2022 Butterfish (*Peprilus triacanthus*) Research Track Assessment Report

Term of Reference 1

Estimate catch from all sources including landings and discards. Describe the spatial and temporal distribution of landings, discards, and fishing effort. Characterize the uncertainty in these sources of data.

Butterfish catch is comprised of a combination of landings and discards. During 2002-2012, the butterfish fishery was largely comprised of discards from the longfin squid (*Doryteuthis (Amerigo) pealeii*) fishery. The directed fishery resumed in 2013, and catches since then have largely been composed of landings from bottom otter trawls. Uncertainty in discards prior to the creation of the Northeast Fisheries Observer Program (NEFOP) in 1989 precludes beginning the time series for use in stock assessment prior to that year. Generally, catch since 1989 has been relatively precise, especially in the last decade.

An analysis was conducted to estimate unobserved discards (i.e., discards not able to be directly sampled by NEFOP observers), which have not been included in the catch time series for stock assessment. The amount of unobserved discards was found to be relatively small and effects on preliminary assessments runs were negligible. Thus, this source of uncertainty was not considered further.

The spatial distribution of catches generally matched observations from surveys. Most notably, butterfish are increasingly spread across the shelf in spring months over the last decade, when historically they have occurred almost exclusively on the shelf edge.

Term of Reference 2

Present the survey data available (e.g., indices of relative or absolute abundance, recruitment, state surveys, age-length data, etc.), and describe the basis for inclusion or exclusion of those data in the assessment. Characterize the uncertainty in these sources of data.

The surveys considered for inclusion were NEFSC spring and fall, Northeast Area Monitoring and Assessment Program (NEAMAP) spring and fall, and 12 different state surveys. The NEFSC spring and fall surveys were considered in two separate time blocks to account for the change in vessel from the Albatross IV (up to and including 2008) to the Bigelow (2009-current). The NEFSC spring survey was not previously included in assessments used for management advice because butterfish were typically unavailable to the survey (e.g., off the shelf), which created conflicting trends with the fall survey and concern that the spring survey did not reflect abundance trends. Since the switch to the Bigelow vessel, butterfish have been more evenly spread across the shelf in the spring, and trends have become more consistent with other surveys. No single state survey provided a synoptic index of abundance. So, six state surveys that met several objective performance criteria were combined to create a coastwide young of year (YOY) index. The indices ultimately included in the assessment were: fall NEFSC Albatross and Bigelow years, spring NEFSC Bigelow years, spring and fall NEAMAP, and the combined state YOY index.

Term of Reference 3

Estimate annual fishing mortality, recruitment and stock biomass (both total and spawning stock) for the time series, and estimate their uncertainty. Include retrospective analyses

(both historical and within-model) to allow a comparison with previous assessment results and projections, and to examine model fit.

A major change in this research track stock assessment was a switch from the statistical catch-at-age framework, ASAP, to the state-space model, WHAM. Briefly, the main distinction between these two models is the ability of WHAM to include process variance in survival, recruitment, or the fishing process that would otherwise be considered deterministic in ASAP. The preferred WHAM configuration was fully state-space (i.e., included process variance) in that it included AR(1) recruitment and temporally autocorrelated deviations in survival from one age to the next. Time series plots of fishing mortality, recruitment, and stock biomass were provided below (Figure 1**??**). This assessment did not have a retrospective pattern.

