Doctoral dissertation summary

This study is important as it provides guidelines for managers and policymakers, for the development of specific management measures that protect vulnerable species while also supporting small-scale fisheries and recreational activities. Additionally, the research highlights the importance of considering local ecological knowledge and engaging with fishers in the management process. By enhancing our understanding of the *S. squammosus* fishery through data collection, research, and collaboration.

It shows how FCM models can be used when dealing with limited quantitative biological or ecological data. They allow for the integration of qualitative knowledge, serving as a valuable tool for decision-making in data-scarce environments. While time series forecasting, applied to catch data in this context, helps reveal temporal patterns and trends in the abundance and distribution of *S. squammosus*. This can be used for decision-making by providing insights into future catch patterns. This is particularly crucial when managing resources that are gaining interest, as it allows for proactive measures to ensure sustainable exploitation and conservation.

The research aims to investigate the current management strategies employed in the *S. squammosus* fishery and focus on the lack of biological and ecological data in Amami-Oshima, Japan. The study focused on Setouchi and Naze FCA to determine the trends in catch, and causes of decline and predict future catch as well as to create a scenario where managers can check the impacts of management measures on a system before it is implemented.

This research was designed to not only shed light on the challenges associated with the *S. squammosus* fishery in Amami-Oshima but also to systematically address these challenges through a multidimensional investigative framework. The adoption of a socio-ecological lens and the incorporation of forecasting methodologies aimed to provide a holistic comprehension of the intricate dynamics influencing the fishery, offering valuable insights for sustainable management practices.

Chapter 2 examined the management of *S. squammosus* fisheries in Setouchi, Amami Oshima, Japan. The catch landed at the Setouchi Fisheries Co-operative Association suggests that the present voluntary measures for management are ineffective as the catch has continued to decline. Based on the collected data, there has been a significant drop in the landed catch, amounting to 73687%, from 2015 to 2020. A study of the biological and physical characteristics of *S. squammosus* revealed a strong seasonal variation in sea surface temperature as indicated by the spawning months and sea surface temperature. The annual catch data for octopus, a predator of (species), showed a significant shift in the predator-prey relationship between 2018 and 2020, implying biological and ecological factors that may be contributing to the decreased catch of *S. squammosus* over the 6-year study period. Therefore, it is imperative to consider these significant factors, especially in data-deficient species, to guarantee their continued viability for commercial or artisanal fishing purposes.

Chapter 3 used the information from interviews and structured surveys to adopt a socio-ecological approach to investigate the drivers of the *S. squammosus* fishery in Setouchi. The FCM model used identified 18 socio-ecological components and 2 of them (SST and COVID-19) were found to be drivers. It was also found that the components of stock biomass, fishing effort and catch landed were very reactive with other components within the system. Management measures were noted to be an important component of the FCA and the fishers therefore a scenario was run to see the effects of increasing management measures on the

fishery components and found that as management measures became more severe the catch landed, fishing effort and income all declined. Indicating perhaps stricter management may not be the solution to the declining catch in Setouchi.

Chapter 4 investigated the management, catch landed and income of the *S. squammosus* fishery in Naze FCA in Amami-Oshima. The 10-year data indicated no significant difference in annual catch of *S. squammosus*. As SST was a driver of the Setouchi FCM model, the SST for the same study period indicated seasonality patterns that followed the summer and winter cycles for Japan. There was a significant difference in the monthly catch, income and SST during the year, yet no annual difference was noted. This fishery despite having 535 fishers involved in catching S. squammosus difference not have any management measures implemented and the fishery was in no danger of decline.

Chapter 5 conducted a time series of the same period at both sites in Amami-Oshima and found there to be significant seasonality and trend patterns in the catch landed at both sites though the two had slight differences. The Seasonal Naïve model, Error Trend Seasonality Model and the Auto AutoRegressive Integrated Moving Average models were used to find the model of best fit to forecast the catch landed at the sites with a 95% confidence interval. This was done to provide the FCA members and other stakeholders a reference point when trying to decide if there is a decline in catch and if management measures need to be implemented. An SST correlation plot with the catch landed showed a very weak relationship where only 0.06% of the of all catch landed at both sites could be explained by the SST. While there was a 27% correlation at Naze with only a 3.38 % increase in SST 11 years while Setouchi experienced an SST increase of 7% in only 6 years. This could be due to lag effects, meaning that SST does not have an immediate impact on S. squammosus populations at all sites and that it is important to sudy the SST at both sites on Amami-Oshima as individual cases. Therefore, SST does not seem to be a major influence yet on catch in general in Amami-Oshima but it is of concern to the Setouchi FCA. The forecast predicted that over the next 4 years there would be a decline and eventual collapse of catch landed at Setouchi while the catch landed at Naze was seen to be continually increasing.

With the rising interest in *S. squammosus*, the lack of baseline data and stock assessments before the peak of exploitation becomes evident. addressing the quantitative data deficiency, the research places increased focus on semi-quantitative and qualitative information obtained from fishers and locals. This approach aims to provide a more holistic view of the various variables influencing the fishery, aiding in the development of effective resource management strategies.

The application of the Social-Ecological Systems (SES) approach, utilizing a Fuzzy Cognitive Mapping (FCM) model, helped explore the diverse facets of the fishery. Identified drivers such as Sea Surface Temperature (SST) and the impact of COVID-19. Scenarios derived from the SES approach enable policymakers and stakeholders to simulate the repercussions of different actions on social, biological, ecological, and economic components within the system. While a time series forecasting model incorporating data from Setouchi and Naze was employed. The model, comparing the Seasonal Naïve (SN), Error Trend, Seasonality (ETS), and AutoRegressive Integrated Moving Average (ARIMA) models, aims to forecast catch values in the study areas for the next four years with a 95% confidence interval. The forecasted values, when compared to actual ones, offer insights into potential future scenarios, assisting in the formulation of adaptive strategies to address the evolving dynamics of the *S. squammosus* fishery.

The research conducted by this PhD candidature has significantly contributed to the comprehension of issues associated with small-scale coastal fisheries at both local and regional scales. By addressing a notable knowledge gap concerning this species, the study not only scrutinizes the existing management strategies and catch status but also employs social-ecological systems models, such as FCM, and time series analysis tools to forecast future catch levels. The applicability of these analytical tools extends beyond the specific species under investigation, offering valuable insights for various contexts lacking sufficient information.
In specific regions of Japan, particularly the Kagoshima and Okinawa areas, the management of *S. squammosus* is gaining prominence. The incorporation of tools like SES and time series analysis can significantly enhance the efficiency of management practices. This multifaceted approach contributes to the sustainability of fisheries and ensures the long-term viability of the *S. squammosus* population and its habitats.

At a broader regional and coastal fishery level, the research not only addresses current concerns but also identifies gaps in data, prompting future investigations to enhance our understanding of coastal fisheries. In summary, the two case studies presented in this research signify significant progress in slipper lobster management, especially in the context of limited data. The integration of fuzzy cognitive mapping models and time series forecasting acknowledges the importance of local knowledge and provides a systematic, data-driven approach to comprehend and manage lesser-known regional fisheries resources. These methodologies play a pivotal role in bridging knowledge gaps, promoting sustainable practices, and ensuring adaptable management strategies in response to evolving circumstances. This progress is crucial for informing fisheries management and potential aquaculture ventures in the future, as the tools and generated data can be applied extensively to other species that remain poorly understood despite their commercial or ecological significance.