Can ecological forecasting help mitigate the risk of collision between whales and commercial vessels? The case of the endangered Southern Resident Killer Whales

Ecology is becoming a more predictive science as new technologies for tracking animals and their environment become available, and statistical approaches for the fusion of dynamic movement models with data are becoming more accessible to ecologists. The endangered Southern Resident Killer Whales (SRKW) spend significant time in the Salish Sea off southern British Columbia, Canada, and northern Washington State, USA, and are exposed to increasing marine traffic in the region. With increased marine traffic comes higher risk of acoustic disturbance and collisions with commercial vessels. With only 73 individuals remaining in December 2021, the loss of a single individual would be catastrophic for the population and the marine ecosystem through cascading effects. Motivated by these concerns, we develop a real-time forecasting system for the endangered SRKW that aims at predicting pod (i.e., matrilineal group) locations with probabilistic predictions of whale directional movement. The statistical framework is based on a state space model and sequential data assimilation, a method for model-data fusion initially developed for numerical weather predictions. Real-time SRKW location information relies on visual sightings from citizen scientists and Passive Acoustic Monitoring (PAM) from a network of underwater hydrophone nodes. This real-time location information is combined with stochastic movement model predictions to provide forecasts of future animal locations and trajectories, as well as estimation of key behavioural parameters. Implementation uses ensemble-based sequential Monte Carlo methods (a particle filter). The movement model is a Continuous Time Correlated Random Walk (CTCRW) that integrates historical SRKW distribution through a drift term computed as the gradient of a potential function. Depending on the abundance and accuracy of location information, our forecasting system can predict the pods' locations up to 2.5 hours in advance with a moderate prediction error (< 5 km), providing reasonable lead-in time to allow commercial vessels to adjust their speed or path to minimize whale-vessel interactions. We argue that that this ecological forecasting framework can be used to improve the conservation of at-risk populations, synthesize diverse data types, improve animal movement models and behavioural understanding, and has the potential to become an important new direction for movement ecology.