

Physical Mechanisms for Variation in Pink Salmon Survival in the Coastal Gulf of Alaska and Prince William Sound Environment

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Presentation to the PCCRC board
January 21st , 2010



Outline

Optimal Stability 'Window' Hypothesis

Part I: Gulf of Alaska

Methods

Results

Part II: Prince William Sound

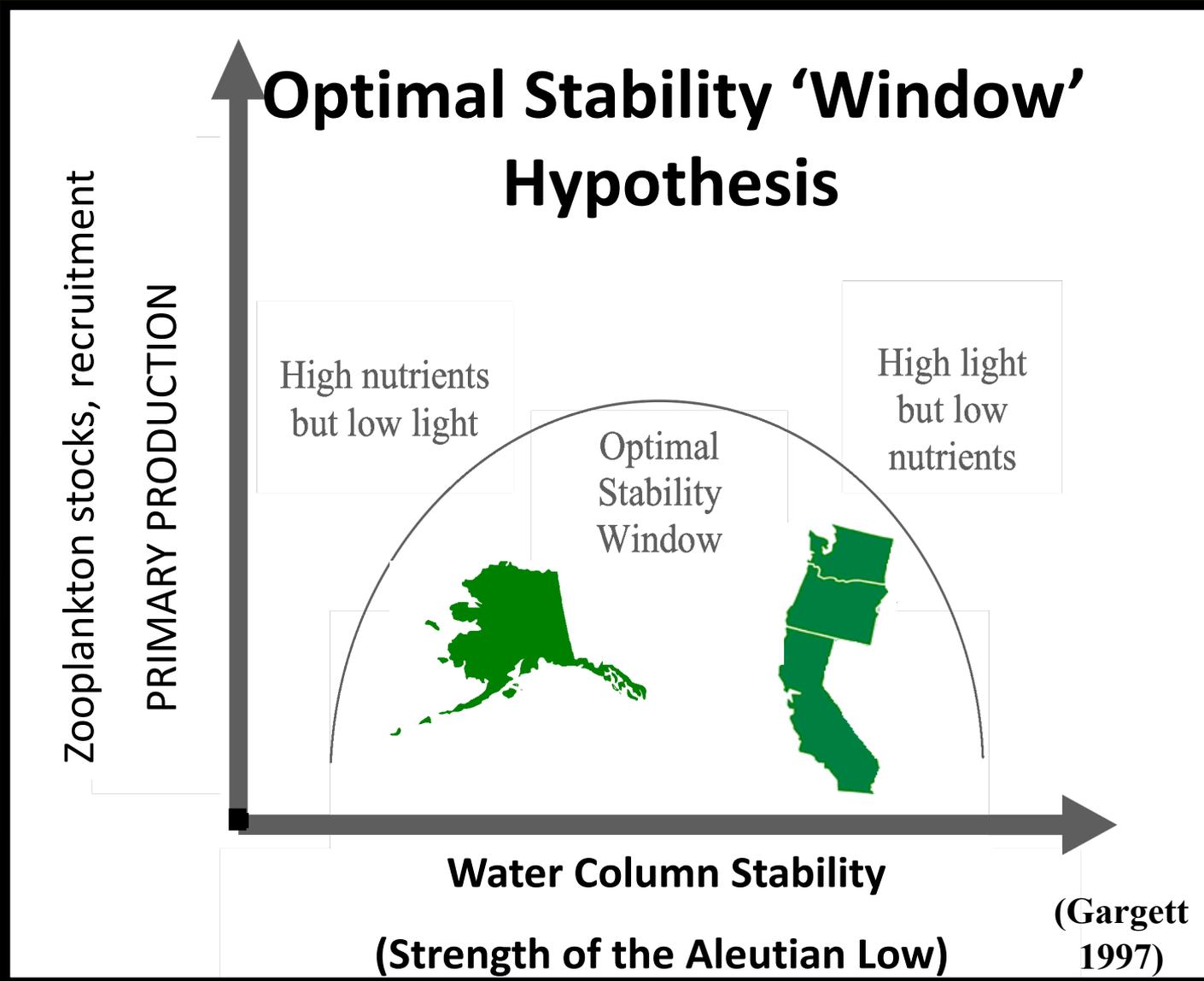
Methods

Results

Conclusions

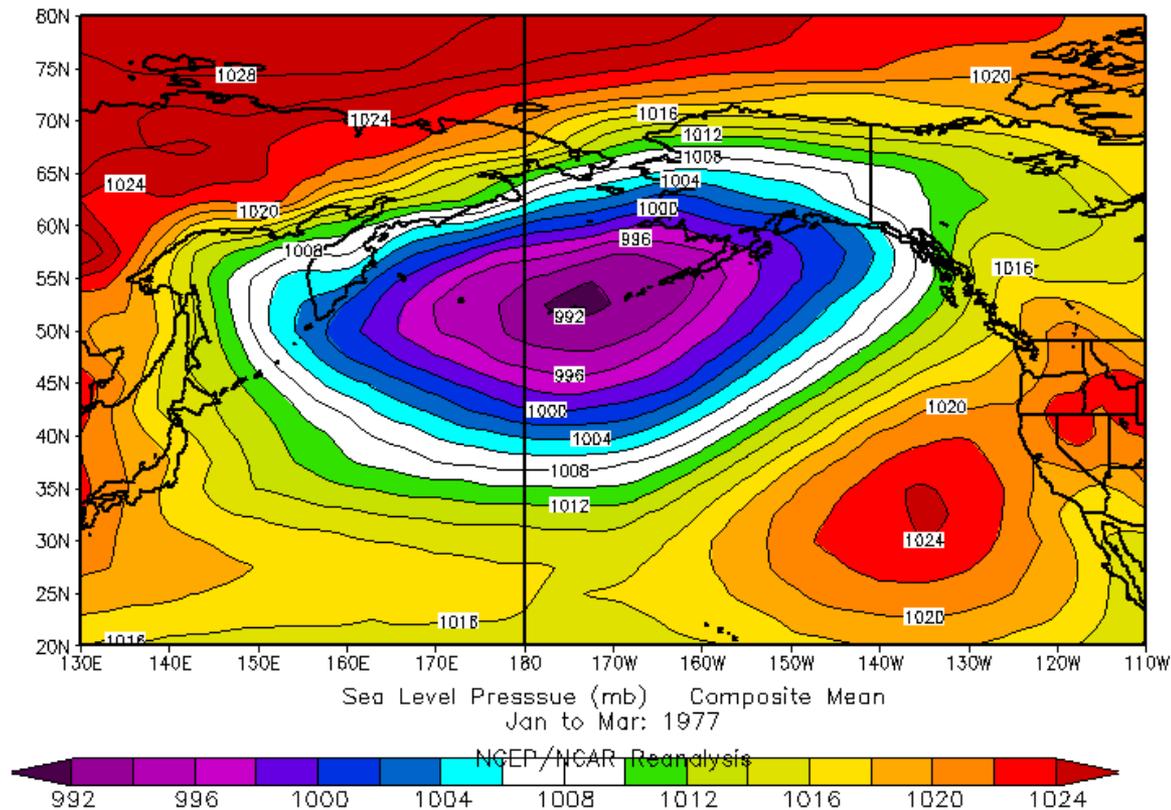
Future Projects

Introduction



Introduction

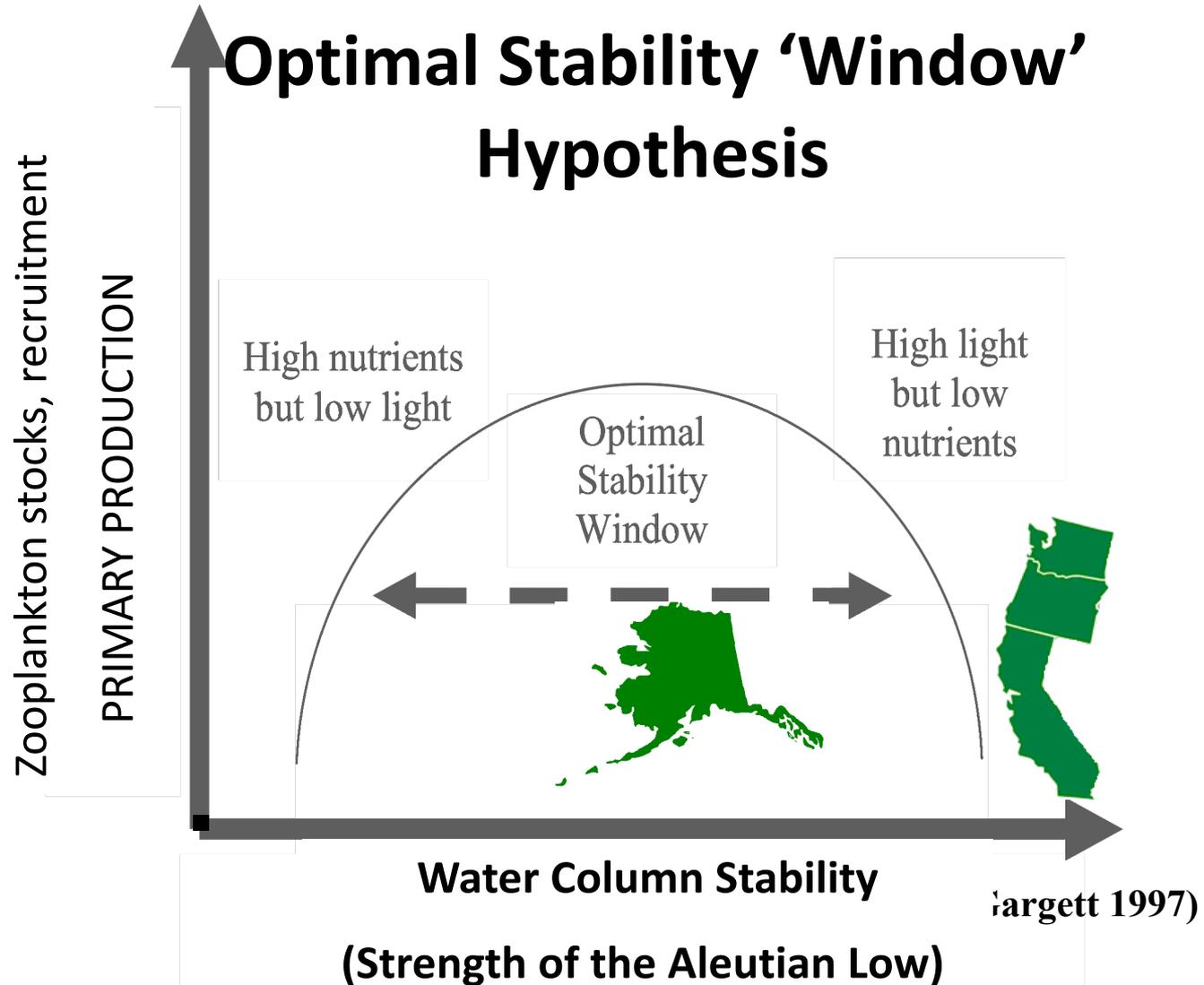
Strong Aleutian Low



NOAA-CIRES/Climate Diagnostics Center

NOAA-CIRES/Climate
Diagnostics Center

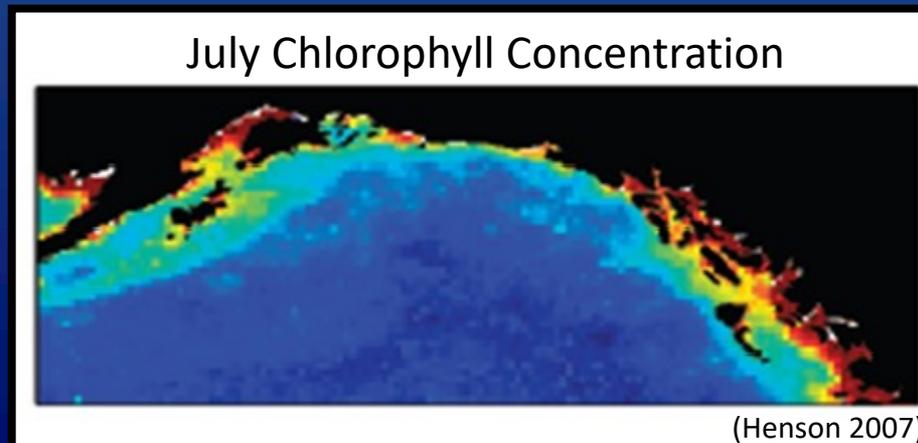
Introduction



Introduction

Previous tests of the OSH (Gulf of Alaska)

- Support link between primary production and GOA stability (satellite data)
- Increased stability linked to increased magnitude (increased chl- a and longer bloom duration) and earlier onset of the spring bloom (Henson 2007)

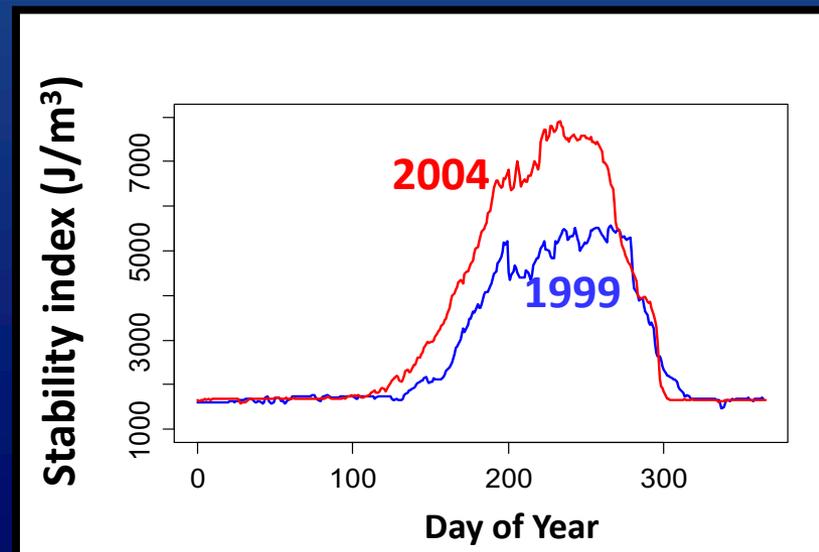


Introduction

Previous tests of the OSH (Eastern Bering Sea)

- As stability \uparrow past the 'optimal' level, post-bloom production on the middle shelf \downarrow , large grazers can not be supported
 - reorganization of trophic levels
- YOY pollock from the middle shelf showed a dietary shift
 - large \longrightarrow small copepods in 2004 relative to 1999
- Accompanied by a 3-fold increase in stability in 2004 relative to 1999 (Coyle et al. 2008)

