Spatial and Temporal Variation in the Size-At-Age of Pacific Cod in the Eastern Bering Sea: Implications for Sampling Strategies

Irina Tolkova (1), Lorenzo Ciannelli (2), Alix Gitelman (2), Grant Thompson (3), Thomas Helser (3), Bob Lauth (3)

(1) University of Washington; WA, USA; (2) Oregon State University; OR, USA; (3) Alaska Fisheries Science Center, National Oceanic and Atmospheric Administration.

What factors determine the distribution and growth rate of Pacific cod in the Eastern Bering Sea?

Introduction

Pacific cod (*Gadus macrocephalus*) is the **second most major fish** in the Bering Sea commercial fisheries (behind walleye pollock).

To sustainably manage this fishery, we must create **accurate stock assessments of Pacific cod**, which in turn depend on estimates of the growth rate. Yet there may be **spatial variability in growth rate.**

Data

This project uses data from the **Alaskan Fisheries Science Center's (AFSC) annual groundfish trawl survey:**
- ranges from 1994 to 2012
- 375 stations from 12 strata
- measurements of environmental variables at all stations
- measurements of the lengths of all fish caught
- measurements of ages of some of the fish caught

Methods

A series of GAMs (**General Additive Models**) were used to describe length as a function of environmental variables. The best model, as given by the R squared and AIC statistics, was found, and used to examine the distribution of size-at-age.

The best model was found to be:
length ~ s(age, temperature, by = sex) + s(position) + s(longitude, latitude) + factor(year)
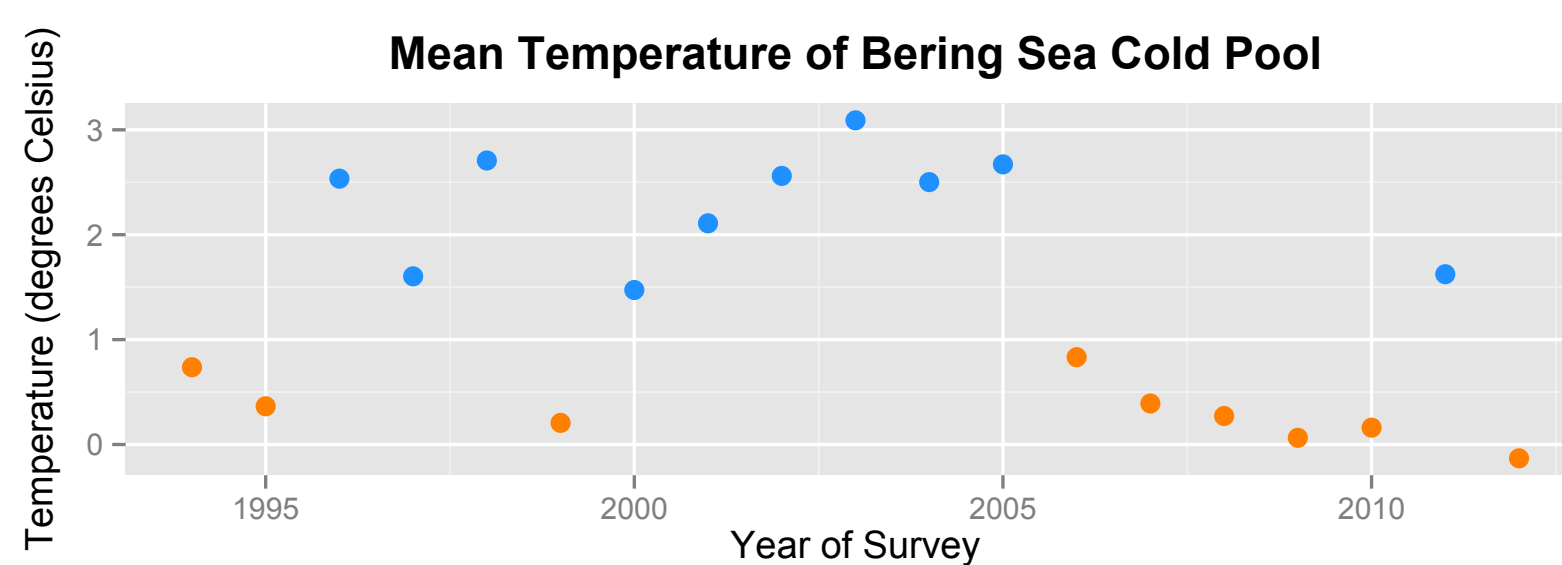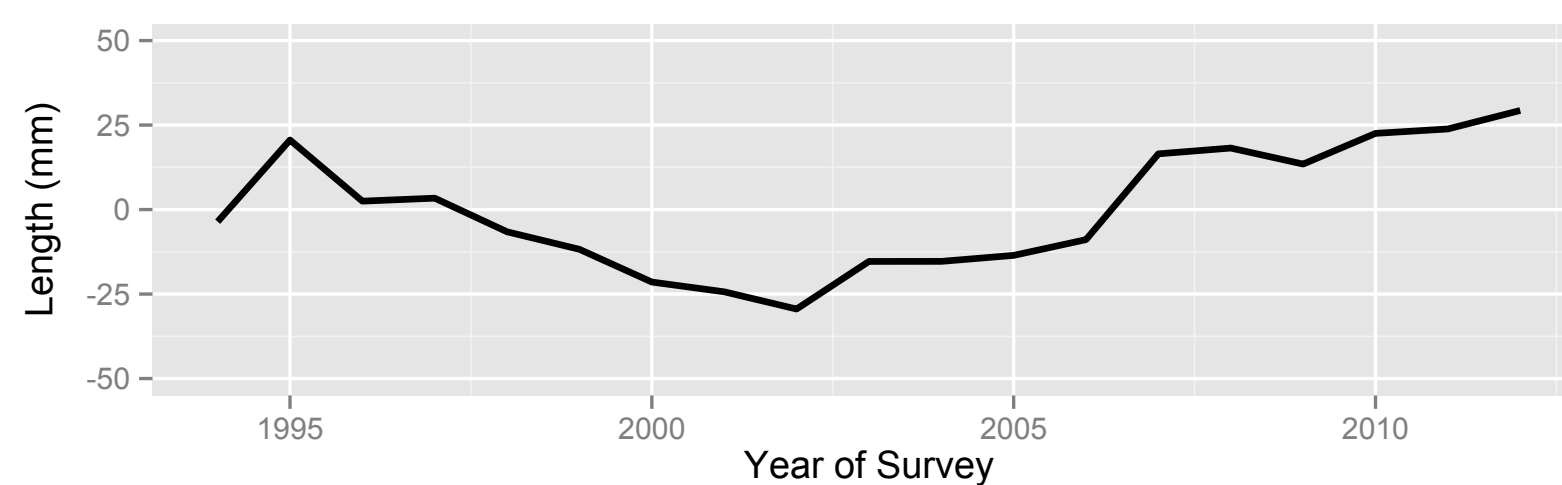
Results

