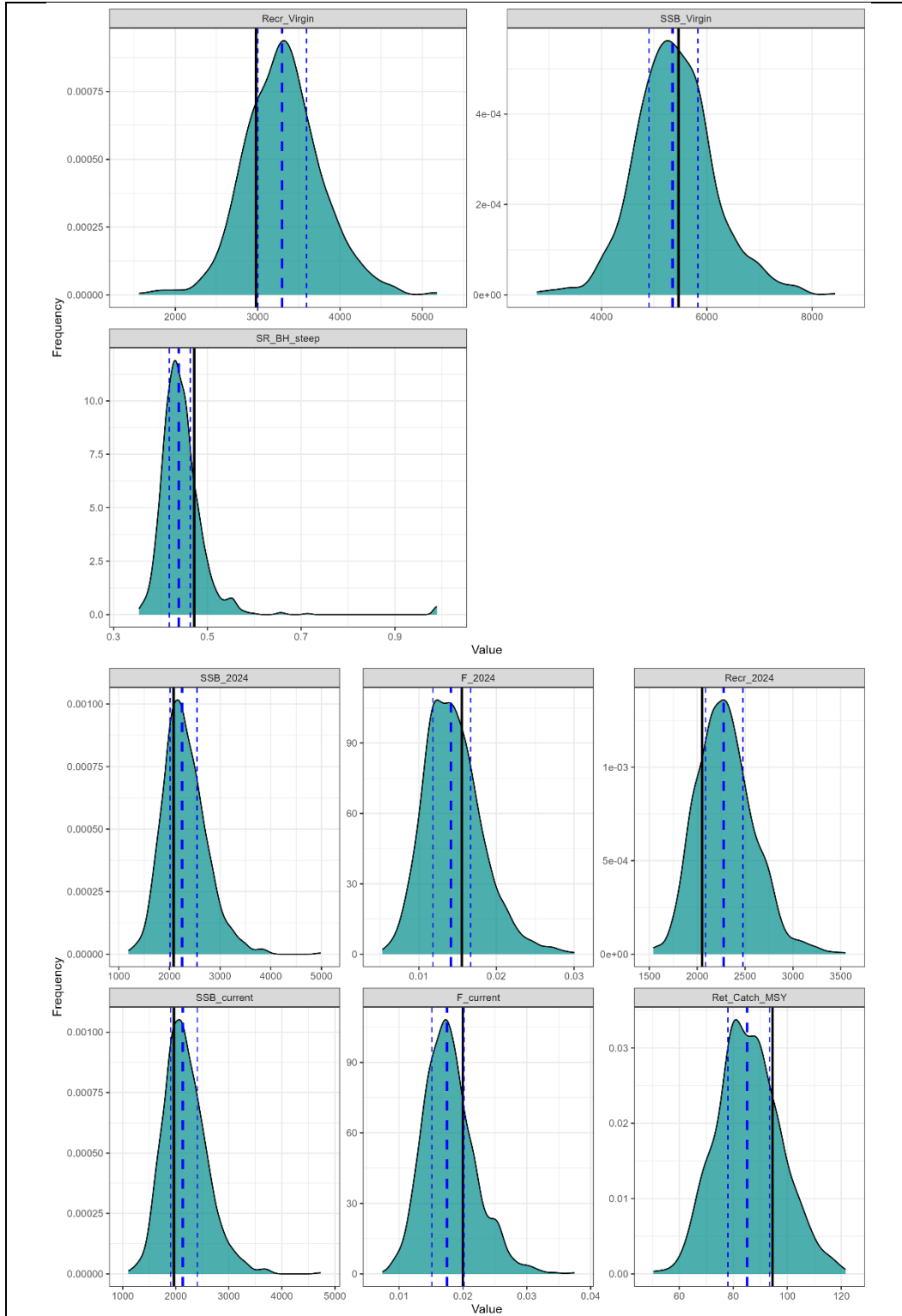


Figure 3.64. Distributions of selected parameter estimates and derived quantities from parametric bootstrapping the SEDAR 94 KEYS base model.

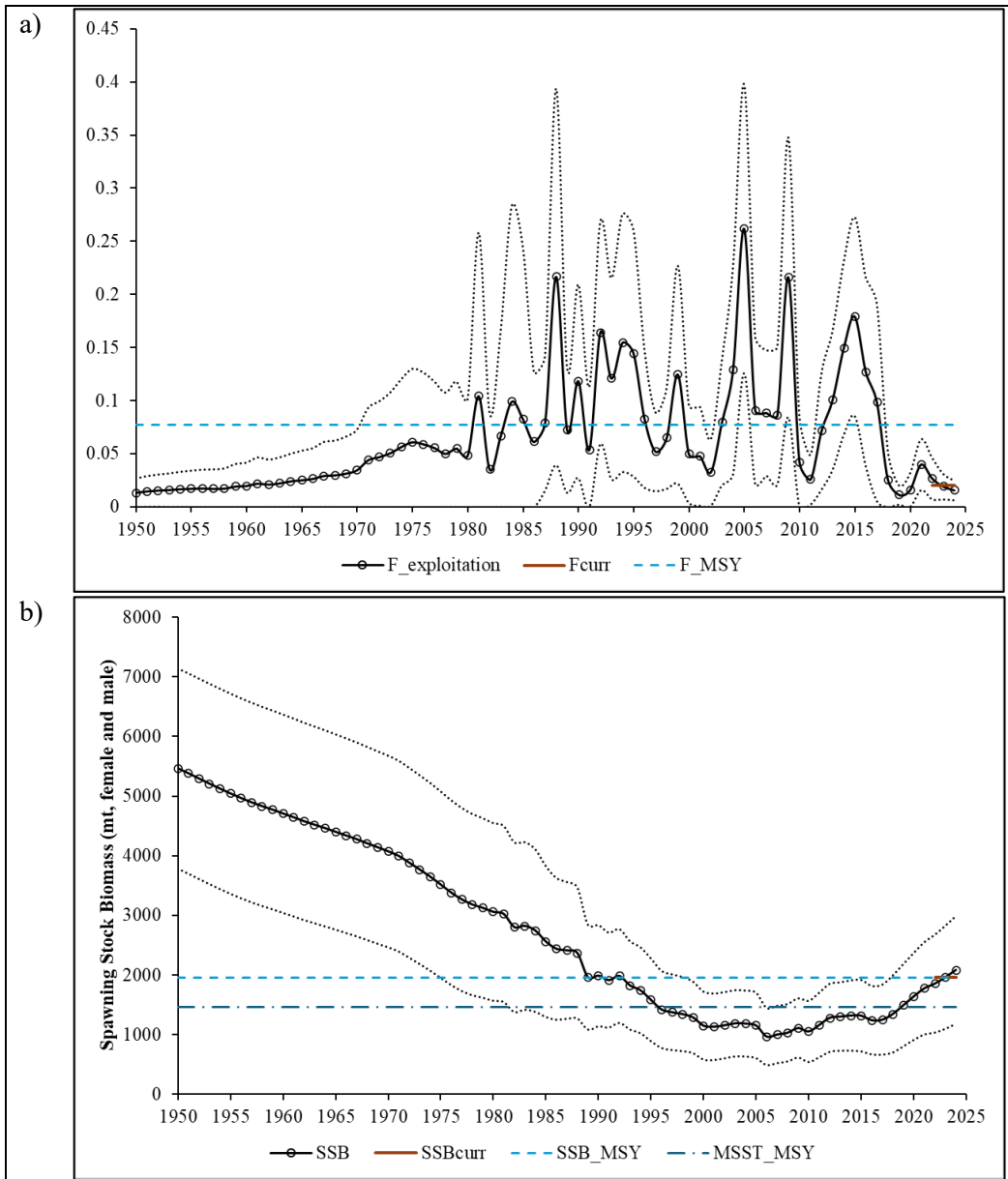


Figure 3.65. Annual estimates of a) exploitation relative to F_{MSY} and the geometric mean of exploitation in the last three years ($F_{current}$), and b) spawning stock biomass (SSB) relative to MSST (75% SSB_{MSY}), SSB_{MSY} , and the geometric mean of SSB in the last three years ($SSB_{current}$) by the SEDAR 94 KEYS base model. Dotted lines represent 95% confidence intervals.

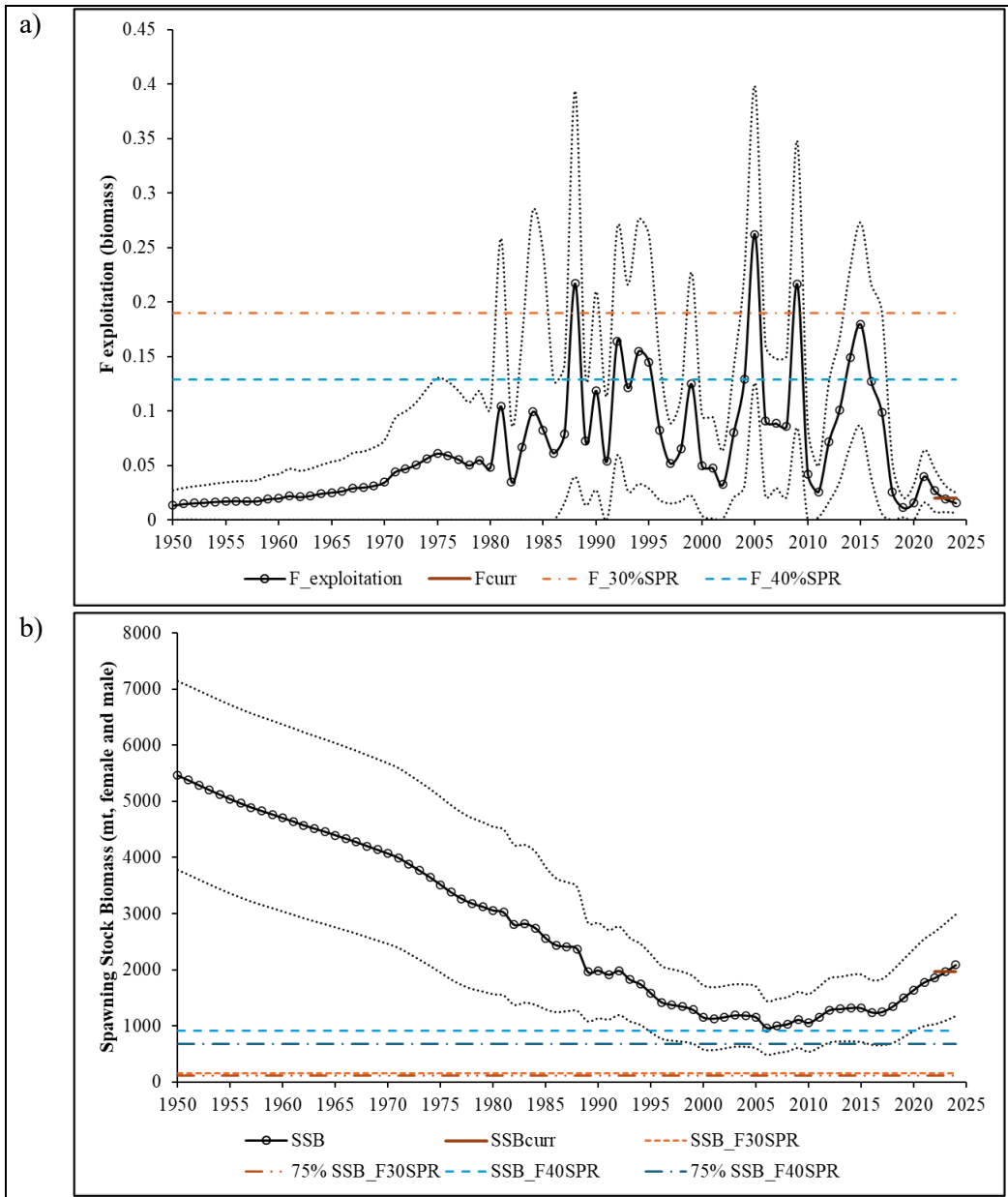


Figure 3.66. Annual estimates of a) exploitation relative to $F_{30\%SPR}$, $F_{40\%SPR}$, and the geometric mean of exploitation in the last three years ($F_{current}$), and b) spawning stock biomass (SSB) relative to 75% $SSB_{F40\%SPR}$, $SSB_{F40\%SPR}$, and the geometric mean of SSB in the last three years ($SSB_{current}$) by the SEDAR 94 KEYS base model. Dotted lines represent 95% confidence intervals.

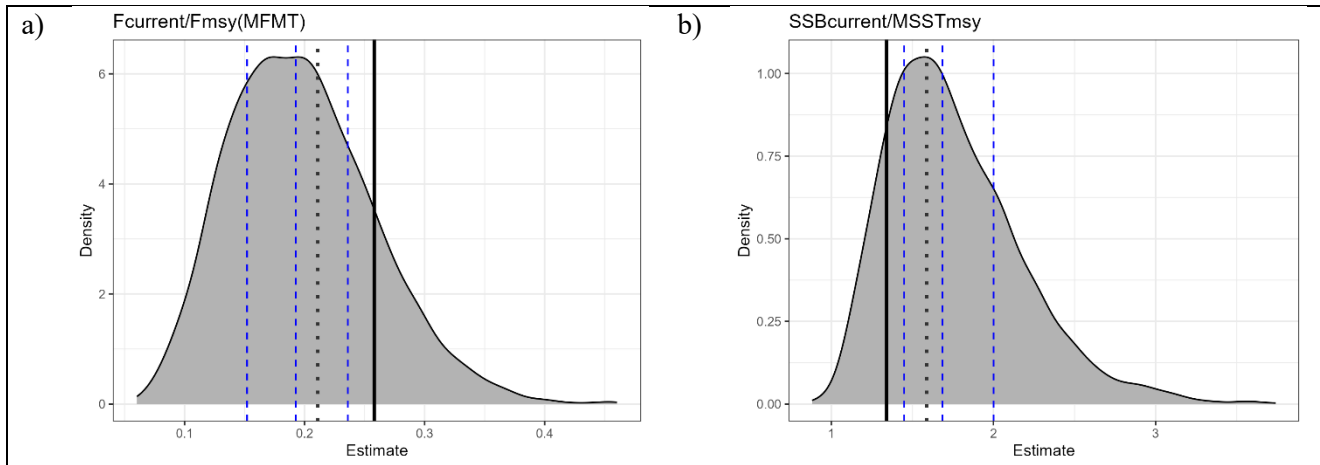


Figure 3.67. The posterior distribution for the F ratio ($F_{current}/F_{MSY}$) and SSB ratio ($SSB_{current}/MSST_{MSY}$) values from the combined six-chain MCMC of the MCMC ‘proxy’ model based on the SEDAR 94 KEYS base model. The blue dashed lines indicate the median and interquartile range, the black dotted line is the estimate from the MCMC ‘proxy’ model, and the solid black line is the estimate from the SEDAR 94 KEYS base model.

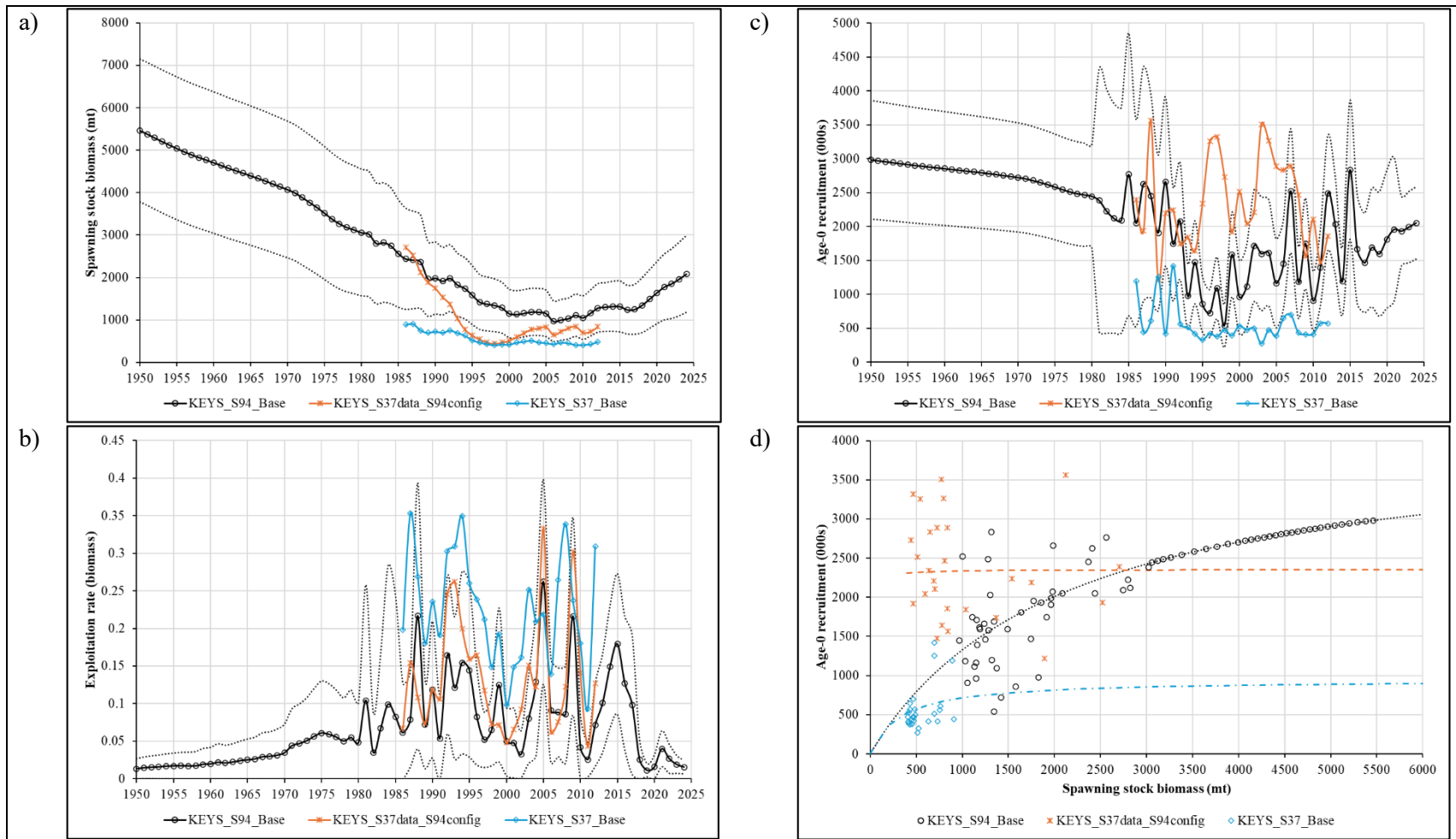


Figure 3.68. A comparison of the results between the SEDAR 94 KEYS base model (KEYS_S94_Base), the bridge building model (KEYS_S37data_S94config), and the SEDAR 37 base model (KEYS_S37_Base) for a) spawning stock biomass, b) exploitation rates, c) age-0 recruitment, and d) the estimated stock-recruitment relationship.

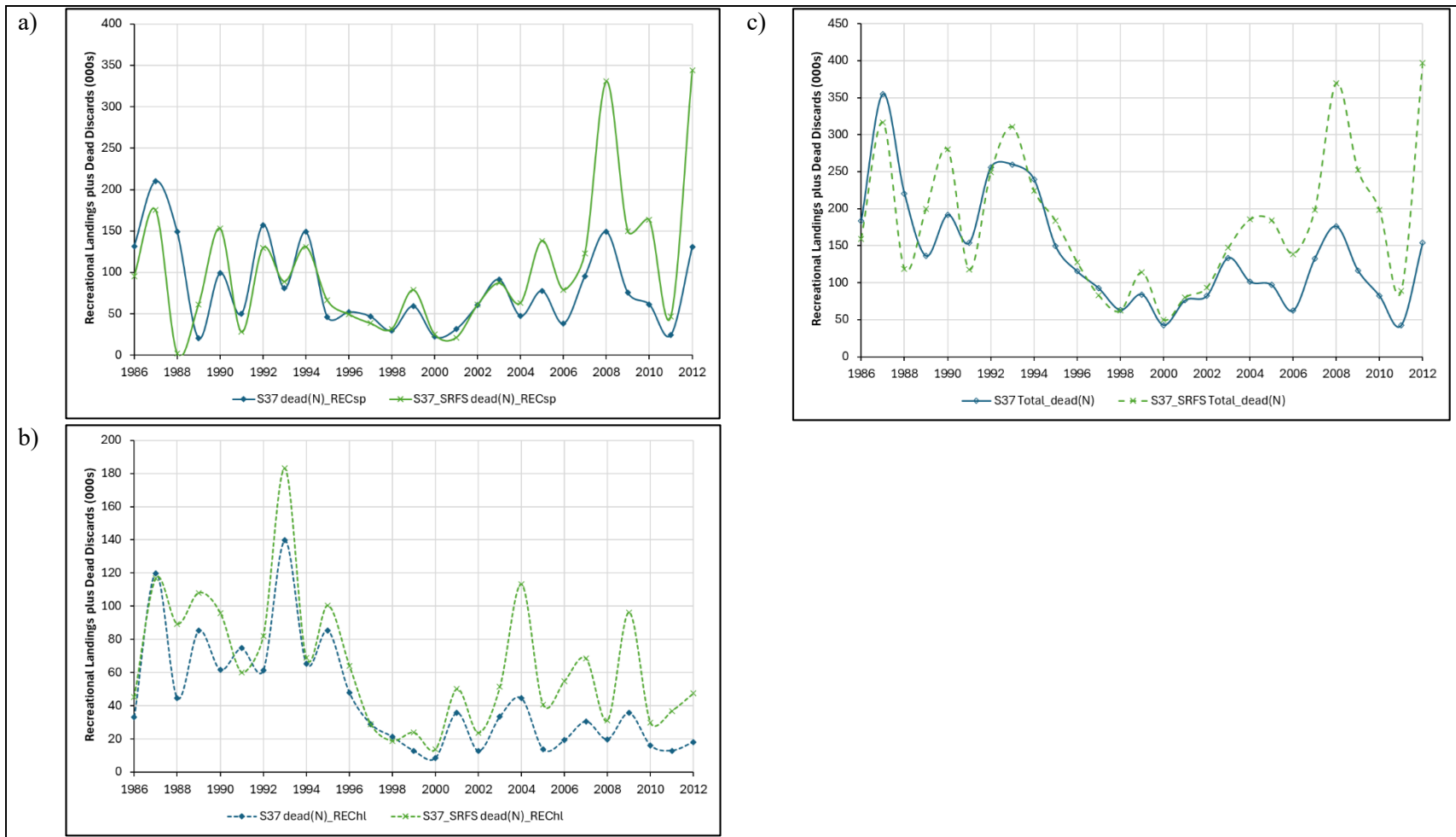


Figure 3.69. A comparison of the input recreational landings plus dead discards in numbers (dead[N]) between the SEDAR 37 base model (S37) and the SEDAR 37 base model containing the ‘Full SRFS’ (S37_SRFS) catch timeseries a) for the spear gear, b) for the hook-and-line gears, and c) when gears were combined as configured for the S94 KEYS base model.

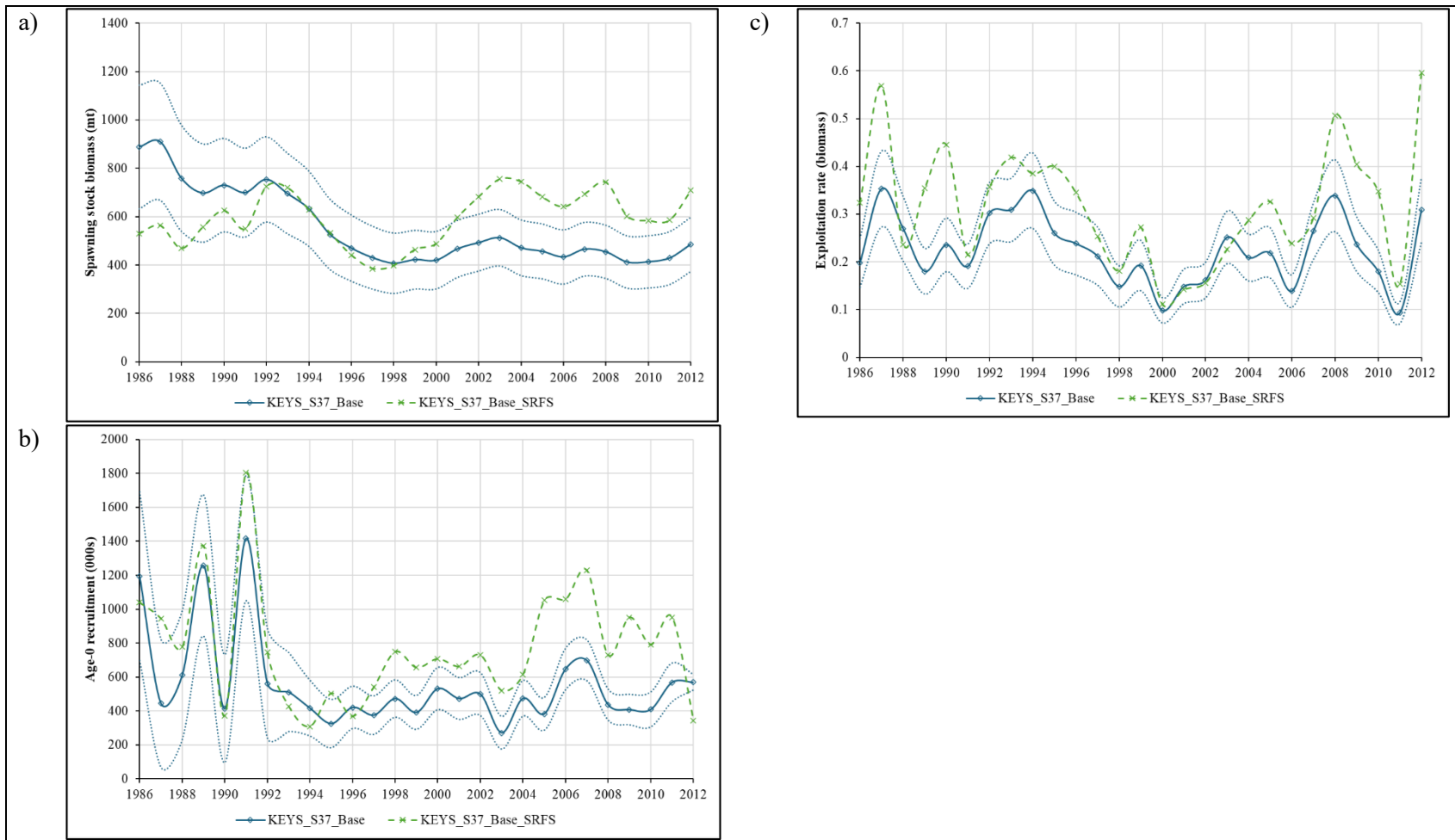


Figure 3.70. A comparison of the results between the SEDAR 37 base model (S37) and the SEDAR 37 base model containing the 'Full SRFS' catch timeseries (S37_SRFS) for a) spawning stock biomass, b) age-0 recruitment, and c) exploitation rates.

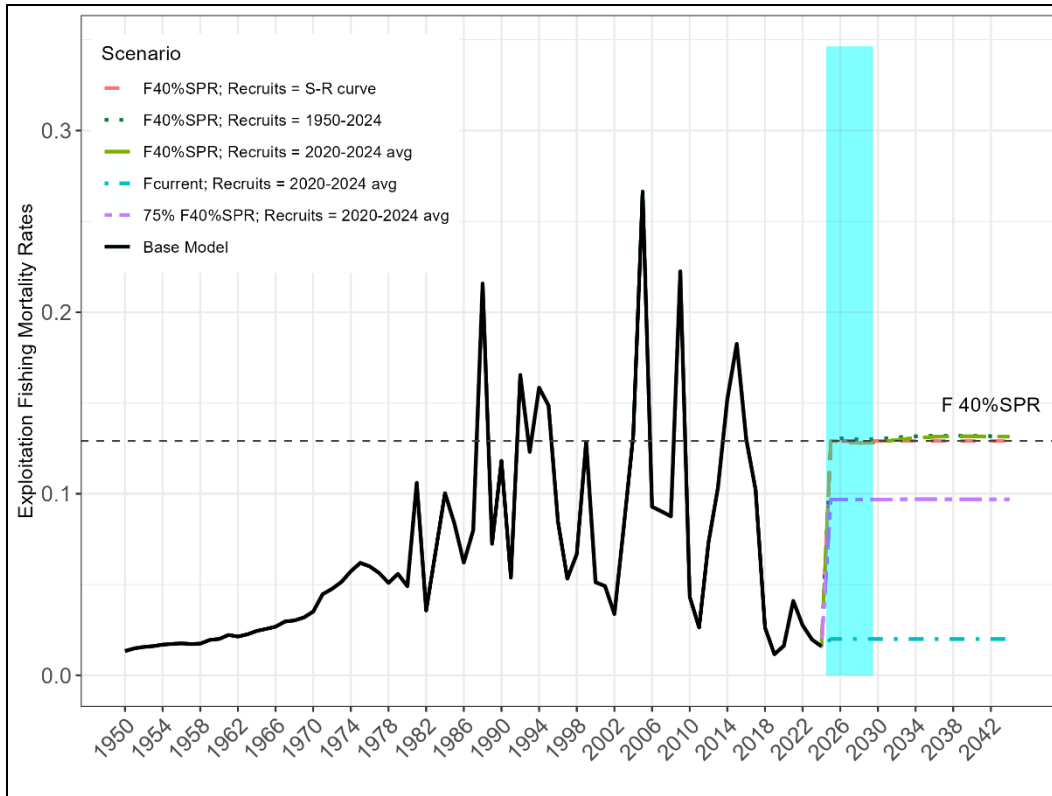


Figure 3.71. Exploitation rates based on projections under long-term equilibrium $F_{40\%SPR}$ using the stock-recruitment curve (red dashed line), long-term equilibrium $F_{40\%SPR}$ using average recruitment from the whole timeseries (dark green dotted line), short-term $F_{40\%SPR}$ (mustard dashed line), $F_{current}$ (teal dot-dashed line), 75% of short-term $F_{40\%SPR}$ (purple short-dash-long-dashed line), and as estimated by the SEDAR 94 KEYS base model (black solid line). The cyan region highlights the first five years of the projection (2025 – 2030).

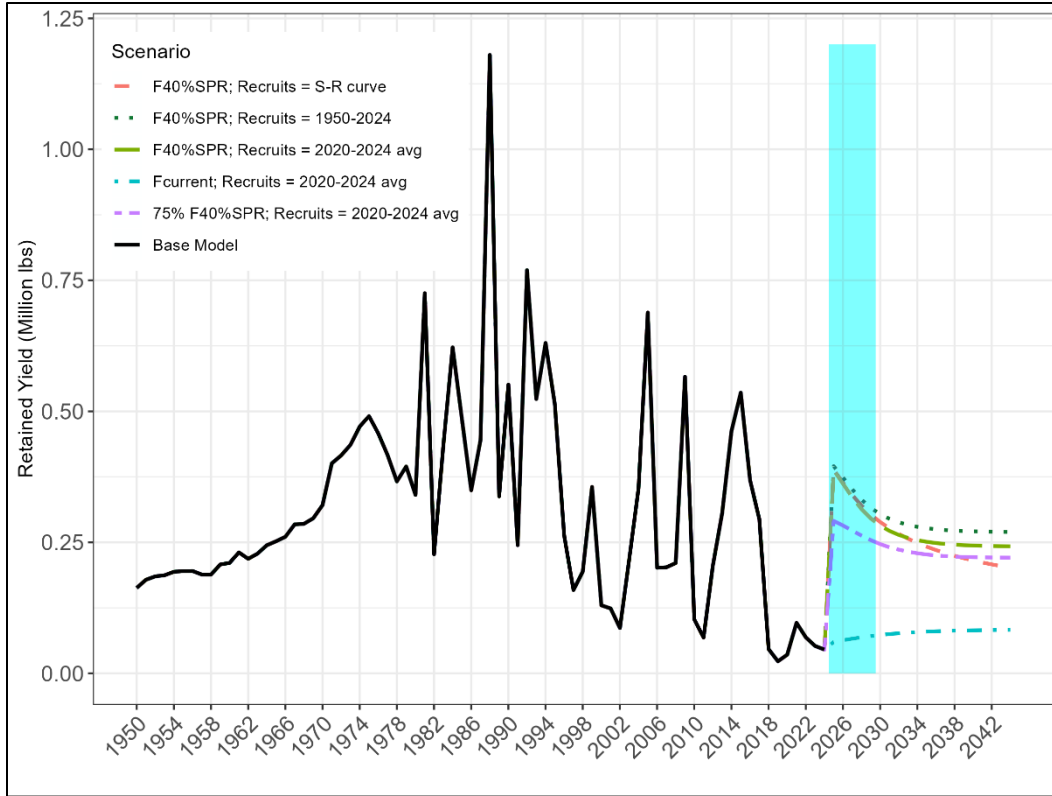


Figure 3.72. Retained yield (million pounds) based on projections under long-term equilibrium $F_{40\%SPR}$ using the stock-recruitment curve (red dashed line), long-term equilibrium $F_{40\%SPR}$ using average recruitment from the whole timeseries (dark green dotted line), short-term $F_{40\%SPR}$ (mustard dashed line), $F_{current}$ (teal dot-dashed line), 75% of short-term $F_{40\%SPR}$ (purple short-dash-long-dashed line), and as estimated by the SEDAR 94 KEYS base model (black solid line). The cyan region highlights the first five years of the projection (2025 – 2030).

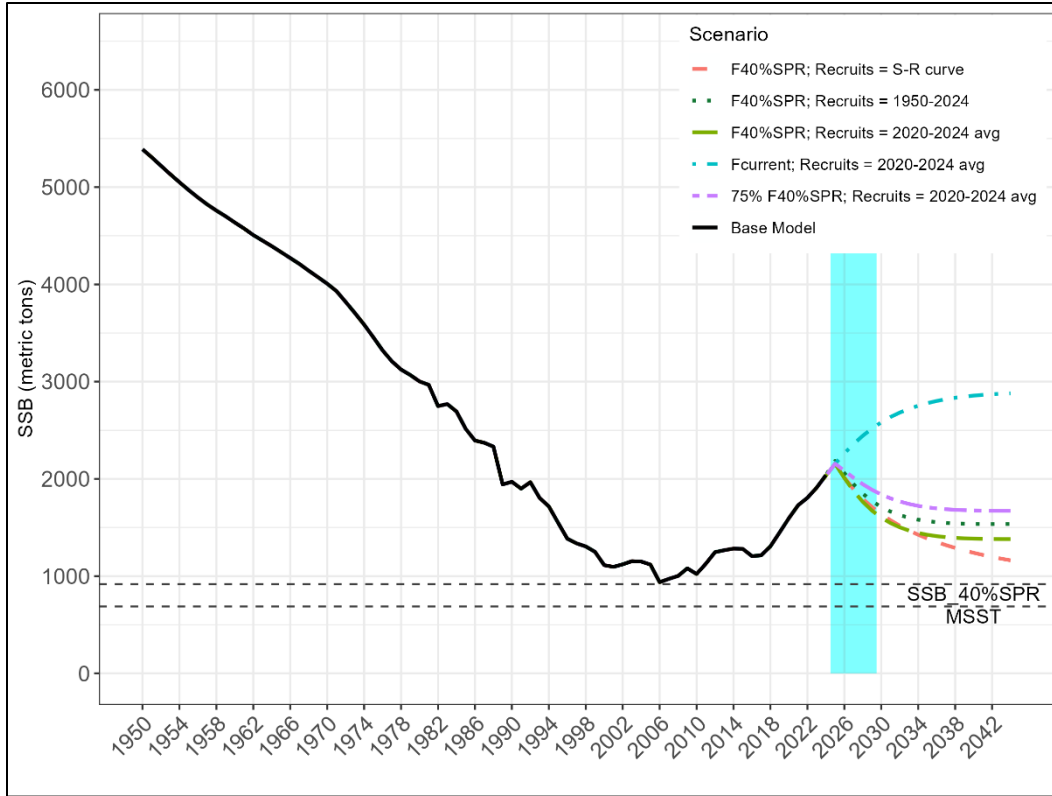


Figure 3.73. Spawning stock biomass (metric tons) based on projections under long-term equilibrium $F_{40\%SPR}$ using the stock-recruitment curve (red dashed line), long-term equilibrium $F_{40\%SPR}$ using average recruitment from the whole timeseries (dark green dotted line), short-term $F_{40\%SPR}$ (mustard dashed line), $F_{current}$ (teal dot-dashed line), 75% of short-term $F_{40\%SPR}$ (purple short-dash-long-dashed line), and as estimated by the SEDAR 94 KEYS base model (black solid line). The cyan region highlights the first five years of the projection (2025 – 2030).

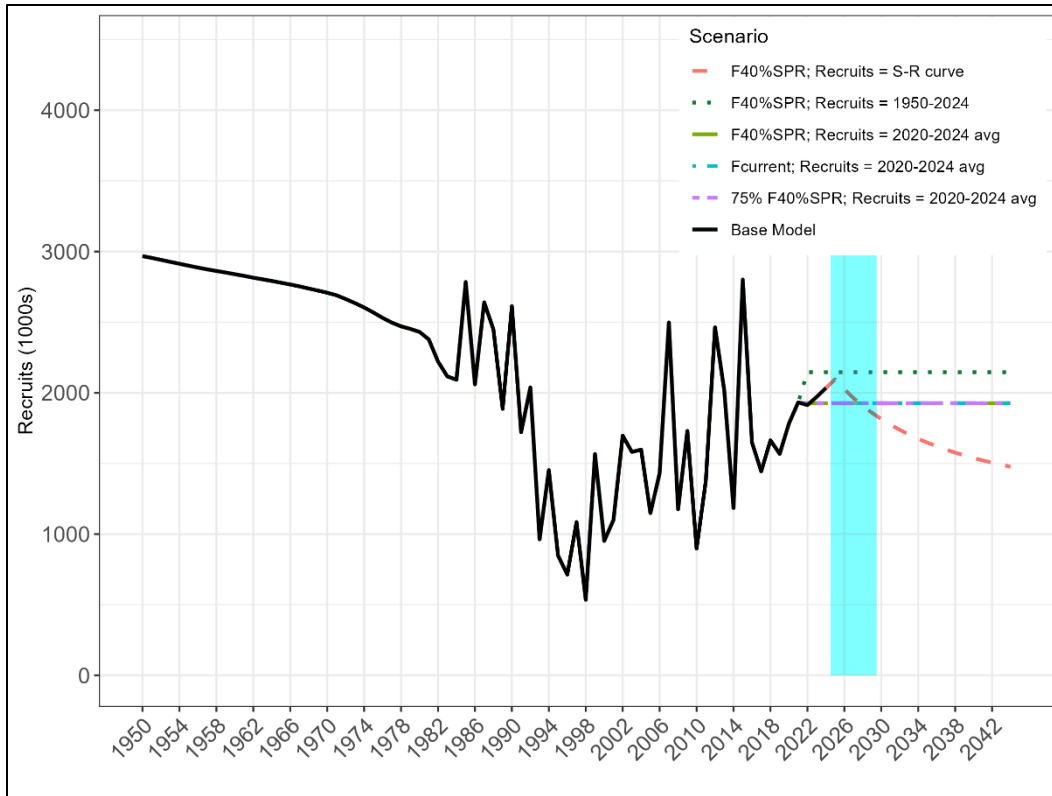


Figure 3.74. Age-0 recruits (in thousands) based on projections under long-term equilibrium $F_{40\%SPR}$ using the stock-recruitment curve (red dashed line), long-term equilibrium $F_{40\%SPR}$ using average recruitment from the whole timeseries (dark green dotted line), short-term $F_{40\%SPR}$ (mustard dashed line), $F_{current}$ (teal dot-dashed line), 75% of short-term $F_{40\%SPR}$ (purple short-dash-long-dashed line), and as estimated by the SEDAR 94 KEYS base model (black solid line). The cyan region highlights the first five years of the projection (2025 – 2030).

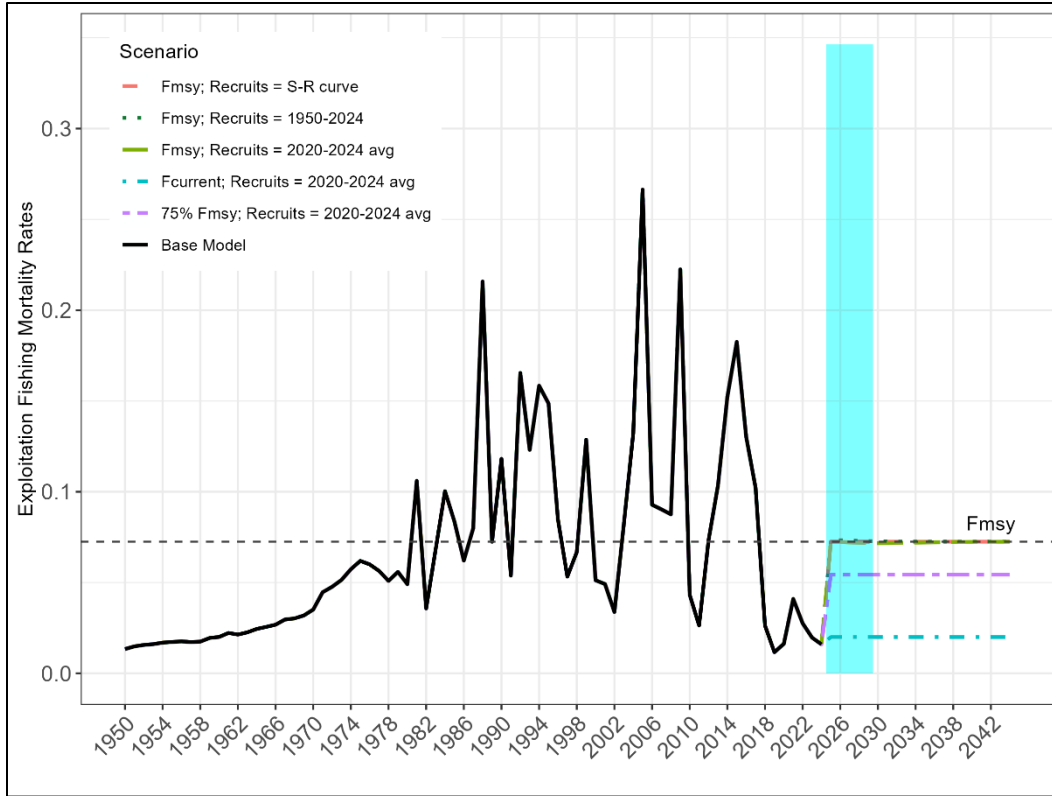


Figure 3.75. Exploitation rates based on projections under long-term equilibrium F_{MSY} using the stock-recruitment curve (red dashed line), long-term equilibrium F_{MSY} using average recruitment from the whole timeseries (dark green dotted line), short-term F_{MSY} (mustard dashed line), $F_{current}$ (teal dot-dashed line), 75% of short-term F_{MSY} (purple short-dash-long-dashed line), and as estimated by the SEDAR 94 KEYS base model (black solid line). The cyan region highlights the first five years of the projection (2025 – 2030).

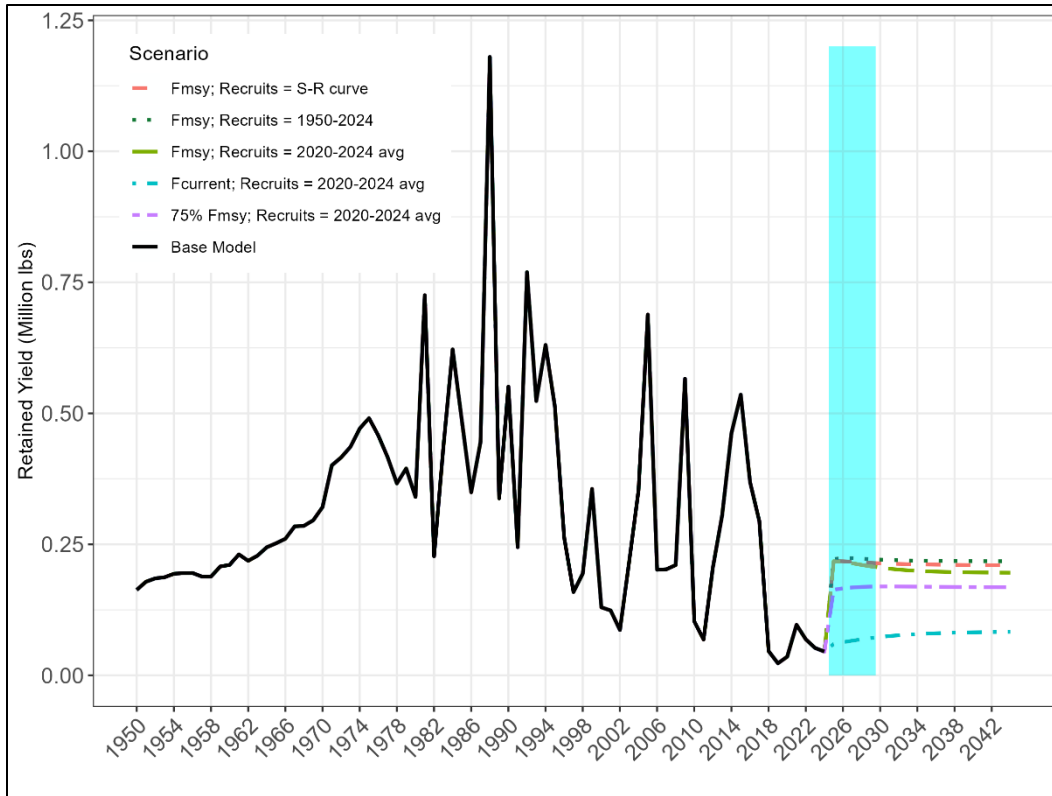


Figure 3.76. Retained yield (million pounds) based on projections under long-term equilibrium F_{MSY} using the stock-recruitment curve (red dashed line), long-term equilibrium F_{MSY} using average recruitment from the whole timeseries (dark green dotted line), short-term F_{MSY} (mustard dashed line), $F_{current}$ (teal dot-dashed line), 75% of short-term F_{MSY} (purple short-dash-long-dashed line), and as estimated by the SEDAR 94 KEYS base model (black solid line). The cyan region highlights the first five years of the projection (2025 – 2030).