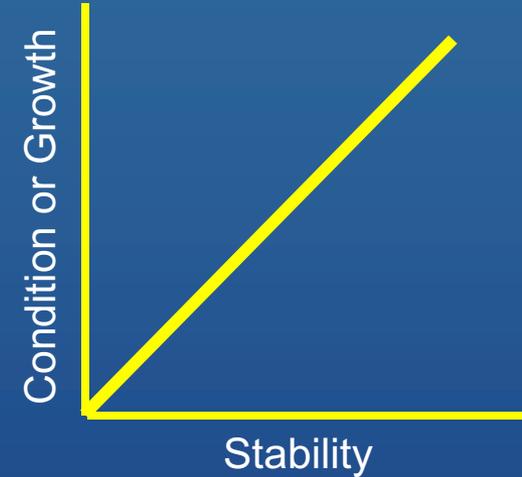
Based on
Mooring data
(M2) provided by
Phyllis Stabeno,
PMEL, NOAA



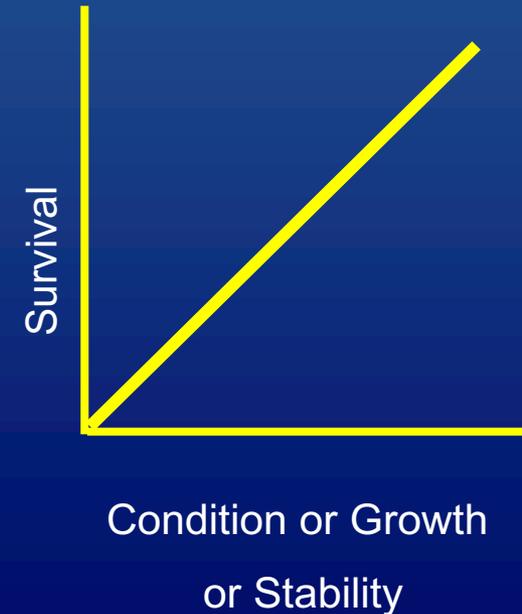
Part I: GOA

Hypotheses

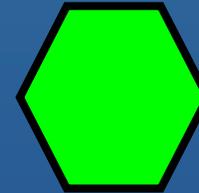
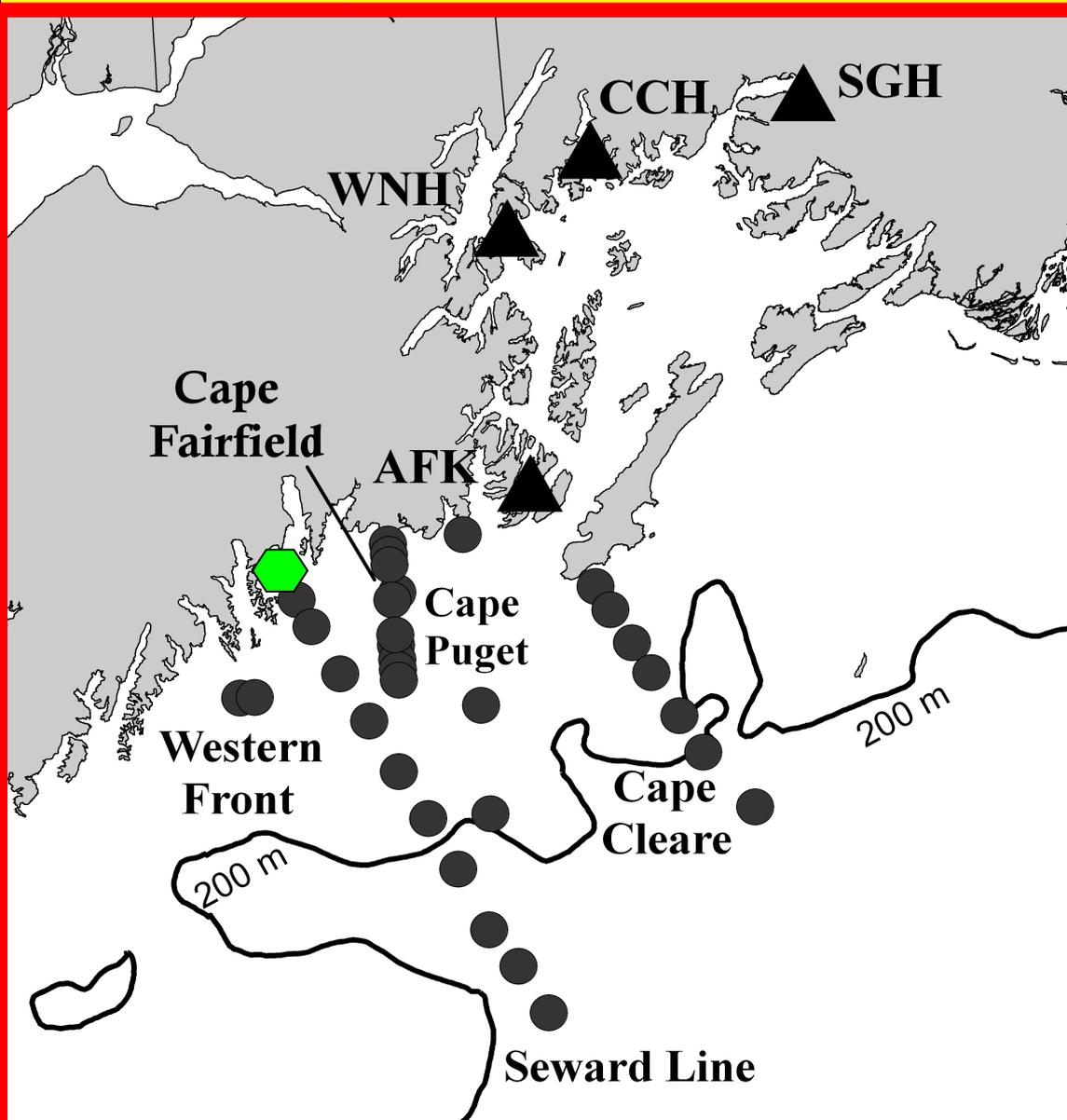
Hypothesis 1: Fish condition and growth have a positive relationship with water column stability in the GOA.



Hypothesis 2: Survival is positively related to fish condition, fish growth, and stability in the GOA.



Methods



GAK 1 Mooring

www.ims.uaf.edu/gak1/



Hatcheries



Samples



Summer



(2000-2004)

Methods

Fish Variables

- Condition Index

n=376 hauls

- Standardized Growth Exponent

n=284 hauls

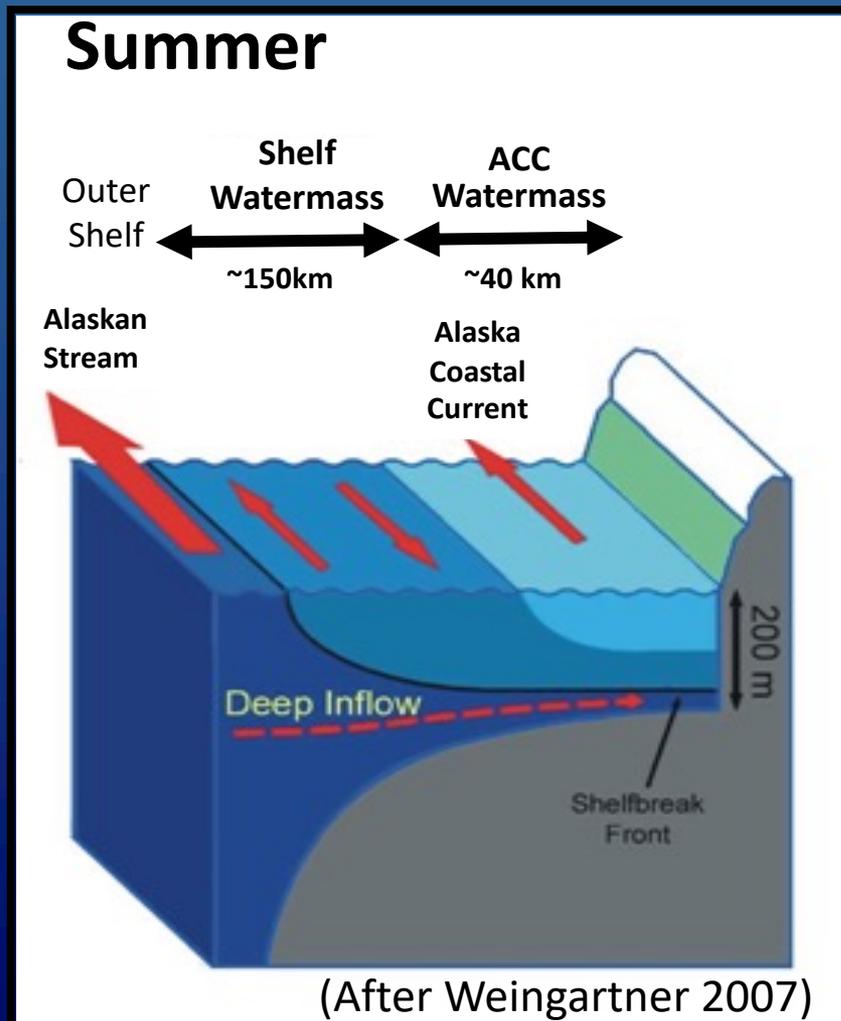
- Haul used as the sampling unit

-year, watermass, origin



Methods

Identification of Watermasses:



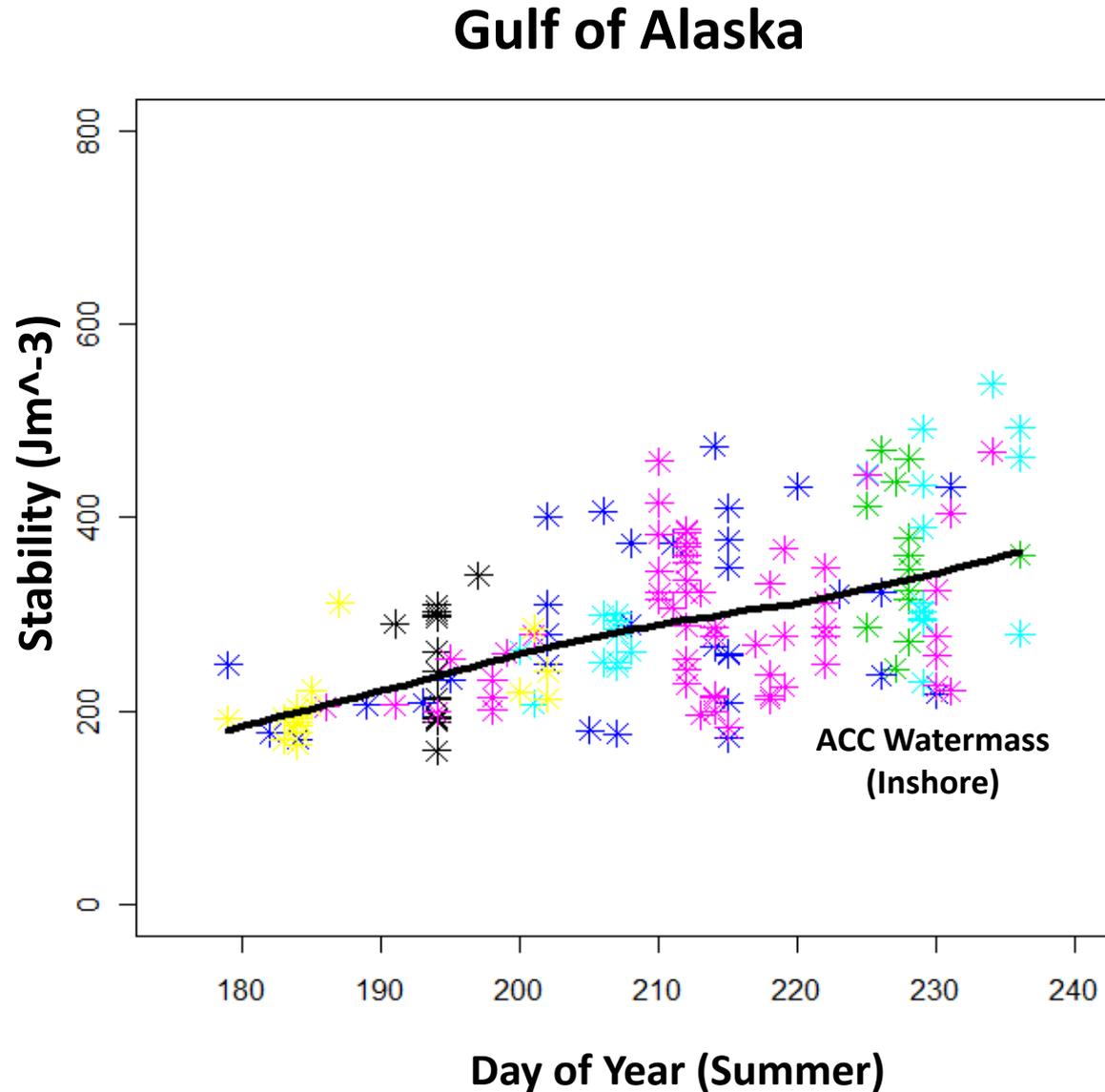
Transect stations separated into two watermasses (ACC and Shelf) based on salinity at surface

- ACC (salinity < 30 at 2m)
- Shelf (salinity ≥ 31.5 at 2m)

