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An application of the Bayesian Length Interval Catch Curve Analysis (FISHBLICC) to Indian Ocean longtail tuna and (*Thunnus tonggol*) and narrow-barred Spanish mackerel (*Scomberomorus commerson*)

Dan Fu, IOTC Secretariat

Summary

In recent years, the assessment of stock depletion using Spawning Potential Ratio (SPR)-based proxies has been advanced by the development of length-based methods such as the Length-Based Spawning Potential Ratio (LBSPR) model. The LBSPR approach has been applied to stock assessments of neritic tuna species by the Indian Ocean Tuna Commission (IOTC), including the current assessment in 2026. However, a key limitation of the LBSPR model is its assumption of asymptotic selectivity, which may not be appropriate for IOTC neritic fisheries that employ selective fishing gears. The recently developed R package FISHBLICC (Bayesian Length Interval Catch Curve Analysis) offers greater flexibility in modeling fishing selectivity. In this study, we applied FISHBLICC to length frequency data for Indian Ocean longtail tuna (*Thunnus tonggol*) and narrow-barred Spanish mackerel (*Scomberomorus commerson*). The exercise demonstrates that incorporating more realistic selectivity patterns (e.g., dome-shaped double normal selectivity) is important for capturing the factors influencing observed length frequencies, and the robustness of the assessment can be enhanced when length data are available from multiple fisheries with contrasting selectivity patterns. Further, while FISHBLICC and similar packages are not specifically designed to model temporal dynamics, further development to enable key estimates to be compared across time would be valuable. Such advancements would allow these assessment models to serve as powerful tools for monitoring the performance of fisheries and stocks over time.

1. Introduction

Assessing the status of neritic tuna stocks in the Indian Ocean presents significant challenges due to limited data availability. Reliable information on stock structure, abundance, and key biological parameters is often lacking. Since 2013, stock assessments for neritic tuna species have relied on data-limited approaches, such as the Catch-MSY (C-MSY) method (Froese et al., 2016). C-MSY is a catch-only method that utilizes historical catch series, combined with knowledge of stock productivity, to estimate plausible stock trajectories, biological reference points, and depletion levels. More recently, length-based methods—such as the Length-Based Spawning Potential Ratio (LBSPR) model (Hordyk et al., 2014)—have been used to provide alternative, SPR-based depletion estimates using length frequency samples from key fisheries. These length-based approaches aim to extract information on growth, mortality, and selectivity from a single length frequency sample, conditioned on life-history traits. As a result, they offer valuable insights into stock depletion and fishing pressure. Together, these data-limited methods allow for the evaluation of different population dynamic assumptions and the usefulness of alternative data sources in determining stock status. In this study, we demonstrate the application of FISHBLICC (Bayesian Length Interval Catch Curve Analysis), an alternative length-based model, to the assessment of IOTC longtail tuna (Thunnus tonggol) and Spanish mackerel (Scomberomorus commerson) stocks. FISHBLICC provides SPR-based depletion estimates similar to those from LBSPR but overcomes some of the limitations of the LBSPR approach, particularly in modeling fishing selectivity.

2. Methods

FISHBLICC (Bayesian Length Interval Catch Curve Analysis) is a recently developed method for data-limited fisheries stock assessments (https://github.com/PaulAHMedley/fishblicc). Like the LBSPR approach, FISHBLICC utilizes length frequency data from fishery catch samples to estimate key parameters such as fishing mortality and spawning potential ratio (SPR), providing a measure of stock depletion relative to the unfished level (SPR0). However, FISHBLICC provides greater flexibility than LBSPR by accommodating both asymptotic (logistic) and dome-shaped selectivity patterns (e.g., double normal selection curves with ascending and descending limbs). This allows for more realistic modeling of fisheries that target smaller fish, such as those using gillnets.

