Implications of the interannual variability in the feeding ecology of juvenile Chinook salmon

Eric Hertz[1,*], Marc Trudel[1,2], Rana W. El-Sabaawi[1], Strahan Tucker[2], Terry D. Beacham[2], and Asit Mazumder[1]

[1]Department of Biology, University of Victoria, PO BOX 3020, Station CSC, Victoria British Columbia, Canada, V8W 3N5.

[2]Pacific Biological Station, Department of Fisheries and Oceans Canada, 3190 Hammond Bay Road, Nanaimo, British Columbia, Canada, V9T 6N7

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PAUL F. GILL

- “Feeding is such a universal and commonplace business that we are inclined to forget its importance. The primary force of all animals is the necessity of finding the right kind of food and enough of it.” Elton, 1927

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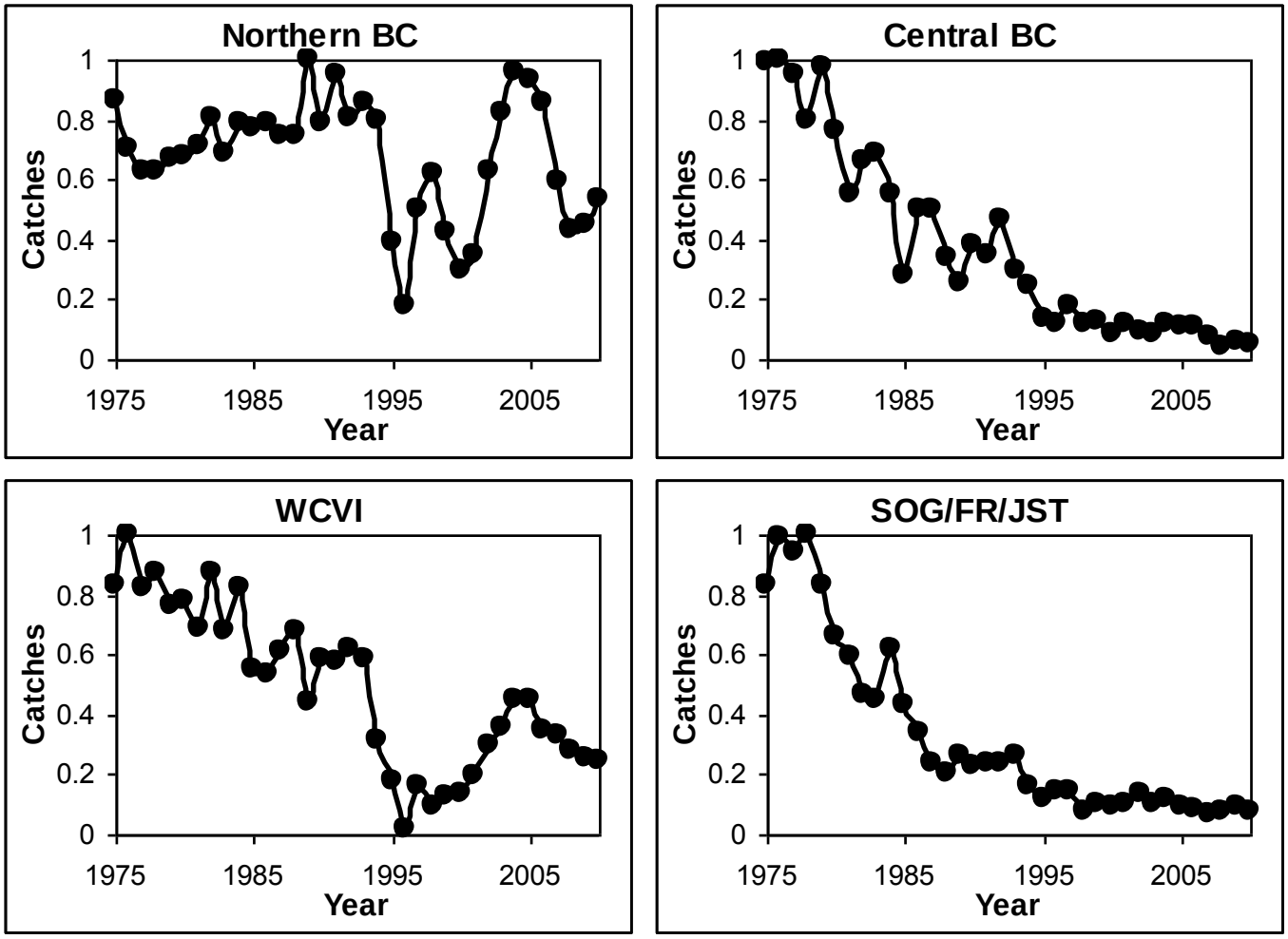
Chinook salmon

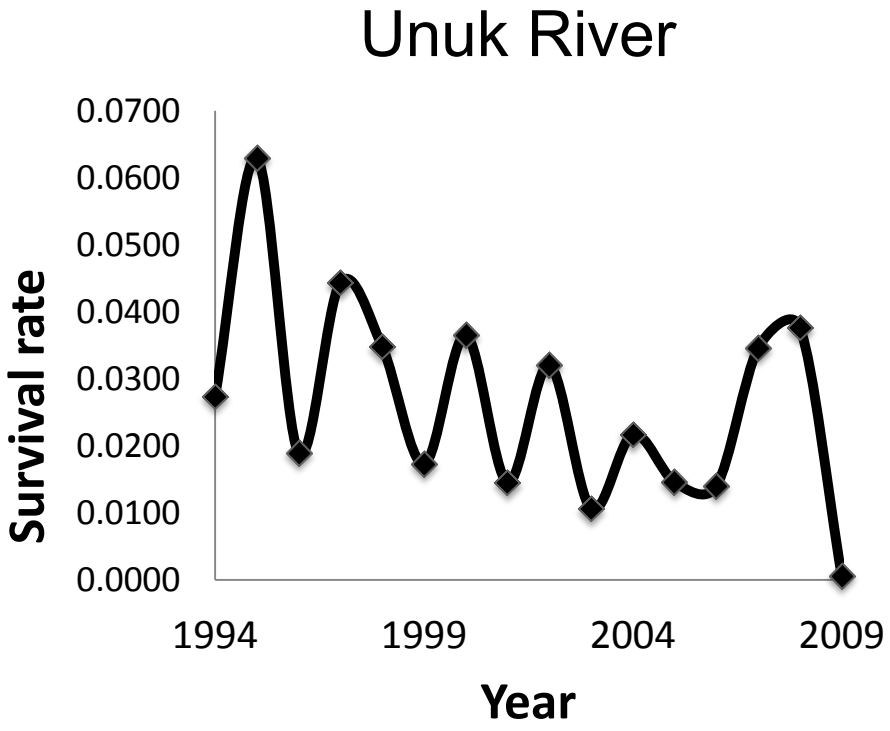
- Largest of the Pacific salmon
- Either spend one full year in freshwater or a few months
- Tend to mature after 2-5 years in the ocean
- Stocks of interest from the West Coast of Vancouver Island (WCVI) and Southeast Alaska (SEAK)

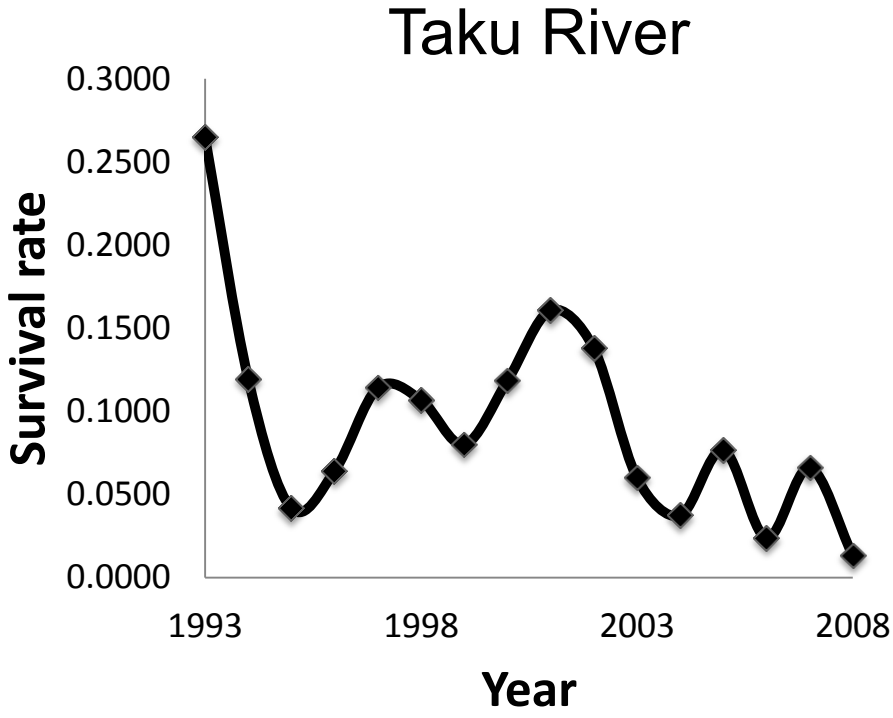
Status of Chinook stocks in B.C.