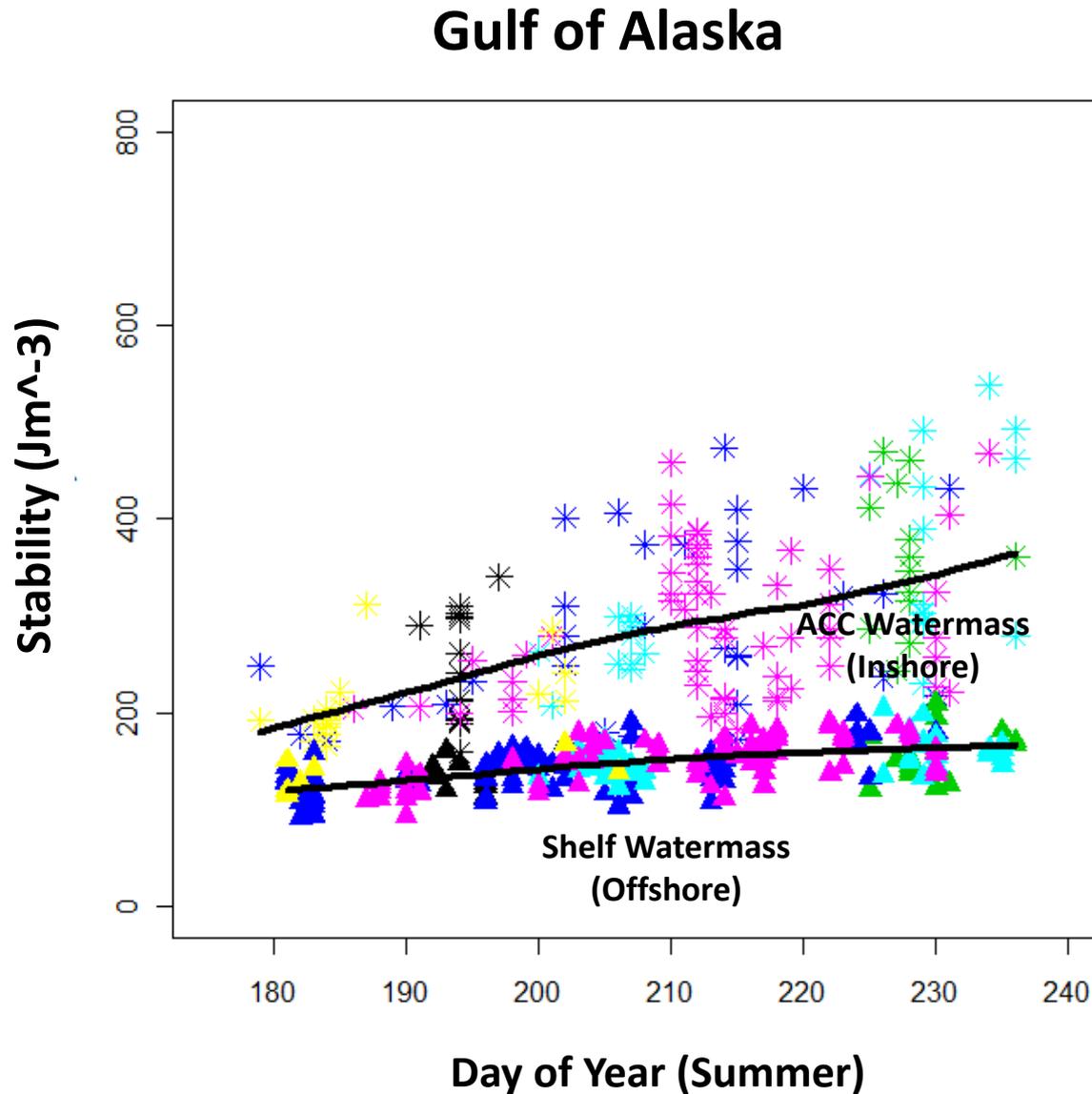
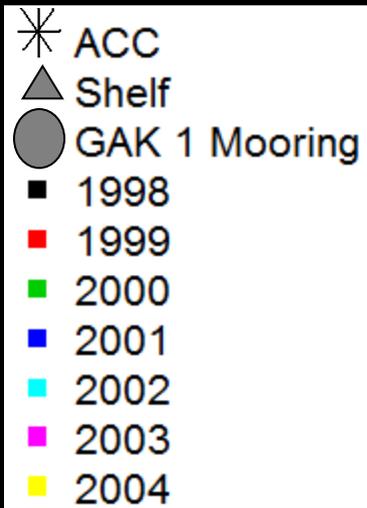
Methods

- Stability index calculated using Simpson et al. 1977
- Work required to redistribute the mass during complete mixing (stratification)
- Calculated down to 100 m at 1 m intervals

Methods

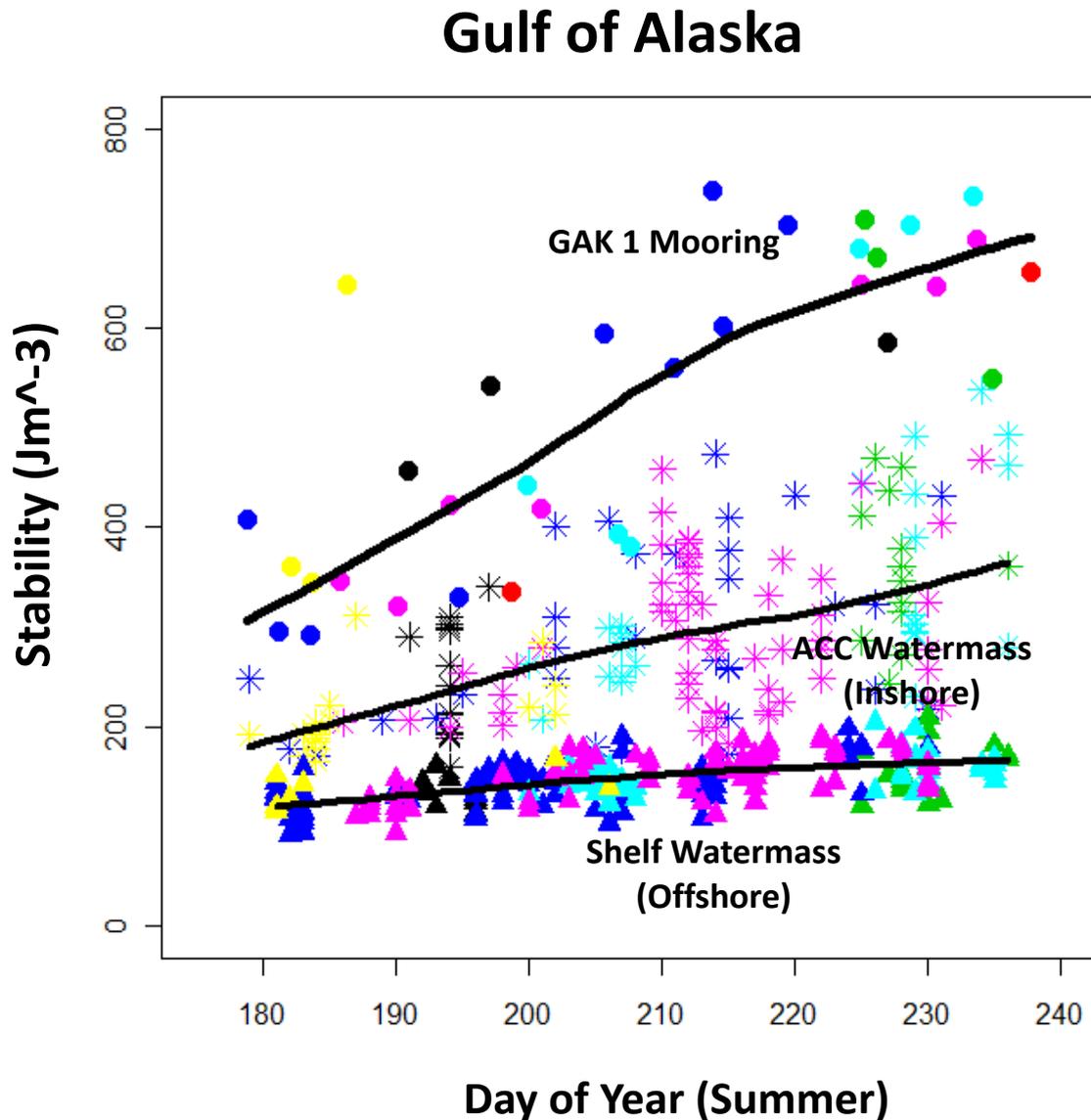


Methods

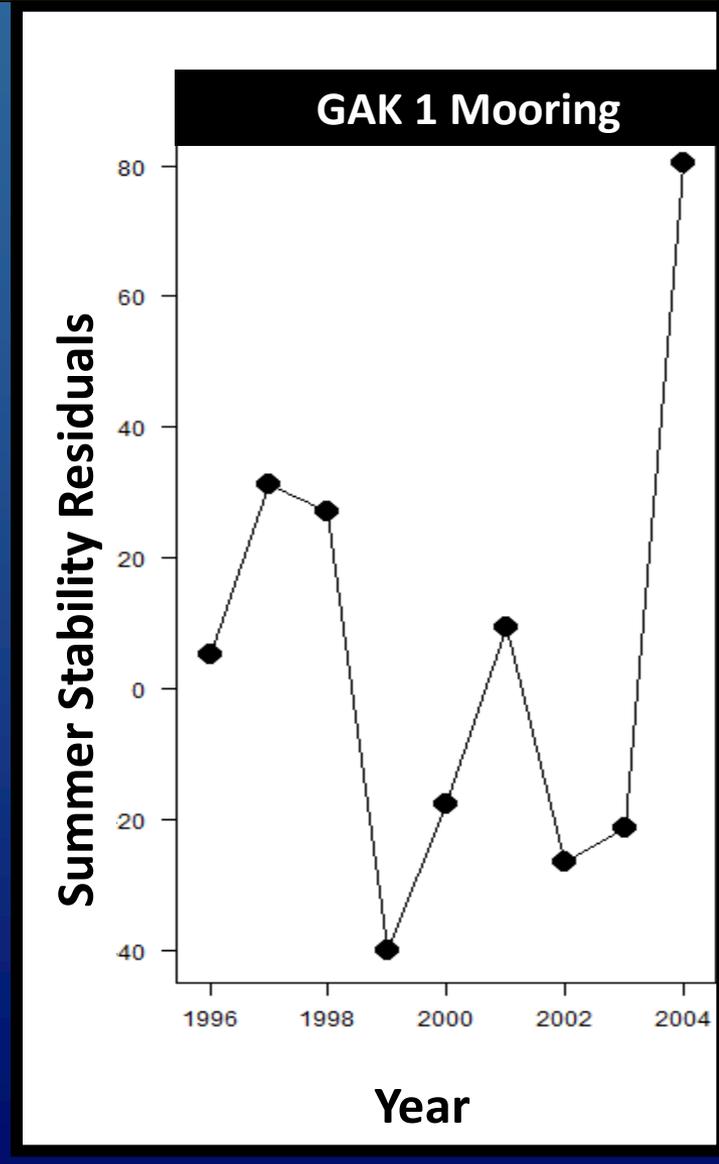
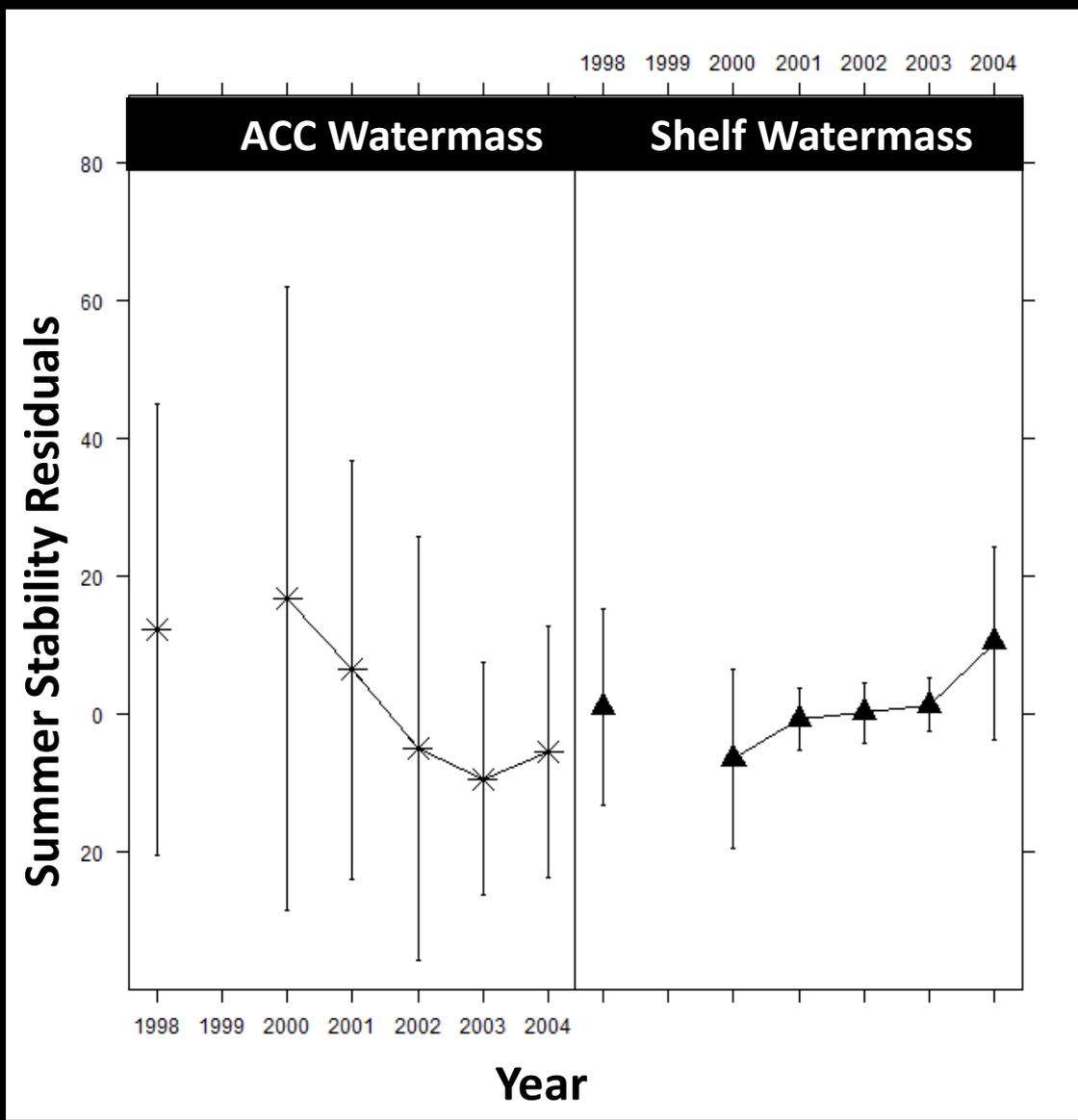


