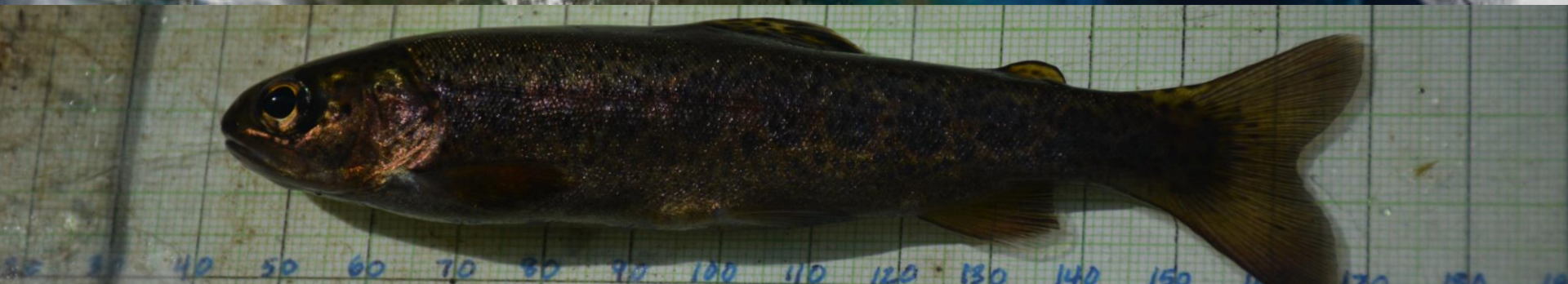
Phenological mismatch, carryover effects and marine survival in wild steelhead trout population

Samantha Wilson, Thomas Buehrens, Jennifer Fisher, Kyle Wilson, and Jonathan Moore*

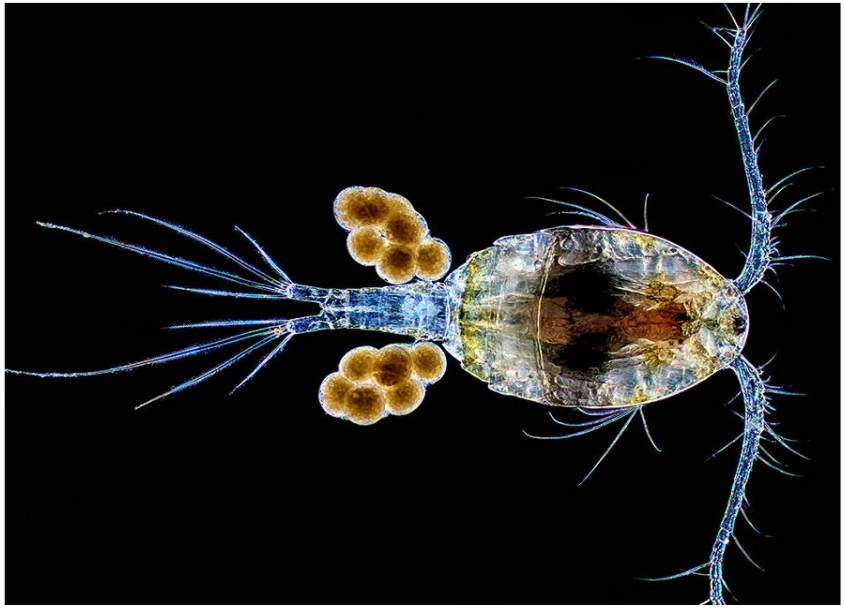


Critical Size, Critical Time

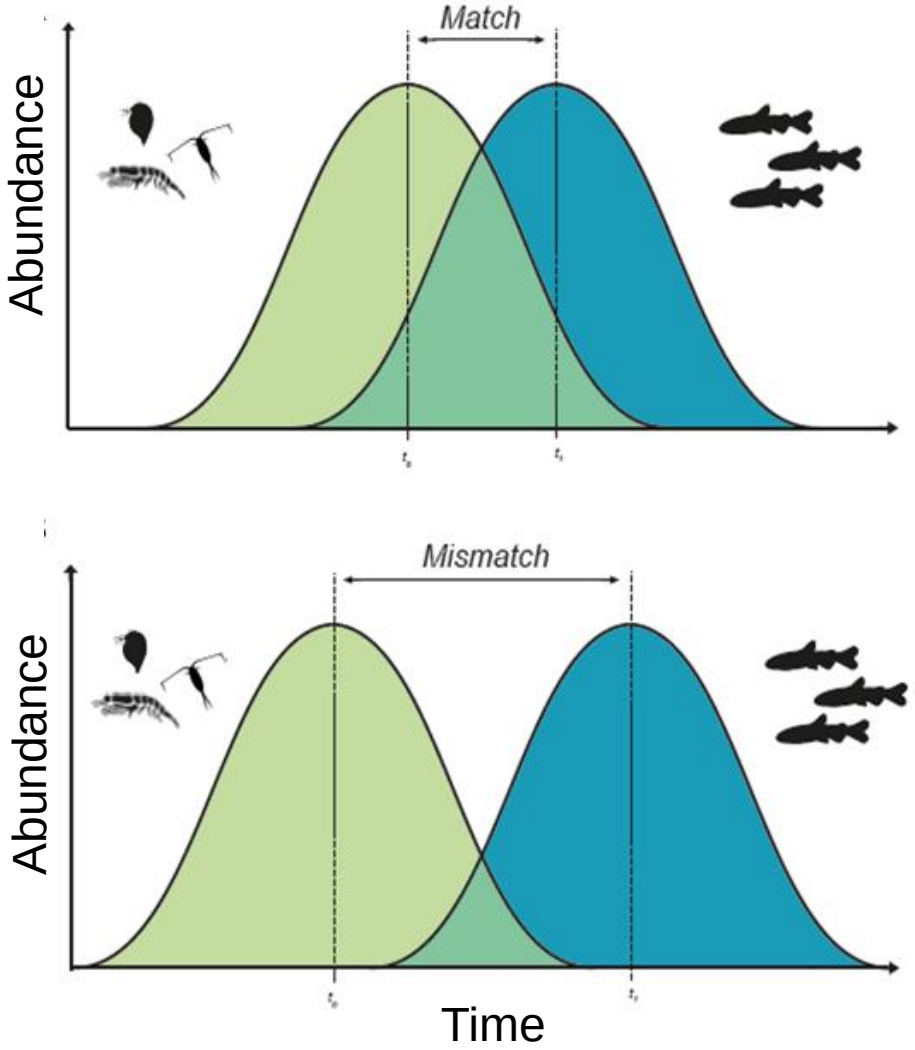
Larger and faster growing fish have higher survival

Fish grow faster when they enter the early marine environment during peak food availability

Could timing matter?

