SEDAR 84

Southeast Fisheries Science Center

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Executive Summary

The SEDAR 84 St. Croix stoplight parrotfish (Sparisoma viride) stock assessment process consisted of four webinars between April 2024 and October 2024. The data available for the assessment included:

- An annual species-specific catch time series from a commercial logbook program
- Fishery-dependent length compositions from a commercial port sampling program
- Fishery-independent length compositions from a stratified random sampling survey of reef fish
- A fishery-independent index of abundance from a stratified random sampling survey of reef fish
- Life history information from otolith analysis and gonad histology

The assessment used Stock Synthesis, a statistical catch-at-age model (Methot et al.). Stock Synthesis models were initially configured using an annual catch time series and compositions that were aggregated across the available years for each source of length data. Model development proceeded stepwise from the simplest configuration to those of moderate complexity. Those sequential steps included the inclusion of the index of abundance and annual fishery-independent length compositions. Models were run with and without the estimation of recruitment deviations. Finally, the sensitivity of the assessment outcomes was investigated using alternative inputs for longevity-informed natural mortality, parameterization of hermaphroditism, and reweighting of the effective sample size of the length composition data.

All of the configurations resulted in inconclusive results, evidenced by high correlations between the scale of the average recruitment and the fishing mortality rate of the initial equilibrium state. Likelihood profile diagnostics further indicate that the configurations explored could not reliably estimate the stock status. Thus, the overfished status of the St. Croix stoplight parrotfish stock remains unknown. However, the available data do not indicate a decline in the abundance index concurrent with a decrease in landings and show constant trends in size composition quarantines. These findings suggest that the St. Croix stoplight parrotfish is not likely to be undergoing overfishing in 2022.

1 Background

The stoplight parrotfish (Sparisoma viride) is a sequential protogynous hermaphrodite that inhabits coral reefs in the Caribbean Sea, Florida, Gulf of Mexico, Bermuda, and Brazil. It is an herbivorous species that is targeted in reef fish fisheries throughout much of the Caribbean, including St. Croix, USVI.

1.1 Management

St. Croix stoplight parrotfish is managed under the St. Croix Fishery Management Plan (Crabtree). In 2023, the Caribbean Fisheries Management Council transitioned from species-based to island-based fisheries management (Figure 1.1). The management measures in the new island-based fishery management plans became effective on October 13, 2022.

The Parrotfish 2 stock complex includes two indicator stocks and five other species. The indicator species are stoplight parrotfish and redtail parrotfish (Sparisoma chrysopterum). The allowable biological catch for the complex was established using tier 4a of the 4-tired ABC control rule. The allowable biological catch and the annual catch limit are 85,135 and 72,365 pounds whole weight, respectively.

The Southeast Fisheries Science Center provided a SEDAR 84 Data Workshop working paper summarizing federal management actions for stoplight parrotfish in St. Croix. On August 29, 2013, a 9-inch federal size limit was instituted by Final Regulatory Amendment 4. The size limit only applies in the U.S. EEZ surrounding St. Croix, defined as the federal waters ranging from 3 to 200 nautical miles (nm) (5.6 – 370 kilometers [km]) from the nearest coastline point of the U.S. Virgin Islands (Figure 1.2).