Methods

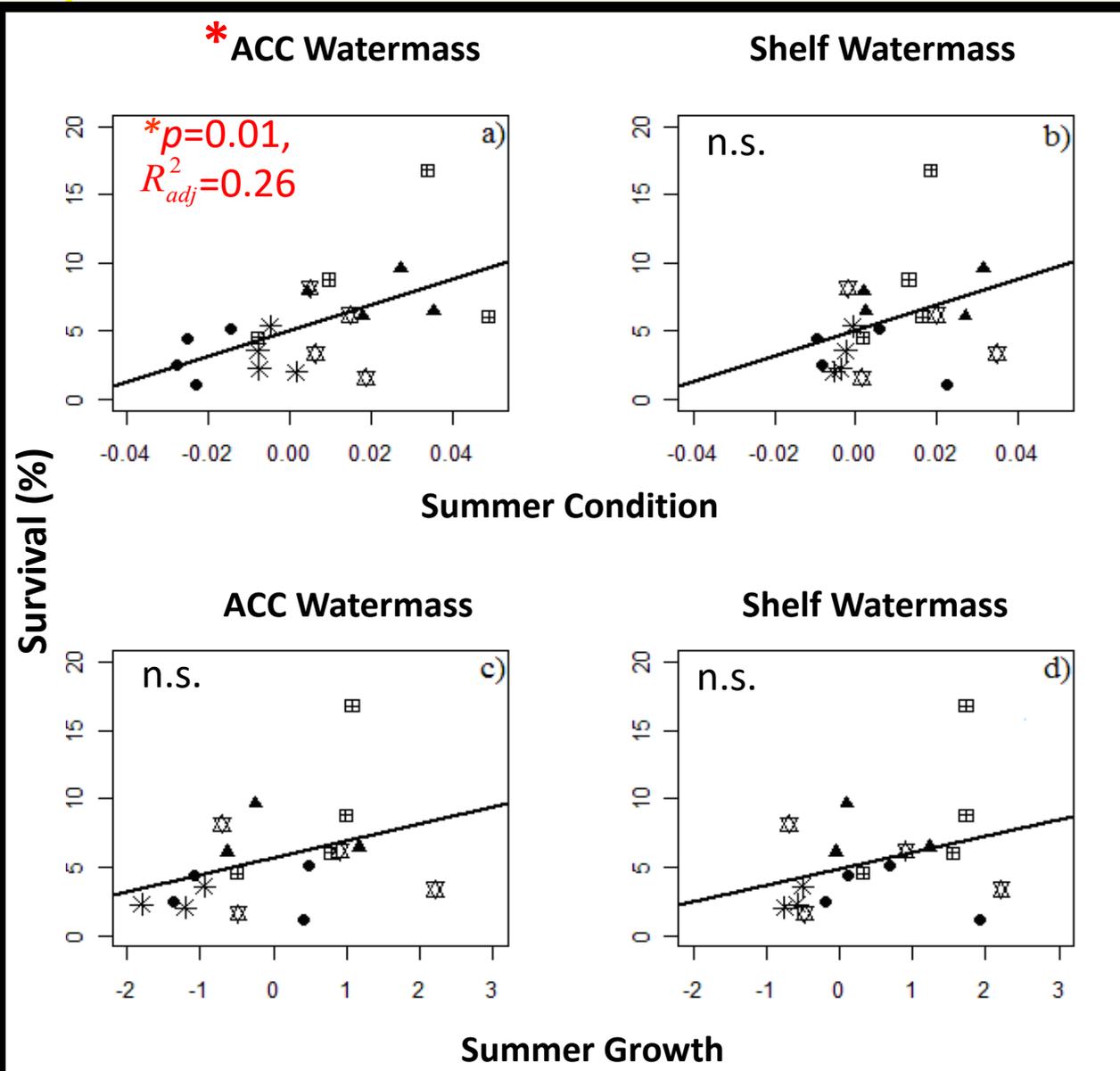
- * ACC
- ▲ Shelf
- GAK 1 Mooring
- 1998
- 1999
- 2000
- 2001
- 2002
- 2003
- 2004



Methods



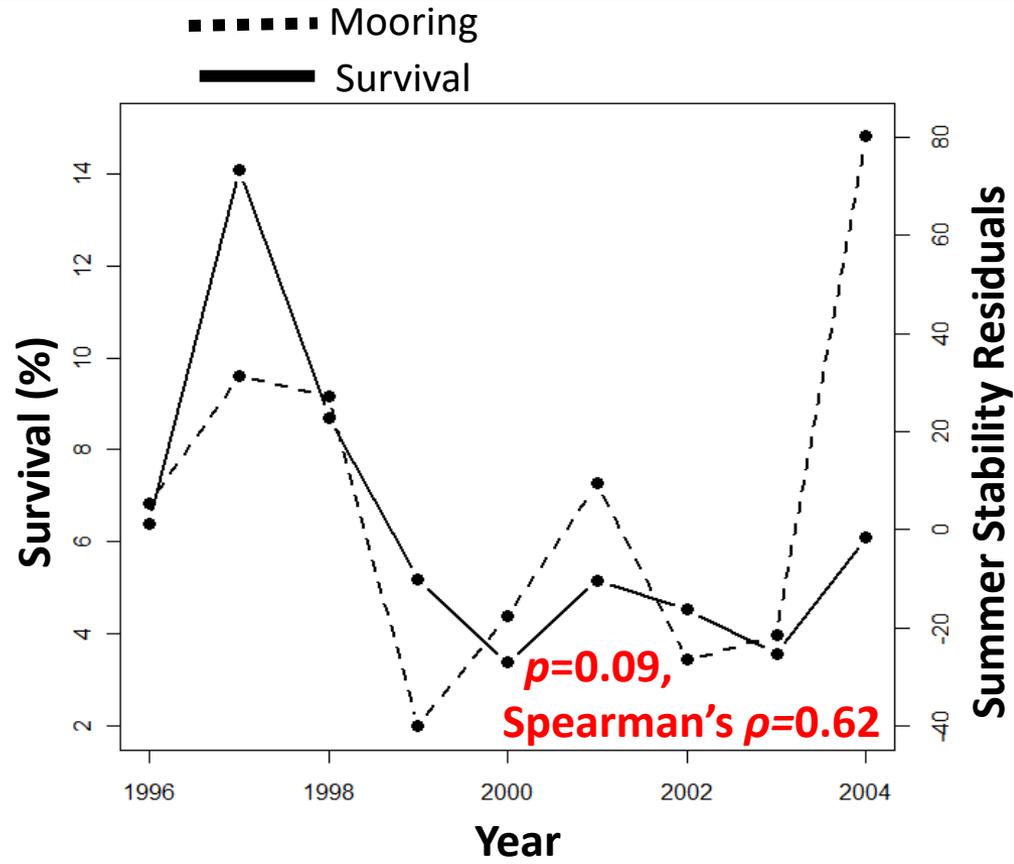
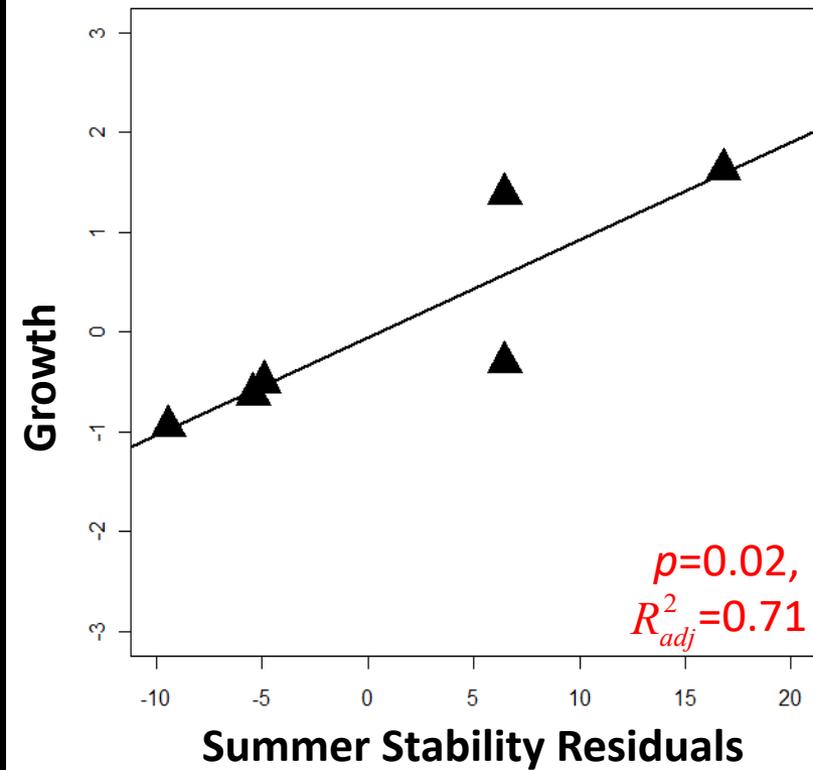
Results



Results

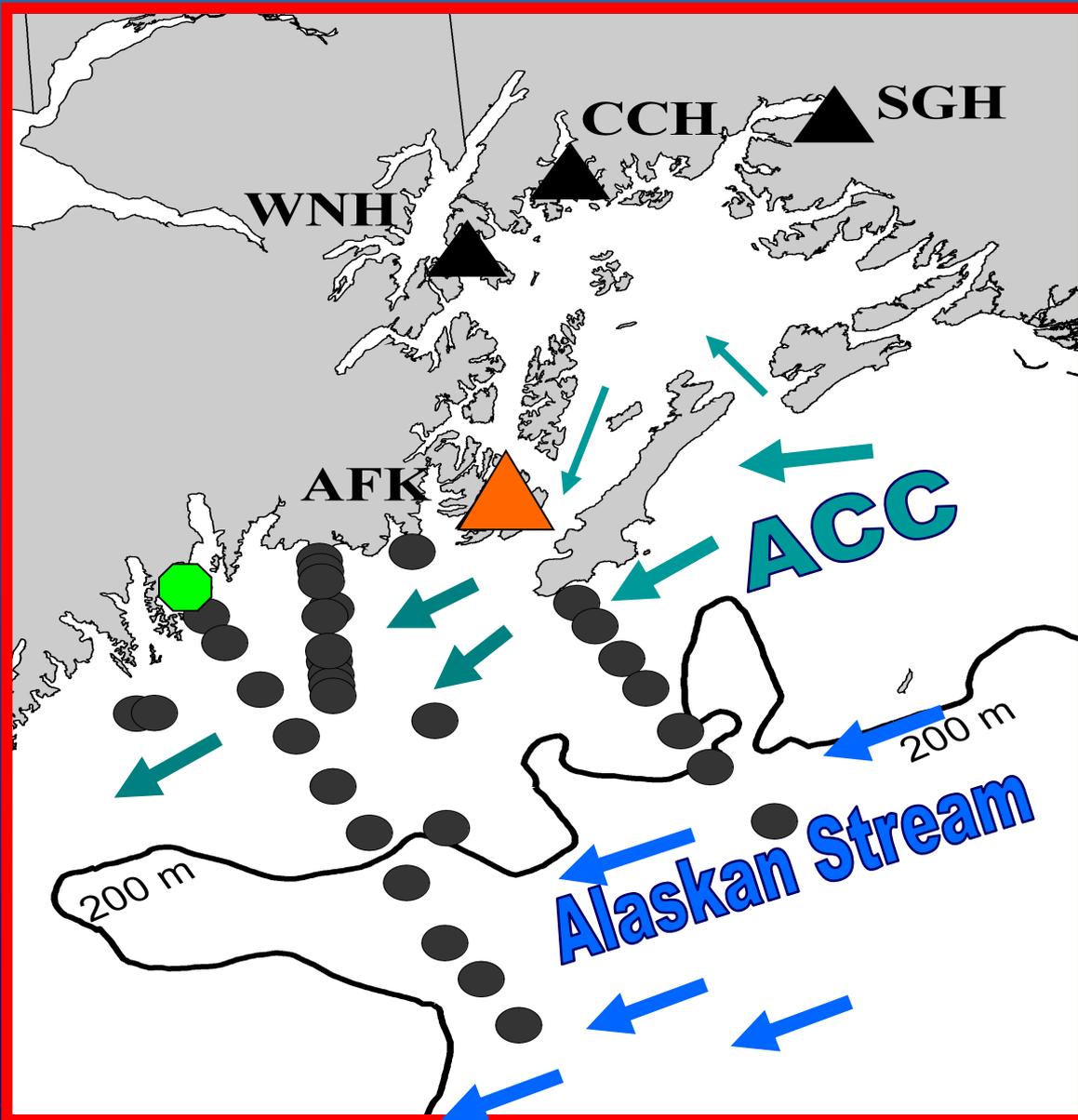
AFK Hatchery Only

* ACC Watermass





Discussion

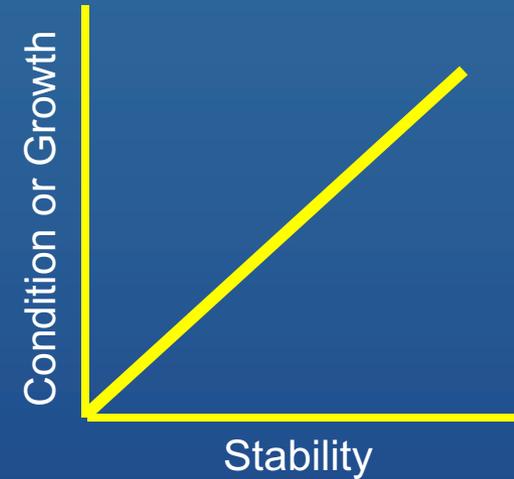


Part II: PWS

Hypotheses

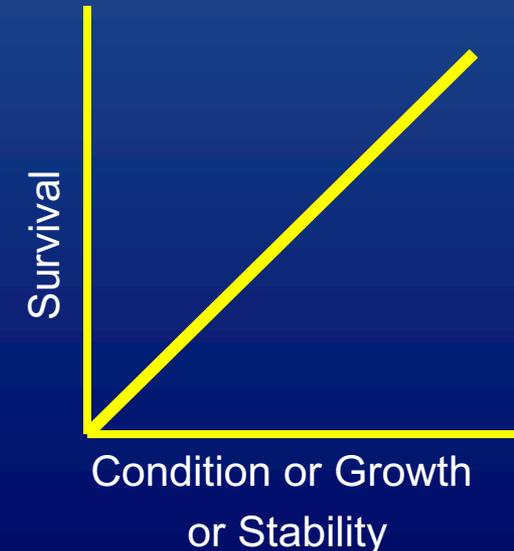
Hypothesis 1:

Condition and growth of salmon originating from hatcheries within the estuary should have a positive relationship with PWS stability during the spring and summer.