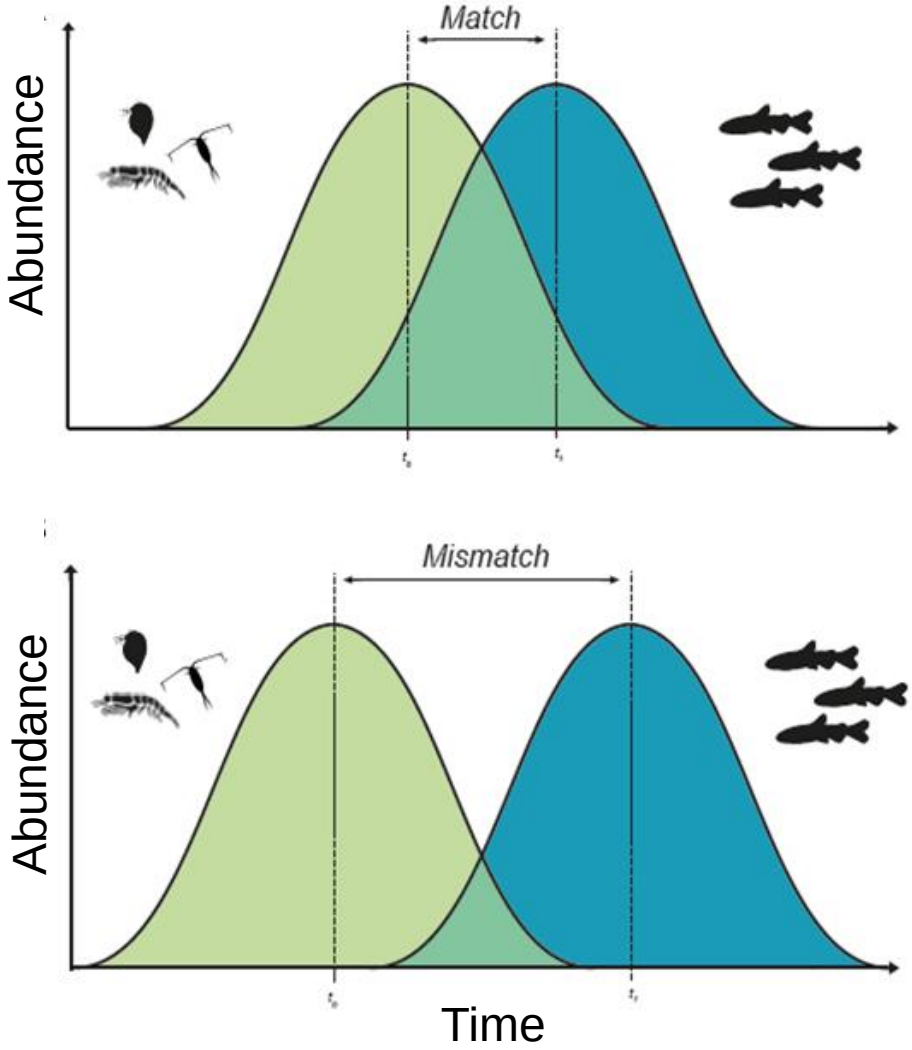


Phenological mismatches



Cushing 1990 Adv.Mar.Biol., Kharouba et al 2018 PNAS

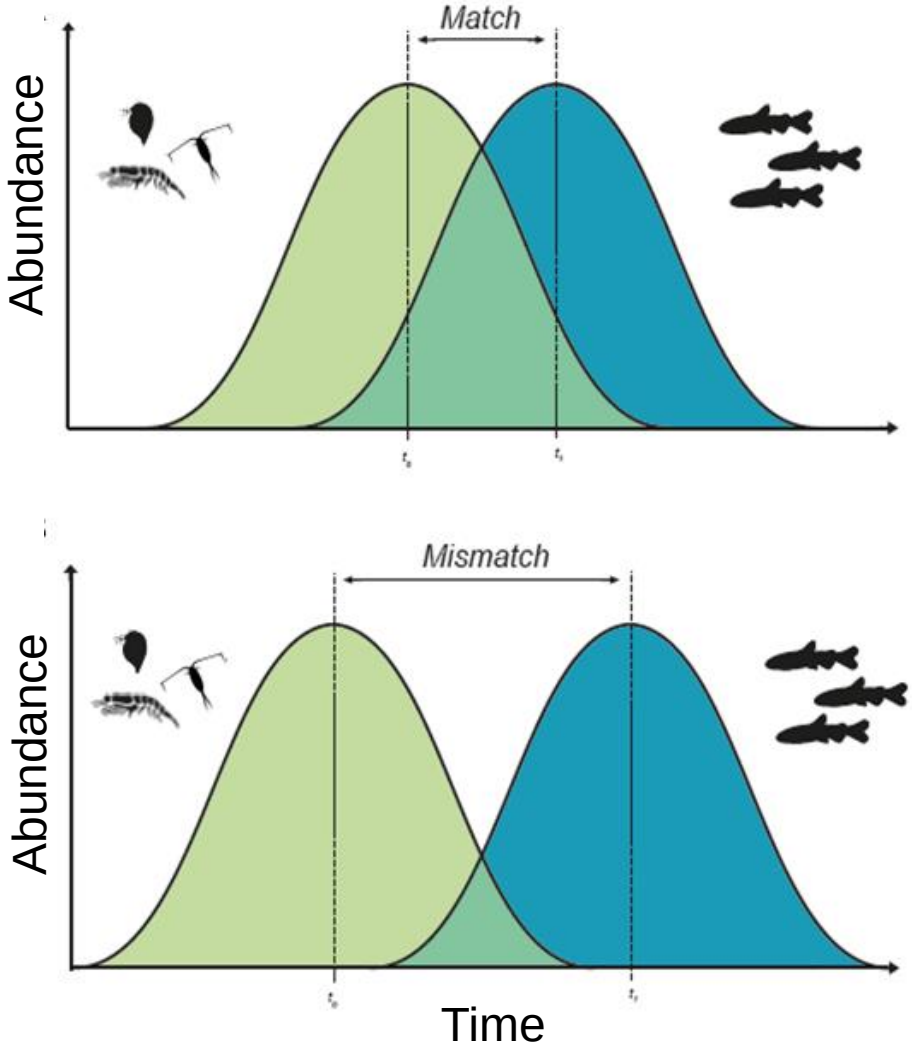
Phenological mismatches



Increased
marine survival

Cushing 1990 Adv.Mar.Biol., Kharouba et al 2018 PNAS

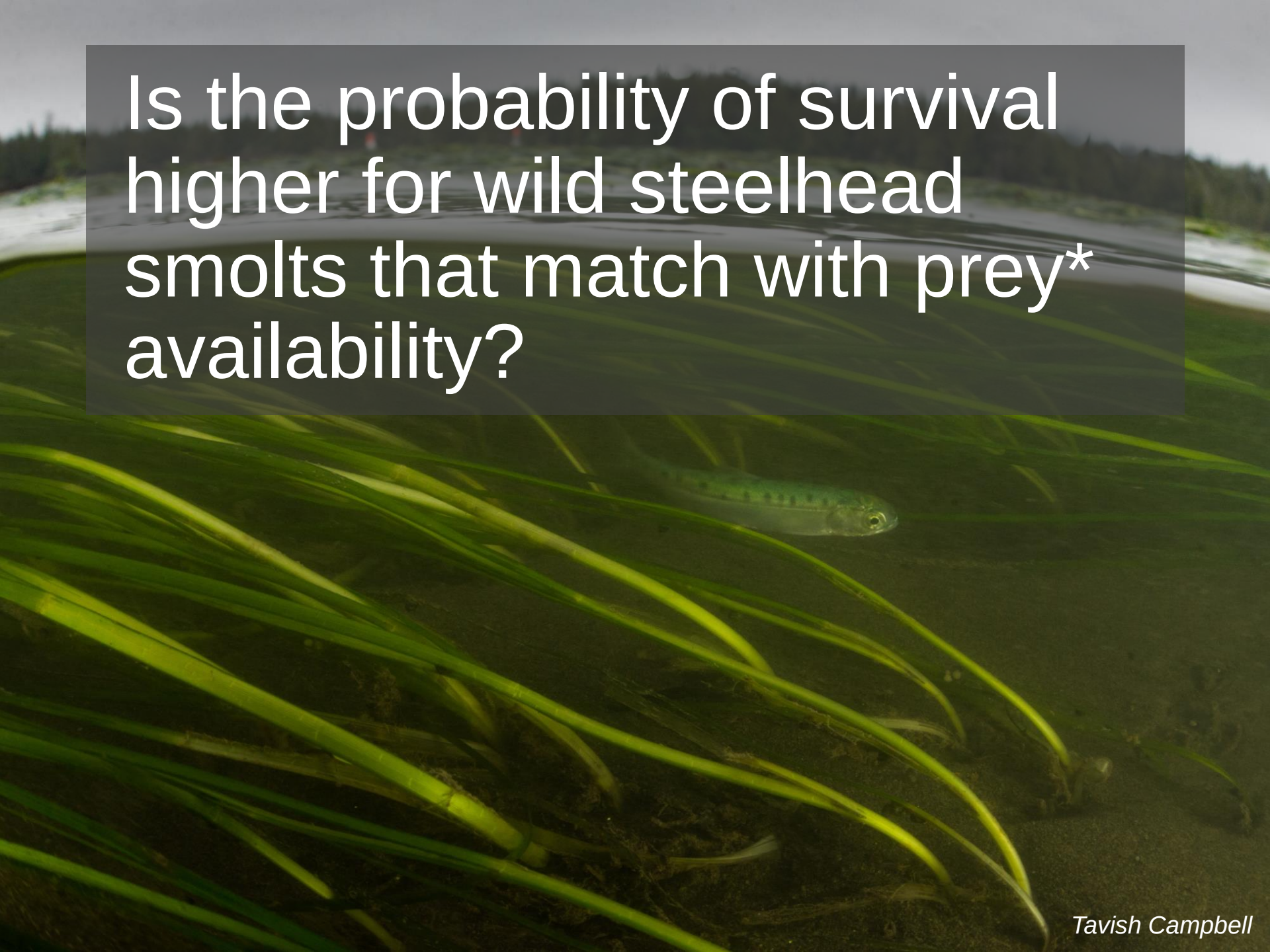
Phenological mismatches



Increased
marine survival

Decreased
marine survival

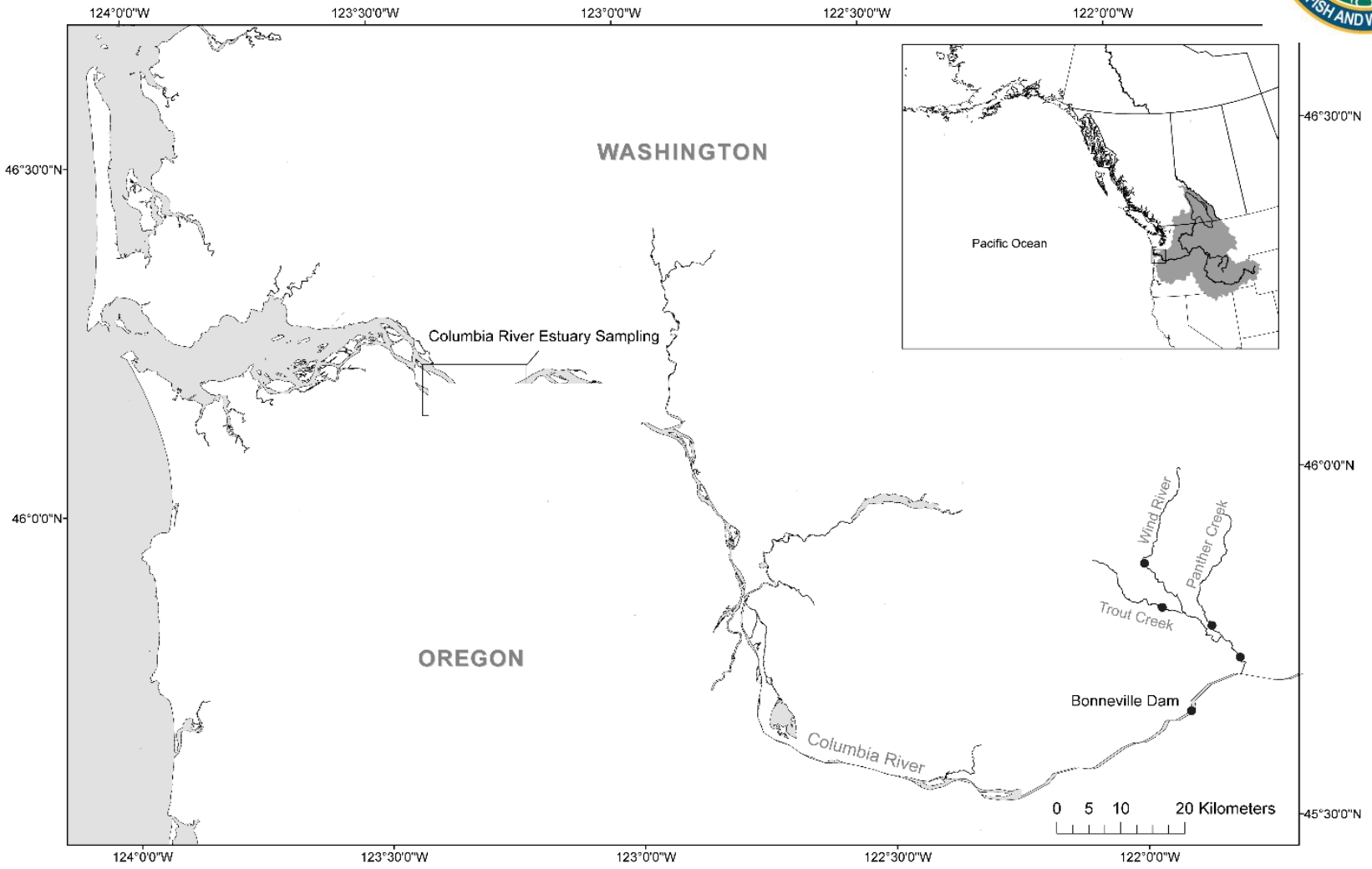
Cushing 1990 Adv.Mar.Biol., Kharouba et al 2018 PNAS



Is the probability of survival higher for wild steelhead smolts that match with prey* availability?

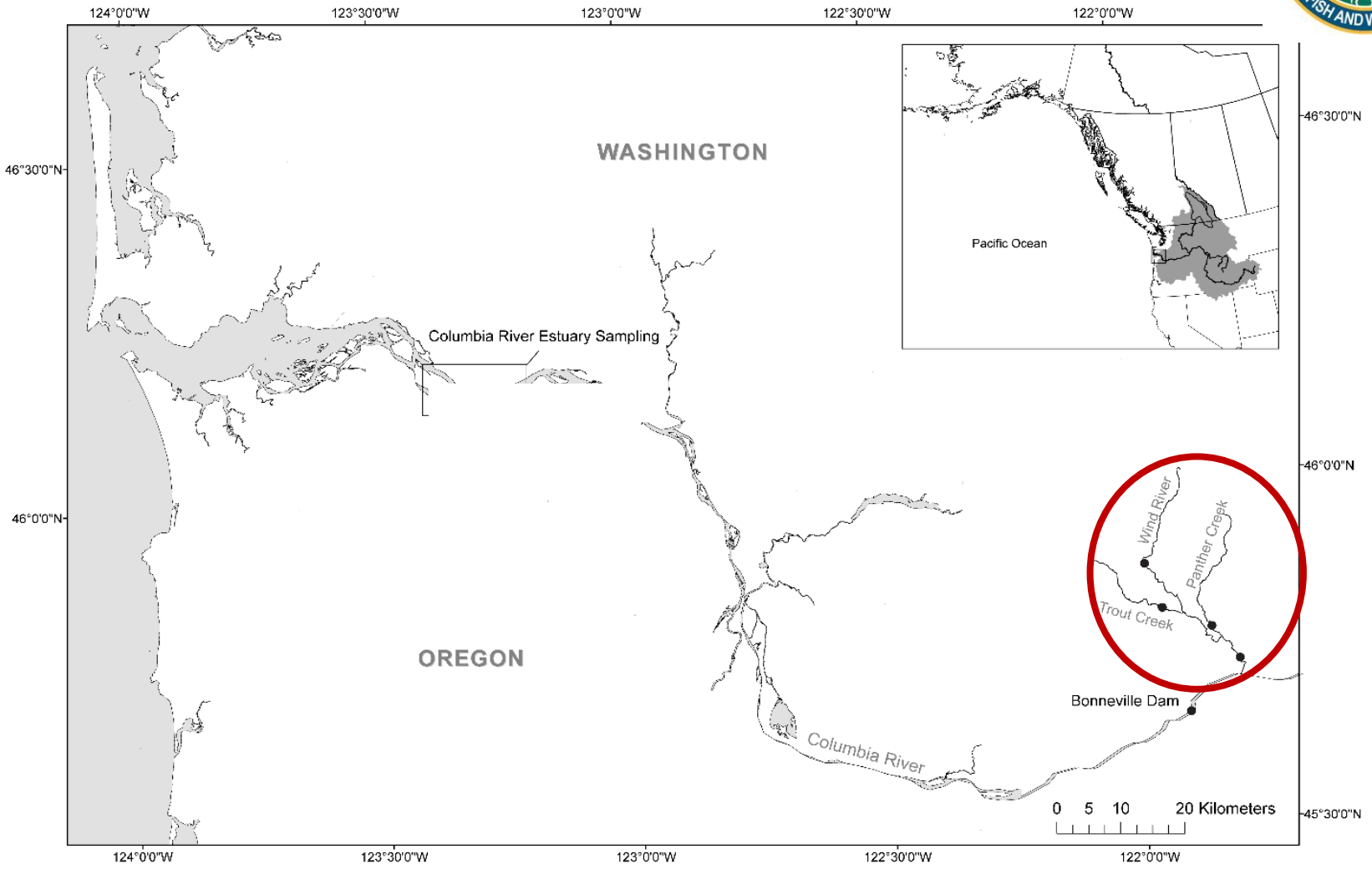
Tavish Campbell

Wild steelhead smolts PIT tagged 2003 - 2014



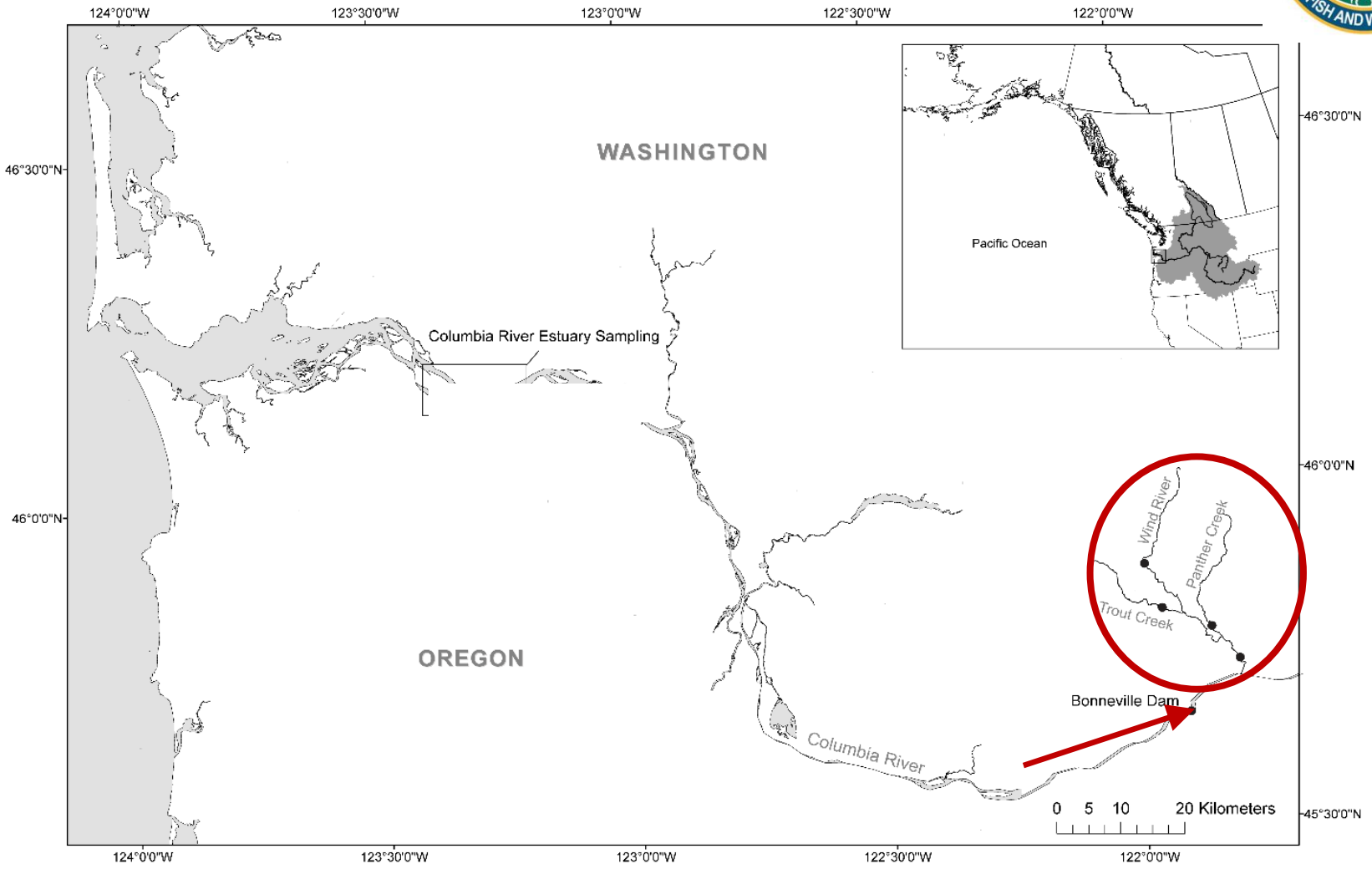
Data courtesy of T. Buerhens, P. Cochran

Wild steelhead smolts PIT tagged 2003 - 2014



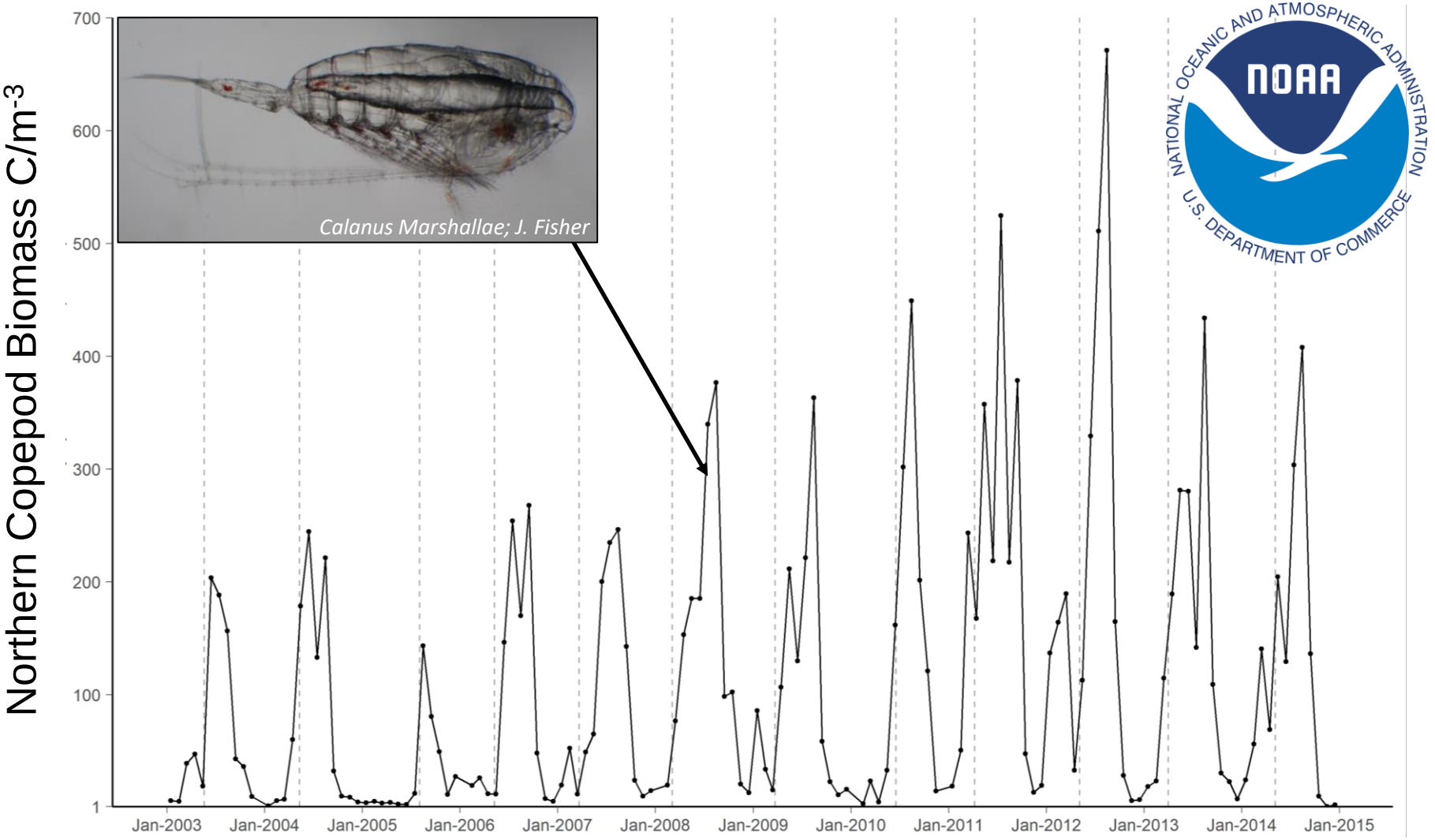
Data courtesy of T. Buerhens, P. Cochran

