FINAL

ISC/24/ANNEX/09

ANNEX 09

24th Meeting of the
International Scientific Committee for Tuna
and Tuna-Like Species in the North Pacific Ocean
Victoria, Canada
June 19-24, 2024

REPORT OF THE BILLFISH WORKING GROUP WORKSHOP

June 2024

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ANNEX 09

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International Scientific Committee for Tuna and Tuna-Like Species in the North Pacific Ocean (ISC)

20-23 April 2024 (CST)
Taipei, Taiwan

1. OPENING AND INTRODUCTION

1.1. Welcoming and Introduction

Michelle Sculley, the International Scientific Committee for Tuna and Tuna-Like Species in the North Pacific Ocean (ISC) Billfish Working Group (WG) chair, opened the biological workshop and working group meeting. Participating scientists were from Chinese Taipei (TWN), Japan (JPN), United States of America (USA), and the Pacific Community (SPC). The list of participating scientists is in Appendix 1.

The WG met to discuss new research available on the biology of North Pacific billfish stocks, the current progress of the International Billfish Biological Sampling (IBBS) program, and to - discuss the rebuilding analysis for Western and Central North Pacific Ocean striped marlin (WCNPO MLS).

1.2. Standard Meeting Protocols

The WG chair introduced protocols for the hybrid meeting. The WG used Webex for this meeting, and working papers and presentations on the agenda were presented and discussed.

1.3. Adoption of Agenda and Assignment of Rapporteurs

The WG adopted the meeting agenda before the meeting (Appendix 2). The WG chair also assigned the rapporteurs J Brodziak, M Kai, YJ Chang, M Kanaiwa, and M Jusup.

1.4. Numbering Working Papers and Distribution Potential

Four working papers and eight presentations were submitted (Appendix 3). **The WG agreed to post WP01 and WP03 on the ISC website and make them publicly available.**

2. COLLABORATIVE PROJECT UPDATES

US Sampling efforts Michael Kinney (Presentation 1)

The US presented an overview of their sampling efforts for the IBBS project now that the sampling program has been running for a little over 2 years. They also shared some maps indicating the breakdown of US sampling by year, month, and sex. To date the US has collected 900 individual fish (439 Swordfish, 272 Striped Marlin, and 189 Blue Marlin) from over 200 fishing trips. In total 2,500 billfish samples for the IBBS program have been collected by all collaborating nations from across the North Pacific (1245 Swordfish, 1055 Striped Marlin, and 251 Blue Marlin). Additionally, the project has already conducted three international, in-person sample exchanges, one in April 2023, another in July 2023, and the most recent in April 2024. Between these exchanges, over 1,000 billfish age and growth samples have been exchanged between IBBS project partner nations. In addition to the in-person exchanges of age and growth samples the US has developed and shared shipping logistics for preserved gonad samples. The first exchange of shipped gonads using these logistics occurred in August 2023 and included 437 striped marlin samples shipped from Japan to the US, all arrived in good condition. The second exchange occurred in February 2024 and included 383 swordfish, and 168 blue marlin gonads shipped from the US to Japan and Taiwan respectively, all samples arrived in good condition.

Discussion

There were questions about if DNA sampling and quality analysis was being done on all three species. The answer was yes but so far only quality testing has been done on swordfish. Currently DNA samples are being collected and stored, no one has volunteered to take on a DNA study for any species but the opportunity is available to anyone interested. The fin clips that have been tested for quality so far were of mediocre quality, but we are hopeful that the muscle plugs will have better results.

Progress report of biological sampling for billfishes collected by Japan in the North Pacific for 2019-2023. Mikihiko Kai and Yuki Ishihara (ISC/24/BILLWG-01/01)

This working paper provides a summary report on the progress of Japanese biological sampling implemented for swordfish, striped marlin, and blue marlin for 2019-2023 under the collaborative study of ISC with US and Taiwan on the growth, the maturity size, and the stock structure in the North Pacific Ocean (NPO). The biological samples include head (otolith), dorsal fins and/or anal fins (spines), gonads (ovary and testis), and tissue samples of muscle (DNA). These samples are collected from one fish with auxiliary information such as body size and capture location using a variety of Japanese fleets such as commercial coastal longline and large-mesh driftnet. The sample sizes of three species are summarized, sampling location are displayed on the maps, and length frequency data are shown. A total number of biological samples (gonads) for swordfish, striped marlin, and blue marlin were 676 (656), 720 (676), and 83 (70), respectively. The summary of Japan's biological sampling of three species for 5 years indicated that there is a limitation of random sampling as well as the achievement of target (sampling protocol) due to biological and physical problems. It is therefore recommended that the working group should review the sampling protocol assigned number of samples by area and species in consideration of current sampling coverage, achievement rates of sampling for each bin compared to their targets, and migration patterns of billfishes especially for the seasonal latitudinal migration of swordfish. It is also recommended that the working group should collect raw gonads fixed by formalin or "Altfix" as much as possible.

Discussion

It was noted that JPN said the latitudinal gradient may be important when considering the swordfish sample analysis, but it may also be important for the striped marlin as well. It was also noted that it will be important to consider gear selectivity when doing the growth analysis to avoid biasing the growth curve**. It was recommended to calculate the growth curve internally using conditional-age-at-length data to account for gear selectivity, if possible, for future stock assessments during the WCNPO MLS peer review**.

Progress of biological sampling for billfishes collected by Taiwan in the Pacific Ocean. Yi-Jay Chang (Presentation 02)

We present a summary of Taiwanese biological sampling progress conducted for swordfish, striped marlin, and blue marlin in the Pacific Ocean from 2010 to 2011, 2017, and 2020 to 2023.

The biological samples, including the head (eyes and otolith), dorsal and/or anal fins (spines), gonad, muscle, and vertebra, were collected by observers aboard longline vessels of Taiwan. Information on body size (length and weight) and capture location was recorded for each sample. The sample sizes for the three species are summarized, sampling locations are shown on maps, and length and weight frequency data for each year are provided. The total sample sizes for swordfish, striped marlin, and blue marlin were 428, 206, and 189, respectively. The summary of Taiwan's biological sampling efforts for these three species indicated comprehensive spatial coverage across the Pacific Ocean, including the South and East Pacific. Length information for each year and species suggested that smaller swordfish and striped marlin (less than 150 cm EFL) were collected from 2020 to 2022, while larger striped marlin (greater than 200 cm EFL) were collected in 2021. This dataset holds the potential to provide broader spatial and finer size information for swordfish and striped marlin to the ISC group.

Discussion

There was a question on if there were enough BUM samples to estimate growth and/or maturity. TWN answered that right now there is not enough capacity to process all the data, but it will be archived and could be analyzed in the future. For maturity, samples for each month are important and more samples are likely needed. There was a clarification that the muscle samples for DNA are frozen.

3. PROGRESS OF GROWTH STUDY ON NP-STRIPED MARLIN

The progress of age estimation for striped marlin in the North Pacific. Ayumu Furuyama, Miwako Funabara, Yuichi Arai, Yuki Ishihara, Mikihiko Kai, Minoru Kanaiwa (Presentation 03)

Billfishes are often aged using their spines, but these can contain false annuli, making identifying the first annual ring crucial for accurate age estimation. To determine the first annulus in the spines of striped marlin (Kajikia audax) from the North Pacific, we estimated age using otolith daily increments and estimated early growth. Otolith sections were prepared from 100 striped marlin specimens (West Area (AreaW): 81 individuals; Central Area (AreaC): 19 individuals) and photographed under a microscope (100x objective). Daily rings were counted from the core to the edge by 2-3 readers, and the median was used as the estimated daily age.

Results showed that 35 individuals (AreaW: 34; AreaC: 1) had indistinct daily rings near the edge, preventing daily age estimation. Log-linear regression of daily age and eye-fork length (EFL) indicated that for AreaW, log(EFL) = 0.380log(daily age) + 2.689, estimating the EFL of 138.473 cm (95%CF: 132.870-141.945) at 365 days. The early growth pattern in AreaW was similar to previous studies in the eastern and southwestern Pacific. In contrast, the relationship in AreaC was log(EFL) = -0.112log(daily age) + 5.440, with some individuals exhibiting remarkably slow growth.

Future work will focus on confirming the first annulus in spines and estimating annulus formation timing, particularly in AreaW where sample collection in April, July, and October-December is lacking. We also propose improving the PIFSC IBBS database to track available specimen information better, replacing the "Valid Specimen?" field with details on the number of samples for each body part.

<u>Discussion</u>

Progress on striped marlin age estimation involves the utilization of spine and otoliths, with a focus on daily otolith ages to establish the eye-fork length (EFL) at one year old. However, challenges arise from inflexed otoliths, which render about 35% of otoliths unreadable due to their unidentifiable edges. In the West Pacific, striped marlin exhibit an EFL at age-1 of approximately 138 cm at 365 days, whereas in the Central Pacific, estimating growth curves is hindered by slow sample collection and necessitates more data, potentially suggesting a biased size around ~119 cm. Previous studies by Kopf, et al., (2011) and Shimose (2019) indicated a length of approximately 137 cm. To enhance data accuracy, there is a pressing need for more small fish spine and otolith samples across all months in the West Pacific, while the Central Pacific requires additional data collection efforts for all sizes and ages.

The future research plan entails a detailed timeline for further investigations. Additionally, recommendations are made for improving the "View Specimens" page of the PIFSC IBBS system. Critical technical details include a polish depth of 0.5 mm for age sectioning and the documentation of transverse otolith sections through photographs. Notably, Kopf's methodology of surface daily ring observations provides estimates of older daily ages but poses challenges in reliable photographic documentation. The WG discussed the use of otoliths for annual aging, but there are challenges reading the otoliths annual growth rings. **The WG also requested the presenter to provide information on the back-calculated birth month.** The presenter showed the estimated birth month spanned the entire year, with peaks in May generally corresponding to Central Pacific samples and July-September generally corresponding to Western Pacific samples.

Development of AI tool as an aid for age determination

The presenter demonstrated an application of Convolutional Neural Networks (CNNs) for age estimation in Pacific Bluefin Tuna (*Thunnus orientalis*) using otolith images. The objective is to assess the feasibility of CNNs as a cost-effective tool for fish age determination, while evaluating potential improvements through imputing missing values in the auxiliary dataset and employing image augmentation techniques. Additionally, a user-friendly web tool has been developed to enable public access to the CNN model. Three trained models, Baseline, Otolith Mass Imputation (OMI), and Otolith Mass Imputation and Image Augmentation (OMIA), are compared and evaluated based on performance metrics. The results highlight the superiority of the OMIA model, achieving the highest accuracy (±1-acc = 72.81%) and the lowest coefficient of variation (CV=7.38%). Heat maps reveal that the attributes used by the model, particularly the opaque zones on the ventral arm of the otolith, mimic the age identification strategies employed by human experts. However, the presenter pointed out challenges of the study, including poor performance and negative impacts on predictions due to data imputation for age groups (ages 4–5 and 25–27) with limited samples. The presenter explained the feasibility of using this method for aging the billfish fish spine section. A sample size of 3000 images was recommended for conducting the analysis by the presenter, and seeking collaboration within the billfish working group.

<u>Discussion</u>

The WG noted this research signifies a significant advancement in machine learning-based age estimation, offering valuable support to traditional fish aging studies and presenting implications for management strategies and future research endeavors, including the potential development of a multispecies billfish spine aging tool.

4. METHODOLOGY FOR FROZEN GONADS OBSERVATION

Fixation methods for frozen gonads of female swordfish. Yuki Ishihara (ISC/24/BILLWG-01/02)

High-quality samples are essential to accurately assess the maturity status of fish through the histological observation of gonads. For highly migratory species like swordfish, however, obtaining pristine gonads can be challenging. Frozen gonads offer a convenient alternative for collection, but tissue degradation due to freezing usually renders them unsuitable for histological analysis. We investigated methods to mitigate tissue degradation by comparing various fixation techniques using frozen ovaries from North Pacific swordfish. Frozen ovarian samples from North Pacific swordfish were subjected to different combinations of temperature conditions (ovary, solution, and fixing) and fixed for varying durations across 15 groups, employing two types of fixatives. The extent of tissue deterioration was assessed through histological examination of the fixed ovaries. Our findings indicate that frozen ovaries fixed in Davidson's solution exhibit less tissue deterioration compared to those fixed in 10% formalin. Moreover, fixing the frozen samples without thawing contributes to further reduction in tissue damage. The optimal fixation temperature was determined to be 1 ℃, with fixation at higher or lower temperatures resulting in increased tissue degradation. Based on these results, the optimal fixation method for frozen ovaries entails fixing unthawed ovaries using Davidson's solution at a temperature of 1 ℃. Using the ovarian tissue fixed by this method allowed us to discern between oocyte maturation stages and certain phases of ovarian reproduction.