Spatial Effect
These figures show the expected lengths of female and male age 2 fish, in mm. Individuals of the same age are about 4-5 cm larger offshore than inshore.


Length distribution of Male Fish of Age 2

Length distribution of Female Fish of Age 2
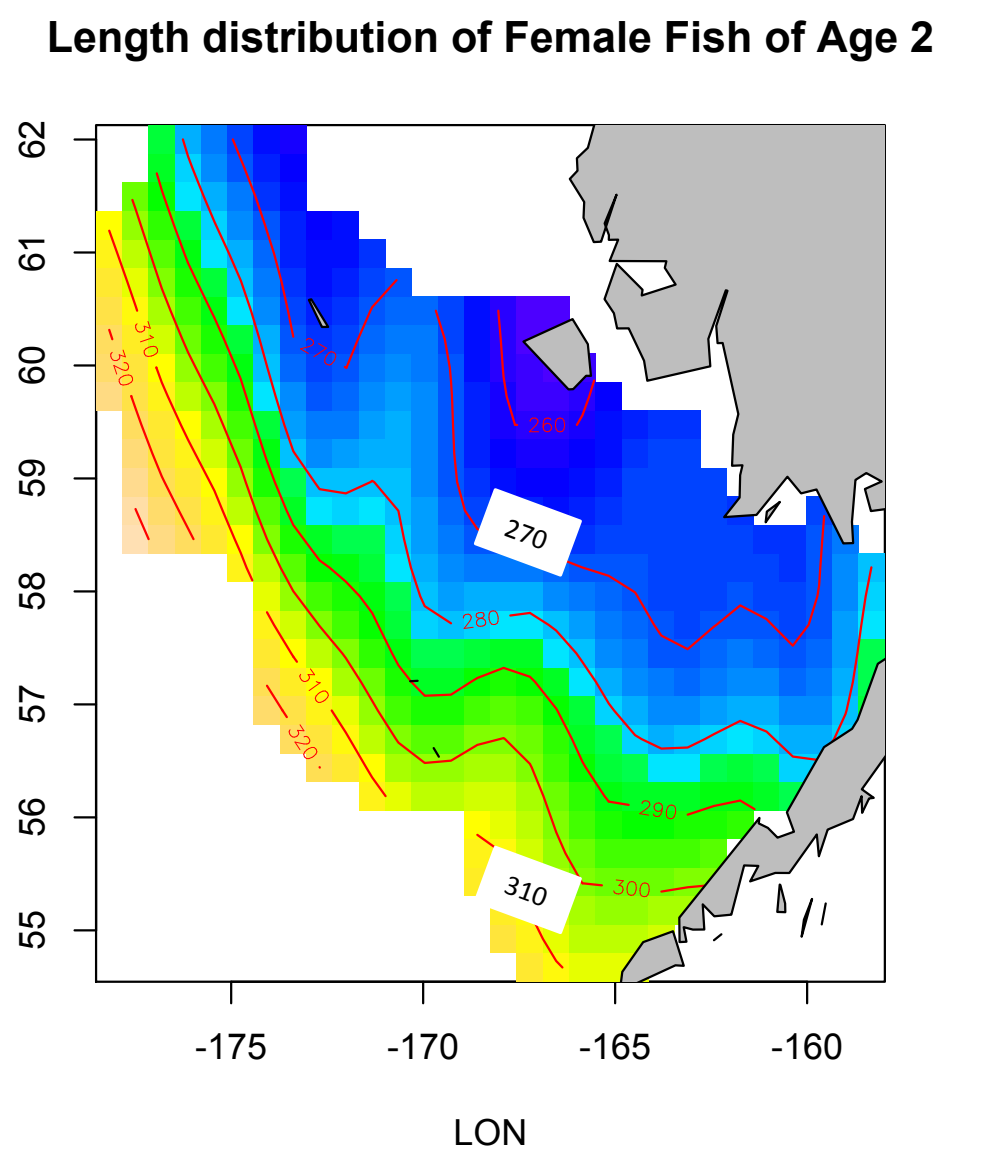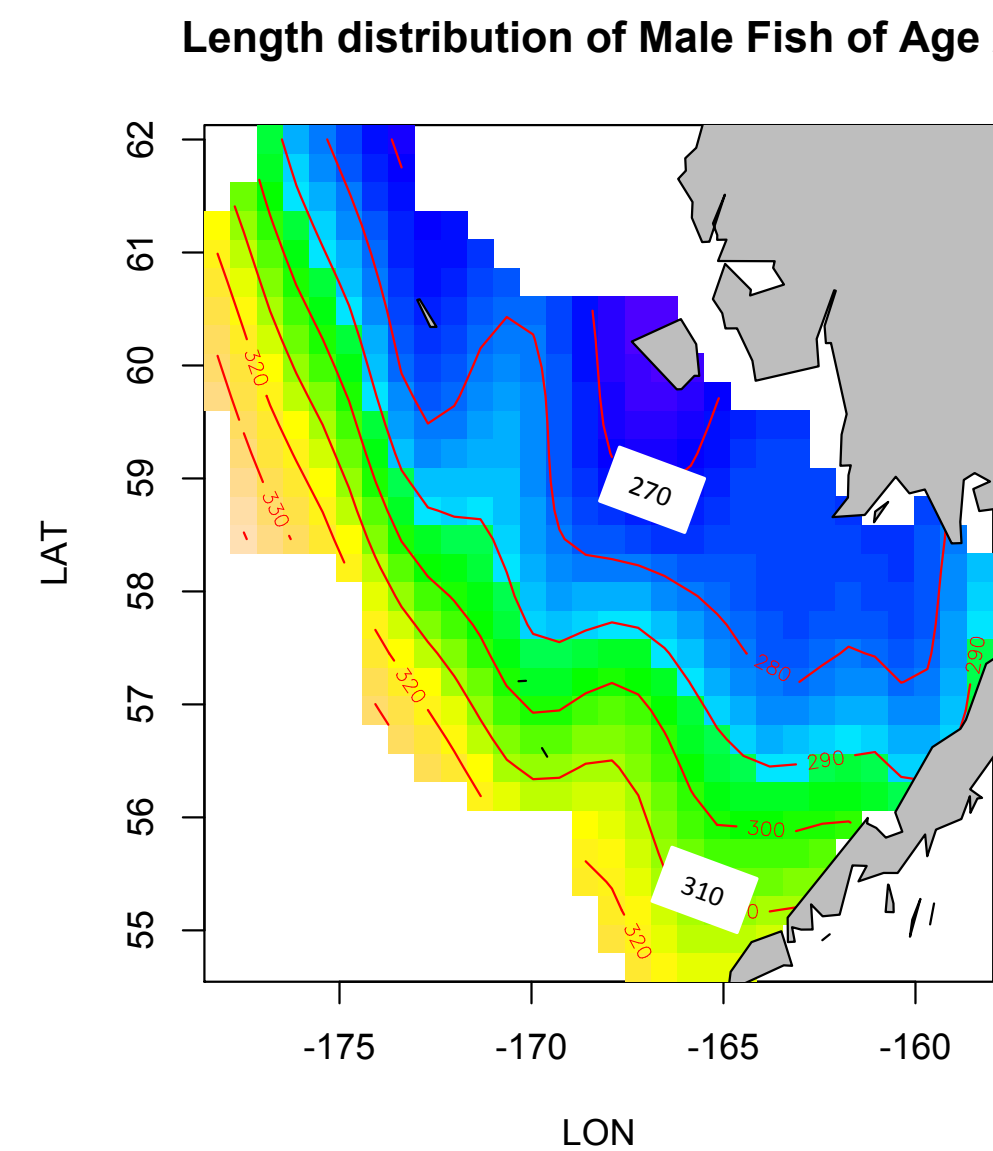
Effect of Year on Fish Length

Mean Temperature of Bering Sea Cold Pool

Year Effect
The top figure shows the expected effect of year of survey on cod length (mm). The bottom figure shows the mean temperature of the cold pool, color-coded by temperature: above-average, warm years (blue) and below-average, cold years (orange). There appears to be a correlation between warm years and shorter fish.