DFO, 2011

Status of SEAK Chinook

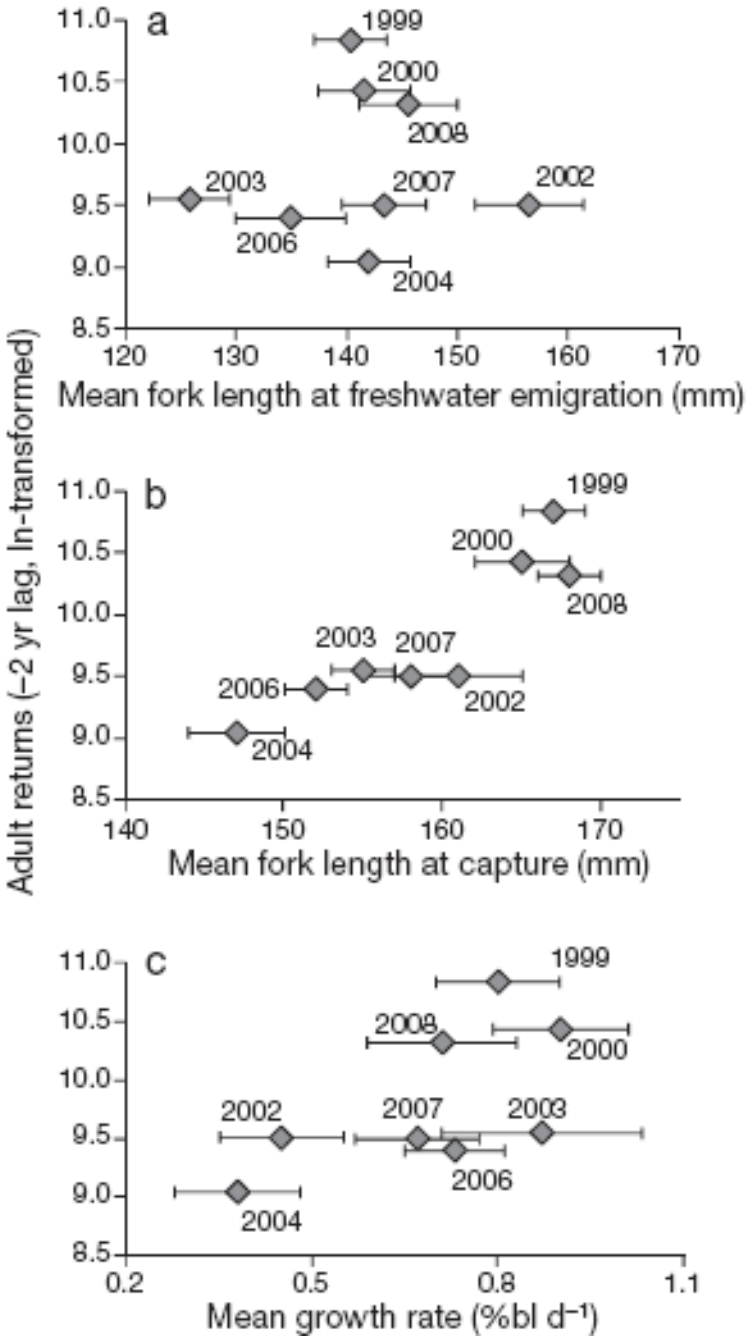




DFO and PSC, 2012

Critical period for salmon survival

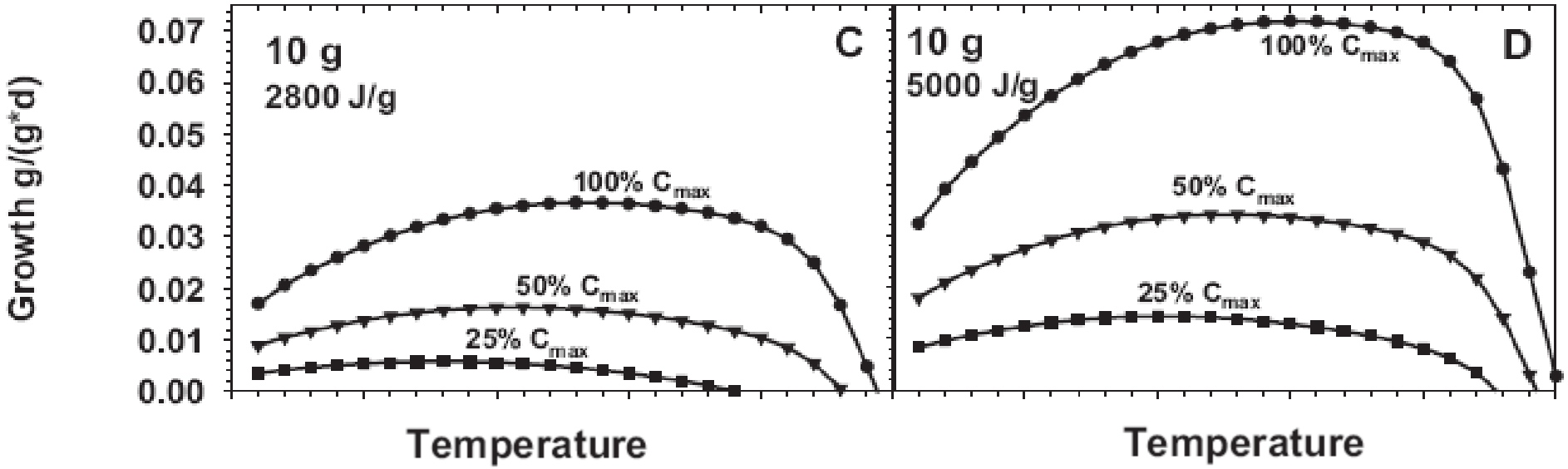
- Large and variable mortality rates during early marine life may define survival rates for salmon.
  - Mortality in early marine life tends to be size-selective.



Tomaro et al., 2012

Factors affecting early marine growth

- Temperature, prey quality, prey quantity



Beauchamp, 2009,

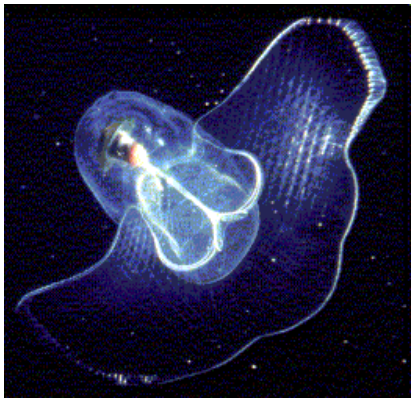
Objective:

- To determine whether feeding ecology of juvenile Chinook affects growth or survival in two contrasting stocks.