<u>Discussion</u>

The WG discussed the choice of temperature treatments evaluated in the study for each step in the fixation process and noted that it was based upon the temperature at which ice crystals form (-1to -5°C), and when it was believed that the most damage occurs to the frozen gonads. The WG also noted that the damage caused by using frozen gonads might alter the estimate of the length at 50% maturity and that a simulation study to explore this possibility would be valuable. The WG noted that this was valuable information for the working group sampling program and that further collaboration between WG members to establish a standard protocol for handling frozen gonad samples would be useful.

5. ANALYTICAL ADVANCES AND VALIDATION WORK

IBBS: spatial (biological) modelling. Nicholas Ducharme-Barth (Presentation 04)

Spatially-varying biological processes are challenge for many fisheries stock assessments both in how to best incorporate them into the assessment but also in how best to model these processes external to an assessment. Specifically, as it relates to ISC billfish, the International Billfish Biological Sampling (IBBS) program was developed to collect data in order to explicitly address this challenge. Namely, to detect and/or model the spatial variation in key biological processes. The IBBS project will generate a large amount of spatially referenced biological data. There is a need to develop a model that appropriately models the spatial (and/or spatiotemporal) variation in biological functions in order to test for the spatial variation in biological functions. This work intends to build on previous research in growth estimation and CPUE standardization to develop such a model initially for growth but in theory could be applied to other biological relationships. This presentation demonstrates what this workflow could look like using a spatiotemporal modelling approach developed in R using TMB as a proof-of-concept using a paired OM-EM simulation study. Expected results from this work include the ability to produce spatially varying growth curves, a spatially averaged growth curve, and the ability to construct spatially varying age-length keys.

Discussion

It was clarified that the "L_2" in the von Bertalanffy growth curve corresponded to the reference length at Age 2 which is smaller than L_{inf}. There was a question on whether the current model can account for seasonal or monthly changes in growth because billfish experience rapid and potentially variable growth rates in their first year. The presenter answered that it could be possible. The WG noted that aging error would be an important component to include in the model due to the possibility of random error or systematic bias in identifying the first annual ring. **The WG suggested that accounting for fishery selectivity, especially for young fish, would be an important addition to the simulation study due to the potential for bias, and requested the evaluation of the spatial variation of sampling**. The WG commented that the high resolution of the spatial pattern of growth has a great benefit. The WG also commented that multiple effects such as time-varying-, year-, season-, mean size-at-age-, and cohort effects in addition to the spatial effect could be considered in the model simultaneously.

Investigating the use of eye lenses to validate fish age. Kristen Dahl (Presentation 05)

Independent age validation studies are a necessary tool to affirm that ageing methodologies, as well as the biological structure (e.g., otoliths, vertebrae, spines, etc.) employed to age a given species, are reflective of the true age of the fish. If estimated ages are deemed inaccurate by the validation method, the age determination criteria can be revised to correct a bias from the true age. Unfortunately, age validation can be difficult to achieve for deep-water and/or pelagic fishes where simple and inexpensive techniques such as marginal increment analysis are often not possible. In fact, direct validation of the accuracy of otolith- or spine derived ageing methods for swordfish has not yet been completed in any ocean. One of the most common approaches for direct age validation is in using the bomb radiocarbon chronometer, however, several factors reduce the suitability of this approach for certain fishes, including billfish, such as small otolith size and the difficulty in obtaining sufficient core mass (~100 ug of C) for robust traditional AMS analysis. A second factor is habitat use below the surface mixed layer where the radioactive isotope signal is diminished at depths >200 m. Given that otoliths derive their carbon sources from dissolved inorganic carbon (DIC), this can result in a depleted signal compared to the radiocarbon reference series (i.e., clock) built from shallow water corals.

A potential way forward is deriving fish birth year Δ14C signatures from eye lenses instead of otoliths. First, eye lenses exhibit several similar characteristics to otoliths, which make them very useful for biological timekeeping applications such as the fact that they form early in life, grow throughout the life of a fish, and are metabolically inert once formed. However, several differences make eye lenses an appealing structure for age validation using the bomb radiocarbon chronometer including a 100% protein composition derived entirely from metabolic carbon resulting in a higher proportion of organic C available in large eye lenses & a surface Δ14C signal. Results from recent studies were discussed showing the application of age validation studies utilizing eye lenses. Given what we know about the biology of swordfish and the difficulty of working with extremely small otoliths, a pilot study was developed to test an eye lens approach to validate otolith- and spine-derived ages in swordfish sampled from the IBBS project.

A second pilot study was discussed using a newer approach to fish ecology called amino acid racemization (AAR). AAR has been used widely as a geochronology tool, as well as applied to estimate age in terrestrial and marine mammals via analysis of eye lens cores formed early in life. It is based on amino acids existing in two mirror forms that convert from one form to the other following "death" or the end of metabolic activity. Given that the cores of eye lenses are inert, they transition from L- to D-form from birth through time at a rate that is temperature dependent, thus species-specific, based on core body temp or environmental temp experienced over lifetime. Emerging research was discussed which shows a strong relationship between AAR rate and otolith-age. Potential positive aspects to this approach include the lack of a need for an appropriate reference series for radiocarbon work, and no a priori need for information on juvenile habitat.

<u>Discussion</u>

There was a question on whether the validation methods are applicable to the billfishes, as both otoliths and spines are used to estimate the ages. The presenter responded that in the Atlantic, the validation has been used for billfish. Additionally, it was noted that there has not been any known work evaluating using fish or shark vertebrae for age validation. The WG discussed that there might be a relationship between fish age and the diameter of the eyeball. There was a discussion about the challenges of extracting the eye lens core as it is inflexible and viscous, but there has been success in freeze-drying the eyeballs and removing the layers one by one. Another WG member also noted that they had looked at the potential for a relationship between the size of each layer and the age of the fish, but that this work was very time and labor intensive.

6. IBBS DATA DISCUSSION

The IBBS Data Discussion centered on two main aspects: Database Improvement and Database Utilization. Under Database Improvement, suggestions were made to enhance the IBBS database, including recording to which nearest unit (i.e., 1 kg, 5 kg, etc.) weight and length data are reported and considering methods to address concerns about sharing latitude and longitude data between Japan and Taiwan. There was a proposal to expand the database content to include a summary report and allow for the download of individual fish data, with the caveat that access control measures would need to be in place to ensure data security and confidentiality.

In terms of Database Utilization, discussions revolved around sharing methods, data exchange, collaboration, and specific improvements needed. Japan highlighted challenges in meeting billfish sampling targets in certain areas due to low fishing effort and proposed refining sampling goals to align with publishing life history results. The USA, which currently has administrative privileges, suggested that its sampling efforts were adequate for the time being. Utilizing the IBBS database, ongoing efforts to track sampling status and identify incomplete size categories for different species were discussed, with suggestions to add lab notes to share information across countries. **The WG agreed to allow authorized users in each country to directly download and access the data, and agreed upon who the users would be for each country.**

There was a discussion about how to exchange biological samples between countries. Currently, otoliths are exchanged in person but gonads and fin spines have been successfully shipped through the mail. At this time there does not appear to be a need to change this method. Further discussion on how to exchange DNA samples or genetic information is needed. Striped marlin and swordfish otoliths were exchanged at this meeting. **ISC BILLFISHWG agreed to continuously exchange the biological samples (otolith, spine, and gonad) of three billfish species (swordfish, striped marlin, and blue marlin) among three countries and the WG confirmed that there are no issues of CITES as well as ABS (The Nagoya Protocol on Access and Benefit-sharing (cbd.int) for these exchanges.**

7. PROJECT PLANNING

Japan highlighted challenges in meeting billfish sampling targets in certain areas due to low fishing effort and proposed refining sampling goals to align with publishing life history results. Japan discussed the ongoing data exchange of blue marlin with Taiwan. Taiwan expressed that a previous growth analysis of blue marlin has been done and will be published in the future. However, this analysis could still be enhanced by incorporating more data. **Although there are currently capacity limitations for the analysis, it was suggested that blue marlin samples could still be collected.** Given the collection of other billfish species, including blue marlin samples, this could be done simultaneously and stored for future updates. **WG members agreed to continue exchanging samples of blue marlin with Taiwan.**

Japan encouraged Taiwan to ensure the cleanliness of samples by removing tissue and oil from the spine, facilitating subsequent analysis. In addition, the US encouraged Taiwan to add sample IDs generated in the database to individual specimens to facilitate information sharing across countries. Taiwan expressed a commitment to enhancing and improving the quality of the biological samples. Japan mentioned that they have a plan to conduct a genetic analysis to determine the stock structure of striped marlin in the Pacific, and pending capacity, swordfish as well. The US and Taiwan expressed interest in the same topic. The collaborative efforts among members on this subject will be addressed in future discussions.

The project planning involved a comprehensive discussion focusing on target species considerations, challenges in sample collection, and the utilization of a sampling plan to guide the process. Specific scheduling is proposed along with delineated next steps and action items. **The WG confirmed the plan for further sample collection and future cooperation for stable isotope analysis. Additionally, preparation techniques involving boiling spines, brushing, sponging, and treating with anti-mold spray are recommended. The WG plans further discussion on genetic sample exchange during the ISC 24 Plenary meeting in Victoria, Canada.**

8. OTHER BIOLOGICAL STUDIES

Seascape population genomics for swordfish. Cheng-Ruei Lee and Yi-Jay Chang (Presentation 06)

In this session, we discussed the possibility and experimental design of population genomics studies in swordfish. Dr. Lee first introduced the general background of whole-genome sequencing and single-nucleotide polymorphism (SNP) calling. After obtaining the SNP information from many samples and hundreds of thousands of SNP across the genome, associated methods for describing individual similarity and population grouping were discussed. Based on the population grouping, Dr. Lee then introduced methods to estimate historical population size changes and estimate the divergence time among populations. Finally focusing on SNP-environment association, Dr. Lee introduced relevant methods to identify potential genomic locations associated with environmental adaptation and how to use this information to predict the future vulnerability of local populations to climate change. Using these concepts, Lee and Chang hope to perform population genomics analyses on swordfish populations across the Pacific, with the potential to obtain samples from other oceans.

Discussion

The presenters clarified that there was no minimum number of samples needed for this type of analysis and that there was a need for more samples from the Indian Ocean, Atlantic Ocean, Mediterranean Sea, and the eastern Pacific Ocean.

Horizontal and vertical movements of striped marlin (Kajikia audax) in the northwestern Pacific Ocean. Wei-Chuan Chiang, Shian-Jhong Lin, Michael K. Musyl, Chi-Lu Sun, Yi-Jay Chang, Yuan-Shing Ho (Presentation 07)

Striped marlin (*Kajikia audax*), is a highly migratory species distributed throughout tropical, subtropical, and temperate waters of the Pacific Ocean. There is a paucity of information on horizontal and vertical movement patterns on the northwestern Pacific Ocean. In the context of regional fisheries management and stock assessments, our study reports the tagging data of striped marlin in northwestern Pacific Ocean. It is suggested that these data will be important to compare diving patterns with other specimens tagged using other fishing methods. To rectify some of these gaps, a preliminary tagging effort used the harpoon fishery to deploy pop-up satellite archival tags (PSATs) on striped marlin off eastern Taiwan. Two striped marlins were tagged near the eastern coast of Taiwan and linear displacements ranged from 2,005 and 945 km (~30 km/day and 9 km/day) from deployment to pop-up locations to the South China Sea and East China Sea. The tagged marlin survived the tagging episode and spent the majority of daytime (mean=36 m ± 31 SD) in the surface mixed-layer and exhibited occasional basking behavior. At nighttime (mean =18 m ± 29 SD), they were confined almost exclusively to the surface. Striped marlin exhibited a crepuscular pattern with the deepest descents and ascents at sunrise and sunset. Depths and ambient water temperatures visited ranged from 0 to 178 m and 30.0° to 15.6 °C, respectively. However, in all cases, the depth distribution appeared primarily limited by an 8 °C change in water temperature. The occupancy of striped marlin near the surface makes them particularly vulnerable to surface fishing gears. This preliminary study represents part of a large-scale international cooperative tagging study to gather data from different areas to provide insights into striped marlin migration behavior and fishery interaction to inform fisheries management.

Discussion

The WG discussed why the diving behavior for the two fish tagging in this study differ from previous tagging information. It was suggested that it could be due to the location the fish were tagged or occupying, the size of the fish, the gear used to catch the fish initially, or the season the fish were at liberty. It was clarified that the Japanese coastal driftnet fleet targets MLS at night in the surface waters and catch larger sized MLS, which is consistent with this information.