The FISHBLICC package further extends selectivity modeling by enabling mixtures of logistic and double normal curves, allowing it to fit complex, multi-modal length frequency distributions. Additionally, FISHBLICC can simultaneously fit length frequency data from multiple fisheries, each with its own selectivity pattern, thereby improving the precision of selectivity and fishing mortality estimates for individual fisheries.

FISHBLICC, like LBSPR, relies on the critical assumption that length frequency data are collected under equilibrium conditions, with no recruitment variability. While life-history parameters (such as the M/K ratio, growth, and maturity) are treated as fixed model inputs, FISHBLICC accounts for uncertainty in fish growth by integrating survivorship over a distribution of L^{∞}, assumed to follow a gamma distribution with an estimable coefficient of variation. The model is also implemented using full Bayesian estimation via the RSTAN package, providing robust quantification of parameter uncertainty.

To complement the LBSPR application, we applied FISHBLICC to the length frequency data for longtail tuna and Spanish mackerel, using the same dataset used in the 2026 assessment for both species (Phillips 2026a, b), specifically, the “Gillnet” fishery data for longtail tuna, and the “Gillnet” and “Line” fishery data for Spanish mackerel. The biological parameter inputs applied in the FISHBLICC models were the same to those used in the LBSPR analyses.

Longtail tuna

Four models were implemented for longtail tuna:

- Models 1 and 2: Fitted to 2024 Gillnet length frequency data only, assuming either logistic or double normal selectivity, respectively. Both models used full Bayesian estimation, with a sample size of 550 (the first 50 samples discarded as burn-in), to derive the full posterior distributions of model parameters, including SPR estimates.
- Models 3 and 4: Fitted to annual length frequency data from 1992–2024 from the Gillnet fishery, again assuming logistic or double normal selectivity. Each annual length frequency is fitted independently, with a full set of parameters estimated for each year. For these models, only the point estimate (mode of the posterior density, MPD) is reported.

The following biological parameters are used as input to the FISHBLICC model for the longtail tuna (IOTC 2015a):

L^{∞} = 135.4 cm

M/K = 1.35 (the ratio of natural mortality M to growth rate K)

L_{50}= 60 cm (length at 50% maturity)

L_{95}=70 cm (length at 95% maturity)

a = 0.07929, b= 2.541 (length weight relationship)

Spanish mackerel

We applied FISHBLICC to length frequency data from both the "Gillnet" and "Line" fishery groups, using.

Two models were implemented:

- Model 1: Fitted to the 2024 Gillnet and Line fisheries length frequency data only. This model was run using full Bayesian estimation, with a sample size of 550 (the first 50 samples discarded as burn-in), to derive the full posterior distributions of model parameters, including SPR estimates.
- Model 2: Fitted to annual length frequency data from 1992 to 2024 for the Gillnet and Line fisheries. Each year's length frequency data was fitted independently, with a full set of parameters estimated for each year. For these models, only the point estimate (mode of the posterior density, MPD) is reported.

The dataset is the same as those used in the LBSPR assessment of Phillip 2026. A key distinction between is that, in LBSPR, the length frequency data from the Gillnet and Line fisheries are modelled separately (as independent models), whereas in this analysis, the length frequencies from both fisheries are fitted simultaneously within a single model. In the analysis, selectivity was modelled as logistic for the Line fishery and as double normal for the Gillnet fishery; catches from the Line and Gillnet fisheries were assigned weightings of 0.25 and 0.75, respectively.

The following input biological parameters are used as input to the FISHBLICC model for the longtail tuna (IOTC 2015b):

L^{∞} = 153 cm

M/K = 1.35 (the ratio of natural mortality M to growth rate K)

L_{50}= 70 cm (length at 50% maturity)

L_{95}=90 cm (length at 95% maturity)

a = 0.0099, b= 2.95(length weight relationship)

3. Results

Longtail tuna

The outcomes of the four models are presented in Figures 1–4. Both the double normal (Figure 1a) and logistic selectivity (Figure 2a) models provided a reasonable fit to the 2024 length frequency data. However, the choice of selectivity assumption led to markedly different stock status estimates. Under the double normal selectivity, the model estimated an SPR distribution ranging from 0.50 to 1.0, with a posterior mode near 0.9—close to the unfished level (Figure 1c). In contrast, the logistic selectivity model produced an SPR distribution between 0.1 and 0.2, with a posterior mode around 0.15, indicating a heavily depleted stock.