$\delta^{15}N$

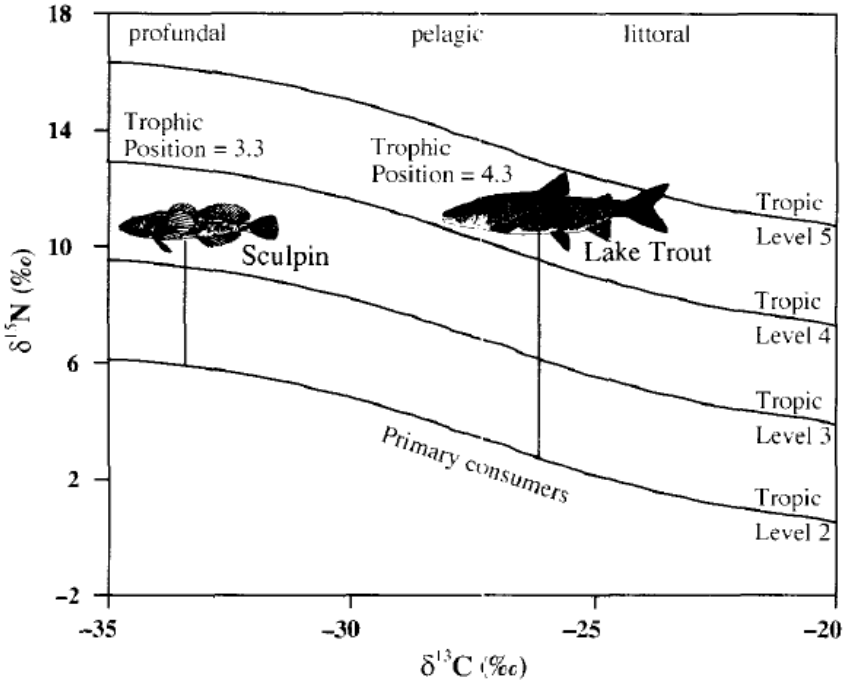
- $\delta^{15}N$ can indicate trophic level.
- Larger prey tend to have greater $\delta^{15}N$.

$\delta^{15}N$ = 9‰ $\delta^{15}N$= 12 ‰



Trophic level

- Can use $\delta^{15}N$ to calculate trophic level.
- Assume zooplankton are at trophic level 2.
- $\delta^{15}N$ increases by ~ 3.4‰ / trophic level.
- So a juvenile salmon feeding only on zooplankton would be 3.4 ‰ above zooplankton and a trophic level of 3.



- Fish prey are generally more energy dense than zooplankton (Davis et al., 1998).
- Larger prey tend to be a more efficient prey choice than smaller prey (Kerr et al., 1971; Pazzia et al., 2002).

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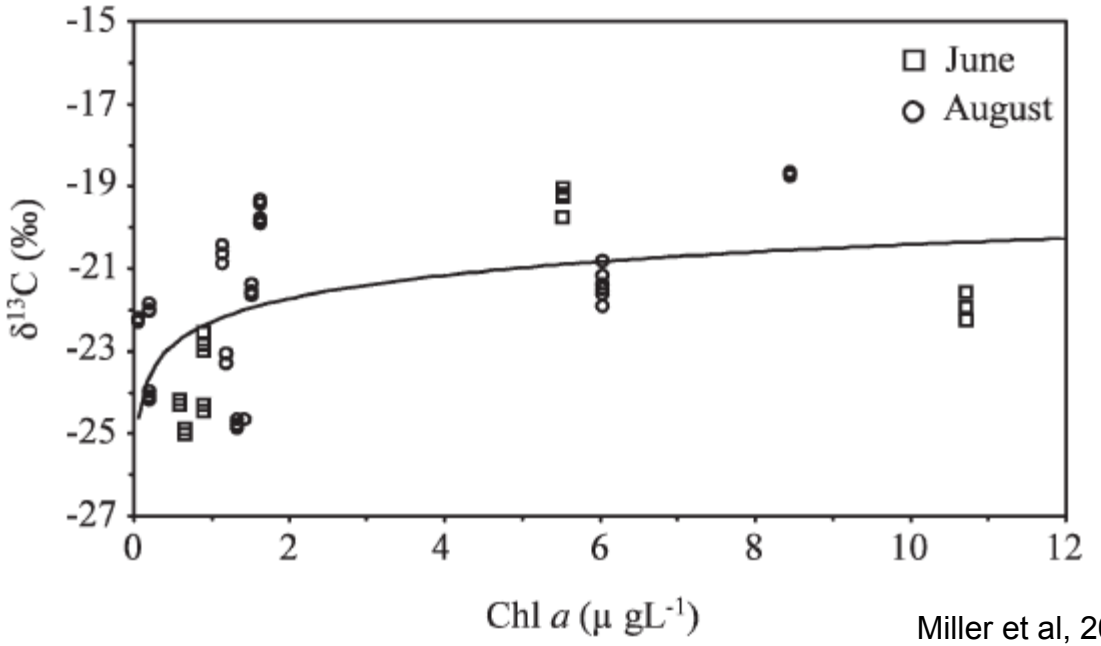
- **Hypothesis # 1: A higher $\delta^{15}N$ and trophic level will correlate with greater growth and survival of Chinook salmon stocks.**

$\delta^{13}C$

- Onshore / offshore gradient in $\delta^{13}C$ within years
- But also may be interannual variability in $\delta^{13}C$ due to shifts in productivity.



Miller et al, 2008

- **Hypothesis # 2. A higher $\delta^{13}C$ value will be linked to higher growth and survival.**

C:N ratio

- Ratio of carbon to nitrogen isotopes can be an indicator of lipid content in aquatic systems.
- Higher C:N indicates higher lipid content.

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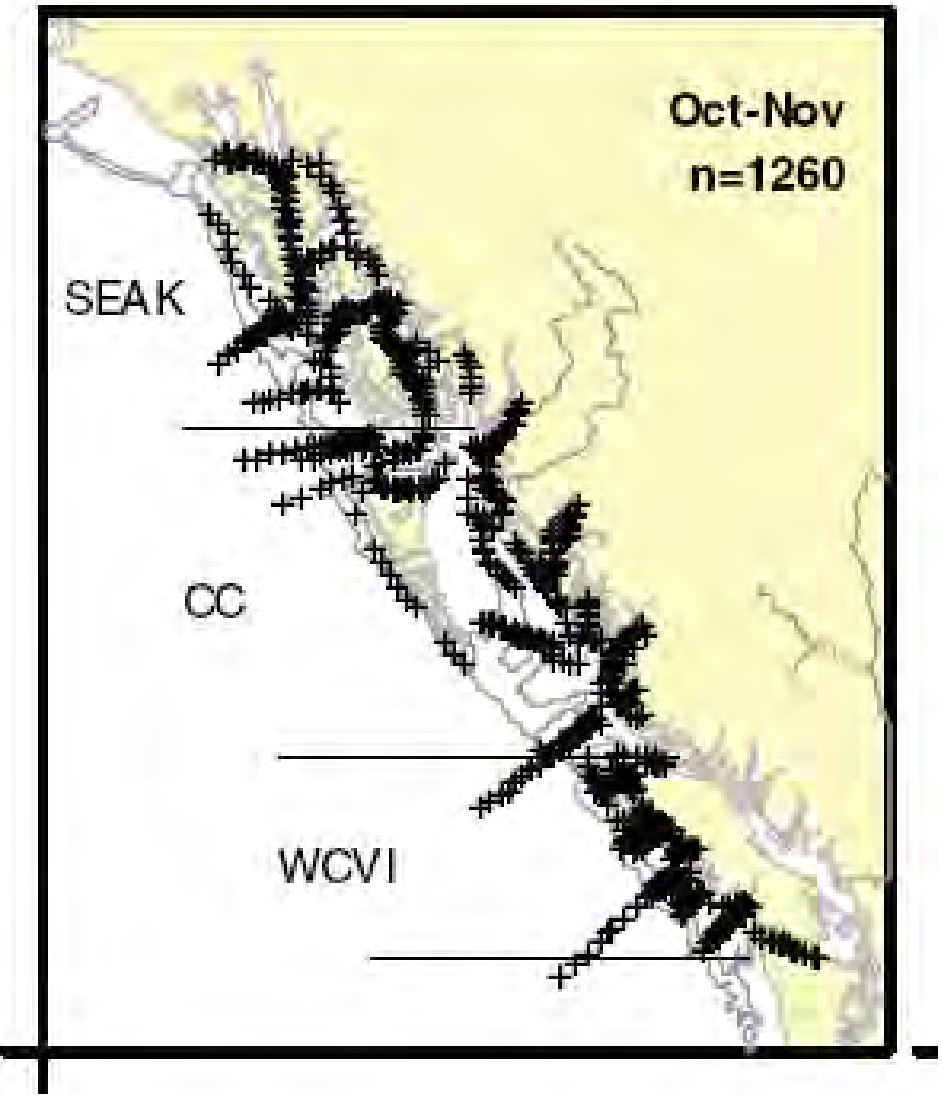
- **Hypothesis # 3: Higher C:N ratios will correlate positively with growth and survival.**

