Quantitative Marine Science

Thesis Abstract

Statistical inference for movement behaviour using animal tracking data

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Satellite tracking provides an opportunity to learn about how animals choose to move and about the covariates of movement. Quantitative methodology for this problem has lagged behind the remote sensing technology that provides both animal tracks and covariate information. A statistical framework capable of providing appropriate hypothesis testing has to couple very different types of data: highly autocorrelated time series of observed locations (the track), with 2-dimensional maps of covariate data. In addition, animals respond to internal motivations, representable only as theorised motivations. Behaviour is likely to be highly complex and to be only approximately understood so that process error cannot be ignored. Observation error should be accounted for separately from process error because longitude is typically more difficult to estimate than latitude, and because estimates of observation error are sometimes available. State space models account separately for observation and process errors, and model the serial correlation inherent in tracks. State space models offer great flexibility, nevertheless, the means of incorporating diverse movement behaviours and covariate information is not immediately clear. Traditionally, these models require that time series be equally spaced in time (seldom the case with observed tracks) and they have presented substantial difficulties in inference.

This thesis presents a flexible Bayesian state space modelling framework suitable for application to tracks. Movement behaviour is incorporated through advection fields that represent movement hypotheses. These are calculated using theories regarding movement behaviour, possibly coupled with covariate information. The deviance information criterion DIC measures the weight given by observed track data to alternative proposed hypotheses regarding movement behaviour. In simulation, DIC successfully discriminated the advection fields, and therefore the movement hypotheses, used to simulate track data. DIC is less sensitive than the Bayes factor is, to the priors, an advantage in a field in which little prior information is available. Markov chain Monte Carlo sampling successfully facilitated nonlinear, non-Gaussian model forms while avoiding the inference problems encountered by practitioners of sequential importance sampling. Latent locations are estimated, allowing realistic, nonlinear path estimation. Inertia, a tendency for directional persistence, is incorporated.

The Bayesian approach allows the incorporation of prior information and eases inference. Temporal shifts in behaviour are also modelled. The method is demonstrated in practice, using satellite tracks from white sharks in Australia. The problem of modelled animals becoming trapped in semi-enclosed areas and stepping across narrow barriers is discussed and a proposed solution, using Laplace's equation to provide advective flow around obstacles, is demonstrated.