1.2 Assessment History

Before the current assessment, only one stock assessment had been attempted for St. Croix stoplight parrotfish (SEDAR, *SEDAR 46 Caribbean Data-Limited Species Stock Assessment Report*). The St. Croix Stoplight Parrotfish SEDAR 46 evaluations were performed using the Data-Limited Methods Toolkit (Carruthers and Hordyk). The approach applied data-limited stock assessment models and management procedures. Ultimately, the results were not used for management advice.
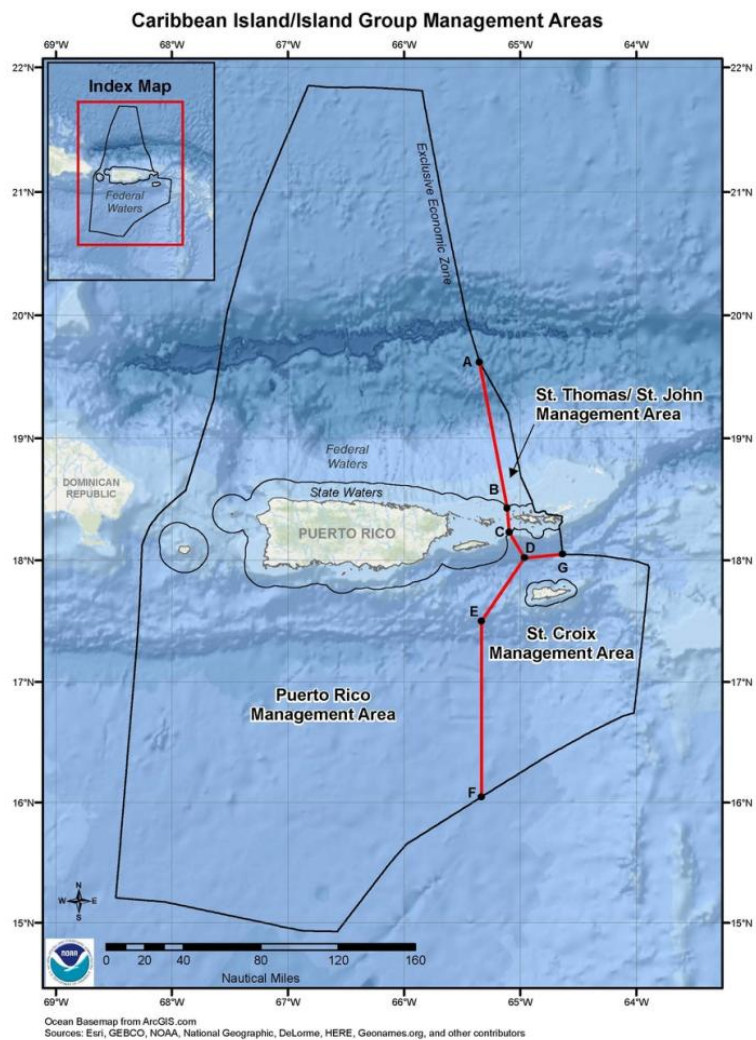
Figure 1.1: Jurisdictional boundaries of the Caribbean Fishery Management Council.
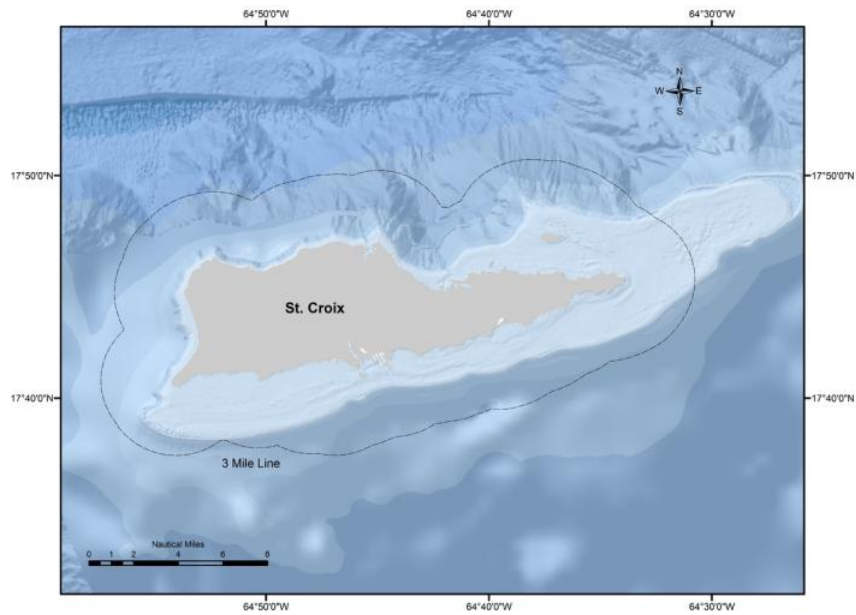
Figure 1.2: The U.S. EEZ is defined as the federal waters ranging from 3 to 200 nautical miles (5.6 – 370 kilometers) from the nearest coastline point of the US Virgin Islands.

2 Modeling Framework

Stock Synthesis was the modeling approach applied in this assessment because of its compatibility with the available data and consistent with standard practices.