Effect of Age and Temperature, by Sex, on Fish Length
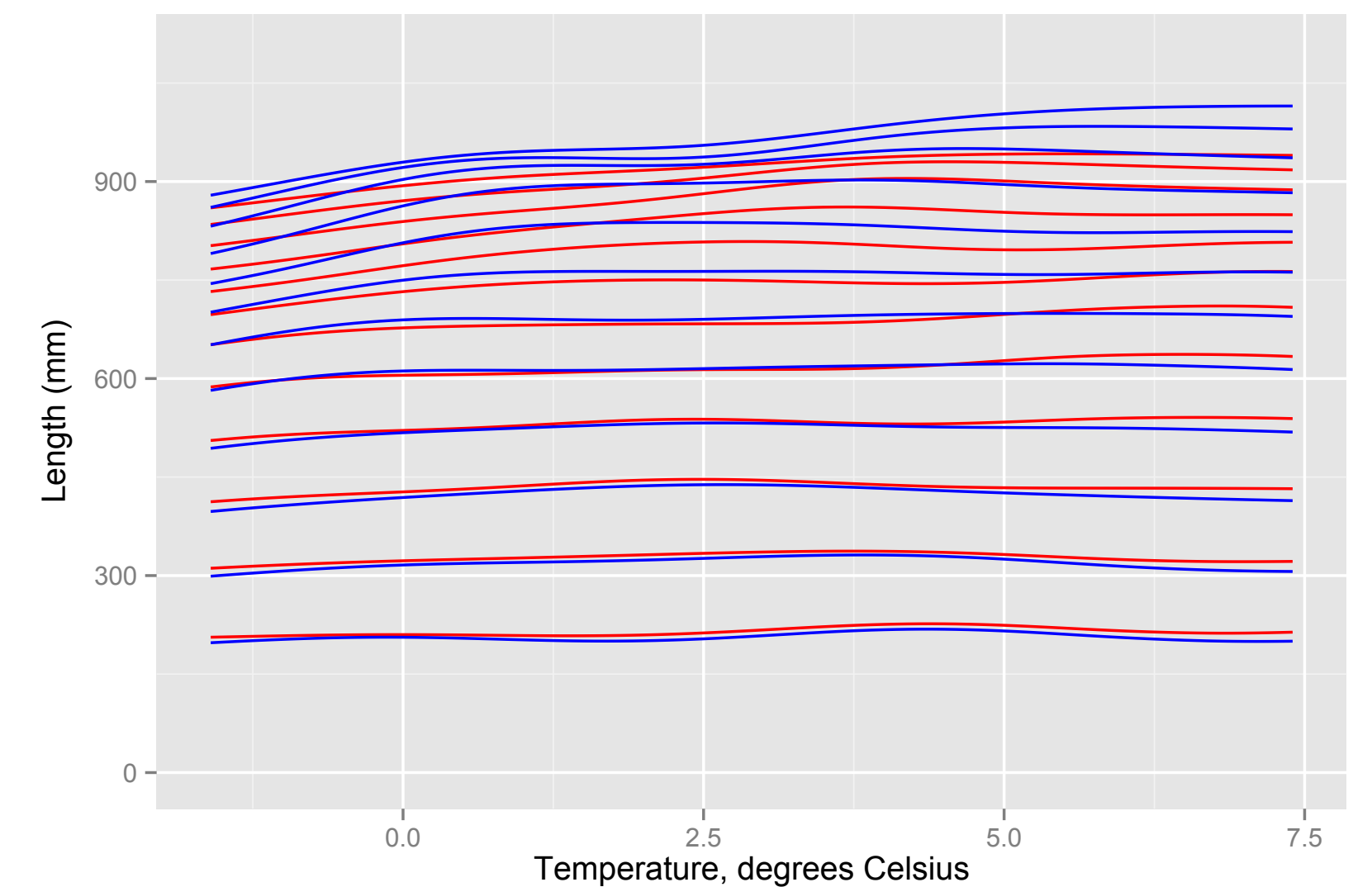
Temperature Effect
The above figure shows the expected lengths of female and male age fish for ages 1-12. Females are in blue, males are in red. Temperature has a generally positive effect on growth.

Does sampling method influence estimates of cod size-at-age due to spatial and temporal variation in growth?

Introduction

To create age estimates of the cod population, a subsample of the fish measured in the survey is aged through otolith analysis.

However, a spatially-uneven sampling method may result in a sample that is not representative of the population.

We simulate random and length-stratified sampling to assess the degree of bias resulting from the sampling process.

Methods

The **length data** has measurements of all of the fish lengths caught in the survey.

The **age data** is a subset of the length data, with otolith-derived ages.

Using the spatial and temporal age-length relationship from the age data, ages are predicted for the rest of the fish. Some age-specific error is added.

Then, a random and length-stratified sampling of the population is simulated.

