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Bayesian mark-recapture model for migrating fish populations:
Ascent of Atlantic salmon (*Salmo salar L.*) in River Kymijoki and the effects of river discharge and recreational fishing

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Introduction

Aim

By creating a bayesian catch - and release probability model, we estimated the size of river Kymijoki ascending salmon population, and how it was affected by river discharge managed by stream regulation, recreational fishing in the river area and its estuary, and transportation of ascending adult fishes over Korkeakoski dam. Complex study problem and availability of paraller catch- and release - and catch-data give good precusitions for applying bayesian modelling in the study.

Backround

Damming and water pollution led to extinction of the inhabiting salmon population of river Kymijoki in 1950s. The population is being sustained by stocking, which after a short period of success, has turned out to be unprofitable.

In spite of improved water quality and sufficient spawning areas in the river area, natural spawning is small-scale, and doesn't make a match for intensive fishing, mainly for the location of dams and related river discharge regulation affecting the number of fishes reaching their spawning grounds.

Transportation of ascending adults over a dam in Korkeakoski tributary during years 2004 and 2005 was attempted as a management measure.

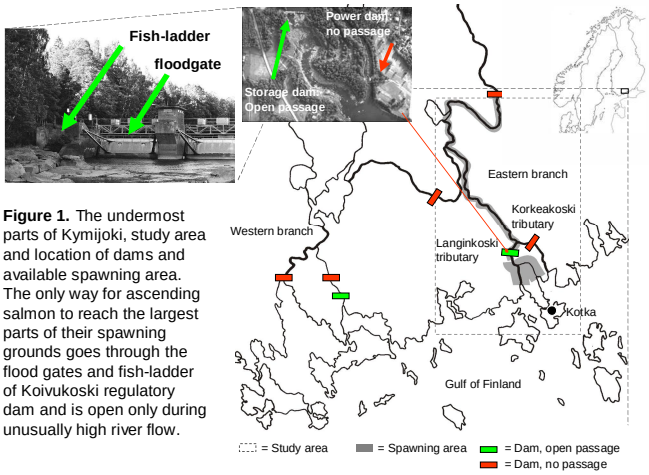

Figure 1. The undermost parts of Kymijoki, study area and location of dams and available spawning area. The only way for ascending salmon to reach the largest parts of their spawning grounds goes through the flood gates and fish-ladder of Koivukoski regulatory dam and is open only during unusually high river flow.

Data and the model

- The data consisted of:
  - Monthly discharge averages
  - Catch statistics from the river and its estuary
  - Recaptures of Carlin-marked fishes ascending the river
  - Over Korkeakoski dam transported arrow-marked individuals, some of which also radio-tracked
- Priors were derived from literature and interviews with experts.
- The data was combined with priors in a hierarchical bayesian probability-model: study area was divided in sections (Fig 2) for which the probabilities of movement and capture of ascending salmon were calculated (Fig 2).

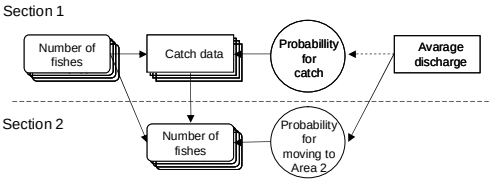

Figure 3. Graphical description of model variables in a model. Number of fishes and catch variables were modelled separately, and were connected with mutual probability variables.

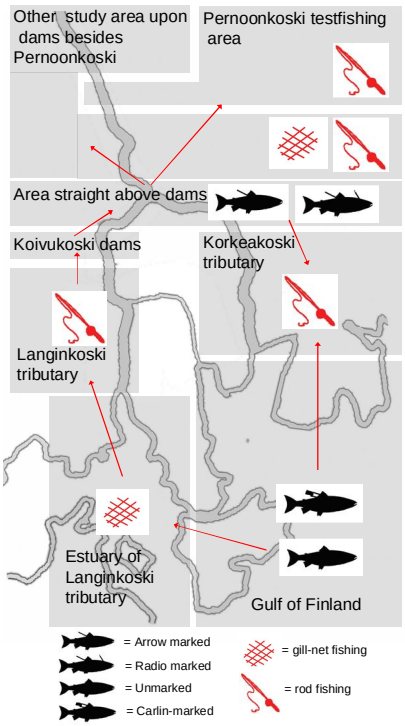

Figure 4. Map showing division of the study area into separate sections (grey areas) and modelled paths of river ascending and transported salmon.

Results

- The estimated probabilities for ascending salmon to enter Langinkoski tributary and crossing the Koivukoski regulatory dam showed a clear pattern of dependence on the river discharges (*Figs 5 and 6*).

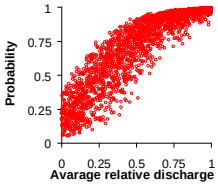

Figure 5. Estimated probability of salmon to enter Langinkoski tributary related to relative discharge of the tributary (to the whole eastern branch).

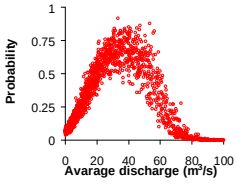

Figure 6. Estimated probability of salmon to cross Koivukoski regulatory dam compared to the average discharge ran through the flood-gate.

- The estimated probability for a capture upstream from the Koivukoski dam, and on the way there, was clearly on its highest in the gill-net fishery located in Langinkoski estuary (Median: 0,64; 95 % probability interval: 0,38 – 0,79).
- The estimated number of transported fishes staying upstream from Korkeakoski dam was low compared that of fishes crossing Koivukoski regulatory dam (*Fig 7*).

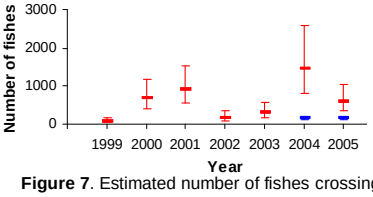

Figure 7. Estimated number of fishes crossing Koivukoski regulatory dam (red series) and transported over Korkeakoski dam (blue series); medians and 95 % probability intervals shown.

Conclusions

- The number of river Kymijoki ascending salmon is diminished by the prevailing river flow regulation and recreational gill-net fishing in the estuary of Langinkoski tributary.
- Transportation of fishes over Korkeakoski dam is an ineffective management measure. Ascent of salmon could be enhanced more effectively by i) changing river flow regulation scheme and ii) regulating fishing-pressure in the river estuary instead.
- Model created in the study can also be applied to study migration in other fish populations. Implications for management can be made by integrating Human induced factors (probability for catch, the effect of discharge etc.) in the model structure.