**Efficient Estimation (and Modelling) of Electrofishing Capture Efficiency for Juvenile Salmon over Large Spatial and Temporal Scales.**

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# Abstract

The use of juvenille salmon abundance estimates based on electrofishing for management and conservation is widespread. For practical reasons single pass electrofishing is often favoured over multipass electrofishing. It is well known that reliable estimates of abundance from electrofishing rely on reliable estimates of capture efficiency, which requires multiple electrofishing passes. Typically hierarchical Bayesian models have been used to model capture probability (and jointly fish density) but these approaches do not scale well to large datasets and so are not, currently, suitable for analyses of national scale datasets. We present an approach based on classical conditional likelihood methods which allow capture probability to be modelled in terms of linear and non-linear (non-parametric) relationships. The use of conditional likelihood provides a simple way to investigate complex covariate relationships. We present a set of best approximating capture probability models for Scotland over the years 1996 to 2014 utilising GIS based covariates which will allow the prediction of capture probability to any new site or to sites on which only single pass electrofishing has taken place. Sampling protocol was the most important covariate, followed by Fish age class (fry, parr) and species (salmon, trout) and day of year, other factors such as width, gradient affected capture probability to a lesser extent. The simplifications introduced over HBMs allowed a full model selection procedure (potentially even model averaging) to be conducted. A simulation study was conducted to show the effect of these simplifying assumptions as well as the overall impact of modelling capture probability.

Keywords: Atlantic Salmon, Fry, Parr, Capture Efficiency / Probability, Electrofishing.

# Introduction

* Estimating density is important for fishery management and conservation
* To estimate density from electrofishing data you need to estimate capture probability
* Capture probability estimation requires multipass fishing
* Often single pass is used for practical reasons
* Recently the trend is to use HBMs to model capture probability, but these become unwieldy in terms of model selection and fitting when faced with large scale datasets
* Conditional likelihood approaches are a simplification over HBMs but provide huge savings in efficiency and allow for complex models to be applied relatively easily using standard tools in R.
* We present an analysis of capture probability for xxxx sites covering Scotland for the years 1996 to 2014.
* We consider covariates that allow predictions to be made for new sites, such as temporal, spatial and GIS derived, and sampling protocol covariates.
* A simulation study is used to support the conclusions and to investigate the implications of simplifying the modelling assumptions.
* In addition, because it is still common practice to ignore the effects of variable capture probability we also use the simulation study to show the effects of assuming it constant.

Refs:

# Materials and Methods

## Study site

* We modelled the capture efficiency of electrofishing in 208 catchments in Scotland between 1980 and 2014. **Figure 1**
* DESCRIBE Scotland? Scotland consists of XX catchments greater than 500? m2 and xx small coastal catchments draining a total of xxx m2. The west coast of Scotland is characterised by fjordic inlets with many Islands and catchments, to the North lies Orkney and Shetland (no data from here so these are excluded from further discussion), while the east coast is characterised by *smooth* coastline and dominated by several large catchments. Landuse varies widely from industrial urban areas in central Scotland to remote uplands (largely deforested due to livestock and deer grazing).
* We use catchment groupings based on SEPA hydrometric area (CAN WE DO BETTER) to define spatial strata of similar areas. Also **Figure 1**

## Data collation

* Data was obtained from the SFCC, MSS, SEPA and Caithness DSFB. Again **Figure 1, and Figure 2** - table.
* Because many data sources do not reliably obtain ages from scale reading, electrofishing data was resolved to life-stage (fry or parr) rather than individual age class.
* Location of sample site, date, sampling protocol (see next), and fishing area were retained. Along with auxiliary site specific information such as whether the site was known to be stocked.

## Fish sampling

* A variety of sampling methods were used: with and without stopnets, backpack electrofishing, bankside generators, boat sampling etc. Only Salmon and Trout were sampled/considered.
* In some cases fish were lengthed and scaled; sometimes only salmon parr were sampled for length, while in other cases only numbers of fry and parr by species were recorded. Data was always collected for each pass.
* Electrofishing samples varied between 2 and 6 passes, however the majority of samples had 3 (84%) or 2 (14%) passes.
* [We can talk about spatial variability in sampling procedures here as we have introduced spatial strata in last section.] For MSS data (and more generally?) hard to reach areas are sampled by backpack electrofishing, while easily reached sites, or those near field stations are sampled using more powerful bankside generators.

## Physical site characteristics

* [TABLE THESE?] Physical Covariates reported to affect capture probability are: velocoty (Bayley and Dowling, 1990; Price and Peterson 2010), cross sectional area (Price and Peterson, 2010), fish length (Price and peterson, 2010; etc.) Wood density, gradient (Hedger et al, 2013), site width (Hedger et al, 2013), total fish captured (Hedger et al, 2013; pregler 2015), temperature, conductivity, undercut bank (pregler 2015, Rodtka, 2015). Turbidity…
* Many of these do not lend themselves well to predicting capture probability at historic single pass fishing sites, or at new sites where it could be impractical to measure all these covariates for every new site. So we sought to find GIS covariates that could act as proxies to the above features.
* The habitat covariates considered are: altitude, upstream catchment area, distance to sea, gradient, landuse and channel width. See Millar et al. for a detailed description of how these covariates were calculated / derived.

## Capture efficiency modelling

* The model for capture efficiency follows that of Huggins and Yip (1997).
* Various people have extended this model to multiple sites: Conroy et al. (2008), Wyatt, Rivot. However all of these approaches also consider density either as a random effect or in terms of covariates and in order to model capture probability end up with a hierarchical Bayesian model.
* Cressie – although HBMs are a very uyseful tool in ecological modelling, they can be difficult to extend to large datasets such as the Scotland wide data being analysed here.

## Simulation testing

# Results

## Covariates

* Data was collated for 2749 discrete sites and 6049 site visits.
* Table all considered covariates, 3 headings: name; data provenance; proxy for.
* Discuss potential correlations
* Plot marginal scatter plots

## Capture efficiency modelling

## Simulation testing

# Discussion

# References

# Tables

# Figures