Original Datasets
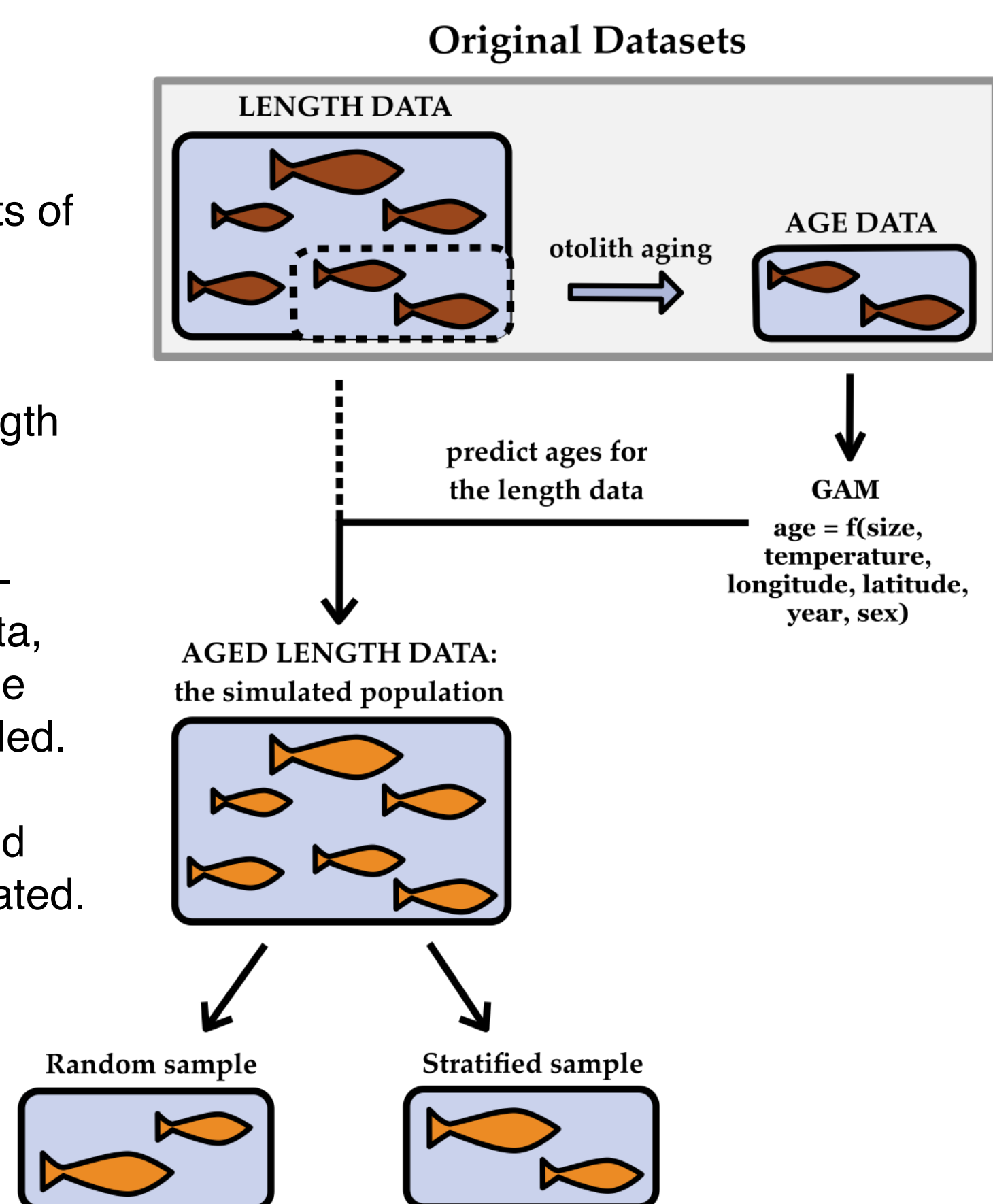
For each sample, two GAMs are constructed: one which describes length as a function of age, and one which