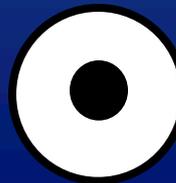
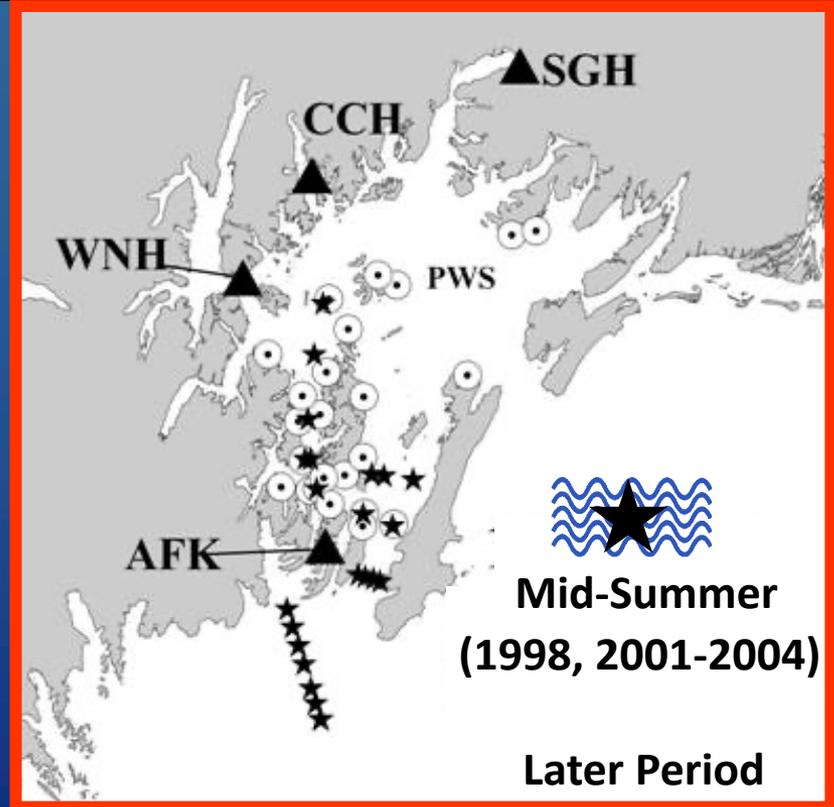
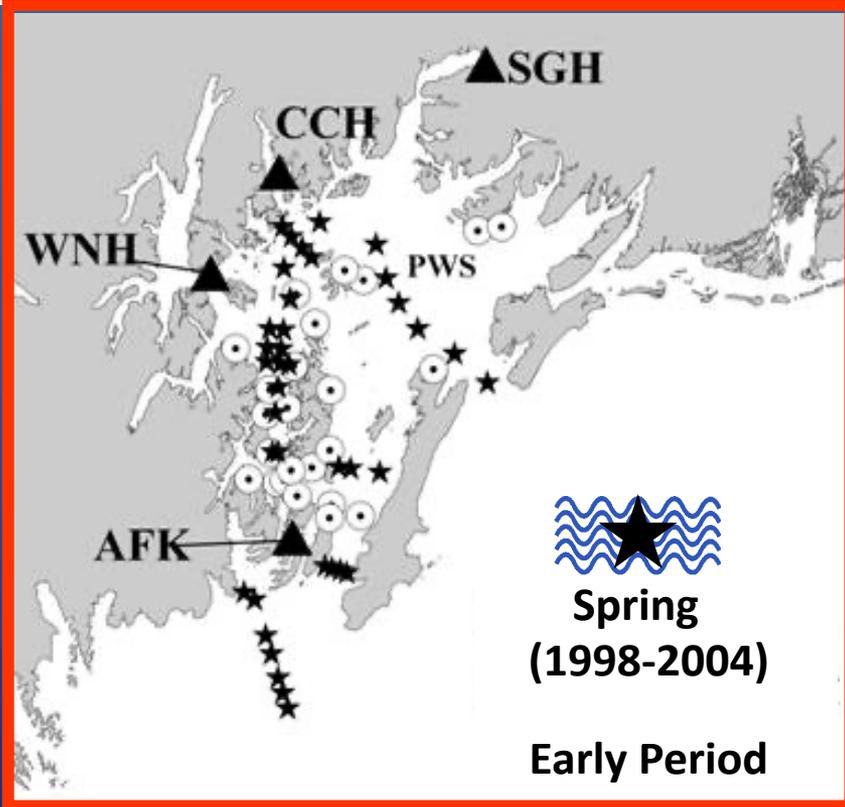
Hypothesis 2:

Survival of estuary salmon should be positively related to fish condition, fish growth, and PWS stability.





Background



Summer
(1997-2005)

Methods

Fish Variables

- Condition Index

n=694 hauls

- Standardized Growth Exponent

n=539 hauls

- Haul used as the sampling unit

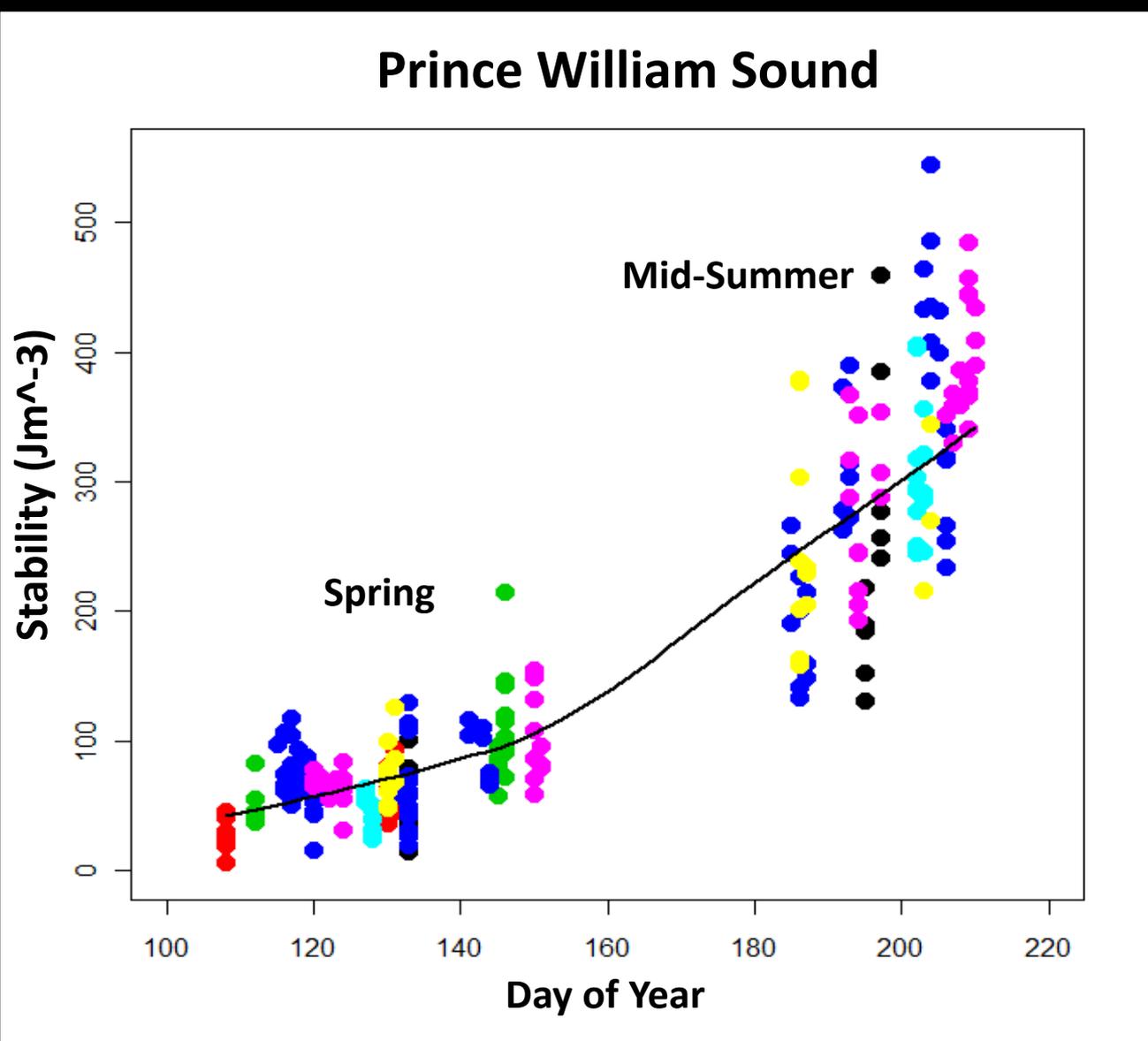
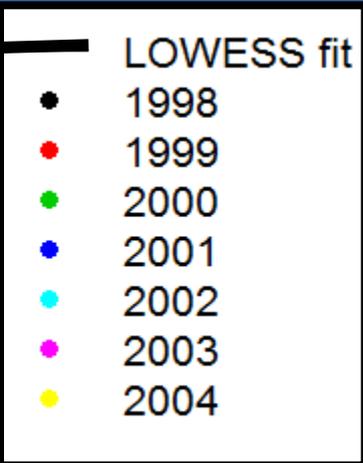
-year, origin



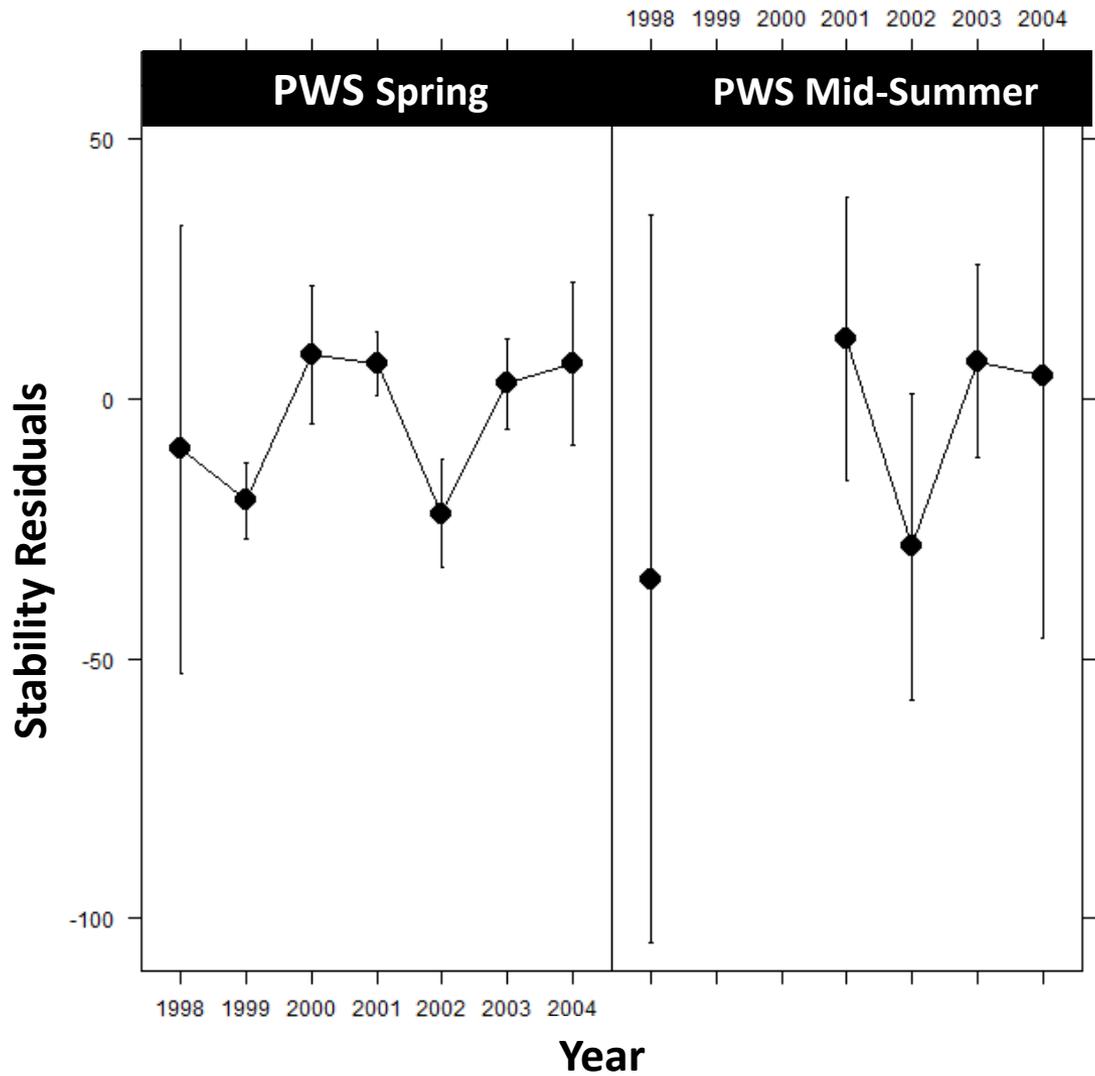
Methods

- Stability index calculated using Simpson et al. 1977
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- Calculated down to 100 m at 1 m intervals

Methods

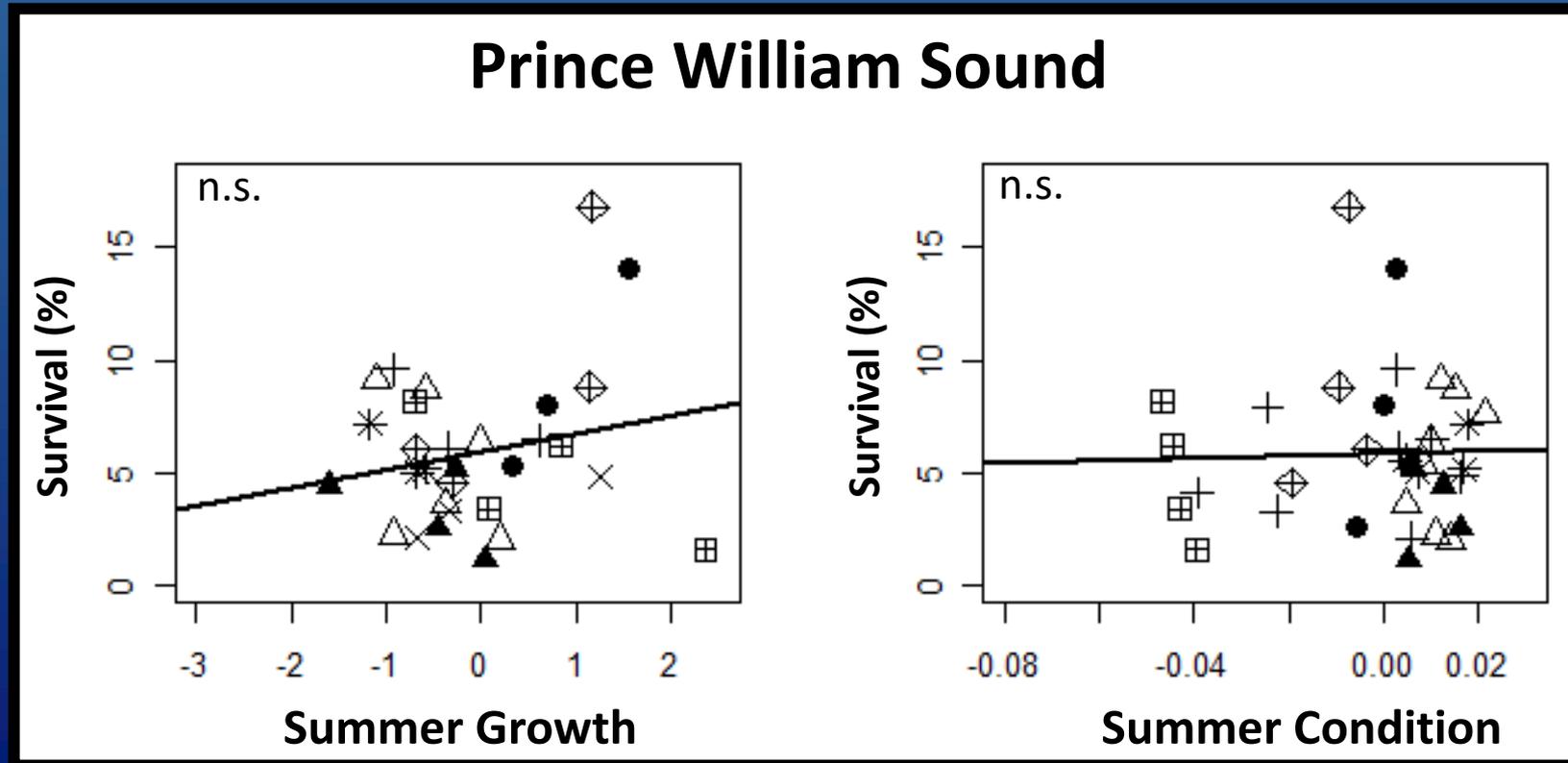
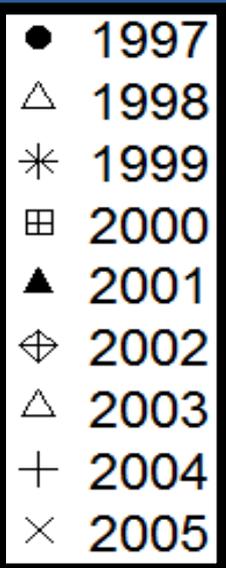


Methods



Results

- No clear relationship between condition (or growth) and survival.