This stark contrast arises from how each model interprets the right-hand side of the length frequency distribution. The double normal model attributes the lack of large fish (over 100 cm) relative to L∞ (145 cm) to strong doming in selectivity, suggesting that fish above this size are not vulnerable to the gear. Conversely, the logistic model, which assumes full selection for large fish, interprets the lack of large individuals as a result of high fishing mortality, leading to an SPR characteristic of a depleted population.

Applying these models to the time series of gillnet fishery length frequencies produced similar conclusons. The dome-shaped selectivity model (Model 3) generally estimated SPR values above 50% of SPR0 in most years (Figure 3c), with occasional lower estimates. The asymptotic selectivity model (Model 4) consistently produced very low SPR estimates (<10% of SPR0) throughout the time series (Figure 4c). Both models indicated a shift in selectivity towards smaller fish over time (Figures 3a, 4a), and a decline in fishing mortality (Figures 3b, 4b), resulting in increased SPR in the last five years compared to earlier periods (Figure 4c).

These results highlight the significant influence of selectivity assumptions on estimates of fishing mortality and stock status (SPR). While gillnets are known for their selectivity—making both small and large fish typically invulnerable—the degree of doming is difficult to quantify, especially in the absence of data on the size structure of an unfished population. The L$^{\infty}$ parameter for longtail tuna is also highly uncertain, with a wide range of estimates across the Indian Ocean. Reducing uncertainty or bias in the assessment would benefit from length frequency samples from a fishery with asymptotic selectivity, which could help clarify the degree of doming in the gillnet fishery.

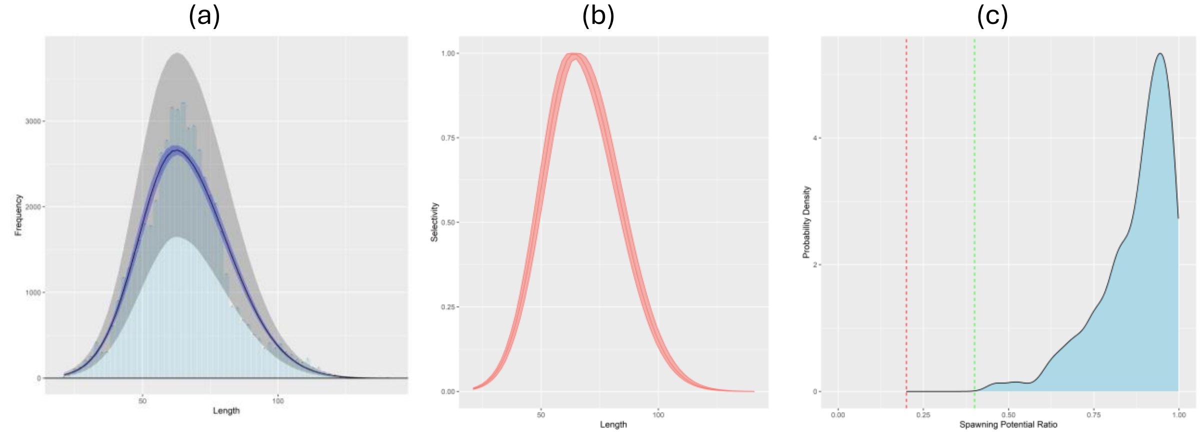

Figure 1: Outputs for the FISHBLICC Model 1 (2024 length frequency from the Gillnet fishery group, double normal selectivity): (a) Posterior fits to the observed length frequency, (b) posterior estimates of logistic fishing selectivity, (c) estimates of the posterior distribution of SPR (red dashed line indicates the reference level of SPR$_{40\%}$)