Stock Synthesis is a statistical catch-at-age model that uses a population model, an observation model, and an estimation model and applies a likelihood function in the estimation process (Methot et al.). Stock Synthesis, commonly referred to as SS3, has been applied extensively worldwide for stock assessment evaluations (Methot and Wetzel). It has also been used for previous data-limited and data-moderate SEDAR assessments, including the SEDAR 57 assessments and subsequent updates for Caribbean Spiny Lobster (Panulirus argus), and the SEDAR 80 assessments for Queen Triggerfish (Belistes vetula) (SEDAR, *SEDAR 57 Stock Assessment Report u.s. Caribbean Spiny Lobster*; SEDAR, *SEDAR 80 – US Caribbean Queen Triggerfish – Puerto Rico Final Stock Assessment Report*).

The Stock Synthesis modeling framework is a compatible tool for SEDAR stock assessments in the U.S. Caribbean because it can accommodate a wide range of model complexities, from data-limited to highly detailed assessments (Cope). Stock Synthesis allows for the characterization of stock, fishing fleet, and survey dynamics through various parameters, which can be either fixed based on external data or estimated when sufficient assessment data are available. Additionally, it can incorporate complex biological dynamics, such as hermaphroditism and continuous recruitment, which are critical for accurately assessing St. Croix Stoplight Parrotfish.

Finally, R packages such as r4ss and ss3diags facilitate critical evaluations of model reliability and model comparisons (Taylor et al.; Carvalho et al.). For example, R4SS provides visualization and diagnostic tools to summarize and interpret fit, convergence, and key output metrics. SS3diags focuses on retrospective analyses, hind-casting, and residual pattern evaluations. The integration of these tools allows rigorous uncertainty analysis, streamlined sensitivity analyses, and enhanced transparency in decision-making.

3 Data informed modeling configurations

The data considered for use in the current assessment are summarized in the SEDAR 84 US Caribbean Stoplight Parrotfish St. Croix Data Workshop Report (SEDAR, *SEDAR 84 US Caribbean Stoplight Parrotfish St. Croix Data Workshop Report*). This section documents the five types of data inputs and their associated model configurations explored using Stock Synthesis.

Additional details are provided across the respective references identified below:

1. Landings from self-reported commercial fisher logbook data (Martínez Rivera et al.)
2. Length compositions from shore-based port sampling of commercial landings (Godwin et al.)
3. Length compositions from a fishery-independent stratified random sampling survey of reef fish (Grove et al.)
4. Index of abundance from a fishery-independent stratified random sampling survey of reef fish (Grove et al.)
5. Life history information from otolith analysis and gonad histology (Rivera Hernández and Shervette)

Based on the available data, the assessment was configured with one areas, one dive fleet and one fishery-independent survey.

3.1 Commercial Dive Fleet

3.1.1 Catch Data

The catch data for the dive fleet came from the Caribbean Commercial Logbook program (Martínez Rivera et al.). **Catch was input as biomass (in metric tons) and was treated as if it occurred over entire fishing season, e.g. the fishing year.** The years of the available species-specific self-reported commercial fisher logbook data determined the start and end years of the Stock Synthesis models. **The start and end years of the model were 2012 and 2022, respectively.** Based on discussions at the data workshop characterizing the diver fleet, **the assessment assumed no discarding nor discard mortality associated with the dive fleet**.

The input standard error for the landings was set to 0.01. When implemented with few data inputs, Stock synthesis will inherently nearly exactly fit the annual landings time series, regardless of the input CV.

It is important to note that the stock was not at an unexploited equilibrium at the start year of the available time series. The fishery had been ongoing for decades, and the total fishing effort in St. Croix in 2012 was undergoing a meaningful decline; thus, an initial F was estimated for the dive fleet, and a corresponding initial equilibrium catch was input. In recent assessments, the initial equilibrium catch is initiated as the geometric mean of the first three years of available catches. Because of the known decline in effort preceding the start year of the assessment webinars, **the initial equilibrium catch was 30 metric tons**, a little over twice the geometric mean of the catches from 2012-2014.

Alternative model configurations associated with the commercial dive fleet data are described later in this report. They included: - higher CV of 0.3 was explored via sensitivity analysis - Initial equilibrium catch was explored via likelihood profiling

3.1.2 Size Composition Data

Gear-specific annual length frequencies came from the commercial shore-based port-sampling Trip Interview Program (Godwin et al.). These data were used to characterize the size-based selectivity pattern for the dive fleet. Since multiple fish can be obtained from a single sampled trip, the lengths are not independent observations. **The relative model weighting of the dive fleet length compositions was based on the number of trips sampled**.

