Apr 6th, 8:30 AM - 8:45 AM

Reconstructing historical patterns of primary production in Puget Sound using growth increment data from shells of long-lived geoducks (Panopea generosa)

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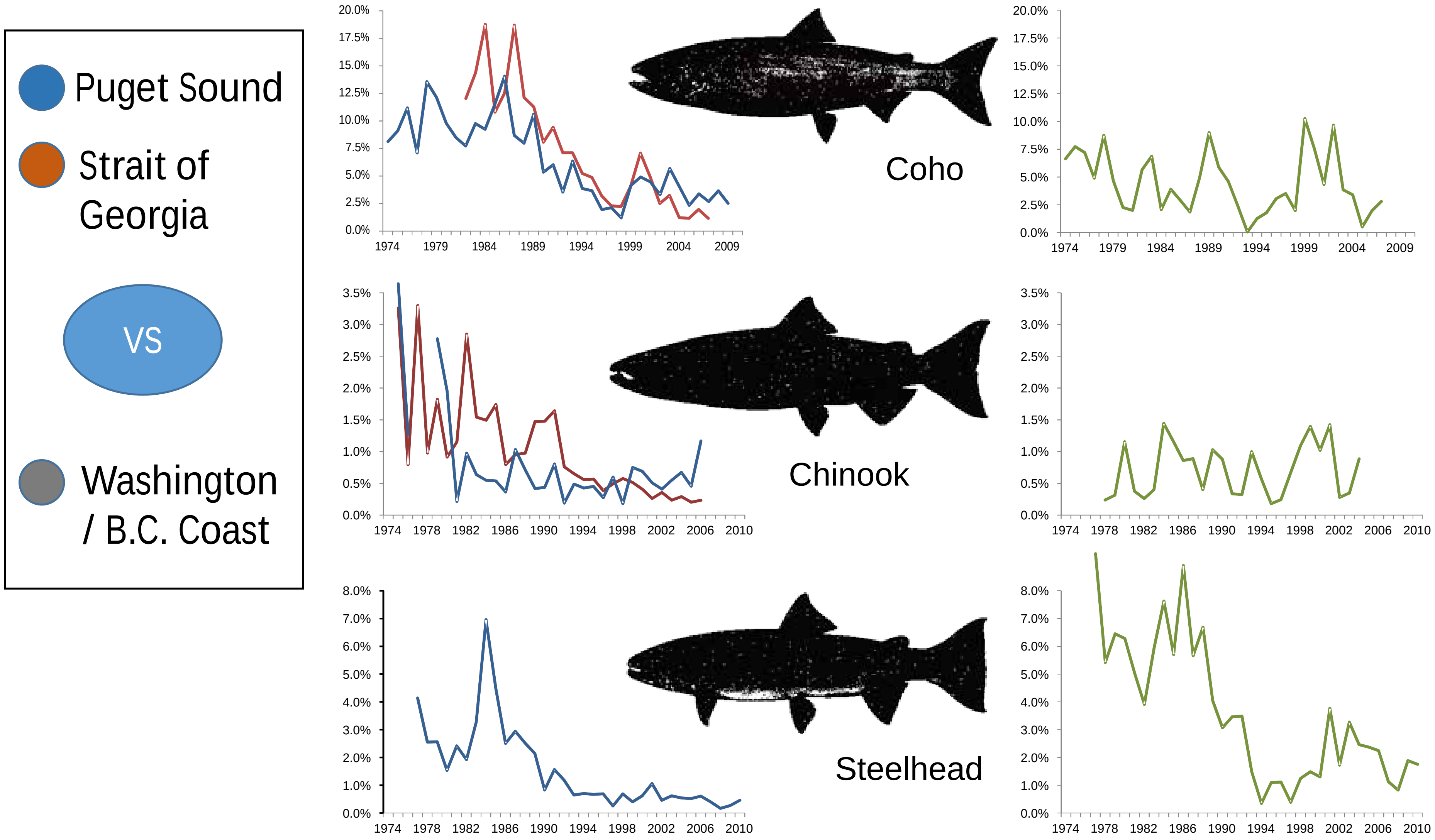
Eccles, Jenny; Greene, Correigh M.; Sobocinski, Kathryn; Stevik, Bethany; Carson, Henry; and Krembs, Christopher, "Reconstructing historical patterns of primary production in Puget Sound using growth increment data from shells of long-lived geoducks (Panopea generosa)" (2018). *Salish Sea Ecosystem Conference*. 429.
https://cedar.wwu.edu/ssec/2018ssec/allsessions/429