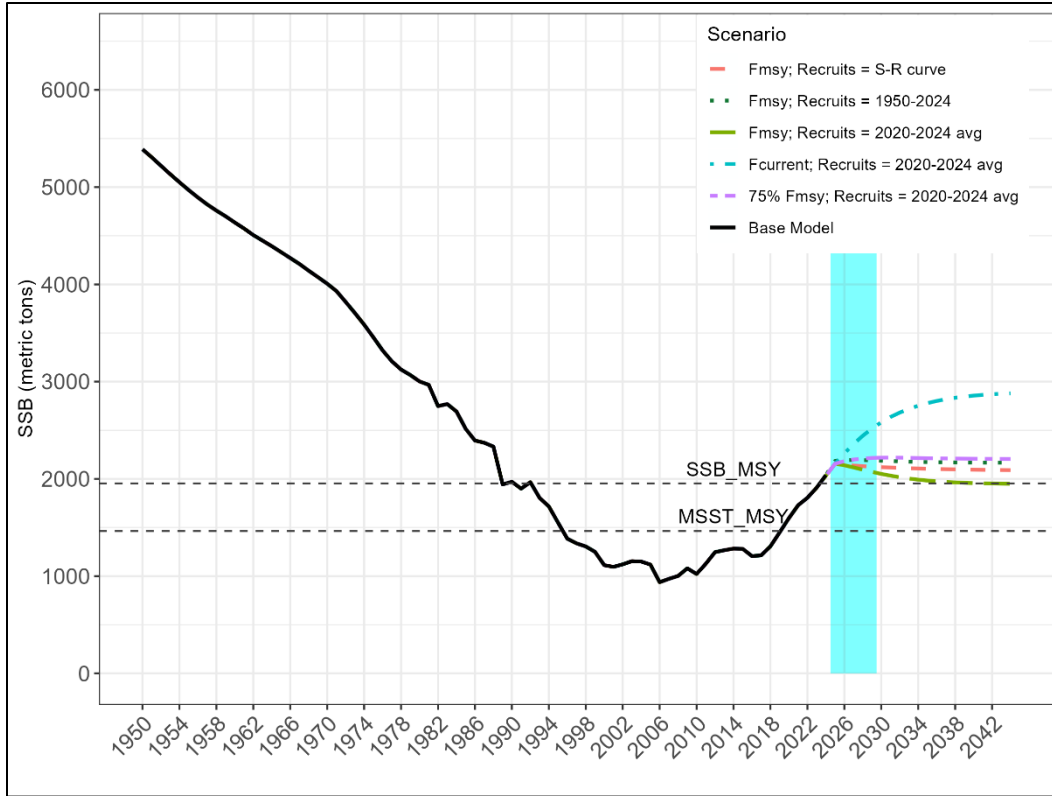


Figure 3.77. Spawning stock biomass (metric tons) based on projections under long-term equilibrium F_{MSY} using the stock-recruitment curve (red dashed line), long-term equilibrium F_{MSY} using average recruitment from the whole timeseries (dark green dotted line), short-term F_{MSY} (mustard dashed line), $F_{current}$ (teal dot-dashed line), 75% of short-term F_{MSY} (purple short-dash-long-dashed line), and as estimated by the SEDAR 94 KEYS base model (black solid line). The cyan region highlights the first five years of the projection (2025 – 2030).

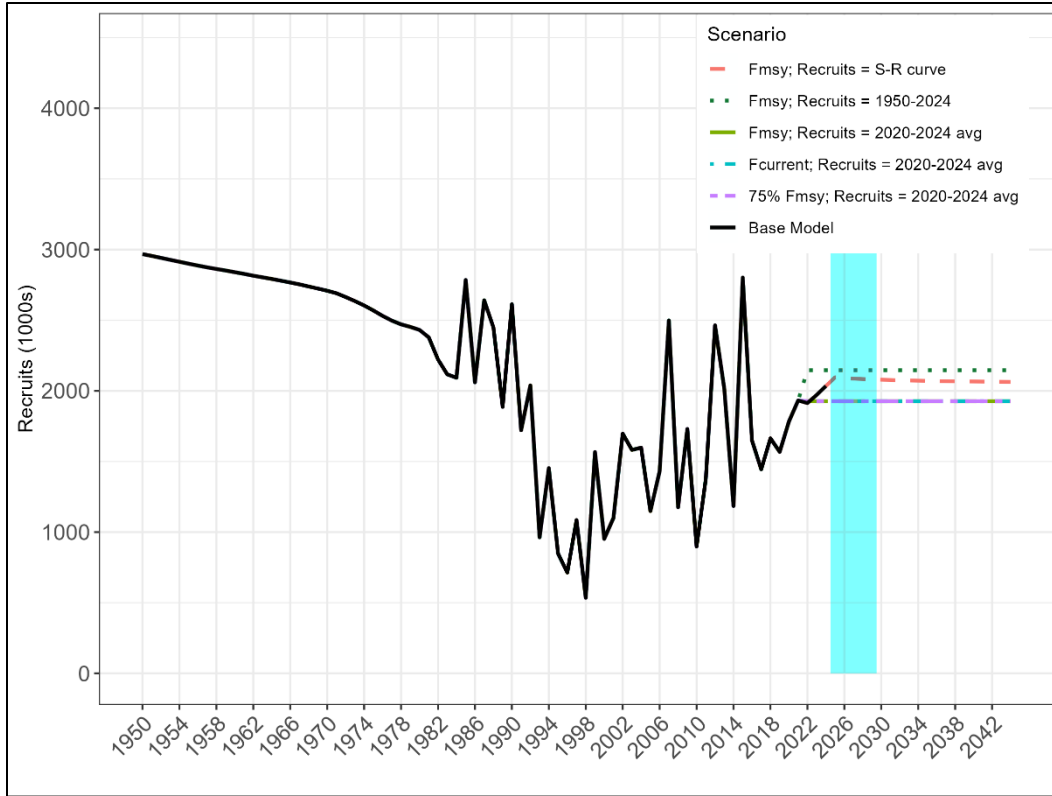


Figure 3.78. Age-0 recruits (in thousands) based on projections under long-term equilibrium F_{MSY} using the stock-recruitment curve (red dashed line), long-term equilibrium F_{MSY} using average recruitment from the whole timeseries (dark green dotted line), short-term F_{MSY} (mustard dashed line), $F_{current}$ (teal dot-dashed line), 75% of short-term F_{MSY} (purple short-dash-long-dashed line), and as estimated by the SEDAR 94 KEYS base model (black solid line). The cyan region highlights the first five years of the projection (2025 – 2030).

4 WFS Stock Synthesis Model Results

4.1 Life History

The WFS base model internally estimated growth where asymptotic length (L_{inf}) was estimated at 89.6 cm FL and the growth coefficient (k) was estimated at 0.083. Using the platoons feature within SS, this corresponded to the 2nd platoon (of the 3 total platoons) which was apportioned 70% of annual recruitment. The estimated mean length-at-age was found similar to the results of the external growth model developed during the Data Workshop (Figure 4.11; see Section 2.3.5 in the Data Workshop Report) and the additional platoons allowed fish to grow faster (i.e., larger) and slower (i.e., smaller). In the first platoon, where 15% of annual recruitment was apportioned, mean fish size at maximum age was as small as 64.7 cm FL; but in the third platoon, also receiving 15% of recruitment, mean fish size was as large as 90.2 cm FL at maximum age. These faster growing fish became vulnerable to the fisheries sooner whereas the slower growing fish encountered the fisheries much less, helping to mimic the “Lee phenomenon” hypothesized to be occurring in this stock. Additionally, the platoon within/between standard deviation ratio parameter was estimated at 0.85, suggesting a shift to lower mean size-at-age has been occurring for this population.

4.2 Landings and Discards

Fits to the landings data for the commercial, recreational hook-and-line, and recreational spear fleets are presented in Figures 4.12 – 14 and were nearly exact (total negative log-likelihood = $4.03134e^{-10}$). Figures 3.15 – 16 compare model estimated landings across fleets in biomass and numbers of fish, respectively.

Fits to the discard data were reasonable (total negative log-likelihood = 19.0468) as most estimates were close to the observed values, were within the 95% confidence intervals, and followed the increasing trend during the latter portion of the timeseries (Figure 4.17).

4.3 Indices

The WFS base model fits to the three fishery-independent indices (seagrass trawl, SEAMAP trawl, and combined video) are presented in Figures 4.18 – 20. Overall model fits to the indices were well estimated (total negative log-likelihood = -8.45446) and exhibited more stable but variable trends across time.

Model fits to the seagrass trawl index were the worst of the three indices (RMSE = 0.6722). The expected trend followed the observed trend but was more relatively stable through time; the model expected lower recruitment in 2012 and higher recruitment during 2013 – 2015 and 2019 (Figure 4.18). As an age-0 recruitment index, this is directly tied to the expected trend in recruitment deviations and fits were thought to have improved if the sum-to-zero constraint was removed; however, when explored during the model development process, this was not found to occur. Changing the index configuration to one with length-based selectivity and added length composition data to investigate potential misspecification, which also would have added more parameters to the model, was not explored due to time and resources.

The fits to the SEAMAP trawl index were largely within the observed error, but overestimated years 2013, 2014, and 2018 and underestimated years 2023 – 2024 (Figure 4.19, RMSE = 0.5280). The expected values tended to be staggered from the seagrass trawl (recruitment) index. For example, higher recruitment in 2012, 2018, and 2021 led to higher expected abundances in 2013, 2019, and 2022. More below average recruitment in 2022 and 2024 may have influenced the complete underestimation of abundance for 2023 – 2024.

The combined video index was fit the best (RMSE = 0.2221), which was expected given the low input values of observed error, and greatly influenced the population's predicted trend in biomass. The fitted values followed the observed trend with poorest fit occurring in outlying years 2010 and 2014 and a slight increasing trend was predicted from 2017 to 2024 (Figure 4.20).

4.4 Length and Age Composition

4.4.1 Data Weighting

Iterative reweighting of length composition data as well as CAAL data was performed according to the Francis composition weighting method TA1.8 (Francis 2011). Francis weights were calculated iteratively until they stabilized to the values presented in Table 4.9, which occurred on the 3rd iteration. All composition data were weighted across fleets and partitions by multiplying the corresponding Francis weights with the input sample sizes to produce the adjusted ('N. adj.') input sample sizes as reported in Figure 4.21. Applying the Francis weights resulted in large reductions to the unweighted base model's objective function. While this mostly occurred in the length composition and CAAL data's likelihood components, improvements to index likelihood components were particularly observed in the seagrass trawl index (Δ negative log-likelihood -8.597 units), and to lesser extents in the combined video index (Δ negative log-likelihood -0.468 units), and SEAMAP trawl index (Δ negative log-likelihood -0.241 units).

4.4.2 Length Composition

The base model fits to the length composition data along with the Pearson residuals associated with the landings, discards, and indices are presented in Figures 4.21 – 25. The quality of the fit varied among fleets and indices and fits aggregated across time were reasonable (total negative log-likelihood = 421.624; Figure 4.21). The model's predicted distributions were able to match the observed overall distributions, smoothing through the noise, and slightly overestimated the peak for the recreational spear.

The length composition data for the commercial fleet were weighted annually by the commercial landings and were aggregated into three super-periods: 1991 – 1999 (N.adj. = 29.5), 2000 – 2017 (N.adj. = 96.9), and 2018 – 2024 (N.adj. = 29.5); no length data were available for year 2004. Fits to these data largely agreed with the observed distributions (Figure 4.22a and 4.25), matched the changes in minimum size limits, and smoothed through jagged-looking length bins. The first super-period has large peaks throughout the length distribution leading to underestimates in the number of smaller and larger fish. The distribution was more concentrated between 28 – 44 cm FL in the second super-period which led to a slight overestimation of the smallest fish and an underestimation of the larger fish. For the most recent super-period the distribution was further concentrated between 32 – 42 cm FL and the peak was slightly underestimated. All super-period distributions reflected a consistent retention of larger individuals through time.

The recreational hook-and-line retained length composition data were weighted annually by the recreational hook-and-line landings, were characterized by comparatively larger sample sizes, and were aggregated into four super-periods: 1986 – 1999 (N.adj. = 210.3), 2000 – 2004 (N.adj. = 103.9), 2005 – 2017 (N.adj. = 423.1), and 2018 – 2024 (N.adj. = 536.9). The length distributions in all four super-periods fit well but exhibited a truncation at larger sizes through time alongside the shift in minimum size limits (Figures 4.22b and 4.25). The first super-period characterized the first time block (no size limits) where length composition data indicated some retention of larger individuals and fits to the data were slightly underestimated at the peak. The second and third super-periods (2000 – 2017; second time block) were split to align with the recreational hook-and-line discards which became available in 2005 (Figure 4.22c) and reflected the shift to a 12" FL (30.5 cm) minimum size limit. Distributions in these super-periods were largely concentrated below 46 cm FL. The third super-period (2018 – 2024) reflected a shift in mode

to the new 14" FL (35.6 cm), however smaller fish were still shown to be retained (Figure 4.22b) and the distribution was more concentrated below 44 cm FL. The recreational hook-and-line discard length compositions in the first super-period were characterized by very low annual sample sizes and no data for years 2006 – 2008, 2010 – 2012, and 2014. Fits to the available data overestimated the number of fish between 22 – 26 cm FL and underestimated the peak at 28 cm FL (Figures 4.22c and 4.25). In the second super-period, annual sample sizes increased and fits to the length compositions were fairly well and were aligned below the 14" FL (35.6 cm) minimum size limit (Figures 4.22c and 4.25).

The recreational spear length composition data were weighted annually by the recreational spear landings, contained generally larger sample sizes than the recreational hook-and-line, and were aggregated into three super-periods: 1986 – 1999 (N.adj. = 192.8), 2000 – 2017 (N.adj. = 422.5), and 2018 – 2024 (N.adj. = 66.4). As observed in the recreational hook-and-line composition data, the length distributions in all three super-periods fit well but indicated truncation at larger sizes through time alongside the shift in minimum size limits (Figures 4.22d and 4.25). The recreational spear fishery was more prominent during the first two super-periods and reflected that in the annual sample sizes; in the third super-period, annual sample sizes diminished and fits to the data underestimated the peak at 36 cm FL (Figure 4.22d).

Model fits were reasonable for the length composition data of the SEAMAP trawl index, but peaks were underestimated for most years (Figures 4.23 and 4.25) and observations were noisy. The mid-size (20 – 30 cm FL) fish were underestimated in the early part of the time series (2011 – 2018), while the smallest sizes (<20 cm FL) were underestimated in the beginning and end of the time series (2010 and 2019 – 2024).

For the length composition data of the combined video index, model fits were reasonable for most years. Low sample sizes led to sharp peaks, noise, and underestimation from 2007 – 2016 (Figures 4.24 and 4.25).

4.4.3 Conditional Age-at-Length

The WFS base model fits to the CAAL data associated with the SEAMAP trawl and fishery-independent spear data are presented in Figures 4.26 – 28. The fit among data sources and to their aggregated mean ages appeared well (total negative log-likelihood = 477.089; Figure 4.26).

The fits to the annual mean ages for the SEAMAP trawl followed the trends of the observations generally well and the mean age between years 2019 – 2023 were observed to decrease by ~1 year (Figure 4.26a). This signal in combination with the seagrass trawl index likely informed the high expected recruitment for years 2018 and 2021 by the WFS base model. The annual fits to the observed ages were reasonable and the WFS base model was able to track the observed ages across length bins (Figure 4.27).

The fishery-independent spear CAAL data were constructed from the life-history research of McBride and Richardson (2007), Collins and McBride (2008, 2011, 2015), and Faletti and Stallings (2021; see Section 2.6 in Data Workshop Report). The trend of the observed mean ages was stable but variable across time with the observed mean age being younger in 1999 and 2017 and older in 1996 and 2005 (Figure 4.26b). The annual fits to the observed ages were well and the WFS base model was able to track the observed ages across length bins, which was important as this was intended to be the primary data source informing the internal estimation of growth within the WFS base model (Figure 4.27).

4.5 Estimated Parameters and Derived Quantities

The SEDAR 94 WFS base model estimated most parameters reasonably well (i.e., $|CV| < 1$; Table 4.10). Of the 124 active parameters, 5 exhibited poor estimation (i.e., $|CV| > 1$); including 4 recruitment

deviations and 1 parameter describing selectivity (i.e., descending se from the commercial fleet). No parameters were estimated near bounds.

4.5.1 Stock Biomass (Total and Spawning)

The predicted total biomass and spawning stock (mature female plus male) biomass are summarized in Table 4.11 and Figures 4.29 – 30. The total biomass generally decreased in trend through 1999, then increased through 2010, before decreasing until 2021 and increasing again in the final years (Table 4.11 and Figure 4.29). The predicted spawning stock biomass largely followed the same trends (Table 4.11, Figure 4.30a).

The unfished spawning stock biomass (SSB_0) was estimated at 1,740 mt (Table 4.11) where the estimated female spawning biomass was 610 mt and the male biomass as 1,130 mt (Figure 4.30b). In 1986, the depletion ratio (SSB/SSB_0) was 0.927 which reflected AW panel discussions that the stock at this point in time had not yet experienced intense fishing pressures like the Florida Keys/East Florida stock. Depletion decreased to an average 0.555 between 1996 – 1999, increased to an average 0.867 between 2008 – 2012, and since 2018 averaged 0.570 (Table 4.11). The changes in biomass appear to be driven more by changes in the female spawning biomass which could be due to greater targeting by the fisheries; as the females decline, the males eventually decline too due to the staggering from the hermaphroditism function, and vice-versa (Figure 4.30b).

4.5.2 Recruitment

The relationship between spawning output and age-0 fish as parameterized by the Beverton-Holt stock-recruitment model is presented in Figure 4.31. The $\ln(R0)$ parameter was estimated at 7.651, which equates to 2.103 million age-0 Hogfish, the *steepness* parameter was fixed at 0.99, and the *sigmaR* parameter was estimated at 0.726 (Table 4.10).

The estimated annual recruitment of age-0 Hogfish to the biological population is summarized in Table 4.11 and Figure 4.32a-b. The WFS base model estimated age-0 recruitment as a stable but variable trend (Figure 4.32a) with notable highs in 1999 (7.222 million fish), 2006 (7.127 million fish), and 2021 (6.834 million fish). Estimated recruitment was below average in 2022 and 2024 (Figure 4.32b) and averaged 1.181 million fish from 2022 – 2024.

Annual deviations of estimated recruitment from the stock-recruitment curve followed the annual trend of the estimated recruitment above (Figure 4.32b) and the expected seagrass trawl index (Figure 4.18). The estimated (and applied) recruitment bias adjustment ramp as recommended by Methot and Taylor (2011) is shown in Figure 4.33.

4.5.3 Fishing Mortality

The annual exploitation fishing mortality rates on West Florida Shelf Hogfish are presented in Table 4.12 and Figure 4.34. Exploitation rates generally followed the trend in catch and were variable from 1986 – 2007 (avg. 0.037 yr^{-1}), then increased and remained variable until 2024 (avg. 0.072 yr^{-1}). Notable highs occurred in 2016 (0.149 yr^{-1}) and 2023 (0.110 yr^{-1}). After the new regulations were implemented near the end of 2017, exploitation averaged 0.0650 yr^{-1} for years 2018 – 2024.

Fleet-specific fishing mortality rates (i.e., instantaneous apical rates representing the fishing mortality level on the most vulnerable age class) are also provided in Table 4.12 and Figure 4.35. Apical fishing mortality rates by fleet were highest for both recreational hook-and-line and spear fleets and generally followed their respective trends in annual catch. Apical fishing mortality rates were stable but variable from 1986 – 2006, increased to the timeseries high in 2016, then decreased again through 2024 (Table 4.12, Figure 4.35). Similarly, the apical fishing mortality rates by the recreational hook-and-line fleet

fluctuated over time through 2012, then they increased through 2024 to a magnitude similar to the timeseries high from the recreational spear fleet (Table 4.12, Figure 4.35). The combined Commercial fleet had the lowest amount of fishing mortality rates and has generally declined in trend from 2016 – 2024 (Table 4.12, Figure 4.35).

4.5.4 Selectivity and Retention

Selectivity for all fleets and indices was estimated using length-based selectivity functions which the WFS base model used to further derive age-based selectivity (Figures 4.36 – 43). Fleet-specific length-based selectivity and retention patterns, as well as assumed discard mortality rates, are illustrated in Figures 4.36 – 38.

Selectivity of Hogfish for the commercial fleet was time-varying to follow changes in minimum size regulations; without discard estimates (which must be assumed negligible) or discard length composition data, selectivity here functions as retention. Selectivity was dome-shaped generally between 39 – 63 cm FL from 1986 – 1999, 30 – 45 cm FL from 2000 – 2017, and 33 – 45 cm FL from 2018 – 2024; an asymptote of 40% was reached in all three time blocks (Figure 4.36). In the first time block, fish became vulnerable beginning at age-2 before becoming more fully selected by ages 9 and 10; age-derived selectivity of fish in the second and third time blocks (2000 – 2024) was much younger, still beginning around age-2 but becoming fully selected at ages 5 and 6 (Figure 4.40).

Dome-shaped selectivity of Hogfish by the recreational hook-and-line fleet was generally between 23 – 53 cm FL and was effectively zero above 60 cm FL (Figure 4.37). Age-derived selectivity began around age-2 and fish were fully selected at ages 4 and 5 (Figure 4.41). Retention was time-varying and followed the minimum size limits through time where fish were fully retained by 37 cm FL from 1986 – 1999 (Figure 4.37a), by 33 cm FL from 2000 – 2017 (Figure 4.37b), and by 39 cm FL from 2018 – 2024 (Figure 4.37c). From 1986 – 1999, there were no discard length composition data; therefore, discards-at-length followed selectivity and the additive inverse of retention. From 2000 – 2017, discards of Hogfish were low and largely between 23 – 33 cm FL (Figure 4.37b); however, from 2018 – 2024 discards increased substantially with the ongoing development of the hook-and-line fishery and became in greater proportion from 23 – 37 cm FL (Figure 4.37c).

Selectivity of Hogfish for the recreational spear fleet was also time-varying to follow changes in minimum size regulations and functioned as retention like the commercial fleet. Selectivity was dome-shaped between 25 – 53 cm FL from 1986 – 1999, 29 – 53 cm FL from 2000 – 2017, and 33 – 53 cm FL from 2018 – 2024 (Figure 4.38). Age-derived selectivity of fish was consistent across all three time blocks beginning about age-2 and were fully selected at ages 5 and 6 (Figure 4.42).

Selectivity of Hogfish by the SEAMAP trawl index was dome-shaped between 13 – 41 cm FL before becoming reaching an asymptote of 5% (Figure 4.39). This corresponded to an age-derived selectivity primarily between ages 1 – 8 before reaching an asymptote of 7%. Fish observed by the combined video index were 50% selected by 21 cm FL and became fully selected by 29 cm FL (Figure 4.39). Age-derived selectivity of this index started at age-1 and became more fully selected by ages 5+ (Figure 4.43).

4.6 Model Diagnostics

4.6.1 Convergence

The SEDAR 94 WFS base model converged with a total objective function of 916.605. The model contained no parameters on the bounds, had a small final gradient <0.0001, and had a positive definite Hessian matrix. Highly correlated parameters were inspected, but all were found to be structurally correlated and therefore left as-is estimated in their different model phases.

The results of the jitter analysis (100 iterations, 20% jitter) found that no jittered runs contained a total likelihood lower than the base model, suggesting that the base model had converged on a global solution (Figure 4.44). From the 100 jittered runs, 37 runs (37%) had at least one parameter bound warning and 41 runs (41%) had a gradient >0.0001 .

4.6.2 Goodness of fit

The joint residual plots for the indices (Figure 4.45a), mean length composition data (Figure 4.45b), and the conditional age-at-length data (Figure 4.45c) indicated varying fits to the data as combined RMSE values were 0.501, 0.125, and 0.094 respectively. As illustrated by the loess-smoother and size of the boxplots, residual variability of the indices had a slight positive bias at the beginning of the timeseries by the combined video and seagrass trawl indices. However, when the SEAMAP trawl index became available in 2010, the trend becomes negatively biased until 2019 when it stabilizes (Figure 4.45a). Residuals and interquartile ranges of the mean length data were stable in early years from the fisheries, then showed interquartile variability in later years from index data becoming available (Figure 4.45b). Residuals of the CAAL data from the SEAMAP trawl index and fishery-independent spear data were relatively consistent throughout the timeseries and mostly centered around zero (Figure 4.45c).

The residual series of all three indices and conditional age-at-length data passed the runs test, indicating residuals were sufficiently random and without significant autocorrelation (Figures 4.46 – 47). Results of the runs test for the mean length residuals for the recreational hook-and-line fleet and the SEAMAP trawl index passed the runs test (Figure 4.48). The mean length residuals of the combined video index exhibited non-random variation with sequential patterns of positive and negative values and three residuals larger than three standard deviations in years 2007, 2008, and 2010 (Figure 4.48). The commercial and recreational spear mean length residuals had too few observations due to the application of the super-periods and were unavailable for this analysis.

4.6.3 Model Consistency

4.6.3.1 Likelihood Profiles

The profile likelihood on the $\ln(R0)$ parameter revealed that the parameter is largely influenced by the length, CAAL, and to a lesser degree the index data components (Figure 4.49). The profile minimum primarily agreed with the WFS base model estimate of 7.651 and further indicated a parameter estimate between $\sim 7.3 - 8.1$ would not produce a significantly worse fit to the data (i.e., change in log-likelihood <2 units). Agreement with the CAAL data component was primarily influenced by the fishery-independent spear ages while agreement with the length data component was primarily driven by the combined video survey that informed a lower $\ln(R0)$ value. The index data component favored a higher $\ln(R0)$ value >7.9 and was influenced mainly by the combined video survey. The recruitment component was completely non-informative to the $\ln(R0)$ parameter and showed no indication of what range the value should be estimated.

4.6.3.2 Age-structured Production Models

The ASPM results indicated that the catch and index data were not particularly informative for informing the production function (Figures 4.50 – 4.51). Compared with the WFS base model, the ASPM estimated both population size and average recruitment to be approximately half as large (Figures 4.50a,c–d, and 4.51a). This smaller estimated population size translated into substantially higher exploitation rates, which were, on average, more than 3.5 times greater than those estimated by the WFS base model (Figure 4.50b). In addition, the relationship between the indices and the landings was weak, further inhibiting a strong signal to the production function. For example, average landings during 2007 onward were approximately double those observed during 1986 – 2006. However, all three indices were collected after

this period (with the exception of the combined video survey, which began in 2006 but actually doubled in relative abundance between 2006 and 2007) and therefore could not adequately capture the populations response over that time period. Furthermore, all three indices were relatively stable over time and the ASPM fit as flat lines through them (Figures 4.51b–d); as removals continued to increase, the indices did not reflect a corresponding decline in abundance (in fact, the SEAMAP trawl index increased during 2023 – 2024).

When the recruitment deviations were included (i.e., in the ASPMdev), the model estimated a significantly larger population magnitude; but, the uncertainty associated with estimates of spawning biomass (Figure 4.50a), recruitment (Figure 4.50c), and virgin recruitment (Figure 4.51a) were greatly enlarged and the average CV across the each timeseries was nearly 1.5. Since the population was estimated to be larger but the catches were unchanged, the estimated exploitation rates were significantly lower (Figure 4.50b). Model fit to all indices improved relative to the WFS base model (Table 4.13, Figure 4.51b-d). The ASPMdev produced trends similar to those of the WFS base model, indicating that process error, represented by variability in age-0 recruitment (Figure 4.50d), was necessary to adequately fit the observed relative abundance indices. However, the considerable uncertainty associated with the ASPMdev estimates further indicated that composition data were needed to reliably estimate population scale.

4.6.3.3 Retrospective Analysis

The retrospective analysis showed a slight pattern in estimates of spawning stock biomass and exploitation rates after removing successive terminal years. Spawning stock biomass tended to decrease in trend while exploitation tended to increase in trend; thus, estimates of the population became more favorable with the addition of each successive year of data (Figure 4.52a-b). All runs converged and no parameters were found on the bounds. The calculated values for Mohn's rho for SSB ($\rho_m = -0.15$; Table 4.14) and F ($\rho_m = 0.19$; Table 4.14) were at or near the bounds of values considered "acceptable" for long-lived species (Hurtado-Ferro et al. 2015). The negative value for SSB indicates a tendency for slight underestimation of biomass in terminal years, while the positive value for F suggests a corresponding tendency to overestimate fishing mortality.

4.6.4 Model Validation (Prediction Skill)

Retrospective forecasting showed that the one year forward projections were largely consistent with the overall estimated trend in the reference base model (Figure 4.52a-b). All retrospective forecasts fell within the 95% confidence interval of the WFS base model. The forecast rho values for spawning stock biomass was the same ($\rho_F = -0.15$) and the forecast rho values for fishing mortality slightly decreased to $\rho_F = 0.18$ (Table 4.14), suggesting model stability as well as consistency when subsequent data became available.

A hindcast with cross-validation of the terminal seven years of data was performed to gauge predictive capacity of the WFS base model (Figures 4.53 – 54, Table 4.15). The seagrass trawl index, the SEAMAP trawl survey, and the combined video survey had MASE scores <1 which suggested the WFS base model contained reasonable prediction skill for these when compared to a naïve forecast (Figure 4.53). The seagrass trawl survey contained the lowest MASE score = 0.56, indicating the ability to predict is closer to twice as accurately as a naïve baseline prediction. The model exhibited predictive capacity (MASE<1) for the mean length data of the SEAMAP trawl survey and the combined video survey (Figure 4.54) and all predicted mean length values across fleets were within the predicted confidence intervals. The model exhibited predictive capacity (MASE<1) for the conditional age-at-length data available from the SEAMAP trawl survey (MASE = 0.34).

4.6.5 Sensitivity Runs

4.6.5.1 Natural mortality

Natural mortality sensitivity runs produced substantial differences in estimated population dynamics and derived quantities relative to the WFS base model (Figure 4.55). Both the ‘Lorenzen_1996’ and ‘HamelCope_age3’ mortality functions resulted in a lower mortality-at-age where M averaged 0.142yr^{-1} and 0.162yr^{-1} across ages 3 – 23, respectively (Figure 4.55a). Both scenarios also resulted in much lower age-0 recruitment estimates (Figure 4.55b). Interestingly, they resulted in different life history dynamics and subsequent population estimates. The ‘Lorenzen_1996’ scenario estimated a larger asymptotic length ($L_{inf} = 114.7$ cm FL) with similar spawning stock biomass (Figure 4.55c) and exploitation rate (Figure 4.55d) estimates as the WFS base model. But the ‘HamelCope_age3’ scenario estimated a much smaller asymptotic length ($L_{inf} = 54.2$ cm FL), resulting in a smaller spawning stock biomass (Figure 4.55c) near the lower confidence limit of the WFS base model and a correspondingly higher exploitation rate (Figure 4.55d). In both scenarios, the model likelihood was significantly greater than the WFS base model, indicating a worsened fit to the data.

In contrast, the ‘est_HamelCope_age3_23_noprior’ model estimated higher mortality-at-age compared to the WFS base model (Figure 4.55a) and indicated that, when given the flexibility, the model wanted an even greater average mortality across ages 3 – 23 ($M = 0.286\text{ yr}^{-1}$). The greater mortality on age-0 individuals resulted in much higher recruitment estimates (Figure 4.55b) with estimates of spawning stock biomass near the upper confidence limits of the WFS base model (Figure 4.55c) and exploitation rates near the lower confidence limits of the WFS base model (Figure 4.55d). Furthermore, L_{inf} was similarly estimated at 86.5 cm FL and the model’s fit to the data was similar to the WFS base model (i.e., within 2 LL units). However, estimating natural mortality added more uncertainty to the model and resulted in annual CVs >0.7 for most estimates of spawning stock biomass, recruitment, and exploitation rates. This was somewhat encouraging because it indicated that the mortality-at-age and life history dynamics configured within the WFS base model were reasonable and the estimated uncertainty was satisfactorily captured.

4.6.5.2 Discard mortality

Discard mortality sensitivity runs showed that assumptions had minimal influence on model outputs (Figure 4.56). The high (59%) and low (23%) discard mortality sensitivity runs produced spawning stock biomass (Figure 4.56a), exploitation rate (Figure 4.56b), and recruitment (Figure 4.56c) estimates that closely tracked the WFS base model (41.1%) throughout the time series. Minor differences were observed in recent exploitation rate and recruitment estimates, but stock-scale trends and biomass dynamics were largely insensitive to changes in discard mortality rate.

4.7 Per-recruit Analyses

The yield-per-recruit (YPR), spawner-per-recruit (SSB/R), static spawning potential ratio (SPR), and total equilibrium yield analyses were computed as a function of the instantaneous exploitation rate on West Florida Shelf Hogfish and are presented in Table 4.16 and Figure 4.57. Presented with these values is also their relation to various SPR-based reference points. The retained yield at $F_{30\%SPR}$ for West Florida Shelf Hogfish was estimated to be 101.489 mt (223,744 lbs.; Figure 4.57d) while the total yield (retained yield plus dead discards) at $F_{30\%SPR}$ was 128.282 mt (282,593 lbs.; Figure 4.57c). The retained yield associated with $F_{40\%SPR}$ was estimated at 84.86 mt (187,085 lbs.; Figure 4.57d) while the total yield at $F_{40\%SPR}$ was estimated to be 104.9 mt (231,264 lbs.; Figure 4.57c).

4.8 Uncertainty in Parameters and Derived Quantities

4.8.1 MCMC Analysis

Of the eight chains produced, only six were found to have converged based on Geweke's diagnostic; thus, a total of 9,000 iterations remained. Convergence was evaluated using trace plots (Figure 4.59) and the Gelman and Rubin's (1992) potential scale reduction factor (PSRF values from the combined six MCMC chains for selected model parameters and derived quantities ($\ln(R0)$, SSB_0 , SSB in 2024, F in 2024, $F_{30\%SPR}$, SSB at $F_{30\%SPR}$) of the SEDAR 94 WFS base model. MCMC convergence was generally acceptable based on PSRF diagnostics. PSRF values for all selected parameters and stock status criteria were close to 1 and since none of the PSRF upper confidence intervals exceeded the 'rule of thumb' value of 1.1, it was concluded that the MCMC converged (Table 4.17).

Posterior distributions were produced for stock-recruitment parameters (Figure 4.60) as well as the derived quantities of $F_{current}$ (Figure 4.61a), $F_{30\%SPR}$ (Figure 4.61b), the retained yield associated with $F_{30\%SPR}$ (Figure 4.61c), $SSB_{current}$ (Figure 4.61d), SSB at $F_{30\%SPR}$ (Figure 4.61e), and 50% of the SSB at $F_{30\%SPR}$ (Figure 4.61f). Results of the WFS base model were found to fall within the interquartile range of the posterior distributions for all considered criteria (Figures 4.60 – 61).

4.8.2 Parametric Bootstrap

Results of the bootstrap analysis indicated that the model exhibited a measure of instability when fitting to the randomly generated data sets. From the 500 bootstrapped data sets, few (2%, $n = 10$) had a gradient >0.0001 and 34% ($n = 168$) had at least one parameter on the bounds. The WFS base model estimates fell within the interquartile ranges (Figures 4.62 – 63).

4.9 Stock Status Determination Criteria

A summary of the West Florida Shelf stock status determination criteria and their values as presented in the TORs and according to the Gulf Council from the SEDAR 94 WFS base model is presented in Table 4.18. Stock status of Hogfish on the West Florida Shelf has been determined in past and current assessments according to the MSY_{proxy} reference point of 30% SPR.

The Maximum Fishing Mortality Threshold (MFMT) for Hogfish is currently defined as $F_{30\%SPR}$ and overfishing is occurring if the recent average of fishing mortality rates ($F_{current}$) exceeds the MFMT. $F_{current}$ is calculated as the geometric mean of Hogfish fishing mortality rates for 2022 – 2024. The MFMT was estimated by the WFS base model to be 0.229 yr^{-1} , $F_{current}$ was estimated to be 0.072 yr^{-1} , and F_{2024} was estimated to be 0.074 yr^{-1} (Figure 4.64). Based on the results of the WFS base model, the WFS Hogfish stock is not experiencing overfishing ($F_{current}/MFMT = 0.314$).

The minimum stock size threshold (MSST) for Hogfish is defined as 50 percent of the spawning stock biomass associated with $F_{30\%SPR}$ ($0.50 * SSB_{F_{30\%SPR}}$). The stock is overfished if the recent average spawning stock biomass ($SSB_{current}$) is less than MSST. The $SSB_{current}$ is calculated as the geometric mean of the spawning stock biomass for 2022 – 2024. The $SSB_{F_{30\%SPR}}$ was estimated by the WFS base model to be 518.9 mt (1,143,979 lbs.) with MSST therefore defined as 259.45 mt (571,989 lbs.). The $SSB_{current}$ was estimated to be 1,086.51 mt (2,395,343 lbs.) and SSB_{2024} was estimated to be 1,106.69 mt (2,439,834 lbs.); Figure 4.65). Based on the results of the WFS base model, the WFS Hogfish stock continues to not be overfished ($SSB_{current}/MSST = 4.188$).

Posterior distributions were produced by the MCMC analysis for the stock status determination criteria and benchmark reference points of $F_{current}$, $F_{30\%SPR}$ (MFMT), the retained yield associated with $F_{30\%SPR}$, $SSB_{current}$, $SSB_{F_{30\%SPR}}$, and 50% of SSB at $F_{30\%SPR}$ (MSST) (Figure 4.61). Based on the median values of the posterior distributions, MFMT was estimated to be 0.230 yr^{-1} , $F_{current}$ was estimated to be 0.065 yr^{-1} ,

$SSB_{F_{30\%SPR}}$ was estimated to be 562.931 mt (1,240,991 lbs.), MSST was 281.466 mt (620,495 lbs.), and $SSB_{current}$ was estimated to be 1206.057 mt (2,646,367 lbs.). Additional posterior distributions of the F_{ratio} ($F_{current}/MFMT$) and SSB_{ratio} ($SSB_{current}/MSST$) are presented in Figure 4.66 where median value of the $F_{ratio} = 0.282$ and the median value of the $SSB_{ratio} = 4.285$. The estimates for these reference points as derived by the WFS base model were near the median values and within the interquartile ranges of these posterior distributions. The distribution of the F_{ratio} was entirely below one, indicating a high probability that overfishing is not occurring, and the distribution for the SSB_{ratio} was entirely above one, indicating a high probability that the stock is not overfished. The MCMC distribution of the retained yield at $F_{30\%SPR}$ (Figure 4.61c) had a median value of 110.475 mt (243,556 lbs.).

4.10 Bridge Building

As part of the TORs for SEDAR 94, a continuity model consistent with the prior update assessment (SEDAR 37U) configuration updated to include the most recent observations, is to be provided. A strict continuity model was determined to be largely unreproducible due to considerable differences in model structure between SEDAR 37U and the current assessment (fleets and surveys), large changes to data streams (e.g. MRFSS to MRIP to SRFS), and survey design changes (e.g. combined video survey). An alternative approach to a strict continuity run was explored by updating the existing SEDAR 37U assessment model to the SEDAR 94 configuration. Important configuration changes to SEDAR 37U include: updating the Stock Synthesis model version (3.24 to 3.30.34), combining three commercial fleets into a single, general commercial fleet, the addition of a regulatory time block in 2000, removal of all fishery dependent indices, changes in selectivity patterns for all fleets/surveys to double normal except for the combined video survey (logistic), applying Francis reweighting to length composition, the addition of three growth platoons, adopting the life history configuration (natural mortality, fixed growth, maturity, hermaphroditism) from SEDAR 94, fixing steepness at 0.99, estimating σ_R , not estimating early recruitment deviations, limiting the estimation of initial F 's to the recreational spear fleet, and adding super periods to the fishery fleet length composition data.

The results of the continuity run were then compared with the SEDAR 37U base model and the SEDAR 94 WFS base model. Annual estimates of spawning stock biomass in the continuity run were scaled much lower than estimates from SEDAR 37U and SEDAR 94, however the trends were very similar but dampened (Figure 4.67). Spawning stock biomass estimates from SEDAR 37U were on the same magnitude and trend as the SEDAR 94 WFS base model estimates, apart from differing initial conditions and differing trajectories around the timeframe the combined video survey was implemented within SEDAR 94 (Figure 4.67a). With the lower biomass estimates, annual exploitation rate estimates in the continuity run were scaled higher than those of SEDAR 37U and the SEDAR 94WFS base model, which comparatively showed similar estimates between them (Figure 4.67b). The estimated $F_{30\%SPR}$ reference point from the SEDAR 94 WFS base model (0.229 yr^{-1}) was slightly lower than in the continuity run (0.240 yr^{-1}) which was higher than the SEDAR 37U model estimate (0.096 yr^{-1}). The estimated $SSB_{F_{30\%SPR}}$ reference point from the SEDAR 94 WFS base model (518.9 mt) was also higher than in the continuity run (282.173 mt) but lower than the SEDAR 37U model estimate (747.4 mt). Annual recruitment estimates were higher and more variable in the SEDAR 94 WFS base model compared to the continuity run and the SEDAR 37U model which were similar in magnitude (Figure 4.67c-d). The estimated SSB_0 from the SEDAR 94 WFS base model was 1,740 mt and the R_0 estimate was 2.103 million fish, both of which were greater than the estimated SSB_0 of 946 mt and R_0 of 0.853 million fish in the continuity run. Within the SEDAR 37U model, SSB_0 was higher (2,748 mt) and R_0 was lower at 0.463 million fish.

Lastly, a continuity model which aimed at exploring the impact of updating the recreational landings timeseries from the old MRFSS/MRIP to the SRFS back-calculated historical timeseries within the SEDAR 37 base model was developed (i.e., “SEDAR 37 SRFS”). For each gear, spear (Figure 4.68a) and hook-and-line (Figure 4.68b), the differences in catch magnitude and trend between the two survey methods were minimal and largely followed the same trend. This was not too surprising as the SRFS estimates for these years (1986 – 2012) behaved more like a scalar reduction to the MRIP estimates. When the gears were combined, the trend in landings followed the more predominant spear gear (Figure 4.68c). Consequently, differences in model estimated population dynamics were minimal as trends in spawning stock biomass (Figure 4.69a), recruitment (Figure 4.69b), and exploitation rate (Figure 4.69c) were often within the uncertainty estimated by the SEDAR 37U base model.

4.11 WFS Discussion

This report provides a stock assessment for Hogfish across the West Florida Shelf that was conducted in SS Version 3.30.24, which is an update from SEDAR 37U (2018) which was conducted in SS Version 3.24F. Compared to SEDAR 37 and its update, this assessment utilized seven years of new data, including revised recreational catch information, updated fishery-independent indices, expanded composition datasets, and a modified fleet structure. The combined video survey underwent a design change in 2020 and the video surveys now have unified survey design (2020 – 2024). The baitfish trawl survey ended in 2017 and was not provided during the Data Workshop, therefore these data were not included in the assessment. It was also determined during the Data Workshop that the fishery-dependent indices were not recommended for inclusion in SEDAR 94. Despite these changes, the WFS base model demonstrated generally acceptable statistical performance, converging on a global solution with no parameters estimated at bounds, a positive-definite Hessian matrix, reasonable predictive skill, and only minor retrospective tendencies.

Several diagnostics highlighted important sources of uncertainty in the assessment. Results from likelihood profile and age-structured production model (ASPM) analyses indicated that stock dynamics and population scale were not strongly informed by a traditional production relationship. Instead, the model relied heavily on length-composition and conditional age-at-length (CAAL) data to estimate population scale and recruitment variability. The ASPM analyses further demonstrated that catch and index data alone were insufficient to adequately characterize abundance dynamics. Although catches generally increased over the time series, the abundance indices did not exhibit corresponding declines or other clear responses. Consequently, the available data provided limited evidence regarding how the population has responded to removals. This lack of a clear relationship between increasing catches and abundance indices contributes substantial uncertainty to the assessment and raises questions about whether the West Florida Shelf Hogfish population has yet exhibited a measurable response to current levels of fishing mortality.