Methods: study area and sampling



Tucker et al, 2011

WCVI Chinook

- Ocean-type
- Hatchery and wild fish
- Average migration date: June 21st (Trudel et al., 2007)
- Survival rate of Robertson Creek (from DFO / PSC) a proxy for survival of all stocks

SEAK Chinook

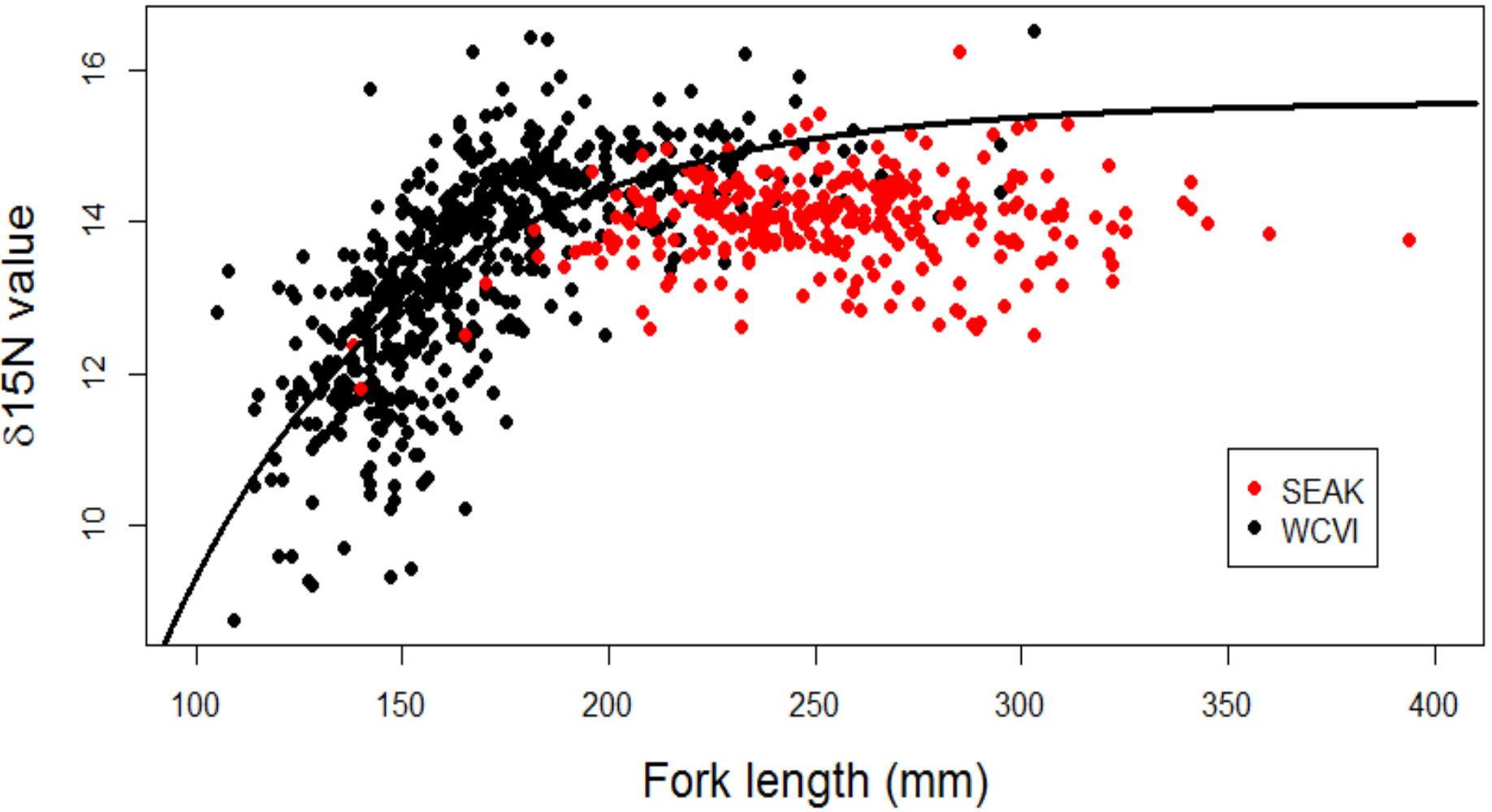
- Stream-type
- Hatchery and wild fish
- Average migration date: May 24th (Trudel et al., 2007)
- Survival rate of Unuk River (from DFO / PSC) a proxy for survival of all stocks

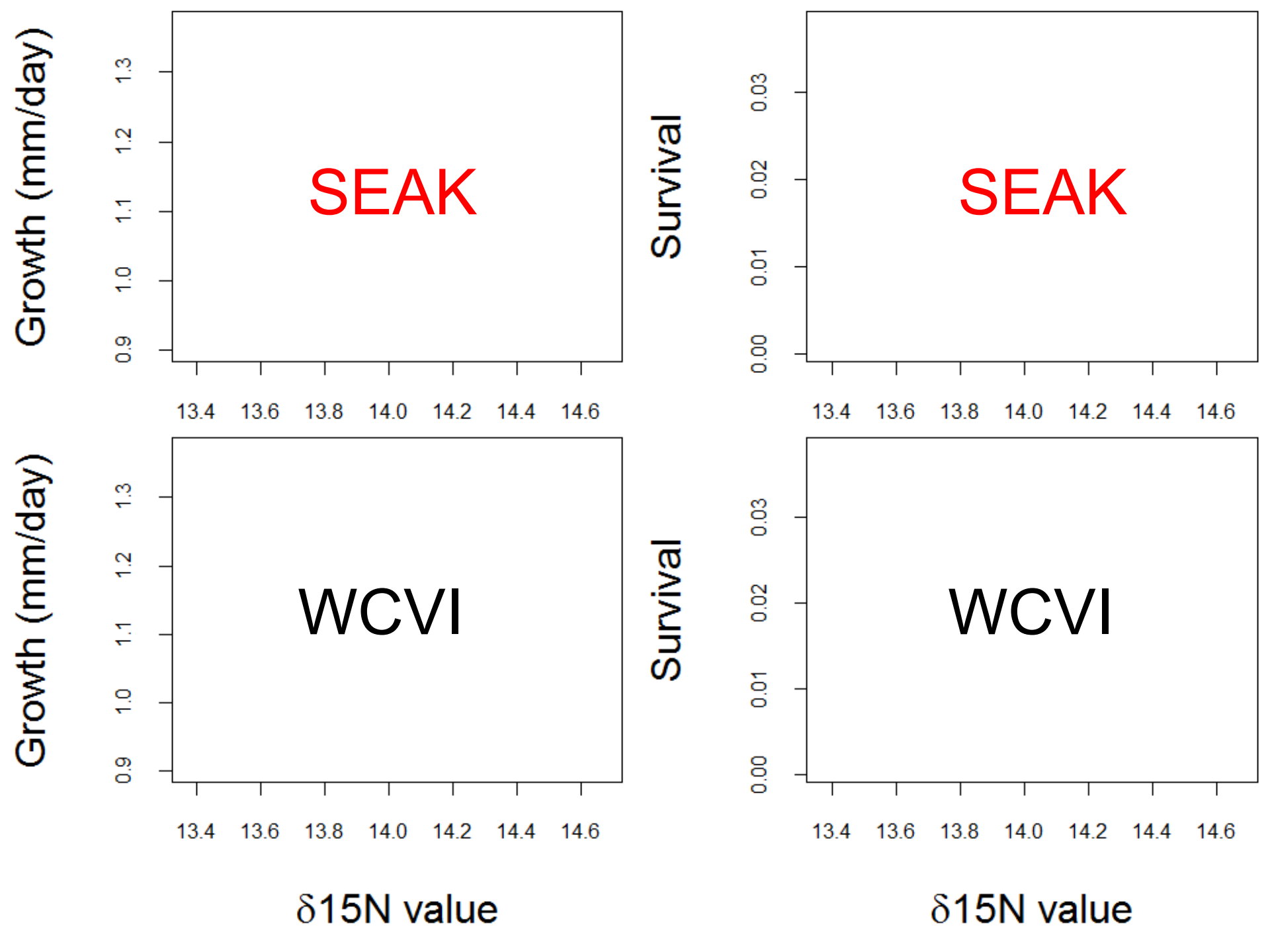
Methods: other

- Time series of stable isotope values of almost 900 juvenile Chinook salmon: 2000-2009.
- Genetic data from DFO to provide stock specificity.
- Growth data – change in fork length over time, with estimated ocean entry size and date (Trudel et al., 2007).