Speaker
Jenny Eccles, Correigh M. Greene, Kathryn Sobocinski, Bethany Stevik, Henry Carson, and Christopher Krembs

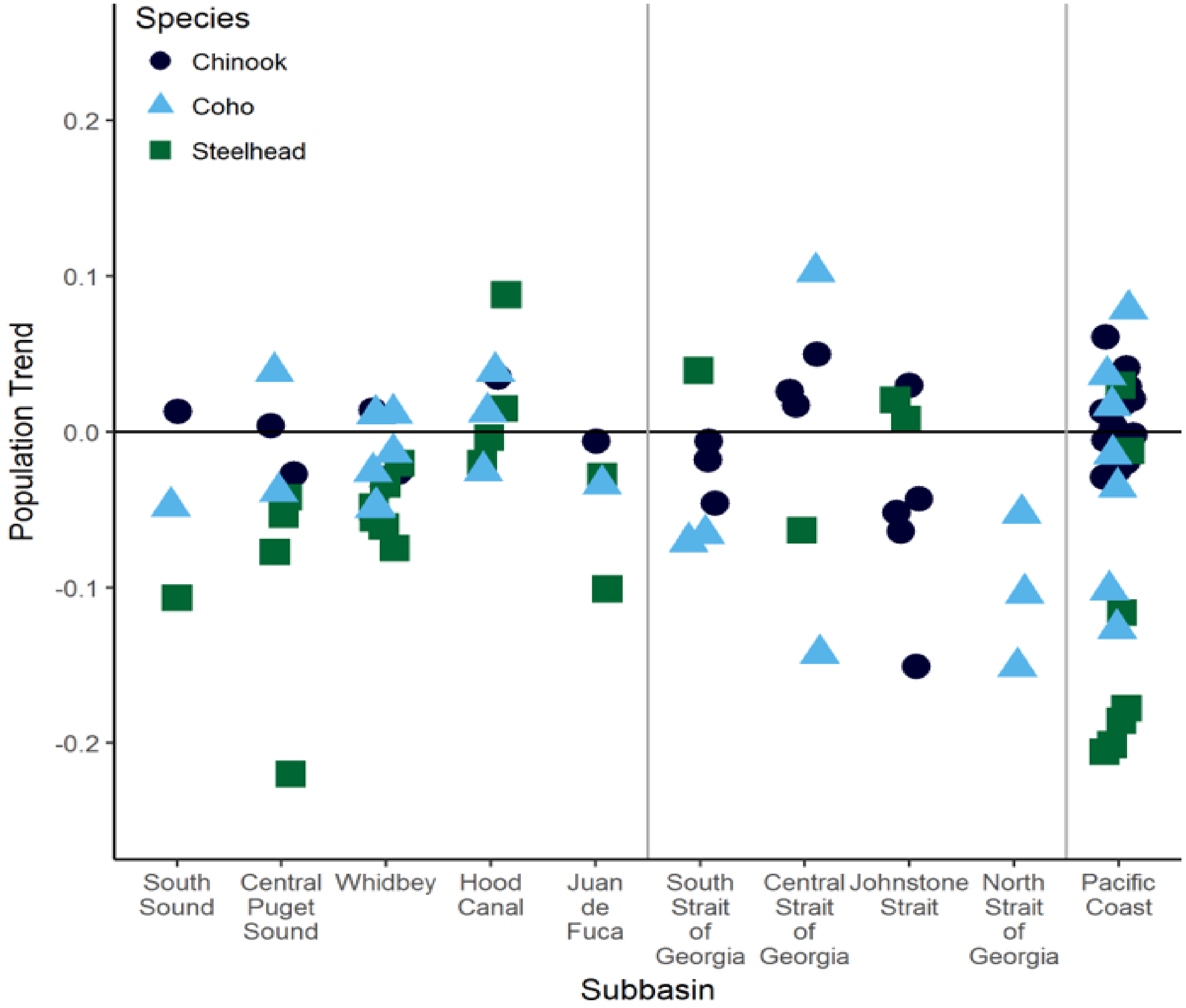
Reconstructing historical patterns of primary production using growth increment data from Geoduck (*Panopea generosa)* shells