Additional uncertainty arose from unresolved spatial dynamics that could not be adequately incorporated into the WFS base model. Hogfish on the West Florida Shelf exhibit substantial spatial variability in distribution, density, habitat use, life-history characteristics (e.g., growth, maturity, and hermaphroditism), and exploitation patterns. However, available data lacked the spatial resolution, precision, and consistency needed to support a spatially explicit assessment framework. Recreational harvest of Hogfish has historically been concentrated in nearshore waters (<30 m) of the West Florida Shelf, as indicated by fishery composition data and corroborated by fishermen during the Data Workshop. As recreational effort—particularly hook-and-line fishing—continues to expand into deeper offshore areas where larger and older Hogfish are prevalent, the population-level response remains uncertain.

Consequently, the assumption of a single-area model may obscure important spatial heterogeneity in population dynamics, productivity, and fishery impacts.

Notable confounding among growth, natural mortality, and population abundance was observed during the model development process. Incorporating fishery-independent spear CAAL data improved the WFS base model's ability to estimate growth internally. In contrast, incorporating CAAL data from the fishery fleets, particularly from recreational hook-and-line fisheries, introduced conflicts among these population processes. Because natural mortality was fixed and population scale was constrained by composition data, the model primarily adjusted growth to accommodate discrepancies in the data. This often led to biologically implausible growth estimates, indicating inconsistency among the available data sources and model assumptions. These became decision points by the panel on why only the SEAMAP trawl and fishery-independent spear CAAL data were retained within the WFS base model as primary information sources to growth. Changing model configuration of these fishery CAAL data to landings-weighted age composition data may have helped alleviate these conflicts, however, time and resources precluded this exploration.

The time series of catch and index data provided limited information to the stock-recruitment dynamics; therefore, the WFS base model struggled to estimate any *steepness* parameter value other than 0.99. Without a corresponding response from the indices to the increasing number of removals (or vice-versa), the model only increased the variability of that average recruitment to accommodate the increased number of removals. The inclusion of the reconstructed recreational catch data during the model development process was also found uninformative to the *steepness* parameter as it only provided a further ramp-up into a catch trend that was already increasing over time. Its inclusion, therefore, added only further uncertainty to the model. An uninformed stock-recruitment relationship was also exhibited by the SEDAR 37 and 37U assessment models, lending further support to this stemming from the data rather than the model configuration. Thus, strong uncertainty surrounding stock productivity of Hogfish on the West Florida Shelf and associated management benchmarks remain.

Under the reference points defined in Gulf Council Reef Fish Amendment 43, where MSY is represented by $F_{30\%SPR}$ and MSST by $50\% SSB_{F30\%SPR}$, the SEDAR 94 WFS base model indicates that the Hogfish stock is neither overfished ($SSB_{current}/MSST > 1.0$) nor undergoing overfishing ($F_{current}/MFMT < 1.0$). Current SSB is estimated at 4.19 times the MSST, and the stock has not been estimated to have been overfished at any point since the model start year of 1986. However, uncertainty around biomass estimates remains, as the lower confidence limits for SSB fluctuated above and below the target $SSB_{F30\%SPR}$ level across the timeseries. Similarly, current exploitation rates are estimated at 31.4% of MFMT. Although no historical overfishing has been estimated, the upper confidence limit for exploitation in 2016 exceeded the MFMT. Applying a more conservative candidate reference point of 40%SPR does not change the overall stock status determination. Under this scenario, current SSB is estimated at 3.13 times the MSST-equivalent level ($SSB_{current}/SSB_{F40\%SPR}$), while the current exploitation rate is estimated at 50.2% of $F_{40\%SPR}$. Because a stock-recruitment relationship could not be reliably estimated, candidate MSY-based reference points could not be derived.

Overall, the SEDAR 94 WFS base model provides a statistically stable and biologically reasonable representation of the stock given the quality of available information. However, uncertainty associated with productivity, composition-driven scaling, and unresolved spatial structure remains important. Future improvements in age and CAAL data and spatially resolved monitoring would likely improve assessment performance and reduce key uncertainties.

4.12 WFS Projections

Short- and long-term deterministic projections were conducted to estimate WFS Hogfish spawning stock biomass and yield under a range of harvest scenarios. These were performed under several assumed conditions: growth, and stock-recruitment parameters were kept constant (at values estimated by the SEDAR 94 base model) while fleet allocations, selectivity, and retention associated with the terminal three years (2022 – 2024) would remain the same into the future. The method to project the assessment results was developed in the R statistical computing environment by SEFSC assessment scientists (<https://github.com/SEFSC/SFD-AllocationForecasting>).

First, long-term deterministic projections were conducted to determine the equilibrium fishing mortality rate that achieves 30%SPR ($F_{30\%SPR}$), as well as the associated spawning stock biomass ($SSB_{30\%SPR}$), by using an iterative process to set fishing mortality rates each year that ensures 1) the MSY_{proxy} (i.e. SPR 30%) is achieved at equilibrium, and 2) annual relative apical fishing mortality between fleets is maintained at the average of the base model's terminal three years (2022 – 2024). This iterative process to achieve equilibrium $F_{30\%SPR}$ is different than the Newton-Raphson method utilized by the base model, thus results will be near-exact rather than identical to base model reference point values (Methot et al. 2026). Projections were for 100 years (2025 – 2124) where recruitment was held constant at the long-term (1986 – 2024) average and that equilibrium was assumed to have been obtained in the final 10 years of the projection (i.e., 2115 – 2124), as recommended by Van Beveren et al. (2021).

Next, short-term deterministic projections, which used a similar iterative process as the long-term projections, were conducted under a range of harvest scenarios and assumed age-0 recruitment remained constant at the recent average (2020 – 2024) estimated by the base model (Schueller et al. 2022; Van Beveren et al. 2021). The first set of short-term projections explored the effects of holding fishing mortality rates constant. The equilibrium $F_{30\%SPR}$ (as determined via the long-term projection above) was applied to produce annual yield values (i.e., the overfishing limit or OFL). Additionally, a constant fishing mortality rate scenario utilizing the $F_{current}$ was conducted.

4.12.1 Results

The projection results for the constant F scenarios including the associated fishing mortality rates, retained landings (in pounds and numbers), spawning stock biomass (mt), and age-0 recruitment (in numbers) as estimated for assessment years (1986 – 2024) and forecast years (2025 – 2044) are presented in Figures 4.70 – 74 and Tables 4.19 – 20. The equilibrium fishing mortality rate that achieved 30% SPR ($F_{30\%SPR}$) in the long-term projections was 0.229 yr^{-1} and was near exact to the base model estimate (0.229 yr^{-1}). Comparable magnitudes and similar to fishing mortality rates estimated earlier in the base model timeseries; however, they are much higher than recent fishing mortality rates ($F_{current} = 0.072 \text{ yr}^{-1}$). Retained landings from the long-term constant $F_{30\%SPR}$ projection scenario initially increased to values greater than historical yields, then quickly declined through the 5-yr projection period from 474,501 lbs. (180,733 fish) in 2025 to 228,955 lbs. (98,588 fish) in 2029 (Table 4.19, Figures 4.72 – 73). Spawning stock biomass immediately declined as well (Table 4.19, Figure 4.74) to lowest historic estimates as recruitment followed the stock-recruitment curve (Table 4.19, Figure 4.71).

In the short-term $F_{30\%SPR}$ scenario, retained landings were 474,495 lbs. (180,731 fish) in 2025 and 263,080 lbs. (106,444 fish) in 2029 (Table 4.19, Figures 4.72 – 73). The projected SSB immediately declined and stabilized after 5 years (Table 4.19, Figure 4.74). Short-term projections for the $F_{current}$ scenario estimated much lower F values (i.e., 0.072 yr^{-1} ; Table 4.20, Figure 4.70) and resulted in retained landings decreasing to 149,434 lbs. (56,932 fish) in 2025 and 141,303 lbs. (54,238 fish) in 2029 (Table 4.20, Figures 4.72 – 73). Projected SSB remained near recent estimates and was at 1,040 metric tons in 2029

(Table 4.20, Figure 4.74) given the average recruitment assumption (Table 4.20, Figure 4.71). In the 75% $F_{30\%SPR}$ scenario, retained landings were 356,321 lbs. (135,733 fish) in 2025 and 237,315 lbs. (94,204 fish) in 2029 (Table 4.20, Figures 4.72 – 73).

4.12.2 Discussion

As for many projection exercises, there were numerous caveats to the methods, including assumptions of recruitment in future years, unchanging fleet selectivity and fleet allocations, growth, natural mortality, stock-recruitment parameters, and other fixed quantities in the WFS base model. Projection results should, therefore, be interpreted carefully. For example, using a constant mean recruitment in the projections assumes there is no variability in recruitment. This may be reasonable for short-term projections where SSB may be unlikely to decrease rapidly in response to decreases in recruitment, but would be inappropriate for long-term or equilibrium projections.

Historically, the stock has not shown an overfished status nor undergone overfishing according to the WFS base model. The results of the $F_{current}$ scenario appeared more consistent with historic yields, with projected retained yield being more conservative than under the $F_{30\%SPR}$ and 75% $F_{30\%SPR}$ runs. The projected SSB under the $F_{current}$ scenario, appears to decline slightly in the short term and then increases gradually in the long term. The other projection scenarios ($F_{30\%SPR}$, 75% $F_{30\%SPR}$) show more dramatic rising retention yields along with declines in SSB within the short term to achieve the goal of the projection. Nevertheless, of the constant F scenarios provided here and as requested by the TORs, the $F_{current}$ scenario is the most conservative followed by 75% $F_{30\%SPR}$.

4.13 WFS Tables

Table 4.1. Historic commercial landings (metric tons) and annual CVs of West Florida Shelf Hogfish by gear for years 1950 – 1985.

Year	Landings (mt)				CV
	Spear	Hook-and-line	Trap	Combined	
1950	0.000	1.588	0.000	1.588	0.25
1951	0.000	3.765	0.000	3.765	0.25
1952	0.000	7.031	0.000	7.031	0.25
1953	0.000	4.400	0.000	4.400	0.25
1954	0.000	2.177	0.000	2.177	0.25
1955	0.000	3.266	0.000	3.266	0.25
1956	0.000	5.851	0.000	5.851	0.25
1957	0.000	13.880	0.000	13.880	0.25
1958	0.000	8.981	0.000	8.981	0.25
1959	0.000	6.260	0.000	6.260	0.25
1960	0.000	8.029	0.000	8.029	0.25
1961	0.000	16.012	0.000	16.012	0.25
1962	0.000	6.396	0.000	6.396	0.20
1963	0.000	5.851	0.000	5.851	0.20
1964	0.000	4.763	0.000	4.763	0.20
1965	0.000	4.082	0.000	4.082	0.20
1966	0.000	5.443	0.000	5.443	0.20
1967	0.000	2.722	0.000	2.722	0.20
1968	0.000	7.983	0.000	7.983	0.20
1969	0.000	4.899	0.000	4.899	0.20
1970	0.000	6.804	0.000	6.804	0.20
1971	0.000	6.078	0.000	6.078	0.20
1972	0.000	5.625	0.000	5.625	0.20
1973	0.000	2.540	0.000	2.540	0.20
1974	0.000	3.992	0.000	3.992	0.20
1975	0.000	6.214	0.000	6.214	0.20
1976	0.000	5.080	0.000	5.080	0.20
1977	0.000	14.901	0.000	14.901	0.20
1978	0.000	16.997	0.000	16.997	0.10
1979	0.000	21.815	0.000	21.815	0.10
1980	0.000	21.160	0.000	21.160	0.10
1981	0.000	20.166	0.000	20.166	0.10
1982	0.000	13.572	0.000	13.572	0.10
1983	0.000	14.698	0.000	14.698	0.10
1984	0.000	16.712	0.000	16.712	0.10
1985	0.000	19.302	0.000	19.302	0.10

Table 4.2. Historic commercial landings (numbers) and annual CVs of West Florida Shelf Hogfish by gear for years 1950 – 1985.

Year	Landings (numbers)				CV
	Spear	Hook-and-line	Trap	Combined	
1950	0	899	0	899	0.25
1951	0	2,131	0	2,131	0.25
1952	0	3,980	0	3,980	0.25
1953	0	2,491	0	2,491	0.25
1954	0	1,233	0	1,233	0.25
1955	0	1,849	0	1,849	0.25
1956	0	3,313	0	3,313	0.25
1957	0	7,858	0	7,858	0.25
1958	0	5,085	0	5,085	0.25
1959	0	3,544	0	3,544	0.25
1960	0	4,545	0	4,545	0.25
1961	0	9,065	0	9,065	0.25
1962	0	3,621	0	3,621	0.2
1963	0	3,313	0	3,313	0.2
1964	0	2,696	0	2,696	0.2
1965	0	2,311	0	2,311	0.2
1966	0	3,082	0	3,082	0.2
1967	0	1,541	0	1,541	0.2
1968	0	4,520	0	4,520	0.2
1969	0	2,773	0	2,773	0.2
1970	0	3,852	0	3,852	0.2
1971	0	3,441	0	3,441	0.2
1972	0	3,184	0	3,184	0.2
1973	0	1,438	0	1,438	0.2
1974	0	2,260	0	2,260	0.2
1975	0	3,518	0	3,518	0.2
1976	0	2,876	0	2,876	0.2
1977	0	8,437	0	8,437	0.2
1978	0	9,623	0	9,623	0.1
1979	0	12,351	0	12,351	0.1
1980	0	11,980	0	11,980	0.1
1981	0	11,417	0	11,417	0.1
1982	0	7,684	0	7,684	0.1
1983	0	8,321	0	8,321	0.1
1984	0	9,461	0	9,461	0.1
1985	0	10,928	0	10,928	0.1

Table 4.3. Commercial landings (metric tons) and annual CVs of West Florida Shelf Hogfish by gear for years 1986 – 2024.

Year	Landings (mt)				CV
	Spear	Hook-and-line	Trap	Combined	
1986	0.000	3.009	0.000	3.009	0.05
1987	0.000	4.353	0.000	4.353	0.05
1988	0.000	5.267	0.000	5.267	0.05
1989	0.000	14.203	0.000	14.203	0.05
1990	2.044	15.638	0.528	18.210	0.05
1991	1.938	14.831	0.501	17.269	0.05
1992	3.433	7.510	1.319	12.263	0.05
1993	4.075	10.398	4.761	19.234	0.05
1994	4.634	7.109	2.293	14.036	0.05
1995	2.937	4.113	0.783	7.832	0.05
1996	3.813	2.831	1.084	7.728	0.05
1997	4.101	2.751	1.821	8.673	0.05
1998	3.184	1.289	1.445	5.918	0.05
1999	2.232	2.140	1.569	5.942	0.05
2000	3.530	4.015	0.840	8.384	0.05
2001	5.659	3.121	1.271	10.051	0.05
2002	7.990	2.348	1.630	11.969	0.05
2003	7.351	2.609	0.604	10.563	0.05
2004	8.088	0.970	0.354	9.412	0.05
2005	5.993	1.226	0.011	7.229	0.05
2006	5.415	0.543	0.001	5.959	0.05
2007	6.226	0.785	0.001	7.011	0.05
2008	9.221	0.952	0.000	10.173	0.05
2009	12.436	1.283	0.000	13.719	0.05
2010	12.700	2.430	0.065	15.195	0.05
2011	17.385	2.508	0.009	19.902	0.05
2012	16.864	1.767	0.000	18.630	0.05
2013	8.619	1.148	0.039	9.807	0.05
2014	14.976	0.670	0.070	15.716	0.05
2015	10.440	1.712	0.019	12.171	0.05
2016	11.204	1.644	0.192	13.040	0.05
2017	6.967	0.343	0.170	7.480	0.05
2018	4.547	0.221	0.070	4.838	0.05
2019	4.321	0.397	0.034	4.752	0.05
2020	3.707	0.149	0.018	3.874	0.05
2021	4.744	0.201	0.000	4.945	0.05
2022	3.953	0.030	0.004	3.987	0.05
2023	3.739	0.210	0.003	3.952	0.05
2024	3.061	0.266	0.000	3.327	0.05

Table 4.4. Commercial landings (numbers) and annual CVs of West Florida Shelf Hogfish by gear for years 1986 – 2024.

Year	Landings (numbers)				CV
	Spear	Hook-and-line	Trap	Combined	
1986	0	1,704	0	1,704	0.05
1987	0	2,465	0	2,465	0.05
1988	0	2,982	0	2,982	0.05
1989	0	8,041	0	8,041	0.05
1990	1,157	8,854	299	10,310	0.05
1991	1,097	8,397	284	9,777	0.05
1992	1,944	4,252	747	6,943	0.05
1993	2,307	5,887	2,695	10,889	0.05
1994	2,624	4,025	1,298	7,946	0.05
1995	1,663	2,329	443	4,434	0.05
1996	2,159	1,603	614	4,375	0.05
1997	2,322	1,558	1,031	4,910	0.05
1998	1,803	730	818	3,351	0.05
1999	1,264	1,212	888	3,364	0.05
2000	1,999	2,273	475	4,747	0.05
2001	3,204	1,767	719	5,690	0.05
2002	4,524	1,329	923	6,776	0.05
2003	4,162	1,477	342	5,981	0.05
2004	4,579	549	201	5,329	0.05
2005	3,393	694	6	4,093	0.05
2006	3,066	307	0	3,374	0.05
2007	3,525	444	0	3,969	0.05
2008	5,220	539	0	5,760	0.05
2009	7,041	727	0	7,767	0.05
2010	7,190	1,376	37	8,603	0.05
2011	9,843	1,420	5	11,268	0.05
2012	9,547	1,000	0	10,548	0.05
2013	4,880	650	22	5,552	0.05
2014	8,479	380	40	8,898	0.05
2015	5,911	969	11	6,891	0.05
2016	6,343	930	109	7,383	0.05
2017	5,011	247	122	5,380	0.05
2018	3,270	159	50	3,480	0.05
2019	3,108	286	24	3,418	0.05
2020	2,667	107	13	2,786	0.05
2021	3,412	145	0	3,557	0.05
2022	2,843	21	3	2,868	0.05
2023	2,690	151	2	2,843	0.05
2024	2,202	191	0	2,393	0.05

Table 4.5. Recreational landings (numbers) of West Florida Shelf Hogfish by gear for years 1981 – 2024 and annual CVs. The ‘Full SRFS’ estimates are comprised of ‘SRFS & SRFS-calibrated Private’ mode, MRIP charter mode, and MRIP shore mode landings estimates. ‘SRFS & SRFS-calibrated Private’ estimates are comprised of SRFS private mode (2021 – 2024) and SRFS ratio-calibrated MRIP private mode (1981 – 2020). The ‘Full SRFS Combined’ is comprised of the ‘Full SRFS’ estimates plus the SRHS estimates.

Year	Landings (thousands)							
	Full SRFS Spear	CV	Full SRFS HL	CV	SRHS HL	CV	Full SRFS Combined	CV
1981	20.604	0.82	5.868	1.03	-	-	26.472	0.70
1982	6.002	0.71	-	-	-	-	6.002	0.71
1983	9.067	0.77	-	-	-	-	9.067	0.77
1984	-	-	-	-	-	-	-	-
1985	-	-	-	-	-	-	-	-
1986	23.356	0.71	2.422	1.00	0.117	0.05	25.213	0.66
1987	46.376	0.60	1.366	1.03	0.034	0.05	46.065	0.60
1988	8.216	0.55	1.467	1.03	0.187	0.05	27.229	0.41
1989	45.383	0.60	6.878	1.03	0.041	0.05	50.838	0.57
1990	12.833	0.87	14.102	1.03	0.147	0.05	27.081	0.70
1991	65.255	0.51	-	-	0.094	0.05	67.592	0.51
1992	20.351	0.82	7.446	0.49	0.213	0.05	35.906	0.56
1993	35.225	0.49	6.577	0.56	0.167	0.05	41.969	0.44
1994	15.482	0.51	9.242	0.51	0.654	0.05	25.379	0.41
1995	29.364	0.53	15.682	0.51	0.465	0.05	47.802	0.41
1996	9.644	0.51	5.077	0.59	0.013	0.05	14.734	0.43
1997	23.000	0.44	11.721	0.60	0.007	0.05	34.728	0.37
1998	27.914	0.42	14.008	0.48	0.025	0.05	37.662	0.36
1999	39.848	0.36	5.115	0.46	0.040	0.05	44.776	0.34
2000	10.043	0.69	12.749	0.47	0.066	0.05	22.859	0.44
2001	30.948	0.52	16.345	0.56	0.057	0.05	47.351	0.41
2002	12.837	0.72	8.948	0.60	0.061	0.05	21.846	0.51
2003	25.289	0.42	29.925	0.48	0.080	0.05	55.295	0.37
2004	42.874	0.54	0.772	0.82	0.053	0.05	43.699	0.53
2005	21.050	0.71	5.304	0.61	0.123	0.05	26.477	0.60
2006	17.784	0.56	10.299	1.02	0.041	0.05	28.124	0.54
2007	27.078	0.53	7.878	0.52	0.076	0.05	35.032	0.44
2008	82.396	0.41	17.076	0.48	0.061	0.05	99.533	0.36
2009	42.329	0.40	11.959	0.48	0.125	0.05	54.413	0.36
2010	94.188	0.42	17.569	0.56	0.430	0.05	112.187	0.39
2011	34.618	0.40	15.892	0.58	2.945	0.05	53.454	0.36
2012	68.411	0.41	12.090	0.63	4.137	0.05	84.638	0.39
2013	89.371	0.53	20.967	0.93	1.975	0.05	112.312	0.49
2014	29.422	0.35	29.323	0.49	2.030	0.05	60.775	0.34
2015	35.510	0.55	14.137	0.48	1.272	0.05	50.919	0.44
2016	103.807	0.48	36.993	0.46	2.553	0.05	143.353	0.39
2017	31.308	0.44	24.370	0.42	2.155	0.05	57.833	0.35
2018	19.476	0.52	15.937	0.31	1.405	0.05	36.817	0.33
2019	14.327	0.41	17.771	0.37	1.645	0.05	33.743	0.33
2020	15.351	0.62	19.041	0.36	1.622	0.05	36.014	0.37
2021	4.786	0.40	28.598	0.23	2.331	0.05	39.391	0.19
2022	13.759	0.53	18.279	0.28	2.168	0.05	36.391	0.26
2023	18.477	0.32	65.229	0.30	2.730	0.05	110.206	0.13
2024	12.064	0.30	43.949	0.21	2.121	0.05	56.686	0.12

Table 4.6. Recreational discards (numbers) of West Florida Shelf Hogfish by gear for years 1981 – 2024 and annual CVs. The ‘Full SRFS’ estimates are comprised of ‘SRFS & SRFS-calibrated Private’ mode, MRIP charter mode, and MRIP shore mode landings estimates. ‘SRFS & SRFS-calibrated Private’ estimates are comprised of SRFS private mode (2021 – 2024) and SRFS ratio-calibrated MRIP private mode (1981 – 2020). The ‘Full SRFS Combined’ is comprised of the ‘Full SRFS’ estimates plus the SRHS estimates.

Year	Discards (thousands)							
	Full SRFS Spear	CV	Full SRFS HL	CV	SRHS HL	CV	Full SRFS Combined	CV
1981	-	-	-	-	-	-	-	-
1982	-	-	-	-	-	-	-	-
1983	-	-	-	-	-	-	-	-
1984	-	-	-	-	-	-	-	-
1985	-	-	-	-	-	-	-	-
1986	-	-	-	-	-	-	-	-
1987	-	-	3.528	1.06	-	-	3.528	1.06
1988	-	-	-	-	-	-	-	-
1989	-	-	1.794	1.06	-	-	1.794	1.06
1990	-	-	-	-	-	-	-	-
1991	-	-	-	-	-	-	-	-
1992	-	-	2.337	1.06	-	-	2.337	1.06
1993	-	-	-	-	-	-	-	-
1994	-	-	-	-	-	-	-	-
1995	-	-	3.758	0.77	-	-	3.758	0.77
1996	-	-	9.260	0.74	-	-	9.260	0.74
1997	-	-	0.392	1.06	-	-	0.392	1.06
1998	-	-	10.981	0.68	-	-	6.686	0.71
1999	-	-	5.012	0.93	-	-	5.012	0.93
2000	-	-	0.895	1.06	-	-	0.895	1.06
2001	-	-	-	-	-	-	-	-
2002	-	-	0.363	1.06	-	-	0.363	1.06
2003	-	-	0.498	1.06	-	-	0.498	1.06
2004	-	-	0.805	1.06	0.003	0.50	0.808	1.06
2005	-	-	2.939	0.79	0.099	0.50	3.038	0.79
2006	-	-	1.901	0.89	0.093	0.50	1.994	0.89
2007	-	-	0.549	1.00	0.012	0.50	0.561	1.00
2008	-	-	8.127	0.68	0.005	0.50	8.132	0.68
2009	-	-	4.420	0.59	0.006	0.50	4.426	0.59
2010	-	-	6.771	0.72	0.022	0.50	6.793	0.72
2011	-	-	0.781	1.06	0.402	0.50	1.183	1.06
2012	-	-	-	-	0.522	0.50	-	-
2013	2.072	0.83	1.587	0.90	0.126	0.50	3.785	0.66
2014	-	-	7.857	0.79	0.128	0.50	7.985	0.79
2015	-	-	0.970	0.63	0.282	0.50	1.252	0.63
2016	-	-	12.875	0.70	0.487	0.50	13.362	0.71
2017	-	-	21.632	0.51	0.777	0.50	22.409	0.51
2018	-	-	25.932	0.41	1.857	0.50	27.789	0.41
2019	-	-	25.941	0.55	2.621	0.50	28.562	0.55
2020	-	-	25.727	0.37	2.393	0.50	28.120	0.38
2021	0.673	1.51	49.466	0.23	4.001	0.50	57.565	0.22
2022	-	-	36.934	0.33	3.587	0.50	40.530	0.33
2023	-	-	112.544	0.35	3.786	0.50	146.228	0.28
2024	-	-	52.939	0.23	2.452	0.50	56.550	0.23

Table 4.7. Historical reconstruction of recreational landings (Full SRFS Combined) of West Florida Shelf Hogfish from 1950 – 1980. The estimated number of saltwater angler participants in Florida was multiplied by the ratio 0.023903 to obtain the estimated number of participants within the West Florida Shelf region. The number of participants was then multiplied by the average catch/number of participants from years 1981 – 1985 (CPUE = 0.929120) to reconstruct the number of landings.

Year	Number of Saltwater Anglers		Reconstructed Landings (numbers)
	Florida	West Florida Shelf	West Florida Shelf
1950	265,900	6,356	5,905
1951	274,187	6,554	6,089
1952	282,475	6,752	6,273
1953	290,762	6,950	6,457
1954	299,049	7,148	6,642
1955	307,337	7,346	6,826
1956	315,624	7,544	7,010
1957	323,911	7,742	7,194
1958	332,199	7,941	7,378
1959	365,676	8,741	8,121
1960	374,577	8,954	8,319
1961	414,720	9,913	9,210
1962	391,199	9,351	8,688
1963	399,699	9,554	8,877
1964	418,956	10,014	9,304
1965	442,416	10,575	9,825
1966	453,819	10,848	10,079
1967	493,510	11,796	10,960
1968	496,090	11,858	11,018
1969	521,289	12,460	11,577
1970	562,752	13,451	12,498
1971	705,592	16,866	15,670
1972	731,204	17,478	16,239
1973	772,865	18,474	17,164
1974	834,392	19,944	18,531
1975	870,670	20,812	19,336
1976	821,995	19,648	18,255
1977	739,438	17,675	16,422
1978	667,847	15,964	14,832
1979	716,261	17,121	15,907
1980	588,882	14,076	13,078

Table 4.8. Indices of relative biomass or abundance values and associated CVs for West Florida Shelf Hogfish from years 2006 – 2024.

Year	Seagrass Trawl		SEAMAP Trawl		Combined Video	
	Index	CV	Index	CV	Index	CV
2006	-	-	-	-	1.111	0.20
2007	-	-	-	-	1.989	0.25
2008	2.060	0.13	-	-	1.860	0.20
2009	0.718	0.24	-	-	1.699	0.19
2010	0.526	0.23	0.828	0.28	0.733	0.24
2011	0.888	0.16	0.423	0.45	0.809	0.14
2012	2.736	0.11	0.955	0.26	1.120	0.14
2013	0.182	0.37	0.506	0.36	0.822	0.22
2014	0.047	0.68	0.376	0.27	0.617	0.16
2015	0.227	0.36	0.608	0.25	0.703	0.18
2016	0.459	0.22	0.513	0.38	0.75	0.14
2017	0.629	0.20	0.714	0.29	0.678	0.11
2018	2.301	0.13	0.39	0.31	0.811	0.12
2019	0.355	0.20	1.329	0.29	0.743	0.15
2020	1.028	0.21	1.488	0.46	0.893	0.12
2021	3.393	0.08	0.805	0.38	0.723	0.12
2022	0.204	0.24	1.108	0.31	0.947	0.11
2023	1.028	0.14	3.043	0.26	0.999	0.11
2024	0.221	0.30	1.916	0.26	0.992	0.11

Table 4.9. Francis weights applied to length and conditional age-at-length data of the SEDAR 94 WFS base model.

Data Type	Fleet/Index	SEDAR 94 WFS Base
		Francis Weights
Length Composition	Commercial	0.687077
	Recreational Hook & Line	2.47439
	Recreational Spear	1.27651
	SEAMAP Trawl	0.811778
	Combined Video	0.240563
Conditional	SEAMAP Trawl	0.726728
Age-at-length	FI_LHR_SP	0.690107

Table 4.10. List of Stock Synthesis parameters for the SEDAR 94 WFS base model. The list includes expected parameter values (Value), lower (Min) and upper (Max) bounds of the parameters, associated standard deviation (Std Dev) and coefficients of variation (CV), prior type (Prior), and the phase (Phase) of estimation. Parameters designated as fixed were held at their initial values and have no associated range or SE.

Parameter Label	Value	Min	Max	Std Dev	CV	Prior	Phase
NatM_Lorenzen_averageFem_GP_1	0.235	0.01	1				Fixed
L_at_Amin_Fem_GP_1	7.617	2	20	0.618	0.081		3
L_at_Amax_Fem_GP_1	89.580	20	130	7.610	0.085		3
VonBert_K_Fem_GP_1	0.083	0.01	0.9	0.013	0.150		4
CV_young_Fem_GP_1	0.526	0.05	0.9	0.068	0.130		7
CV_old_Fem_GP_1	0.163	0.05	0.9	0.046	0.280		7
Wtlen_1_Fem_GP_1	0.000	-3	3				Fixed
Wtlen_2_Fem_GP_1	2.927	-3	4				Fixed
Mat50%_Fem_GP_1	1.090	1	4				Fixed
Mat_slope_Fem_GP_1	-5.450	-6	-0.1				Fixed
Eggs_scalar_Fem_GP_1	1.000	-3	3				Fixed
Eggs_exp_wt_Fem_GP_1	1.000	-3	3				Fixed
NatM_Lorenzen_averageMal_GP_1	0.000	-1	1				Fixed
L_at_Amin_Mal_GP_1	0.000	-1	1				Fixed
L_at_Amax_Mal_GP_1	0.000	-1	1				Fixed
VonBert_K_Mal_GP_1	0.000	-1	1				Fixed
CV_young_Mal_GP_1	0.000	-1	1				Fixed
CV_old_Mal_GP_1	0.000	-1	1				Fixed
Wtlen_1_Mal_GP_1	0.000	-3	3				Fixed
Wtlen_2_Mal_GP_1	2.927	-3	4				Fixed
Herm_Infl_age	8.410	1	11				Fixed
Herm_stdev	4.180	1	5				Fixed
Herm_asymptote	0.999	0.01	1				Fixed
CohortGrowDev	1.000	0	1				Fixed
Platoon_SD_Ratio	0.853	0.1	3	0.317	0.372		1
FracFemale_GP_1	1.000	0	1				Fixed
SR_LN(R0)	7.651	2	20	0.212	0.028		1
SR_BH_steep	0.990	0.3	0.99				Fixed
SR_sigmaR	0.726	0.1	2	0.092	0.127		7
SR_regime	0.000	-5	5				Fixed
SR_autocorr	0.000	0	0				Fixed
SR_regime_BLK2repl_1985	-0.076	-5	5	0.155	-2.048		3
Main_RecrDev_1986	0.651	-4	4	0.313	0.480		3
Main_RecrDev_1987	-0.502	-4	4	0.444	-0.885		3
Main_RecrDev_1988	-0.203	-4	4	0.360	-1.769		3
Main_RecrDev_1989	0.433	-4	4	0.244	0.564		3
Main_RecrDev_1990	-0.159	-4	4	0.291	-1.827		3
Main_RecrDev_1991	-0.578	-4	4	0.304	-0.526		3
Main_RecrDev_1992	-0.344	-4	4	0.250	-0.727		3
Main_RecrDev_1993	-1.146	-4	4	0.297	-0.259		3
Main_RecrDev_1994	-0.566	-4	4	0.235	-0.415		3
Main_RecrDev_1995	-0.593	-4	4	0.236	-0.398		3
Main_RecrDev_1996	0.653	-4	4	0.168	0.256		3
Main_RecrDev_1997	0.000	-4	4	0.226	1220.707		3
Main_RecrDev_1998	-0.862	-4	4	0.360	-0.418		3
Main_RecrDev_1999	1.479	-4	4	0.142	0.096		3
Main_RecrDev_2000	0.107	-4	4	0.224	2.092		3
Main_RecrDev_2001	-0.197	-4	4	0.236	-1.196		3
Main_RecrDev_2002	0.240	-4	4	0.191	0.797		3
Main_RecrDev_2003	-0.703	-4	4	0.273	-0.389		3
Main_RecrDev_2004	-0.150	-4	4	0.215	-1.433		3
Main_RecrDev_2005	1.018	-4	4	0.176	0.173		3
Main_RecrDev_2006	1.464	-4	4	0.179	0.122		3
Main_RecrDev_2007	0.314	-4	4	0.297	0.944		3
Main_RecrDev_2008	0.807	-4	4	0.123	0.152		3
Main_RecrDev_2009	-0.363	-4	4	0.179	-0.493		3
Main_RecrDev_2010	-0.530	-4	4	0.178	-0.336		3
Main_RecrDev_2011	0.362	-4	4	0.131	0.361		3
Main_RecrDev_2012	0.819	-4	4	0.101	0.124		3
Main_RecrDev_2013	-0.579	-4	4	0.195	-0.338		3

Main_RecrDev_2014	-0.801	-4	4	0.264	-0.329		3
Main_RecrDev_2015	0.061	-4	4	0.186	3.036		3
Main_RecrDev_2016	-0.304	-4	4	0.175	-0.577		3
Main_RecrDev_2017	-0.141	-4	4	0.168	-1.192		3
Main_RecrDev_2018	0.820	-4	4	0.116	0.141		3
Main_RecrDev_2019	-0.234	-4	4	0.173	-0.741		3
Main_RecrDev_2020	0.126	-4	4	0.170	1.351		3
Main_RecrDev_2021	1.423	-4	4	0.093	0.065		3
Main_RecrDev_2022	-1.201	-4	4	0.230	-0.192		3
Main_RecrDev_2023	0.383	-4	4	0.145	0.379		3
Main_RecrDev_2024	-1.004	-4	4	0.291	-0.290		3
LnQ_base_SEAGRASS_TW(4)	-7.627	-18	5				Fixed
LnQ_base_SEAMAP_TW(5)	-6.816	-18	5				Fixed
LnQ_base_COMB_VIDEO(6)	-6.908	-18	5				Fixed
Size_DblN_peak_COM(1)	55.213	15	70	1.530	0.028		3
Size_DblN_top_logit_COM(1)	-2.927	-15	15	0.806	-0.275		4
Size_DblN_ascend_se_COM(1)	5.645	0.01	15	0.177	0.031		3
Size_DblN_descend_se_COM(1)	1.248	0.01	15	1.320	1.057	Sym_Beta	5
Size_DblN_start_logit_COM(1)	-999.000	-15	15				Fixed
Size_DblN_end_logit_COM(1)	-0.398	-15	15	0.408	-1.027		3
Size_DblN_peak_REC_HL(2)	38.900	15	70	1.513	0.039		3
Size_DblN_top_logit_REC_HL(2)	-12.511	-15	15	43.508	-3.477		4
Size_DblN_ascend_se_REC_HL(2)	5.189	0.01	15	0.253	0.049		5
Size_DblN_descend_se_REC_HL(2)	4.391	0.01	15	0.111	0.025		5
Size_DblN_start_logit_REC_HL(2)	-999.000	-15	15				Fixed
Size_DblN_end_logit_REC_HL(2)	-999.000	-15	15				Fixed
Retain_L_infl_REC_HL(2)	27.128	10	50	0.856	0.032		3
Retain_L_width_REC_HL(2)	1.955	0.01	15	0.486	0.249		4
Retain_L_asymptote_logit_REC_HL(2)	5.490	-15	15	0.811	0.148		5
Retain_L_maleoffset_REC_HL(2)	0.000	-1	1				Fixed
DiscMort_L_infl_REC_HL(2)	0.100	0	1				Fixed
DiscMort_L_width_REC_HL(2)	0.100	0	1				Fixed
DiscMort_L_level_old_REC_HL(2)	0.414	0	1				Fixed
DiscMort_L_male_offset_REC_HL(2)	0.000	-1	2				Fixed
Size_DblN_peak_REC_SP(3)	36.665	15	70	1.312	0.036		3
Size_DblN_top_logit_REC_SP(3)	-3.154	-15	15	0.731	-0.232		4
Size_DblN_ascend_se_REC_SP(3)	4.227	0.01	15	0.208	0.049		3
Size_DblN_descend_se_REC_SP(3)	4.084	0.01	15	0.244	0.060		5
Size_DblN_start_logit_REC_SP(3)	-999.000	-15	15				Fixed
Size_DblN_end_logit_REC_SP(3)	-999.000	-15	15				Fixed
Size_DblN_peak_SEAMAP_TW(5)	23.229	10	50	1.011	0.044		3
Size_DblN_top_logit_SEAMAP_TW(5)	-10.809	-15	15	62.201	-5.754		4
Size_DblN_ascend_se_SEAMAP_TW(5)	3.783	0.01	15	0.216	0.057		3
Size_DblN_descend_se_SEAMAP_TW(5)	4.324	0.01	15	0.394	0.091		5
Size_DblN_start_logit_SEAMAP_TW(5)	-999.000	-15	15				Fixed
Size_DblN_end_logit_SEAMAP_TW(5)	-2.931	-15	15	0.698	-0.238		3
Size_inflection_COMB_VIDEO(6)	21.156	15	40	0.855	0.040		3
Size_95%width_COMB_VIDEO(6)	5.152	0.01	15	0.988	0.192		4
Size_DblN_peak_COM(1)_BLK1repl_2000	35.594	15	70	1.948	0.055		3
Size_DblN_peak_COM(1)_BLK1repl_2018	36.286	15	70	1.816	0.050		3
Size_DblN_ascend_se_COM(1)_BLK1repl_2000	2.867	0.01	15	0.648	0.226		5
Size_DblN_ascend_se_COM(1)_BLK1repl_2018	1.883	0.01	15	1.115	0.592	Sym_Beta	5
Size_DblN_peak_REC_HL(2)_BLK1repl_2000	36.193	15	70	0.640	0.018		3
Size_DblN_peak_REC_HL(2)_BLK1repl_2018	33.036	15	70	0.504	0.015		3
Size_DblN_ascend_se_REC_HL(2)_BLK1repl_2000	3.981	0.01	15	0.124	0.031		5
Size_DblN_ascend_se_REC_HL(2)_BLK1repl_2018	3.335	0.01	15	0.114	0.034		5
Retain_L_infl_REC_HL(2)_BLK1repl_2000	29.077	10	50	0.231	0.008		3
Retain_L_infl_REC_HL(2)_BLK1repl_2018	34.649	10	50	0.144	0.004		3
Retain_L_width_REC_HL(2)_BLK1repl_2000	1.166	0.01	10	0.166	0.143		4
Retain_L_width_REC_HL(2)_BLK1repl_2018	1.089	0.01	10	0.080	0.073		4
Size_DblN_peak_REC_SP(3)_BLK1repl_2000	36.506	15	70	1.083	0.030		3
Size_DblN_peak_REC_SP(3)_BLK1repl_2018	35.682	15	70	0.979	0.027		3
Size_DblN_ascend_se_REC_SP(3)_BLK1repl_2000	3.493	0.01	15	0.242	0.069		5
Size_DblN_ascend_se_REC_SP(3)_BLK1repl_2018	1.581	0.01	15	0.603	0.382		5

Table 4.11. Predicted total biomass (metric tons, pounds), spawning stock biomass (SSB; metric tons, pounds), age 1+ abundance (1000s of fish), age-0 recruits (1000s of fish), and depletion (SSB/SSB₀) for West Florida Shelf Hogfish. Virgin is the estimated unfished condition while Initial is the estimated initial conditions of the stock before the model start year.

Year	Biomass (mt)	Biomass (lbs.)	SSB (mt)	SSB (lbs.)	Age-1+ Abundance (000s)	Age-0 Recruits (000s)	B/B ₀	SSB/SSB ₀
Virgin	1,814	3,998,502	1,740	3,835,933	2,188	2,103	1.000	1.000
Initial	1,682	3,707,073	1,613	3,556,365	2,028	1,950	0.927	0.927
1986	1,703	3,754,230	1,613	3,556,365	2,028	3,318	0.939	0.927
1987	1,678	3,699,842	1,598	3,522,789	2,559	1,042	0.925	0.918
1988	1,622	3,575,567	1,579	3,481,275	1,887	1,398	0.894	0.908
1989	1,612	3,553,962	1,544	3,403,805	1,735	2,627	0.889	0.887
1990	1,541	3,398,073	1,468	3,236,629	2,101	1,445	0.850	0.844
1991	1,482	3,268,088	1,439	3,172,827	1,807	946	0.817	0.827
1992	1,379	3,039,271	1,341	2,957,457	1,435	1,189	0.760	0.771
1993	1,303	2,872,204	1,272	2,803,178	1,360	530	0.718	0.731
1994	1,200	2,645,569	1,175	2,589,947	1,024	942	0.662	0.675
1995	1,118	2,465,518	1,086	2,394,044	1,019	912	0.617	0.624
1996	1,054	2,324,003	987	2,175,883	968	3,165	0.581	0.567
1997	1,045	2,303,522	958	2,112,793	1,866	1,647	0.576	0.551
1998	1,014	2,234,870	970	2,139,452	1,686	696	0.559	0.558
1999	1,076	2,371,402	949	2,092,072	1,236	7,222	0.593	0.545
2000	1,139	2,512,145	973	2,144,278	3,650	1,833	0.628	0.559
2001	1,212	2,672,532	1,154	2,543,848	2,699	1,353	0.668	0.663
2002	1,249	2,754,213	1,190	2,623,721	2,098	2,095	0.689	0.684
2003	1,271	2,802,208	1,218	2,684,856	2,115	816	0.701	0.700
2004	1,239	2,730,579	1,200	2,645,900	1,562	1,418	0.683	0.690
2005	1,250	2,756,109	1,152	2,538,645	1,525	4,559	0.689	0.662
2006	1,363	3,004,438	1,164	2,565,674	2,764	7,127	0.751	0.669
2007	1,478	3,258,697	1,305	2,877,407	4,420	2,258	0.815	0.750
2008	1,602	3,531,056	1,499	3,303,715	3,334	3,696	0.883	0.861
2009	1,621	3,573,296	1,532	3,376,468	3,400	1,147	0.894	0.880
2010	1,628	3,588,508	1,589	3,504,204	2,426	971	0.897	0.914
2011	1,549	3,414,299	1,493	3,290,950	1,818	2,369	0.854	0.858
2012	1,533	3,378,738	1,429	3,149,325	2,074	3,740	0.845	0.821
2013	1,452	3,200,164	1,365	3,009,067	2,695	925	0.800	0.784
2014	1,327	2,925,071	1,296	2,858,095	1,841	740	0.732	0.745
2015	1,261	2,779,787	1,219	2,687,567	1,384	1,752	0.695	0.701
2016	1,199	2,642,527	1,146	2,526,255	1,547	1,216	0.661	0.659
2017	1,021	2,249,972	974	2,148,268	1,308	1,430	0.563	0.560
2018	994	2,190,339	907	2,000,448	1,322	3,737	0.548	0.522
2019	988	2,178,445	896	1,975,075	2,264	1,303	0.545	0.515
2020	996	2,195,198	940	2,073,426	1,757	1,867	0.549	0.541
2021	1,082	2,385,732	939	2,070,641	1,763	6,834	0.597	0.540
2022	1,141	2,516,114	1,002	2,209,781	3,766	496	0.629	0.576
2023	1,206	2,658,422	1,156	2,549,139	2,227	2,432	0.665	0.665
2024	1,163	2,563,866	1,107	2,439,834	2,245	614	0.641	0.636

Table 4.12. Annual exploitation rates on West Florida Shelf Hogfish combined across all fleets as well as annual estimates of instantaneous apical fishing mortality rates by fleet. Apical fishing mortality rates represent the instantaneous fishing mortality level on the most vulnerable age class for each fleet.