additionally incorporates environmental variables.
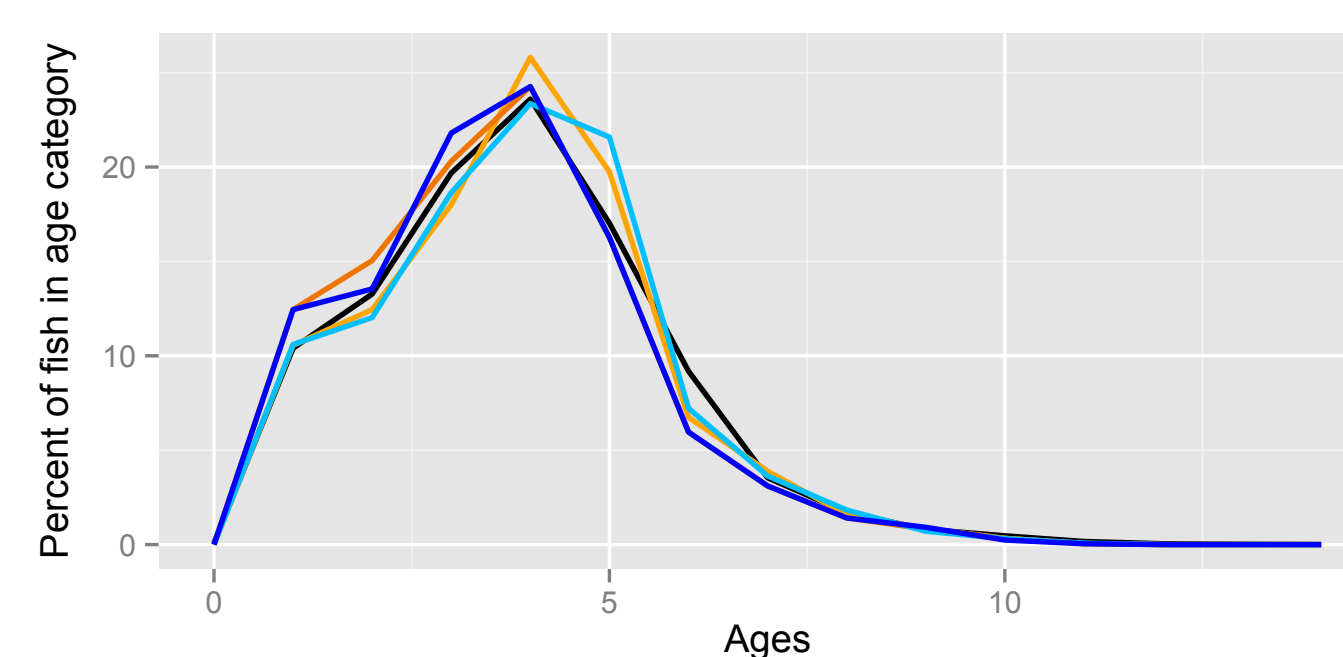
These GAMs are used to predict ages for the length data. Now, the age