Wild steelhead smolts PIT tagged 2003 - 2014



Data courtesy of T. Buerhens, P. Cochran

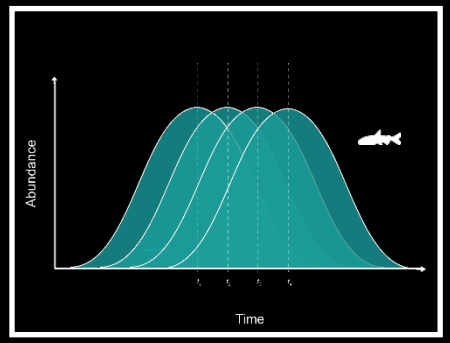
Zooplankton peak timing varies annually



Data courtesy of J. Fisher, W. Peterson

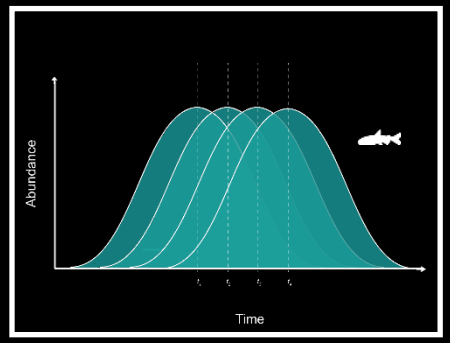
Hypotheses – individual survival

Migration timing

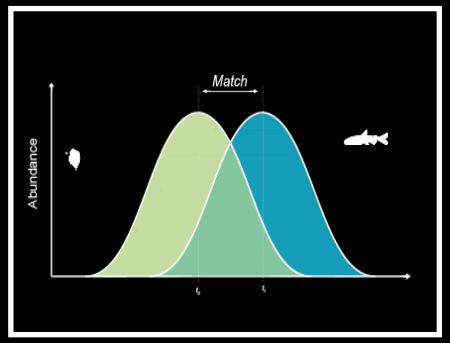


Hypotheses – individual survival

Migration timing

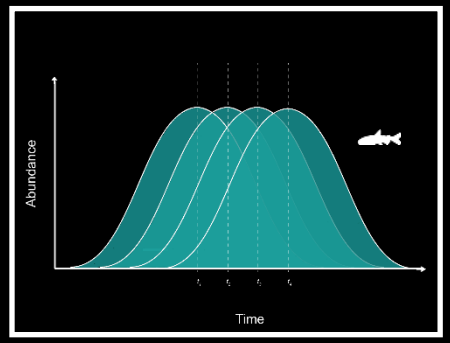


Match/ mismatch



Hypotheses – individual survival

Migration timing



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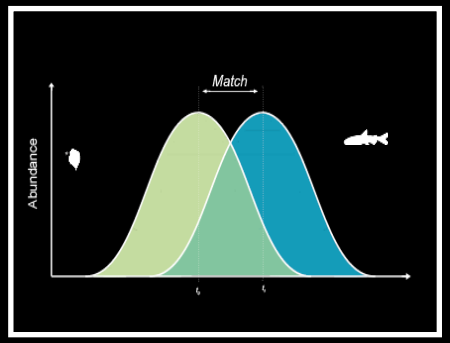
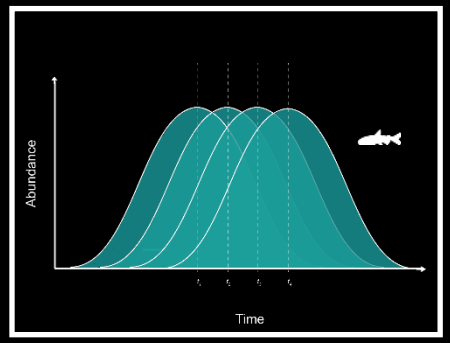


