AN AGE-STRUCTURED FISHERIES DYNAMIC MODEL: THE IMPORTANCE OF NET SELECTIVITY FOR LONG-TERM BIOMASS AND ECONOMIC SUCCESS

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Introduction

Fisheries are indispensable in ensuring global food security, providing livelihoods, and preserving cultural heritage, especially for coastal communities. They supply a significant portion of the world's protein intake and are pivotal to the economic prosperity of many regions. However, the sustainability of fisheries is increasingly threatened by overfishing, habitat destruction, and climate change. These challenges not only put marine biodiversity at risk but also hurt the economies of fishing communities (Sumaila et al., 2019; Sala et al., 2018).

Reports from the Food and Agriculture Organization (FAO) underscore the urgency of effective management strategies, noting that a significant proportion of global fisheries are overexploited (FAO, 2022). A comprehensive understanding of fisheries dynamics is crucial for developing sustainable practices. In this case, modeling serves as a vital tool in fisheries science. Models help simulate and predict fish population dynamics under various scenarios, offering insights into strategic planning and policy formulation (Heymans et al., 2011; Lancker et al., 2019).

Age-structured models are particularly valuable as they provide detailed insights by considering the population dynamics across different age groups. Net selectivity, the focus of this study, pertains to the specific range of fish sizes targeted by fishing gear. This selectivity significantly influences the demographic structure of fish populations and, consequently, their sustainability (Costello et al., 2016; Grafton et al., 2012).

Methods

This study employs an age-structured fisheries dynamic model developed using STELLA Architect. This model is designed to explore the long-term impacts of various net selectivity strategies on fish populations and the economic outcomes for fisheries. The model incorporates key biological and ecological parameters, including growth rates, fecundity, natural mortality, and fishing mortality.

It simulates multiple scenarios to evaluate the effects of different selectivity patterns on fish stocks and fishery profits. The base scenario represents a typical fishery with varying net selectivity across different age groups. This scenario serves as a benchmark against which alternative strategies are compared.

Each scenario in the model targets specific age groups of fish, adjusting the net selectivity to understand its impact on biomass and economic returns. For instance, the base scenario includes a progression from juvenile to adult fish, with varying probabilities of capture. Subsequent scenarios focus on single age groups or pairs of age groups to identify the most sustainable and profitable fishing strategies.

Results

The base scenario illustrated the progression of a developing fishery, starting with one gill net fishing boat and expanding to eight boats. This expansion led to a decline in both the fishery and profits over time due to overfishing. The net selectivity in this scenario varied among age groups, with juveniles being less susceptible to capture compared to adults. The cumulative net selectivity for this scenario was 0.101.

Alternative scenarios targeting single age groups showed that focusing on juveniles or adults alone did not enhance profits and often led to diminished returns. For example, Run 2 targeted 'Juvenile 1' with a net selectivity of 0.101, while Run 6 focused on 'Adult 3' with the same selectivity. Both scenarios resulted in lower profits and did not outperform the base scenario.

Scenarios targeting pairs of age groups were also evaluated. Run 8, which targeted 'Juvenile 1' and 'Juvenile 2' each with a net selectivity of 0.0505, demonstrated that this approach did not significantly improve profits. However, Scenario 4, which focused on 'Adult 1' and 'Adult 2', showed more promise by maintaining a stable biomass and incurring only minor losses, suggesting that this strategy might be more sustainable in the long term.

Discussion

The findings underscore the importance of integrating empirical data with advanced modeling techniques to develop effective management strategies. Although the model provides valuable theoretical insights, there is a need for empirical data on net selectivity to validate the findings. Future research should focus on gathering net selectivity data to refine the model further and ensure its robustness and practical applicability.

In conclusion, while no single alternative strategy outperformed the base scenario in terms of profits, the study suggests that targeted fishing, when combined with appropriate economic interventions, can create a more balanced and sustainable fisheries management model. This highlights the necessity of a holistic approach that considers both ecological and economic factors in developing sustainable fishing practices.