Variations in size, growth and survival of hatchery Columbia River Chinook salmon in the Northern California Current

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Abundance of Columbia River Spring Chinook salmon adults varies inter-annually

Smolt production relatively constant during this period

There is an emerging consensus that ocean conditions limit adult salmon abundance

Adult spring Chinook at Bonneville (USACE)  ~ 5-fold variation

Good ocean

Bad ocean – PDO positive
warm temps poor feeding

Return year
Yearling Chinook salmon Columbia River hatchery production ~ 33 million/year

6 major stocks

- Mid & Upper Columbia River
- West Cascade Rivers
- Willamette River
- Snake River
Early marine habitat of juvenile salmon is typically confined to the continental shelf. Parr from different stocks are widely spaced geographically, leading to an increase in potential for interactions as fish smolt and migrate to the ocean. All juvenile salmon pass under the bridge at Astoria, which is located within a distance of less than 50 km.
Goal: generate discussion on interactions between ocean resources, smolt abundance and smolt size on a stock-specific basis.

Outline:

- marine growth and survival
- varying size-biased survival of hatchery smolts
- size and marine growth
Data: NOAA Juvenile Salmon Ocean Survey, 1998 - present
NOAA Salmon Survey
May, June and September
starting in 1998

2013, 2014 June only

This talk:
May and June data

Yearling Columbia River Chinook salmon
Why does marine survival vary?

Adult spring Chinook at Bonneville
What do juvenile salmon do in the ocean? Eat & Grow
Marine growth* varies between years, growth is related to survival
(Columbia River spring Chinook Salmon)

Growth* of UCR/SnkR Spring Chinook varies between years

Growth is related to adult return

*Growth in June ~ 2 - 6 weeks post-ocean entry
** IGF1 is a hormone that reflects growth rate
Growth varies

=> Food is limited in some years

If food is limited

=> there is competition for food
Change focus from the ocean to hatcheries
Most (all?) hatcheries have size @
release targets

How does smolt size at release relate to marine survival?
1. Does size of smolts relate to survival?
2. Does this vary between years (ocean conditions)?

Historic - compare release groups of different mean size (CWT)

1. Yes, big > small
2. Not explicitly addressed, experiments expensive
   => limited to a couple of years

Present – new opportunity = PIT-tags, compare individuals

1. Lots of data, surprisingly little analysis
2. Wait for ~ 2 minutes
Examining effects of smolt size on survival: data fishing at Carson NFH

- Release PIT-tagged fish
- Above Bonneville (interrogate adults)
- Relatively close to ocean: less influence riverine and hydro-system mortality
- No Barging
- Consistent annual timing of PIT-tagging (2003 – 2010)
Overall adult returns vary during 8 years of Carson data: ocean conditions vary

Adult spring Chinook at Bonneville

Highest survival

Lowest survival
Smolt size of surviving Carson adults varies by year in relation to ocean conditions.

- Highest survival
- Lowest survival

Not mean size of all smolts, mean smolt size for surviving adults.

Ocean entry year:
- 2003
- 2004
- 2005
- 2006
- 2007
- 2008
- 2009
- 2010

$r^2 = 0.83$
Pattern is similar across 3 age classes: smolt size of surviving Carson adults is greater in bad ocean years

(-PDO = “good” for salmon)
Size selective mortality occurs in 1st ocean year (same pattern multiple ages)

More intense selection in “bad” ocean years (larger smolt size of surviving adults with + PDO)
Why does survival vary with size?
What about salmon in the ocean?
NOAA Juvenile Salmon Ocean Survey
1998 - present
Yearling Columbia R Chinook salmon: marine growth varies with size

2006 - 2011, May, all stocks

p<0.001, r²=0.20
IGF1 - size relationships vary between years in May
(slope of regression line)

Snake River spring Chinook salmon
IGF vs Length slope varies with ocean conditions

![Graph showing the relationship between IGF and Length slope with different ocean conditions.](image)
IGF1 - size relationships vary between years due to varying ocean conditions.

Snake River spring Chinook salmon
Size-biased growth occurs

Big fish have higher growth than smaller fish in “bad” ocean years.
More hatchery data
Release size of yearling Chinook salmon varies 2-fold by stock

Fish Released (millions)

Release Size

Weight (g)

Fish Passage Center
What about salmon in the ocean?
NOAA Juvenile Salmon Ocean Survey
Weight of fish caught in the ocean varies > 2-fold by stock

2006-2011
Smallest fish have the lowest growth by stock

Growth in May

IGF1

Downriver Spring

Upriver Summer/Fall

Upriver Spring
Different stocks have differing smolt sizes

Different stocks have differing early marine growth rates
Do different stocks have differing size-based marine mortality rates?

Do stock specific size-based mortality rates vary with ocean conditions?
Data and analysis needed to confirm preliminary analysis

Stock-specific survival data
  (hatchery and wild)

More smolt size - survival analysis (and data) by stock

Acknowledgement of interactions:
  years (ocean conditions)
  stock
  size
Time dependent bonus slide?
Biomass (abundance x weight) varies by stock, month and year.
Summary:

- marine growth is limited in some years
- marine survival is related to marine growth
- size selective marine mortality occurs
- more intensive marine size selection in low marine growth years
- differences in growth between big and small fish are greater in years with low marine growth
- size varies among stocks
Interesting questions about current management practices:

1. How many smolts should be released?
   Should this vary by year?
   How many smolts from what stocks?

2. What should smolt release size be?
   Should there be a size limit?

3. When should smolts be released?
   Create “windows” of low competition?
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