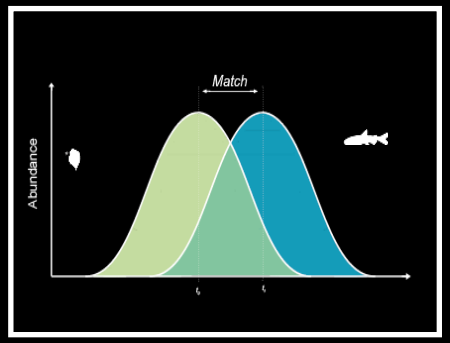
Zooplankton abundance

Hypotheses – individual survival

Migration timing

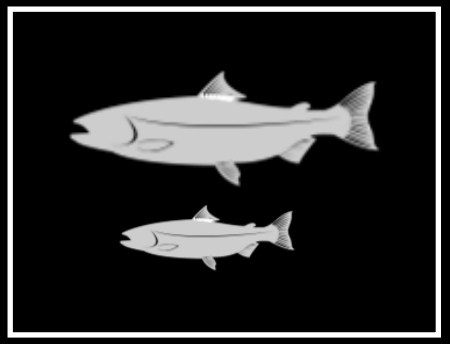


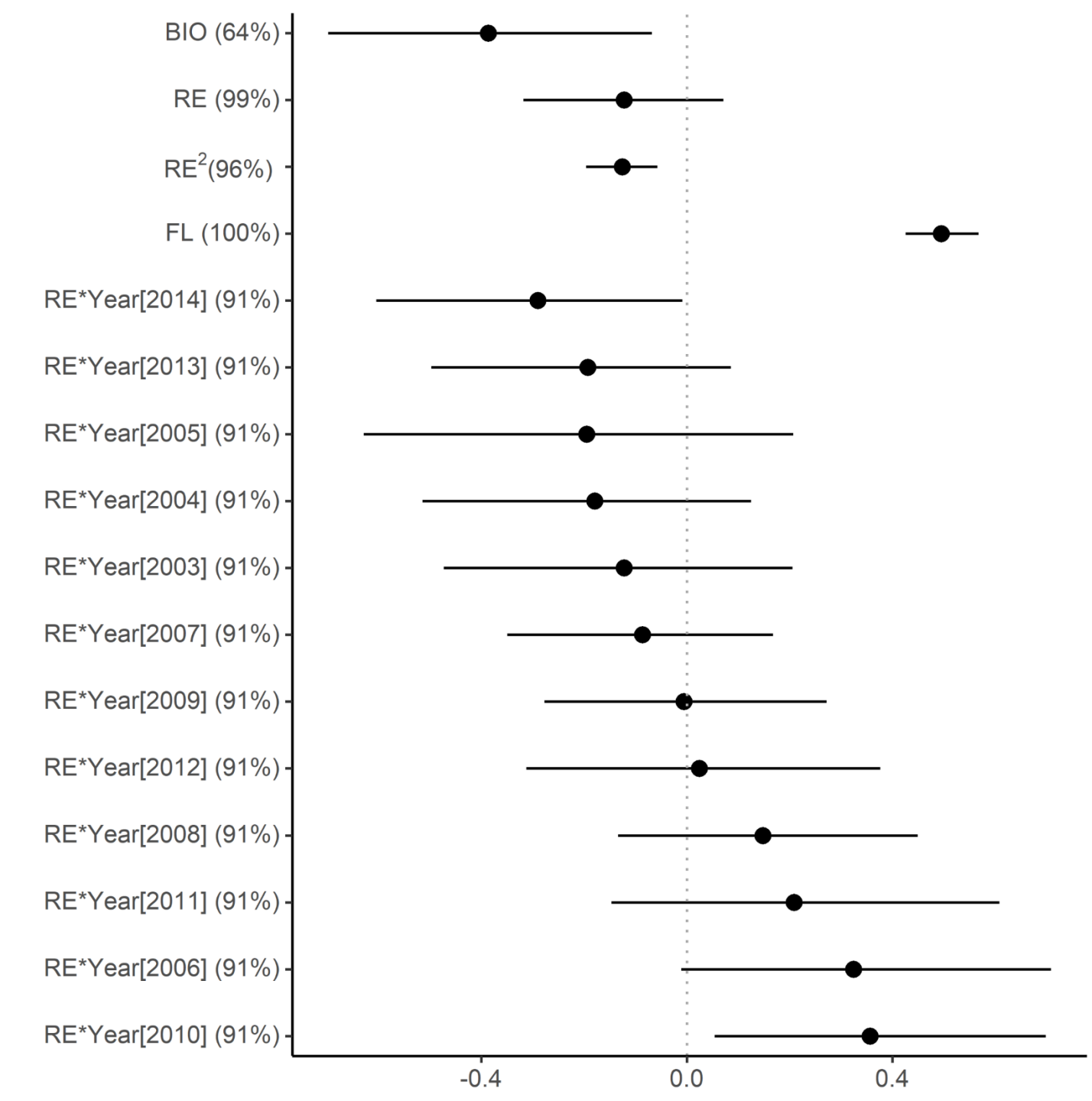
Match/ mismatch

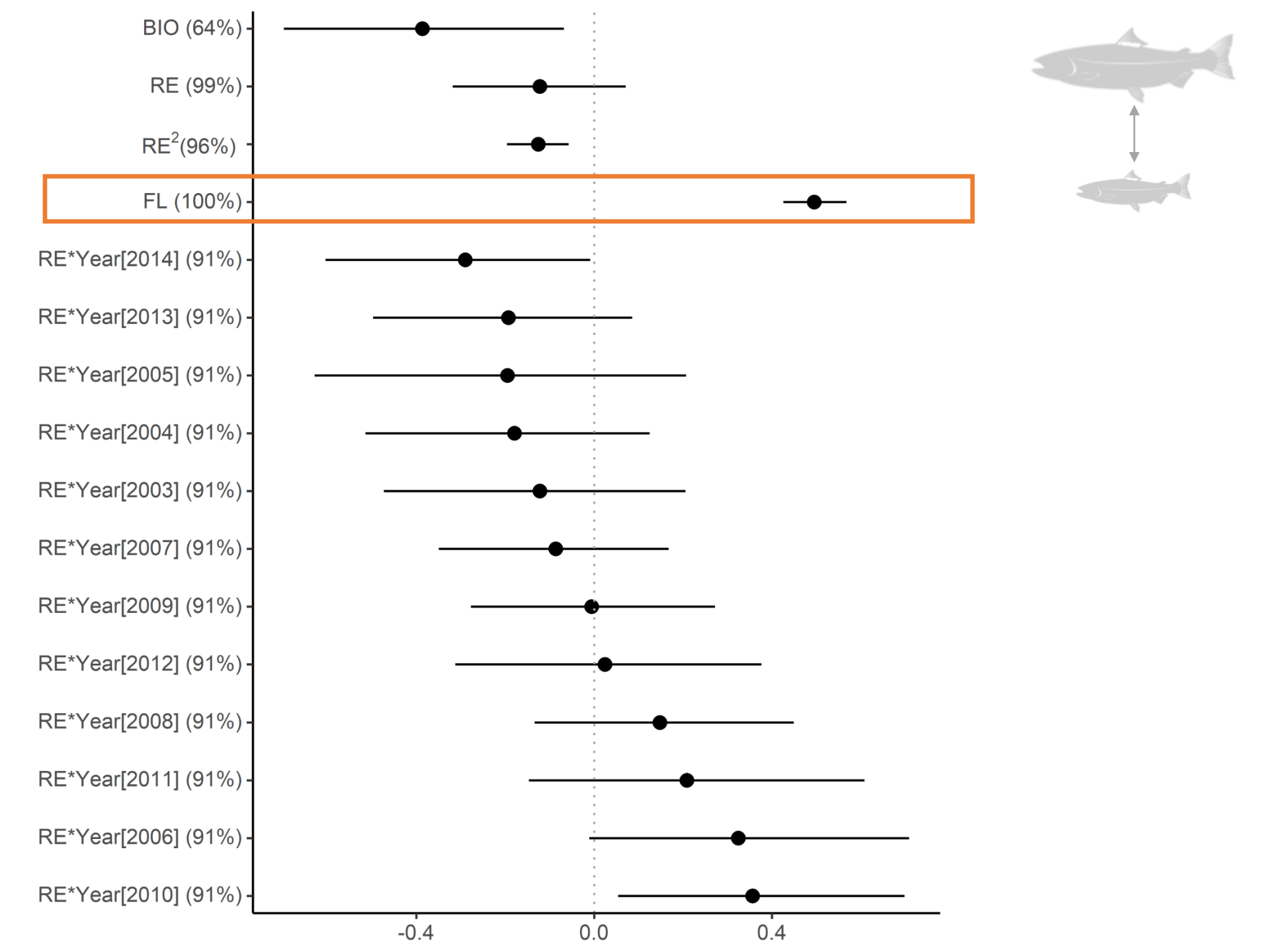


Zooplankton abundance

Size




BIO (64%)
RE (99%)
RE^2(96%)
FL (100%)
RE*Year[2014] (91%)
RE*Year[2013] (91%)
RE*Year[2005] (91%)
RE*Year[2004] (91%)
RE*Year[2003] (91%)
RE*Year[2007] (91%)
RE*Year[2009] (91%)
RE*Year[2012] (91%)
RE*Year[2008] (91%)
RE*Year[2011] (91%)
RE*Year[2006] (91%)
RE*Year[2010] (91%)
-0.4
0.0
0.4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RE*Year[2011] (91%)
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RE*Year[2010] (91%)
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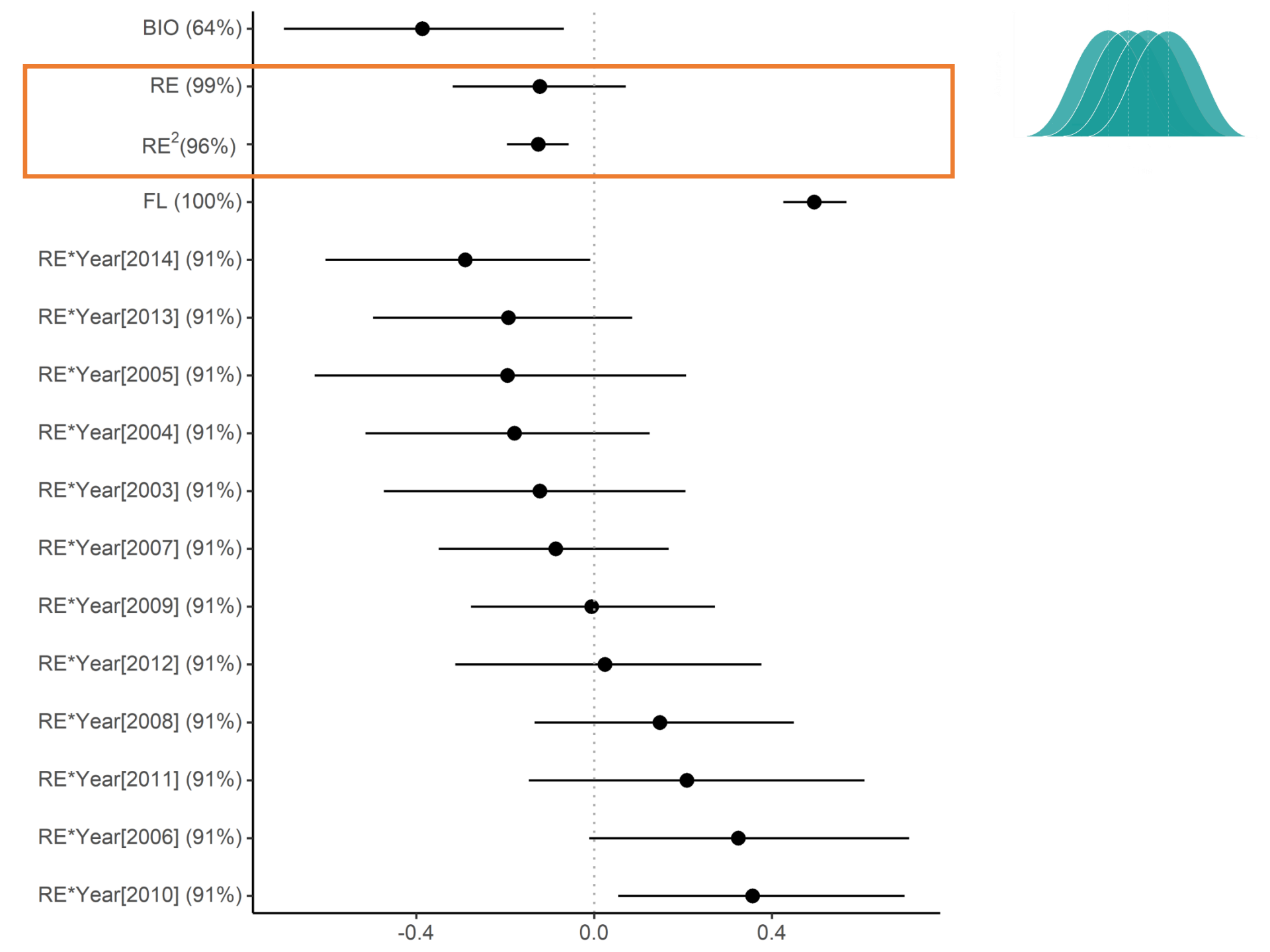
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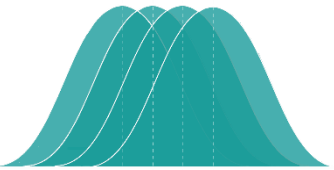
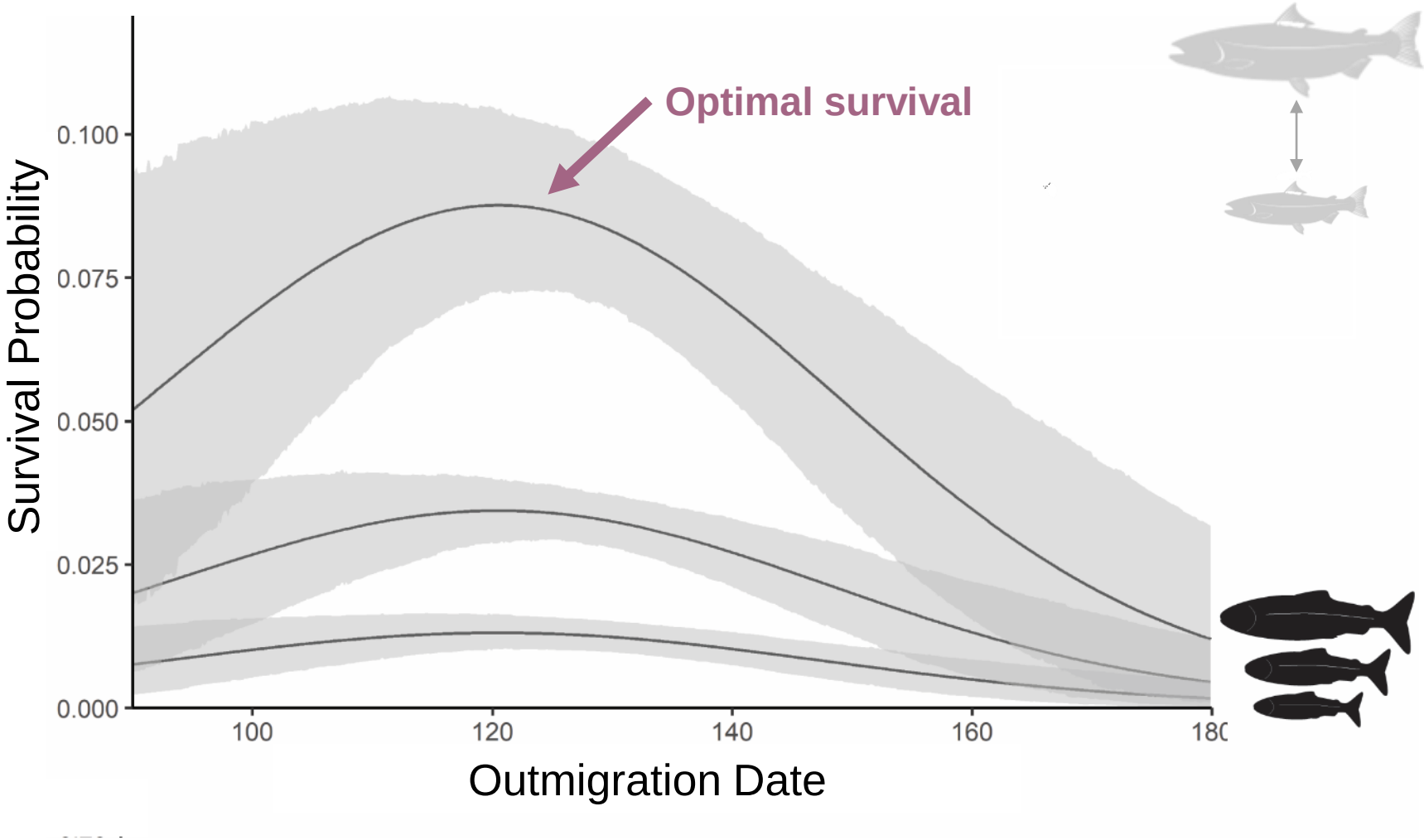
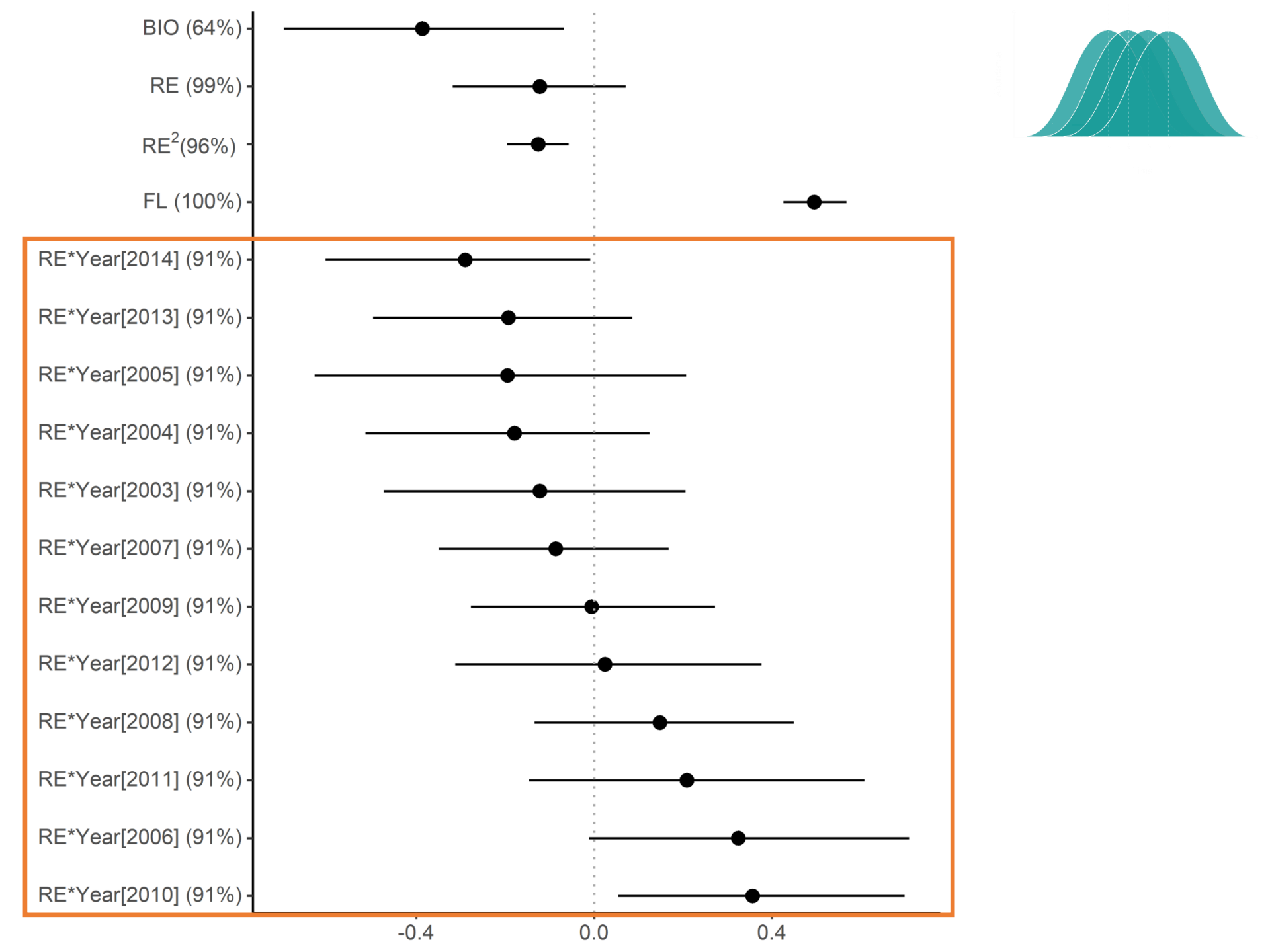
RE*Year[2008] (91%)
RE*Year[2011] (91%)
RE*Year[2006] (91%)
RE*Year[2010] (91%)
-0.4
0.0
0.4

Optimal day of outmigration across years



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RE (99%)
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RE*Year[2014] (91%)
RE*Year[2013] (91%)
RE*Year[2005] (91%)
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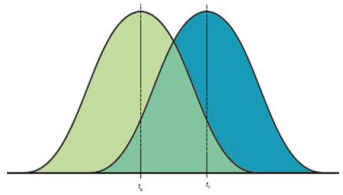
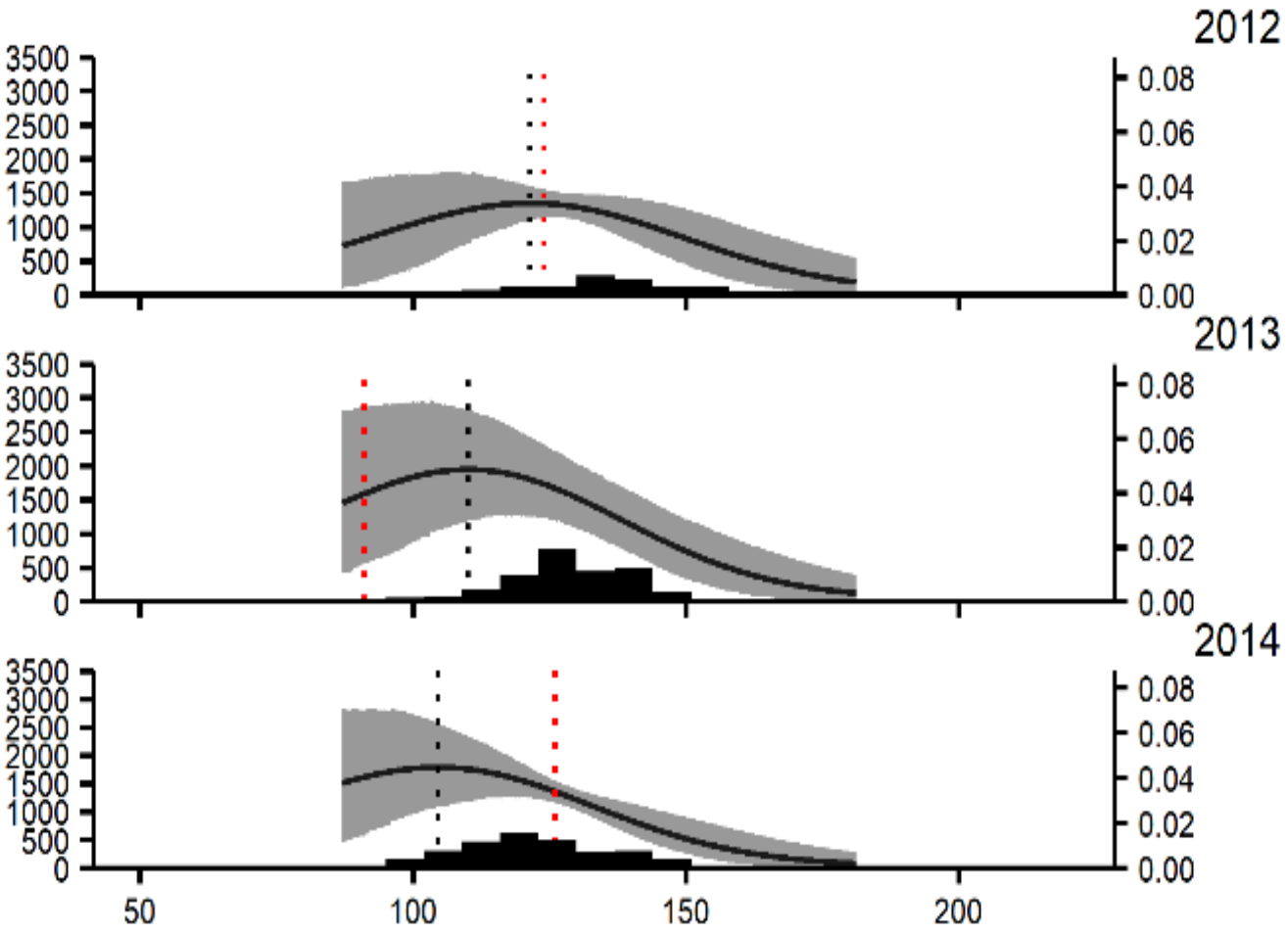
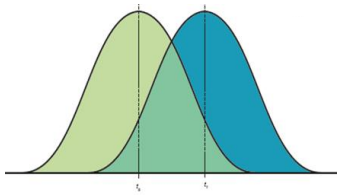
RE*Year[2012] (91%)
RE*Year[2008] (91%)
RE*Year[2011] (91%)
RE*Year[2006] (91%)
RE*Year[2010] (91%)
-0.4
0.0
0.4

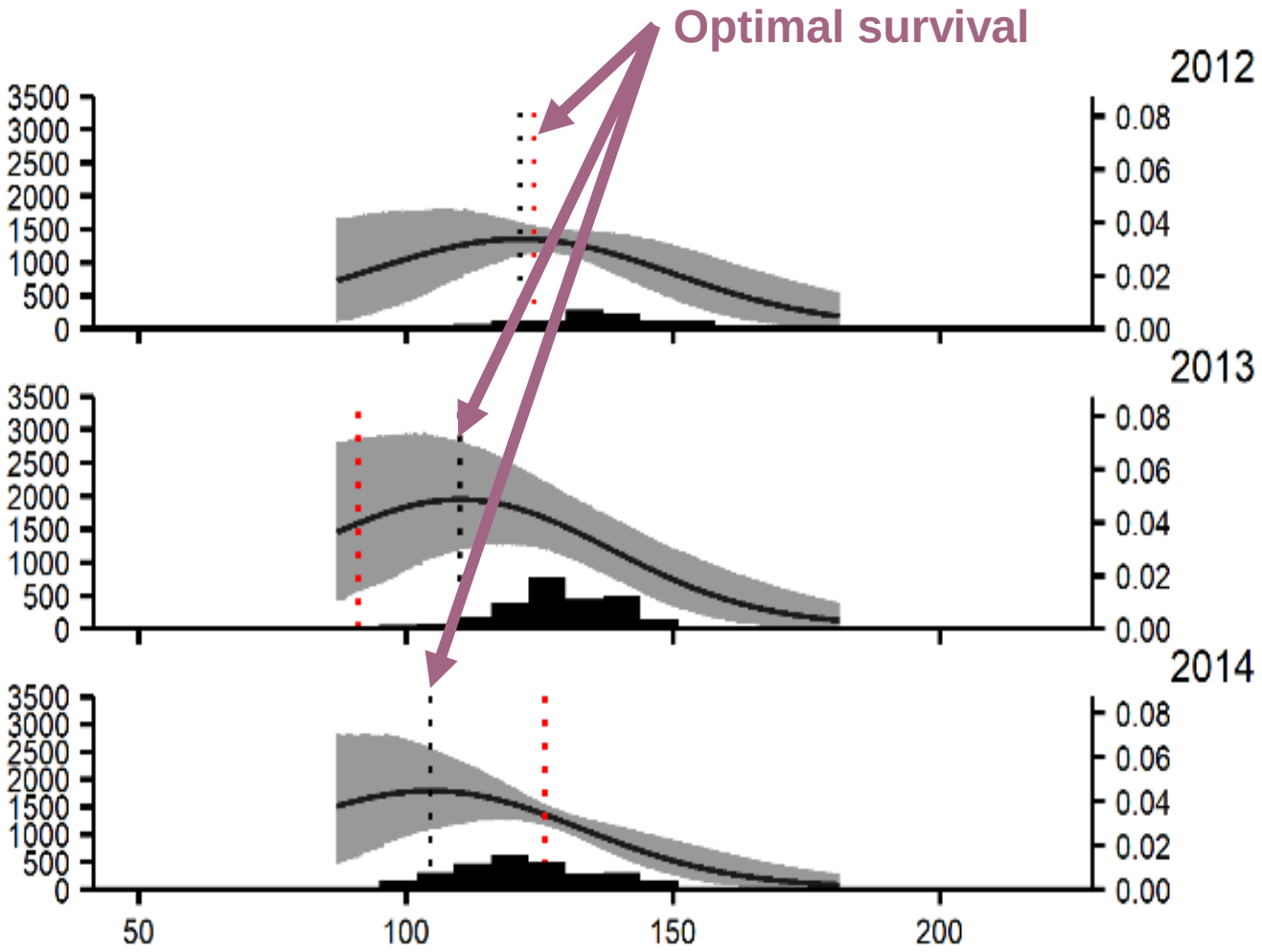
Date when survival is highest varies by year