(a) (b) (c)

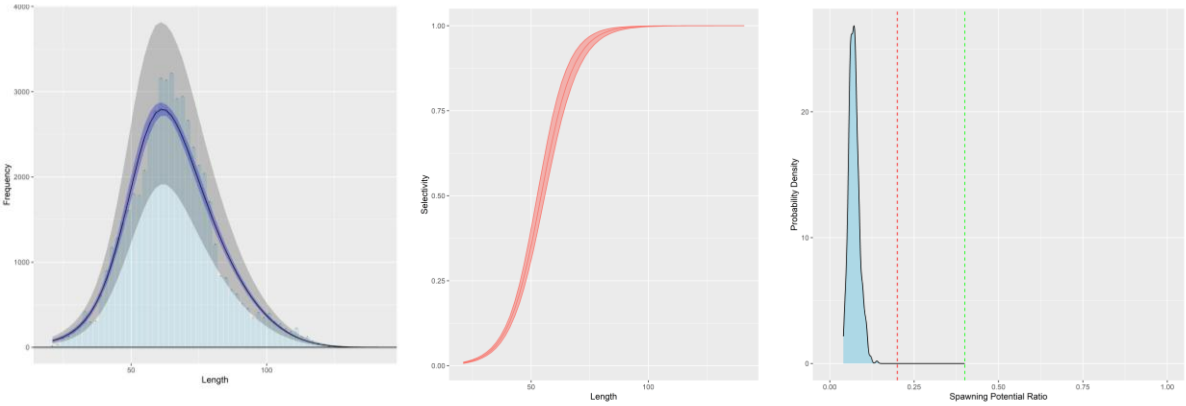

Figure 2: Outputs for the FISHBLICC Model 2 (2024 length frequency from the Gillnet fishery group, logistic selectivity): (a) Posterior fits to the observed length frequency, (b) posterior estimates of logistic fishing selectivity, (c) estimates of the posterior distribution of SPR (red dashed line indicates the reference level of SPR$_{40\%}$)

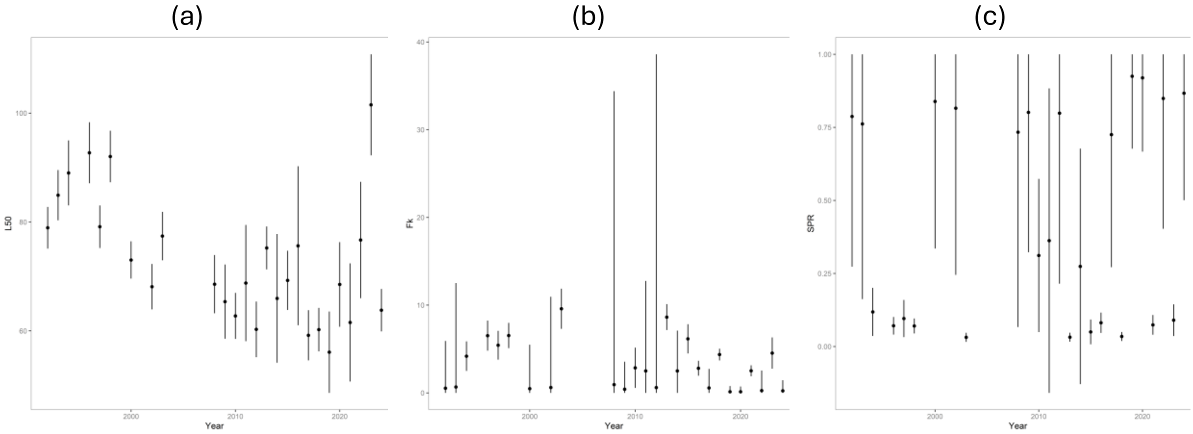

Figure 1: Outputs for the FISHBLICC Model 3 (1992-2024 length frequencies from the Gillnet fishery group, double normal selectivity): (a) Estimated selectivity parameter L$_{50}$ (length at 50% selection) for each year, (b) Estimated fishing morality (relative to K) for each year (c) estimates of SPR for each year. The dot represents MPD estimate, the line represents estimated standard error.