Results

Nitrogen and size




Growth (mm/day)
0.9
1.0
1.1
1.2
1.3
SEAK
13.4
13.6
13.8
14.0
14.2
14.4
14.6
Survival
0.00
0.01
0.02
0.03
SEAK
13.4
13.6
13.8
14.0
14.2
14.4
14.6
Growth (mm/day)
0.9
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δ15N value
Survival
0.00
0.01
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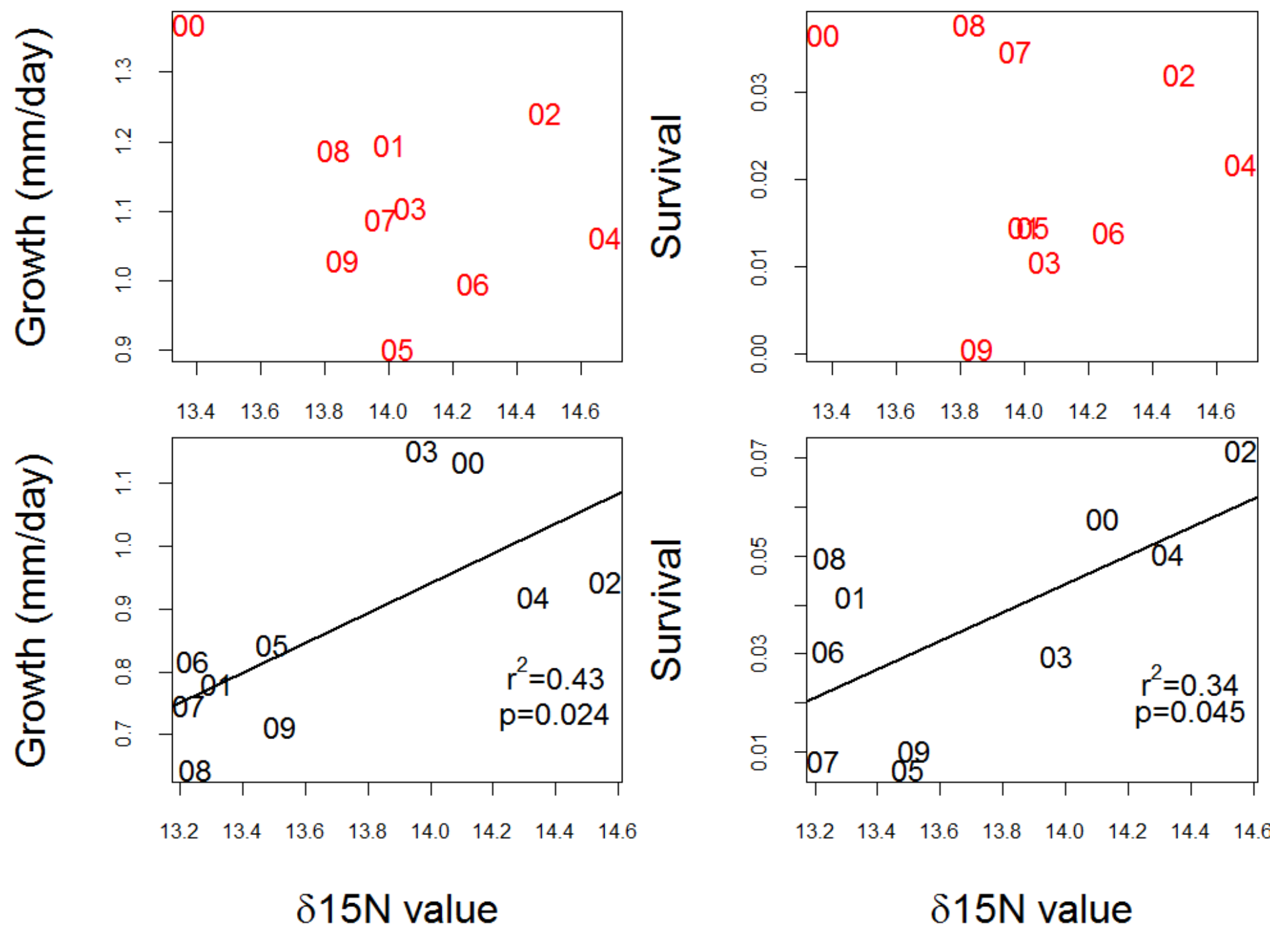
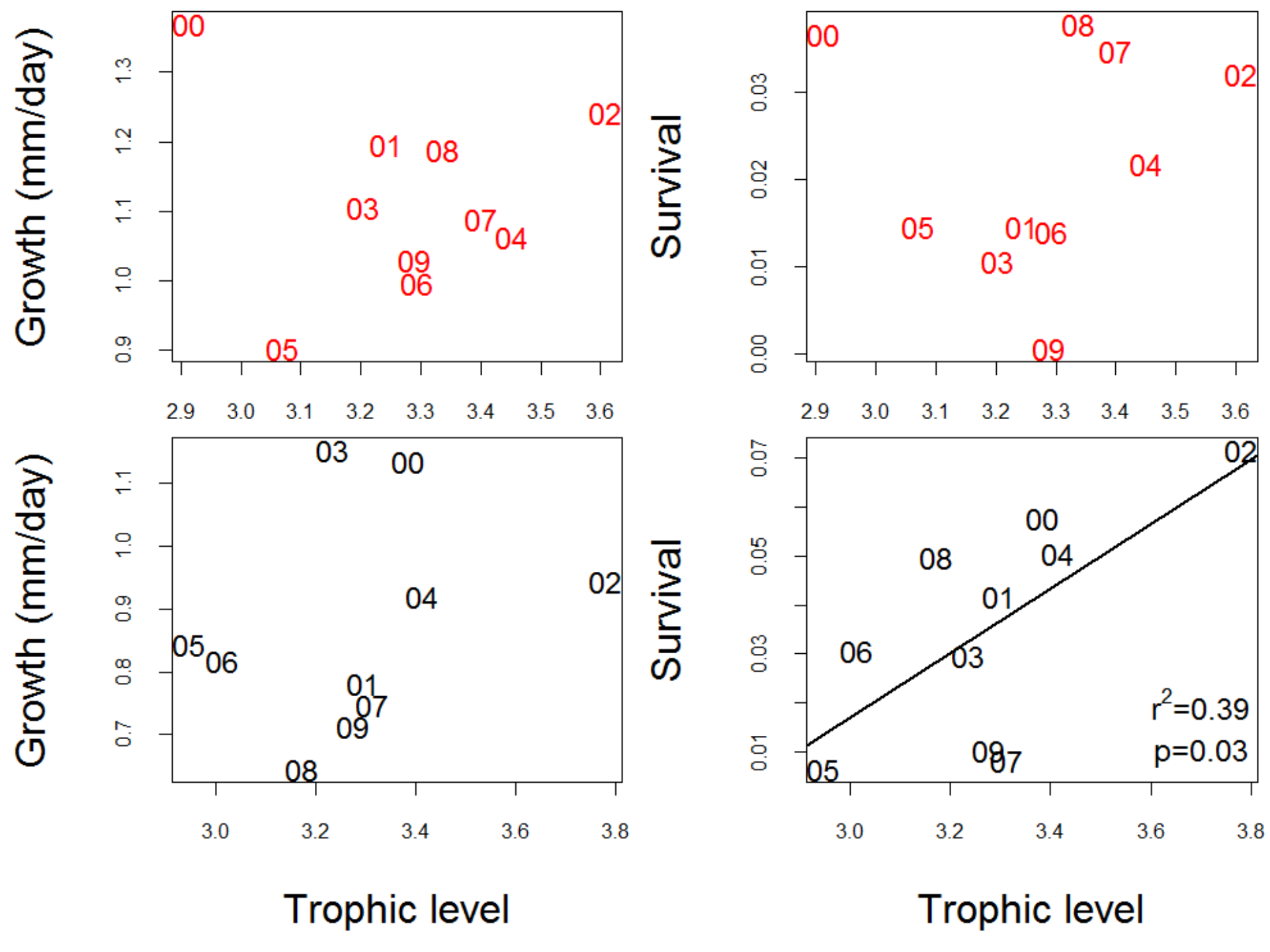
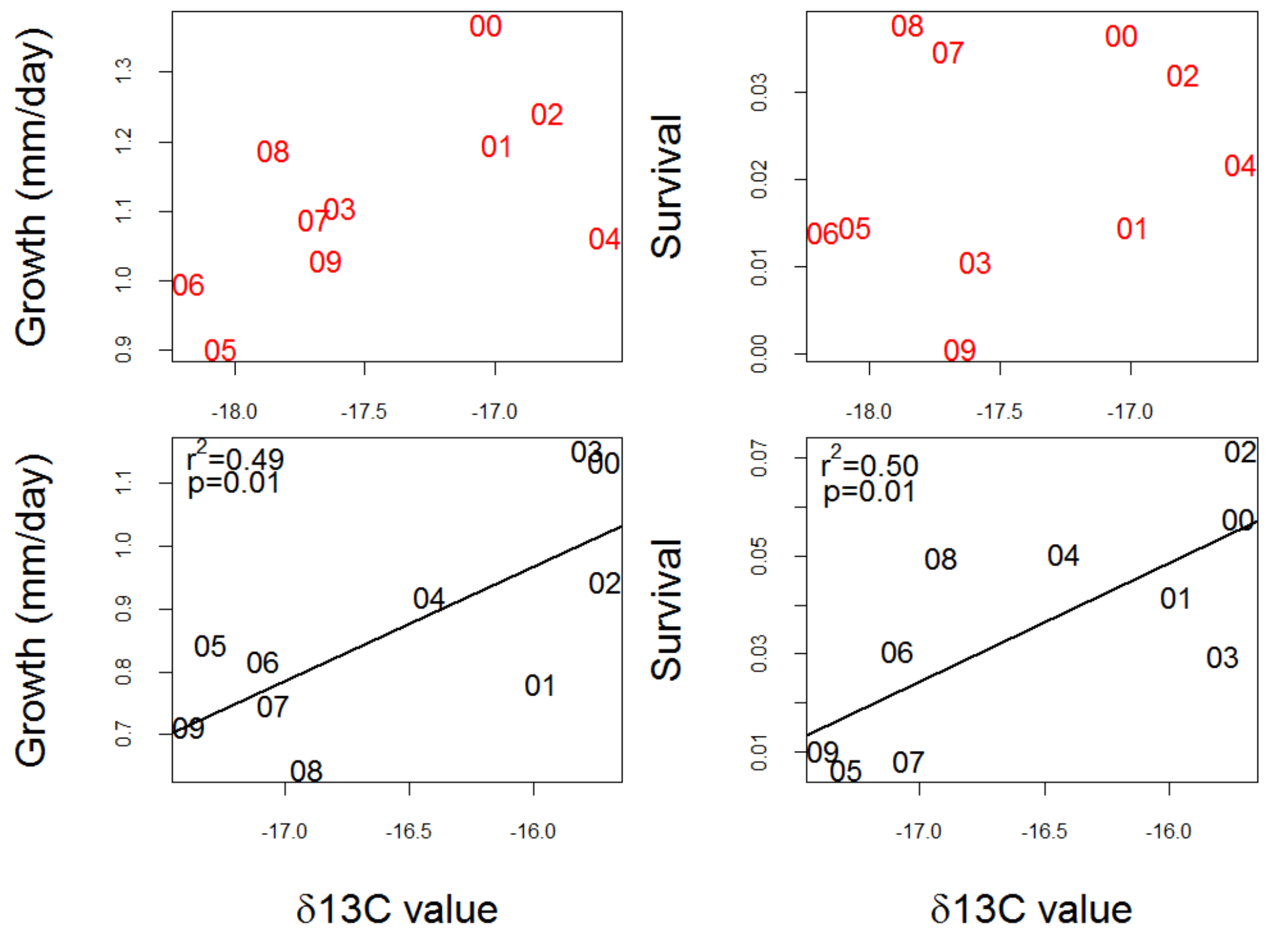
0.03
WCVI
13.4
13.6
13.8
14.0
14.2
14.4
14.6
δ15N value