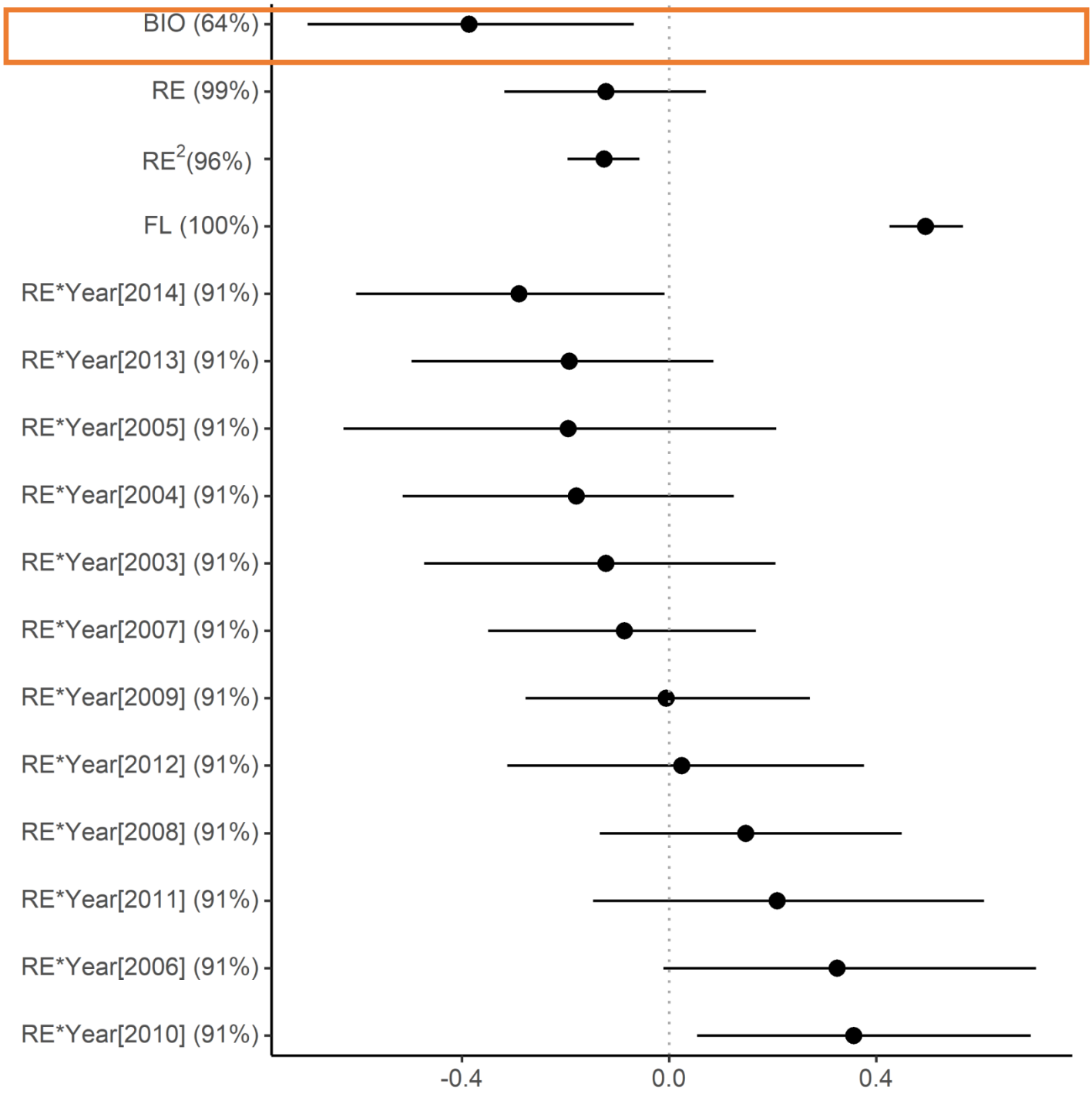




Date when survival is highest varies by year



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RE*Year[2012] (91%)
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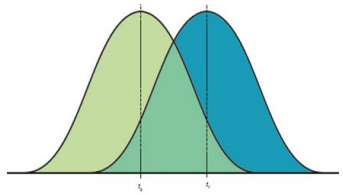
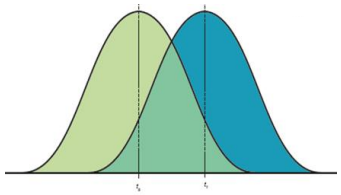
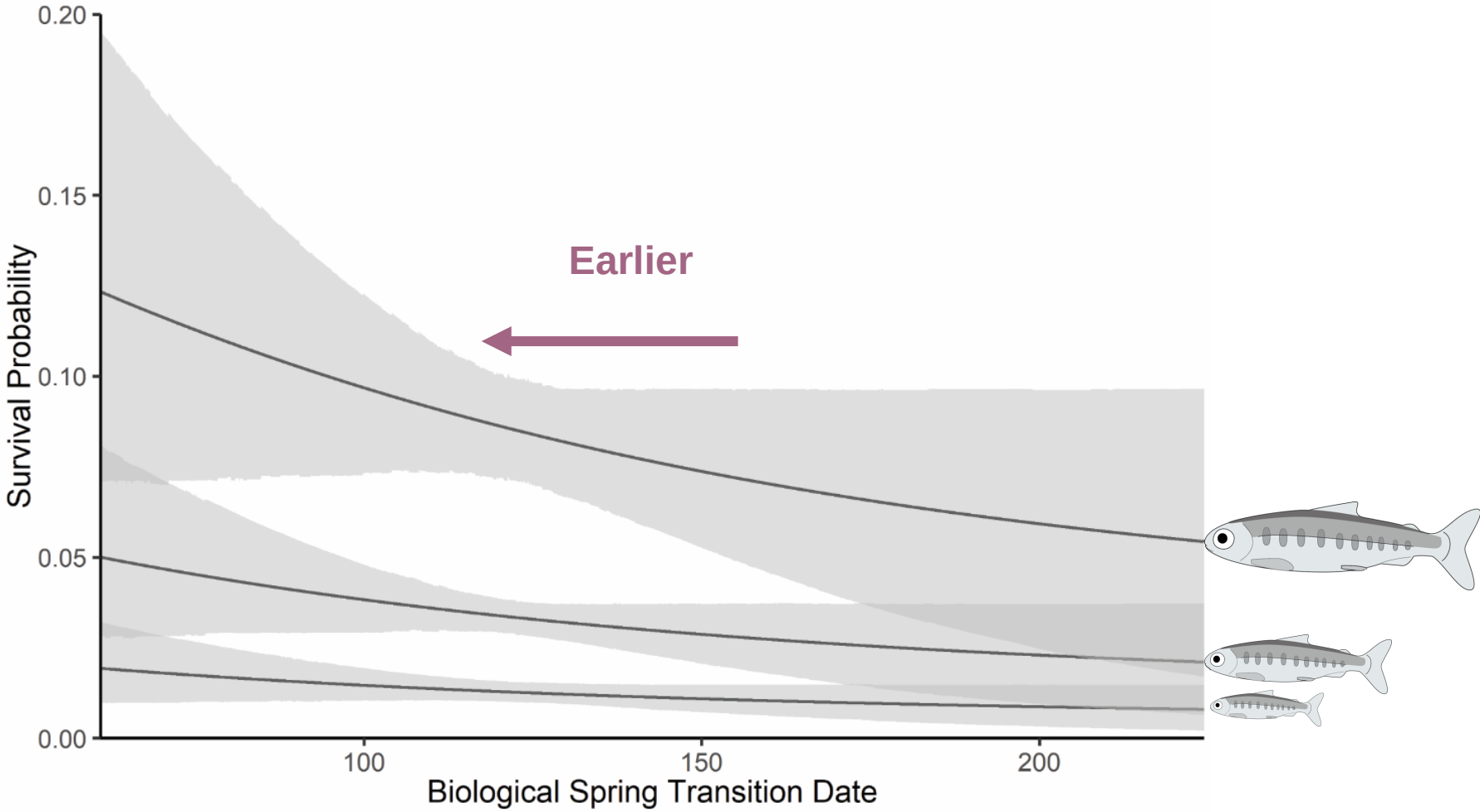
-0.4
0.0
0.4



Larger fish and years with earlier prey timing have higher survival





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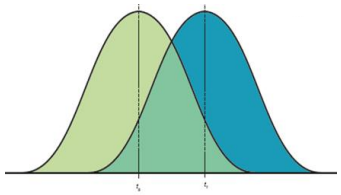
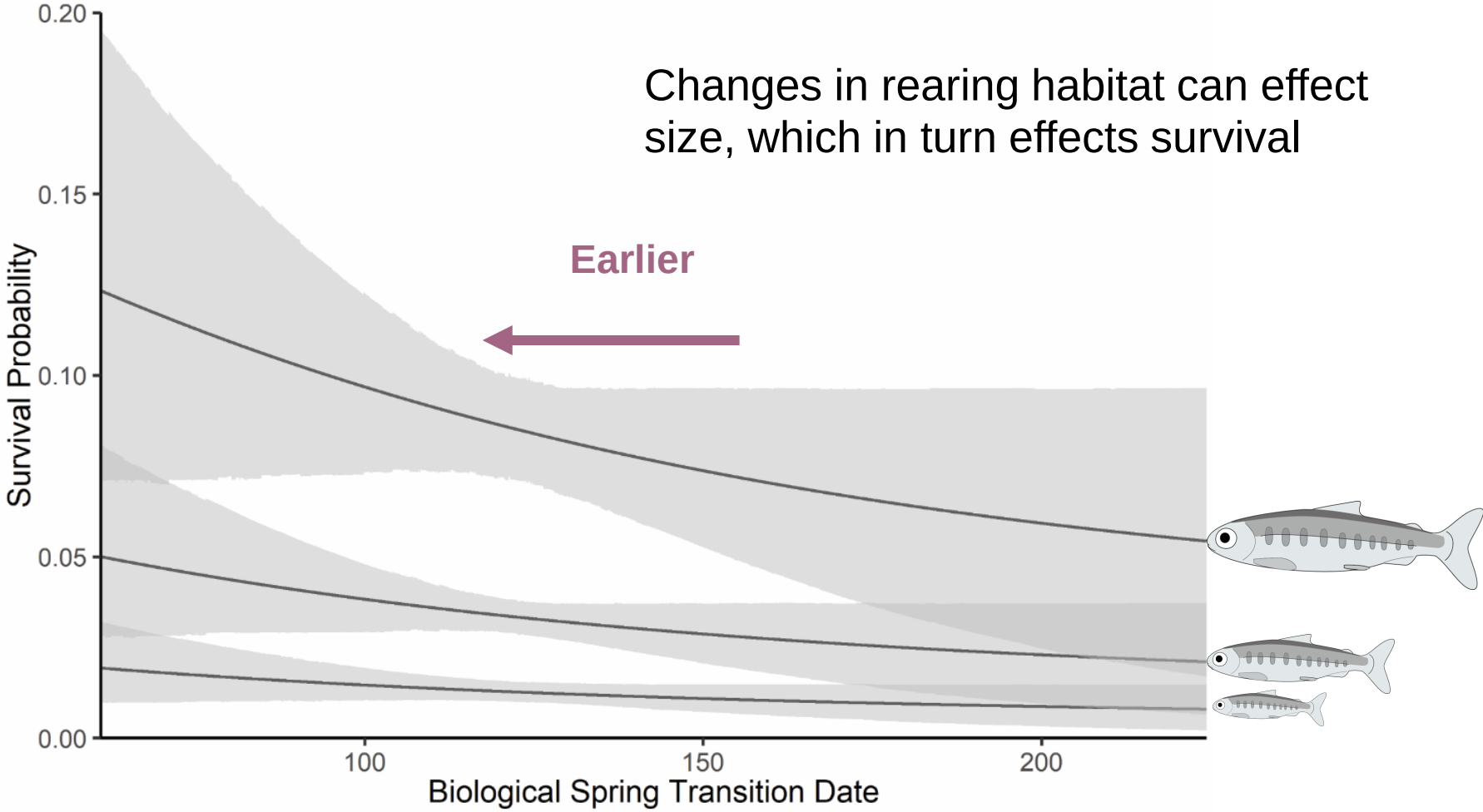
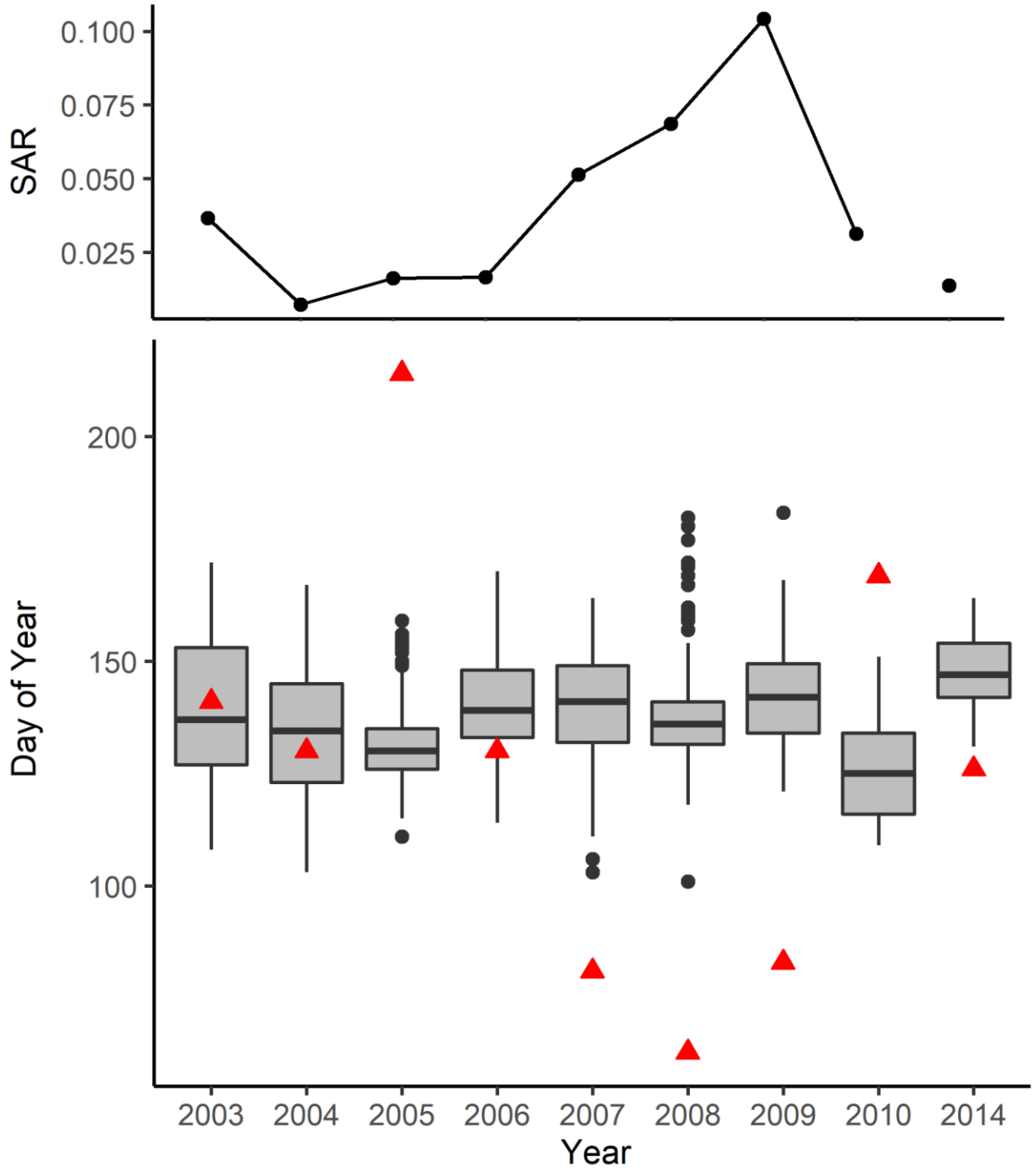
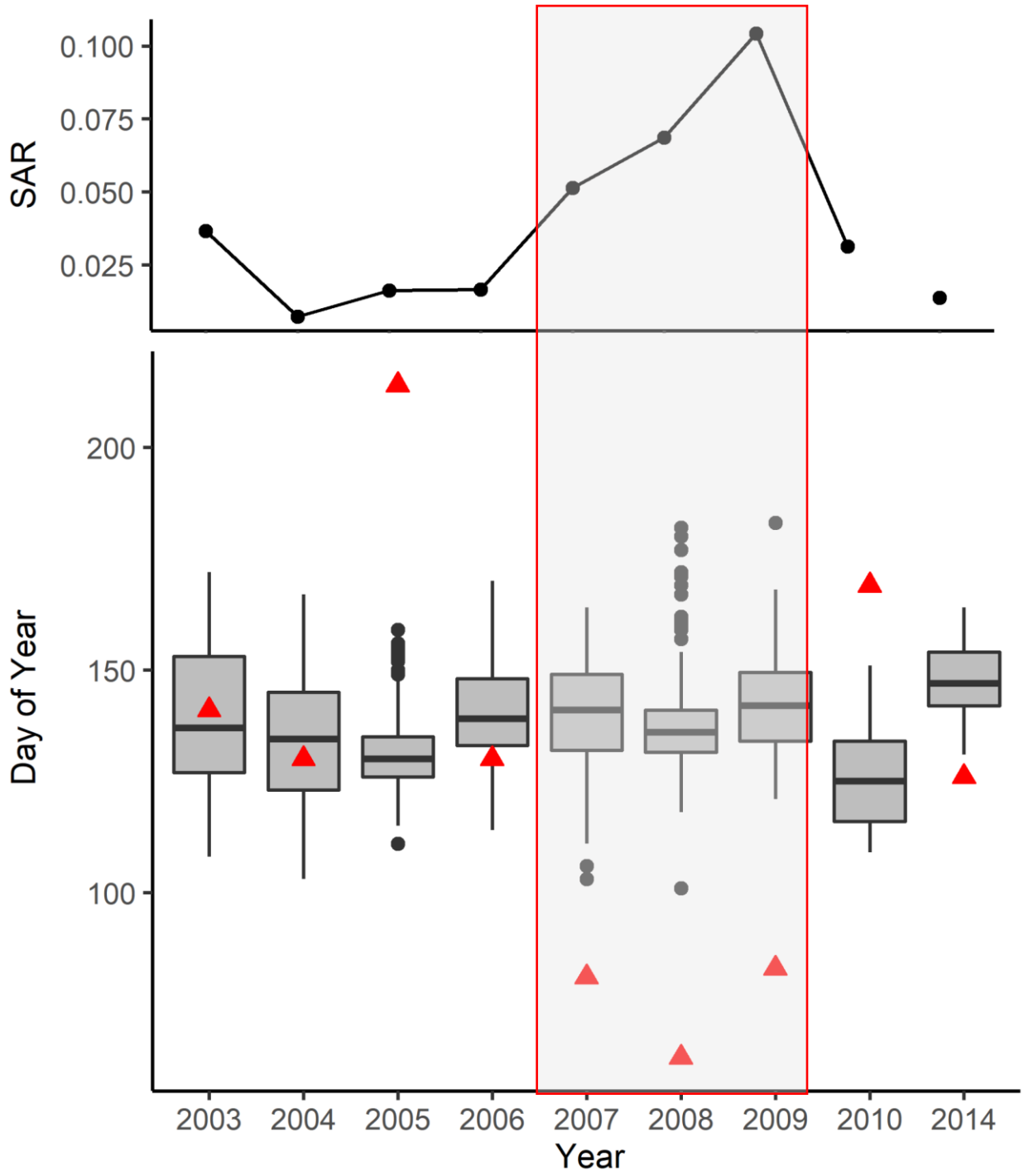