Due to low sample sizes, the fishery-dependent commercial dive fleet length composition data were collapsed across all years

The length compositions of the commercial dive fleet were assumed to be representative of total catch. Although a federal minimum size limit exists, it does not apply in USVI territorial waters extending from land to 3 nautical miles offshore. Discussions emphasized that no regulations conclusively affecting retention were in place.

A double normal function was used to model the the relative vulnerability of capture by length for the dive fleet. However, only two parameters were estimated to describe a logistic selectivity for the commercial dive fleet. The double normal function allows for domed or logistic selectivity and combines two normal distributions; the first describes the ascending limb, while the second describes the descending limb. Domed selectivity was not explored for St. Croix Stoplight Parrotfish. However, achieving the logistic shape with the double normal Stock Synthesis pattern facilitated model configuration. The two parameters used to achieve a logistic selectivity shape were the size associated with peak selectivity and the width of the ascending limb.

3.2 Survey Data

3.2.1 Index of abundance

Annual abundance observations and associated standard errors were from the National Coral Reef Monitoring Program Reef Visual Census (Grove et al.). In stock syntheses, this was configured as a index in numbers with a lognormal error distribution. The associated length composition data, described in the following subsection, suggested that the index reflected the abundance of juveniles and adults.

3.2.2 Size Composition Data

Since multiple fish can be observed from a single dive, lengths are not independent observations. **The relative model weighting of the National Coral Reef Monitoring Program survey length compositions across years was based on the number of paired dives.**

The three most recent years of the National Coral Reef Monitoring Program survey in St. Croix provided counts by individual lengths measured to the nearest centimeter. However, prior to 2017 the length observations were collected in 5-centimeter bins. **The length data inputs for both the dive fleet and the three years of the survey with 1-centimeter length measurements were binned to match the survey's 2012 and 2015 5-centimeter bins.**

Note that SS3 allows the length bins of the data inputs to be larger than the bins used in the population model. **Although the size bins of all the length data inputs were large (5 centimeters), the model's simulated population bin size was 1-centimeter bins, with a plus group for the largest bin, greater than or equal to 41 centimeters fork length.** Although the population is modeled at a higher resolution concerning bin size, the likelihood function, which aims to match the observed data inputs and the simulated population estimates, operates at the resolution of the data inputs.

A large proportion of small fish were observed in the National Coral Reef Monitoring Program survey. **The smallest two bins, [1-6) and [6-11), were collapsed into a single bin [1-11).**

The length compositions provided reasonable support that younger and older fish were available to the National Coral Reef Monitoring Program survey. **Selectivity for the NCRMP survey was fixed at 1 for all sizes.**

Models were initially configured in Stock Synthesis with length compositions aggregated across the available years for each source of length data and proceeded stepwise from the simplest configuration to those of moderate complexity. The steps included the inclusion of annual fishery-independent length compositions. The sequential model configurations are described later in this report.

3.3 Life History Data

The life history data used in the assessment included longevity-informed natural mortality, growth (length-age), length-weight, maturity, and sex ratios obtained from 1,801 samples of Stoplight Parrotfish collected across the U.S. Caribbean from 2013 to 2023 (Rivera Hernández and Shervette).

Hermaphroditism directly influences reproductive potential and stock sustainability, making it essential to model sex transitions appropriately.

Assuming a single pulse of annual recruitment oversimplifies the population structure by failing to account for the continuous presence of multiple size classes in the stock. Continuous recruitment modeling enables the assessment to recognize that fish born within the same calendar year can reach vulnerable sizes at different times, affecting catch dynamics and stock projections.

Alternative model configurations associated with the life history data are described later in this report. They included:

- models configurations were explored with the estimation of recruitment deviations
- higher CV of 0.3 was explored via sensitivity analysis

3.3.1 Growth

The SS3 growth formulation requires five parameters:

- Length at the youngest age
- Length at the maximum age
- Von Bertalanffy growth parameter (K)
- Coefficient of variation at the youngest age
- Coefficient of variation at the maximum age

Parameter estimates for K and the length at maximum age (L∞) were based on samples of Stoplight Parrotfish collected across the U.S. Caribbean from 2013 to 2023 (Rivera Hernández and Shervette).