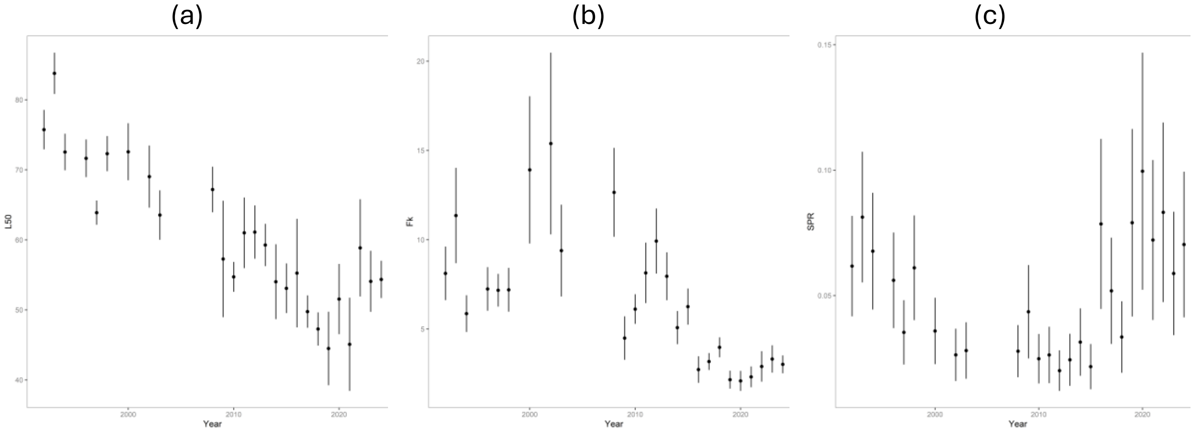

Figure 2: Outputs for the FISHBLICC Model 2 (2024 length frequency from the Gillnet fishery group, logistic selectivity): (a) Posterior fits to the observed length frequency, (b) posterior estimates of logistic fishing selectivity, (c) estimates of the posterior distribution of SPR (red dashed line indicates the reference level of SPR$_{40\%}$)

Spanish mackerel

The outcomes of the two models are presented in Figures 5 and 6. Both models provided a reasonable fit to the 2024 length frequency data for the gillnet and line fisheries (Figure 5a). The estimated selectivity curve for the gillnet fishery exhibited a similar ascending limb and length at full selection as the line fishery (Figure 5b). However, the dome-shaped selectivity for the gillnet fishery is supported by the lower proportion of large fish (e.g., >120 cm) observed in the gillnet length frequency compared to the line fishery. The model estimated an SPR distribution ranging from 0.25 to 0.70, with the posterior mode slightly above 0.40—a level generally considered as the management target (Figure 5c).

Applying these models to the time series of length frequency data from both fisheries revealed that selectivity patterns appeared highly variable over the period. Fishing mortality estimates for the gillnet fishery were consistently higher than those for the line fishery and showed a declining trend over time. SPR estimates prior to 2024 were much below the target of 40% SPR0. The observed variability in selectivity may reflect real changes in fishing practices or gear, but it could also be an artifact of sampling variability in the length frequency data over time. It would be valuable to explore a scenario in which selectivity is assumed to be constant over time, as this could improve the comparability of SPR estimates across years.