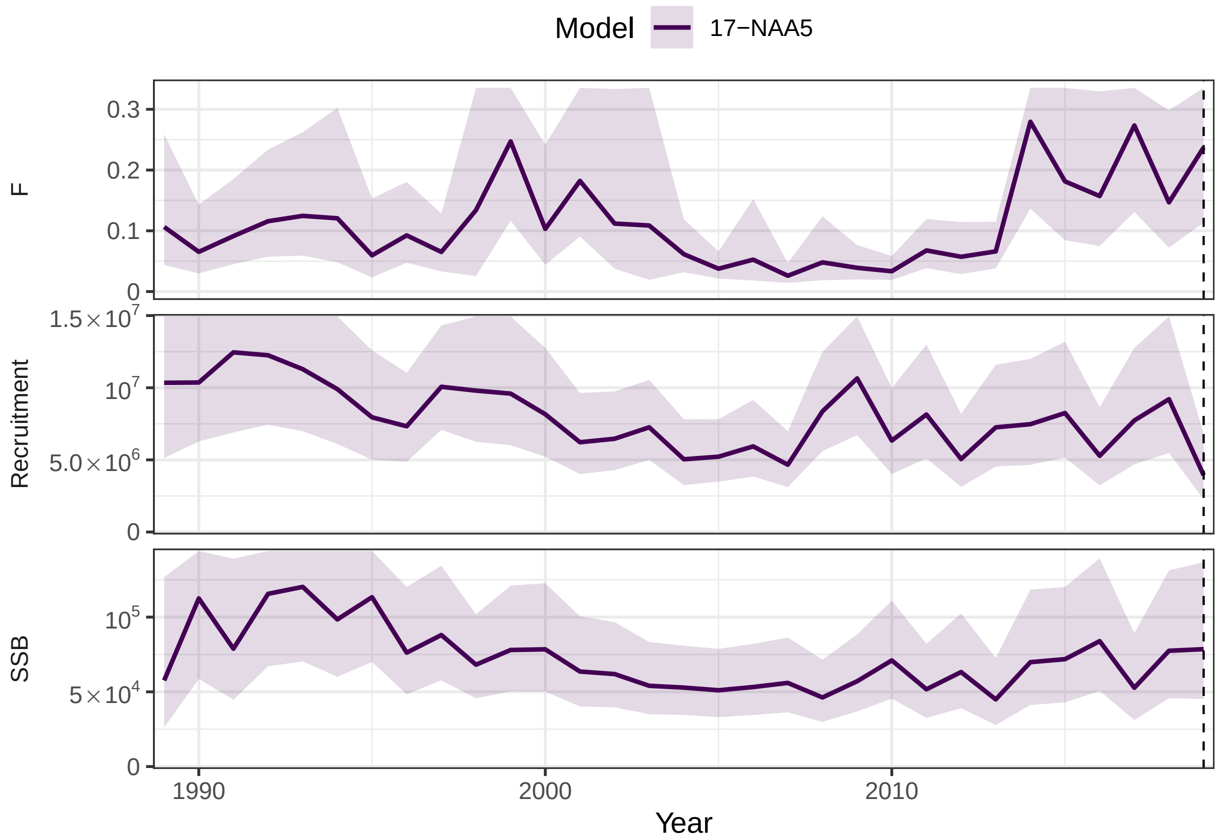

Figure 1: Figure 1. Time series estimates of F at age-4 (fully-selected; F), recruitment, and spawning stock biomass (SSB)

Term of Reference 4

Update or redefine status determination criteria (SDC point estimates or proxies for BMSY, BTHRESHOLD, FMSY and MSY) and provide estimates of their uncertainty. If analytic model-based estimates are unavailable, consider recommending alternative measurable proxies for BRPs. Comment on the scientific adequacy of existing BRPs and the "new" (i.e., updated, redefined, or alternative) BRPs.

A stock-recruitment relationship could not be reliably estimated in this stock assessment and so SDC were based on proxies. The SSB/R calculations upon which the SDC relied assumed fishery selectivity equaled the values-at-age from the most recent selectivity block (2014-2019), and weight- and maturity-at-age equaled an average of the most recent five years, which is consistent with other stocks in the region. Recruitment was assumed to equal the average since 2011 (2011-2019), which was premised on research done for TOR A1. B_{proxy} equaled half of the unfished biomass level, which implicitly assumes a symmetrical production function where $B_{MSY} = 0.5B_{F=0}$ (e.g., as in a Schaefer model; Table 1**??**). $B_{threshold} = 0.5B_{proxy}$, which is consistent with the $B_{threshold}$ definition for other stocks in the region. F_{proxy} equaled the fishing mortality rate that would drive the stock to B_{proxy}, which in this case equates to $F_{50\%}$ (Table 1**??**). The working group acknowledged that the production function for butterfish was unlikely to be symmetrical, but more likely to be skewed left (i.e., $B_{MSY} < B_{proxy}$) because the fish mature before they are selected by the fishery. Thus, the suggested reference points are likely to be relatively precautionary in terms of risk of stock depletion, which is consistent with guidance from the Mid-Atlantic Fishery Management Council for the management of forage fish.