Changes in rearing habitat can effect size, which in turn effects survival

Earlier



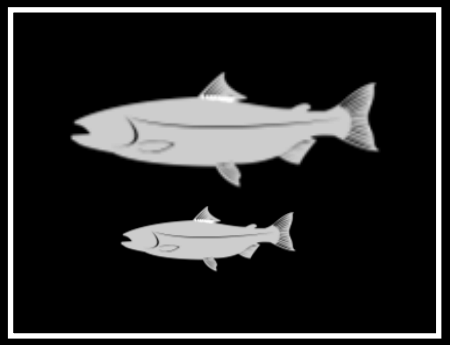

SAR
0.100
0.075
0.050
0.025
Day of Year
200
150
100
2003
2004
2005
2006
2007
2008
2009
2010
2014
Year


SAR
0.100
0.075
0.050
0.025
Day of Year
200
150
100
2003
2004
2005
2006
2007
2008
2009
2010
2014
Year

Hypotheses

Individual survival …

Size



✓ Is higher for larger fish

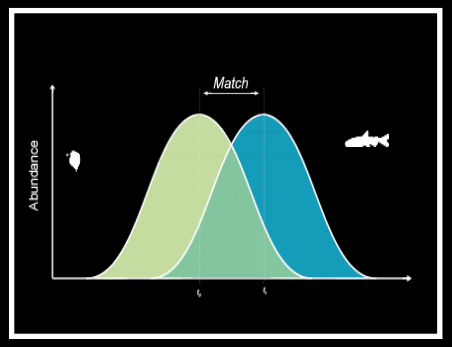
Zooplankton abundance

≠ No effect

Hypotheses

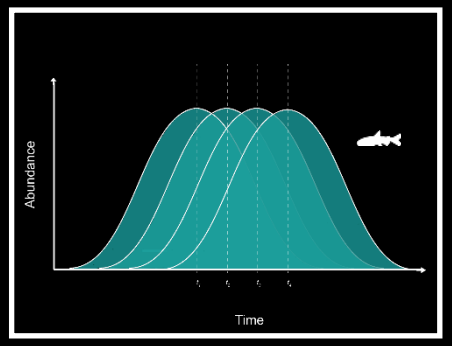
Individual survival …

Match/ mismatch

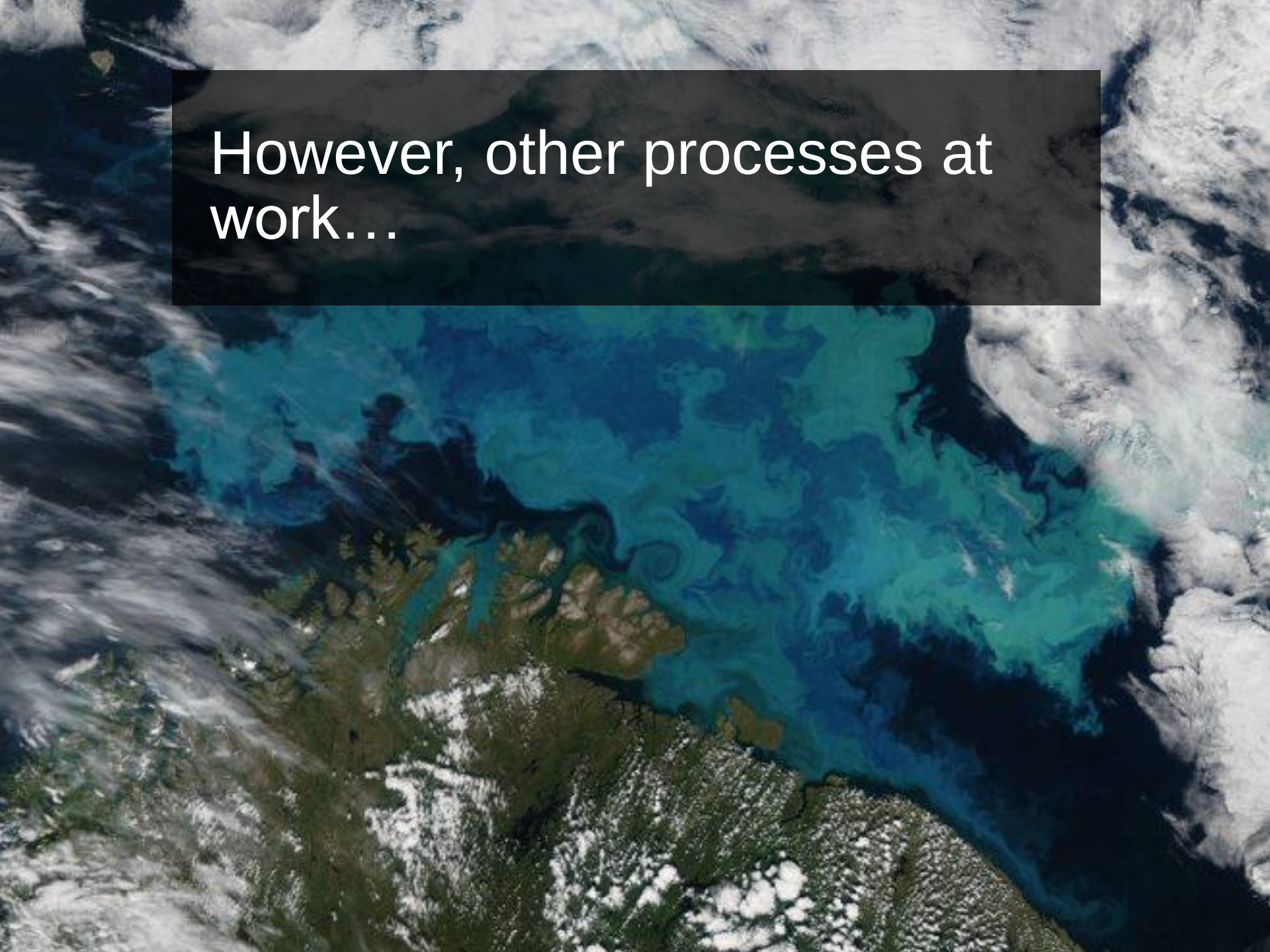


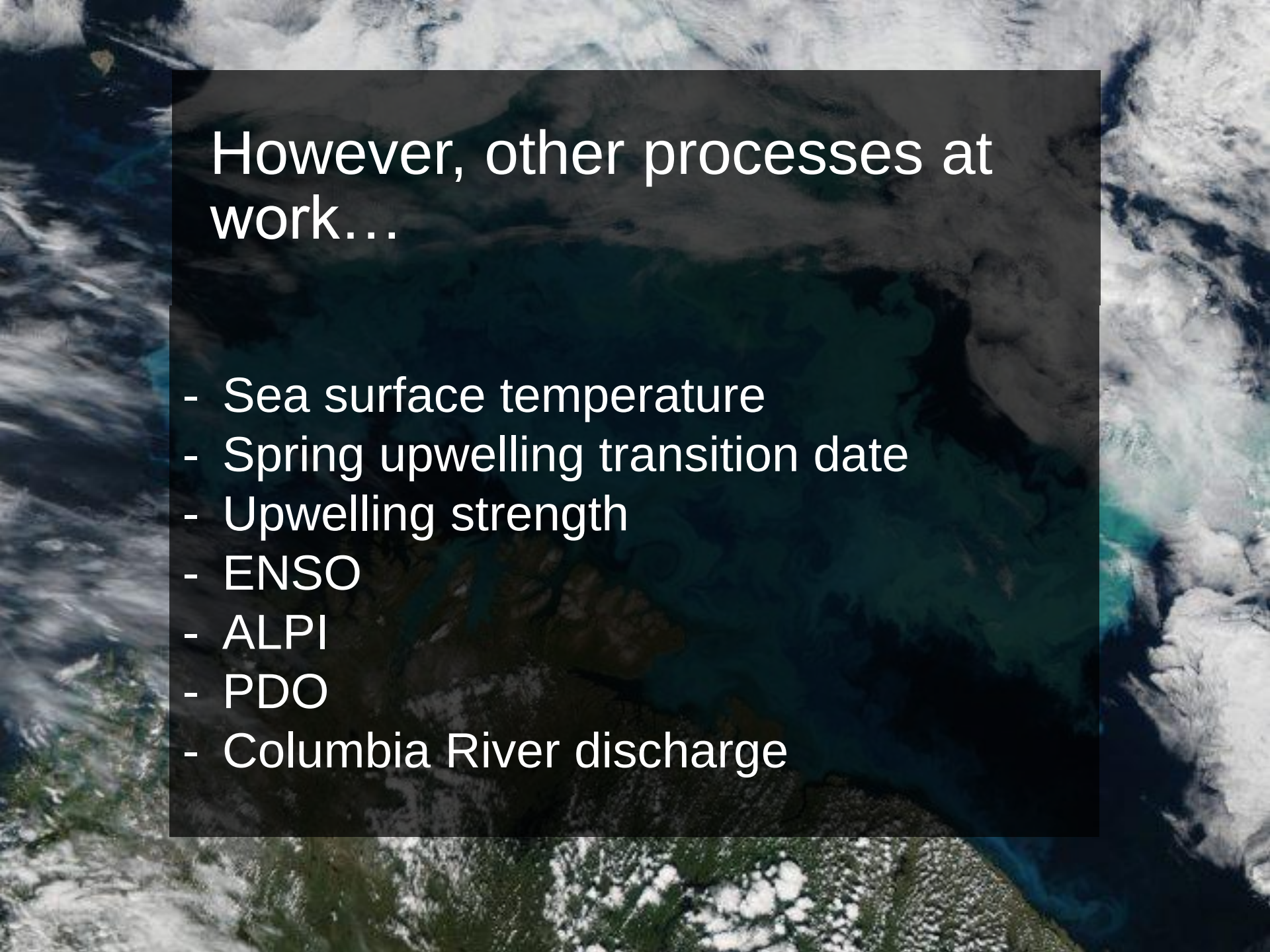
Is higher when zooplankton availability occurs earlier

Migration timing



Optimal outmigration date varies by year

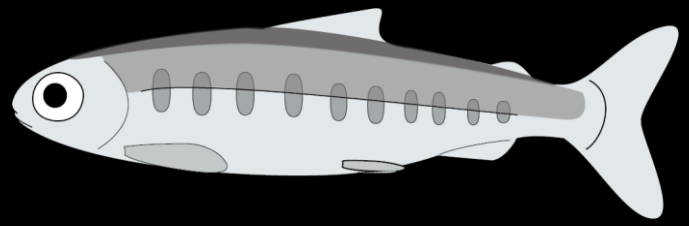

However, other processes at work…



However, other processes at work…

- Sea surface temperature
- Spring upwelling transition date
- Upwelling strength
- ENSO
- ALPI
- PDO
- Columbia River discharge

Conclusions



- Larger fish have higher survival, independent of ocean conditions
- Optimal outmigration date varied annually, with marine and freshwater conditions
- Earlier coldwater zooplankton peak correlates with higher marine survival (annual mismatch)
- Conditions faced in freshwater impact size and condition of fish upon ocean entrance and can impact marine survival (a.k.a. Carryover effects)

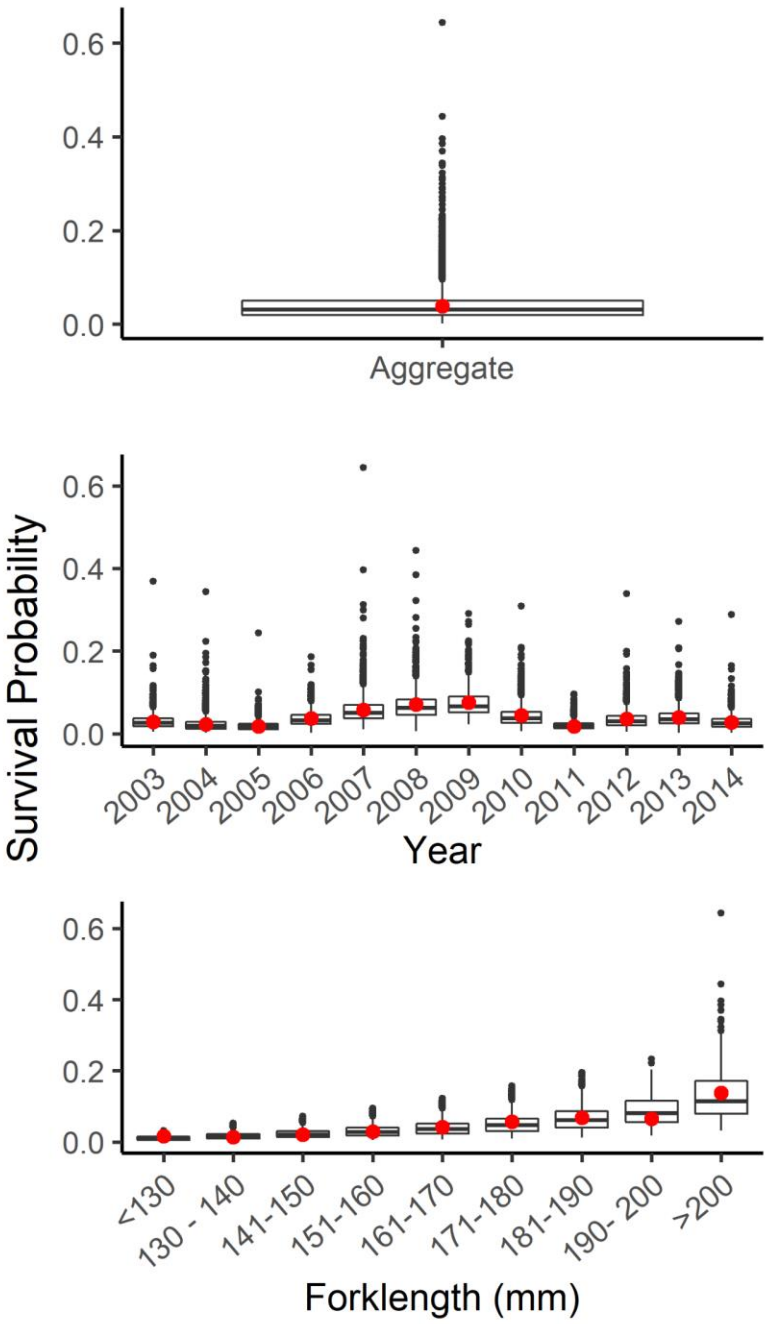
Thank You!