The estimated size at age zero from otolith analysis by Rivera Hernández and Shervette was modified in Stock Synthesis so that the size of the youngest age, age 0, was set to zero. Without this modification the model would be unable to fit to the substantial amounts of small (<10cm) stoplight parrot observed in the survey data.

Coefficients of variation for both younger and older ages were initially set to 0.15. Ideally, growth coefficients of variation should be derived from observed length-at-age data, however the assumed values are consistent with species of moderate growth variability. Growth

CV can be tested in sensitivity runs, especially if overly constrained values lead to poor model fits.

Alternative model configurations associated with the growth data are described later in this report. They included: - higher growth CVs of 0.25 for younger ages was explored via sensitivity analysis - higher growth CVs of 0.25 for both younger and older ages was explored via sensitivity analysis

3.3.2 Morphometric Conversion

The relationship between weight in grams and length in millimeters provided by Rivera Hernández and Shervette was converted to weight in grams and length in centimeters and used as a fixed model input. The length-weight relationship was W = 3.18 x 10^-5 L^ 2.9, with weight in kilograms and length in centimeters.

3.3.3 Natural Mortality

The Natural Mortality Tool and the SEDAR 84 life history values were used to obtain estimates of natural mortality (Cope and Hamel). A value of 0.3 was used in initial model runs based on Then et al.

3.3.4 Maturity, Fecundity, and Hermaphroditism

Maturity was modeled as a logistic function. Parameter estimates for maturity were based on 1,801 samples of Stoplight Parrotfish collected across the U.S. Caribbean from 2013 to 2023 (Rivera Hernández and Shervette). The fecundity of Stoplight Parrotfish was estimated with a proxy (body weight * maturity at age).

Hermaphroditism was parameterized into the SS3 assessment framework in two ways. The primary method used an average age of transition, an associated standard deviation, and a maximum transition rate input as fixed parameters in a two-sex model. Although this approach allows explicitly modeling numbers by sex and age over time, this approach could not capture the early age at transition and the overlap of both sexes directly observed across the range of ages studied by Rivera Hernández and Shervette. A second method for parameterizing hermaphroditism was explored as a sensitivity analysis (see **?@sec-methods-sensitivity**). It involved using a female-only model and accounting for sex transition to males as a reduction in fecundity. A fecundity-at-age vector derived from a logistical fit to the sex-at-age data was multiplied by maturity-at-age and fecundity-at-age. A caveat of using a single-sex model is that the exclusion of males does not allow for any potential sperm limitation.

3.3.5 Stock Recruitment

A Beverton-Holt stock-recruit function was used to parametrize the relationship between spawning output and resulting recruitment of age-0 fish. The stock-recruit function requires three parameters:

- Steepness (h) characterizes the initial slope of the ascending limb (i.e., the fraction of recruits produced at 20% of the unfished spawning biomass)
- The virgin recruitment (R0; estimated in log space) represents the asymptote or unfished recruitment levels.
- The variance term (sigma R) is the standard deviation of the log of recruitment (it both penalizes deviations from the spawner-recruit curve and defines the offset between the arithmetic mean spawner-recruit curve and the expected geometric mean from which the deviations are calculated).

Only the virgin recruitment (R0) was estimated. Sigma R and steepness were fixed at 0.7 and 0.99, respectively. The primary assumption for steepness was that this stock is not a closed population, so recruitment may not be strongly tied to the local spawning stock biomass. Annual deviations from the stock-recruit function were not estimated.

References

Carruthers, Thomas R., and Adrian R. Hordyk. "The Data-Limited Methods Toolkit (DLM-tool): An R Package for Informing Management of Data-Limited Populations." *Methods in Ecology and Evolution*, edited by Samantha Price, vol. 9, no. 12, Sept. 2018, pp. 2388–95, https://doi.org/10.1111/2041-210x.13081.

Carvalho, Felipe, et al. "A Cookbook for Using Model Diagnostics in Integrated Stock Assessments." *Fisheries Research*, vol. 240, Aug. 2021, p. 105959, https://doi.org/10.1016/j.fishres.2021.105959.

Cope, Jason. *Stock Assessment Continuum Tool.* 2024, https://github.com/shcaba/SS-DL-tool.