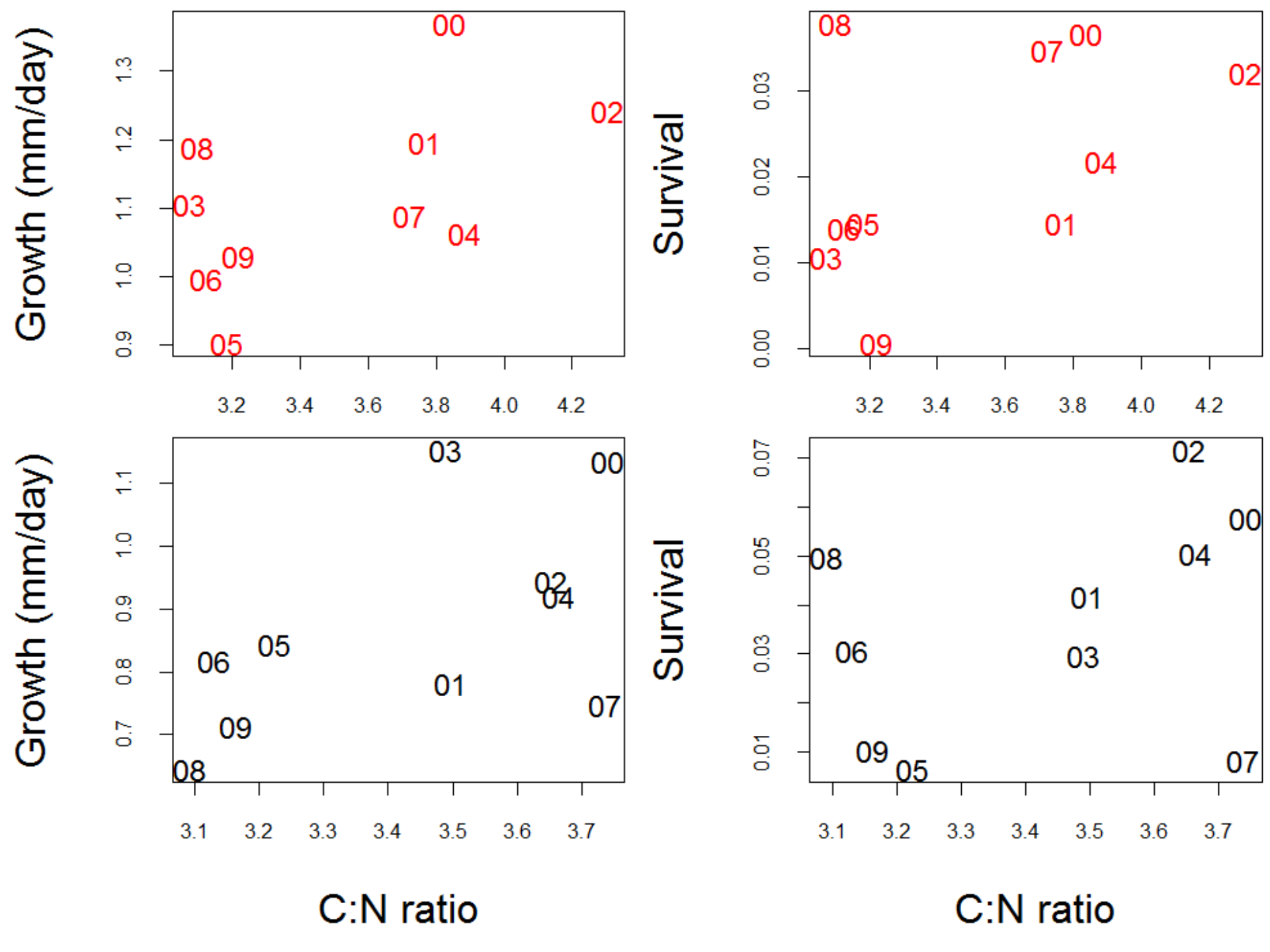

Growth (mm/day)
Survival
δ15N value
δ15N value
r2=0.43
p=0.024
r2=0.34
p=0.045


Growth (mm/day)
Survival
Growth (mm/day)
Survival
Trophic level
Trophic level
r2=0.39
p=0.03