Table 1: Table 1. Updated SDC from the preferred WHAM assessment

	Value
Bproxy	37318 (mt)
Bthreshold	18659 (mt)
Fproxy	6.6

Previous reference points were proxies premised on $F_{proxy} = 2/3M$. This proxy, however, was based on relatively dated research that analyzed VPA output for a number of groundfish stocks with the intent of identifying an F reference point that would maximize stock stability, which does not necessarily have any relationship to F_{MSY}. Thus, the working group abandoned the use of these proxies in favor of assuming a symmetrical production function, which at the least has a theoretical basis to produce proxy reference points.

Term of Reference 5

Make a recommended stock status determination (overfishing and overfished) based on new modeling approaches developed for this peer review.

According to the preferred WHAM model, the stock is not overfished and is not experiencing overfishing. F in 2019 = 0.26, which is less than F_{proxy} ($F_{2019}/F_{proxy} = 0.04$). SSB in 2019 = 77,621mt, which is greater than $B_{treshold}$ and B_{proxy} ($B_{2019}/B_{threshold} = 4.16$ and $B_{2019}/B_{proxy} = 2.08$).

Term of Reference 6

Define the methodology for performing short-term projections of catch and biomass under alternative harvest scenarios, including the assumptions of fishery selectivity, weights at age, and maturity.

Throughout the course of the assessment, projections were conducted using several different F values. Results using F_{proxy} were reported here (Figure 2**??**). Fishery selectivity equaled the values-at-age from the most recent selectivity block (2014-2019), and weight- and maturity-at-age equaled an average of the most recent five years, which is consistent with other stocks in the region. Unlike previous assessments, the preferred WHAM model included autocorrelated process variance in survival and recruitment. This process variance was carried forward in the projections. Projected catch was not reported here because future management track assessments will update input time series and likely use different F scenarios for setting catch advice. Thus, reporting anticipated catch here could inadvertently create a focus on relatively moot values, and so emphasis was placed on the methodology as opposed to the outcomes.