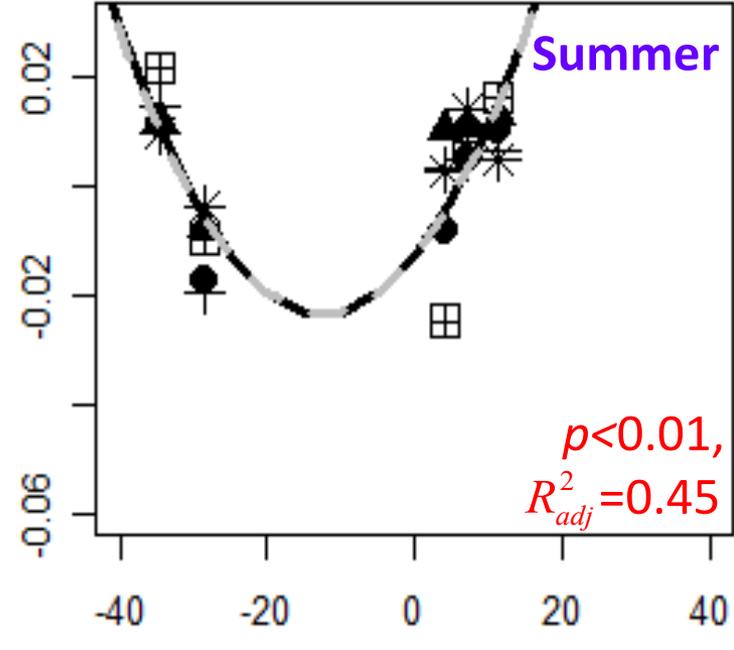
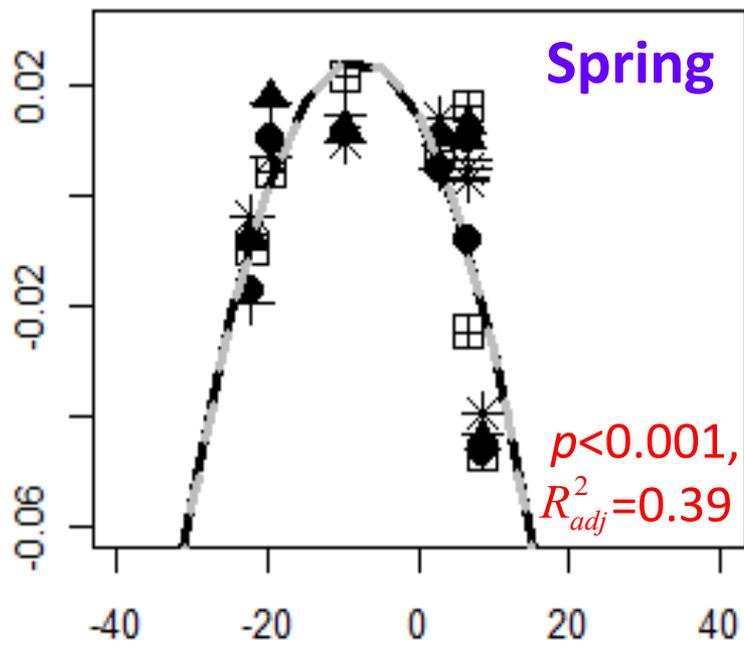


Results

- * CCH
- ▣ SGH
- ▲ WNH
- Wild
- + AFK
- Estuary+AFK
- Estuary

Prince William Sound

Summer Condition

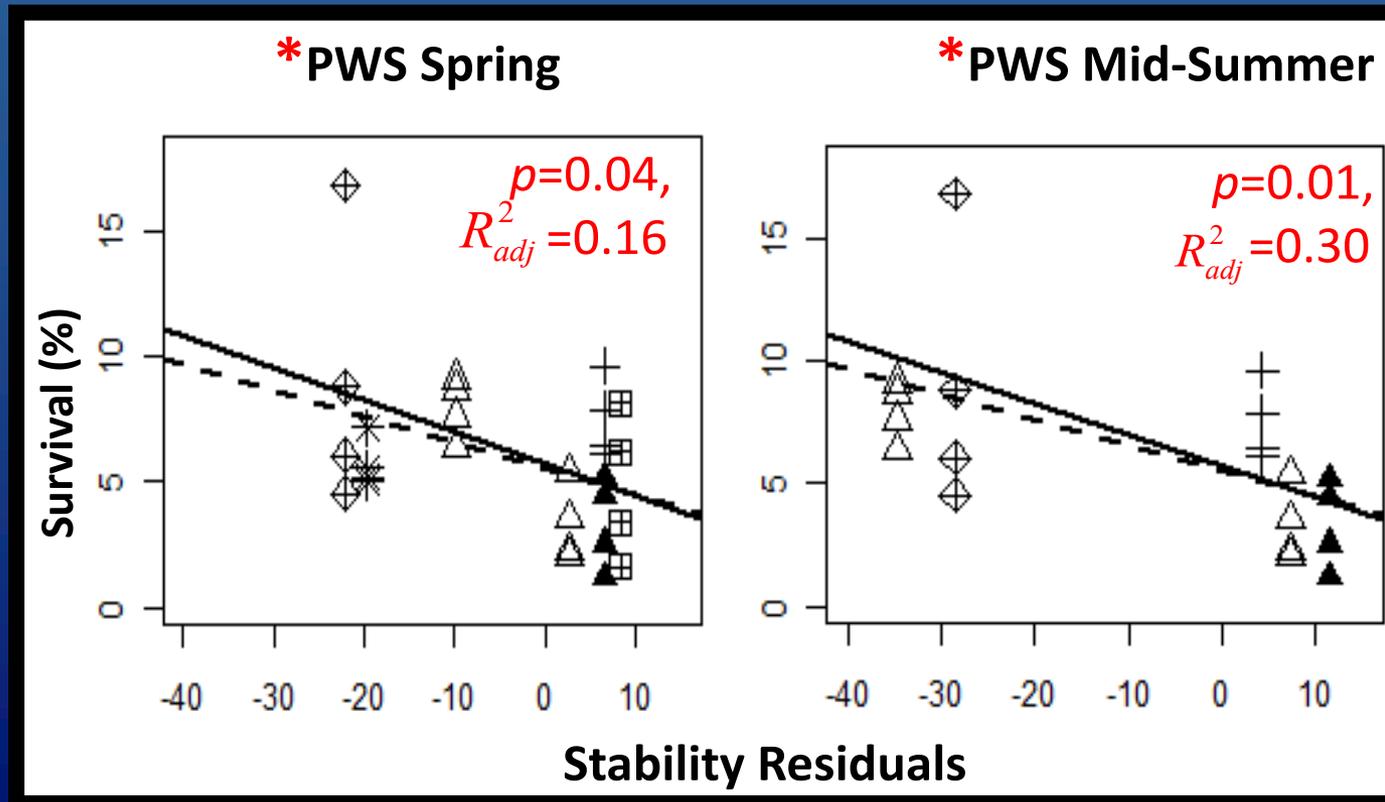
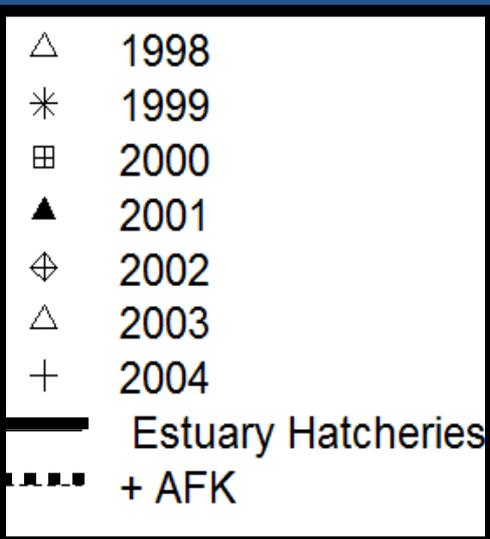


Stability Residuals

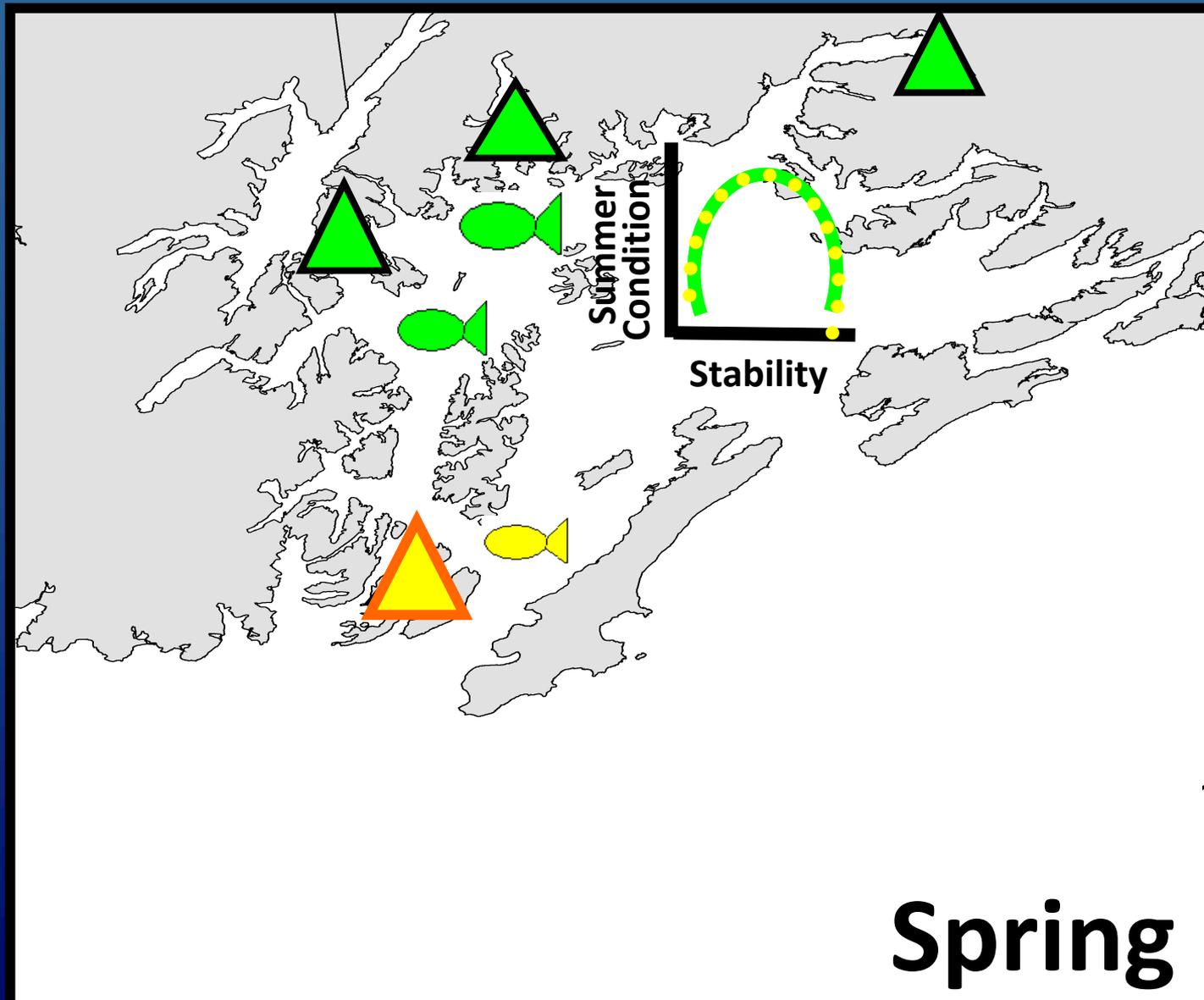
Stability Residuals

Results

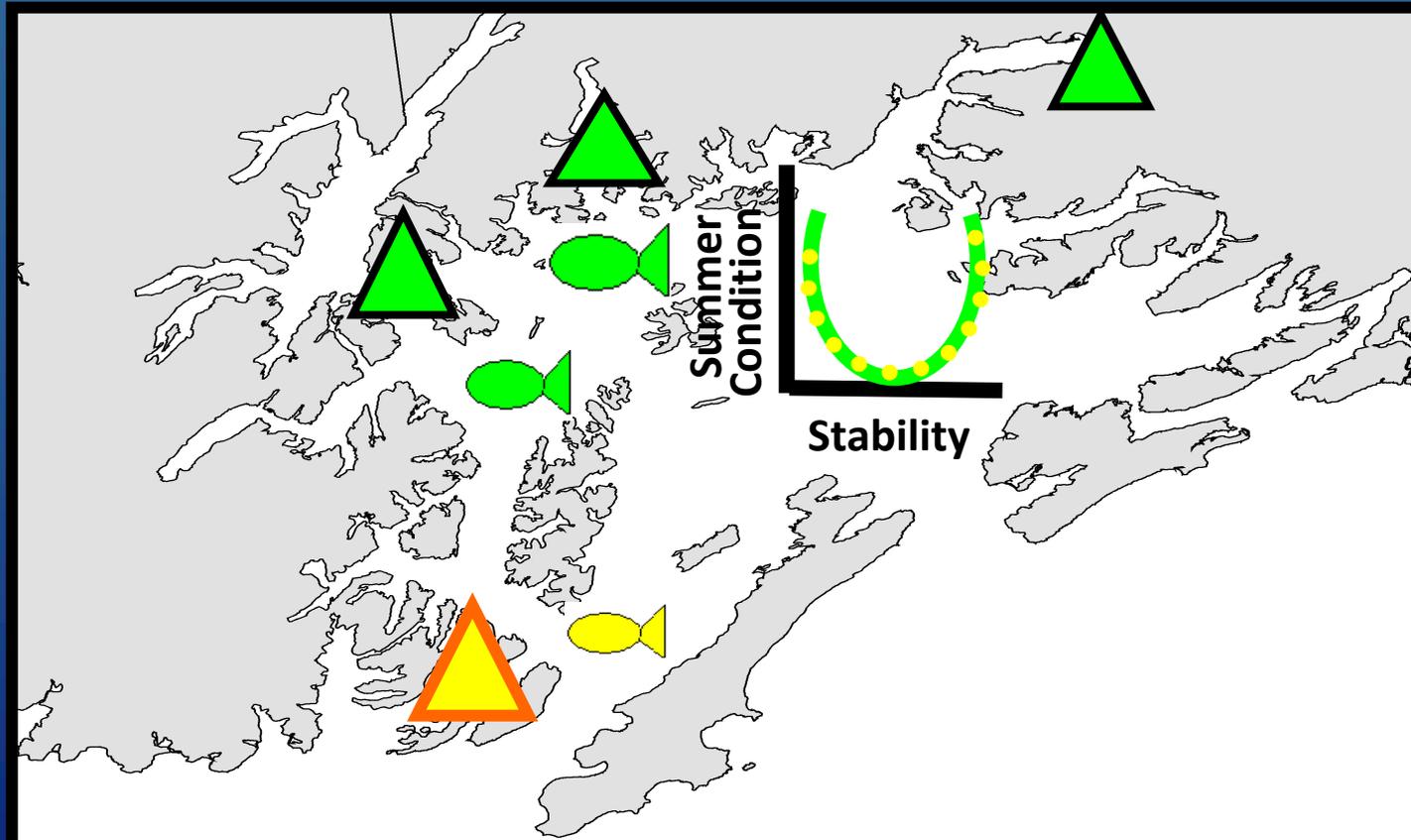
- Relationship between the PWS spring and mid-summer stability and adult hatchery survivals the following year was significant and negative.