Trophic Ecology of Marine Fish: Evidence from a Multiple-Tissue Isotope Approach. Chung, Ming-Tsung, Kao, Li-Ling, Yi-Jay Chang (Presentation 08)

Under environmental pressure and anthropogenic disturbance, the response of marine fishes is dynamically changing, reflecting on their habitat and dietary shifts and the adjustment of energy use. However, the adapted or acclimated behaviors of marine fishes in the natural environment are difficult to investigate. Accordingly, the isotope-based method has been widely applied to fish biological studies, because stable isotope values recorded in organic tissues or calcified structures provide a possibility to evaluate the movement, trophic levels, and metabolism of marine fishes. To introduce the applicability, we summarize the current use of stable isotope systems in marine fish studies, including stable carbon and nitrogen isotopes. Also, we detail the advantages and limits to analyzing these isotopes in various tissues or structures, such as muscle, eye lens, otoliths, and vertebrae. Most importantly, we demonstrate a multiple-tissue isotope approach to obtain more comprehensive life history information in an individual, which is valuable for fisheries management and model predictions of swordfish population dynamics in the future ocean.

Discussion

The WG discussed how the samples were analyzed and clarified the difference between using freeze-dried eye lenses and air-dried eye lenses, noting that obtaining the individual layers for analysis was easier for the air-dried lenses. It was clarified that ISC members are collecting some eye lenses as part of the IBBS program. The presenter noted that bone provides a longer timer series of isotope ratios for trophic information during the individual's life span, however the WG noted that bone collection was difficult. The WG noted that understanding the species' migration patterns was important when considering this type of analysis.

9. WCNPO MLS REBUILDING ANALYSIS

Summary of information about MLS catch from the Billfish Research Plan Michelle Sculley (Presentation 09)

At the Western and Central Pacific Fisheries Commission (WCPFC) 19th Scientific Committee (SC19) meeting, working paper SC19-SA-WP-16 was presented on Project 112, the billfish research plan. In this document information about the encounter rate and catch rate for striped marlin in the WCPFC convention area was presented. These data are summarized again for the BILLWG to provide some context on how reductions in WCNPO MLS catch may be achieved based upon the results of the rebuilding analysis.

Discussion

The author noted that this was summary data, and it was available on the google drive for WG members to explore. There would be a need for standardization to fully identify how this type of information could be used to inform management decisions.

WCNPO MLS Rebuilding Analysis. Jon Brodziak (ISC/24/BILLWG-01/03)

In this working paper, we describe some analyses and stochastic stock projections to develop an interim rebuilding plan for the Western and Central North Pacific Ocean (WCNPO) striped marlin stock. This stock is currently estimated to be depleted and experiencing excess fishing mortality relative to maximum sustainable yield-based reference points. The projection analyses described in this working paper are based on 2023 benchmark stock assessment of WCNPO striped marlin. The rebuilding plan has the goals of rebuilding the spawning biomass of the stock to 20% of the unfished level, or $20\%SB_{F=0}$ = 3,660 mt, within a rebuilding time horizon of 10 years (2025–2034) and with a probability of rebuilding success of least 60%. There are four management strategy scenarios developed for these rebuilding analyses: constant fishing mortality, constant quota, phased fishing mortality and phased catch quota. The constant F scenario was designed to determine the constant fishing mortality rate and associated fishing effort to be applied during 2025–2034 to rebuild the stock with at least 60% probability by 2034. Similarly, the constant quota scenario was designed to determine the constant catch biomass quota to be applied during 2022–2034 to rebuild the stock with at least 60% probability by 2034. The phased rebuilding scenarios were designed to gradually reduce harvest quotas for the international longline and other fleets in order to rebuild the stock by 2034 and provide some periods of stable annual catch quotas for reducing fishing mortality on striped marlin. Given the projected catch quotas and spawning biomasses to meet the rebuilding goals, the probabilities of rebuilding the stock were calculated for each of the rebuilding scenarios under a 3-model ensemble for recruitment. The three alternative recruitment models represented different temporal hypotheses about future recruitment given the observed long-term declines in recruitment since the mid-1990s; these were the short-term, medium-term and long-term recruitment models. The results of the rebuilding analyses showed that the constant F to achieve the target was F=0.373. The constant annual catch quota to achieve the rebuilding target was 2,175 mt. The phased F and phased catch quota scenarios to achieve the rebuilding target were phased F = (0.55, 0.37) and phased catch quota = (2,400, 2,150) mt during 2025-2027 and 2028-2034. Sensitivity results show the rebuilding target could be achieved with moderate harvest reductions under the long-term recruitment model. In contrast, substantial harvest reductions would be required to rebuild the stock under the short-term recruitment model while achieving the target would require intermediate harvest reductions under the medium-term recruitment model. Overall, these rebuilding analyses indicate that the target spawning biomass could be achieved with 60% probability under each of the management strategies examined.

Discussion

The WG discussed the use of AGEPRO as the projection software instead of using the forecast mode of SS3, which was the model used for the 2023 WCNPO MLS assessment. It was clarified that using AGEPRO had the advantage of allowing for stochasticity in recruitment, as well as variability in natural mortality, maturity-at-age, catch-at-age, weight-at-age, and fishery selectivity-at-age, that SS3 is unable to model. It was noted that this means the AGEPRO projections would better reflect the uncertainty around projections of the stock assessment. In addition, it was noted that AGEPRO has an annual time step and SS3 uses a quarterly time step for growth and fishery removals, which would result in some differences between the model results. A comparison of AGEPRO without stochastic recruitment and SS3 was provided for three scenarios: recruitment equal to the average recruitment from 2001-2020 with (A) constant catch and (B) $F=F_{MSY}$, and recruitment calculated from the stock recruitment curve with (C) constant catch. The comparison of annual estimated biomass and the final year numbers at age is shown in Figures 1-6. The median absolute relative difference for SSB for scenario A was 3% overall and the relative difference in 2030 was -4% for AGEPRO relative to SS3. The median absolute relative difference for SSB for scenario B was 3% overall and the relative difference in 2030 was -3% for AGEPRO relative to SS3. The median absolute relative difference for SSB for scenario C was 2% overall and the relative difference in 2030 was -1% for AGEPRO relative to SS3. Furthermore, AGEPRO tends to estimate fewer numbers at age for the oldest ages of the cohorts recruited to the fishery in 2021-2024. The WG noted that AGEPRO tends to provide more conservative estimates of SSB in the near-term relative to SS3.

The WG noted that two projections for fishing mortality limits and six projections for catch based limits were provided that meet the requirements of the rebuilding plan – 60% probability that the SSB is over 20%$SSB_{F=0}$ in 2034, including two runs that have a 120cm EFL size limit limit with low (0.2) and high (0.4) survivorship probability for fish released (Figures 7-17). In addition, two F scenarios projecting at F_{MSY} and $F_{status\ quo}$ (the average F from 2018-2020) were provided but did not meet the rebuilding plan requirements. The WG also reviewed the results of these runs using an ensemble model of the three recruitment scenarios: long term recruitment from the stock-recruitment curve, medium term recruitment as an empirical cumulative distribution function from estimated recruitment of the last 20 years, and short term recruitment empirical cumulative distribution function from estimated recruitment of the last 20 years with each model weighted 0.04, 0.84, and 0.12 respectively, and the results of the projections under each recruitment scenario individually. Model weights were calculated using inverse prediction error variance weights (see WP03 for more information). The model weights for the ensemble model are based upon the inverse error-variance of the prediction error calculated for 2020 and 2021.

In the projection scenarios, it was assumed that management measures would be implemented in 2025, and catch or fishing mortality from 2021-2024 were estimated from reported catch or the average fishing mortality by fleet in 2018-2020. The average catch from the last assessment from 2018-2020 was 2428 mt and the average fishing mortality from 2018-2020 was 0.68. The four F scenarios and six catch scenarios are summarized in Table 1 and Figures 15 - 17. Some of the scenarios incorporated phased reductions in F or catch. The phased reduction scenarios were timed to coincide with future planned stock assessments of WCNPO MLS in 2027 and 2032.

In response to concerns raised by a WCPFC CCM, the WG noted that the catch biomass estimated in the stock assessment is typically larger than the catch biomass reported to the WCPFC by member countries. As addressed in previous WG reports (ISC, 2021), this is largely due to the use of catch in numbers of fish that are converted to biomass in the assessment model for some Japanese longline fleets, the adjustment of catch to account for discards or misidentification for the US longline fleet, and the inclusion of catch data from Japanese research and training vessels. The WG noted that although the absolute values of catch are different, the relative change in catch or F should be considered when interpreting the results of this analysis.

WCPFC 16 requested the BILLWG provide potential rebuilding scenarios to meeting the goal of the rebuilding plan for WCNPO MLS. Pending approval from the ISC Plenary, the WG will provide the results of the rebuilding analysis described in this report.

Table 2. Summary of SSB, Catch and probability of meeting the rebuilding target for each projection scenario, and two F scenarios which do not meet the rebuilding target (F_{MSY} and $F_{status\ quo}$).

Year	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**2031**	**2032**	**2033**	**2034**
Scenario 1: $F_{2025-2034}$ =0.373														
Catch	2912	3382	3318	3030	1750	2003	2162	2249	2291	2310	2318	2321	2323	2322
Biomass	2229	2576	2869	2520	2712	3228	3564	3748	3845	3884	3903	3913	3919	3920
Probability of reaching target	0.02	0.02	0.12	0.05	0.12	0.32	0.46	0.53	0.58	0.59	0.599	0.6	0.6	0.61
Scenario 2: $Catch_{2025-2034}$ = 2,175 mt														
Catch	2911	3383	3319	3033	2175	2175	2175	2175	2175	2175	2175	2175	2175	2175
Biomass	2227	2577	2868	2521	2565	2893	3216	3481	3694	3856	3976	4072	4158	4215
Probability of reaching target	0.02	0.02	0.13	0.05	0.12	0.29	0.39	0.46	0.51	0.54	0.57	0.58	0.598	0.61
Scenario 3: $F_{2025-2027}$ = 0.55, $F_{2028-2034}$ = 0.37														
Catch	2911	3383	3319	3033	2425	2526	2526	1880	2081	2200	2261	2291	2305	2314
Biomass	2227	2577	2868	2521	2487	2624	2712	3009	3426	3686	3819	3884	3918	3928
Probability of reaching target	0.02	0.02	0.13	0.05	0.06	0.1	0.12	0.23	0.40	0.51	0.56	0.59	0.61	0.61
Scenario 4: $Catch_{2025-2027}$ = 2,400 mt; $Catch_{2028-2034}$ = 2,150 mt														
Catch	2913	3382	3318	3028	2400	2400	2400	2150	2150	2150	2150	2150	2150	2150
Biomass	2228	2577	2868	2519	2483	2672	2859	3101	3379	3622	3819	3966	4084	4181
Probability of reaching target	0.02	0.02	0.13	0.05	0.11	0.23	0.31	0.38	0.44	0.49	0.53	0.56	0.59	0.6
Scenario 5: $Catch_{2025-2027}$ = 2,250 mt; $Catch_{2028-2034}$ = 2,175 mt														
Catch	2914	3383	3322	3036	2250	2250	2250	2175	2175	2175	2175	2175	2175	2175
Biomass	2228	2577	2868	2523	2544	2820	3099	3354	3574	3754	3904	4018	4106	4180
Probability of reaching target	0.02	0.02	0.13	0.06	0.12	0.27	0.36	0.43	0.48	0.52	0.55	0.57	0.59	0.6
Scenario 6: $Catch_{2025-2027}$ = 2,400 mt; $Catch_{2028-2032}$ = 2,200 mt; $Catch_{2033-2034}$ = 2,100 mt														
Catch	2830	3358	3324	3033	2400	2400	2400	2200	2200	2200	2200	2100	2100	2100
Biomass	2229	2577	2871	2522	2492	2681	2873	3097	3343	3548	3717	3889	4036	4176
Probability of reaching target	0.02	0.01	0.12	0.05	0.11	0.23	0.31	0.37	0.43	0.48	0.51	0.54	0.58	0.60
Scenario 7: 120 cm EFL size limit with low release survival probability = 0.2 and $Catch_{2025-2034}$ = 2,180 mt														
Catch	2830	3358	3306	3024	2180	2180	2180	2180	2180	2180	2180	2180	2180	2180
Biomass	2227	2588	2903	2561	2604	2929	3237	3486	3685	3830	3953	4041	4118	4190

Year	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**2031**	**2032**	**2033**	**2034**
Probability of reaching target	0.02	0.02	0.14	0.06	0.13	0.30	0.40	0.46	0.51	0.54	0.56	0.58	0.59	0.60
Scenario 8: 120 cm EFL size limit with high release survival probability = 0.4 and $\text{Catch}_{2025\text{-}2034}$ = 2,185 mt														
Catch	2733	3329	3292	3012	2185	2185	2185	2185	2185	2185	2185	2185	2185	2185
Biomass	2228	2603	2943	2602	2644	2964	3273	3517	3715	3864	3972	4059	4139	4190
Probability of reaching target	0.02	0.02	0.16	0.07	0.15	0.31	0.41	0.47	0.51	0.54	0.56	0.58	0.59	0.60
$F = F_{MSY}$														
Catch	2927	2575	3328	3043	2710	2723	2724	2731	2725	2713	2721	2717	2716	2718
Biomass	2913	3382	3319	3033	2700	2704	2716	2725	2724	2720	2719	2721	2720	2722
Probability of reaching target	0.02	0.02	0.13	0.05	0.04	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
$F = F_{status\ quo}$														
Catch	2912	3382	3320	3032	2864	2805	2782	2772	2771	2769	2765	2766	2767	2772
Biomass	2228	2576	2867	2518	2331	2266	2239	2232	2230	2228	2231	2225	2225	2229
Probability of reaching target	0.02	0.02	0.12	0.05	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.03	0.02	0.02

