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Capture-recapture models with heterogeneous temporary emigration

There exist several capture-recapture (CR) models for estimating population size and, in open populations, arrival and departure times of individuals. Existing models either assume that emigration is permanent and each individual performs a single visit to the surveyed site, or rely on a specialised sampling scheme, which assumes population closure for parts of the sampling period, referred to as Pollock's robust design. However, in practice, emigration is often temporary, and methods relying on Pollock's robust design cannot be employed.

We propose a novel approach for modelling CR data on open populations that exhibit temporary emigration, whilst also accounting for individual heterogeneity to allow for differences in visit patterns and capture probabilities between individuals. Our modelling approach combines changepoint processes -- fitted using an adaptive approach -- for inferring individual visits, with Bayesian mixture modelling -- fitted using a nonparametric approach -- for identifying clusters of individuals with similar visit patterns or capture probabilities. The proposed method is extremely flexible as it can be applied to any CR data set and is not reliant upon specialised sampling schemes.

We fit the new model to motivating data on salmon anglers collected annually at the Gaula river in Norway. Our results when analysing data from the 2017, 2018 and 2019 seasons reveal two clusters of anglers -- consistent across years -- with substantially different visit patterns. Most anglers are allocated to the “occasional visitors” cluster, making infrequent and shorter visits with mean total length of stay at the river of around four days, whereas there also exists a small cluster of ``super visitors'', with regular and longer visits as well as higher fishing ability, with mean total length of stay between 15 and 20 days in a season. Our estimate of the probability of catching salmon whilst at the river is more than three times higher than that obtained when using a model that does not account for temporary emigration, giving us a better understanding of the impact of fishing at the river. Finally, we discuss the effect of the covid-19 pandemic on the angling population by modelling data from the 2020 season.