distributions predicted by the samples can be compared to the "assigned" ages.
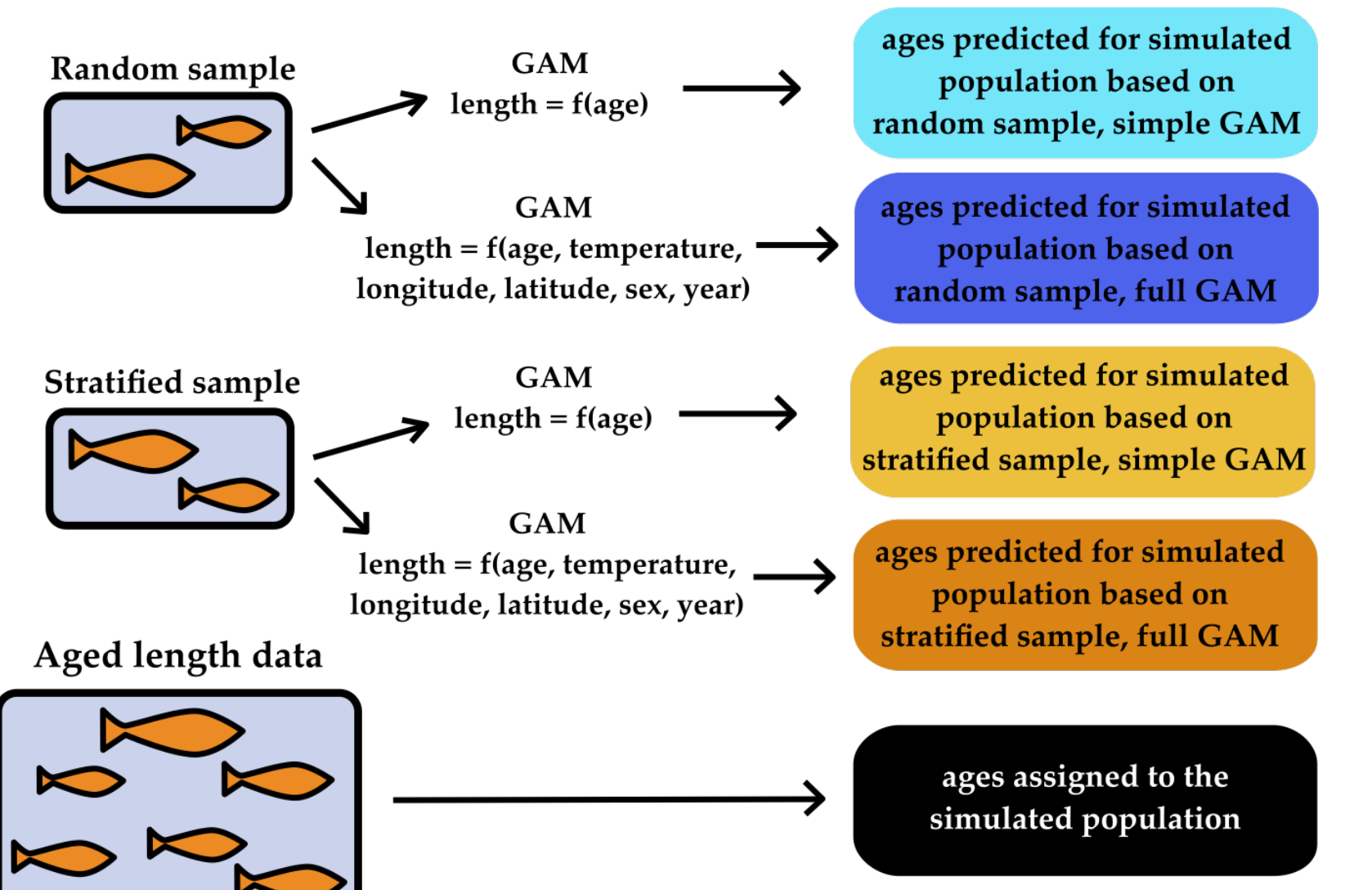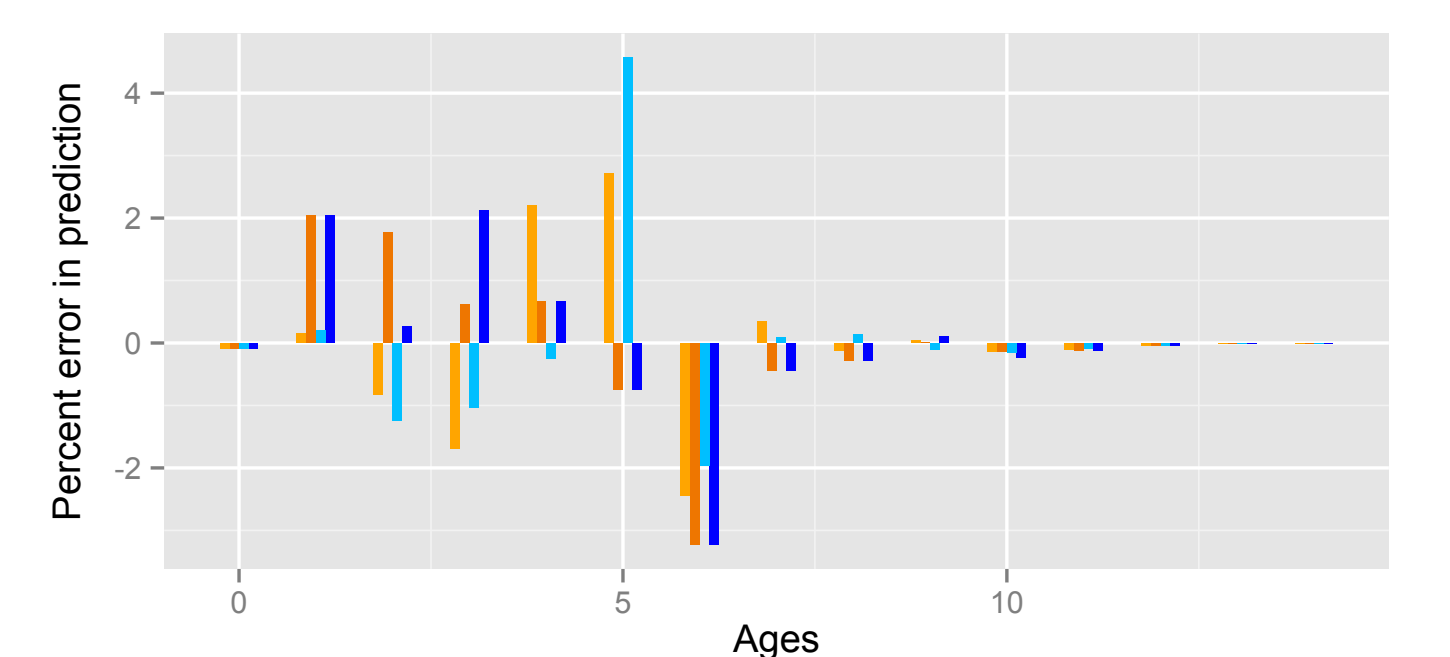