Overall Conclusions

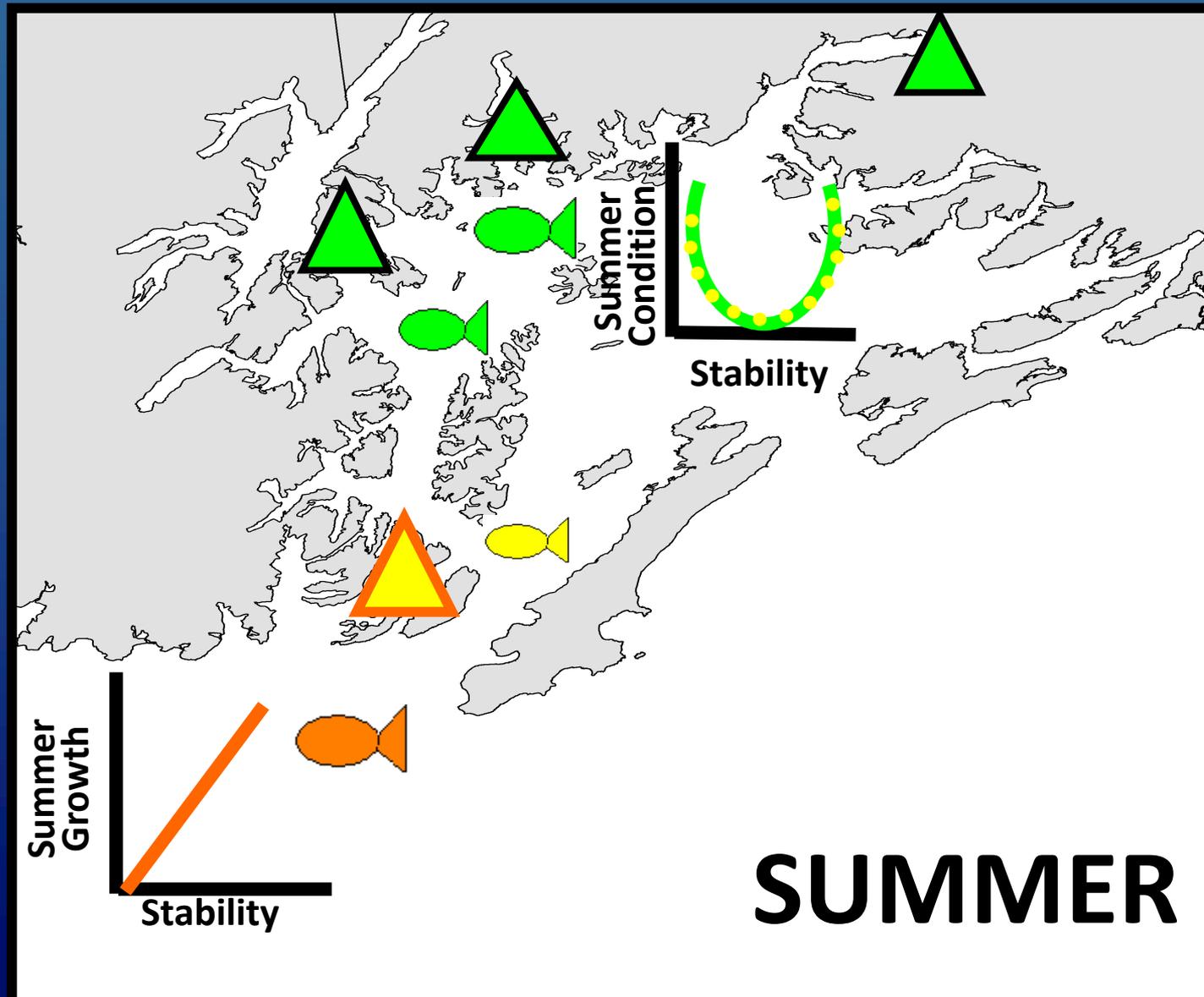


Overall Conclusions



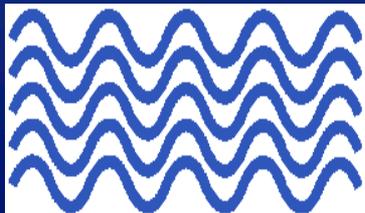
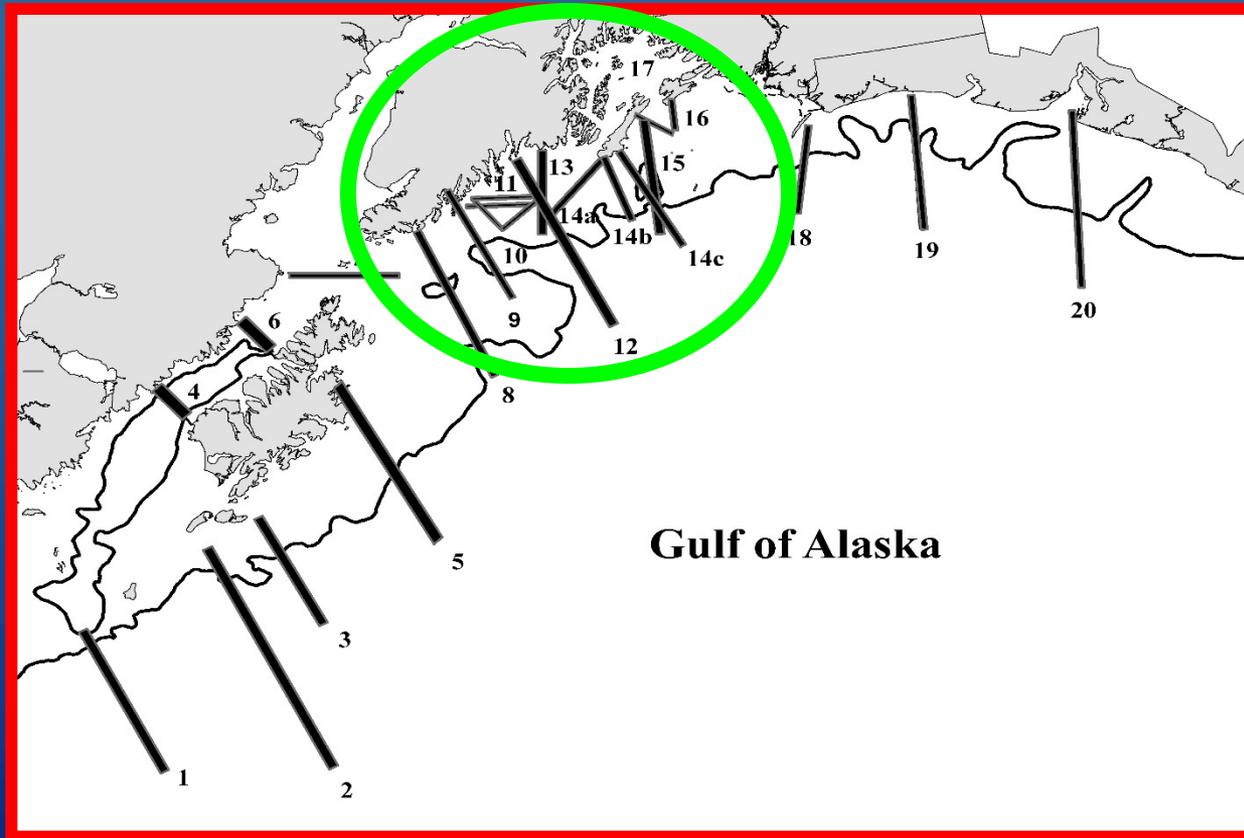
SUMMER

Overall Conclusions





Future Projects



June to October
1997-2004

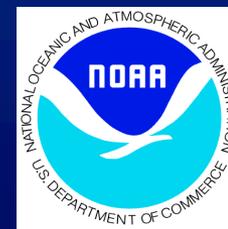


June to October
1997-2004

Acknowledgements

- Milo Adkison, Lew Haldorson (UAF, co-authors)
- Steve Moffitt (ADFG, Cordova)
- Jamal Moss, Ed Farley (NOAA, OCC)
- Jack Piccolo (UAF, GLOBEC)
- Mike Malick (UAF)
- Jennifer Boldt (UAF, UW)
- Ken Coyle (UAF)
- Keith Criddle (UAF)
- Ned Cokelet (NOAA)
- Lisa Eisner (NOAA)
- Stephanie Henson (University of Maine)
- Richard Thomson (Institute of Ocean Sciences)
- Nandita Sarkar (NOAA)
- Dione Cuadra (ADFG)

Funding: PCCRC, GLOBEC, NSF



References

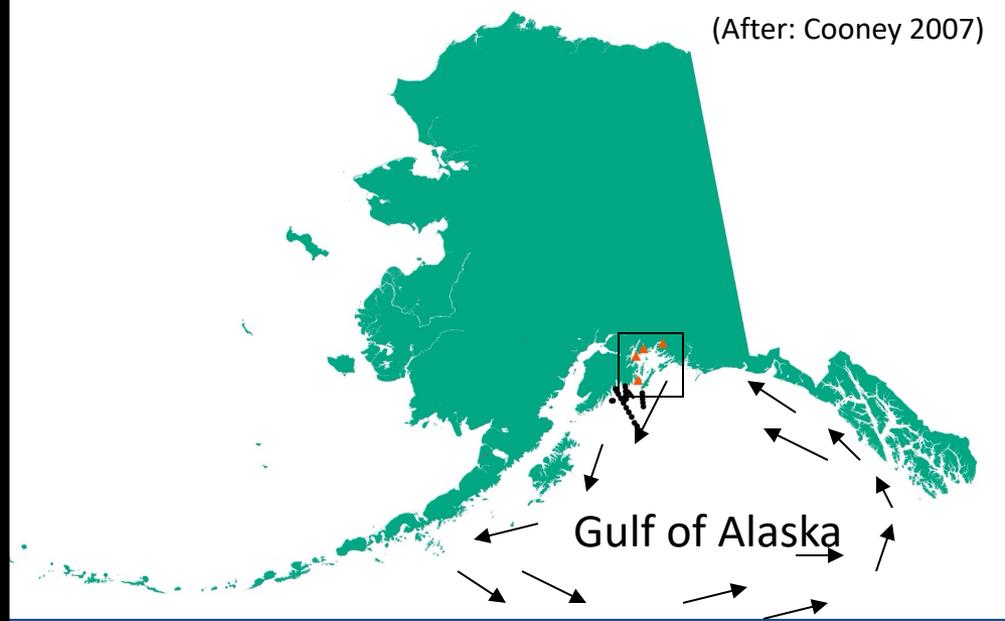
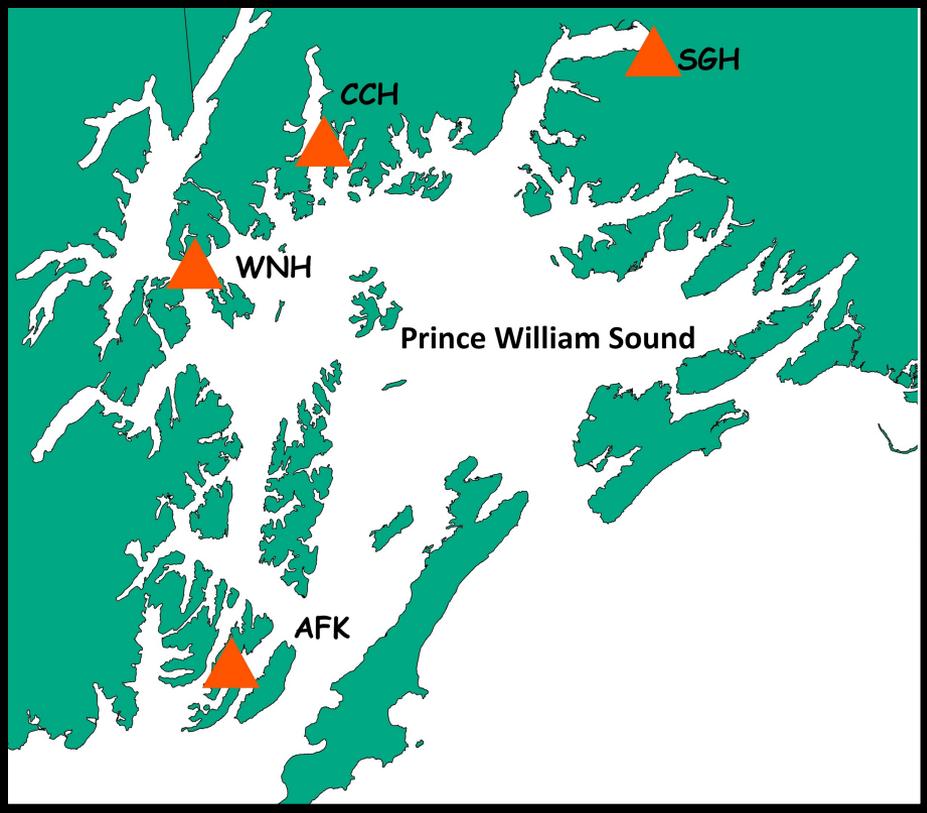
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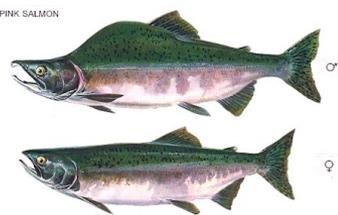
EXTRA SLIDES

The hydrographic information was averaged over a two week time period because in the northern GOA,

- sigma t at 75 m has been found to have 14 to 18 day fluctuations from April to July (Niebauer et al., 1981),
- on average the spring bloom commences about 10 days after stability is established (Henson, 2007), which, after a short time lag, supports high densities of zooplankton, that provide food for juvenile salmon and salmon prey (Cooney and Coyle, 1988; Boldt and Haldorson, 2003).