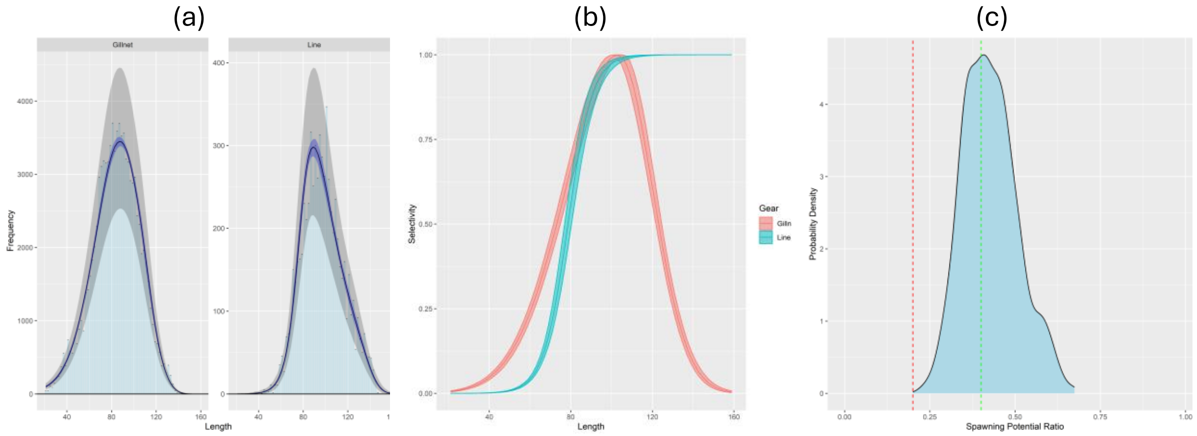

Figure 5: Outputs for the FISHBLICC Model 2 (2024 length frequency from the Gillnet fishery group, logistic selectivity): (a) Posterior fits to the observed length frequency, (b) posterior estimates of logistic fishing selectivity, (c) estimates of the posterior distribution of SPR (red dashed line indicates the reference level of SPR$_{40\%}$)

(a) (b) (c)

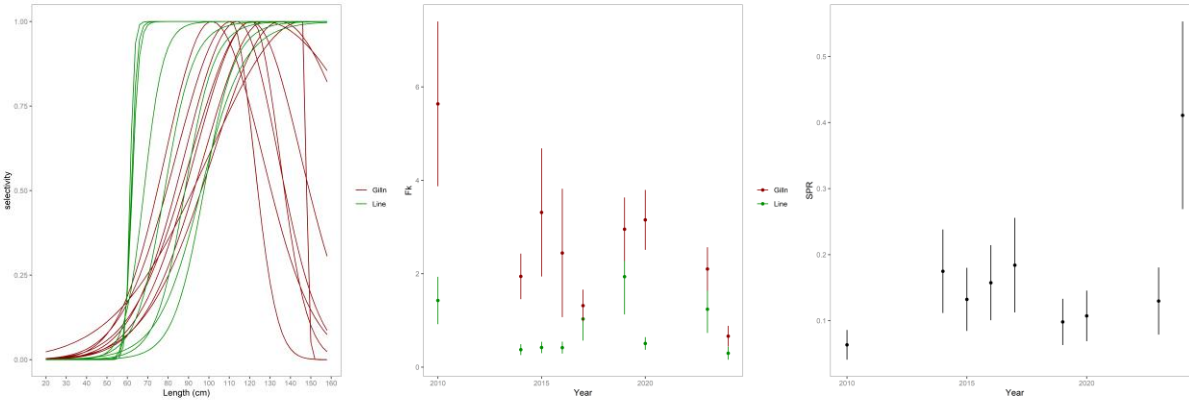

Figure 6: Outputs for the FISHBLICC Model 2 (2024 length frequency from the Gillnet fishery group, logistic selectivity): (a) Posterior fits to the observed length frequency, (b) posterior estimates of logistic fishing selectivity, (c) estimates of the posterior distribution of SPR (red dashed line indicates the reference level of $SPR_{40\%}$)