- **Hypothesis # 1: A higher $\delta^{15}N$ and trophic level will correlate with greater growth and survival of Chinook salmon stocks.**
  - **Hypothesis #1 is supported for WCVI, but not for SEAK.**

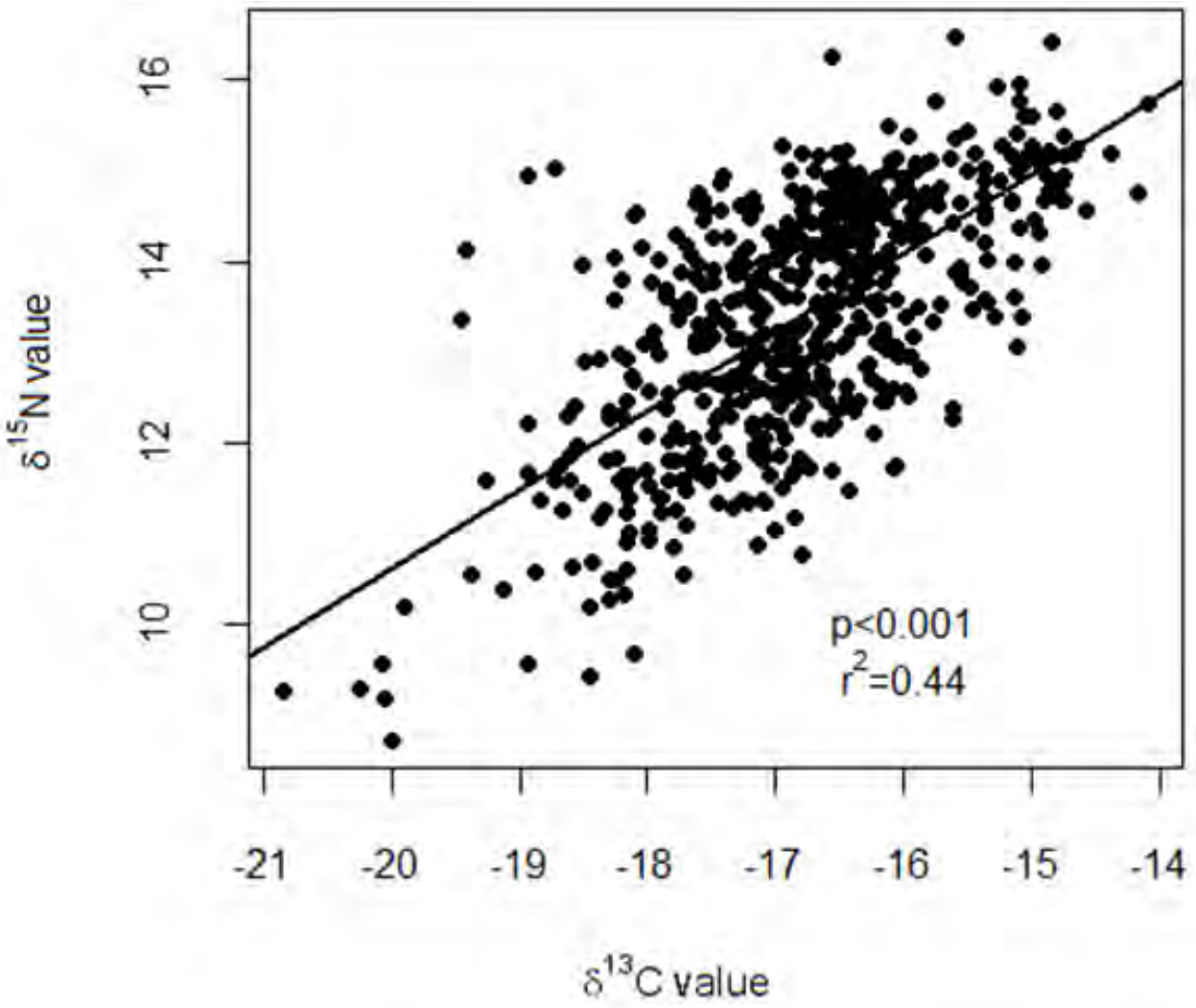

Growth (mm/day)
Survival
Growth (mm/day)
Survival
r²=0.49
p=0.01
r²=0.50
p=0.01
δ13C value
δ13C value

- **Hypothesis # 2. A higher $\delta^{13}C$ value will be linked to higher growth and survival.**
  - **Hypothesis #2 is supported for WCVI, but not for SEAK.**

