Appendix 2-L. Improvements in modelling needed to develop an 'Advanced Warning System'

Improvements to operational oceanography

Three workstreams are needed to improve operational oceanography to inform SEAPDOYM. Workstream 1 needs to focus on developing and applying an operational framework to mitigate the influence of present-day biases in Earth System Models (ESMs) on future regional ocean physical and biogeochemical projections. Present-day biases in ESMs can significantly compromise the reliability of regional projections. For instance, the strong cold-tongue bias in the IPSL-CM6A-LR model leads to greater warming and chlorophyll decrease in the western equatorial Pacific Ocean compared to the eastern region, whereas bias-corrected simulations show opposite patterns. Current research has focused on applying corrections in the bulk formulae and to flux perturbations (i.e., developing an oceanic counterpart of dynamical atmospheric approaches to mitigate the influence of background atmospheric biases on future atmospheric projections). Operationalising these methods would be a central activity of this workstream. Regionalizing ESMs is an active research area in oceanography and the framework will remain flexible to new and novel approaches to bias correction.

Workstream 2 needs to focus on improvements to the historical environmental forcings used to optimise parameters in the SEAPODYM model. Extending the historical time-series (i.e., to periods before satellite observation) in the atmospheric reanalysis models (e.g., ERA-Interim, ERA5, JRA55) facilitates splitting the historical period into training and validation periods allowing for improved optimisation of the SEAPODYM models. Atmospheric reanalysis models used for optimisation are subject to bias which requires correction before application in SEAPODYM. Operationalizing this bias correction would be an important component of this workstream. Development of historical forcings using ERA6 in a coupled reanalysis, using both atmospheric and ocean observations, is needed. ERA6 has the potential to generate an even more balanced and consistent Earth System climate reconstruction. Historical forcing generated from higher-resolution reanalyses (e.g., GLORYS) would be prepared for downscaled EEZ-scale hindcasts. Environmental forcing for forecasting will need to be developed under this workstream to provide the AWS with this capacity

Workstream 3 needs to focus on inclusion of additional biogeochemical (BGC) models to the environmental forcing ensemble. BGC models provide a framework to integrate chlorophyll-a, nutrients, carbon, and oxygen cycles to estimate lower trophic level structure and function in marine ecosystems. They are the foundation for estimating the distribution and abundance of tuna prey in the SEAPODYM model. PISCES has been the only BGC used in SEAPODYM to date. Workstream 3 needs to add the WOMBAT BGC to the ensemble. It also needs to include validation of BGC outputs and assimilation of observation data with lower- and mid-trophic biomass estimates from SEAPODYM. This later task is necessary for identifying and quantifying uncertainty in prey field estimation.

Improvements to SEAPODYM

Two workstreams are needed to improve the SEAPODYM model:

1. Developing a more realistic model structure to account for variable growth of tuna depending on their feeding conditions. This is essential for accurately representing differences in tuna weight-at-age measurements observed in various oceanic areas with distinct ecosystem traits and productivity.
2. Refining the model resolutions to improve spatial variability and to better estimate tuna abundance at smaller scales, such as EEZs, as well as regionally.

However, these improvements cannot be achieved without first parallelizing the model's computer code. Parallelization experiments indicate that a speedup of 70-90 times from the current sequential processing can be achieved using 76-151 processors, respectively. The implementation of SEAPODYM parallelization and improvements to the numerical solver will need to be done in several stages and will take 1-2 years to complete. After this, it will be possible to proceed to high-resolution simulations. Further development of variable growth (Item 1) will need to be the next priority, focusing on improving reference models and quantitative model applications to tuna populations by integrating available observations from industrial fishing, port sampling, and scientific campaigns.

Development of fleet dynamics and economic models

This workstream will need to establish a fleet dynamics model suitable for evaluating the impacts of climate change on Pacific tuna fisheries. Two complementary approaches will need to be undertaken. The first will focus on econometric (or similar) models that integrate environmental, fleet behavior and cost structures to identify the underlying drivers of fishing decisions. This set of models will also need to facilitate the provision of short-term outlooks to guide application of short-duration adaptive responses to changing fishing activity. The second approach will need to focus on coupling fleet dynamics to the SEAPODYM model to facilitate projection of the dual impact of fishing and climate change on fishery economic performance (at both regional and EEZ scales). The coupled model will facilitate detailed evaluation of current and alternate policies, practices, and adaptations to the impacts of climate change across short-, medium-, and long-term time horizons.

Provision of observational data to validate EEZ-scale outputs

This last component of work will need to provide the necessary observational data to validate outputs from the Advanced Warning System. Three workstream will be needed for this. The first will need to apply modern methods to estimate the absolute abundances of tuna and the population structure of tuna in the Pacific Ocean. Validating abundance is necessary for estimating the realistic impacts of tuna redistribution on the expected economic returns for each participating country and to evaluate the performance of alternate policy and adaptive measures. Quantifying tuna population structure similarly is necessary for establishing the potential impacts of shifting tuna distributions. Methods to quantify each of these needs have been established. The second workstream will need to focus on the collection of market and vessel data necessary to parameterize and validate the fleet dynamics models. The third workstream will need to focus on supporting ocean monitoring data collection by fishing vessels and fisheries observers. Two priority data needs should be the focus: acoustic measurements of tuna prey; and water temperature profiles. Methods for these forms of data collection have been established along with the necessary processes for post-collection data processing and dissemination for use in model validation and assimilation.