(After: Cooney 2007)



<p>Late Summer</p> 	<p style="writing-mode: vertical-rl; transform: rotate(180deg);">First Winter (7-8 Months)</p>	<p>Late April – Early June</p> 	<p>May-June</p> 	<p>July - Aug</p> 	<p style="writing-mode: vertical-rl; transform: rotate(180deg);">Second Winter (11 Months)</p>	<p>Summer</p> 
<p>Hatcheries spawn eggs</p>		<p>Hatcheries release fry into PWS</p>	<p>Near Shore Areas</p>	<p>Enter GOA (Samples collected)</p>		<p>Return to PWS Returns + Harvest /Releases=Survival %</p>

Methods

Condition index:

- Using the log transformed standard allometric equation, the estimates for large fish condition were biased
- Suggests fish exhibiting size dependent growth
- LOWESS models were fit with a range of smoothness values (0.2 – 0.9)
- Residuals examined from each of the fits to determine the proper smoothness value
- Residuals (condition index) from the LOWESS model were calculated for each fish

Methods

Standardized Growth Exponent:

$$G = \ln\left(\frac{W_c}{W_r}\right) / t$$

W_c =weight at time of capture

W_r =weight at time of release

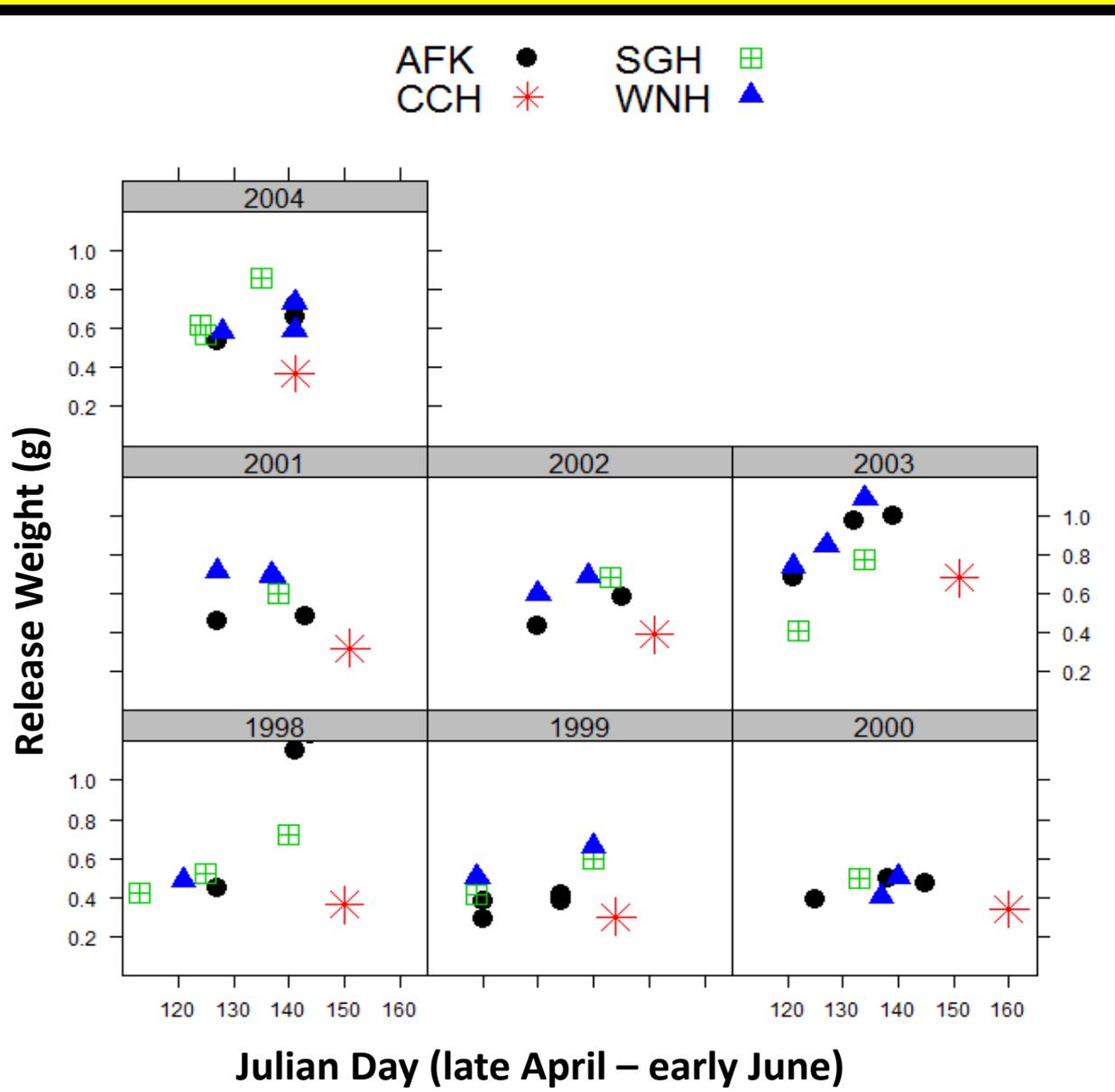
t =number of days between release and capture

$$G_{\text{stand}} = \frac{G - \bar{G}_i}{S_i}$$

i =AFK, CCH, SGH, or WNH



Methods



Methods

Summer Water Column Stability Calculation (Simpson et al. 1977)

$$\bar{v} = \frac{1}{h} \int_{-h}^0 (\bar{\rho} - \rho) g z dz; \quad \bar{\rho} = \frac{1}{h} \int_{-h}^0 \rho dz$$

where h =water column depth

z =vertical coordinate

g =acceleration of gravity,

ρ =density

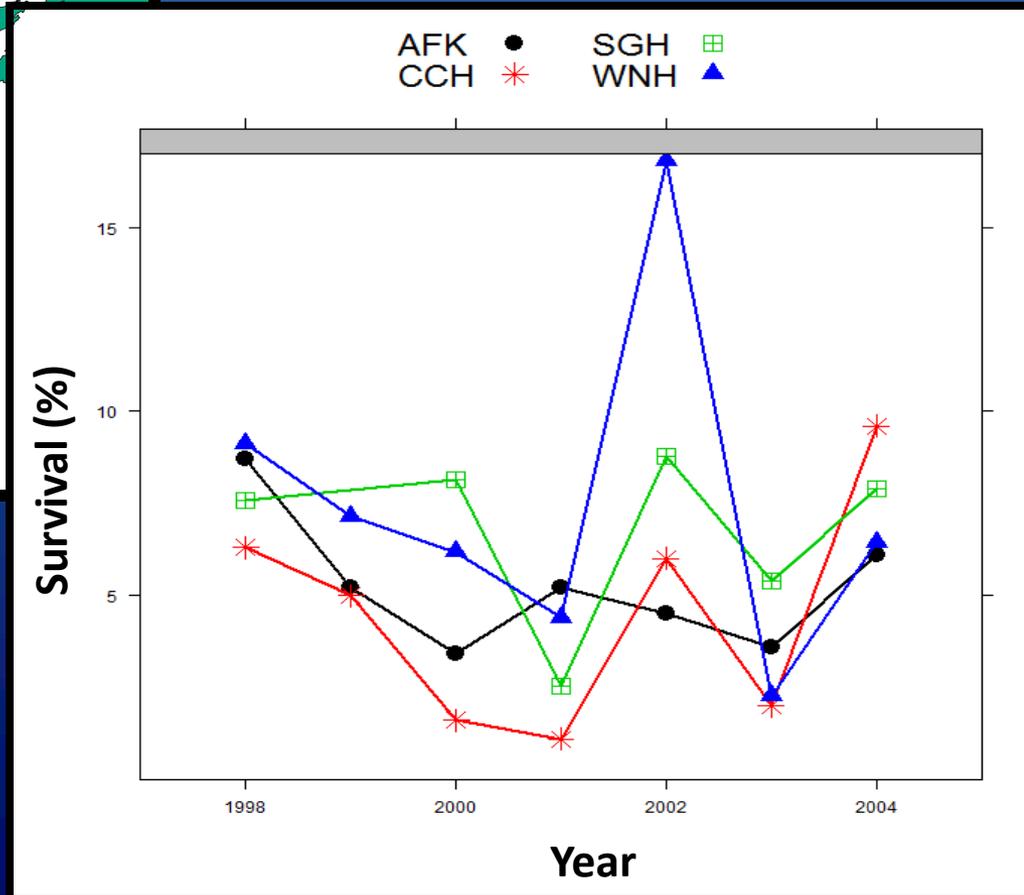
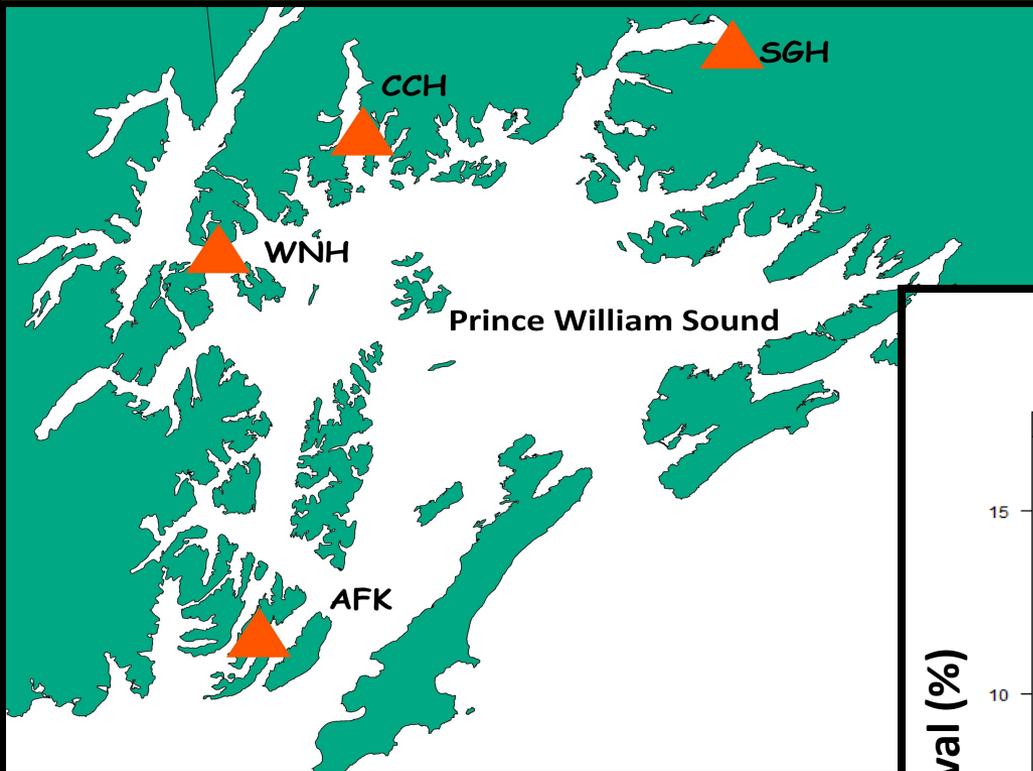
\bar{v} =work required to redistribute the mass during complete mixing
(stratification)

- Calculated down to 100 m at 1 m intervals

Methods

- Onset of stratification (about May) on inner shelf (ACC watermass) depends primarily on three-dimensional processes, circulation and mixing, that are driven by winds and coastal freshwater run-off.
- Onset of stratification (after inner shelf) is mainly driven by one-dimensional vertical mixing and air-sea heat exchange on the outer shelf (shelf watermass) (Weingartner et al. 2005).

Background



Results

PWS Dataset									
Fish variable	Source	df	SS	<i>F</i> -value	Significance	SS	<i>F</i> -value	Significance	
Condition index	Poly (Stability) (Early period)	2	0.0049	6.5472	0.0084	0.0049	9.6676	0.0008	
	Origin	3	0.0002	0.1813	0.9075				
	Stabilityxorigin	6	0.0001	0.0645	0.9986				
	Error	16	0.0060						
Condition index	Poly (Stability) (Later period)	2	0.0014	9.9022	0.0069	0.0014	8.7983	0.0024	
	Origin	3	0.0002	0.7722	0.5413				
	Poly (Stability)xorigin	6	0.0006	1.4694	0.2994				
	Error	8	0.0006						
Standardized growth exponent	Stability (Early period)	1	0.0938	0.0714	0.7943				
	Origin	5	5.6980	0.8670	0.5328				
	Stabilityxorigin	2	4.6158	1.7559	0.2179				
	Error	11	14.4581						
Standardized growth exponent	Poly (Stability) (Later period)	2	4.0275	18.8718	0.0092				
	Origin	4	2.7195	6.3714	0.0502				
	Poly (Stability)xorigin	3	6.3978	19.9856	0.0072				
	Error	4	0.4268						

Results

PWS Dataset				
	Coefficient	SE	<i>t</i>	<i>p</i> -value
Dependent variable: Condition index		$R^2_{adj}=0.3910$	$F(p\text{-value})=9.668(0.0008)$	
Intercept	-0.0021	0.0030	-0.7040	0.4879
Stability (Early period)	-0.0297	0.0160	-1.8580	0.0750
Stability ² (Early period)	-0.0636	0.0160	-3.9850	0.0005
Dependent variable: Condition index		$R^2_{adj}=0.4508$	$F(p\text{-value})=8.798(0.0024)$	
Intercept	0.0039	0.0020	1.9720	0.0651
Stability (Later period)	0.0060	0.0089	0.6760	0.5079
Stability ² (Later period)	0.0368	0.0089	4.1400	0.0007
Dependent variable: Growth (WNH)		$R^2_{adj}=0.5954$	$F(p\text{-value})=5.415(0.0727)$	
Intercept	-0.4068	0.3165	-1.2850	0.2680
Stability (Later period)	-0.9107	0.8375	-1.0870	0.3380
Stability ² (Later period)	-2.6014	0.8375	-3.1060	0.0360
Dependent variable: Survival		$R^2_{adj}=0.1640$	$F(p\text{-value})=4.923(0.0389)$	
Intercept	5.6968	0.7361	7.7390	<0.0001
Stability (Early period)	-0.1282	0.0578	-2.2190	0.0389
Dependent variable: Survival		$R^2_{adj}=0.3010$	$F(p\text{-value})=7.0300(0.0110)$	
Intercept	5.4820	0.9247	5.9280	0.0001
Stability (Later period)	-0.1164	0.0439	-2.6510	0.0200