博士論文の要約

博士の専攻分野の名称：　博士（食資源学）　　　　　氏名　Wiwiet Teguh Taufani

学位論文題名

Precision of growth curve parameters and biological reference points estimated from the length fish data: A case study of Yellowfin tuna (*Thunnus albacares*) in Indonesia

（体長データから推定した成長曲線パラメータと生物学的管理基準の精度：
インドネシアのキハダマグロ（*Thunnus albacares*）の事例研究）

I. General Introduction

Fisheries resources are vital to global food security and the livelihoods of millions of people. As demand for fish continues to rise, ensuring the sustainable use of these resources has become a major focus of fisheries management. Stock assessments play a fundamental role in this effort by providing the necessary information to evaluate fish stock status and guide management decisions. Among the various approaches available, length-based methods are particularly favoured in data-limited situations due to their simplicity, affordability, and ease of application.

Despite their advantages, length-based methods are susceptible to misestimation, especially when the number of data is limited, which can lead to inaccurate stock assessments and potentially compromise management outcomes. Therefore, this research aims to provide a rigorous evaluation of precision through quantitative analysis for estimating growth parameters and biological reference points in data-limited situations. This research will offer new insights into the performance of length-based methods, thereby supporting researchers, policymakers, and fisheries managers in improving data collection and analysis practices. In doing so, it contributes to the sustainable management of fisheries resources, helping to ensure food security through science-based policies and responsible governance.

II. Materials and Methods

Bootstrapping simulations were used to assess the precision of growth parameter estimates and biological reference points (BRPs) under different data scenarios. The dataset consisted of length-frequency data from yellowfin tuna (*Thunnus albacares*) collected over 24 months (2013–2014) in Indonesian Fisheries Management Area 573, with a total of 14,190 individuals. Data scenarios included reducing the number of months (24, 18, 12, 6, and 3 months) and decreasing the number of data per month (100%, 75%, 50%, 25%, and 10%). Each scenario was bootstrapped 1,000 times, generating distributions of growth parameters and BRPs to assess variability.

The von Bertalanffy growth model (VBGM) was applied to estimate growth parameters such as L_{∞}, K, and t_0. To ensure biological plausibility, estimates with t_0 values less than -1 were omitted. Subsequently, BRPs such as $F_{0.1}$, $F_{\max}$, and $F_{0.5}$, were calculated. Additionally, the coefficient of variation (CV) was used to measure the precision of the parameter estimates, with lower CV values indicating more stable results.

III. Results and Discussions of Growth Curve Parameters

The estimates of growth parameters displayed variability with changes in data availability.

In the scenario utilizing full data (24 months 100% data), the estimated mean values were 166.50 cm FL (fork length) for L_∞ and 0.76 y^{-1} for K with CVs of 2.55% and 23.04%, respectively. As data availability decreased, the CV for these estimates increased, indicating a rise in uncertainty. Notably, in scenarios with 10% of the data, the CV for L_∞ increased to 13.36% (a fivefold increase) and for K to 67.72% (a threefold increase) relative to the full dataset. These findings quantitatively demonstrate the critical importance of comprehensive data collection, as limited datasets resulted in variability of up to threefold in the parameter estimates.

Different combinations of L_∞ and K may describe the similar shape of the growth curve. The growth performance index or phi prime (Φ'), which integrates L_∞ and K, was used to assess the difference of shape of the growth curve. The analysis showed that Φ' had lower CV compared to L_∞ and K, with CVs ranging from 2.35 to 5.13% across scenarios, indicating consistency and reliability. Scenarios with higher Φ' values corresponded to more stable parameter estimates, suggesting its suitability for data-limited fisheries. These results highlight that while length-based methods are practical for evaluating fish growth in data-limited fisheries, the reliability of such methods is heavily dependent on the quality and quantity of available data.

IV. Results and Discussions of Biological Reference Points

Using growth parameters derived from bootstrapping simulations, the estimates values and CVs for $F_{0.1}$, $F_{\max}$, and $F_{0.5}$ were calculated. For the full dataset, the mean values were 0.64 for $F_{0.1}$, 1.06 for $F_{\max}$, and 0.50 for $F_{0.5}$, with CVs of 21.03%, 18.17%, and 25.31%, respectively. As data availability decreased, the CVs for these BRPs increased markedly. For example, in the scenario with 10% of the data, the CVs rose to 22.14% for $F_{0.1}$, 78.82% for $F_{\max}$, and 72.81% for $F_{0.5}$, highlighting reduced precision in the estimates under data-limited conditions.

It has been believed that the length-based methods produce imprecise growth curve parameters, which leads to unreliable BRPs. However, our results show that even with 50% of the data, the CVs for $F_{0.1}$ and $F_{0.5}$ remained below 30%, indicating fair precision. Notably, in some cases, CVs for $F_{0.1}$ and $F_{0.5}$ were much lower than those for K, suggesting that the worse precision of VBGM parameters does not necessarily result in unreliable BRPs. On the other hand, $F_{\max}$ showed much higher variability, with CVs exceeding 30% in 50% data. This suggests that $F_{0.1}$ and $F_{0.5}$ are more reliable for stock assessments, while $F_{\max}$ is less suitable due to its low precision.

To determine the minimum data required for reliable estimates, we assessed several scenarios using a 10% threshold below the mean values of $F_{0.1}$ and $F_{0.5}$ from full dataset. Reliable results were achieved in the following scenarios: 24 months at all data percentages; 18, 12, and every 2 months at more than 50%; and every 3 months at 100%. Despite the reduction in data, the CV values of $F_{0.1}$ across all scenarios remained low comparing with CV of $F_{0.5}$ and $F_{\max}$, providing a precautionary and safe estimate for fisheries management.

V. General Conclusions

This study examines the precision of growth curve parameters and the BRPs using length-based methods, especially in data-limited situations, by using bootstrapping simulations.

The methodology and procedures used in this study, particularly the t_0 filtering approach, are adaptable and can be applied to other species and situations, especially for estimating length-based VBGM parameters. While the findings highlight that yellowfin tuna required specific sampling designs to achieve reliable precision, the necessary data volume may vary depending on the species and context. To ensure practical precision, it is crucial to consider CV thresholds for BRPs and Φ', which tend to exhibit lower variability compared to VBGM parameters. Future studies should refine these criteria further, adapting sampling designs to the specific biological and fisheries conditions of the target species.

The results demonstrate that length-based methods estimate the BRPs precisely enough with adequate data. Comprehensive length data collection will support sustainable fisheries management.