Density Dependence
A data (and thought) exploration

Brian Burke and Laurie Weitkamp
Density-dependence
(limiting factors that depend on population size)

What exactly depends on density?

- Feeding/Growth
  Direct competition for prey resources

- Movement/Behavior/Habitat Use
  Physical and behavioral competition for space

- Survival
  Predator rates, cannibalism, antagonistic behavior
Why is density-dependence important?

DD reduces growth and impacts size distribution

Size-dependent survival

Can we just look at size distributions to study DD?
Changes in Length Distributions

**Effect of Growth**
- Time 1
- Time 2

**Effect of Size-dependent Survival**
- All smolts
- Surviving smolts

**Effect of Thinning**
- Time 1
- Time 2

**Real Data:** growth and thinning or size-dependent survival?
No, we can’t just look at size distributions. We must study the mechanisms.
Methods

- 1,897 stomachs analyzed
- 1,411 hatchery fish (H) and 486 not tagged (W)
- 4 species groups (Chinook sub, Chinook yr, Coho yr, and Steelhead)
- 6 years (2007-2012)
- 2 stations (North Channel and Trestle Bay)
- Between 6 and 10 cruises per year, which included multiple hauls at each of the two stations
Response variable

% BW (percent body weight) = weight of stomach contents / weight of fish

I lazily called this % BW, but it’s a proportion, so ranges from 0 to 1

Model

% BW ~ salmonDensity * species/LHT * H/W + year + day + station

Beta regression, link="loglog"
What we had when we initially brought this up as a possible Ocean Forum topic

Salmon Density

Subyearling Chinook | Yearling Chinook | Coho | Steelhead

% BW

Wild

Hatchery

Salmon Density
Density varies across many factors (hatcher/wild, year, species, timing)

Subyearling Chinook
Model Results

Coefficients (mean model with loglog link):

|                  | Estimate | Std. Error | z value | Pr(>|z|) |
|------------------|----------|------------|---------|----------|
| (Intercept)      | -1.6430421 | 0.0391660  | -41.951 | < 2e-16  *** |
| allSalmon        | 0.0021382  | 0.0007651  | 2.795   | 0.00519  **  |
| species_ageChinook yr | -0.0171318 | 0.0255450  | -0.671  | 0.50244  |
| species_ageCoho yr  | -0.0944385 | 0.0496873  | -1.901  | 0.05735  |
| species_ageSteelhead juv | -0.1283440 | 0.0277555  | -4.624  | 3.76e-06 *** |
| hatwildW         | -0.0222196 | 0.0115642  | -1.921  | 0.05468  |
| stationTrestle Bay | 0.0197273  | 0.0086065  | 2.292   | 0.02190  *  |
| year2008         | -0.0730788 | 0.0154154  | -4.741  | 2.13e-06 *** |
| year2009         | -0.0408124 | 0.0161459  | -2.528  | 0.01148  *  |
| year2010         | -0.1573894 | 0.0161351  | -9.754  | < 2e-16  *** |
| year2011         | -0.1124735 | 0.0161818  | -6.951  | 3.64e-12 *** |
| year2012         | -0.0523495 | 0.0181181  | -2.889  | 0.00386  **  |
| day              | 0.0004534  | 0.0001580  | 2.869   | 0.00412  **  |
| allSalmon:species_ageChinook yr | -0.0036725 | 0.0011685  | -3.143  | 0.00167  **  |
| allSalmon:species_ageCoho yr  | 0.001281  | 0.0019389  | 2.129   | 0.03324  *  |
| allSalmon:species_ageSteelhead juv | -0.019922  | 0.0012588  | -1.583  | 0.11351  |
| species_ageChinook yr:hatwildW | 0.0355027 | 0.0346695  | 1.024   | 0.30582  |
| species_ageCoho yr:hatwildW | 0.0684460 | 0.0361496  | 1.893   | 0.05830  |
| species_ageSteelhead juv:hatwildW | 0.0503721 | 0.0256221  | 1.966   | 0.04930  *  |
Summary

• This is not conclusive.

• I was forced to separately account for the effect of year and location because there may be inherent differences in productivity, prey availability, predator density, etc. I wouldn’t want to attribute low stomach contents to fish density if it was mainly due to interannual differences in productivity, for example.

• If we had an independent estimate of food availability, we could account for these effects directly.

• Similar effect with differences between hatchery and wild fish. Hatchery fish had less food in their stomachs and were often found in higher densities, but this doesn’t necessarily imply a cause and effect relationship – it could also have been due to differences in migration timing. Independent estimates of prey availability at varying levels of abundance would be required to refine this analysis.