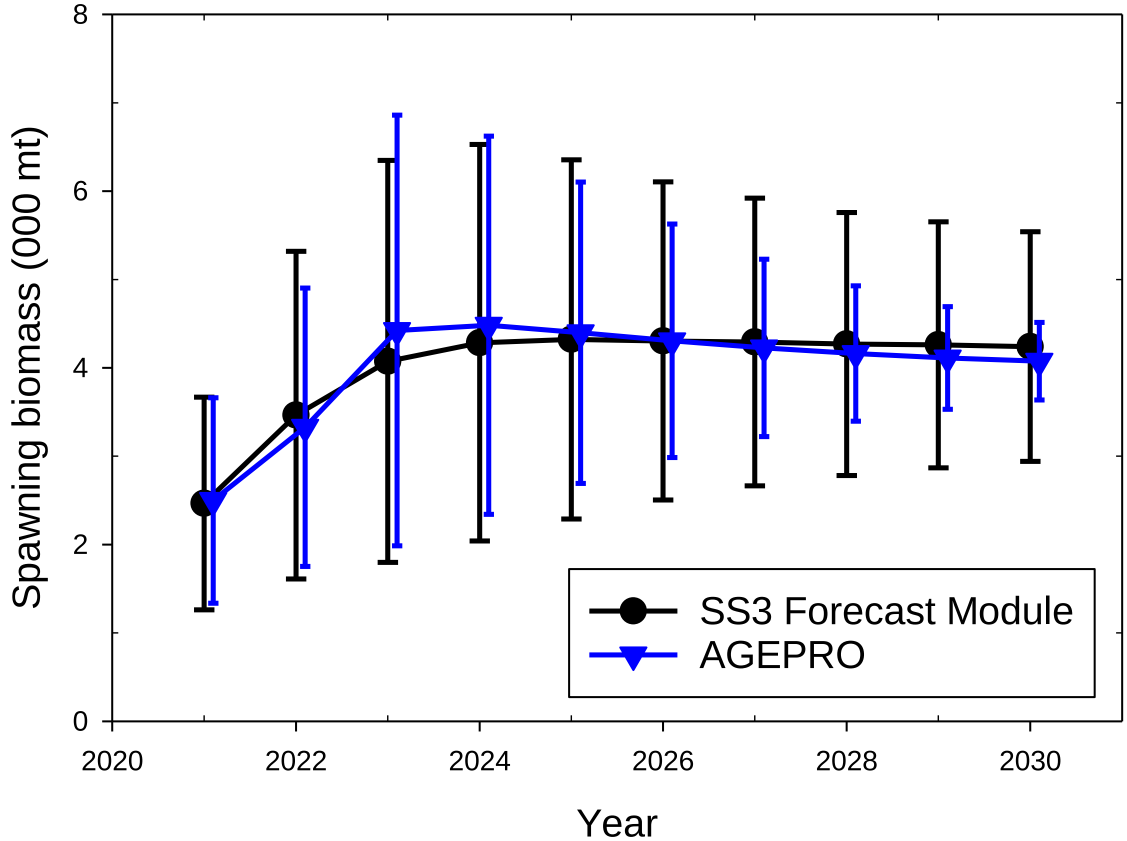

Figure 1. Comparison of SS3 and AGEPRO spawning stock biomass estimates for scenario A with Catch = 2,300 mt and recruitment set equal to the average of the 2001-2020 estimated recruitment in the SS3 assessment model. Blue line and triangles are the results from the AGEPRO model, black line and solid circles are results from the SS3 model. Error bars are the 95% confidence intervals of the 100 bootstrap runs of the SS3 model and AGEPRO model.

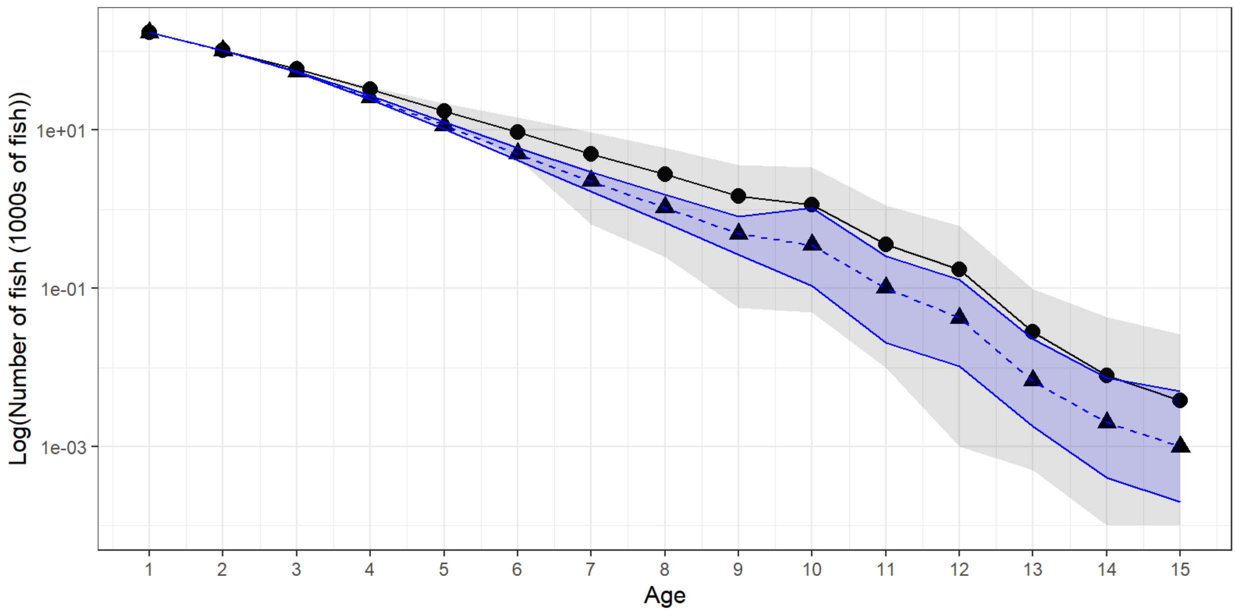

Figure 2. Comparison of SS3 and AGEPRO estimated numbers at age in 2030 for scenario A projections with Catch = 2,300 mt and recruitment set equal to the average of the 2001-2020 estimated recruitment in the SS3 assessment model. Blue dashed line and triangles indicate the AGEPRO model and black solid line and circles indicate the SS3 model, 90% confidence intervals for each model are shaded. Note the y-axis is in log-space.

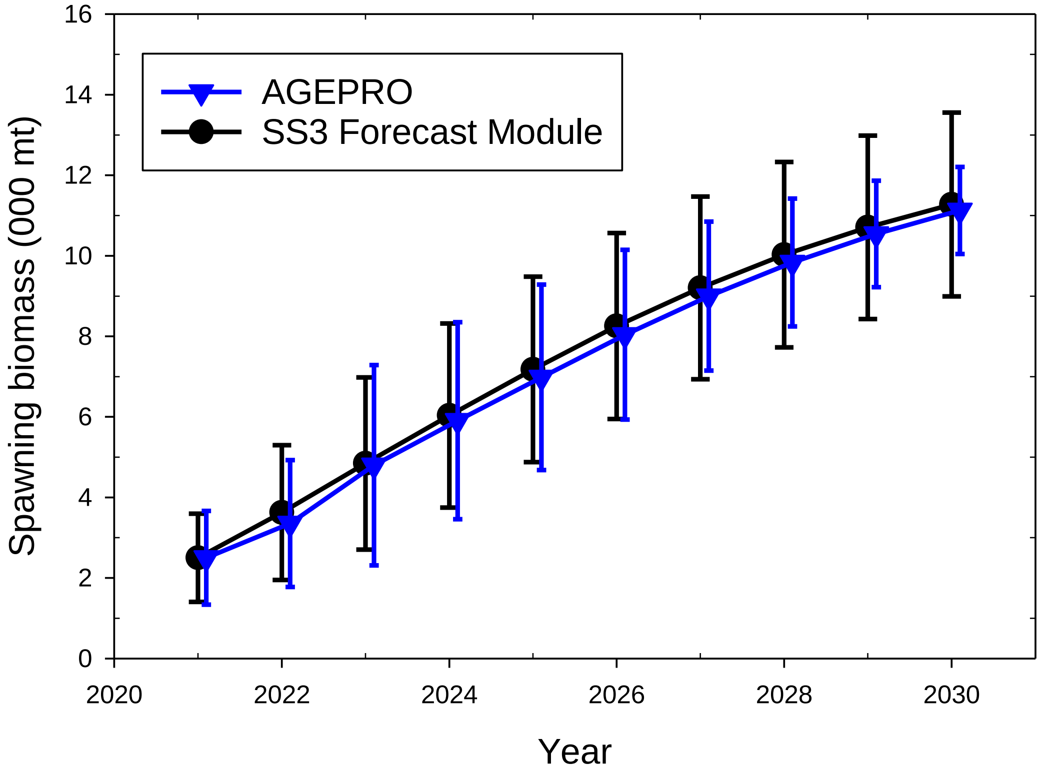

Figure 3. Comparison of SS3 and AGEPRO spawning stock biomass estimates for scenario B with Catch = 2,300 mt and recruitment calculated from the stock-recruitment curve. Blue line and triangles are the results from the AGEPRO model, black line and solid circles are results from the SS3 model. Error bars are the 95% confidence intervals of the 100 bootstrap runs of the SS3 model and AGEPRO model.

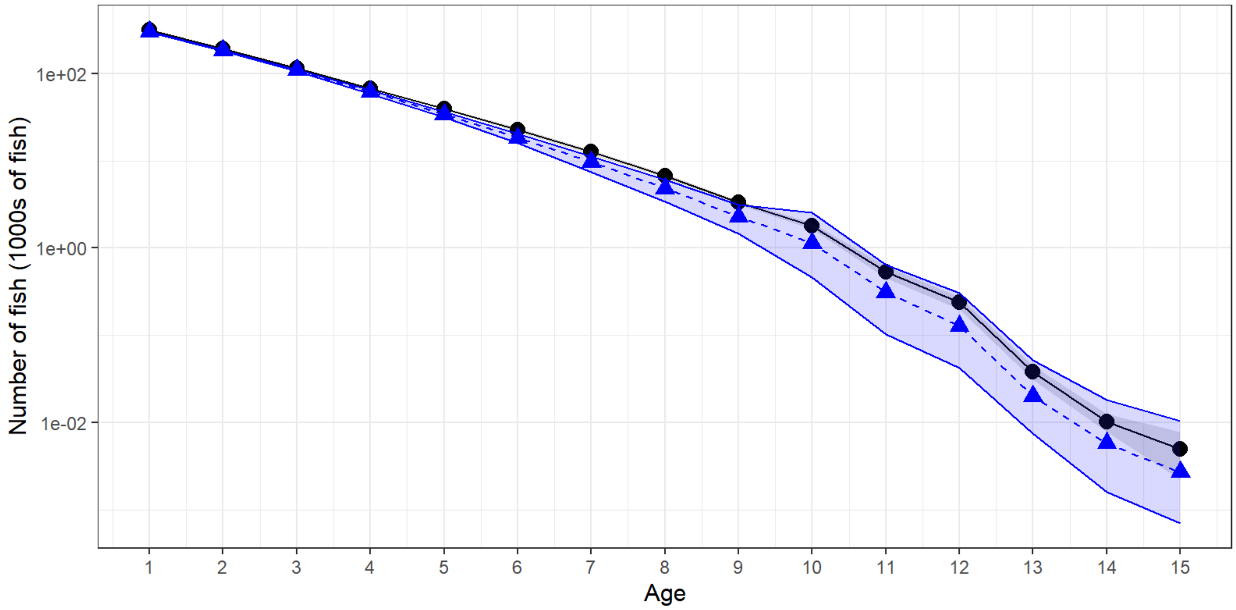

Figure 4. Comparison of SS3 and AGEPRO estimated numbers at age in 2030 for scenario B projections with Catch = 2,300 mt and recruitment calculated from the stock recruitment curve. Blue dashed line and triangles indicate the AGEPRO model and black solid line and circles indicate the SS3 model, 90% confidence intervals for each model are shaded. Note the y-axis is in log-space.