Year	Exploitation (Biomass)	Commercial	Recreational Hook-and-line	Recreational Spear
1986	0.0176	0.0038	0.0068	0.0605
1987	0.0306	0.0057	0.0037	0.1190
1988	0.0094	0.0070	0.0043	0.0205
1989	0.0430	0.0191	0.0189	0.1207
1990	0.0310	0.0255	0.0420	0.0366
1991	0.0554	0.0255	0.0003	0.1924
1992	0.0302	0.0191	0.0249	0.0646
1993	0.0486	0.0314	0.0246	0.1257
1994	0.0351	0.0245	0.0415	0.0641
1995	0.0522	0.0149	0.0810	0.1451
1996	0.0234	0.0161	0.0290	0.0535
1997	0.0418	0.0195	0.0627	0.1155
1998	0.0444	0.0141	0.0607	0.1137
1999	0.0494	0.0143	0.0205	0.1499
2000	0.0290	0.0205	0.0577	0.0441
2001	0.0479	0.0209	0.0508	0.0956
2002	0.0285	0.0218	0.0239	0.0338
2003	0.0563	0.0189	0.0842	0.0694
2004	0.0483	0.0174	0.0026	0.1322
2005	0.0320	0.0140	0.0201	0.0751
2006	0.0300	0.0119	0.0410	0.0678
2007	0.0299	0.0130	0.0249	0.0831
2008	0.0715	0.0160	0.0393	0.1881
2009	0.0441	0.0196	0.0251	0.0869
2010	0.0850	0.0212	0.0386	0.1983
2011	0.0530	0.0291	0.0472	0.0842
2012	0.0792	0.0299	0.0508	0.2058
2013	0.0946	0.0175	0.0835	0.3138
2014	0.0617	0.0289	0.1108	0.1020
2015	0.0554	0.0229	0.0571	0.1287
2016	0.1488	0.0281	0.1882	0.4779
2017	0.0717	0.0187	0.1536	0.1761
2018	0.0585	0.0135	0.2075	0.1584
2019	0.0538	0.0138	0.2280	0.1153
2020	0.0553	0.0108	0.1955	0.1010
2021	0.0579	0.0130	0.2563	0.0275
2022	0.0459	0.0102	0.1603	0.0745
2023	0.1101	0.0091	0.4198	0.0797
2024	0.0738	0.0072	0.2650	0.0481

Table 4.13. Index root mean square error (RMSE) values from the SEDAR 94 WFS base model (Base), the age-structured production model (ASPM), and the ASPM with estimated recruitment deviations (ASPMdev).

Fleet/Survey	Base	ASPM	ASPMdev
Seagrass Trawl Survey	0.672	1.407	0.450
SEAMAP Trawl Survey	0.528	0.587	0.527
Combined Video Survey	0.222	0.259	0.232

Table 4.14. Mohn's rho (ρ_M) and forecast Mohn's rho (ρ_F) values calculated from the retrospective and retrospective forecasting analyses, respectively, on estimates of spawning stock biomass (SSB) and fishing mortality rates (F) from the SEDAR 94 WFS base model. Analyses were performed across 6 successive years of removal from the terminal year 2024.

Quantity	Year Peel	Mohn's Rho (ρ_M)	Forecast Mohn's Rho (ρ_F)
SSB	2023	-0.019	-0.026
SSB	2022	-0.044	-0.055
SSB	2021	-0.071	-0.070
SSB	2020	-0.233	-0.220
SSB	2019	-0.357	-0.332
SSB	2018	-0.204	-0.190
SSB	Combined	-0.155	-0.149
F	2023	0.024	0.033
F	2022	0.050	0.056
F	2021	0.072	0.074
F	2020	0.266	0.241
F	2019	0.475	0.463
F	2018	0.233	0.198
F	Combined	0.187	0.177

Table 4.15. Hindcast cross-validation summary statistics for the SEDAR 94 WFS Base Model. N = number of observations to compute each statistic. MASE = mean absolute scaled error, with values < 1 (in green) indicative of superior prediction skill over a naïve baseline forecast (random walk) and values > 1 (in red) indicative of poor prediction skill. Model MAE = mean absolute error of model prediction residuals. Naïve MAE = mean absolute error of naïve predictions.

Model Component	Data Source	MASE	Model MAE	Naïve MAE	N
Index of Abundance	Seagrass Trawl	0.56	0.94	1.68	6
	SEAMAP Trawl	0.94	0.59	0.62	6
	Combined Video	0.85	0.12	0.14	6
	Joint	0.67	0.55	0.81	18
Length Composition	SEAMAP Trawl	0.79	0.08	0.10	6
	Combined Video	0.71	0.06	0.09	6
	Joint	0.75	0.07	0.09	12
Conditional Age-at-Length	SEAMAP Trawl	0.34	0.10	0.28	6
	Joint	0.34	0.10	0.28	6

Table 4.16. The yield-per-recruit (YPR), spawner-per-recruit (SSB/R), static spawning potential ratio (SPR), and total equilibrium yield in metric tons computed over a range of exploitation rates on West Florida Shelf Hogfish.

Exploitation	YPR	SSB/R	SPR	Total Yield (mt)
0.000	0.000	0.827	1.000	0.027
0.018	0.013	0.688	0.832	26.753
0.039	0.023	0.580	0.701	48.660
0.062	0.032	0.494	0.598	66.791
0.088	0.039	0.427	0.516	81.940
0.115	0.045	0.373	0.451	94.718
0.145	0.050	0.329	0.398	105.596
0.175	0.055	0.294	0.356	114.940
0.206	0.059	0.266	0.321	123.038
0.238	0.062	0.242	0.293	130.114
0.269	0.065	0.223	0.269	136.347
0.301	0.068	0.207	0.250	141.881
0.331	0.070	0.193	0.233	146.829
0.361	0.073	0.182	0.219	151.283
0.390	0.075	0.172	0.208	155.319
0.418	0.076	0.163	0.197	158.997
0.445	0.078	0.156	0.188	162.366
0.471	0.080	0.150	0.181	165.470
0.496	0.081	0.144	0.174	168.341
0.520	0.082	0.139	0.168	171.008
0.543	0.084	0.134	0.162	173.495
0.566	0.085	0.130	0.158	175.823
0.587	0.086	0.127	0.153	178.009
0.608	0.087	0.124	0.149	180.067
0.628	0.088	0.121	0.146	182.011
0.647	0.089	0.118	0.142	183.851
0.666	0.090	0.115	0.139	185.597
0.684	0.090	0.113	0.137	187.257
0.701	0.091	0.111	0.134	188.839
0.718	0.092	0.109	0.131	190.348
0.735	0.093	0.107	0.129	191.791
0.751	0.093	0.105	0.127	193.173
0.767	0.094	0.103	0.125	194.499
0.782	0.095	0.102	0.123	195.771
0.797	0.095	0.100	0.121	196.995
0.811	0.096	0.099	0.120	198.172
0.826	0.097	0.098	0.118	199.308
0.840	0.097	0.096	0.116	200.403
0.853	0.098	0.095	0.115	201.460
0.867	0.098	0.094	0.114	202.482

Table 4.17. Gelman and Rubin's (1992) potential scale reduction factor (PSRF) values from the combined four MCMC chains for selected model parameter ($\ln(R0)$) and derived quantities (SSB_0 , SSB in 2024, F in 2024, $F_{30\%SPR}$, SSB at $F_{30\%SPR}$, and the retained yield at $F_{30\%SPR}$) of the SEDAR 94 WFS base model.

PSRF	PSRF Upper CI	Parameter or Derived Quantity
1.04	1.06	$\ln(R0)$
1.04	1.06	SSB_0
1.05	1.07	SSB_{2024}
1.00	1.01	F_{2024}
1.01	1.04	$F_{30\%SPR}$
1.04	1.06	$SSB_{F_{30\%SPR}}$
1.05	1.06	Retained yield at $F_{30\%SPR}$

Table 4.18. The stock status determination criteria for the WFS Hogfish stock according to the Gulf of Mexico Fishery Management Council (GMFMC). Values were derived from the SEDAR 94 WFS base model using the MSY_{proxy} of 30%SPR or 40%SPR.

Gulf of Mexico Fishery Management Council			
Criteria	Definition	40% SPR	30% SPR
MSY	The retained yield at F_{MSY} (or proxy, $F_{30\%SPR}$)	85.098 mt (187,608 lbs.)	101.489 mt (223,745 lbs.)
F_{MSY} or proxy	The fishing mortality rate associated with MSY (or proxy, 30% SPR)	0.143 yr ⁻¹	0.229 yr ⁻¹
MFMT (Maximum Fishing Mortality Threshold)	F_{MSY} or 30% SPR	0.143 yr ⁻¹	0.229 yr ⁻¹
$F_{current}$ (recent average fishing mortality rate)	The geometric mean of F for 2022 – 2024	0.072 yr ⁻¹	0.072 yr ⁻¹
SSB_{MSY} or proxy	The estimated spawning stock biomass associated with F_{MSY} or $F_{30\%SPR}$	693.335 mt (1,528,542 lbs.)	518.900 mt (1,143,979 lbs.)
MSST (Minimum Stock Size Threshold)	$0.50 * SSB_{MSY}$ or $F_{30\%SPR}$	346.668 mt (764,271 lbs.)	259.450 mt (571,989 lbs.)
$SSB_{current}$ (recent average of SSB)	The geometric mean of SSB for 2022 – 2024	1,086.509 mt (2,395,342 lbs.)	1,086,509 mt (2,395,342 lbs.)
OY (Optimum Yield)	75% of OFL	63.824 mt (140,708 lbs.)	76.117 mt (167,809 lbs.)

Table 4.19. Projection results when exploitation fishing mortality rates = $F_{30\%SPR}$ for WFS Hogfish. Equilibrium projections assume predicted recruitment follows the spawner-recruit curve. Short-term projections assume predicted age-0 recruitment is equal to the average from 2020 to 2024 (2.45 million). Recruitment (Recruits) is in millions of age-0 fish, F is fishing mortality rate, SSB is in metric tons (female SSB), Retained Yield is in pounds (whole weight), and Retained Num is in numbers of fish.

Year	$F_{30\%SPR}$ Long-Term Projections					$F_{30\%SPR}$ Short-Term Projections				
	Age-0 Recruits	F	SSB	Retained Yield	Retained Num	Age-0 Recruits	F	SSB	Retained Yield	Retained Num
2025	2,148.99	0.229	1,098.320	474,501	180,733	2,448.48	0.229	1,098.320	474,495	180,731
2026	2,148.99	0.229	879.571	391,917	146,774	2,448.48	0.229	883.079	394,511	147,869
2027	2,148.99	0.229	730.788	313,153	119,436	2,448.48	0.229	746.092	318,423	122,269
2028	2,148.99	0.229	637.676	265,442	104,935	2,448.48	0.229	667.239	277,113	110,467
2029	2,148.99	0.229	589.817	244,981	98,588	2,448.48	0.229	632.402	263,080	106,444
2030	2,148.99	0.229	565.137	236,158	95,548	2,448.48	0.229	617.618	258,978	105,059
2031	2,148.99	0.229	551.677	232,121	93,977	2,448.48	0.229	611.254	258,190	104,625
2032	2,148.99	0.229	543.855	230,198	93,104	2,448.48	0.229	608.374	258,447	104,521
2033	2,148.99	0.229	539.213	229,322	92,612	2,448.48	0.229	607.102	259,004	104,540
2034	2,148.99	0.229	536.386	228,955	92,326	2,448.48	0.229	606.531	259,561	104,591

Table 4.20. Projection results when exploitation fishing mortality rates = $F_{current}$ and 75% $F_{30\%SPR}$ for WFS Hogfish. Equilibrium projections assume predicted recruitment follows the spawner-recruit curve. Short-term projections assume predicted age-0 recruitment is equal to the average from 2020 to 2024 (2.45 million). Recruitment (Recruits) is in millions of age-0 fish, F is fishing mortality rate, SSB is in metric tons (female SSB), Retained Yield is in pounds (whole weight), and Retained Num is in numbers of fish.

Year	$F_{current}$ Short-Term Projections					75% $F_{30\%SPR}$ Short-Term Projections				
	Age 0 Recruits	F	SSB	Retained Yield	Retained Num	Age 0 Recruits	F	SSB	Retained Yield	Retained Num
2025	2,448.48	0.072	1,098.320	149,434	56,932	2,448.48	0.172	1,098.320	356,321	135,733
2026	2,448.48	0.072	1,049.180	148,782	55,441	2,448.48	0.172	943.152	317,531	118,738
2027	2,448.48	0.072	1,037.880	144,058	53,833	2,448.48	0.172	844.351	274,487	104,221
2028	2,448.48	0.072	1,034.770	141,132	53,641	2,448.48	0.172	781.040	247,796	96,958
2029	2,448.48	0.072	1,040.260	141,303	54,238	2,448.48	0.172	749.438	237,315	94,204
2030	2,448.48	0.072	1,050.700	142,908	54,996	2,448.48	0.172	734.913	233,816	93,146
2031	2,448.48	0.072	1,063.030	144,887	55,733	2,448.48	0.172	728.430	232,904	92,762
2032	2,448.48	0.072	1,075.120	146,781	56,388	2,448.48	0.172	725.537	232,910	92,646
2033	2,448.48	0.072	1,086.240	148,466	56,960	2,448.48	0.172	724.428	233,252	92,650
2034	2,448.48	0.072	1,096.040	149,905	57,448	2,448.48	0.172	724.160	233,671	92,701

4.14 WFS Figures

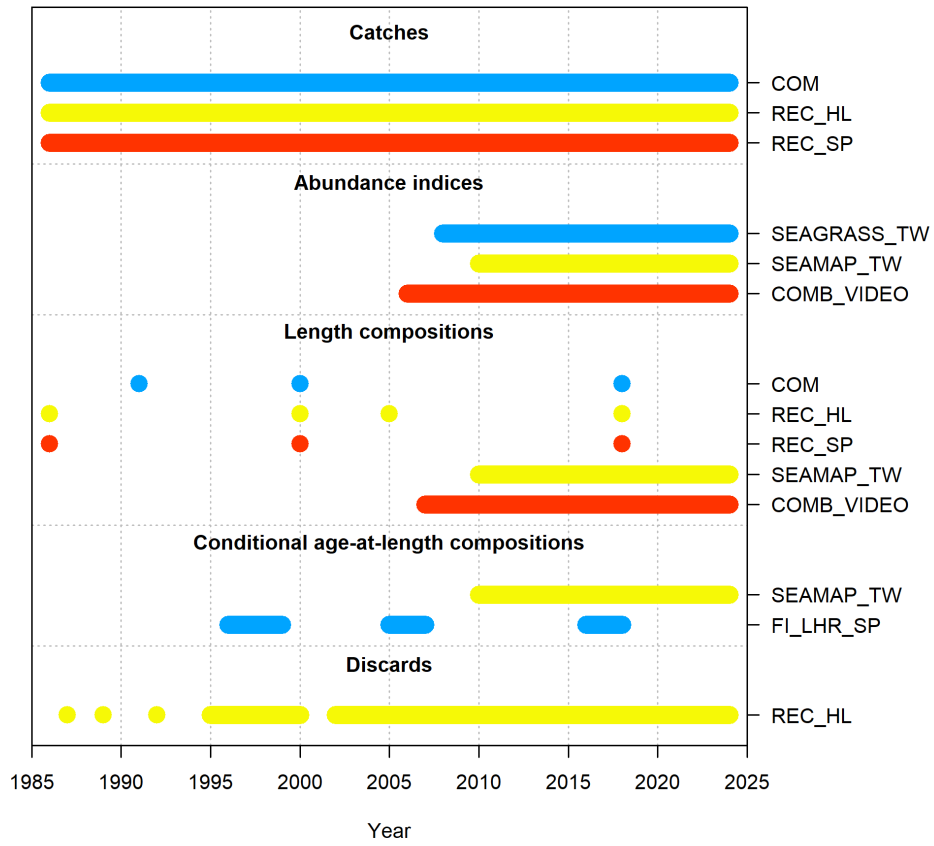


Figure 4.1. Data sources used in the West Florida Shelf Hogfish Stock Synthesis assessment model (WFS base model).

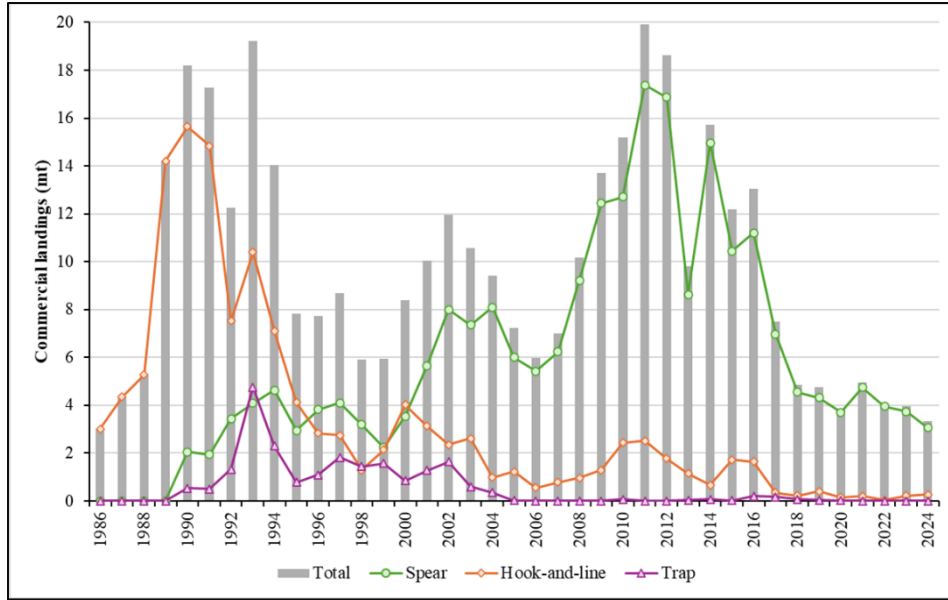


Figure 4.2. Commercial landings (metric tons) of West Florida Shelf Hogfish by gear for years 1986 – 2024.

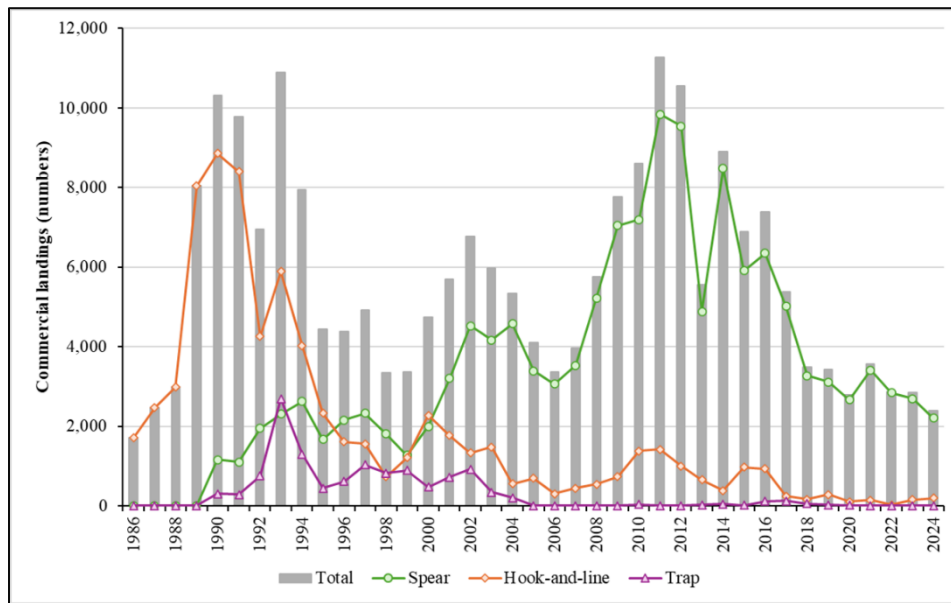


Figure 4.3. Commercial landings (numbers) of West Florida Shelf Hogfish by gear for years 1986 – 2024.

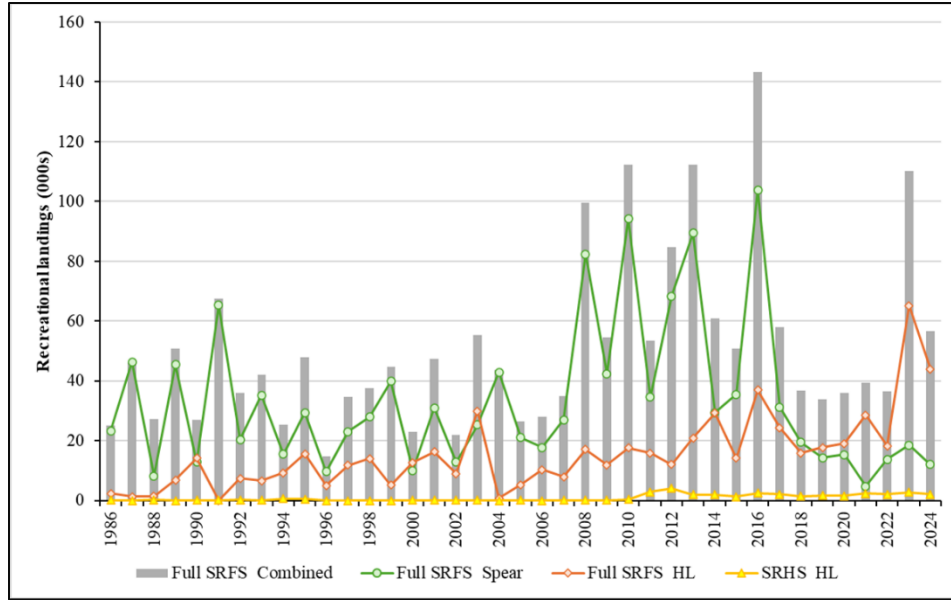


Figure 4.4. Recreational landings (numbers) of West Florida Shelf Hogfish by gear for years 1986 – 2024. The ‘Full SRFS’ estimates are from 1986 – 2024 (grey bars) and are comprised of ‘SRFS & SRFS-calibrated Private’ mode, MRIP charter mode, and MRIP shore mode landings estimates. ‘SRFS & SRFS-calibrated Private’ estimates are comprised of SRFS private mode (2021 – 2024) and SRFS ratio-calibrated MRIP private mode (1981 – 2020). The ‘Full SRFS Combined’ is comprised of the ‘Full SRFS’ estimates plus the SRHS estimates.

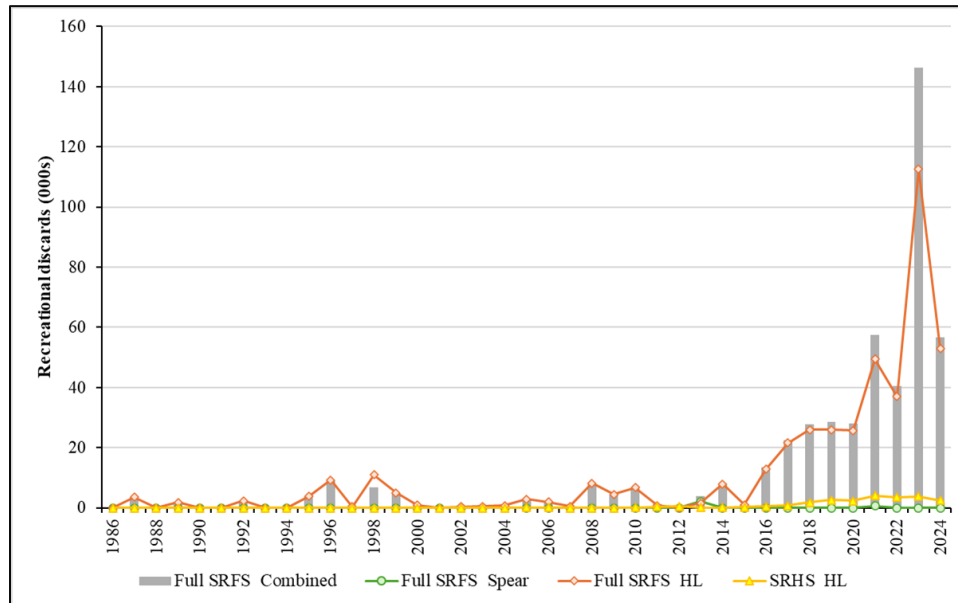


Figure 4.5. Recreational discards (numbers) of West Florida Shelf Hogfish by gear for years 1987 – 2024. The ‘Full SRFS’ estimates are comprised of ‘SRFS & SRFS-calibrated Private’ mode, MRIP charter mode, and MRIP shore mode landings estimates. ‘SRFS & SRFS-calibrated Private’ estimates are comprised of SRFS private mode (2021 – 2024) and SRFS ratio-calibrated MRIP private mode (1981 – 2020). The ‘Full SRFS Combined’ is comprised of the ‘Full SRFS’ estimates plus the SRHS estimates.

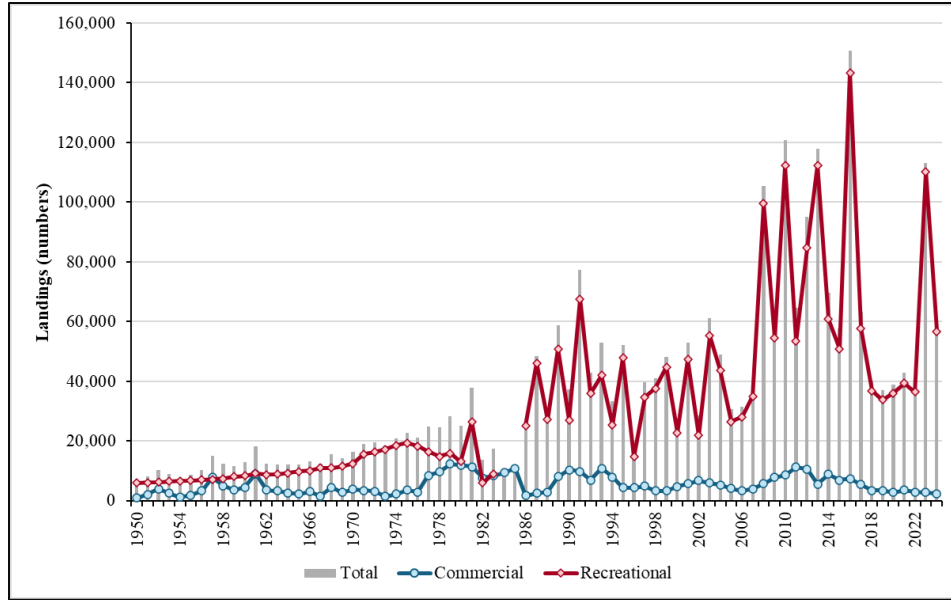


Figure 4.6. A comparison of the historic commercial (numbers; blue dots) and recreational (numbers; red diamonds) landings estimates of West Florida Shelf Hogfish from 1950 – 2024.

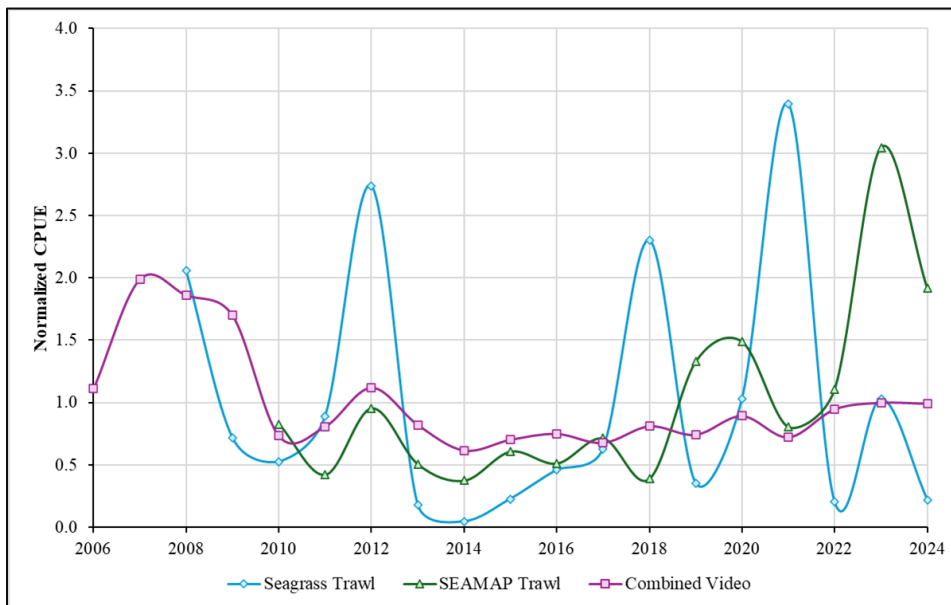


Figure 4.7. Normalized indices of relative abundance for West Florida Shelf Hogfish from 2006 – 2024 from the seagrass trawl, SEAMAP trawl, and combined video surveys.

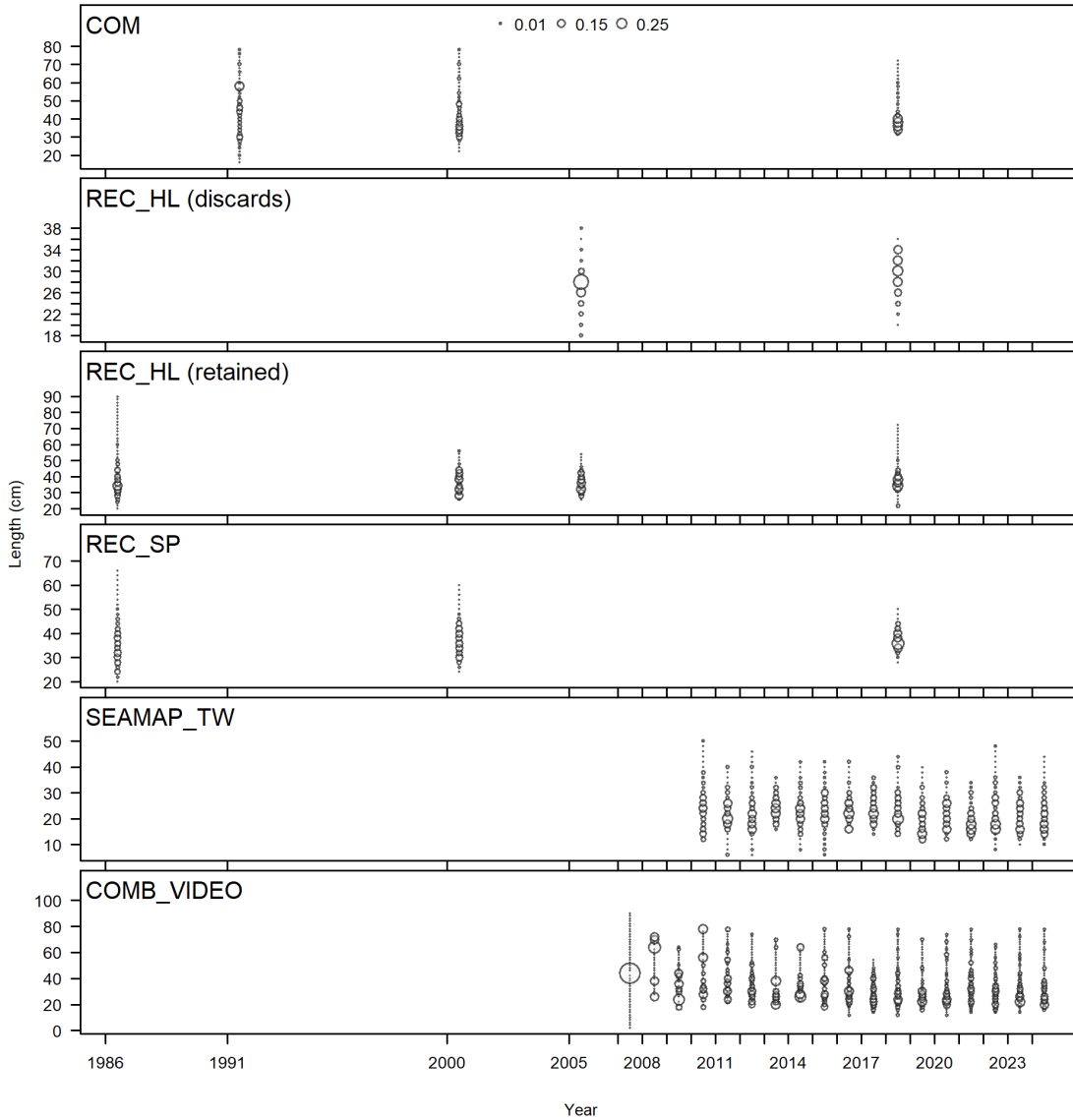


Figure 4.8. Catch-weighted length compositions (2 cm FL bins) of West Florida Shelf Hogfish landings (retained) and discards by fishery for years 1986 – 2024. Commercial = COM, Full SRFS hook-and-line plus SRHS hook-and-line = REC_HL, Full SRFS Spear = REC_SP, SEAMAP trawl survey = SEAMAP_TW, and combined video survey = COMB_VIDEO.

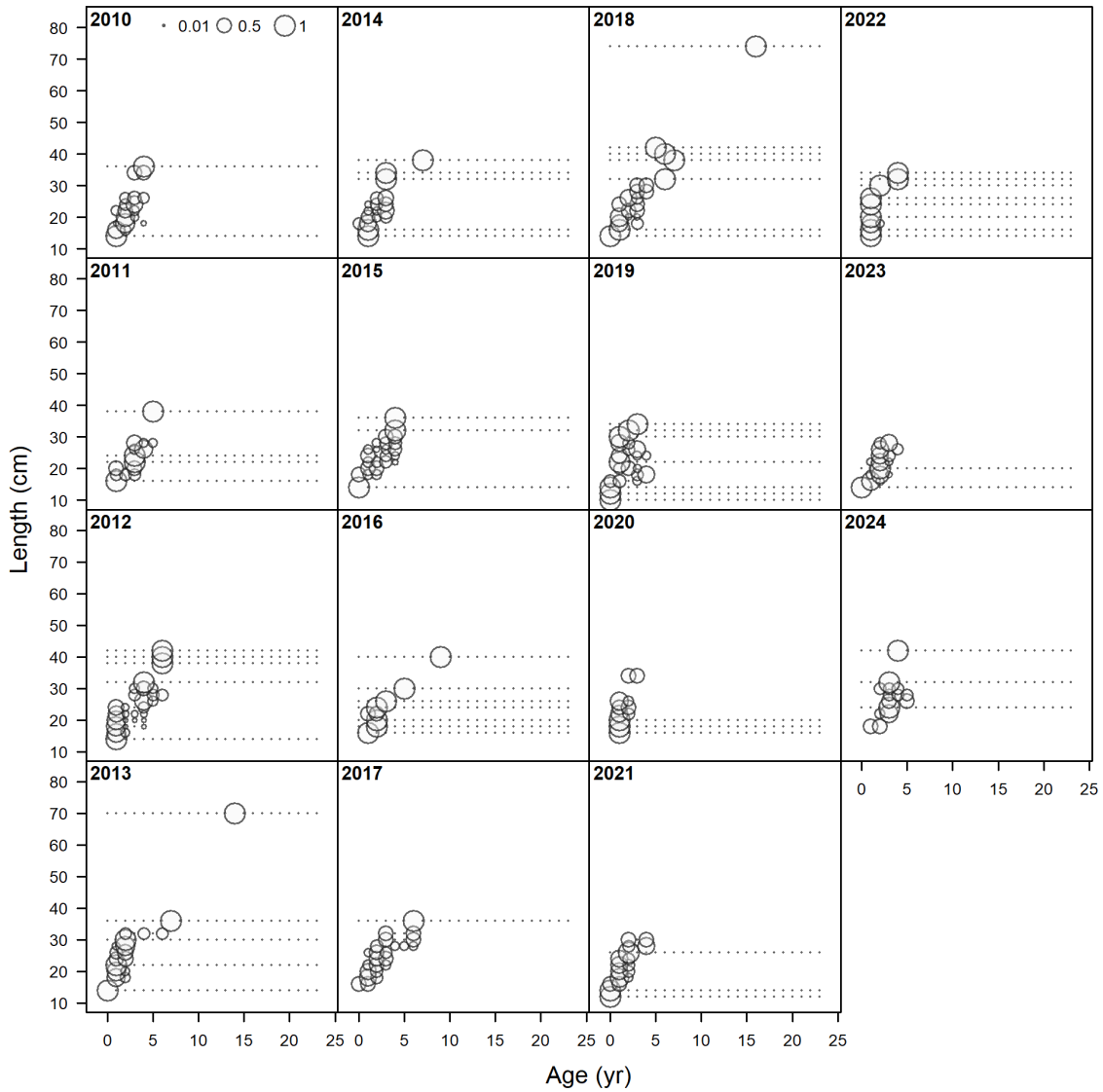


Figure 4.9. Observed conditional age-at-length in 2 cm FL bins of West Florida Shelf Hogfish for the SEAMAP trawl survey during years 2010 – 2024.

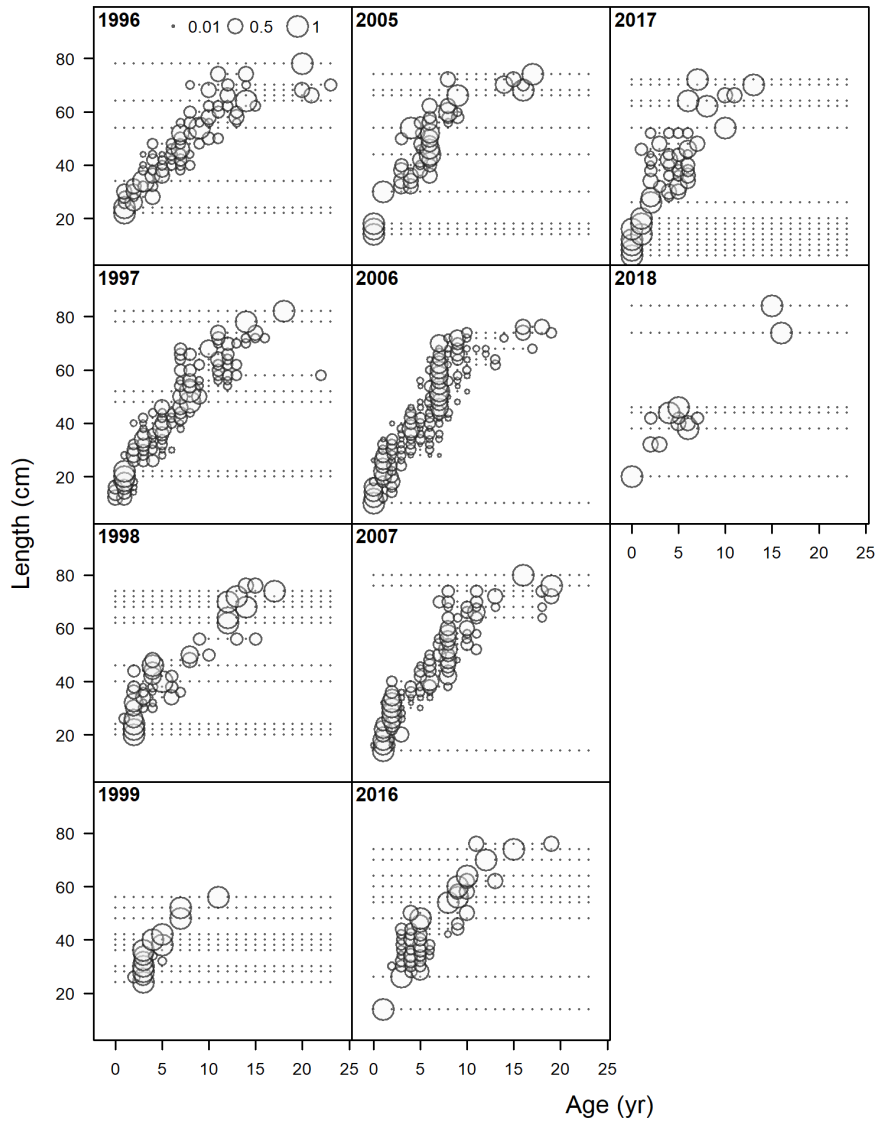


Figure 4.10. Observed conditional age-at-length in 2 cm FL bins of West Florida Shelf Hogfish collected by the spear gear from fishery-independent data sources during years 1996 – 2018.

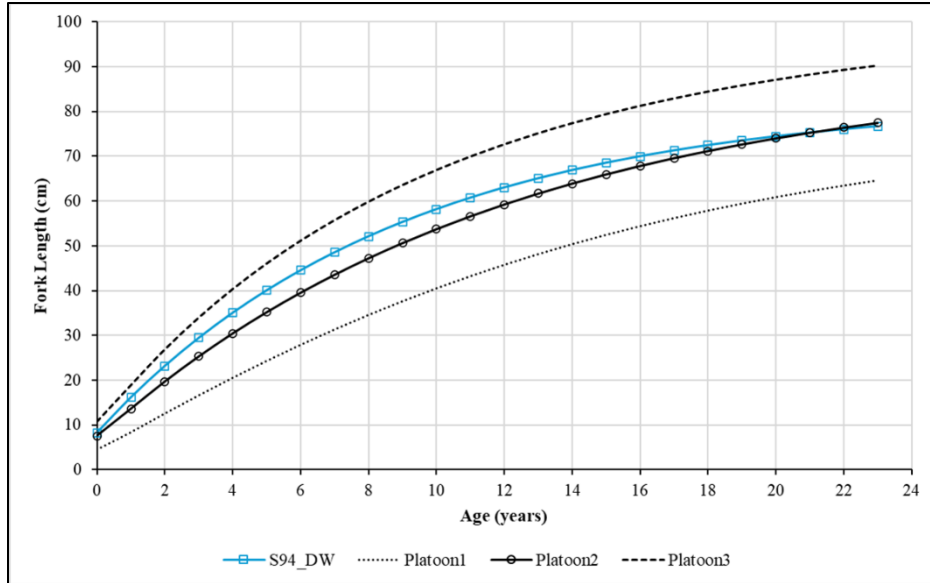


Figure 4.11. Mean size-at-age across 3 platoons for West Florida Shelf Hogfish as estimated by the SEDAR 94 WFS base model. Distribution of recruitment among platoons approximated a normal distribution (0.150, 0.700, 0.150) and the 2nd platoon (black circles) followed the L_{inf} (89.6 cm FL) and k (0.083) parameters estimated by the SEDAR 94 WFS base model. A comparison with the external growth model developed during the Data Workshop (S94_DW) is shown by the blue squares.

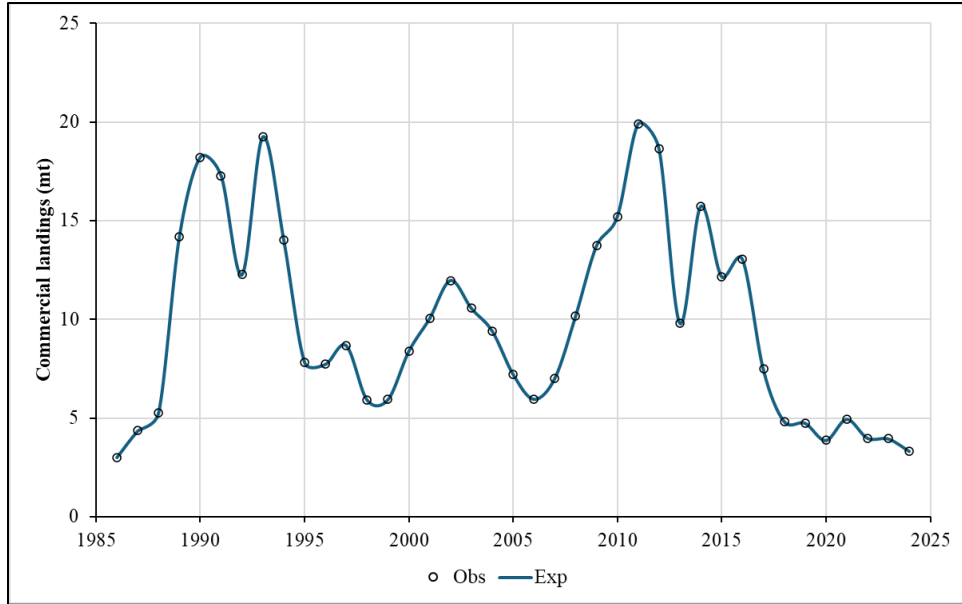


Figure 4.12. West Florida Shelf Hogfish observed (dots) and expected (solid line) landings by the commercial fleet (in metric tons) from the SEDAR 94 WFS base model.