4. Discussions

This analysis demonstrates the application of the newly developed FISHBLICC method as an alternative to the widely used LBSPR approach for estimating Spawning Potential Ratio (SPR)—a well-established biological reference point—using life history parameters and length composition data. Like LBSPR, FISHBLICC has the potential to provide a cost-effective assessment tool for IOTC neritic tuna stocks, especially since length data are among the easiest and most affordable data types to collect for many small-scale, data-poor fisheries. In contrast to catch-only methods, which require accurate and complete catch statistics, length-based methods such as FISHBLICC only require representative length frequency data, which is often more feasible to obtain for many IOTC neritic tuna species.

It is important to note that the length frequency data analysed in this study are simple aggregations across broad fishery groups. For both longtail tuna and Spanish mackerel, the "Gillnet" fishery group encompasses a range of gillnet gears operated by different fleets (CPCs) in various areas, while the "Line" fishery group includes trolling, handline, and coastal longline gears. Although these gears may have broadly similar operational characteristics, they may represent fisheries with different fishing pressures and selectivity patterns. Aggregating length frequencies from these diverse fisheries may not adequately represent the overall size structure and could introduce bias or variability that masks true signals in abundance or fishing mortality. A more appropriate approach would involve detailed analysis of length frequencies by fleet and gear type, which could provide more accurate indicators of fishing mortality and stock depletion at the regional fishery level. Alternatively, a rigorous approach to deriving an overall length frequency—using stratified sampling principles—could help reduce sampling variability and improve representativeness.

LBSPR remains the most widely used length-based, data-limited method. However, its restriction to asymptotic selectivity is a significant limitation, particularly for fisheries exhibiting dome-shaped selectivity, such as gillnet fisheries, which are dominant in the Indian Ocean neritic tuna fishery. The more flexible selectivity options provided by FISHBLICC represent a major improvement over LBSPR. Application of FISHBLICC to the gillnet length frequency data for longtail tuna revealed markedly different results under asymptotic versus dome-shaped selectivity assumptions. Notably, modeling dome-shaped selectivity alone can be confounded with fishing mortality, as the absence of large fish in the length frequency can be explained either by the declining limb of selectivity or by increased fishing mortality—factors that are often difficult to disentangle. While both selectivity assumptions can adequately represent possible selectivity-mortality trade-offs, the resulting SPR estimates under each scenario may be extreme, ranging from near-virgin to heavily exploited states. Quantifying this bias is challenging, especially given additional uncertainty in growth parameters, especially L^∞. Although double normal selectivity is likely more appropriate, additional information—such as length frequency data from unfished populations or from fisheries with asymptotic selectivity—would help improve model accuracy.

This is illustrated in the Spanish mackerel analysis, where SPR estimates appear more reasonable due to the availability of length frequency data from multiple fisheries. The level of doming in the double normal selectivity for the gillnet fishery is better informed by the line fishery data, for which selectivity is assumed to be asymptotic. This highlights another powerful feature of FISHBLICC: the ability to simultaneously fit length data from multiple gears or fisheries, allowing for more accurate estimation of selectivity for individual fisheries and thereby potentially reducing bias in SPR estimates.

Neither LBSPR nor FISHBLICC is designed to model length frequencies as a time series. Each annual length frequency is assumed to represent an equilibrium condition, and the models do not account for the dynamics between sampling periods or the cumulative effects of fishing. Nevertheless, annual estimates still provide useful “snapshots” of population status under the equilibrium assumption. While estimates from individual length frequencies may be biased due to interactions among mortality, selectivity, growth, and recruitment variability, trends in the time series are less likely to be affected by these confounding factors, provided they impact the entire series consistently. As such, time series estimates can serve as a useful monitoring tool for detecting trends in population abundance and fishing pressure. An enhanced module is currently under development to allow selectivity parameters to be shared across the time series, which would enable more comparable estimates of fishing mortality and SPR over time (P. Medley, pers. comm.).

5. References

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