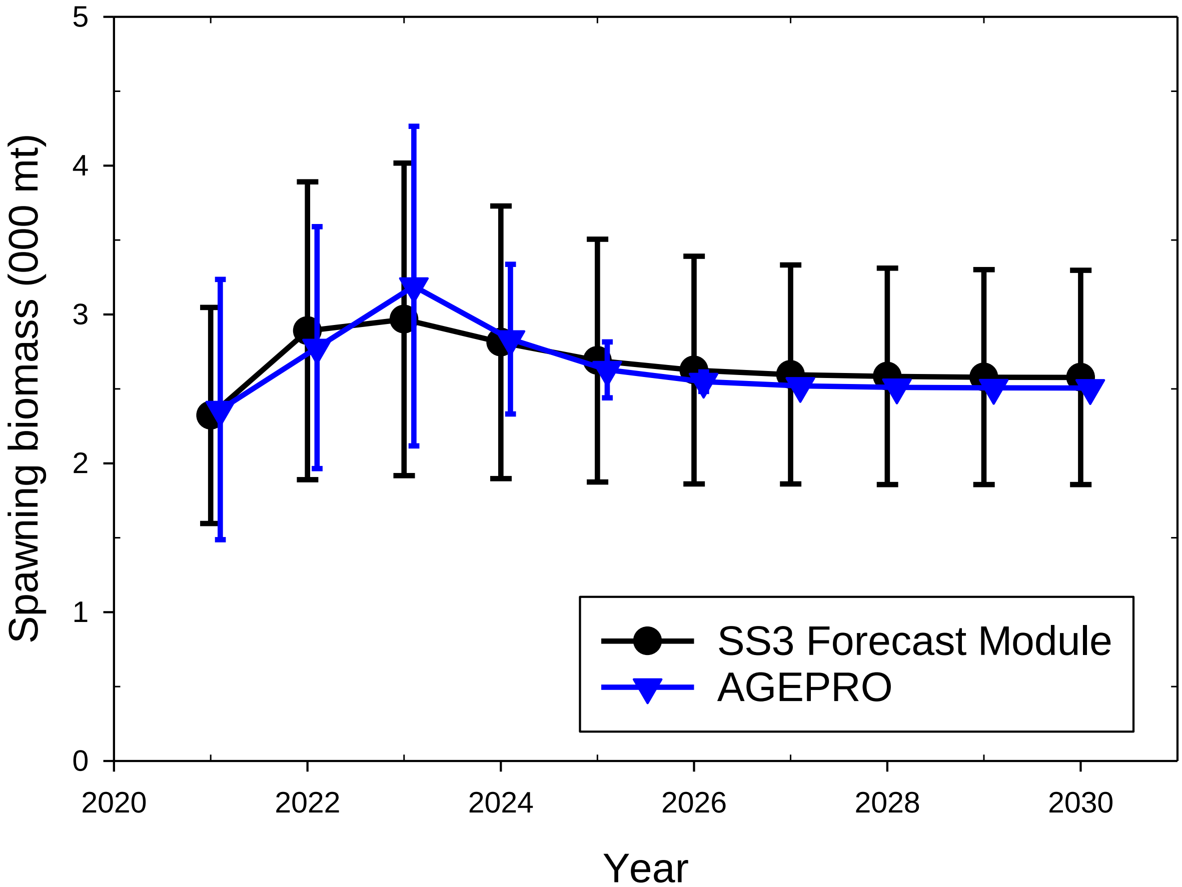

Figure 5. Comparison of SS3 and AGEPRO spawning stock biomass estimates for scenario C with $F=F_{MSY}$ and recruitment set equal to the average of the 2001-2020 estimated recruitment in the SS3 assessment model. Blue line and triangles are the results from the AGEPRO model, black line and solid circles are results from the SS3 model. Error bars are the 95% confidence intervals of the SS3 model.

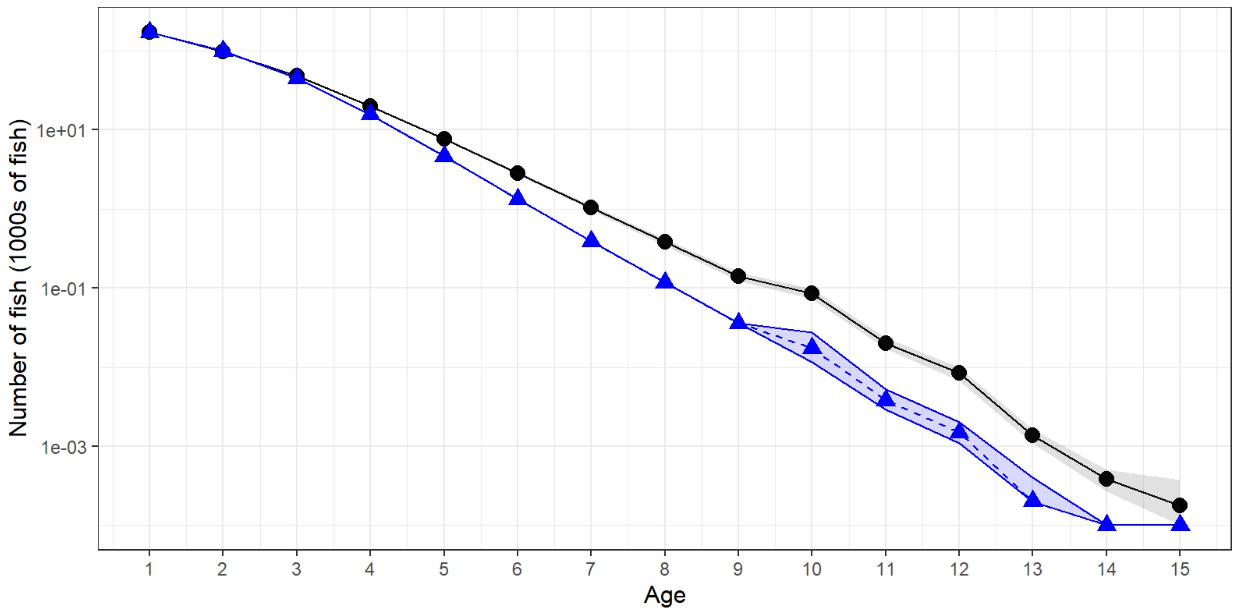

Figure 6. Comparison of SS3 and AGEPRO estimated numbers at age in 2030 for scenario C projections with $F=F_{MSY}$ and recruitment set equal to the average of the 2001-2020 estimated recruitment in the SS3 assessment model. Blue dashed line and triangles indicate the AGEPRO model and black solid line and circles indicate the SS3 model, 90% confidence intervals for each model are shaded. Note the y-axis is in log-space.

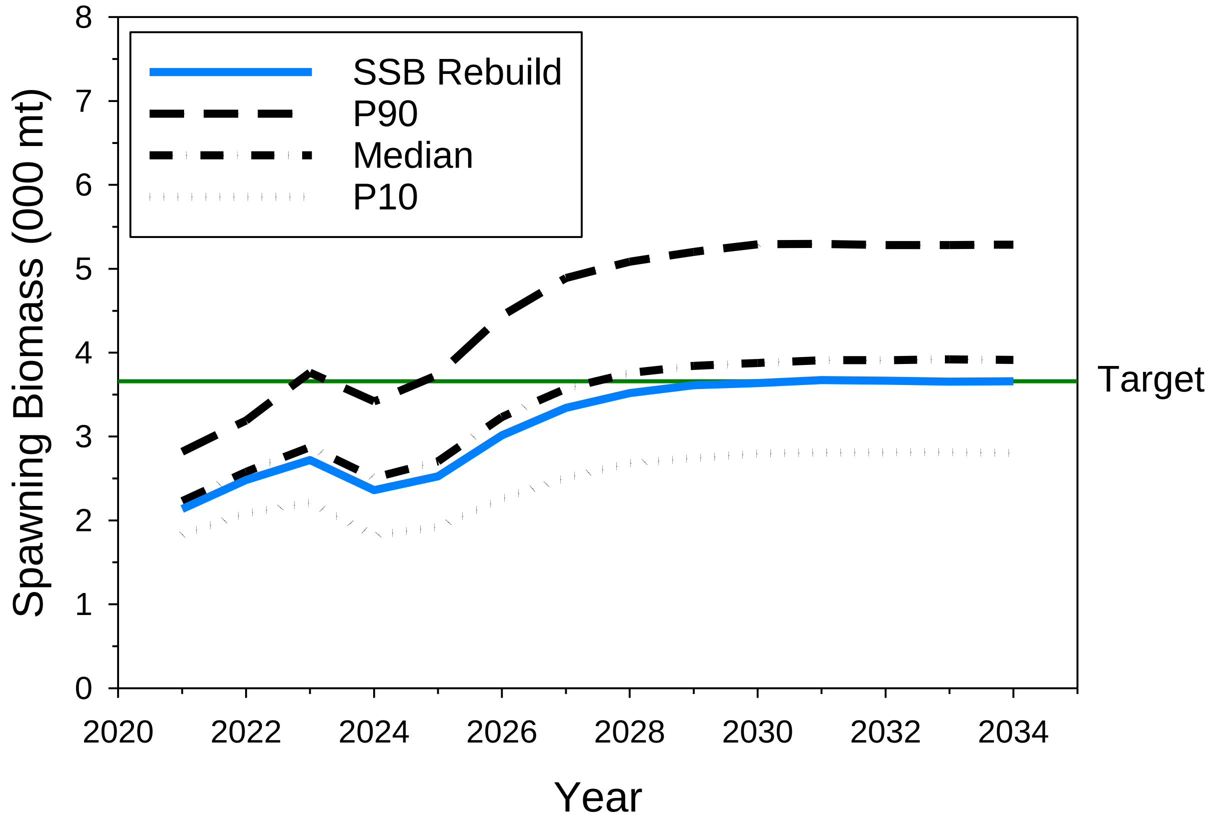

Figure 7. The time series of median spawning biomasses to rebuild the stock under scenario 1: the constant F rebuilding scenario, F = 0.373 (SSB Rebuild, P60, blue solid line) along with the 10th (P10, dotted line), median (dash-dotted line), and 90th (P90, dashed line) percentiles of the annual spawning biomass distributions relative to the rebuilding target of 3,660 mt.

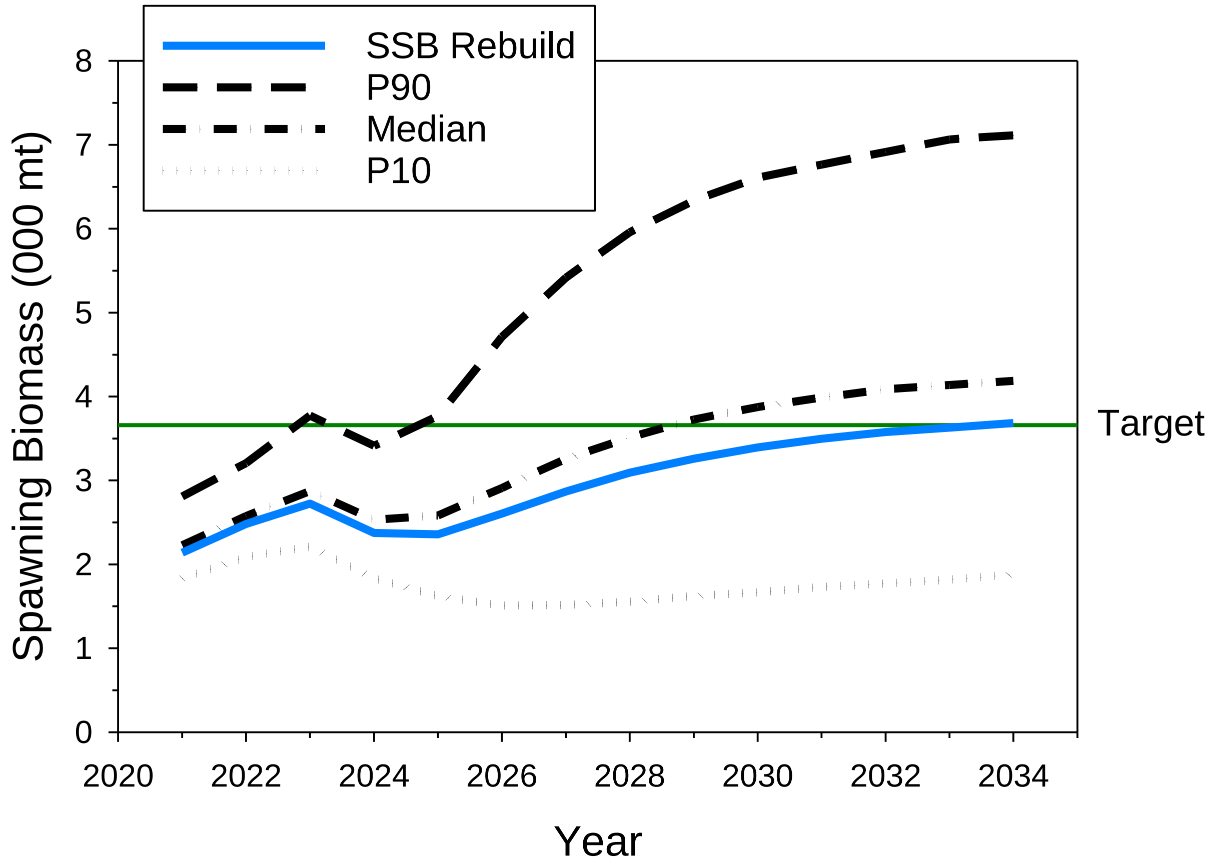

Figure 8. The time series of median spawning biomasses to rebuild the stock under scenario 2: a constant catch rebuilding scenario with $Catch_{2025\text{-}2034}$ = 2,175 mt (SSB Rebuild, P60, solid blue line) along with the 10th (P10, dotted line), median (dash dotted line), and 90th (P90, dashed line) percentiles of the annual spawning biomass distributions relative to the rebuilding target of 3,660 mt.