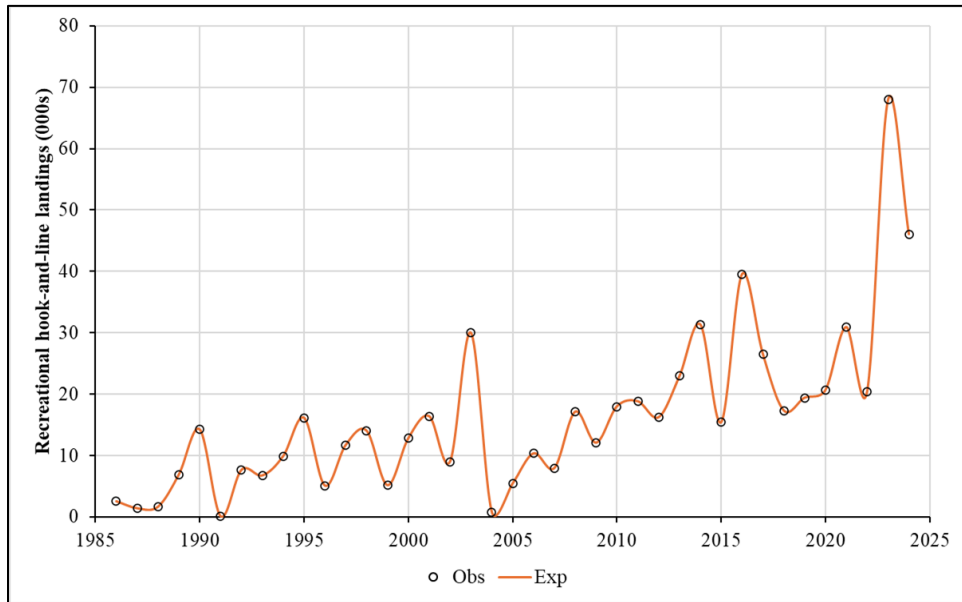


Figure 4.13. West Florida Shelf Hogfish observed (dots) and expected (solid line) landings by the recreational hook-and-line fleet (in thousands of fish) from the SEDAR 94 WFS base model.

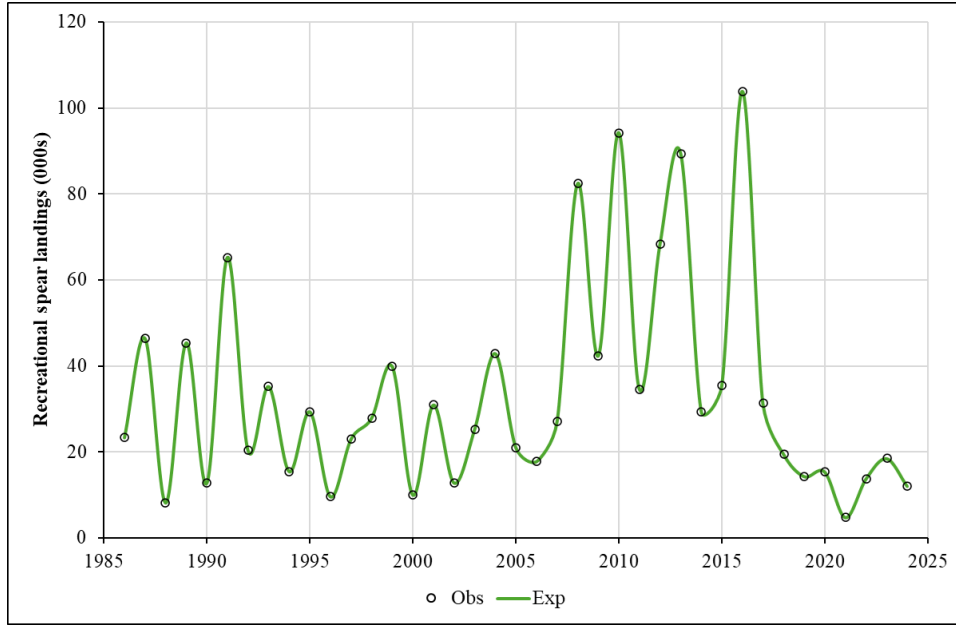


Figure 4.14. West Florida Shelf Hogfish observed (dots) and expected (solid line) landings by the recreational spear fleet (in thousands of fish) from the SEDAR 94 WFS base model.

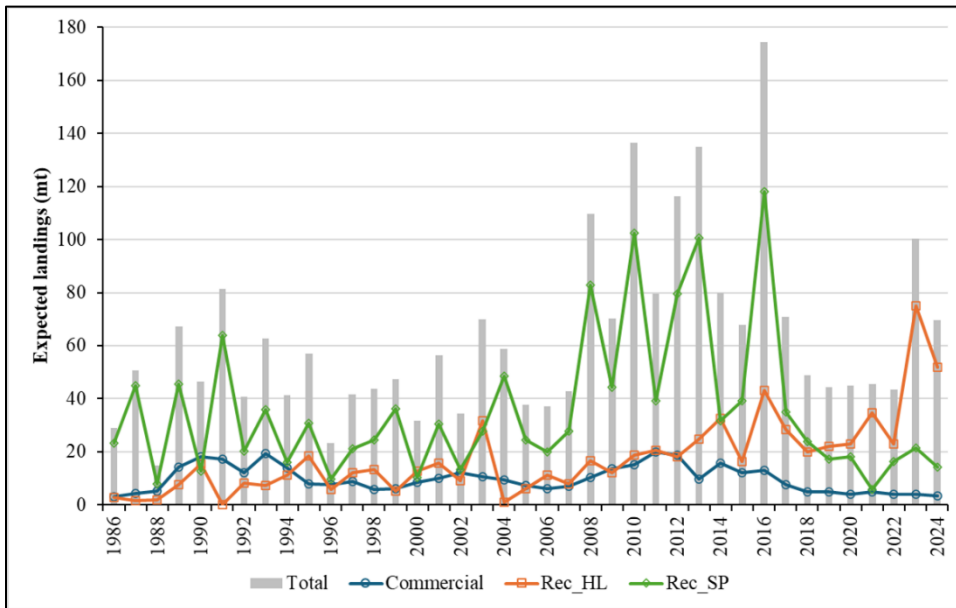


Figure 4.15. Expected landings of West Florida Shelf Hogfish by fleet (in metric tons) as estimated from the SEDAR 94 WFS base model.

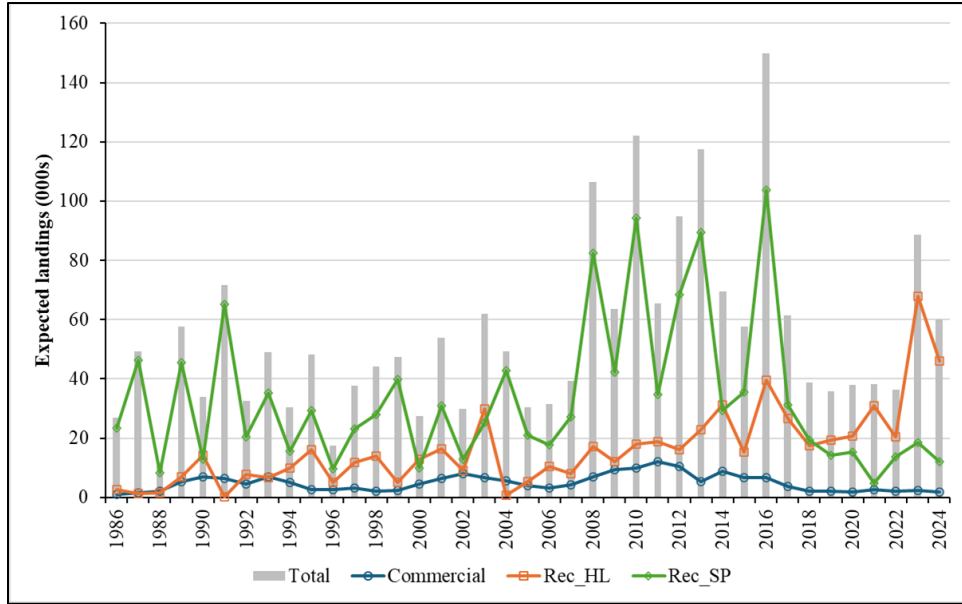


Figure 4.16. Expected landings of West Florida Shelf Hogfish by fleet (in thousands of fish) as estimated from the SEDAR 94 WFS base model.

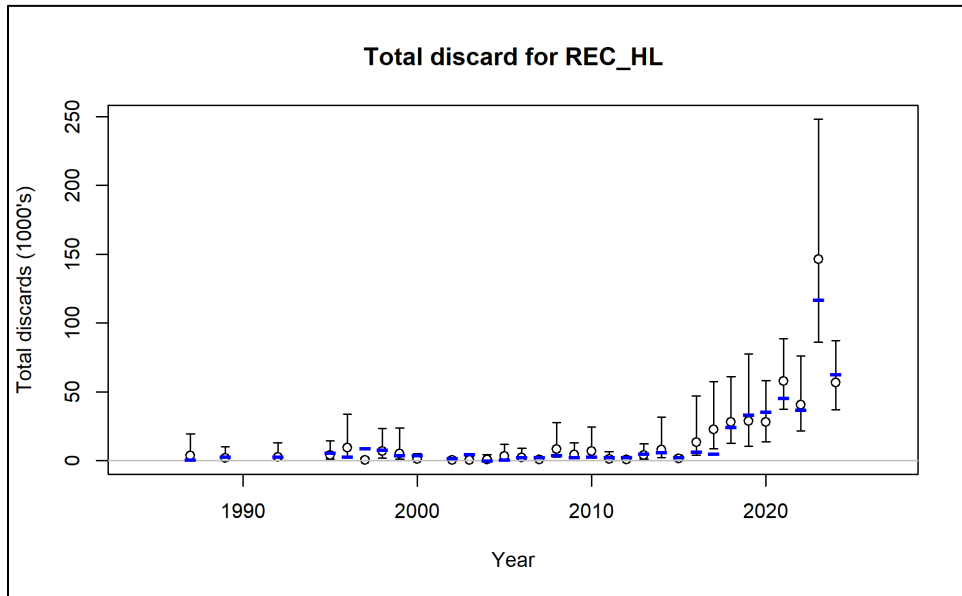


Figure 4.17. West Florida Shelf Hogfish observed (dots with 95% confidence intervals) and expected (blue dashes) discards (i.e., before applying the discard mortality rate for each fleet) by the recreational hook-and-line fleet (in thousands of fish) from the SEDAR 94 WFS base model.

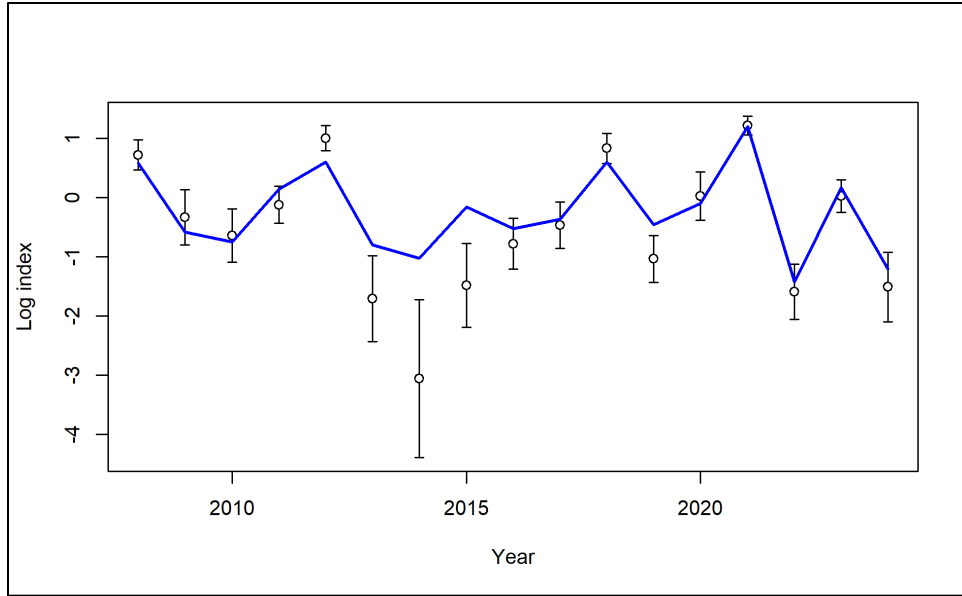


Figure 4.18. The WFS Hogfish observed (dots with 95% confidence intervals) and predicted (blue line) seagrass trawl index of relative abundance (log-transformed) for SEDAR 94.

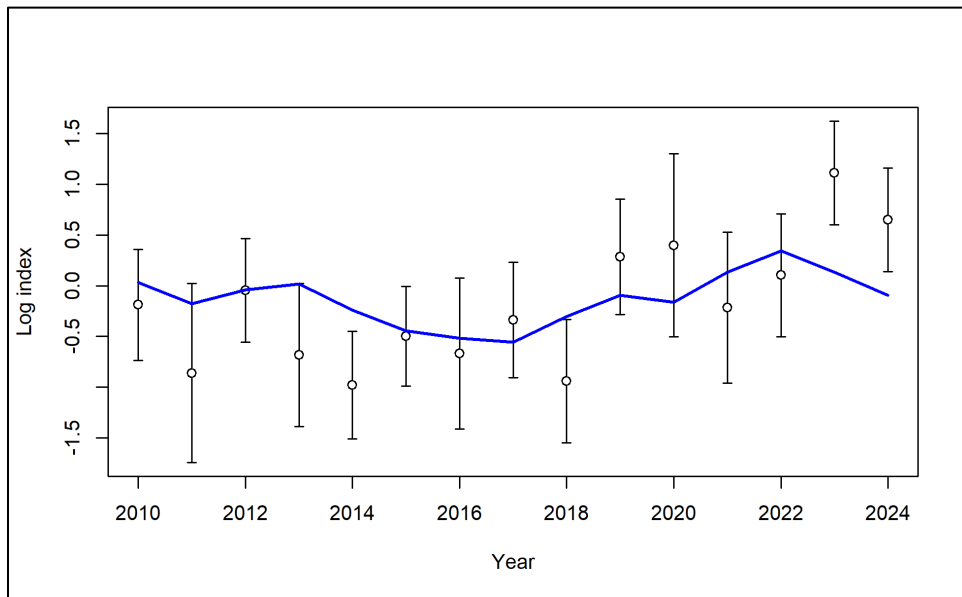


Figure 4.19. The WFS Hogfish observed (dots with 95% confidence intervals) and predicted (blue line) SEAMAP index of relative abundance (log-transformed) for SEDAR 94.

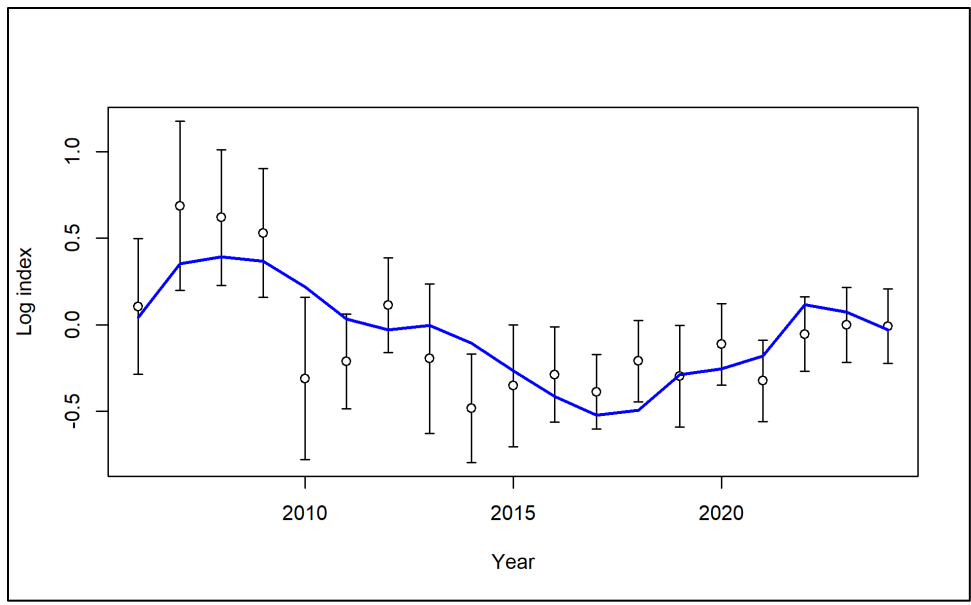


Figure 4.20. The West Florida Shelf Hogfish observed (dots with 95% confidence intervals) and predicted (blue line) combined video index of relative abundance (log-transformed) from the SEDAR 94 WFS base model.

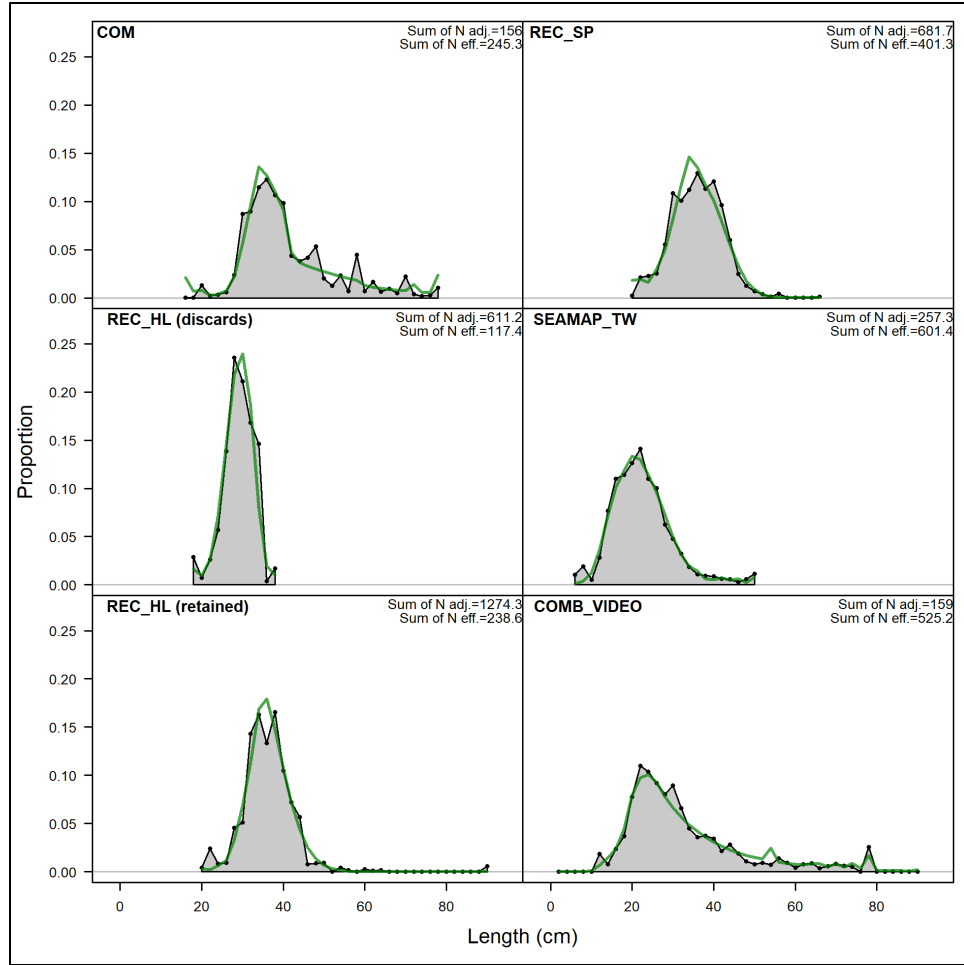


Figure 4.21. Model fits to the length composition of retained and discarded catch aggregated across years within a given fleet or survey for West Florida Shelf Hogfish. Green lines represent predicted length compositions, while grey shaded regions represent observed length compositions. In the upper right hand corners, 'N adj.' is the input sample size after applying the Francis data-weighting adjustment while 'N eff.' is the calculated effective sample size used in the McAllister-Ianelli tuning method.

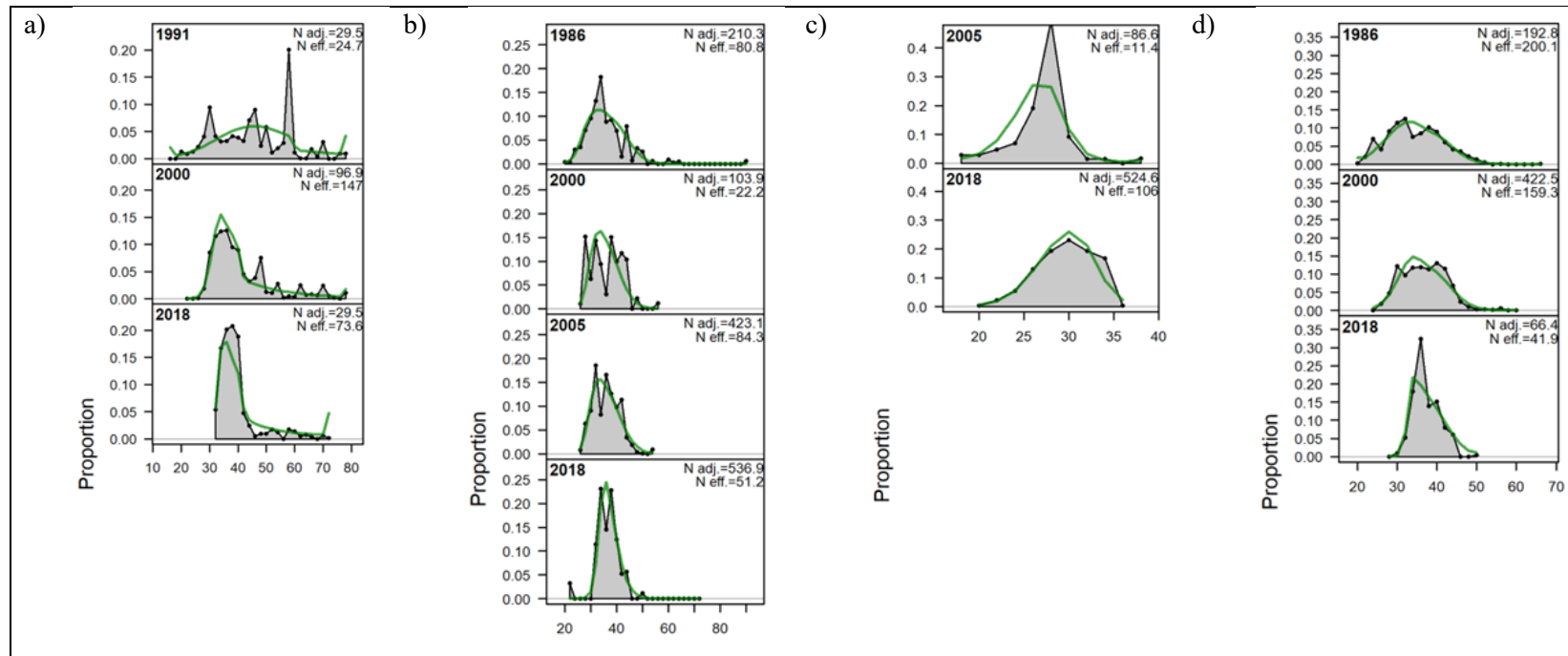


Figure 4.22. Model fits to the length composition of a) retained catch by the commercial fleet, b) retained catch by the recreational hook-and-line fleet, and c) discards for the recreational hook-and-line fleet, and d) retained catch by the recreational spear fleet by super-period for West Florida Shelf Hogfish. Green lines represent predicted length compositions, while grey shaded regions represent observed length compositions. In the upper right hand corners, 'N adj.' is the input sample size after applying the Francis data-weighting adjustment while 'N eff.' is the calculated effective sample size used in the McAllister-Ianelli tuning method. Data are in 2 cm fork length bins.

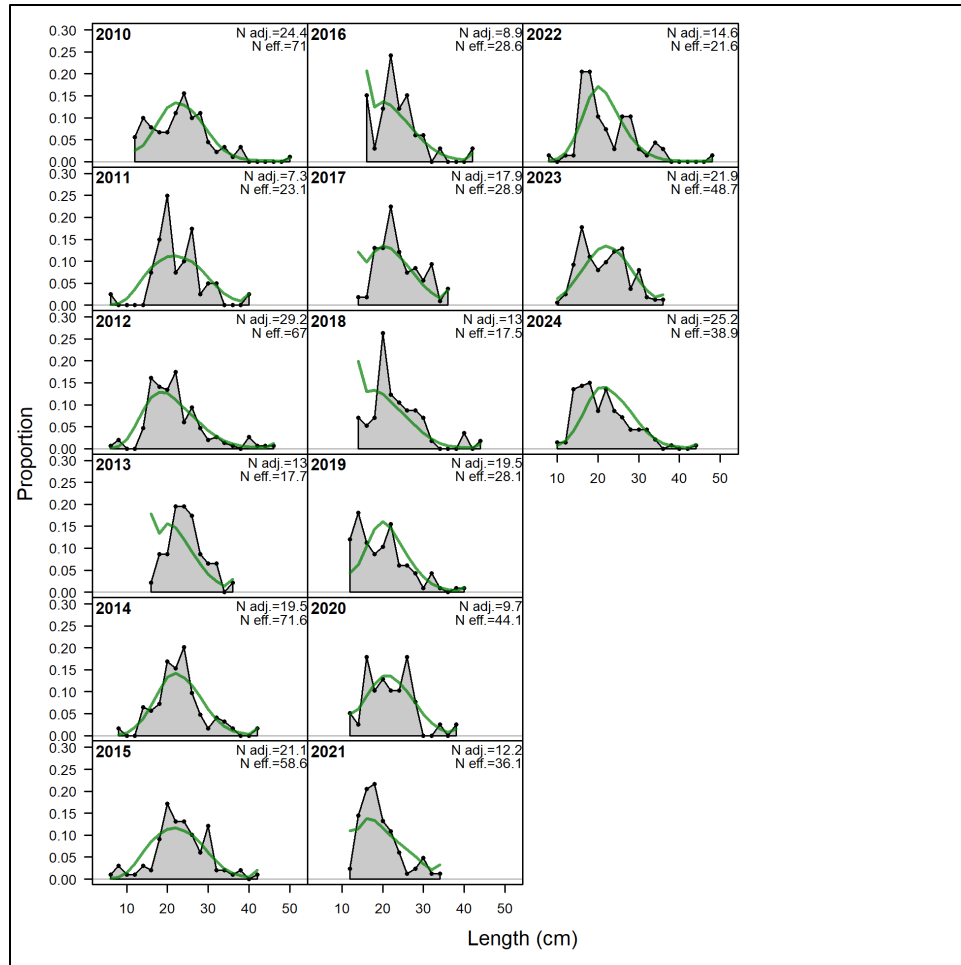


Figure 4.23. Model fits to the length composition data for the SEAMAP trawl index for West Florida Shelf Hogfish. Green lines represent predicted length compositions, while grey shaded regions represent observed length compositions. In the upper right hand corners, 'N adj.' is the input sample size after applying the Francis data-weighting adjustment while 'N eff.' is the calculated effective sample size used in the McAllister-Ianelli tuning method. Data are in 2 cm fork length bins.

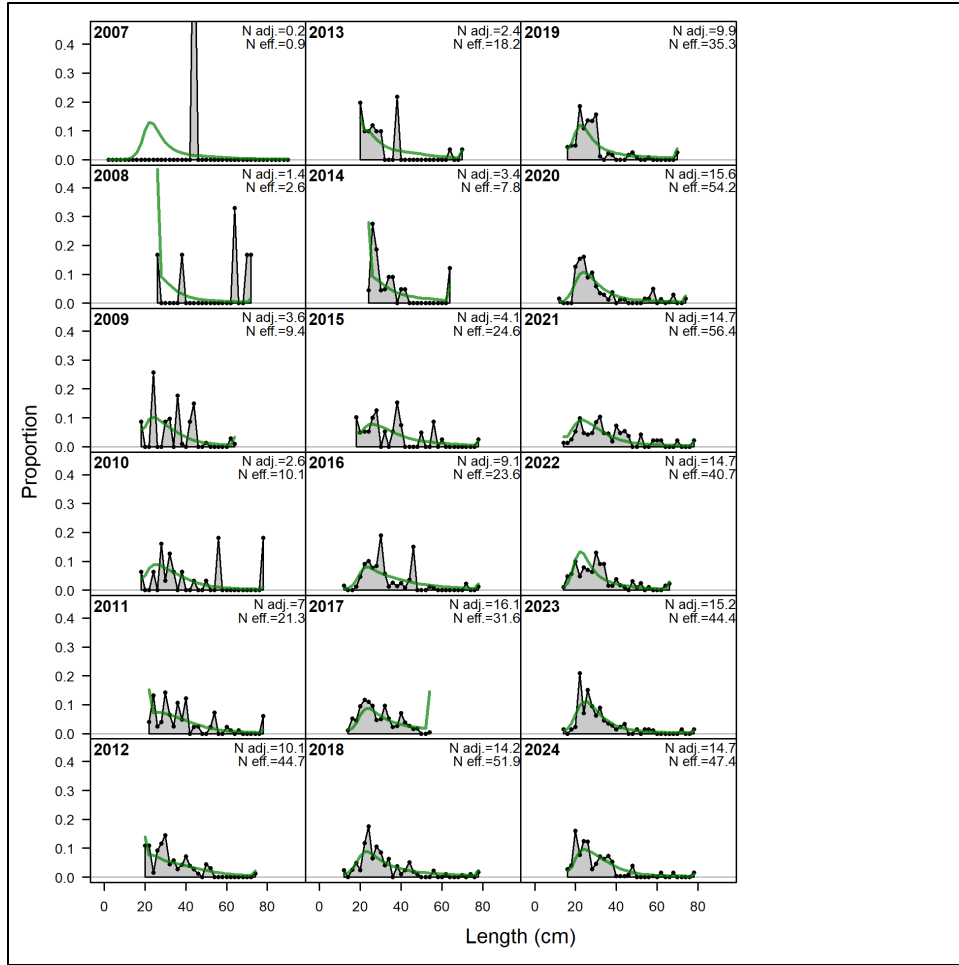


Figure 4.24. Model fits to the length composition data for the combined video index for West Florida Shelf Hogfish. Green lines represent predicted length compositions, while grey shaded regions represent observed length compositions. In the upper right hand corners, 'N adj.' is the input sample size after applying the Francis data-weighting adjustment while 'N eff.' is the calculated effective sample size used in the McAllister-Ianelli tuning method. Data are in 2 cm fork length bins.

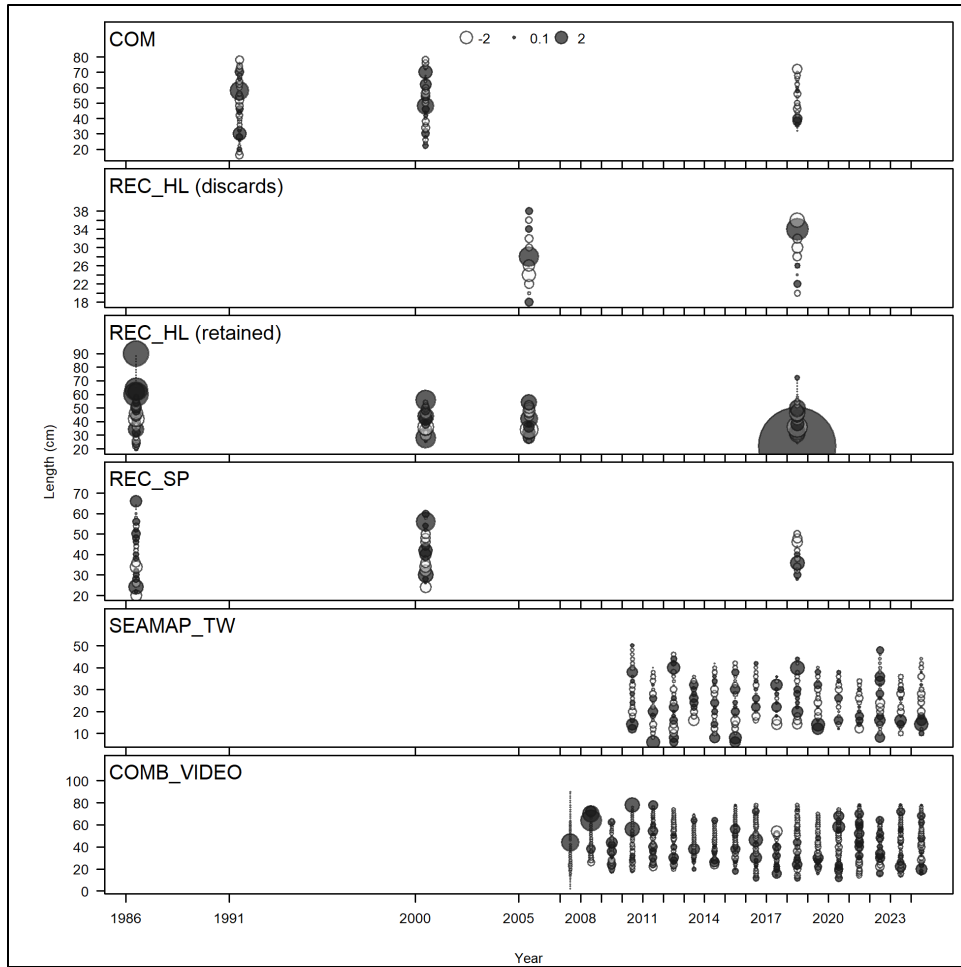


Figure 4.25. Pearson residuals for length composition data by year compared across a given fleet or survey for West Florida Shelf Hogfish. Closed bubbles are positive residuals (observed > expected) and open bubbles are negative residuals (observed < expected).

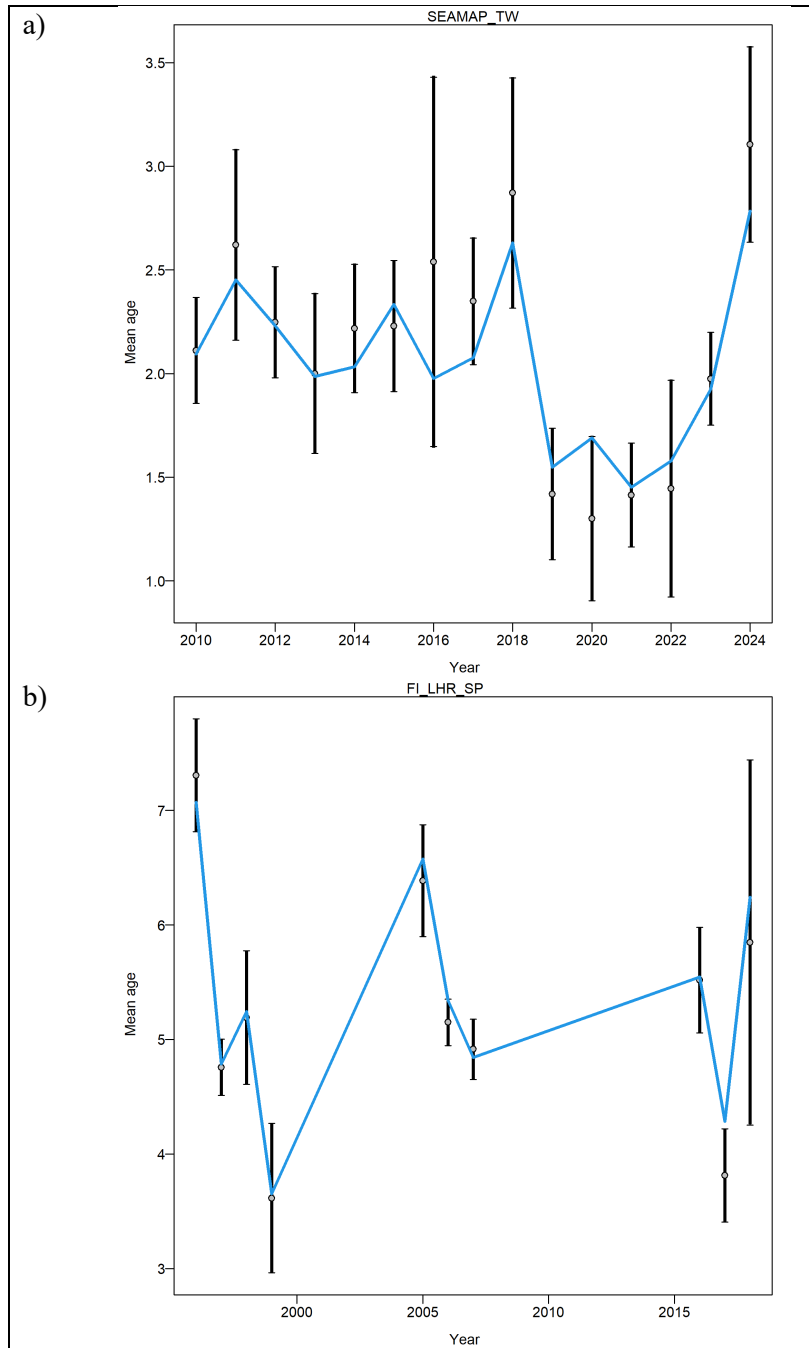


Figure 4.26. Mean ages of West Florida Shelf Hogfish conditional age-at-length data collected by a) the SEAMAP trawl survey (SEAMAP_TW) and b) fishery-independent research using the spear gear (FI_LHR_SP) aggregated across length bins. Observed values are dots with 95% confidence intervals and predicted values are the blue lines.

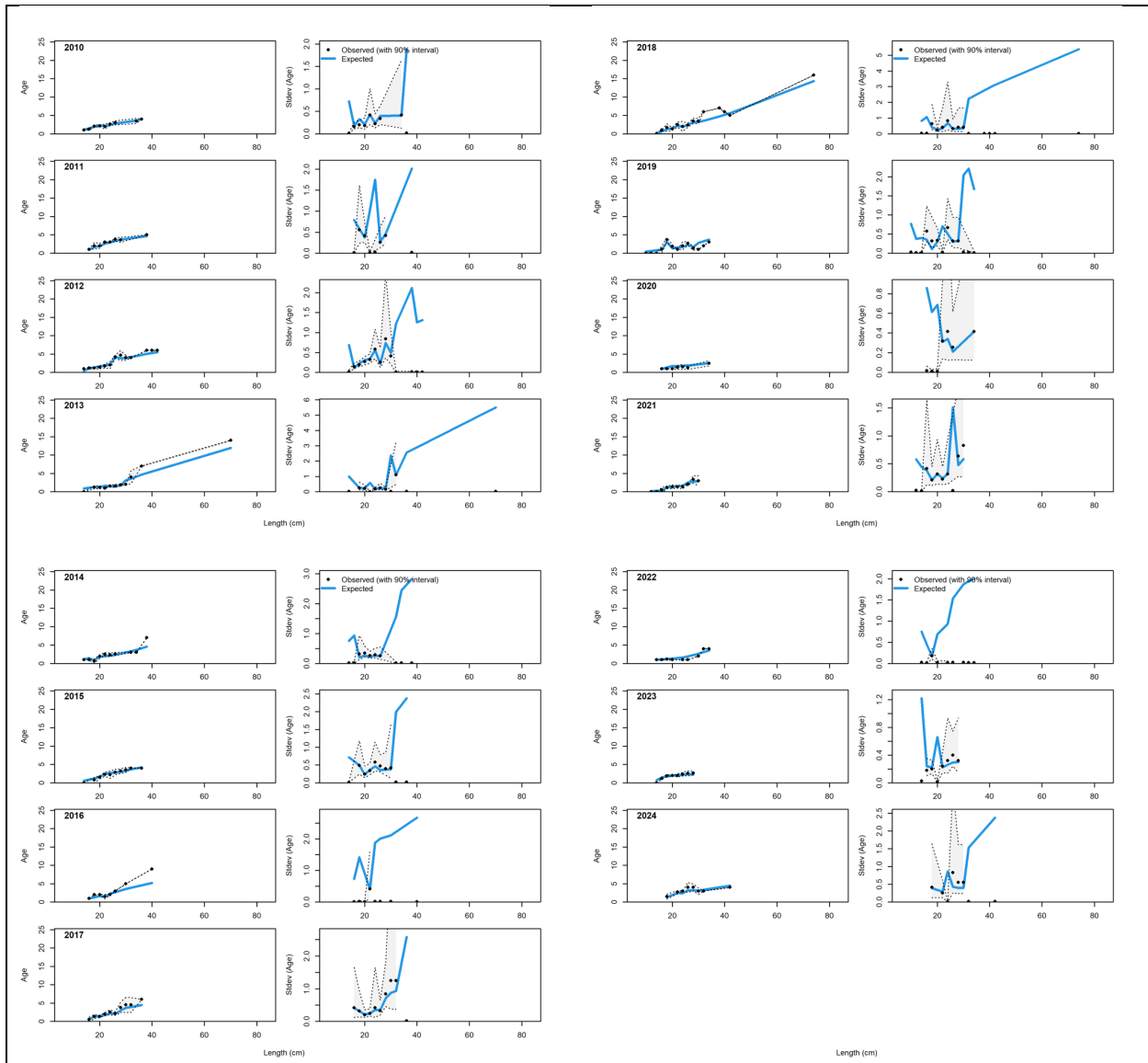


Figure 4.27. Model fits to the annual conditional age-at-length data by the SEAMAP trawl survey for West Florida Shelf Hogfish. In the left plots, the blue lines represent predicted mean age-at-length by size class while the black dots and grey shaded regions represent the observed mean age-at-length by size class with 90% confidence intervals. In the right plots, the blue lines represent predicted standard error of mean age-at-length by size class while the black dots and grey shaded regions represent the observed standard error of mean age-at-length by size class with 90% confidence intervals.

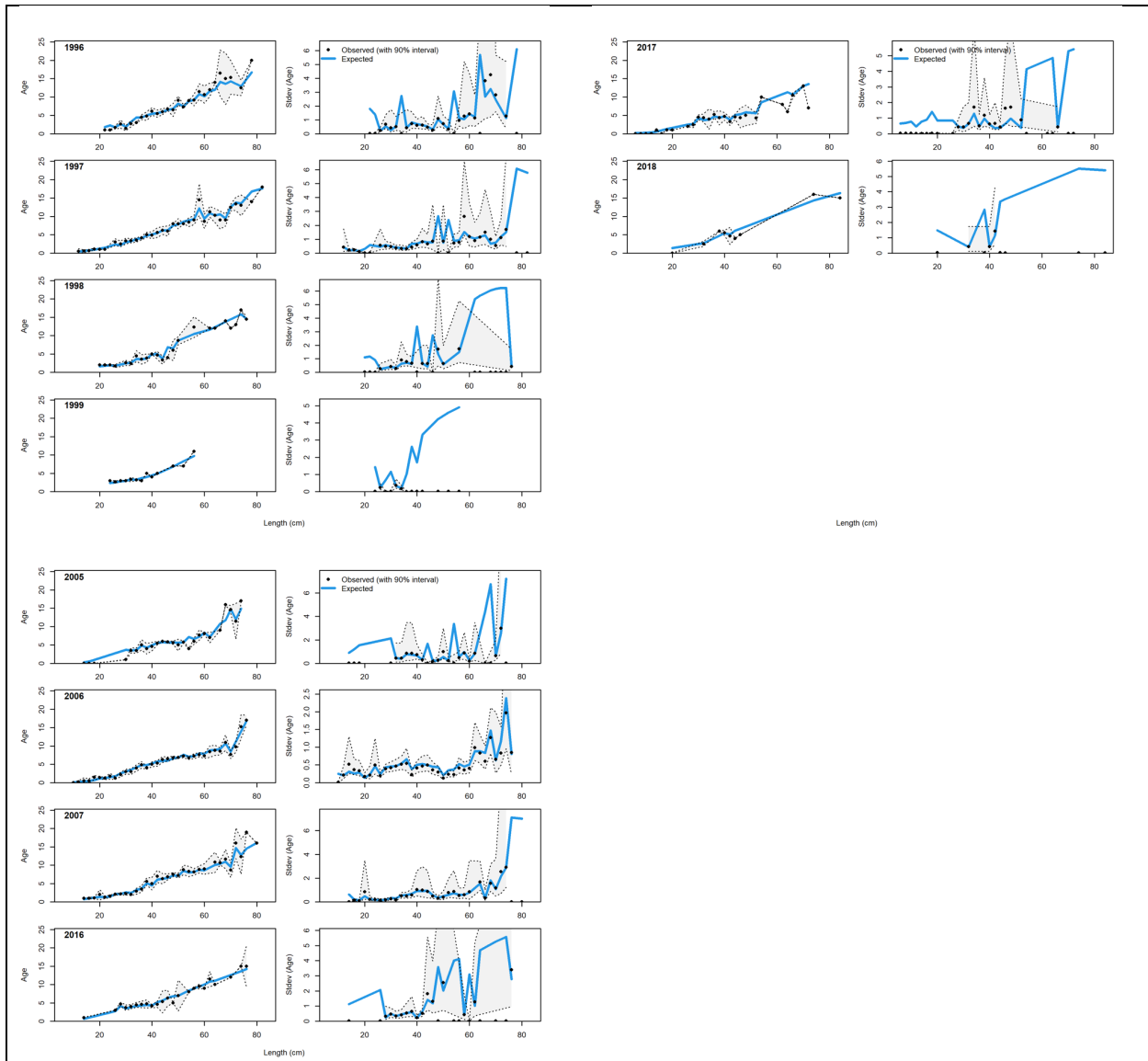


Figure 4.28. Model fits to the annual conditional age-at-length data from fishery-independent research collected using the spear gear for West Florida Shelf Hogfish. In the left plots, the blue lines represent predicted mean age-at-length by size class while the black dots and grey shaded regions represent the observed mean age-at-length by size class with 90% confidence intervals. In the right plots, the blue lines represent predicted standard error of mean age-at-length by size class while the black dots and grey shaded regions represent the observed standard error of mean age-at-length by size class with 90% confidence intervals.