Cope, Jason, and Owen S. Hamel. "Upgrading from M Version 0.2: An Application-Based Method for Practical Estimation, Evaluation and Uncertainty Characterization of Natural Mortality." *Fisheries Research*, vol. 256, Dec. 2022, p. 106493, https://doi.org/10.1016/j.fishres.2022.106493.

Crabtree, Roy E. *Comprehensive Fishery Management Plan for the St. Croix Exclusive Economic Zone Including Environmental Assessment, Regulatory Impact Review, and Fishery Impact Statement.* 2019, https://repository.library.noaa.gov/view/noaa/45275.

Godwin, Katherine, et al. *SEDAR 84 Trip Interview Program (TIP) Size Composition Analysis of Stoplight Parrotfish (Sparisoma Viride) in St. Croix, u.s. Caribbean, 1983-2022.* 2024, p. 10, https://sedarweb.org/documents/sedar-84-dw-11-sedar-84-trip-interview-program-tip-size-composition-analysis-of-stoplight-parrotfish-sparisoma-viride-in-st-croix-u-s-caribbean-1983-2022/.

Grove, Laura Jay W., et al. *Fishery-Independent Reef Fish Visual Survey Population Density and Length Composition for Stoplight Parrotfish in the St. Croix.* 2024, p. 11, https://sedarweb.org/documents/sedar-84-dw-14-fishery-independent-reef-fish-visual-survey-population-density-and-length-composition-for-stoplight-parrotfish-in-the-st-croix/.

Martínez Rivera, Stephanie, et al. *SEDAR 84 Commercial Fishery Landings of Stoplight Parrotfish (Sparisoma Viride) in St. Croix, US Caribbean, 2012-2022.* 2024, p. 20, https://sedarweb.org/documents/sedar-84-dw-03-sedar-84-commercial-fishery-landings-of-stoplight-parrotfish-sparisoma-viride-in-st-croix-us-caribbean-2012-2022/.

Methot, Richard D., et al. "Stock Synthesis User Manual : Version 3.30.15." *Northwest Fisheries Science Center (U.S.)*, 2020, https://doi.org/10.25923/5WPN-QT71.

Methot, Richard D., and Chantell R. Wetzel. "Stock Synthesis: A Biological and Statistical Framework for Fish Stock Assessment and Fishery Management." *Fisheries Research*, vol. 142, May 2013, pp. 86–99, https://doi.org/10.1016/j.fishres.2012.10.012.

Rivera Hernández, Jesús M., and Virginia Shervette. *Report on the Status of U.S. Caribbean Stoplight Parrotfish Sparisoma Viride Age, Growth, and Reproductive Biology for the SEDAR84 Stock Assessment.* 2024, p. 22, https://sedarweb.org/documents/sedar-84-ap-01-report-on-the-status-of-u-s-caribbean-stoplight-parrotfish-sparisoma-viride-age-growth-and-reproductive-biology-for-the-sedar84-stock-assessment.

SEDAR. *SEDAR 46 Caribbean Data-Limited Species Stock Assessment Report.* Apr. 2016, https://sedarweb.org/documents/sedar-46-final-stock-assessment-report-caribbean-data-limited-species/.

---. *SEDAR 57 Stock Assessment Report u.s. Caribbean Spiny Lobster.* 2019, p. 232, http://sedarweb.org/sedar-57.

---. *SEDAR 80 – US Caribbean Queen Triggerfish – Puerto Rico Final Stock Assessment Report.* July 2022, https://sedarweb.org/documents/sedar-80-us-caribbean-queen-triggerfish-puerto-rico-final-stock-assessment-report/.

---. *SEDAR 84 US Caribbean Stoplight Parrotfish St. Croix Data Workshop Report.* 2024, https://sedarweb.org/documents/sedar-84-us-caribbean-stoplight-parrotfish-st-croix-data-workshop-report/.

Taylor, Ian G., et al. "Beyond Visualizing Catch-at-Age Models: Lessons Learned from the R4ss Package about Software to Support Stock Assessments." *Fisheries Research*, vol. 239, July 2021, p. 105924, https://doi.org/10.1016/j.fishres.2021.105924.

Then, Amy Y., et al. "Evaluating the Predictive Performance of Empirical Estimators of Natural Mortality Rate Using Information on over 200 Fish Species." *ICES Journal of Marine Science*, vol. 72, no. 1, Aug. 2014, pp. 82–92, https://doi.org/10.1093/icesjms/fsu136.