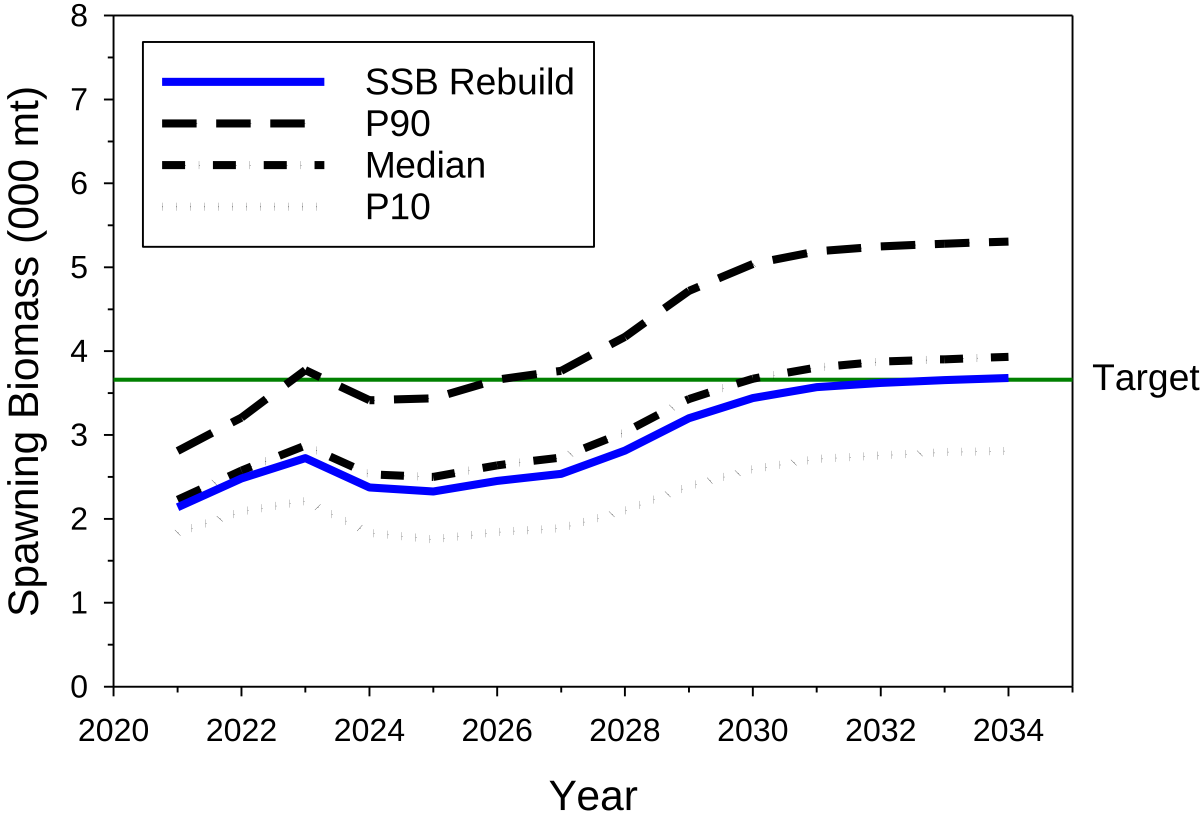

Figure 9. The time series of median spawning biomasses to rebuild the stock under scenario 3: the phased-F rebuilding scenario, $F_{2025\text{-}2027}$ = 0.55, $F_{2028\text{-}2034}$ = 0.37 (SSB Rebuild, P60, solid blue line) along with the 10th (P10, dotted line), median (dash-dotted line), and 90th (P90, dashed line) percentiles of the annual spawning biomass distributions relative to the rebuilding target of 3,660 mt.

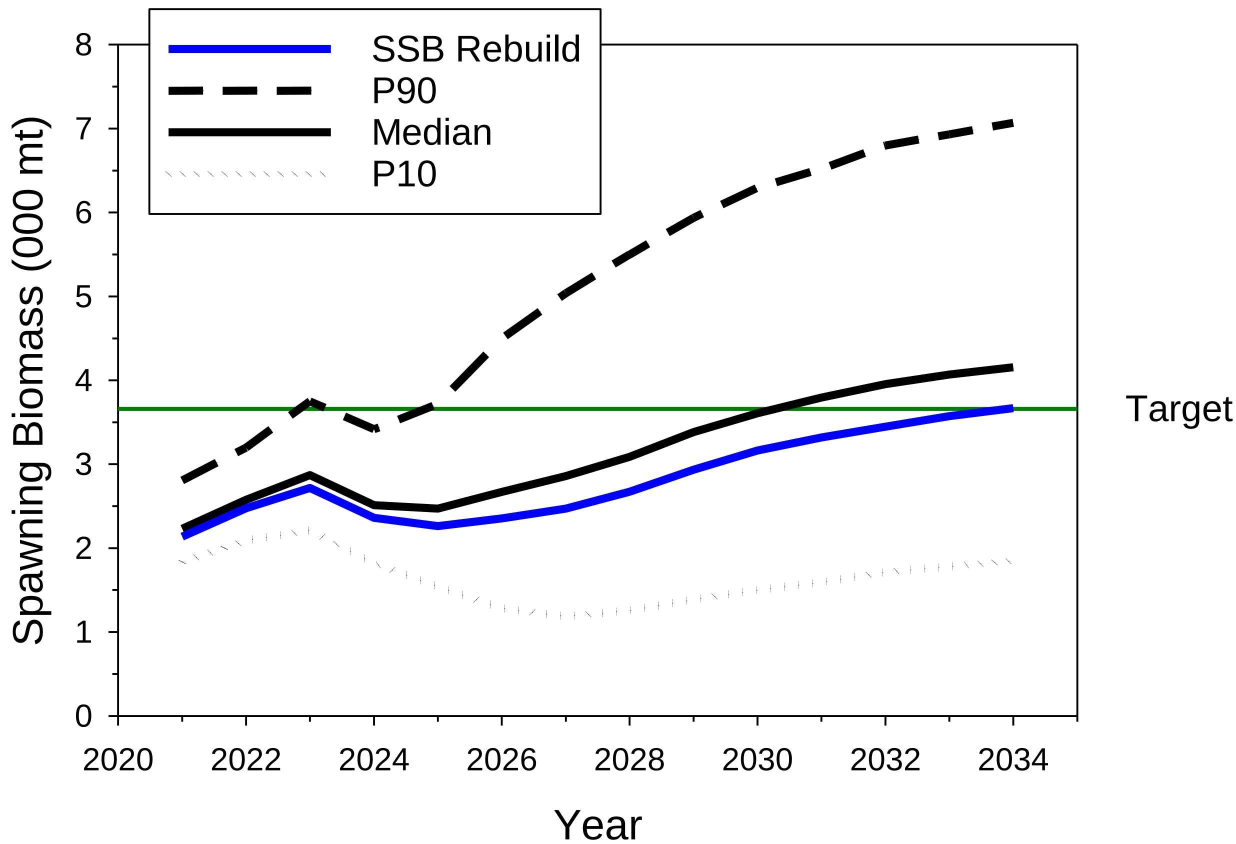

Figure 10. The time series of median spawning biomasses to rebuild the stock under scenario 4: the phased-Catch rebuilding scenario with $Catch_{2025-2027}$ = 2,400 mt, $Catch_{2028-2034}$ = 2,150 mt (SSB Rebuild, P60, solid blue line) along with the 10^{th} (P10, dotted line), median (dash-dotted line), and 90^{th} (P90, dashed line) percentiles of the annual spawning biomass distributions relative to the rebuilding target of 3,660 mt.

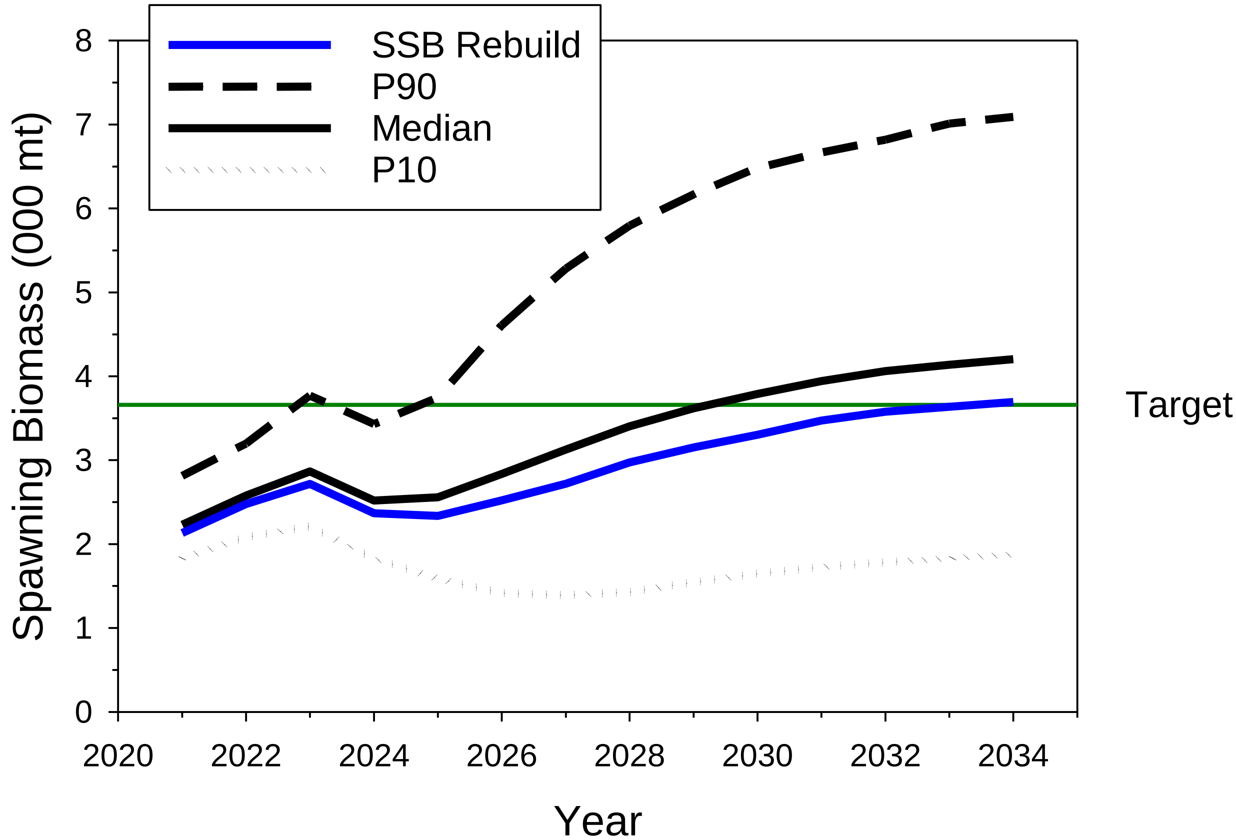

Figure 11. The time series of median spawning biomasses to rebuild the stock under scenario 5: the phased-Catch rebuilding scenario with $Catch_{2025\text{-}2027}$ = 2,250 mt, $Catch_{2028\text{-}2034}$ = 2,175 mt (SSB Rebuild, P60, solid blue line) along with the 10^{th} (P10, dotted line), median (dash-dotted line), and 90^{th} (P90, dashed line) percentiles of the annual spawning biomass distributions relative to the rebuilding target of 3,660 mt (green line, target).