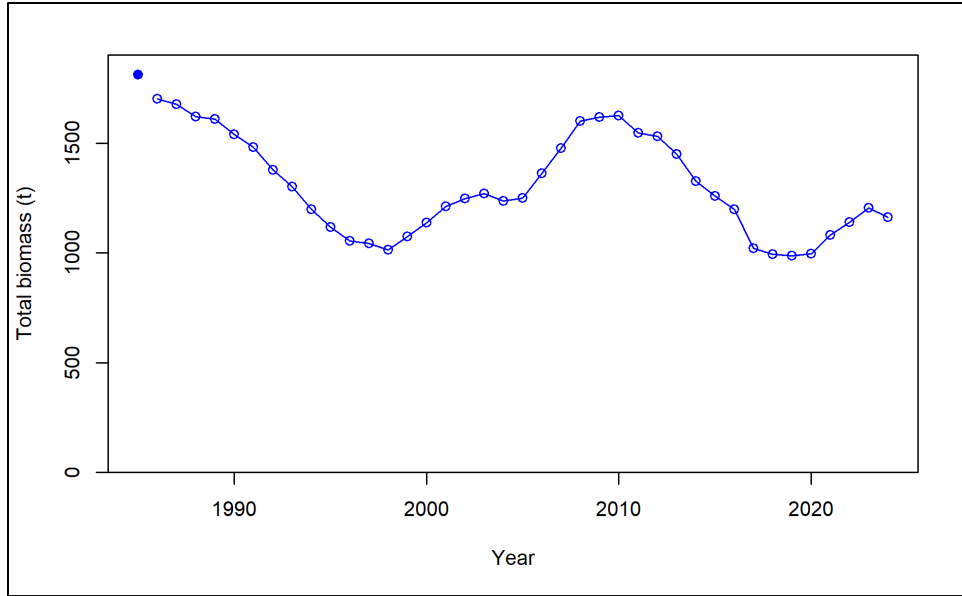


Figure 4.29. Estimates of total biomass (in metric tons) of West Florida Shelf Hogfish (open circles) from 1986 – 2024. The solid blue dot is the estimated unfished total biomass.

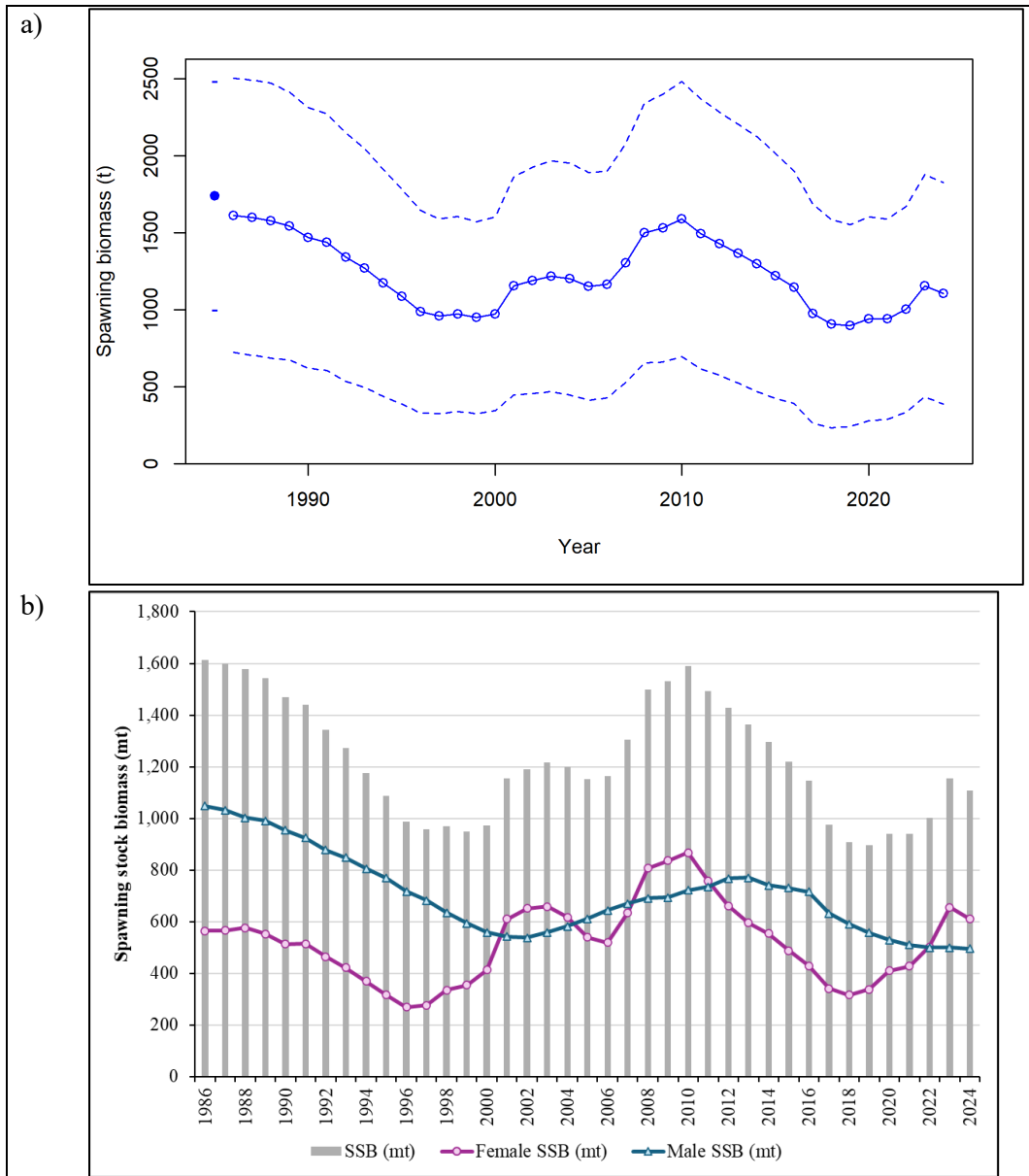


Figure 4.30. Estimates of mature female and male spawning stock biomass a) combined (in metric tons, open circles) with approximate 95% confidence intervals (dashed lines) where the solid blue circle is the estimated unfished spawning stock biomass, and b) separated by sex (female = purple circles, male = blue triangles, combined = grey bars) for West Florida Shelf Hogfish from 1986 – 2024.

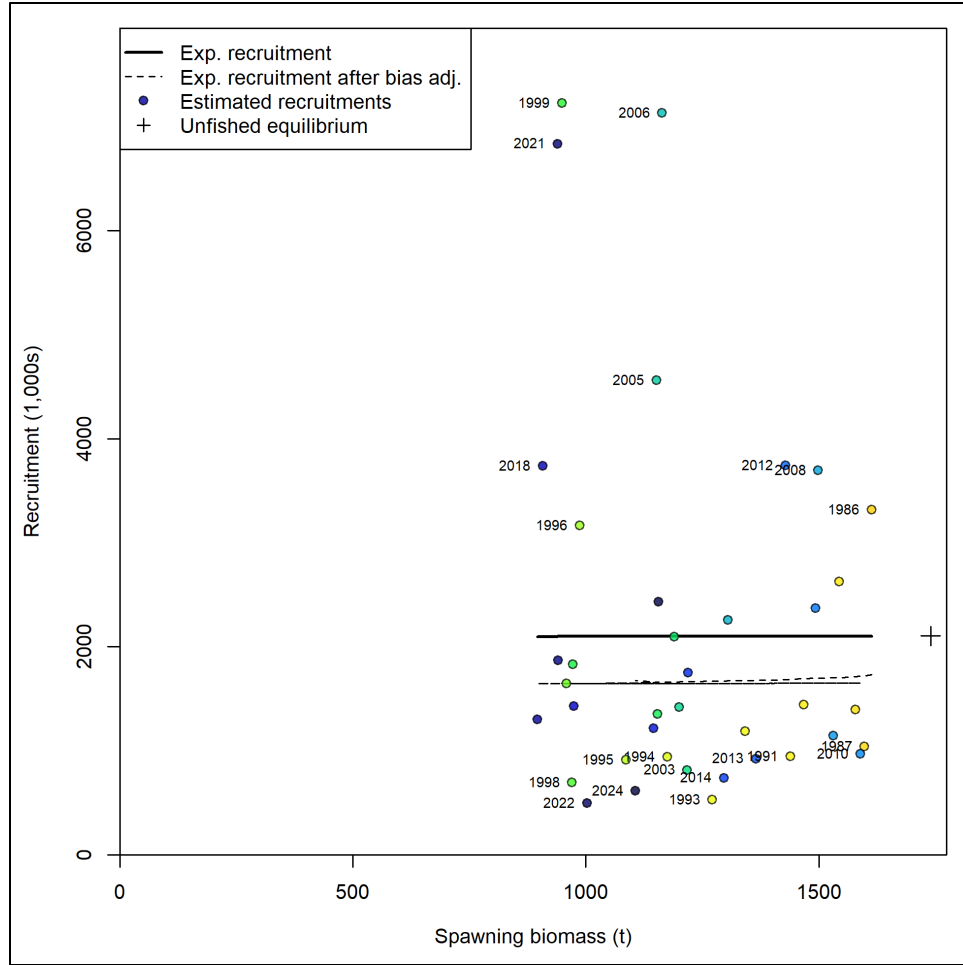


Figure 4.31. Expected stock-recruitment relationship for West Florida Shelf Hogfish. Steepness was fixed at 0.99, thereby representing average recruitment across time, and σ_R was estimated at 0.726. Plotted are expected annual recruitments from the SEDAR 94 WFS base model (circles), expected recruitment from the stock-recruitment relationship (black line), and bias adjusted recruitment from the stock-recruit relationship (dashed line). Point colors indicate year, with warmer colors indicating earlier years and cooler colors showing later years.

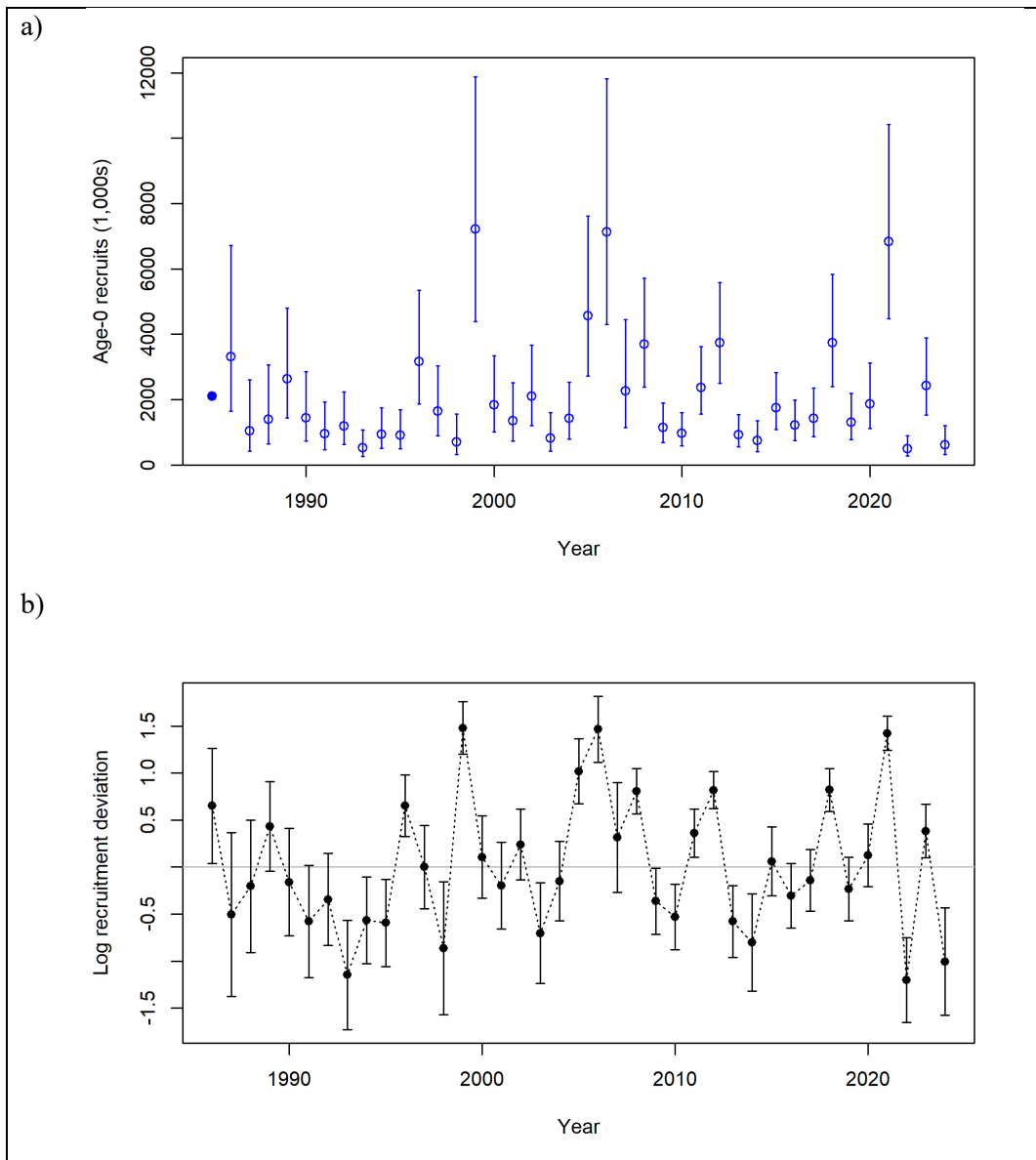


Figure 4.32. Estimated recruitment for West Florida Shelf Hogfish. a) Annual estimated age-0 recruitment (open circles) with 95% confidence intervals (lines) as well as estimated initial equilibrium recruitment (blue dot). b) Log-scaled main recruitment deviations (dots) with 95% confidence intervals (lines) from 1981 – 2021.

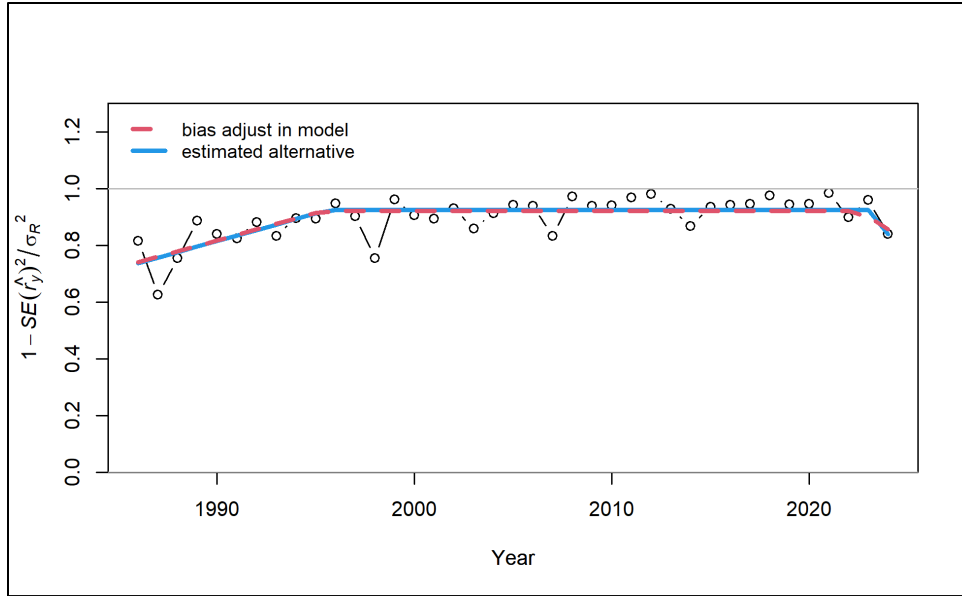


Figure 4.33. Points are transformed variances. Red line shows current settings for bias adjustment specified for the SEDAR 94 WFS base model, which coincides with the least squares estimate of alternative bias adjustment relationship for recruitment deviations (dashed red line). For more information, see Methot and Taylor (2011).

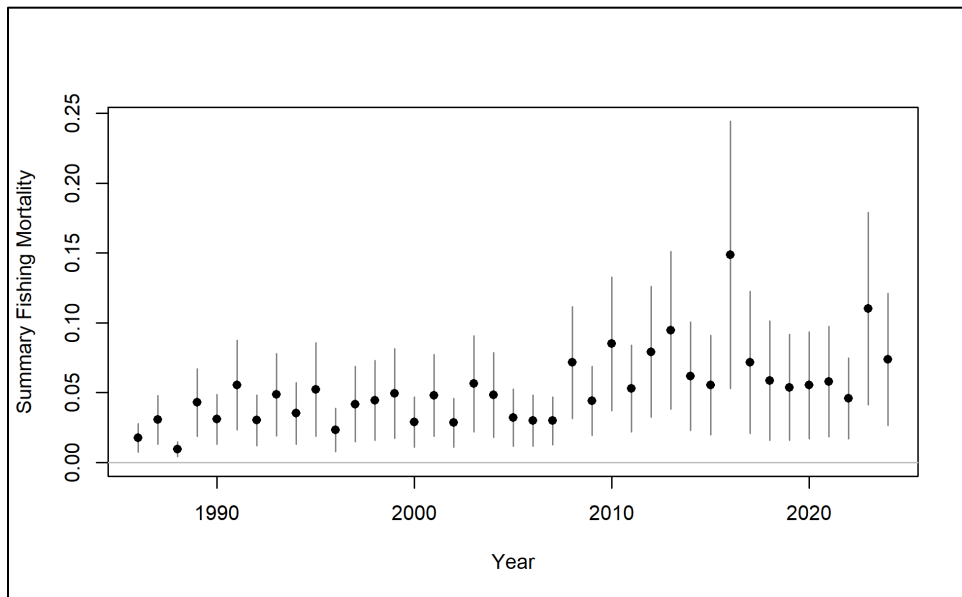


Figure 4.34. Annual exploitation fishing mortality rates, calculated as the ratio of the total annual catch in biomass to the age-1+ biomass at the beginning of the year, for West Florida Shelf Hogfish with 95% confidence intervals from the SEDAR 94 WFS base model.

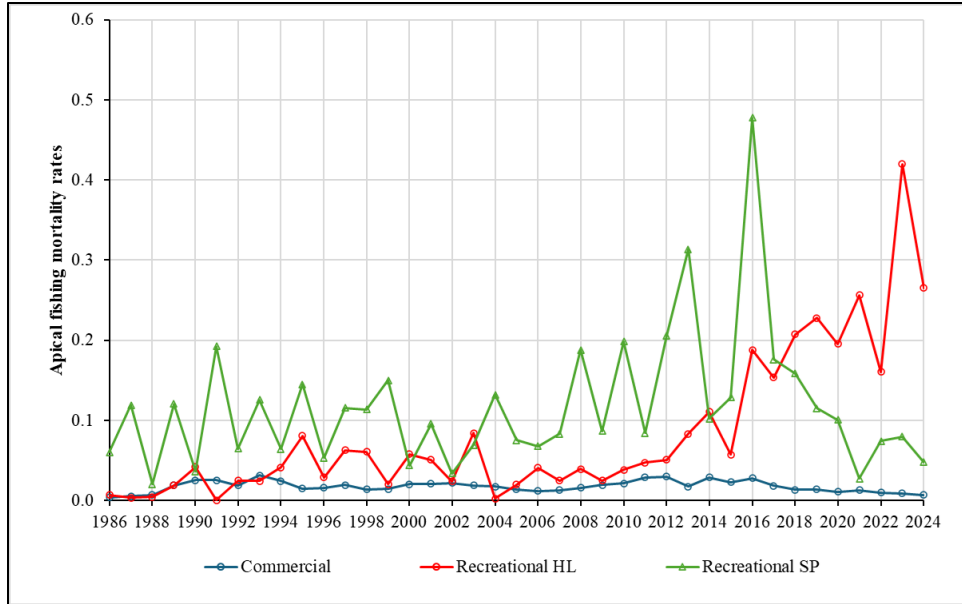


Figure 4.35. Annual fleet-specific instantaneous apical fishing mortality rates for West Florida Shelf Hogfish from the SEDAR 94 WFS base model. This represents the instantaneous fishing mortality level on the most vulnerable (i.e., selectivity = 1) age class for each fleet.

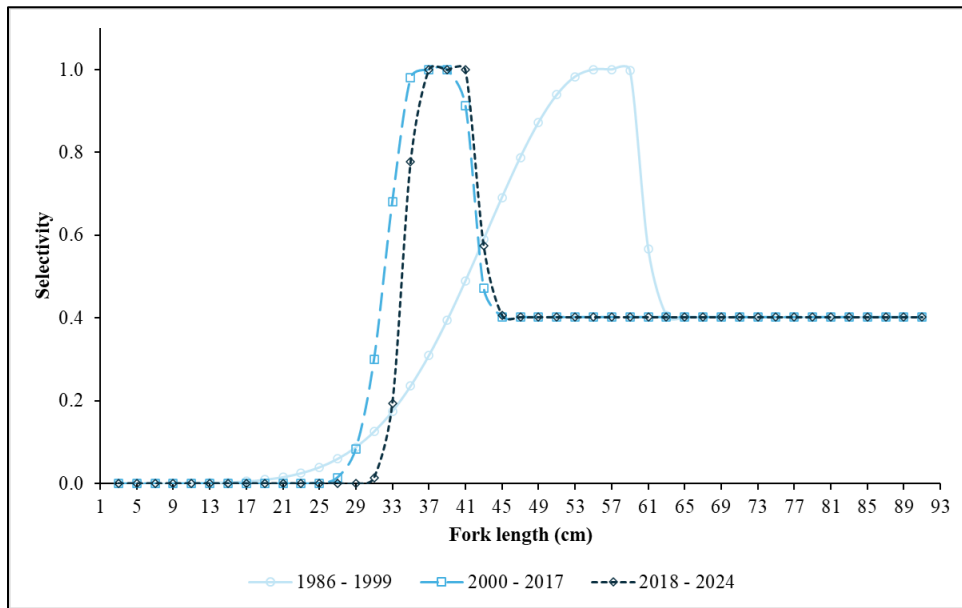


Figure 4.36. Length-based selectivity of the commercial fleet by time block for West Florida Shelf Hogfish from the SEDAR 94 WFS base model.

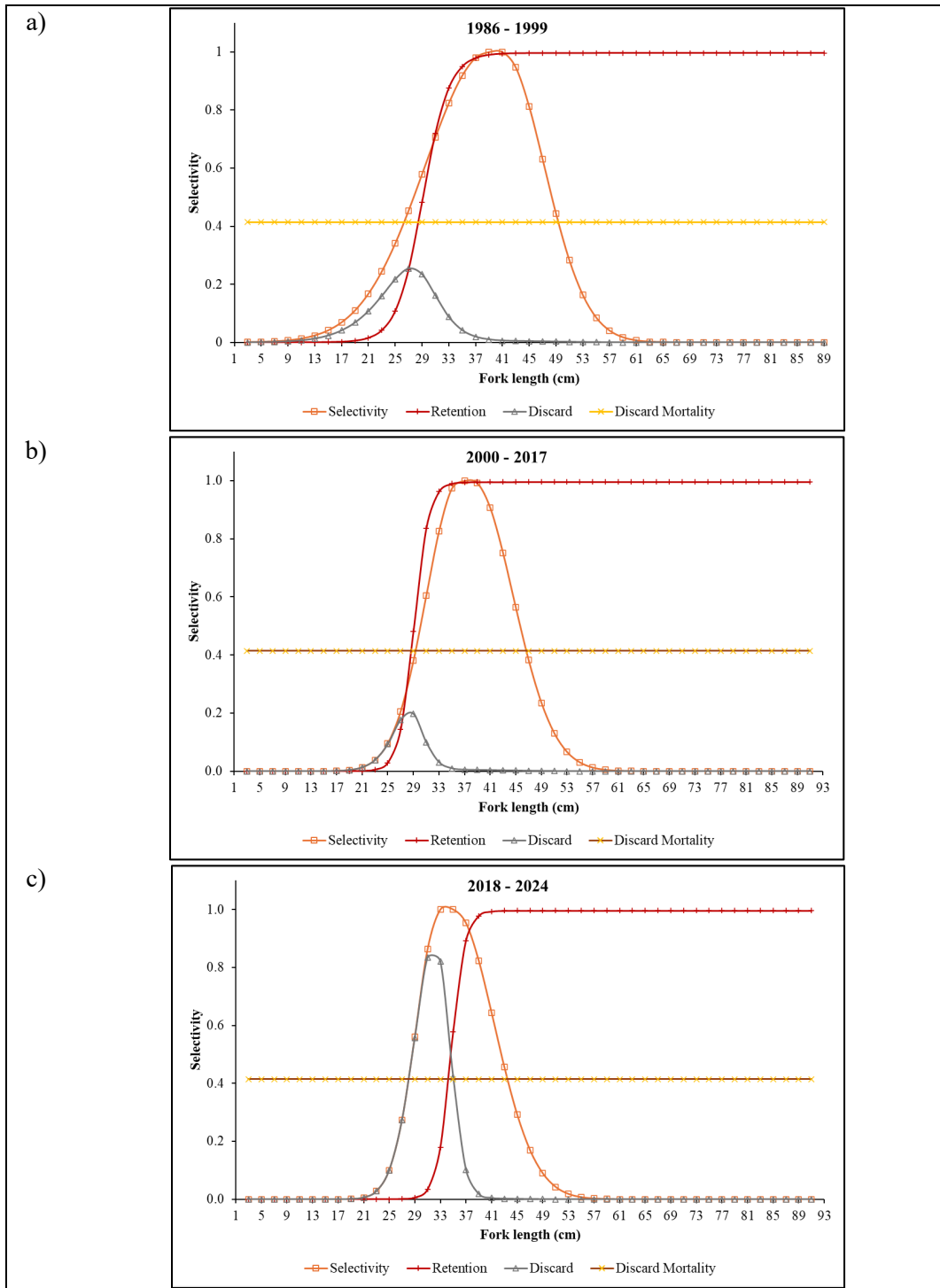


Figure 4.37. Length-based selectivity, retention, discard, and discard mortality (41.4%) patterns of the recreational hook-and-line fleet by time block a) 1986 – 1999, b) 2000 – 2017, and c) 2018 – 2024 for West Florida Shelf Hogfish from the SEDAR 94 WFS base model.

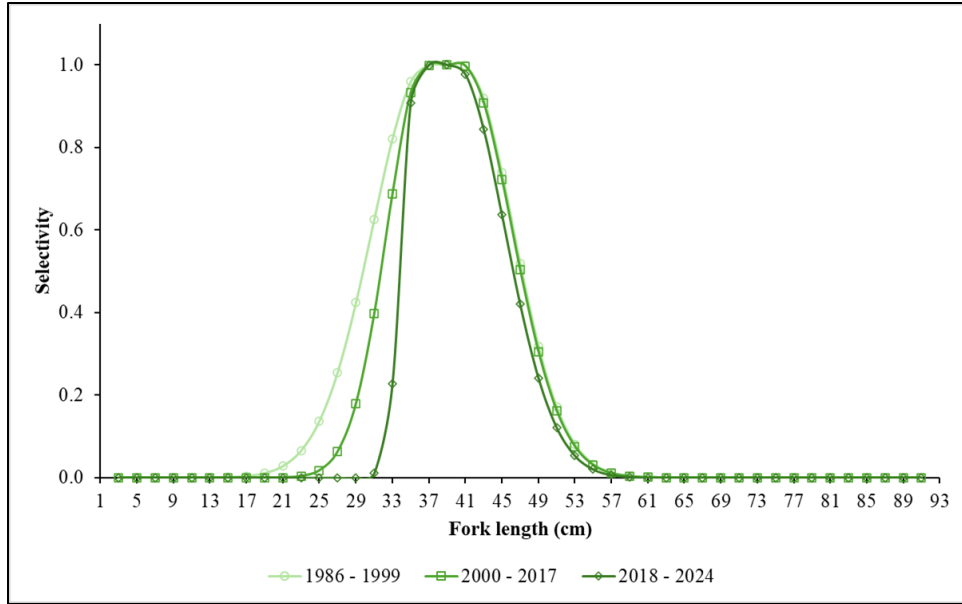


Figure 4.38. Length-based selectivity of the recreational spear fleet by time block for West Florida Shelf Hogfish from the SEDAR 94 WFS base model.

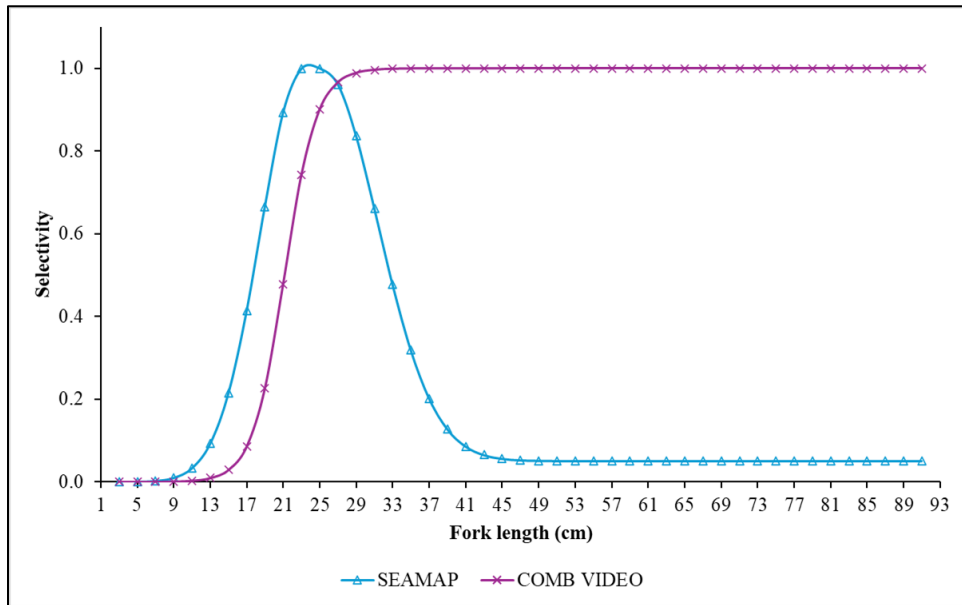


Figure 4.39. Length-based selectivity of the SEAMAP trawl index (blue triangles) and combined video index (purple x's) for West Florida Shelf Hogfish from the SEDAR 94 WFS base model.

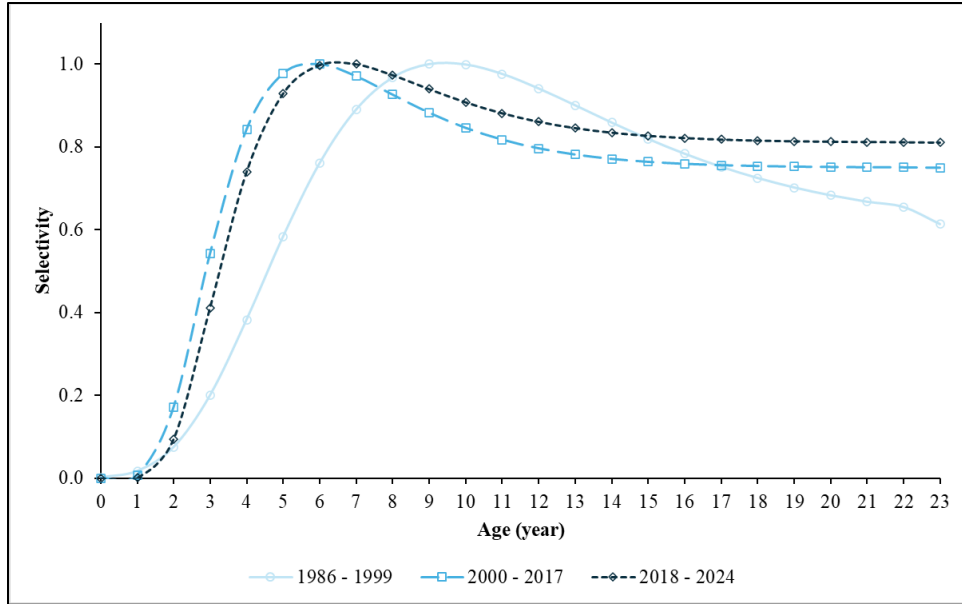


Figure 4.40. Age-derived selectivity of the commercial fleet by time block for West Florida Shelf Hogfish from the SEDAR 94 WFS base model.

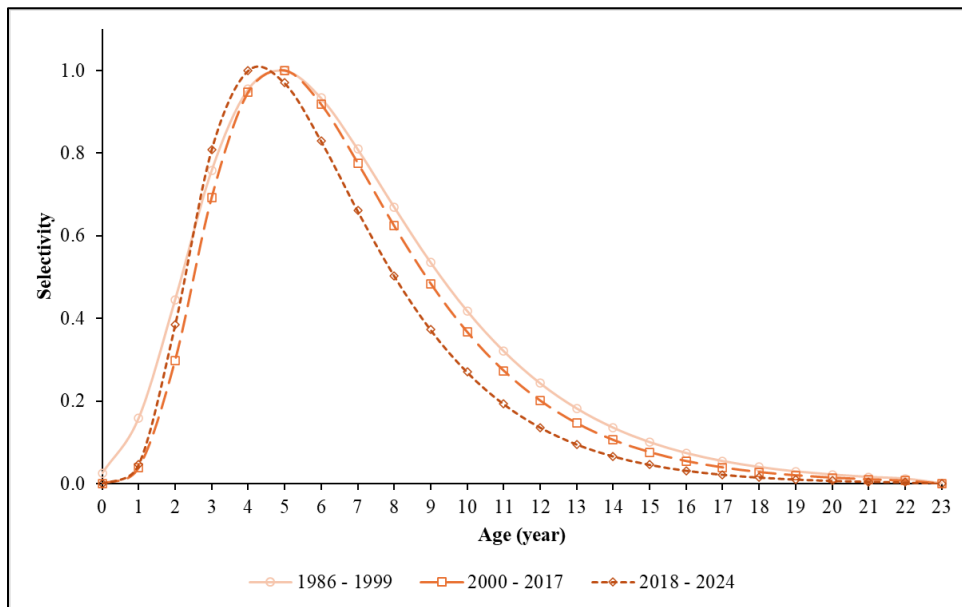


Figure 4.41. Age-derived selectivity of the recreational hook-and-line fleet by time block for West Florida Shelf Hogfish from the SEDAR 94 WFS base model.

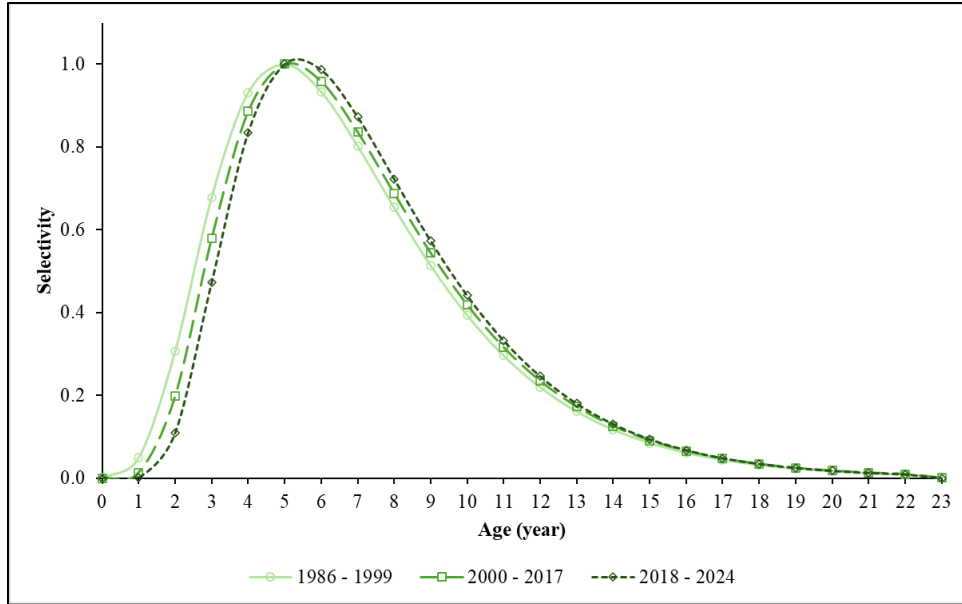


Figure 4.42. Age-derived selectivity of the recreational spear fleet by time block for West Florida Shelf Hogfish from the SEDAR 94 WFS base model.

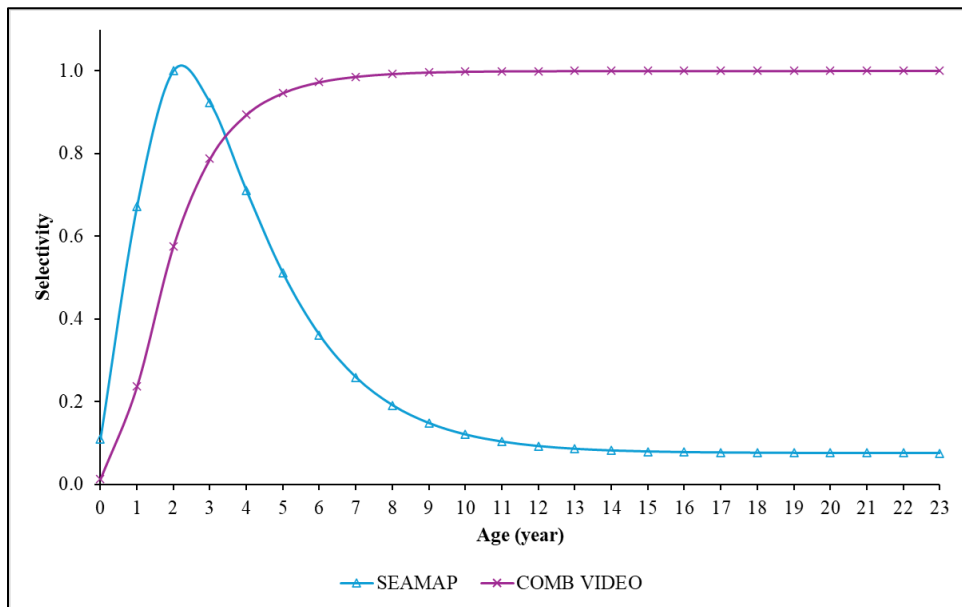


Figure 4.43. Age-derived selectivity of the SEAMAP trawl index (blue triangles) and combined video index (purple x's) for West Florida Shelf Hogfish from the SEDAR 94 WFS base model.

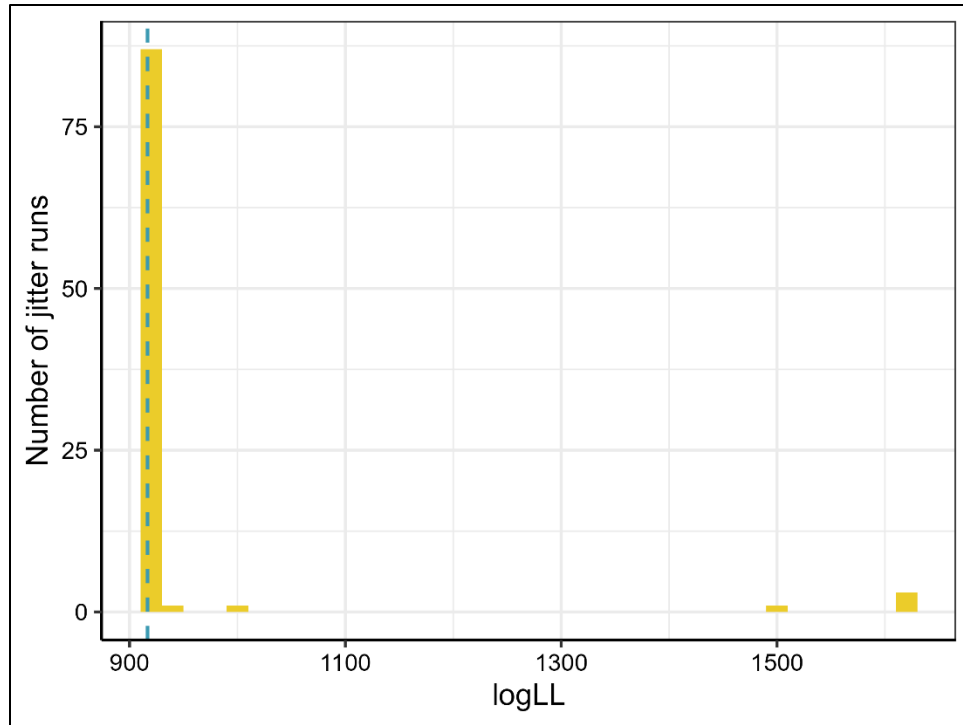


Figure 4.44. Total log-likelihood values of model runs performed by the jitter analysis (yellow bars) and the SEDAR 94 WFS base model (blue dashed line).

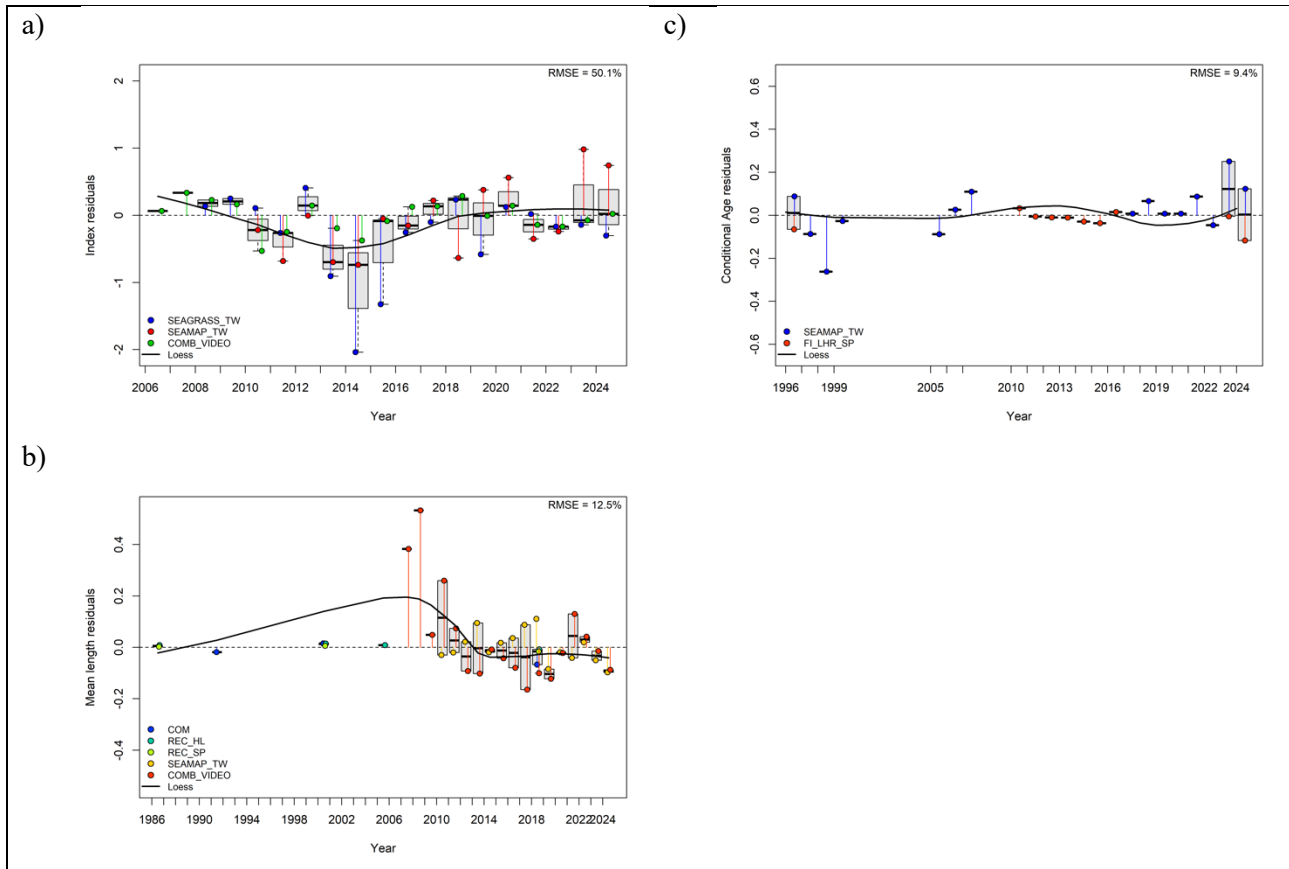


Figure 4.45. Joint residual plots for a) the indices of abundance, b) the annual mean length estimates, and c) the annual conditional age-at-length estimates of available fleets and indices from the SEDAR 94 WFS base model. Vertical lines with points show the residuals, boxplots show residual medians and quantiles, and solid black lines are a loess smoother. Root-mean squared errors (RMSE) are included in the upper right-hand corner of each plot.