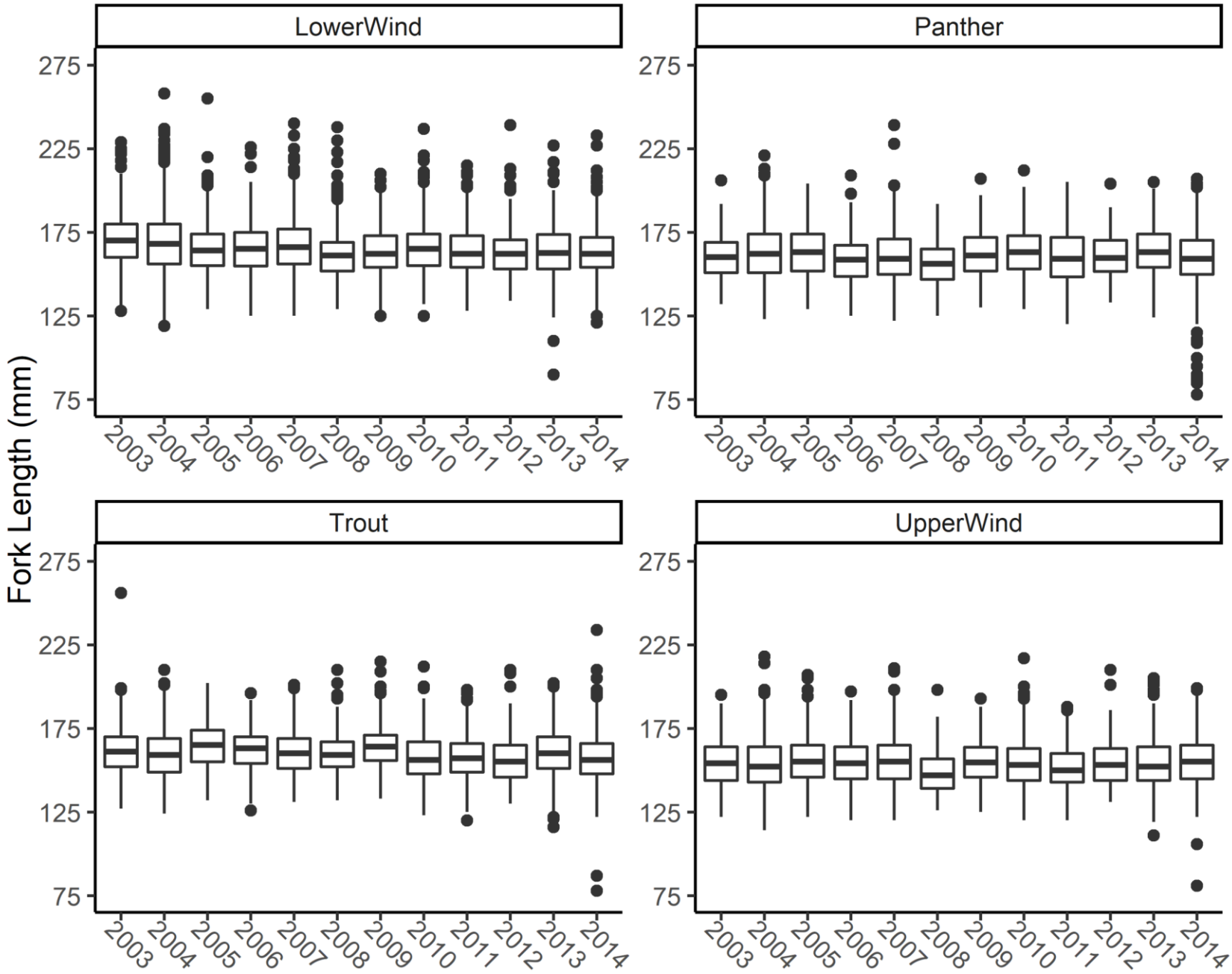
Thomas Buehrens (WDFW)*
Patrick Cockran (WDFW)
Jennifer Fisher (NOAA)*
Kyle Wilson (SFU)*

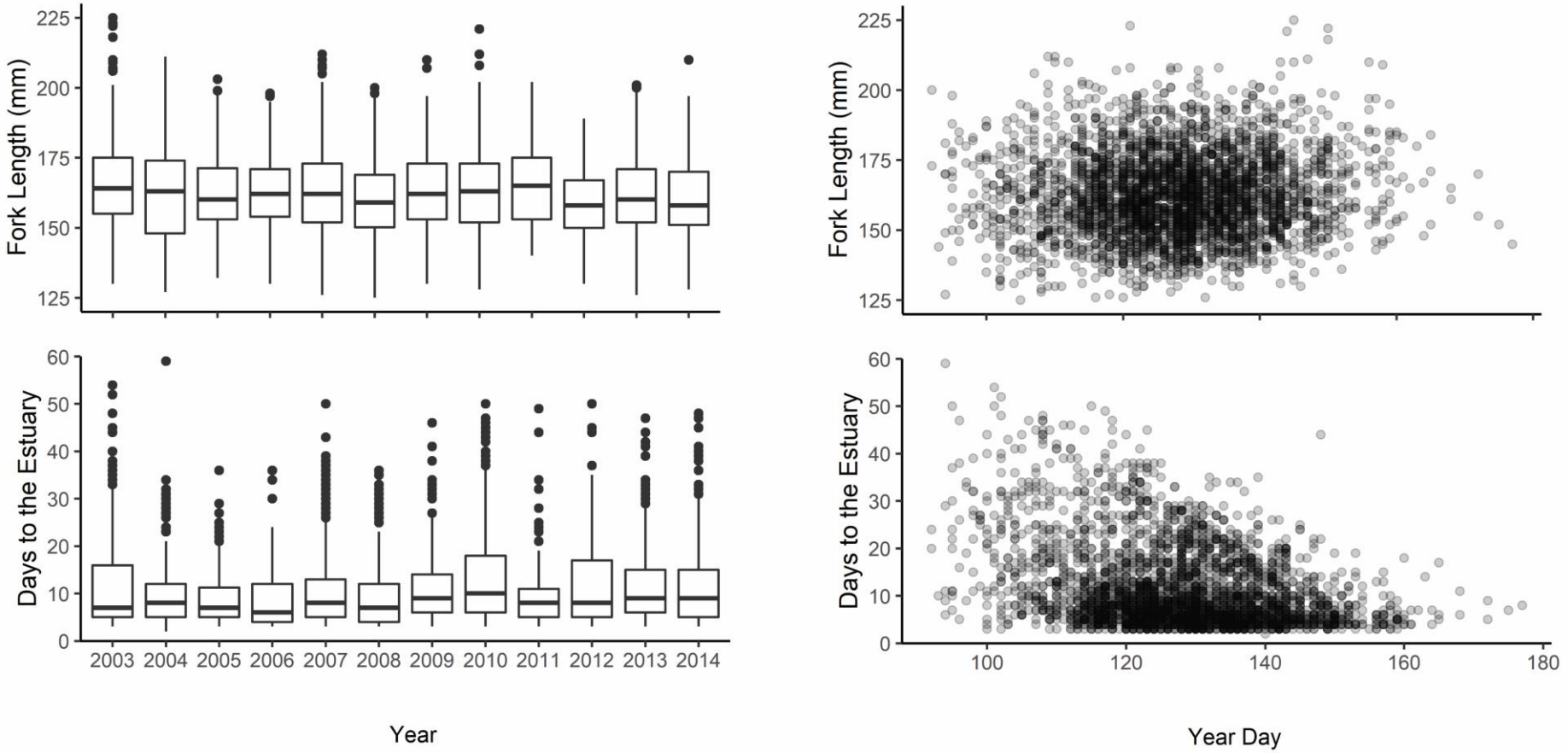
Thank You!

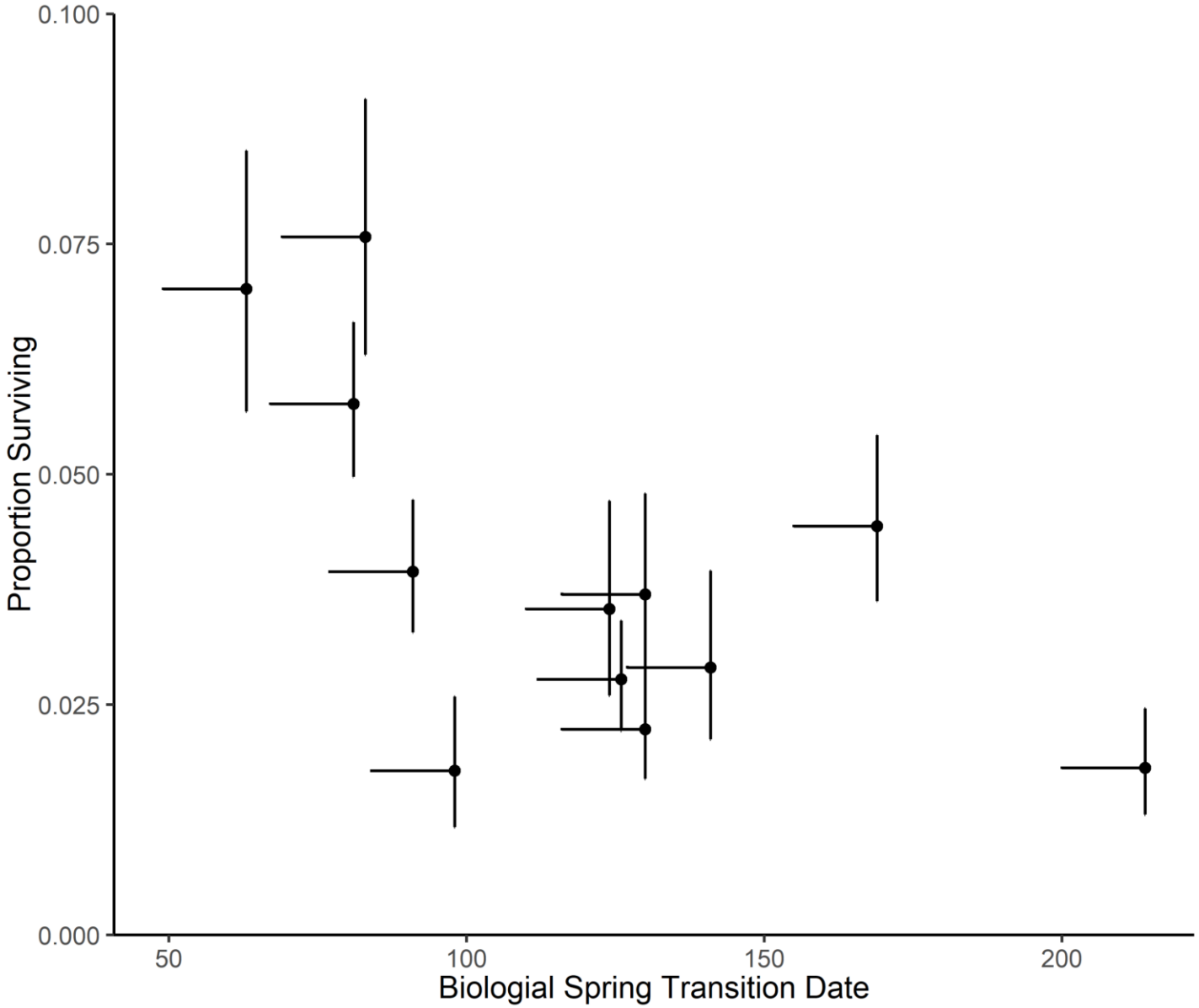
Contact me at:
swa130@sfu.ca

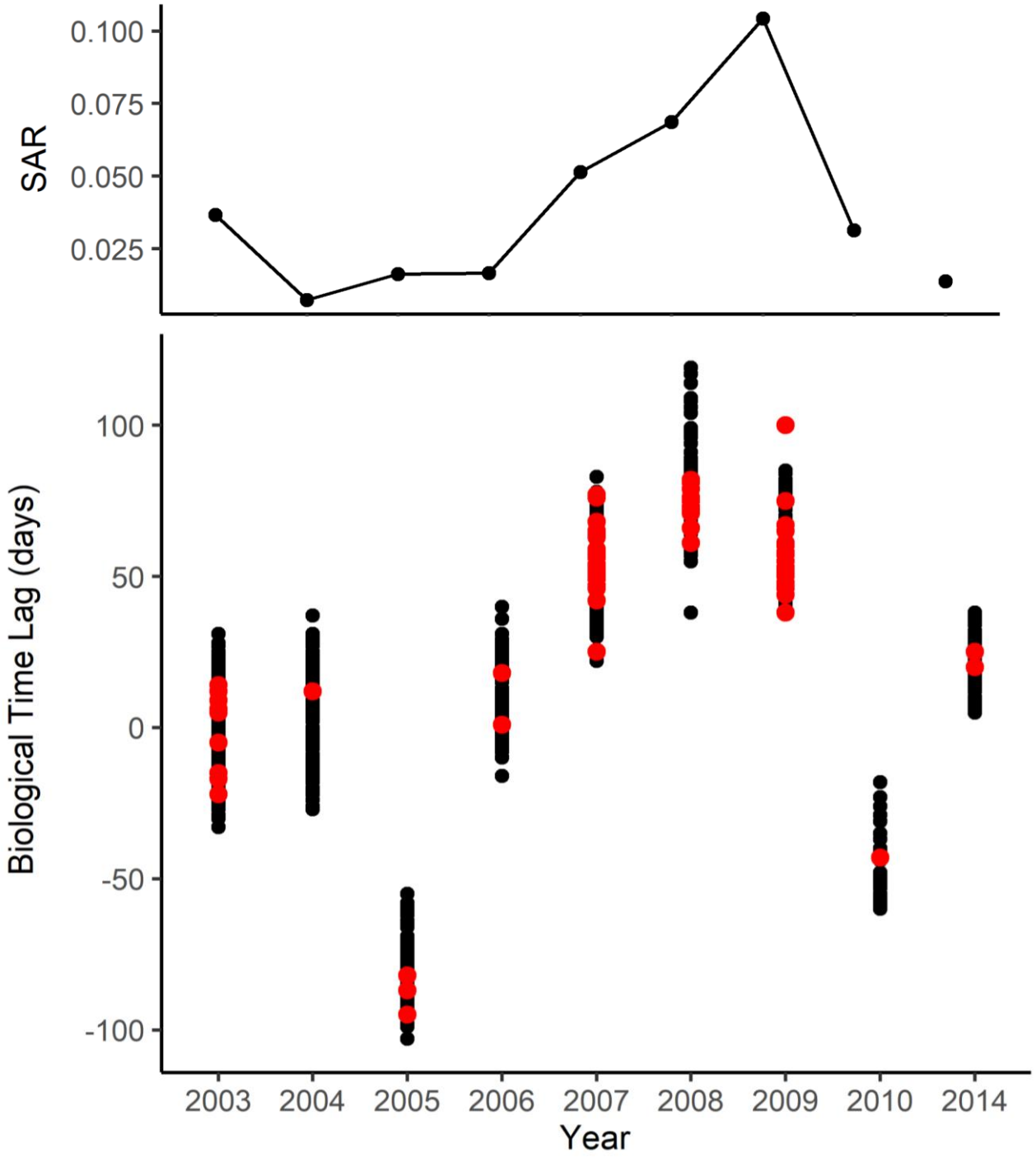
Wilson, S.M., Buehrens, T., Fisher, J., Wilson, K., Moore, J.W. 2021. Phenological mismatch, carryover effects, and marine survival in a wild steelhead trout Oncorhynchus mykiss population. Progress in Oceanography 193:102533