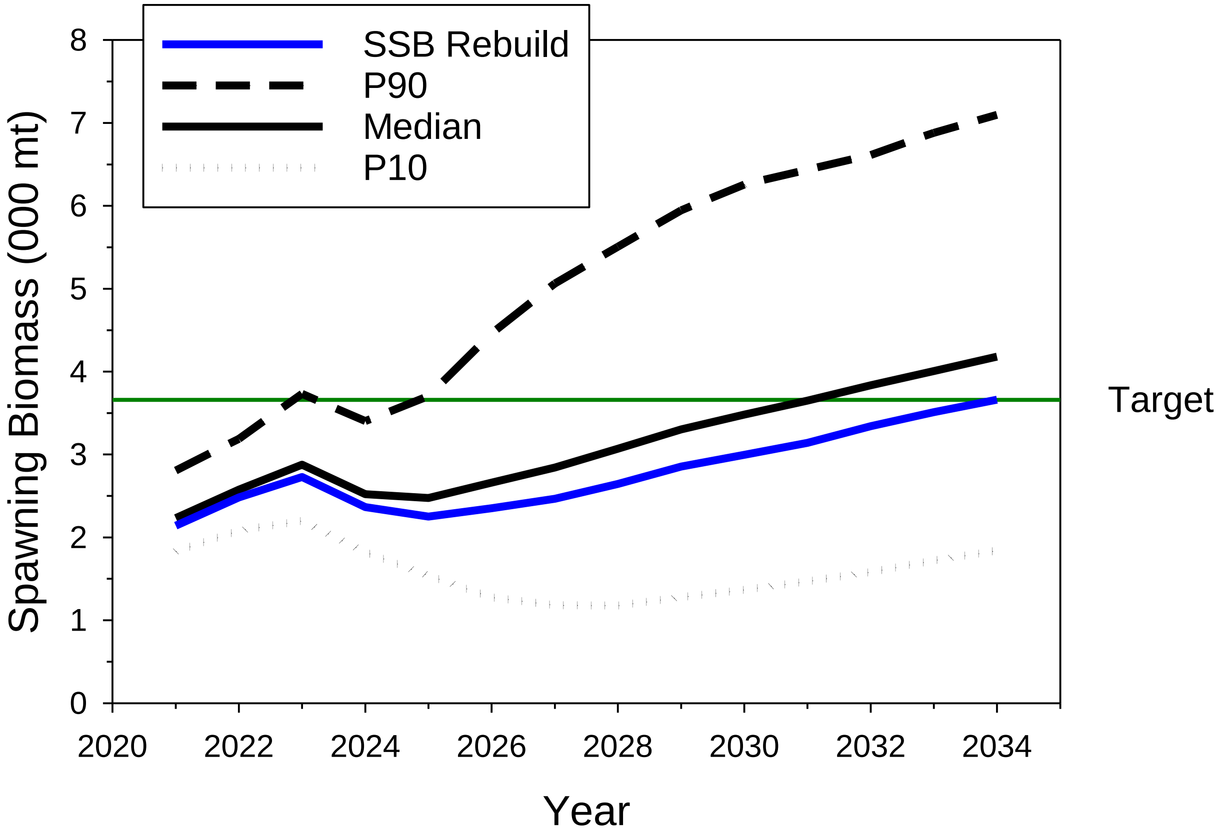

Figure 12. The time series of median spawning biomasses to rebuild the stock under scenario 6: the phased-Catch rebuilding scenario with $\text{Catch}_{2025\text{-}2027}$ = 2,400 mt, $\text{Catch}_{2028\text{-}2032}$ = 2,200 mt, and $\text{Catch}_{2033\text{-}2034}$ = 2,100 mt (SSB Rebuild, P60, solid blue line) along with the 10th (P10, dotted line), median (dash-dotted line), and 90th (P90, dashed line) percentiles of the annual spawning biomass distributions relative to the rebuilding target of 3,660 mt (green line, target).

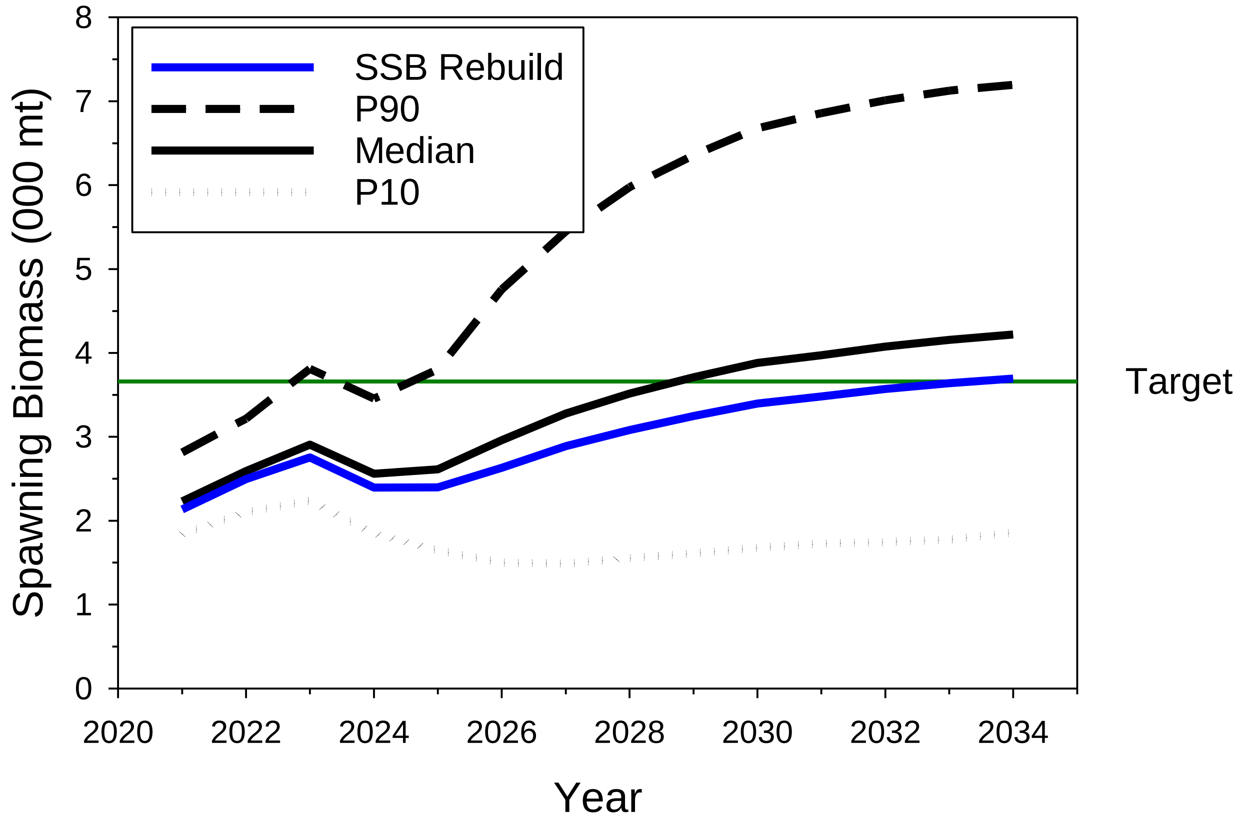

Figure 13. The time series of median spawning biomasses to rebuild the stock under scenario 7: 120 cm EFL size limit with low release survivorship with $Catch_{2025\text{-}2034}$ = 2,180 mt, (SSB Rebuild, P60, solid blue line) along with the 10^{th} (P10, dotted line), median (dash-dotted line), and 90^{th} (P90, dashed line) percentiles of the annual spawning biomass distributions relative to the rebuilding target of 3,660 mt (green line, target).

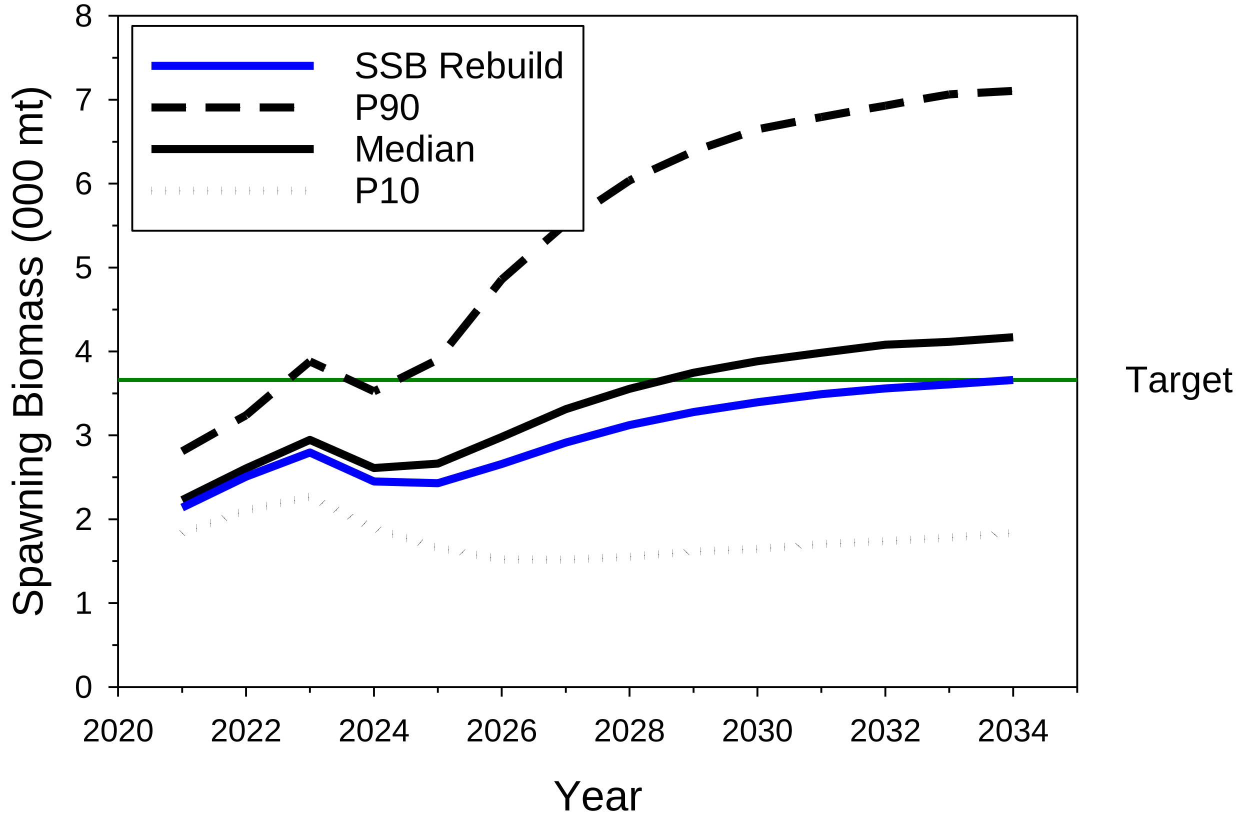

Figure 14. The time series of median spawning biomasses to rebuild the stock under scenario 8: 120 cm EFL size limit with high release survivorship with $Catch_{2025-2034}$ = 2,185 mt, (SSB Rebuild, P60, solid blue line) along with the 10^{th} (P10, dotted line), median (dash-dotted line), and 90^{th} (P90, dashed line) percentiles of the annual spawning biomass distributions relative to the rebuilding target of 3,660 mt (green line, target).

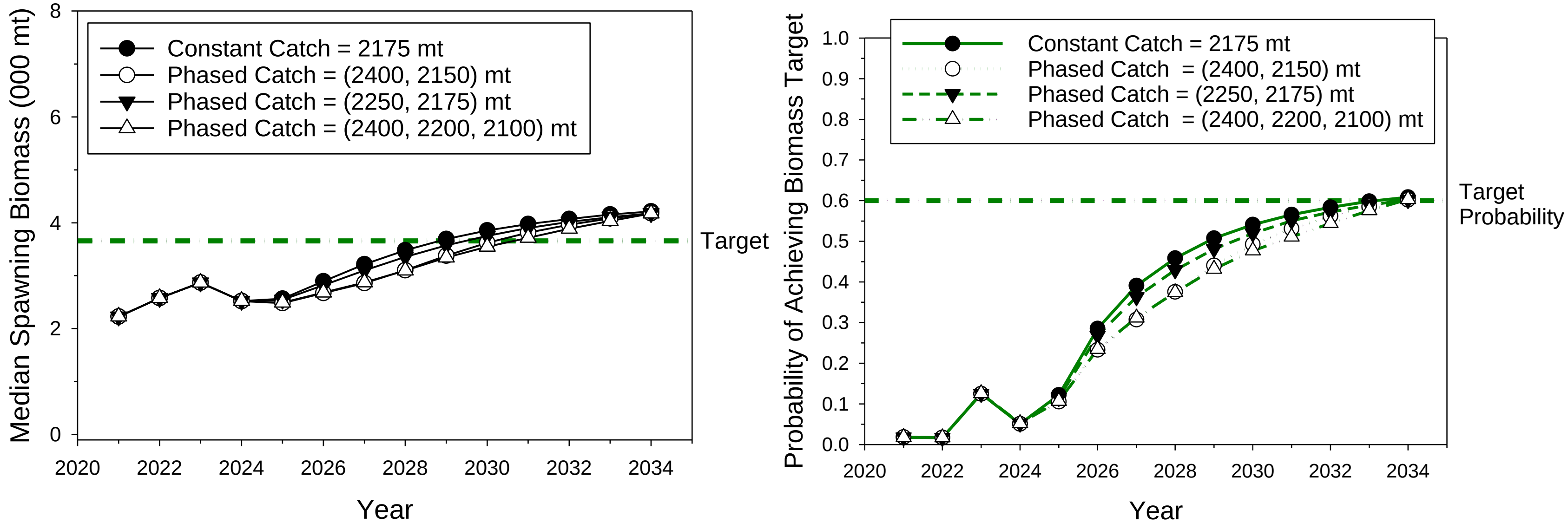

Figure 15. Comparison of the central tendencies of spawning stock biomass distributions to rebuild the stock (left panel) and Comparison of annual probabilities of achieving the rebuilding target of 3,660 mt of spawning biomass with at least 60% probability during 2021–2034 (right panel) under the catch scenarios: scenario 2 $Catch_{2025\text{-}2034}$ = 2,175 mt (closed circles); scenario 4 $Catch_{2025\text{-}2027}$ = 2,400 mt, $Catch_{2028\text{-}2034}$ = 2,150 mt (open circles); scenario 5 $Catch_{2025\text{-}2027}$ = 2,250 mt, $Catch_{2028\text{-}2034}$ = 2,175 mt (closed triangles); and scenario 6 $Catch_{2025\text{-}2028}$ =2,400 mt, $Catch_{2028\text{-}2023}$ = 2,200 mt, $Catch_{2032\text{-}2034}$ = 2,100 mt. Green dashed line indicates the 20%$SSB_{F=0}$ rebuilding target of 3,360 mt.

