Spatio-temporal Paper Draft Story Summary

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## Introduction

1. The challenges facing sustainable fisheries management are multifaceted and include interactions between complex ecological, socio-economic, and political factors. Fisheries management regions were often delineated as a result of political or geographic considerations rather than biological or ecological rationale.
2. Longstanding challenge in fisheries science is accounting for both spatial and temporal heterogeneity in processes driving population dynamics . We know it may be a problem but no tools to solve problem. This is really annoying because fisheries science has some amazing data to do this. Tools used to understand spatial patterns often limited.
3. But there are these SDMs which have been used a fair bit, but typically been limited temporally (but that is changing). In recent years tools have been developed which can better account for both space and time in one model.

* ***We could stop intro here and save for methods, but its a short intro.***

1. GB and how important it is to fisheries in general
2. Cod and Yellowtail are two cool species in rough shape on GB.
3. We are going to use INLA and our objectives are:
   * quantify any long-term shifts in the distribution of these stocks
   * quantify any seasonal changes in the SDMs using survey data collected in the winter, spring and fall
   * quantify any changes in *core area* within Canadian and U.S. waters
   * quantify the effect of a suite of static environmental layers on the distribution of these stocks

## Methods

What we’ve shown with the Closure paper.

## Results

1. There are both seasonal and long term shifts in the distribution of both stocks
   * With our SDM models we can observe and quantify the changes. Talk specifics for both stocks, including
     + Significant shifts in the distribution of both stocks occurs relatively frequently (≤ 5 years)
     + Distributions shifts for both stocks due to loss of *core area* in West & South (i.e. US), Canada stable
     + The seasonal distribution changes, yellowtail doesn’t change much, big shift for cod in Fall
2. Environmental covariates
   * Few of the static environmental variables were associated with the distribution of either stocks
   * Depth, SST, and Sediment (yellowtail) only consistently significant predictors.
3. Model Hyperparameters
   * Distribution of cod tended to be correlated across a longer range than yellowtail
   * Distribution of cod more variable in the Fall (higher SD of RF), yellowtail similar throughout the year
4. Prediction and Validation
   * Model validation indicates out of sample prediction unbiased and relatively accurate
   * Model able to predict OP up to 3 years in the future with only a modest increase in error
   * The predictive ability of the models is largely informed by the random fields - Predictions using just the random fields and the models with covariates perform very similarly.

## Discussion

1. Summarize results.
   * The SDMs developed here can be used to identify regions of consistently high/low OP
   * quantify changes in the size of a *core area* over time and between seasons (surveys)
   * quantify how rapidly shifts in their distributions occur
   * and provide short term forecasts of the spatial OP patterns in future years.
2. Atlantic cod results
   * Decline in OP consistent with observed cod declines across NW Atlantic, been relatively stable since this period
   * Fall distribution shifting to NW and likely part of population is off the bank in Fall. Implications…
3. Yellowtail flounder results
   * Yellowtail tend to be found on sandy bottoms within a narrow depth band
   * Yellowtail like region straddling Can/US more than environmental covariates can explain
   * Likely this is last bastion for YT on GB, if environmental shifts continue YT are screwed
4. Environmental Covariates and Random Fields
   * Few of these static layers mattered
   * Depth makes sense and results consistent with known life history (i.e. depth matters more for YT than cod)
   * SST a bit surprising
     + May be due to it capturing general widespread oceanographic features across the bank domain.
     + A reflection of connection between surface waters and the benthos given vertical mixing on GB?
   * Unexpectedly, models without ECs did just as good a job at out of sample prediction as models with ECs
5. Conclusion
   * We quantify how the distribution of both stocks changes both seasonally and inter-annually
   * Simple static environmental covariates generally aren’t great
     + Only average SST (1997-2008), depth, and bottom type (yellowtail only) ECs mattered consistently
   * Inter-annual shifts show increasing importance of Canada for both stocks on GB (environmental change?)
   * Directed environmental change increasing risk of extirpation for both stocks on GB irrespective of FM
   * The utilization of the spatio-temporal information contained in these models provides novel insights which
     + Can be used to improve science advice
     + Lead to more informed fisheries management decisions.