Results

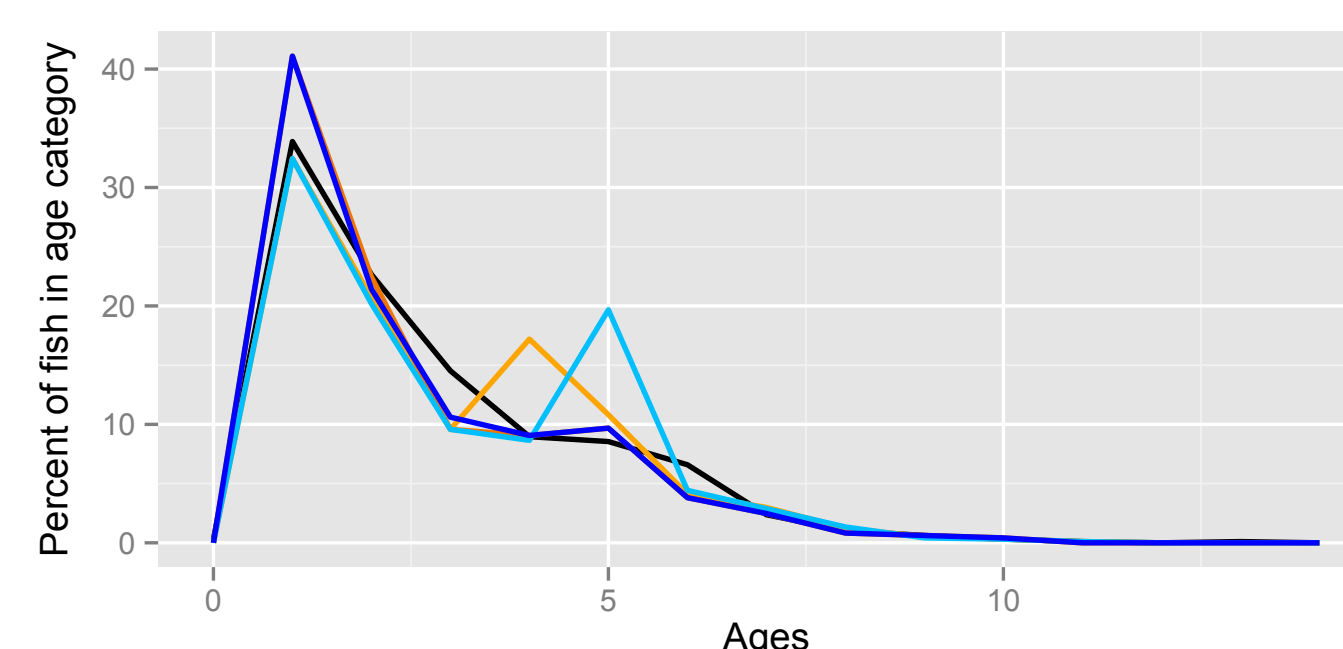Predicted age distributions, by sampling method — All strata for year 2000