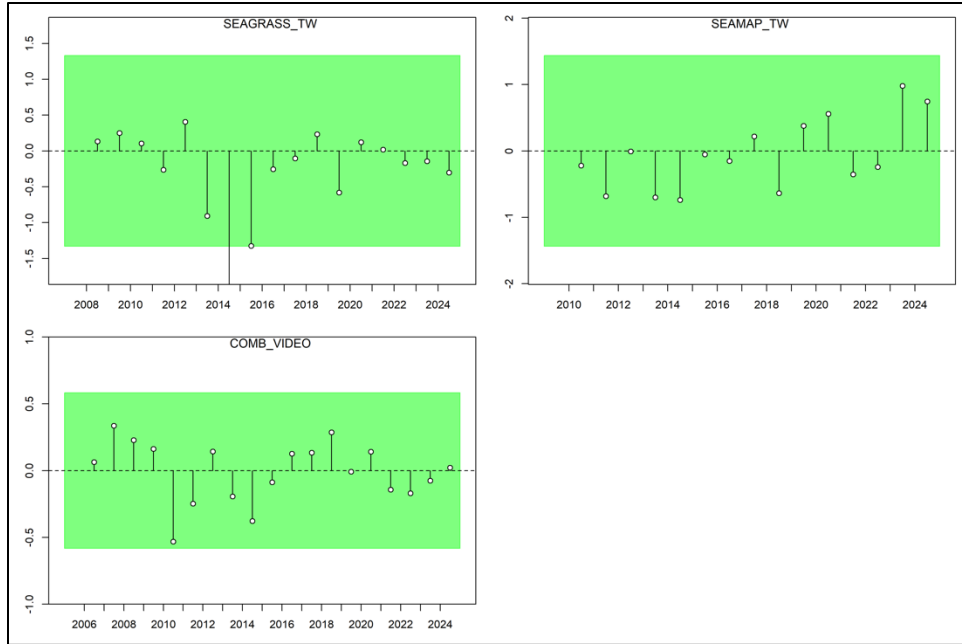


Figure 4.46. Runs tests results for the indices of abundance from the SEDAR 94 WFS base model. Green shading indicates no evidence ($p \geq 0.05$) and red shading evidence ($p < 0.05$) to reject the hypothesis of a randomly distributed time-series of residuals, respectively. Shaded regions span three residual standard deviations to either side from zero and red points outside of the shading indicate a violation of that ‘three-sigma limit’.

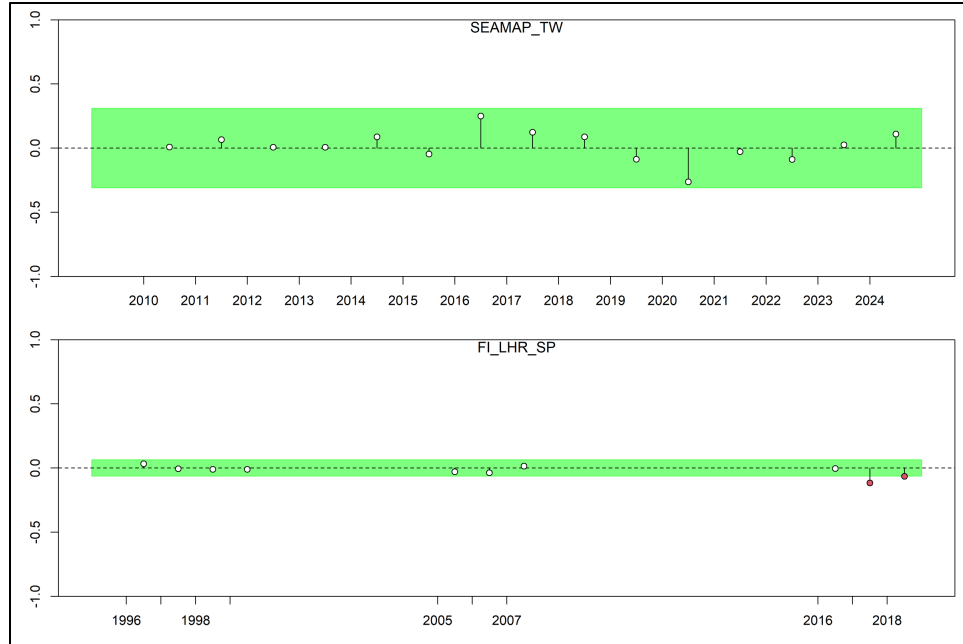


Figure 4.47. Runs tests results for the conditional age-at-length estimates (b) from the SEDAR 94 WFS base model. Green shading indicates no evidence ($p \geq 0.05$) and red shading evidence ($p < 0.05$) to reject the hypothesis of a randomly distributed time-series of residuals, respectively. Shaded regions span three residual standard deviations to either side from zero and red points outside of the shading indicate a violation of that ‘three-sigma limit’.

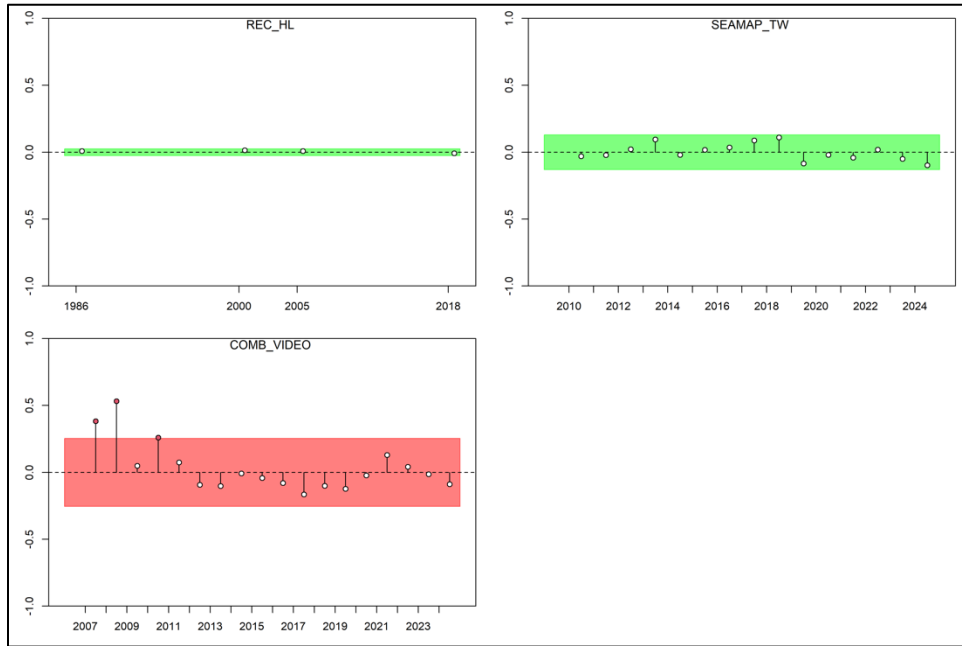


Figure 4.48. Runs tests results for the annual mean length estimates from the SEDAR 96 WFS base model. Green shading indicates no evidence ($p \geq 0.05$) and red shading evidence ($p < 0.05$) to reject the hypothesis of a randomly distributed time-series of residuals, respectively. Shaded regions span three residual standard deviations to either side from zero and red points outside of the shading indicate a violation of that ‘three-sigma limit’.

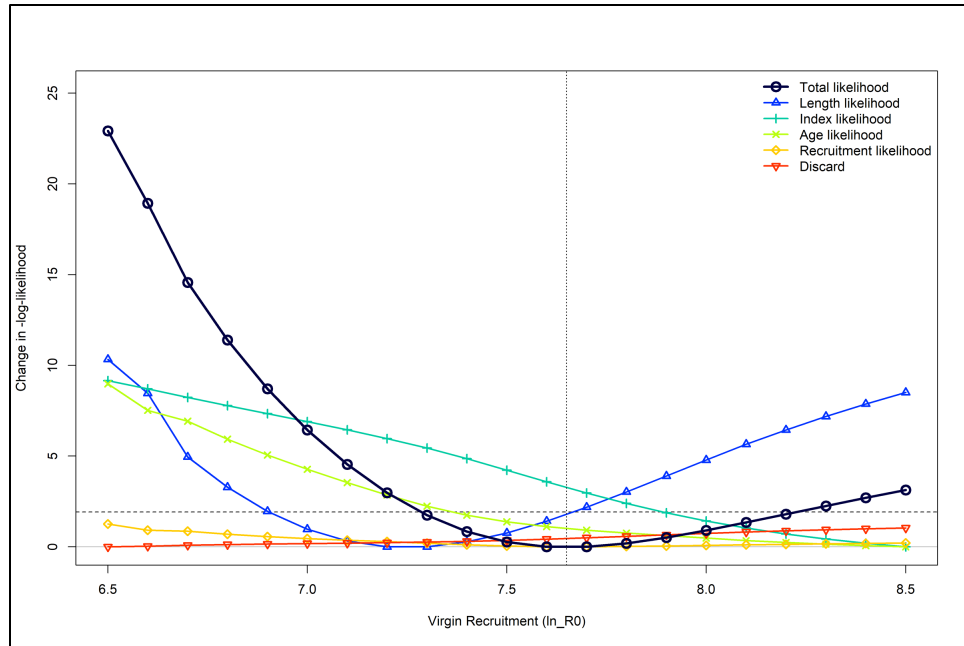


Figure 4.49. Log-likelihood profiles of the unfished (i.e., virgin) recruitment ($\ln(R0)$) parameter for various data components in the SEDAR 94 WFS base model.

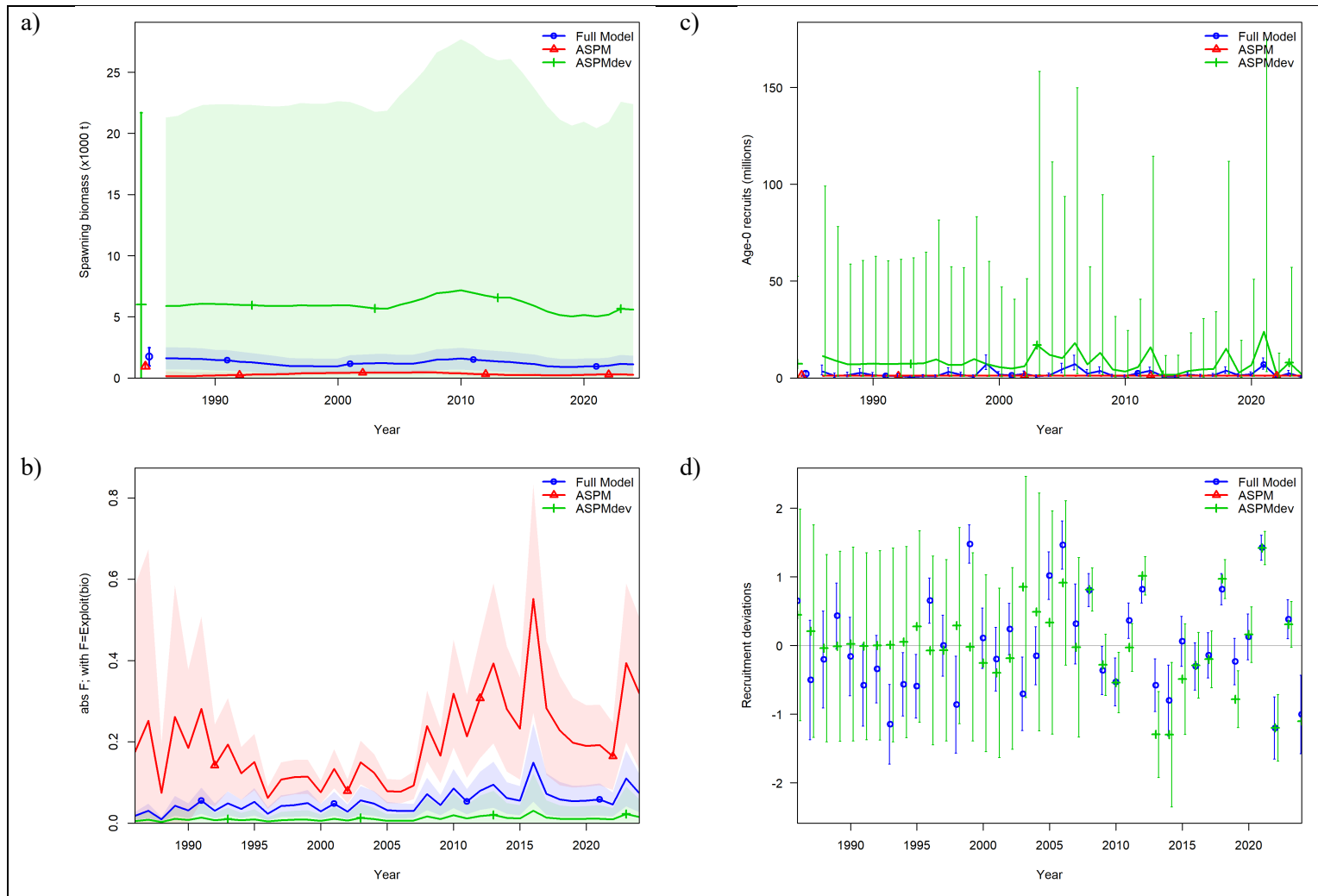


Figure 4.50. Results comparison between the SEDAR 94 WFS base model (Full Model), the deterministic Age-Structured-Production Model (ASPM), and the ASPM with recruitment deviations (ASPMdev) showing a) spawning stock biomass, b) exploitation rates, c) estimates of age-0 recruitment, and d) estimates of recruitment deviations.

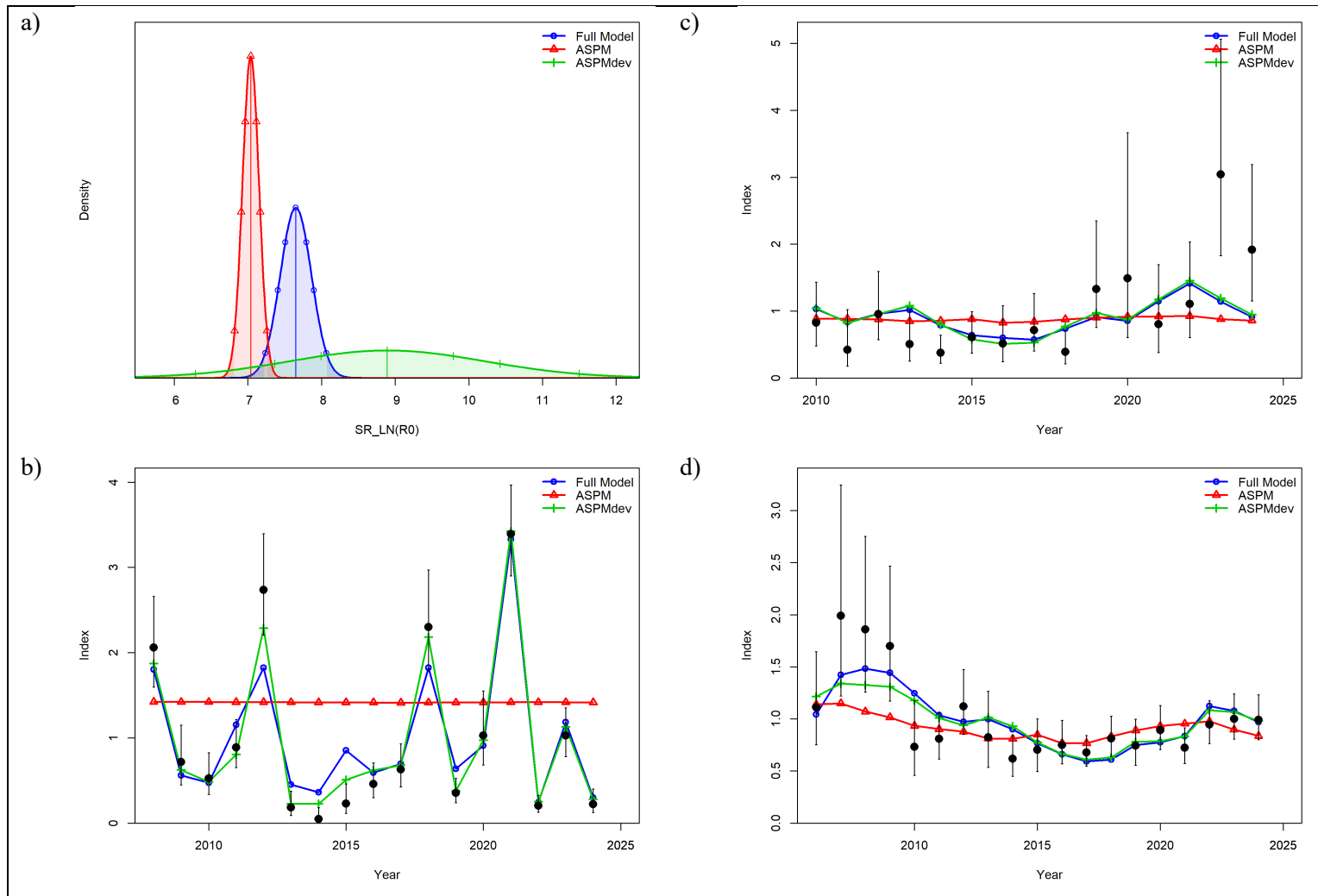


Figure 4.51. Results comparison between the SEDAR 94 WFS base model (Full Model), the deterministic Age-Structured-Production Model (ASPM), and the ASPM with recruitment deviations (ASPMdev) showing a) estimates of the virgin recruitment parameter in log-space $\ln(R0)$, b) observed and predicted values for the seagrass trawl index, c) observed and predicted values for the SEAMAP trawl index, and d) observed and predicted values for the combined video index.

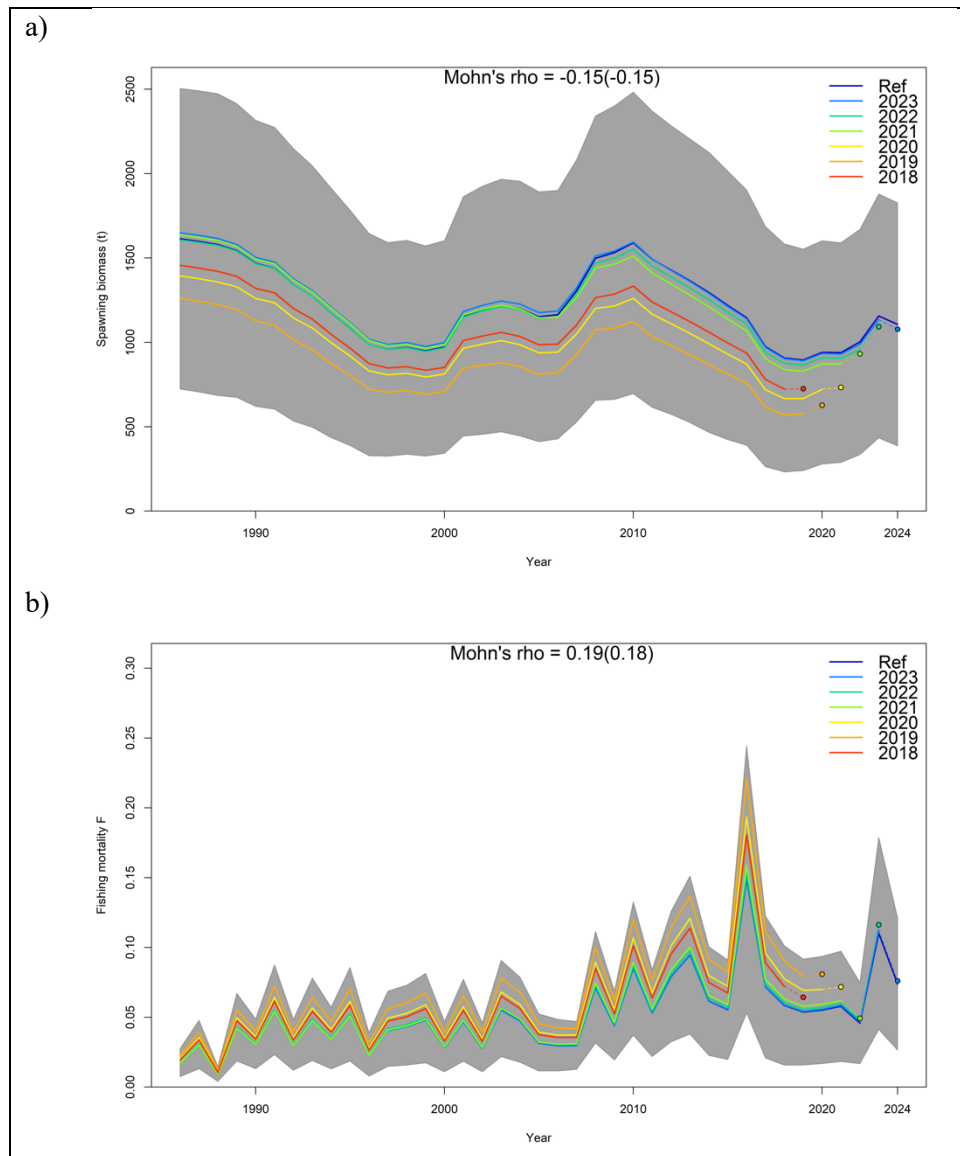


Figure 4.52. Retrospective forecast results of a) spawning stock biomass and b) exploitation rates conducted by re-fitting the SEDAR 94 WFS base model (Ref) after sequentially removing six years of observations. The Mohn's rho (ρ_M) statistic and corresponding forecast rho (ρ_F) values (in parenthesis) are provided at the top of each panel. One-year-ahead projections denoted by color-coded dashed lines with terminal points are shown for each peel. Grey shaded areas are the 95% confidence intervals from the SEDAR 94 WFS base model.

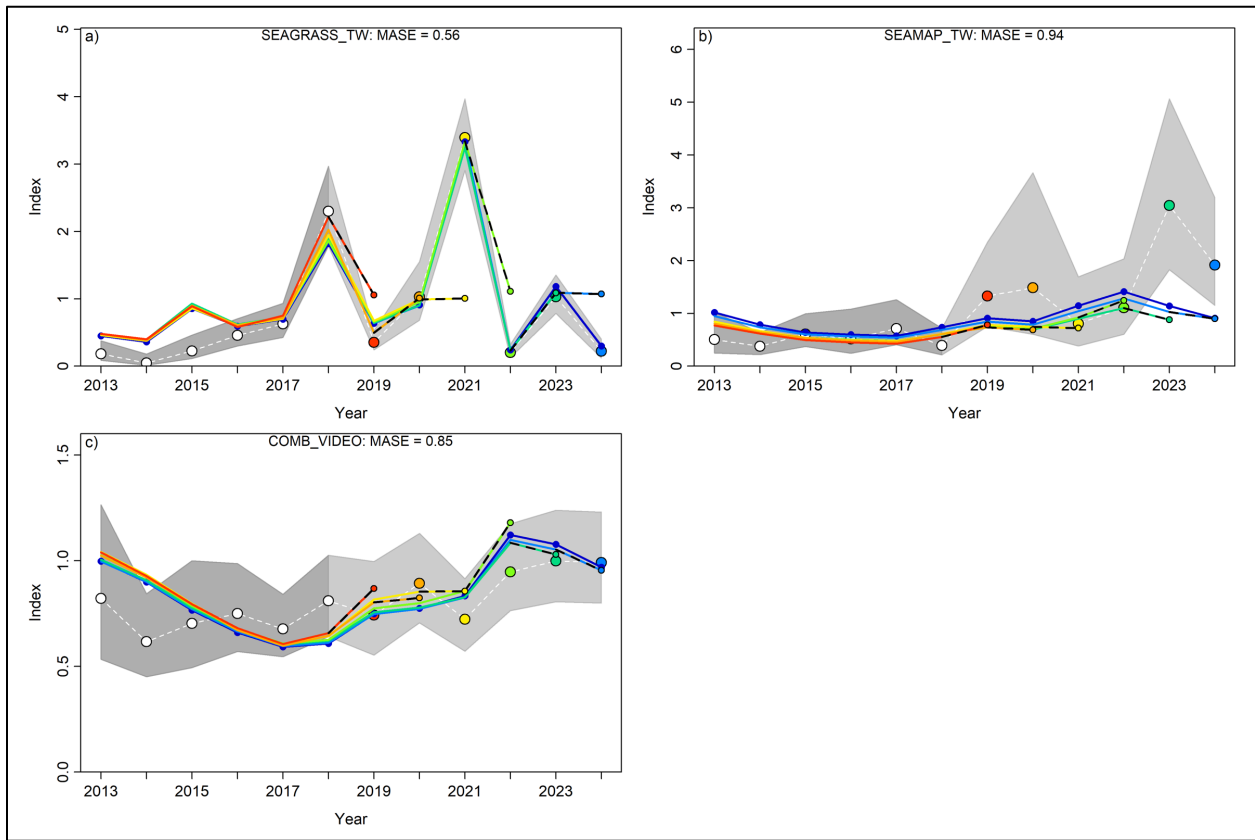


Figure 4.53. Hindcasting cross-validation results for the a) seagrass trawl index, b) SEAMAP trawl survey, and c) combined video survey from the SEDAR 94 WFS base model showing observed (large white points connected with dashed line), fitted (solid lines), and one-year ahead forecast values (small terminal points). The color-coded solid circles are the observations used for cross-validation and the light-gray shaded area is the associated 95 % confidence intervals. The mean absolute scaled error (MASE) scores for each index are provided at the top of each panel.

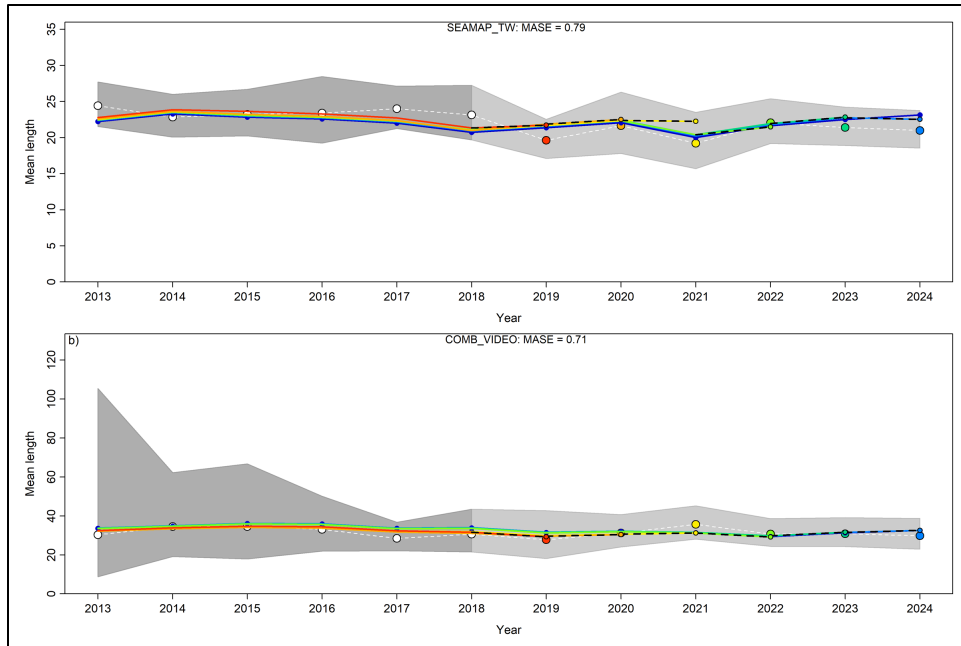


Figure 4.54. Hindcasting cross-validation results for a) SEAMAP trawl survey and b) combined video survey annual mean length estimates from the SEDAR 94 WFS base model showing observed (large white points connected with dashed line), fitted (solid lines), and one-year ahead forecast values (small terminal points). The color-coded solid circles are the observations used for cross-validation and the light-gray shaded area is the associated 95 % confidence intervals. The mean absolute scaled error (MASE) scores for each length composition series are provided at the top of each panel.

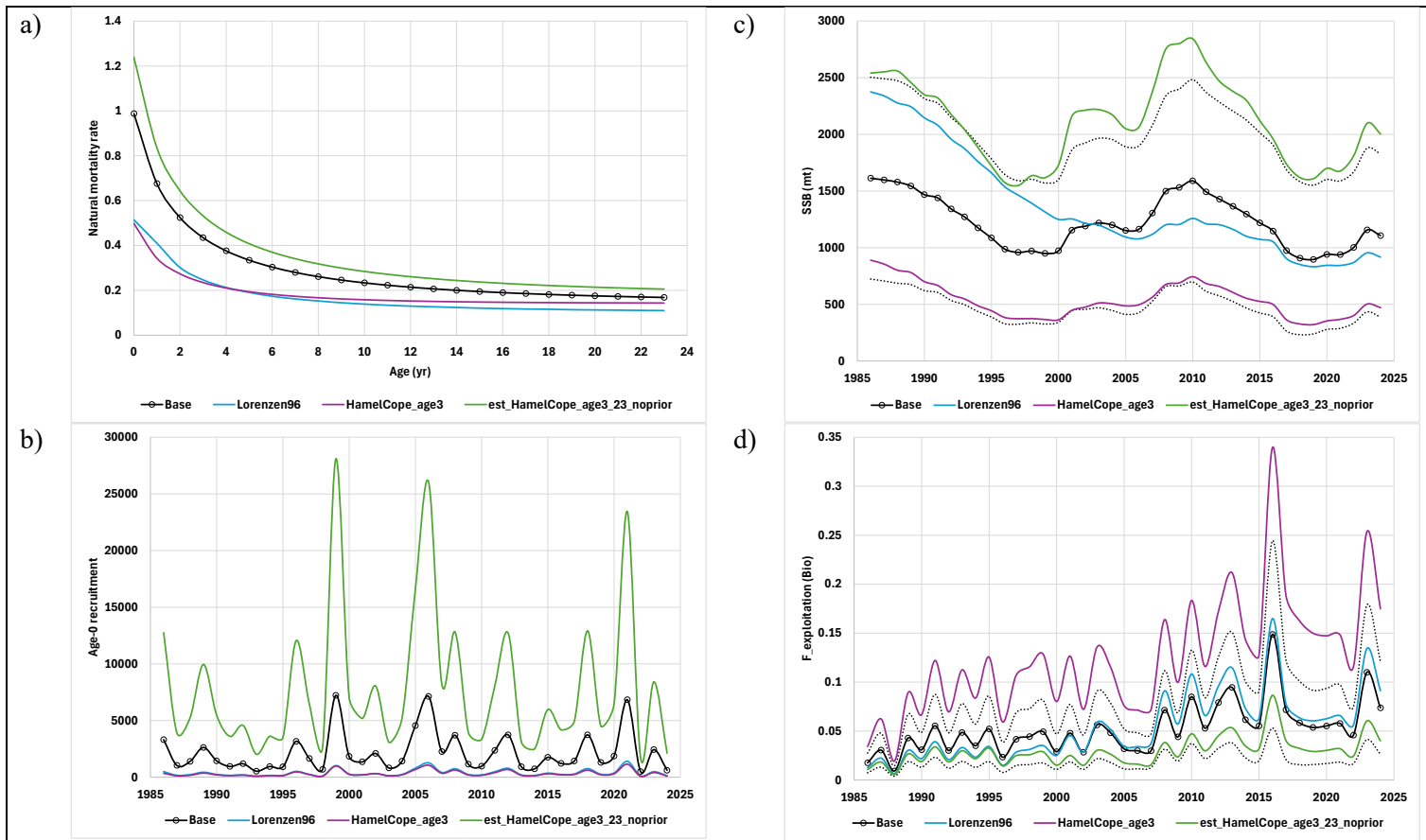


Figure 4.55. Comparison of natural mortality sensitivity runs for estimated M, age-0 recruitment, spawning stock biomass (SSB), and fishing mortality (F) for the WFS base model. Sensitivity runs included Lorenzen (1996) mortality-at-weight, Hamel and Cope (2022) age-3 specified M, and Hamel and Cope (2022) age-3 estimated M without a prior constraint.

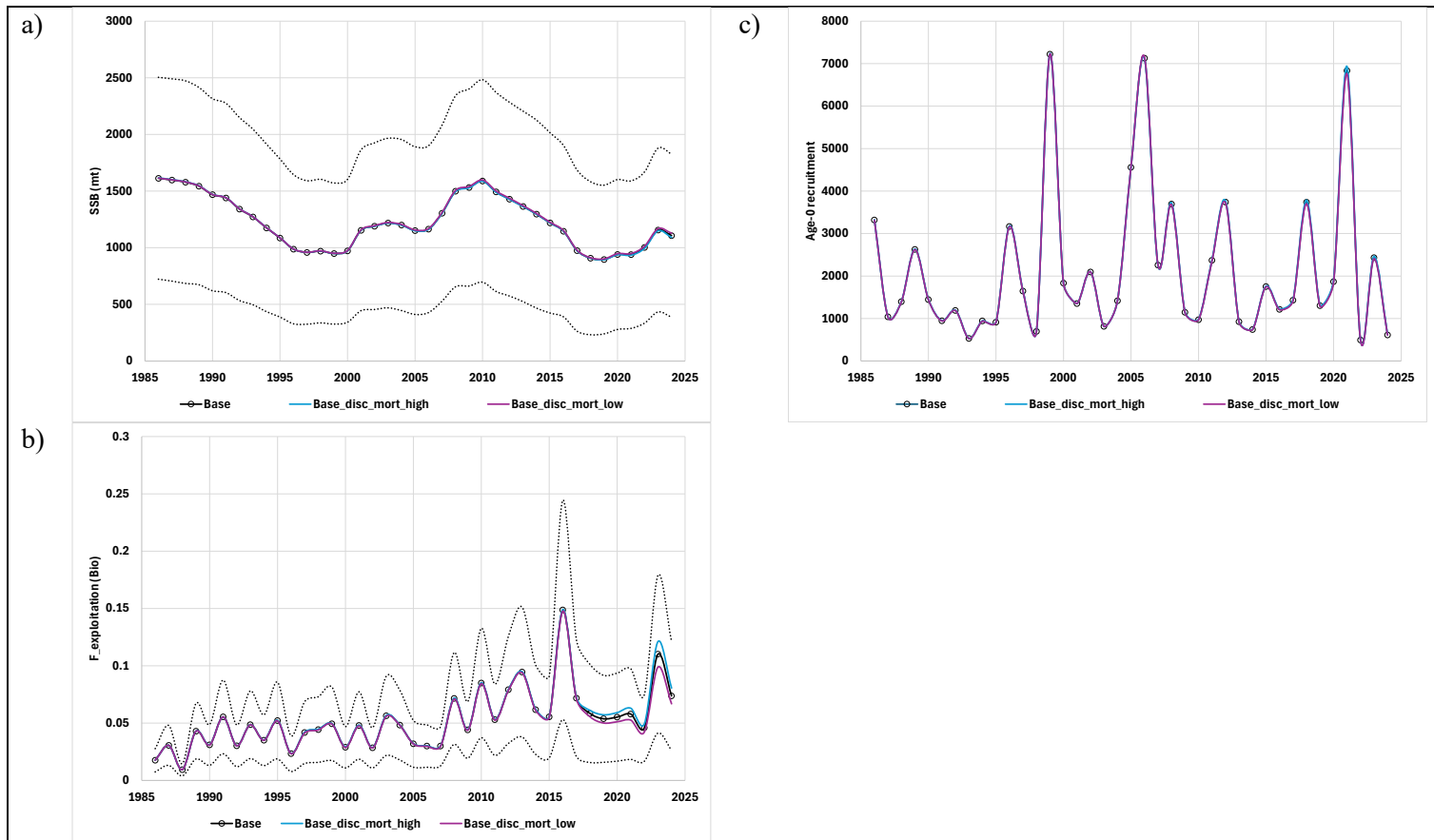


Figure 4.56. Comparison of model outputs from discard mortality sensitivity runs, including age-0 recruitment, spawning stock biomass (SSB), and fishing mortality (F), for the WFS base model and alternative high and low discard mortality scenarios applied to the recreational hook and line fleet.

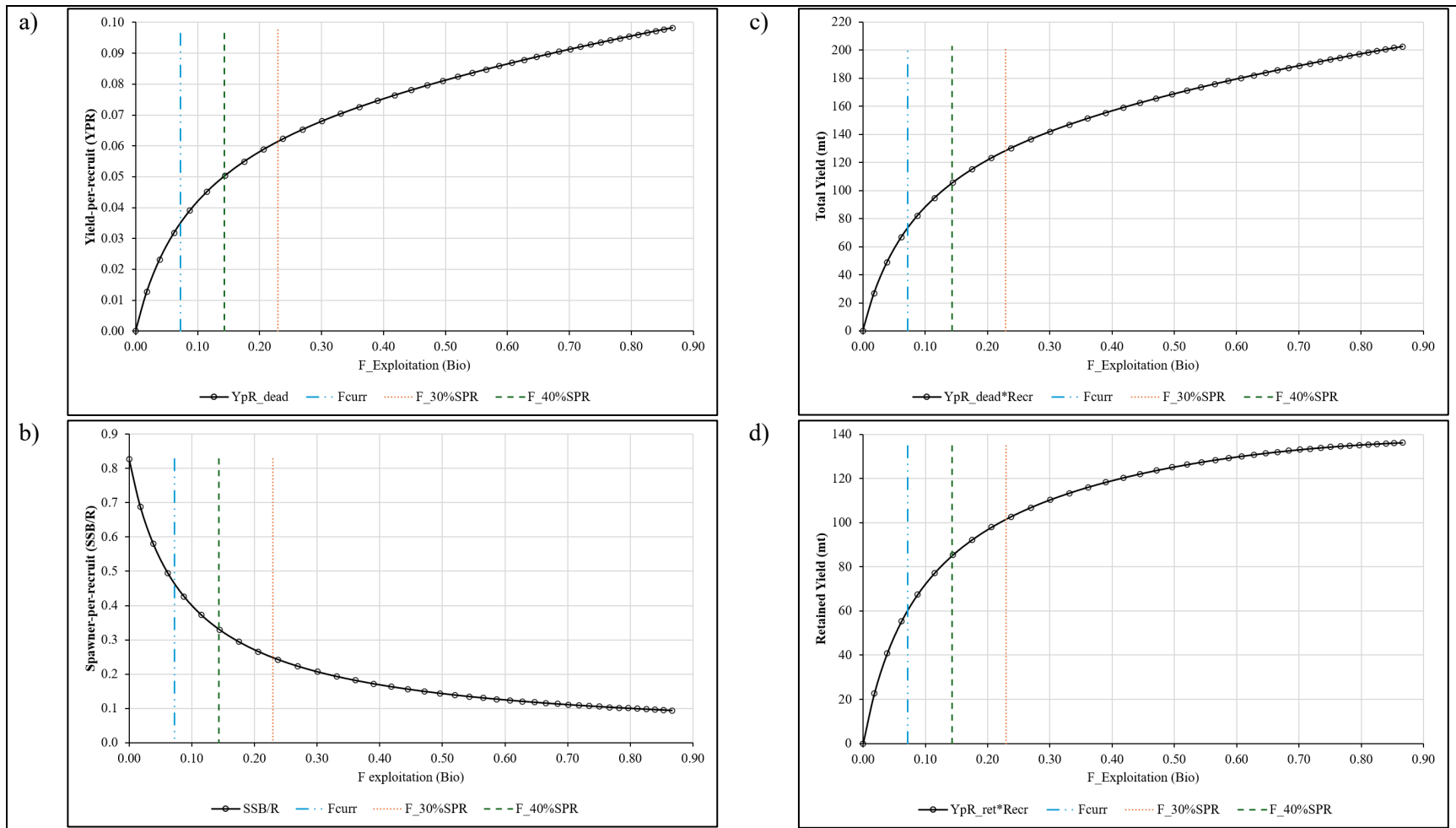


Figure 4.57. The a) yield-per-recruit, b) spawner-per-recruit, c) total equilibrium yield, and d) retained equilibrium yield computed as a function of the instantaneous exploitation rate on West Florida Shelf Hogfish.

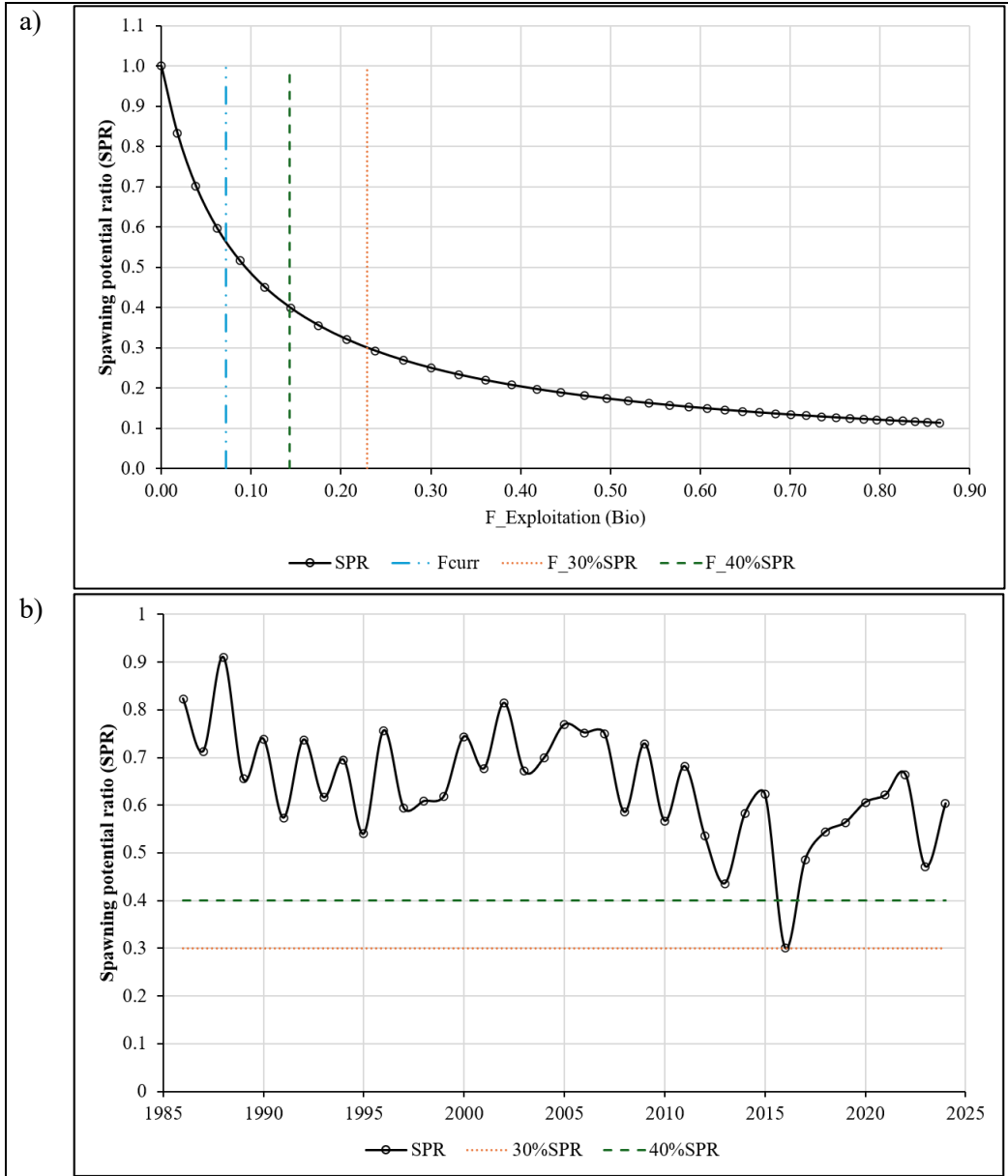


Figure 4.58. The a) static spawning potential ratio (SPR) computed as a function of the instantaneous exploitation rate, and b) static spawning potential ratio (SPR) by year for West Florida Shelf Hogfish.