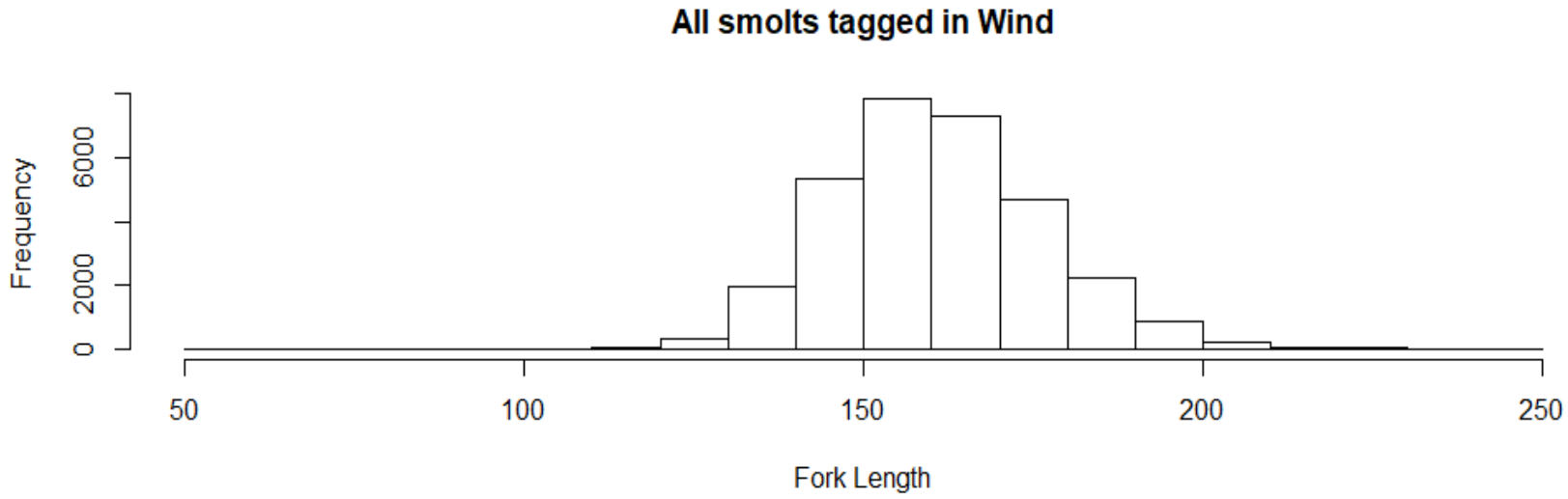

0.6
0.4
0.2
0.0
Aggregate
Survival Probability
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
Year
<130
130 - 140
141-150
151-160
161-170
171-180
181-190
190- 200
>200
Forklength (mm)

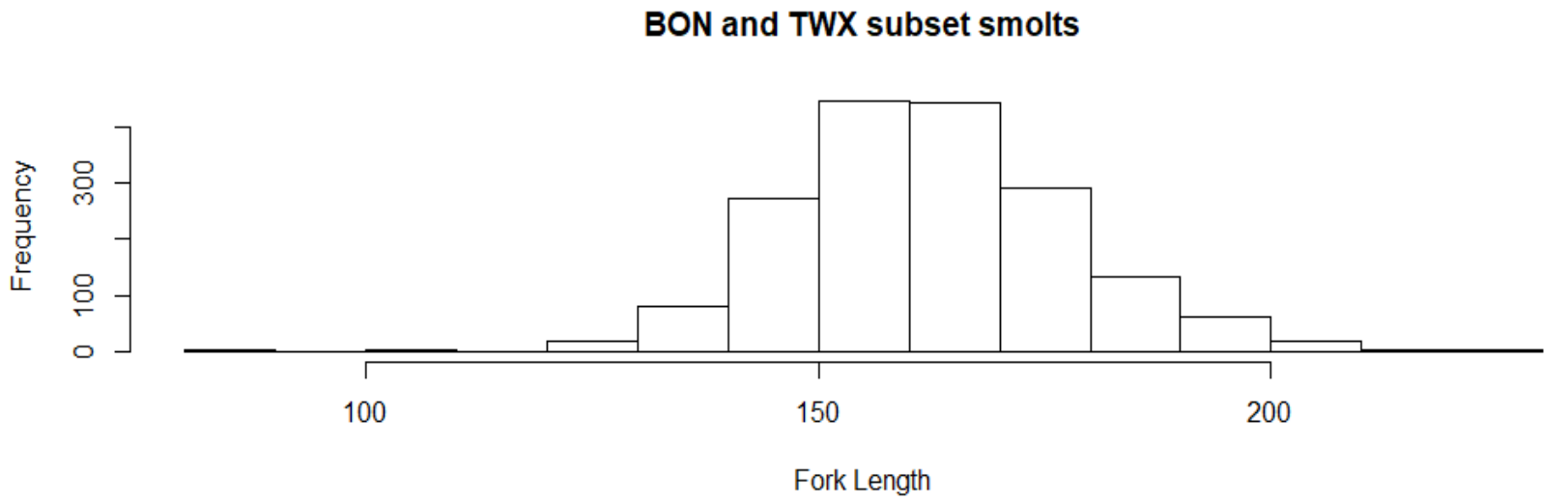

LowerWind
Panther
Trout
UpperWind
Fork Length (mm)
275
225
175
125
75
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014

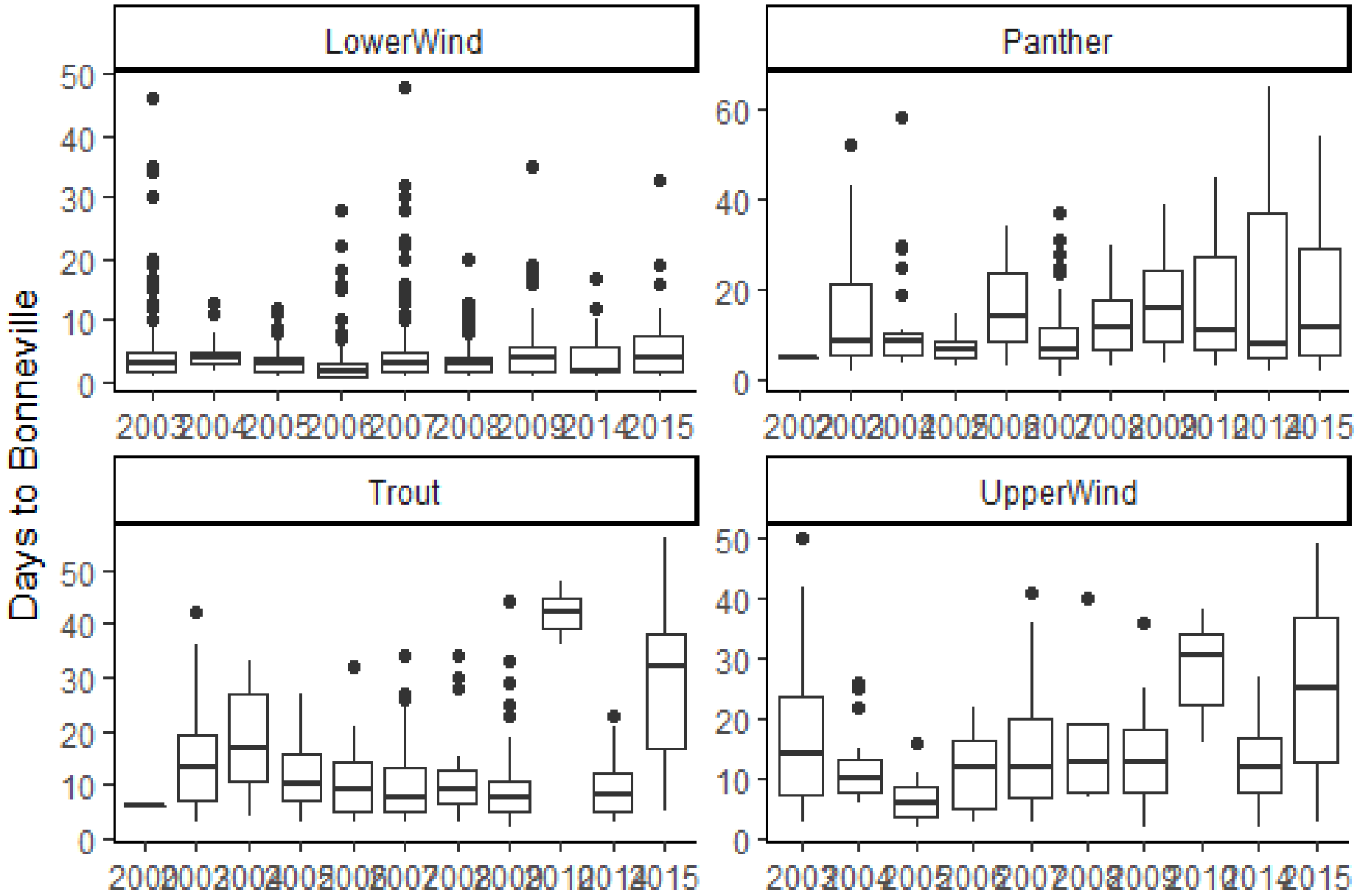

Fork Length (mm)
225
200
175
150
125
Days to the Estuary
60
50
40
30
20
10
0
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
Year
Fork Length (mm)
225
200
175
150
125
Days to the Estuary
60
50
40
30
20
10
0
100
120
140
160
180
Year Day


0.100
0.075
0.050
0.025
0.000
Proportion Surviving
50
100
150
200
Biologial Spring Transition Date


SAR
0.100
0.075
0.050
0.025
Biological Time Lag (days)
100
50
0
-50
-100
2003
2004
2005
2006
2007
2008
2009
2010
2014
Year

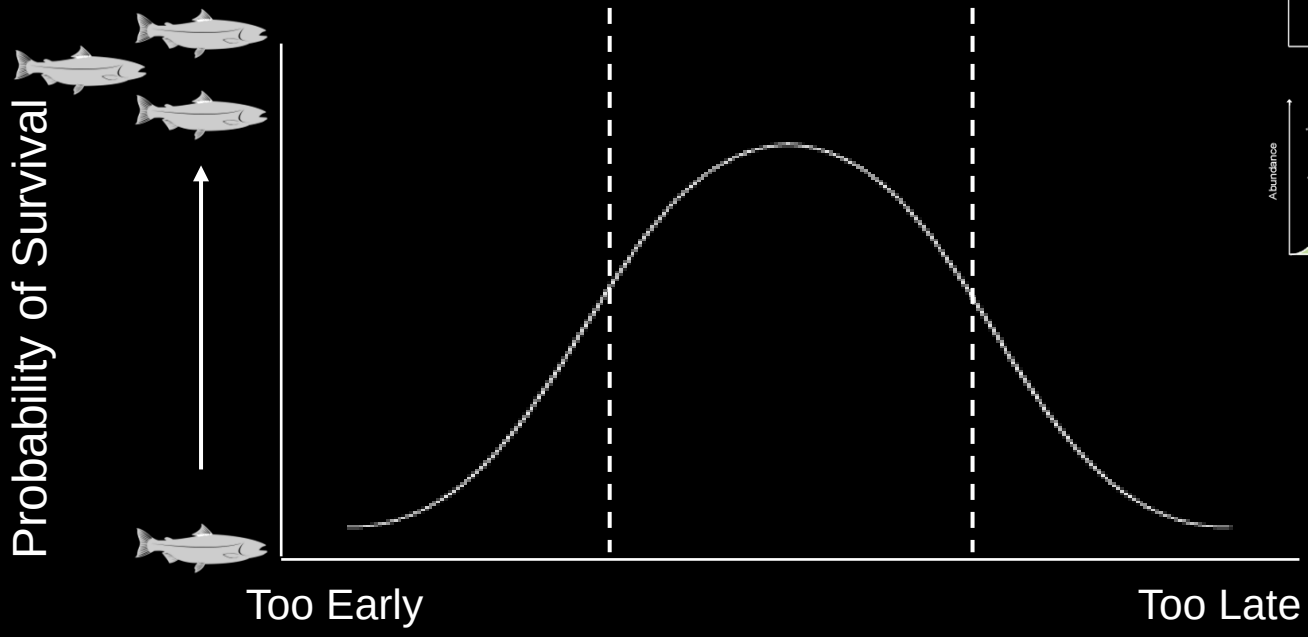

All smolts tagged in Wind
Frequency
0
2000
6000
50
100
150
200
250
Fork Length

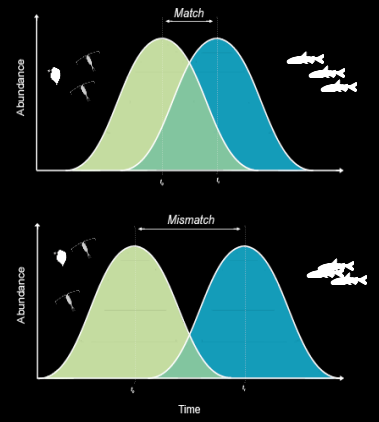

BON and TWX subset smolts
Frequency
0
100
300
100
150
200
Fork Length

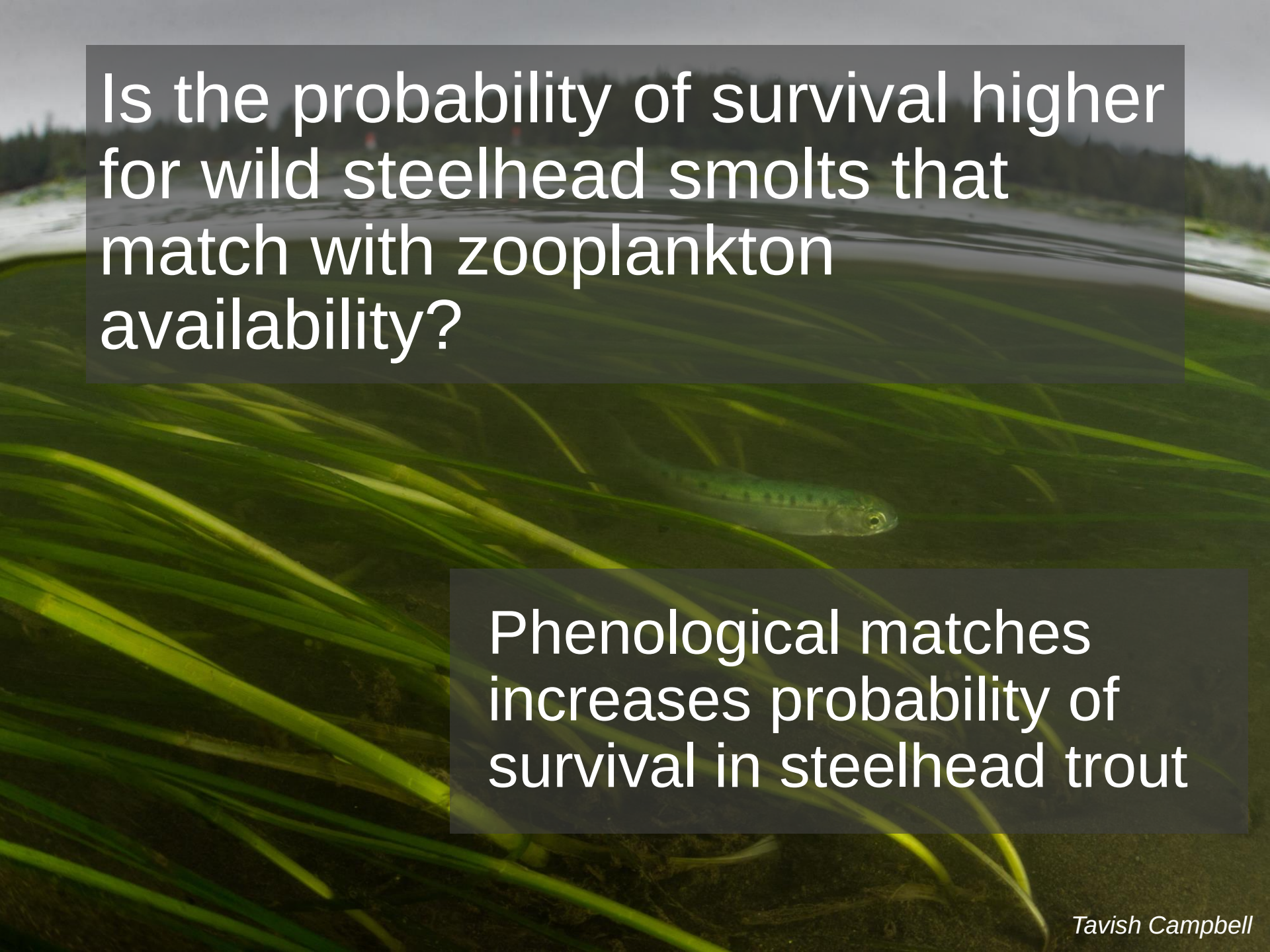

LowerWind
Panther
Trout
UpperWind
Days to Bonneville
0
10
20
30
40
50
60
2003
2004
2005
2006
2007
2008
2009
2014
2015

Is the probability of survival higher for steelhead smolts that enter the estuary during peak food availability?

Predictions







Is the probability of survival higher for wild steelhead smolts that match with zooplankton availability?

Phenological matches increases probability of survival in steelhead trout

Tavish Campbell

Early Marine Survival

Predators

Prey