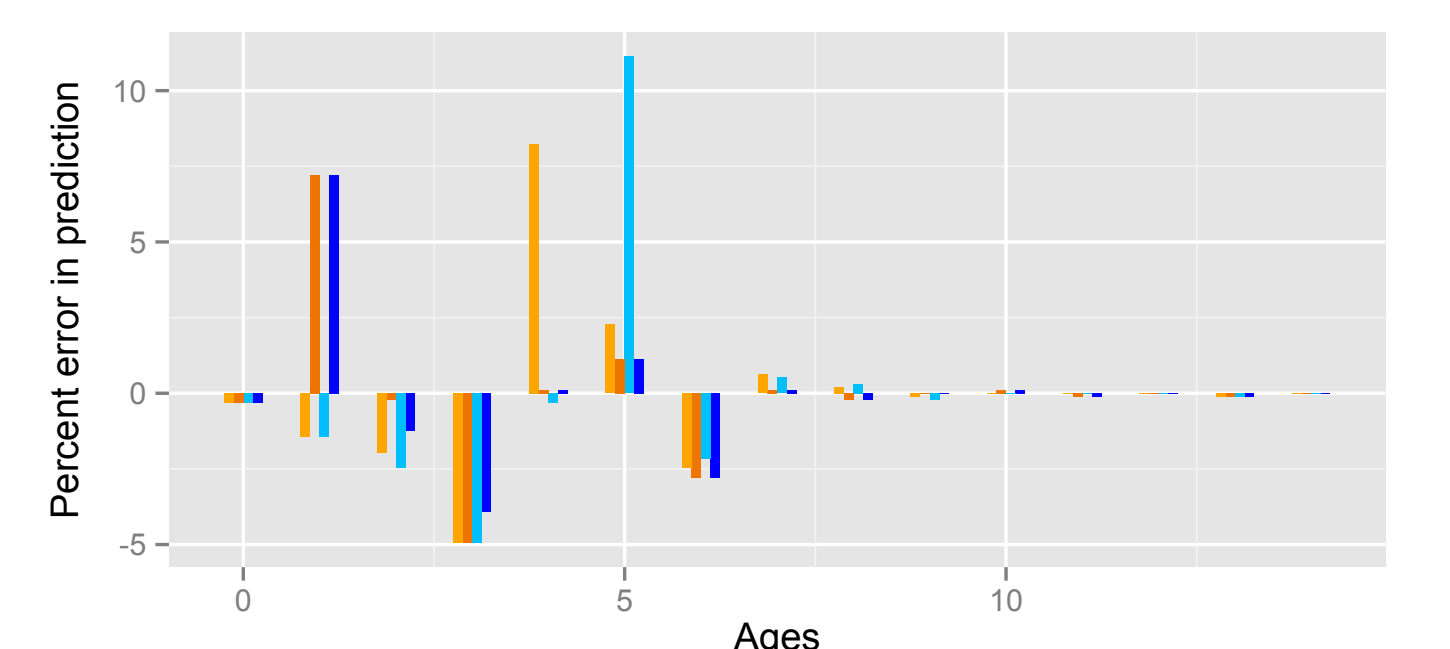Prediction error of fish in age categories, by sampling method — All strata for year 2000

Predicted age distributions, by sampling method — Stratum 10 for year 2000

Prediction error of fish in age categories, by sampling method — Stratum 10 for year 2000

On the right are the age distributions predicted by the two samples with two GAMs per sample (a simple age-length key and a more complex environmentally informed age-length key). On the left is the percent error in prediction for each age and sampling method. The top figures show this distribution and error for the full region in the year 2000, while the bottom figures correspond to a particular stratum in 2000.

Summary and Conclusions

An analysis of the size-at-age of Pacific Cod across the Eastern Bering Sea in the years 1994-2012 shows significant spatial and temporal variation in growth rate.
- Fish are about 4-5 cm larger offshore than inshore for a given age.
- Temperature has a positive effect on growth.
- Fish were smaller around 2000-2005, which may be correlated with temperature regime.

Both random and stratified samples predict reasonably accurate age distributions for the overall population. However, these predictions become less accurate for age distributions over individual strata.

Acknowledgements

Thank you!

UNIVERSITY of WASHINGTON

Oregon State UNIVERSITY — OSU College of Earth, Ocean, and Atmospheric Sciences

NSF

itolkova@uw.edu