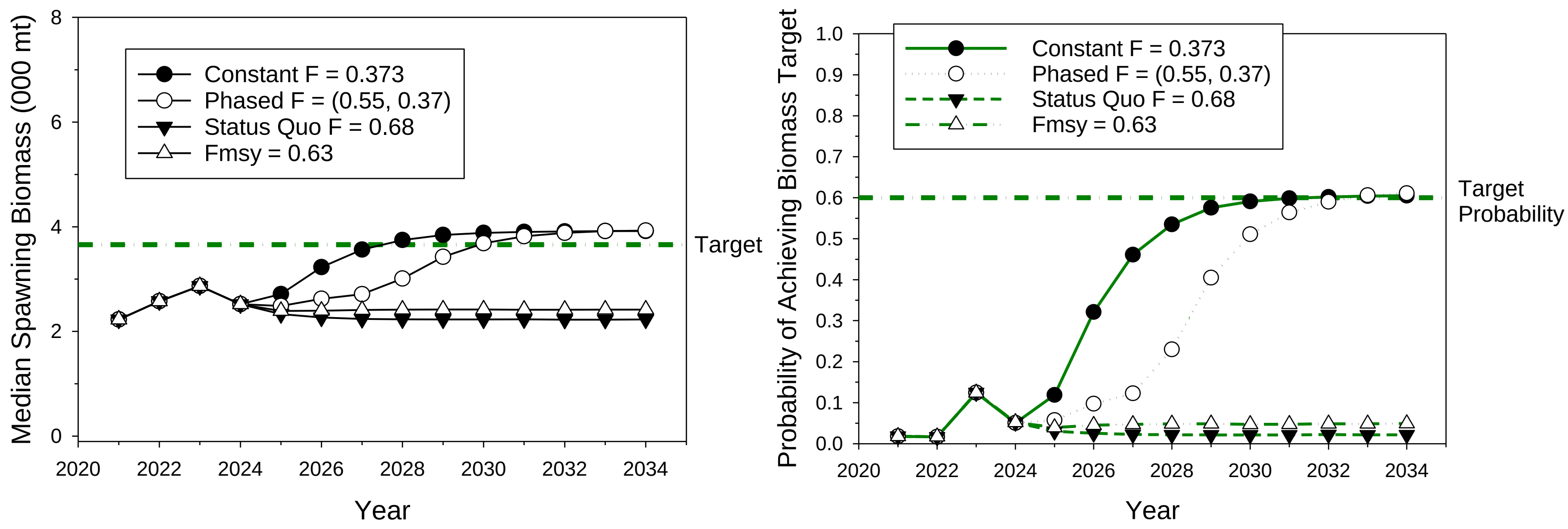

Figure 16. Comparison of the central tendencies of spawning stock biomass distributions to rebuild the stock (left panel) and Comparison of annual probabilities of achieving the rebuilding target of 3,660 mt of spawning biomass with at least 60% probability during 2021–2034 (right panel) under the Fishing Mortality-based rebuilding scenarios: scenario 1 $F_{2025\text{-}2034} = 0.373$ (closed circles); scenario 3 $F_{2025\text{-}2027} = 0.55$, $F_{2028\text{-}2034} = 0.37$ (open circles) with $F_{\text{status quo}}$ (closed triangles) and F_{MSY} (open triangles) projections. Green dashed line indicates the 20%$SSB_{F=0}$ rebuilding target of 3,360 mt.

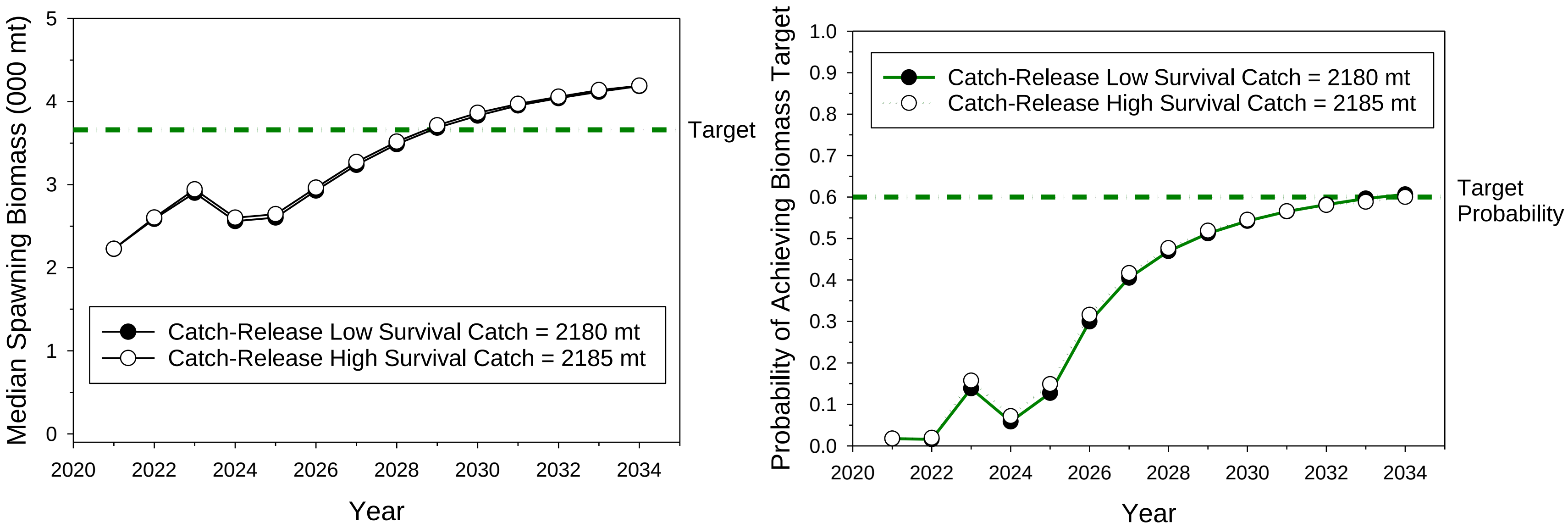

Figure 17. Comparison of the central tendencies of spawning stock biomass distributions to rebuild the stock (left panel) and comparison of annual probabilities of achieving the rebuilding target of 3,660 mt of spawning biomass with at least 60% probability during 2021–2034 (right panel) for scenario 7: 120 cm EFL size limit with low release survivorship with $Catch_{2025\text{-}2034}$ = 2,180 mt (closed circle), and scenario 8: 120 cm EFL size limit with high release survivorship with $Catch_{2025\text{-}2034}$ = 2,185 mt (open circle). Green dashed line indicates the $20\%SSB_{F=0}$ rebuilding target of 3,360 mt.

10. OTHER ITEMS

The WG agreed to a tentative meeting scheduled for 13-17 January 2025 in Honolulu, Hawaii, USA to discuss ongoing billfish research.

11. CIRCULATE WORKSHOP REPORT

The WG Chair made a draft of the workshop document and distributed it to the WG members. The WG members reviewed the draft.

12. ADOPTION

The WG adjourned the working group meeting at 2:01 on April 23, 2024 (CST).

13. REFERENCES

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APPENDIX 2. MEETING AGENDA

BILLFISH WORKING GROUP (BILLWG)
International Scientific Committee for Tuna and Tuna-like Species in the North Pacific Ocean

BIOLOGICAL WORKSHOP and MEETING

April 20 and 22-23, 2024
Institute of Oceanography, National Taiwan University
Taipei, Taiwan

Meeting time: 9:00AM-5:00PM CST
Call in information:
WEBEX Meeting
https://ntucc.webex.com/ntucc-en/j.php?MTID=m76cd08a1277b88567749356202177dbf

AGENDA

1. **Opening of workshop**
   a. Welcoming Remarks
   b. Introductions
2. **Meeting Logistics**
   a. Meeting Protocol
   b. Review and Adoption of Agenda
   c. Assignment of Rapporteurs
   d. Group Photo
3. **Collaborative Project Updates**
   a. Progress and Summary of Sampling
      i. Overview of US's sampling efforts (Mike)
      ii. Overview of Japan's sampling efforts (Kai)
      iii. Overview of Taiwan's sampling efforts (Yi-Jay)
4. **Progress of Growth Study on NP-Striped Marlin**
   a. Update on growth study progress
   b. Development of AI tool as an aid for age determination
5. **Methodology for Frozen Gonads Observation**
   a. Presentation on improvement methodologies
   b. Discussion on observations and findings
6. **Analytical advances and validation work**
   a. Advances in growth studies
      i. Simulation study from US
   b. Advances in growth validation studies
      i. General discussion of methods
      ii. Progress to date
7. **IBBS Data Discussion**
   a. Database Improvement

        i. Suggestions for IBBS database enhancement
        ii. Discussion on unit of weight data
    b. Database Utilization
        i. Sharing methods and collaboration
        ii. Specific improvements needed

8. **Project Planning**
    a. Target Discussion
        i. Consideration of target species
        ii. Challenges in collecting samples
        iii. Use of sampling plan to direct sampling
    b. Scheduling and Next Steps
        i. Proposal of a specific schedule
        ii. Next steps and action items
9. **Other biological studies**
    a. Ongoing and future collaborative study
        i. Seascape population genomics for swordfish (Cheng-Ruei & Yi-Jay)
        ii. NP-Striped Marlin movement and diving behavior (Riyar)
        iii. Regional difference in ontogenetic trophic shift of swordfish (Ming-Tsung & Yi-Jay)
10. **WCNPO MLS Rebuilding Analysis**
    a. Review of Information on MLS catch (Sculley)
    b. AGEPRO Projection analysis (Brodziak)
11. **Administrative Matters**
12. **Other matters**
13. **Clearing of Meeting Report**
14. **Adjournment**

APPENDIX 3: WORKING PAPERS

WP number	Author(s)	Title
WP01	Mikihiko Kai and Yuki Ishihara	Progress report of biological sampling for billfishes collected by Japan in the North Pacific for 2019-2023
WP02	Yuki Ishihara	Fixation methods for frozen gonads of female swordfish
WP03	Jon Brodziak	WCNPO MLS Rebuilding Analysis
WP04	Wei-Chuan Chiang, Shian-Jhong Lin, Michael K. Musyl, Chi-Lu Sun, Yi-Jay Chang, Yuan-Shing Ho	Horizontal and vertical movements of striped marlin (Kajikia audax) in the northwestern Pacific Ocean.
Presentation Number		
P01	Mike Kinney	Progress and Summary of US IBBS Sampling
P02	Yi-Jay Chang	Progress of biological sampling for billfishes collected by Taiwan in the Pacific Ocean
P03	Ayumu Furuyama, Miwako Funabara, Yuichi Arai, Yuki Ishihara, Mikihiko Kai, Minoru Kanaiwa	The progress of age estimation for striped marlin in the North Pacific
P04	Nicholas Ducharme-Barth	IBBS: spatial (biological) modeling
P05	Kristen Dahl	Investigating the use of eye lenses to validate fish age
P06	Cheng-Ruei Lee & Yi-Jay Chang	Seascape population genomics for swordfish
P07	Ming-Tsung & Yi-Jay Chang	Regional difference in ontogenetic trophic shift of swordfish
P08	Michelle Sculley	Summary of information about MLS catch from the Billfish Research Plan