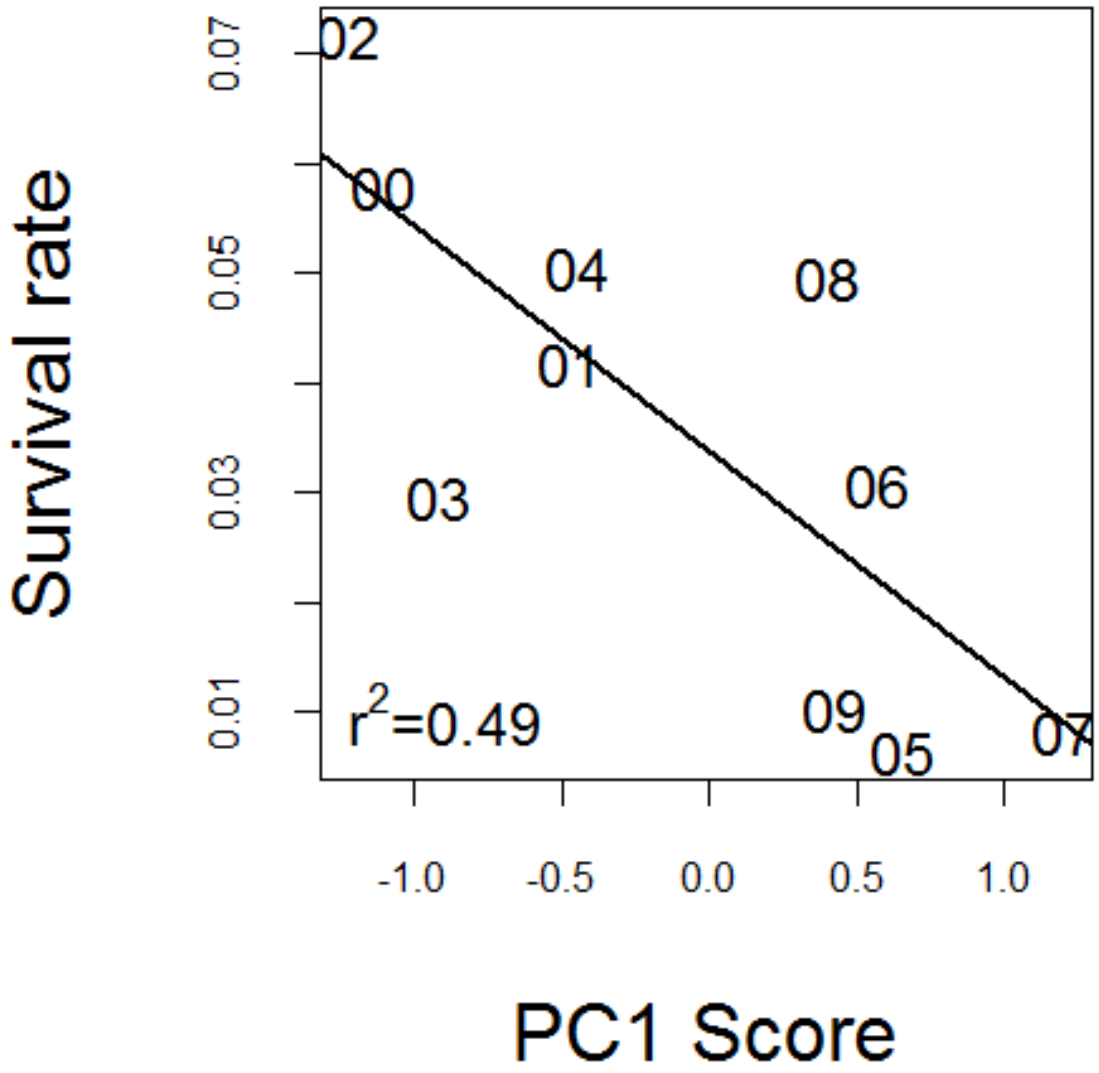

Growth (mm/day)
Survival
C:N ratio
C:N ratio
00
01
02
03
04
05
06
07
08
09

- **Hypothesis # 3: Higher C:N ratios will correlate positively with growth and survival.**
- **No evidence for WCVI or SEAK.**

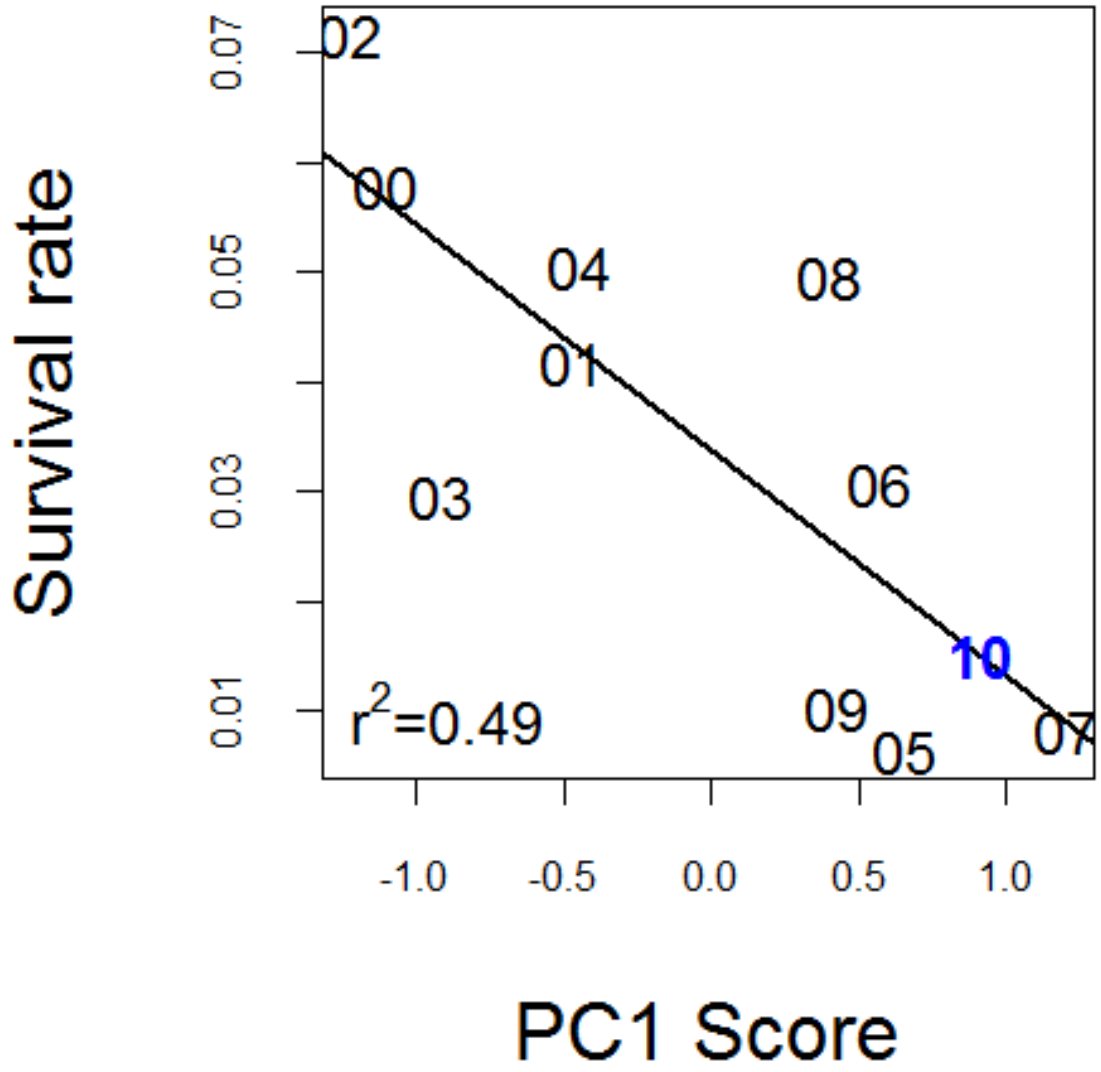
WCVI


δ15N value
16
14
12
10
-21
-20
-19
-18
-17
-16
-15
-14
δ13C value
p<0.001
r2=0.44

PCA results


Survival rate
0.07
0.05
0.03
0.01
02
00
04
08
01
03
06
r^2=0.49
09
05
07
-1.0
-0.5
0.0
0.5
1.0
PC1 Score

2010 predictions (2013 returns)



Stoplight Indicators for WCVI

Environmental Variables	*1998*	*1999*	*2000*	*2001*	*2002*	*2003*	*2004*	*2005*	*2006*	*2007*	*2008*	*2009*	*2010*	*2011*
PDO (May-Sep)	8	3	5	4	9	13	12	14	10	11	1	7	6	2
NPGO (May-Sep)	12	4	3	2	8	9	11	14	13	7	1	10	5	6
ENSO (May-Sep)	11	2	6	7	13	8	10	9	12	3	5	14	1	4
Mean SST - WCVI (Amphitrite) - Mar-Jun	13	1	6	2	3	10	12	14	9	4	5	7	11	8
C/N Zooplankton Ratio (WCVI)	13	6	12	7	5	8	3	14	10	9	1	11	4	2
Northern (Boreal) Copepods	14	3	6	7	4	9	11	13	12	5	1	2	8	10
Southern Copepods	14	7	8	5	4	13	10	12	11	3	2	1	9	6
Sockeye prey (3 to 5 mm T. spinifera)	9	2	1	6	7	12	3	14	11	5	4	8	10	13
Coho prey (T. spinifera > 19 mm)	10	12	4	5	3	11	7	13	6	9	13	2	8	1
WCVI Coho Summer Growth	13	1	3	7	2	8	4	14	9	10	6	11	5	12
Mean Rank	11.7	4.1	5.4	5.2	5.8	10.1	8.3	13.1	10.3	6.6	3.9	7.3	6.7	6.4
Rank of Mean Ranks	13	2	4	3	5	11	10	14	12	7	1	9	8	6

Environmental variables are scored from 1 (best for salmon) to 14 (worst for salmon)

Conclusions

- Feeding ecology of WCVI Chinook linked to growth and survival
  - Higher $\delta^{15}N$ and trophic level correlated with greater growth and survival
  - Higher $\delta^{13}C$ correlated with higher survival
- Feeding ecology of SEAK fish not linked to survival or growth
  - Critical period of feeding may be earlier
  - Top-down processes (LaCroix et al., 2009)?

Questions?

- Thanks to:
  - Funding agencies: NSERC Strategic Grant, Bonneville Power Administration, Genome BC
  - DFO for support with samples and data