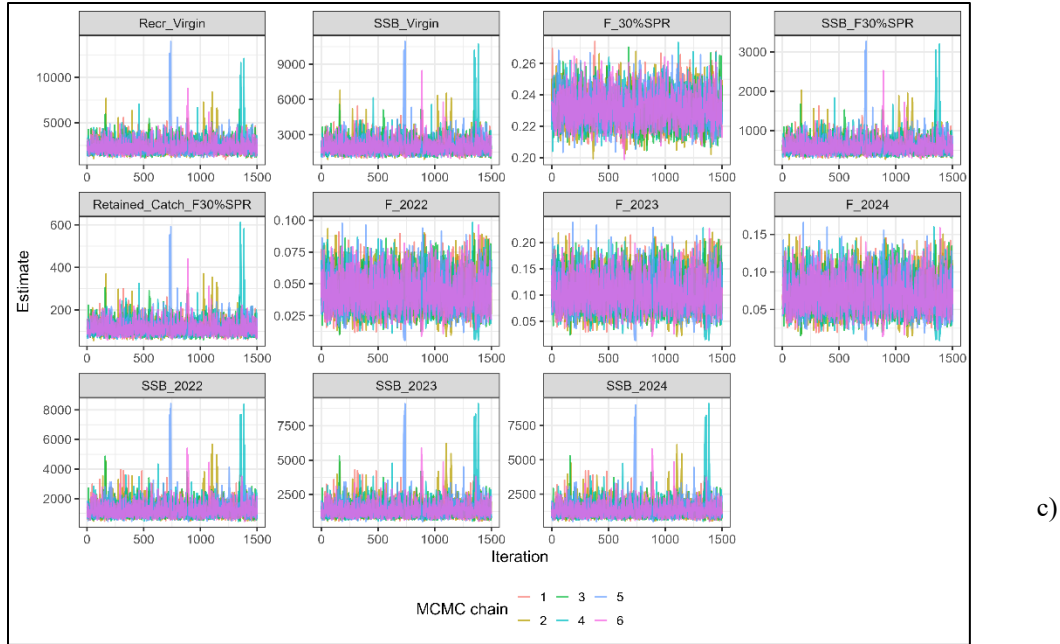


Figure 4.59. Combined trace plots of the six MCMC chains for selected parameters and derived quantities from the SEDAR 94 WFS base model.

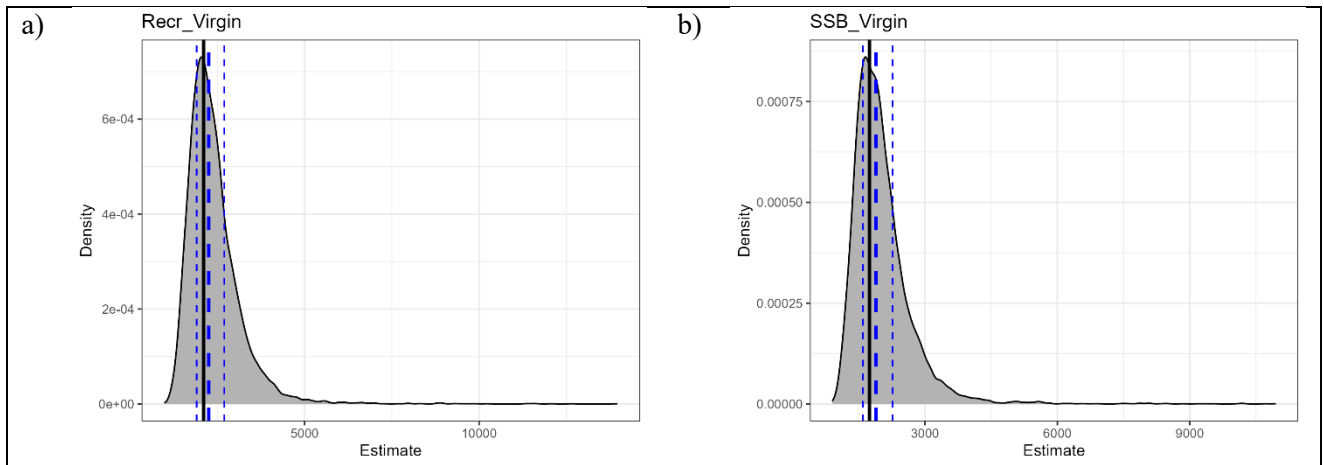


Figure 4.60. The posterior distributions for a) R_0 (i.e., virgin recruitment) and b) SSB_0 (i.e., virgin spawning stock biomass) the combined four-chain MCMC. The blue dashed lines indicate the median and interquartile range while the solid black line is the estimate from the SEDAR 94 WFS base model.

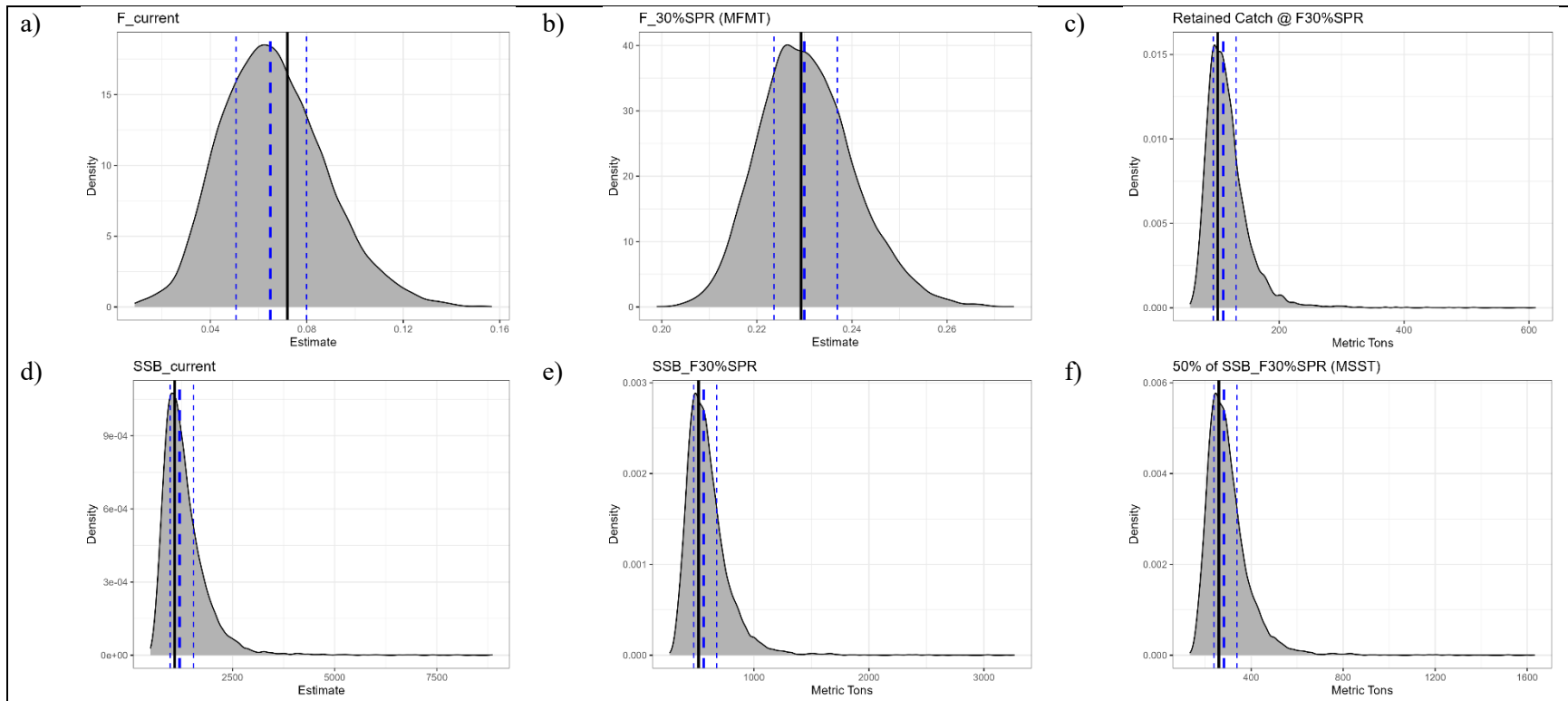


Figure 4.61. The posterior distributions for a) $F_{current}$ (i.e., geometric mean of F for years 2022 – 2024), b) $F_{30\%SPR}$ (i.e., MFMT), and c) the retained yield associated with $F_{30\%SPR}$, d) $SSB_{current}$ (i.e., geometric mean of SSB for years 2022 – 2024), e) SSB at $F_{30\%SPR}$, and f) 50% of SSB at $F_{30\%SPR}$ (i.e., MSST) from the combined six-chain MCMC. The blue dashed lines indicate the median and interquartile range while the solid black line is the estimate from the SEDAR 94 WFS base model.

c)

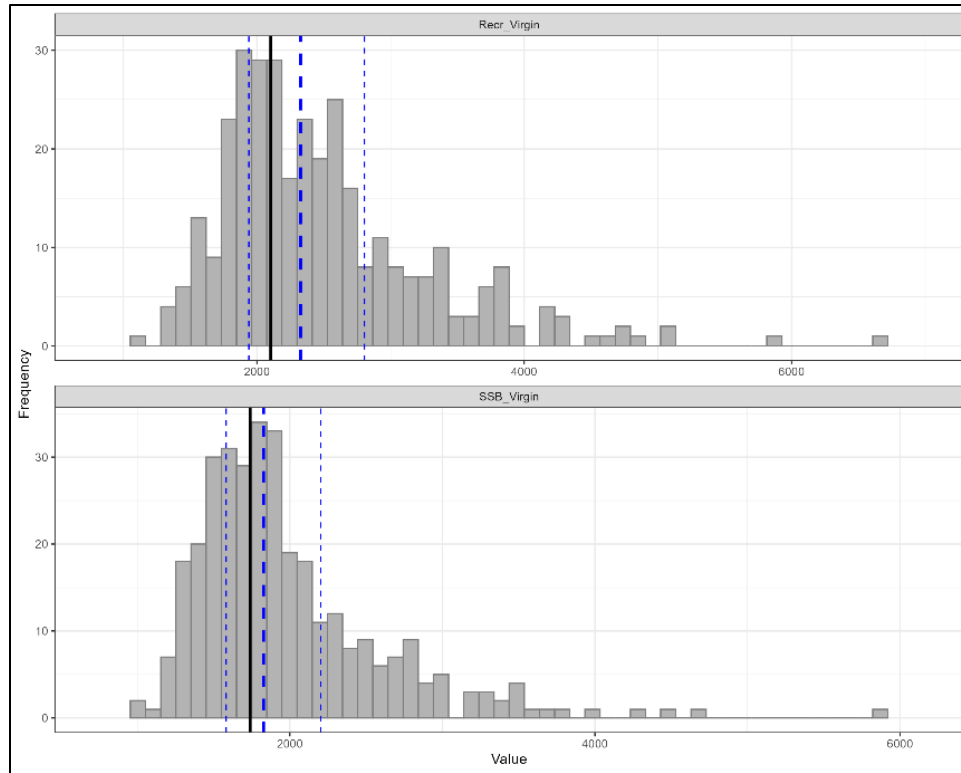


Figure 4.62. Distributions for R_0 (i.e., virgin recruitment) and SSB_0 (i.e., virgin spawning stock biomass) from parametric bootstrapping the SEDAR 94 base model. The blue dashed lines indicate the median and interquartile range while the solid black line is the estimate from the SEDAR 94 WFS base model.

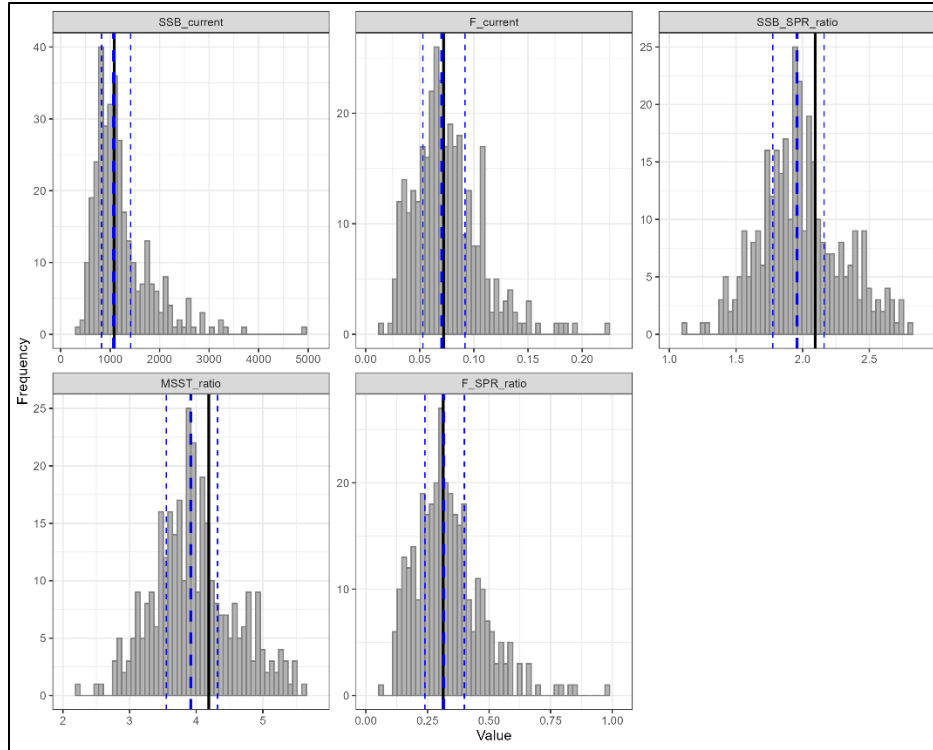


Figure 4.63. Distributions of selected parameter estimates and derived quantities from parametric bootstrapping the SEDAR 94 base model. The blue dashed lines indicate the median and interquartile range while the solid black line is the estimate from the SEDAR 94 WFS base model.

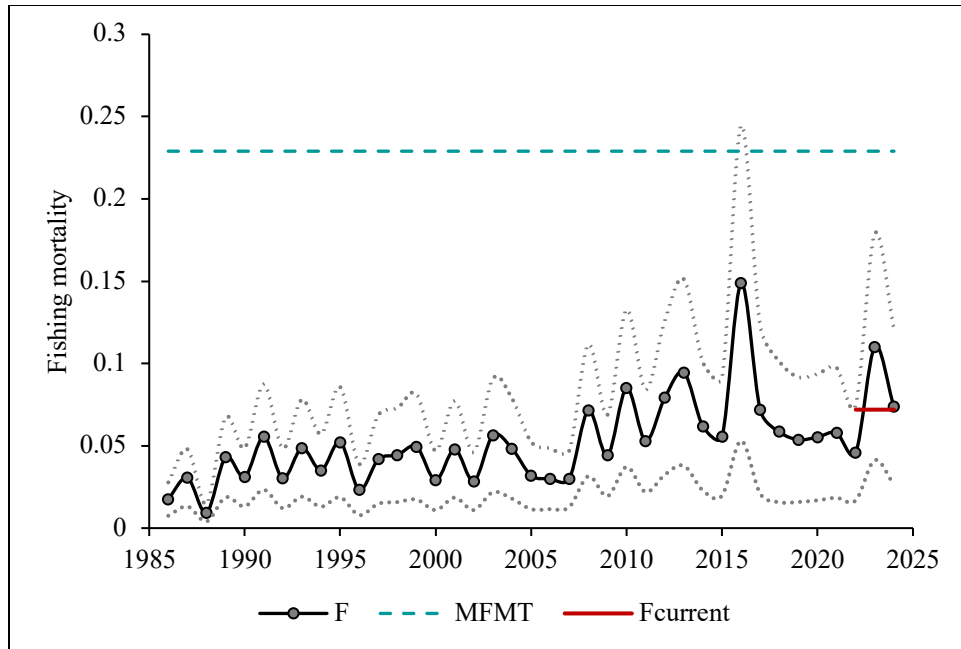


Figure 4.64. Annual estimates of fishing mortality relative to MFMT (i.e., $F_{30\%SPR}$) and the geometric mean of fishing mortality in the last three years ($F_{current}$) from the SEDAR 94 WFS base model. Dotted lines represent 95% confidence intervals.

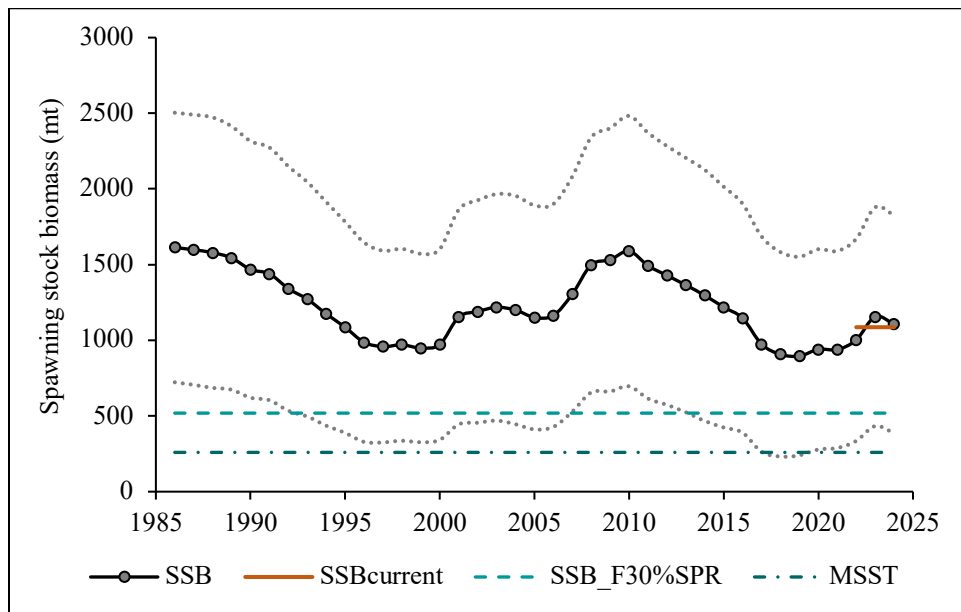


Figure 4.65. Annual estimates of spawning stock biomass (SSB) relative to MSST (i.e., 50% $SSB_{F30\%SPR}$), $SSB_{F30\%SPR}$, and the geometric mean of SSB in the last three years ($SSB_{current}$) from the SEDAR 94 WFS base model. Dotted lines represent 95% confidence intervals.

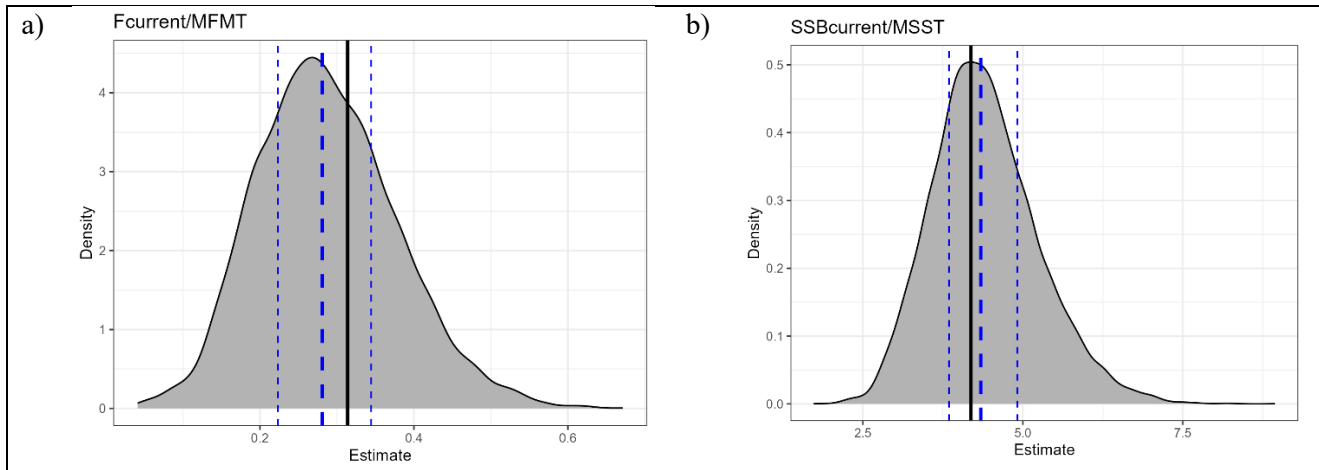


Figure 4.66. The posterior distribution for the F ratio ($F_{\text{current}}/\text{MFMT}$) and SSB ratio ($\text{SSB}_{\text{current}}/\text{MSST}$) values from the combined six-chain MCMC. The blue dashed lines indicate the median and interquartile range while the solid black line is the estimate from the SEDAR 94 WFS base model.

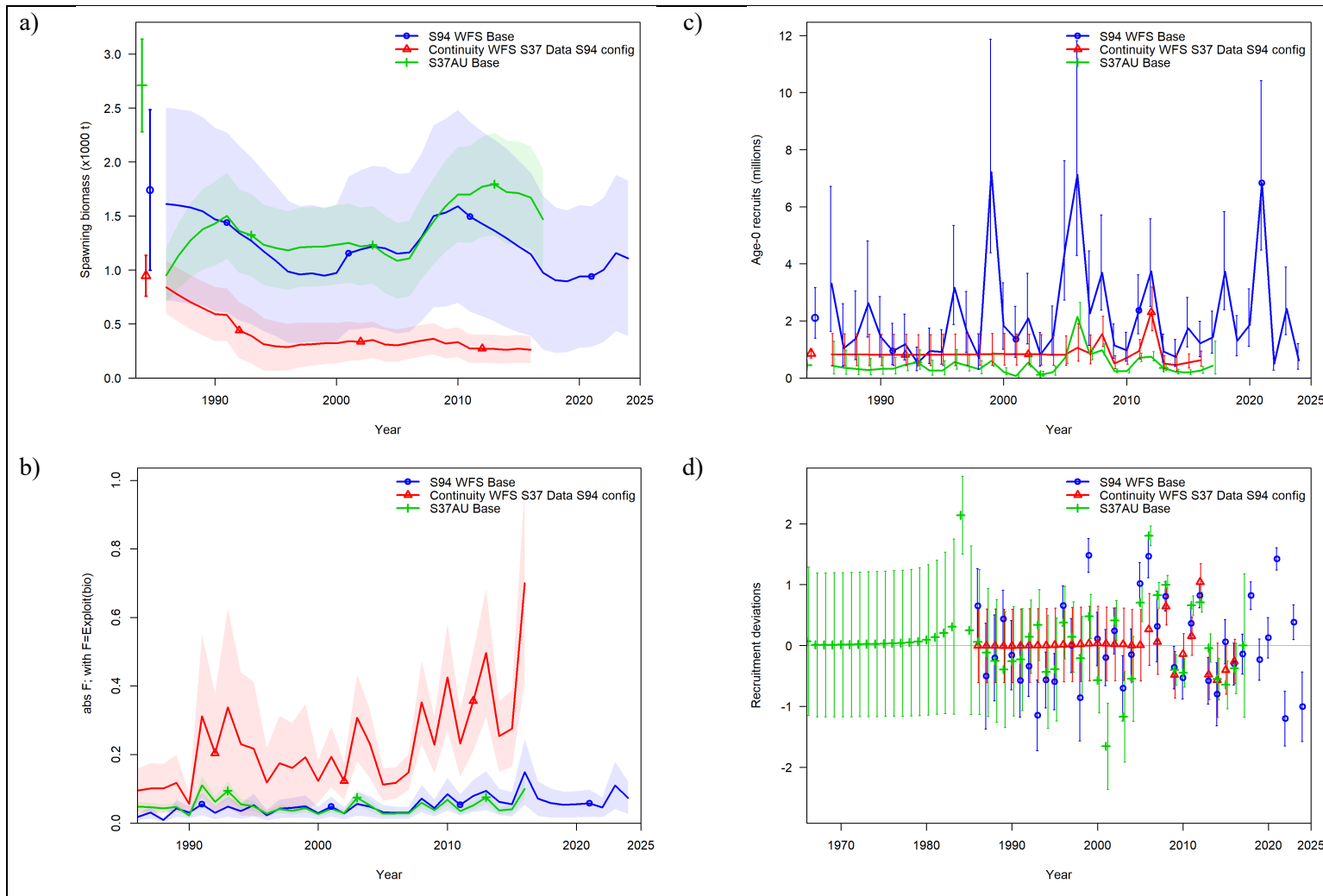


Figure 4.67. A comparison of the results between the SEDAR 37 Update base model (“S37U Base”), the SEDAR 94 WFS Base model (“S94 WFS Base”) and the Continuity run using data from S37U with the model configuration of S94 (“Continuity WFS S37 Data S94 config”) for a) spawning stock biomass, b) fishing mortality, c) age-0 recruits, and d) recruitment deviations.

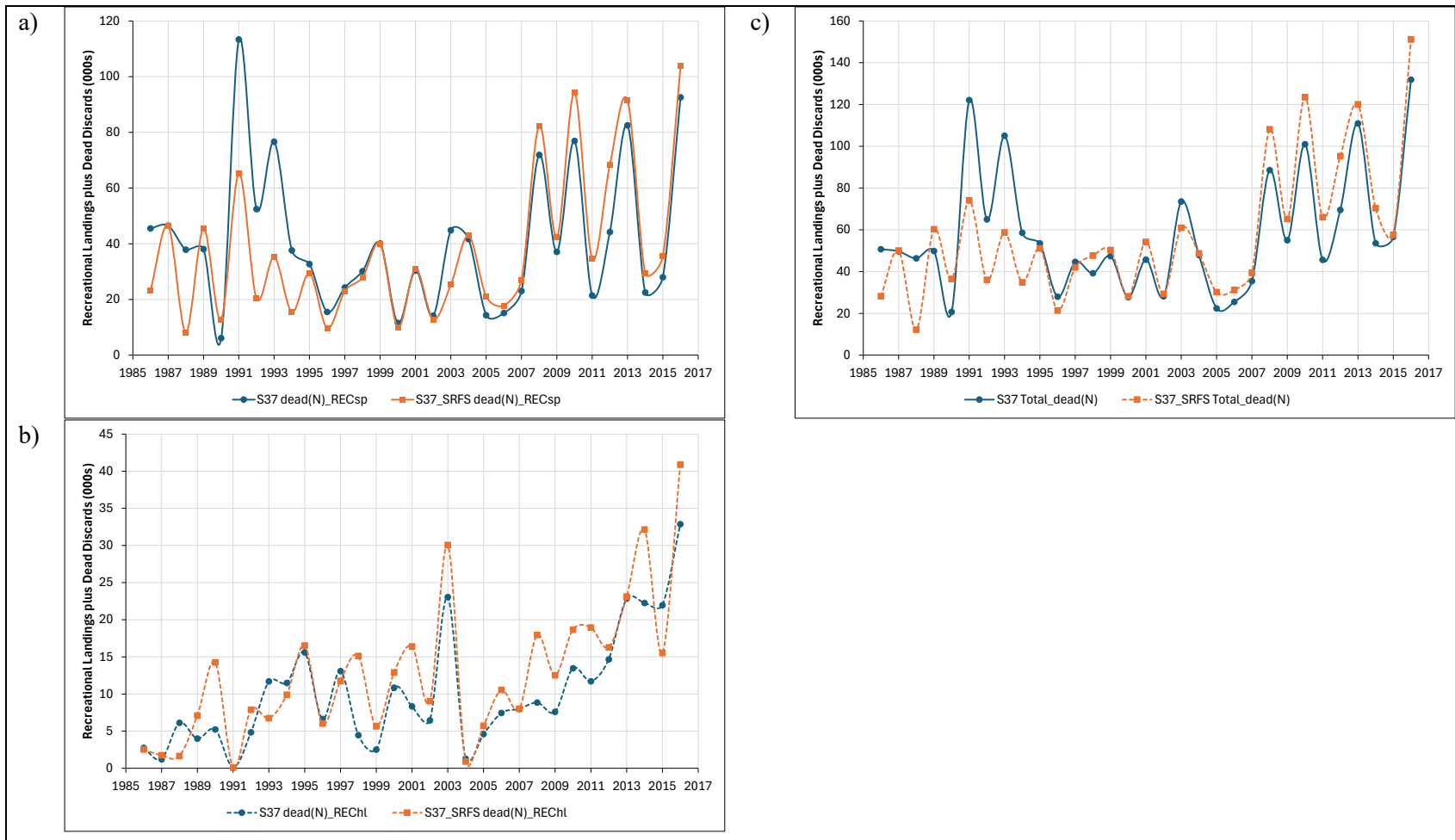


Figure 4.68. A comparison of the input recreational landings plus dead discards in numbers (dead[N]) between the SEDAR 37 WFS base model (S37) and the SEDAR 37 WFS base model containing the ‘Full SRFS’ (S37_SRFS) catch timeseries a) for the spear gear, b) for the hook-and-line gears, and c) when gears were combined as configured for the S94 WFS base model.

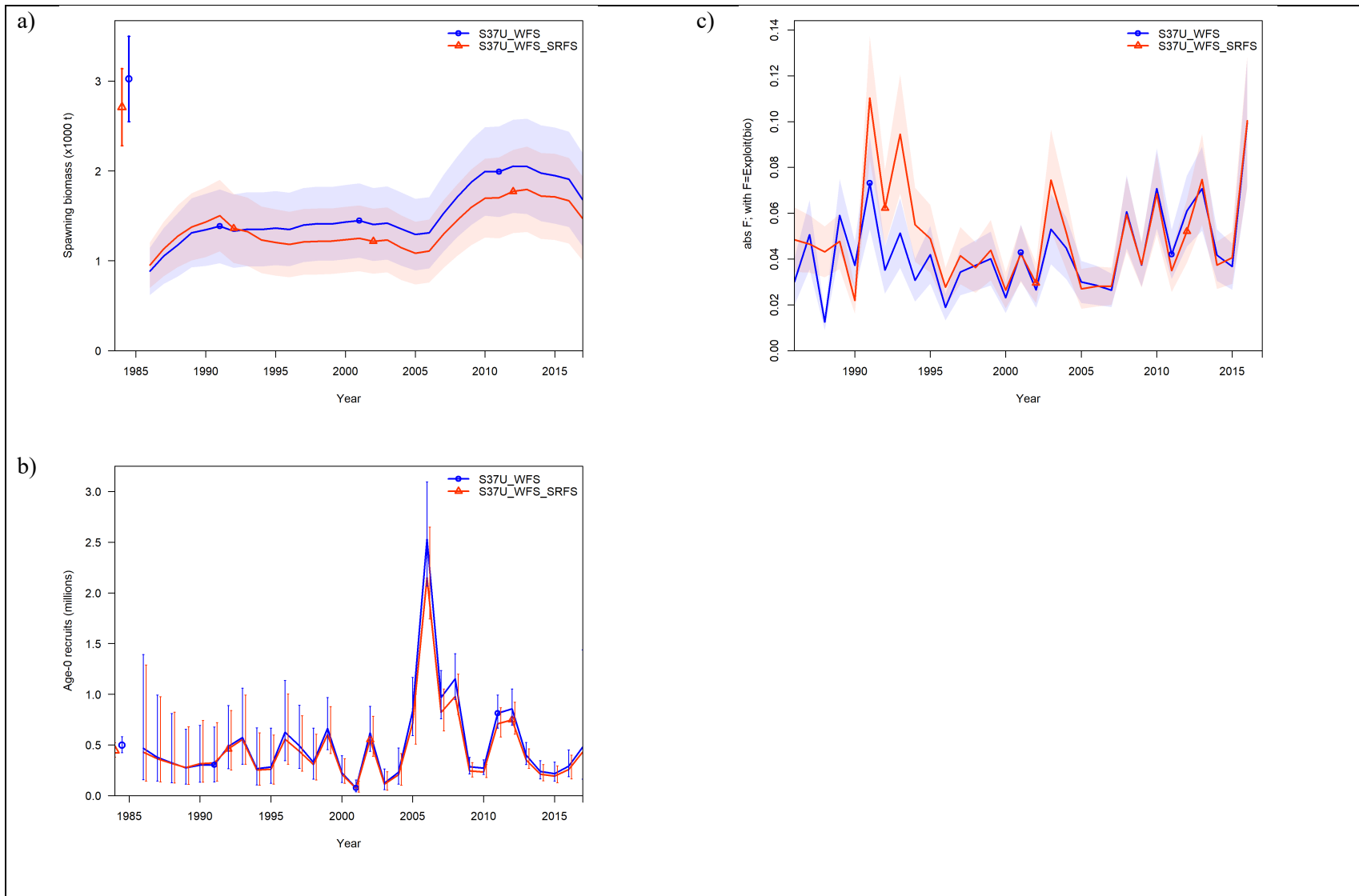


Figure 4.69. A comparison of the results between the SEDAR 37 update WFS base model (S37U_WFS) and the SEDAR 37 update WFS base model containing the ‘Full SRFS’ catch timeseries (S37U_WFS_SRFS) for a) spawning stock biomass, b) age-0 recruitment, and c) exploitation rates.

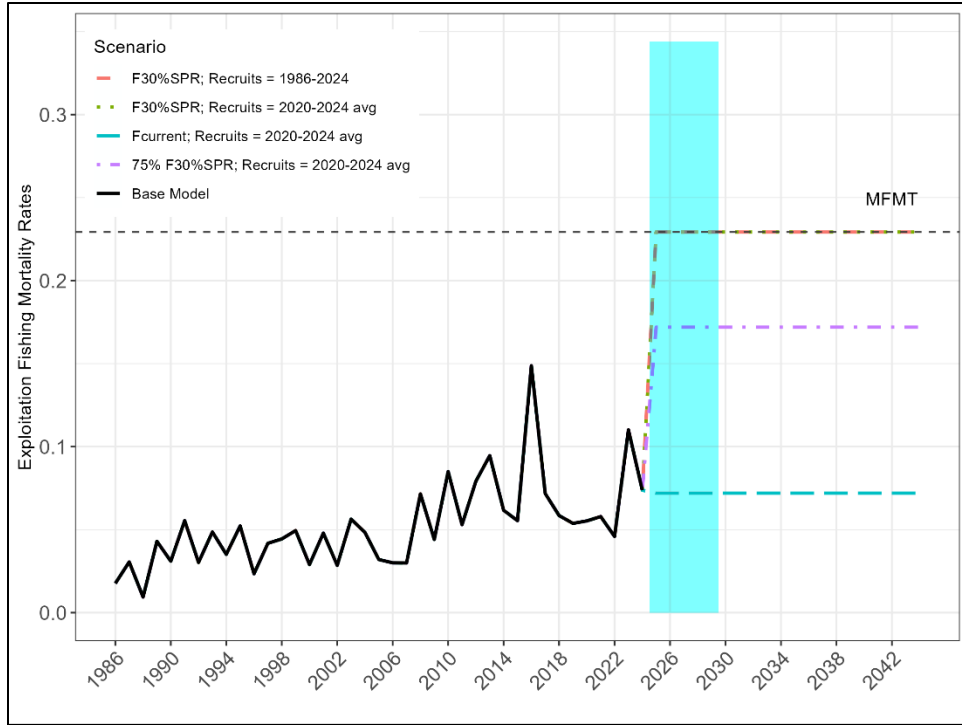


Figure 4.70. Exploitation fishing mortality rates based on projections under long-term equilibrium $F_{30\%SPR}$ (red dashed line), short-term $F_{30\%SPR}$ (green dotted line), $F_{current}$ (teal dashed line), the level that corresponds to 75% $F_{30\%SPR}$ (purple dot-dashed line), and as estimated by the SEDAR 94 WFS base model (black solid line). The cyan region highlights the first five years of the projection (2025-2029).

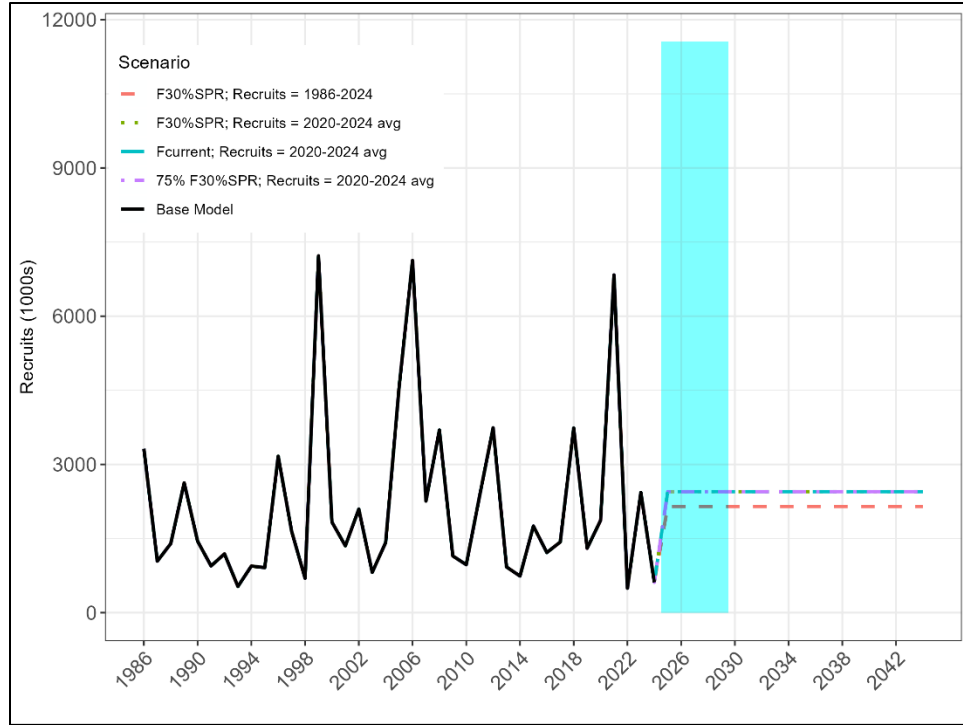


Figure 4.71. Age-0 recruits (in thousands) based on projections under long-term equilibrium $F_{30\%SPR}$ (red dashed line), short-term $F_{30\%SPR}$ (mustard dotted line), $F_{current}$ (teal dashed line), the level that corresponds to 75% $F_{30\%SPR}$ (purple dot-dashed line), and as estimated by the SEDAR 94 WFS base model (black solid line). The cyan region highlights the first five years of the projection (2025-2029).

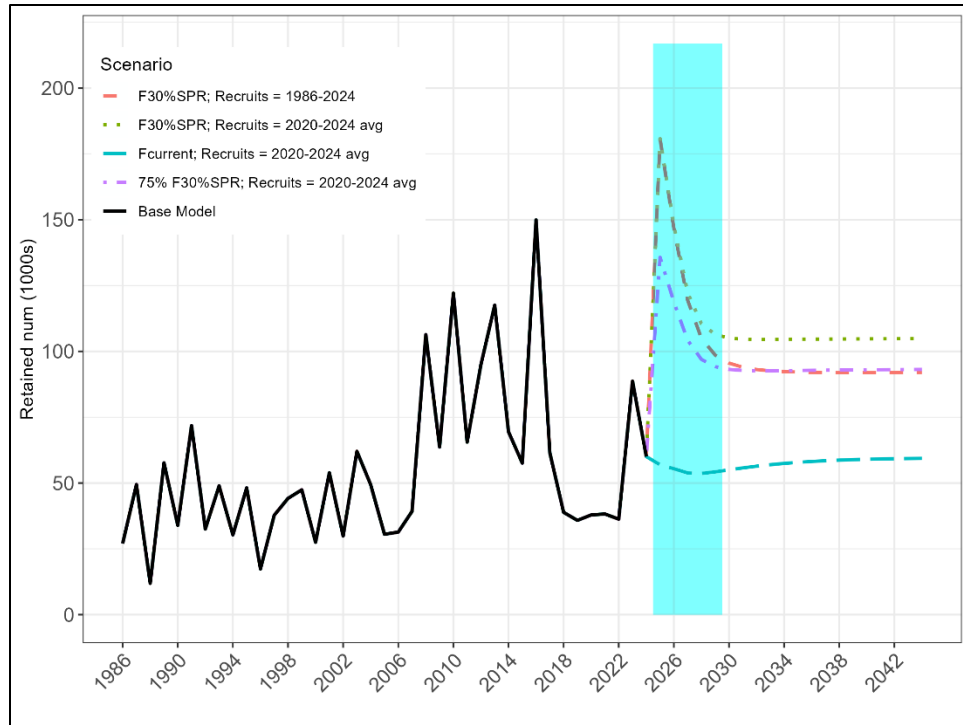


Figure 4.72. Retained yield (numbers) based on projections under long-term equilibrium $F_{30\%SPR}$ (red dashed line), short-term $F_{30\%SPR}$ (mustard dotted line), $F_{current}$ (teal dashed line), the level that corresponds to 75% $F_{30\%SPR}$ (purple dot-dashed line), and as estimated by the SEDAR 94 WFS base model (black solid line). The cyan region highlights the first five years of the projection (2025 – 2029).

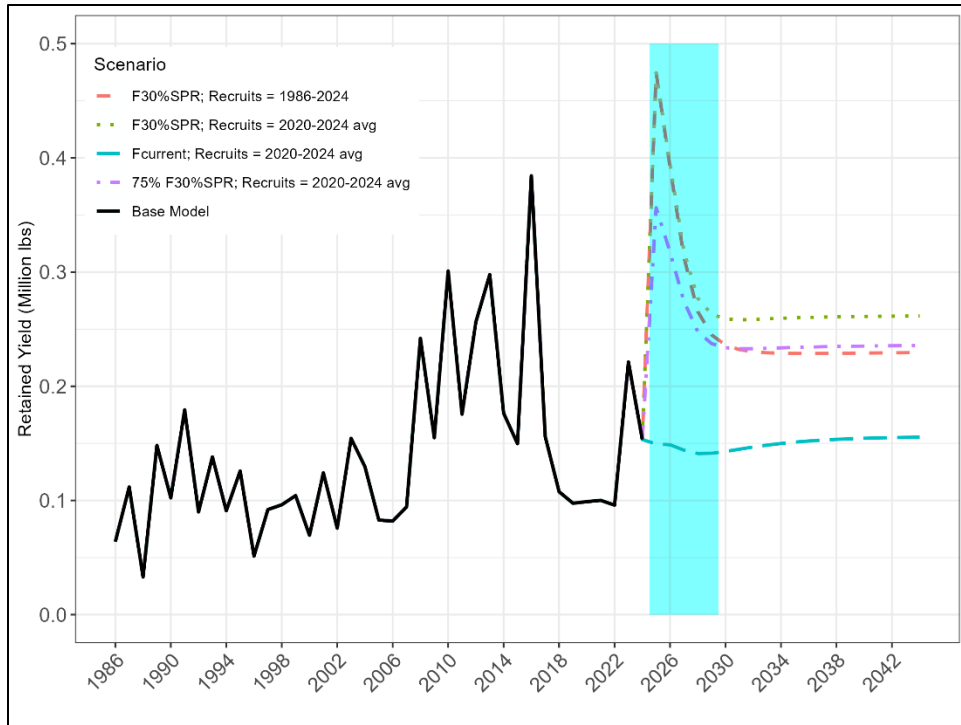


Figure 4.73. Retained yield (million pounds) based on projections under long-term equilibrium $F_{30\%SPR}$ (red dashed line), short-term $F_{30\%SPR}$ (mustard dotted line), $F_{current}$ (teal dashed line), the level that corresponds to 75% $F_{30\%SPR}$ (purple dot-dashed line), and as estimated by the SEDAR 94 WFS base model (black solid line). The cyan region highlights the first five years of the projection (2025 – 2029).

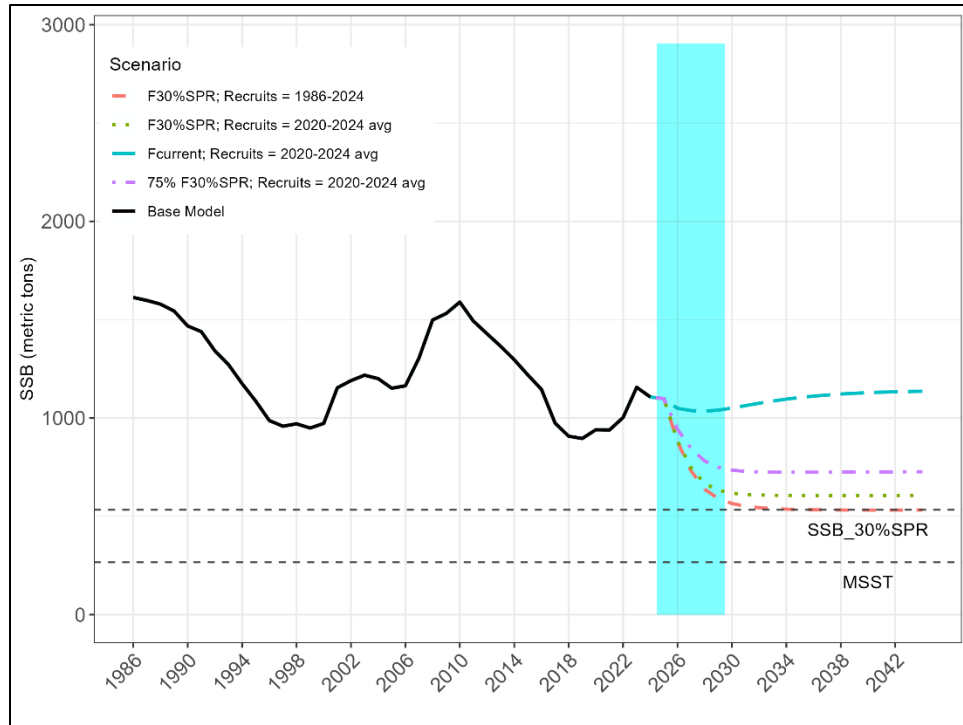


Figure 4.74. Spawning stock biomass (metric tons) based on projections under long-term equilibrium $F_{30\%SPR}$ (red dashed line), short-term $F_{30\%SPR}$ (mustard dotted line), $F_{current}$ (teal dashed line), the level that corresponds to 75% $F_{30\%SPR}$ (purple dot-dashed line), and as estimated by the SEDAR 94 WFS base model (black solid line). The cyan region highlights the first five years of the projection (2025 – 2029).

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