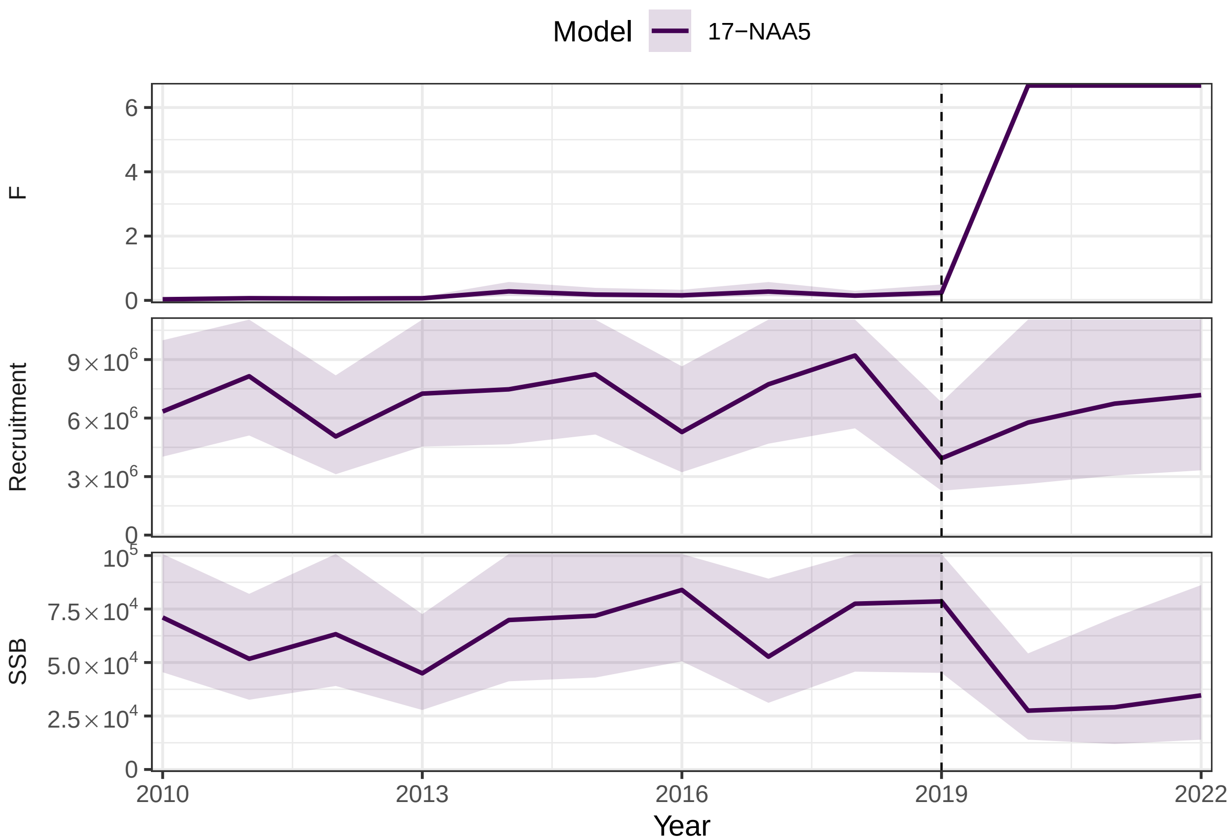

Figure 2: Figure 2. Projection results at F-proxy from the preferred WHAM assessment

Term of Reference 7

Review, evaluate and report on the status of the Stock Assessment Review Committee (SARC) and Working Group research recommendations listed in most recent SARC reviewed assessment and review panel reports, as well as the most recent management track assessment report. Identify new research recommendations.

Progress was evaluated and documented for previous research recommendations and new recommendations were developed.

Term of Reference 8

Develop a "Plan B" for use if the accepted assessment model fails in the future.

As in the 2020 management track assessment, the "plan B" was to use the so-called "Plan B Smooth" (https://github.com/cmlegault/PlanBsmooth), which is an index based method that scales recent catches based on the most recent 3-year trends in indices of abundance. For butterfish, this method would include re-scaling the NMFS spring and fall surveys and the NEAMAP spring and fall surveys by their respective time series averages, and then creating a single index for use in the "Plan B Smooth" by taking annual averages among the four surveys.

Term of Reference A1

Describe life history characteristics and the stock's spatial distribution, including any changes over time. Describe ecosystem and other factors that may influence the stock's productivity and recruitment. Consider any strong influences and, if possible, integrate the results into the stock assessment.

Since about 2009, butterfish have been increasingly dispersed across the shelf instead of along the shelf break in the spring. This shift in spatial distribution was observed in fishery and survey data, and supported the inclusion of the NMFS spring bottom trawl survey in the stock assessment (TOR 2), which had not been included previously. Research was also presented on butterfish habitat suitability and projected future spatial distribution under several climate change scenarios. This research could be used in future assessments to update estimates of survey catchability and possibly inform time-varying dynamics as they respond to climate change.

Multiple significant change points in butterfish condition have been observed since 1992, with the most recent occurring in 2011. These changes were linked to ocean temperature and copepod abundance, which also had similar change points. These analyses supported the use of average recruitment since 2011 to define reference points (TOR 4). The estimated recruitment time series also shifts from a general decline to an increasing and then stable trend in ~2011, lending additional support to the approach.

Term of Reference A2

Evaluate consumptive removals of butterfish by its predators, including (if possible) marine mammals, seabirds, tunas, swordfish and sharks. If possible, integrate results into the stock assessment.

Relatively detailed analyses were carried out to quantify consumptive removals of butterfish by marine mammals, seabirds, and finfish. In all cases, however, the consumption of butterfish was generally negligible relative to biomass and assumed overall natural mortality. Only anectodotal observations were available for other predators of butterfish.