Jennifer Eccles, Correigh Greene, Kathryn Sobocinski, Bethany Stevik, Chistopher Krembs, and Henry Carson

Declines in Salish Sea Marine Survival



Declines in Salish Sea Marine Survival



- Declines are basin specific
- Species within each basin are affected differently
- Effects of top-down and bottom-up processes are being considered
- **Our Question:** *Has primary production shifted in a way that is detrimental to marine survival?*

Primary Production

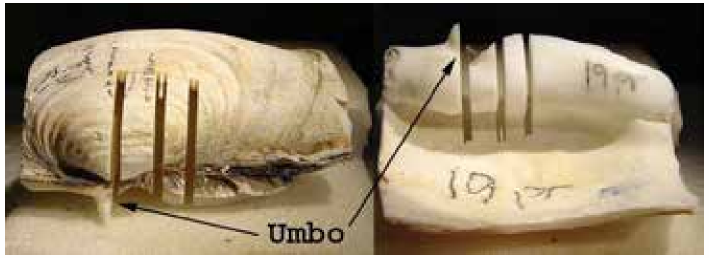
- Lack of a long term record for primary production
  - Some sampling from 1975-1989, more consistent sampling from 1990 onward
  - Record is sporadic spatially and temporally with disconnect between methods
- Is there a way to back-date the chlorophyll record as a metric of historical primary production?

Year	Admiralty I.	Central S.	Hood Canal	San Juans	South S.	SSOG	JDF	Whibey
1978			6					3
1979			12		30			11
1980			19		48			15
1981		4	21		36			14
1982		14	24		24			16
1983		13	18		19			12
1984		13	18		26			11
1985		14	19		45			14
1986		8	8		8			6
1987		12	15		18			8
1988	2	10	7		57	10	2	4
1989		11	3		28	8		7
1990	28	69	46	8	188	50	20	47
1991	48	105	92	34	157	45	48	56
1992	50	152	54	18	125	37		42
1993	60	89	41	4	161	44	8	40
1994	52	105	34	20	61	47	32	60
1995	64	183	45	38	100	40		98
1996	55	74	36	17	159	63	2	50
1997	57	82	32	31	90	82	16	62
1998	59	138	33		98	30		100
1999	57	78	29		191	22	46	26
2000	76	102	38		93	83	135	39
2001	63	113	32		110	32	83	30
2002	48	102	31		120	27	26	31
2003	32	65	29	15	67	43	15	46
2004	49	119	30		81	33	16	41
2005	96	172	146		264	80		85
2006	34	58	59		152	33		37
2007	28	78	80		100	57		37
2008	24	52	58		107	25		34
2009	38	112	80		119	41		48
2010	57	159	81		201	44		63
2011	45	105	66		201	60		53
2012	65	92	66		200	69		63
2013	62	93	68		195	73		68
2014	92	154	105	26	241	85	20	70
2015	90	187	122	27	199	33		68

Numbers in cells represent the number of samples taken per year at all depths (DOE)

Geoduck

- Geoduck are long lived (>100 years) and produce annual growth rings
- Growth likely occurs Mar-Oct[1] and is correlated with sea surface temperature and PDO.
- Filter feeders which are assumed to feed on phytoplankton



Are Strom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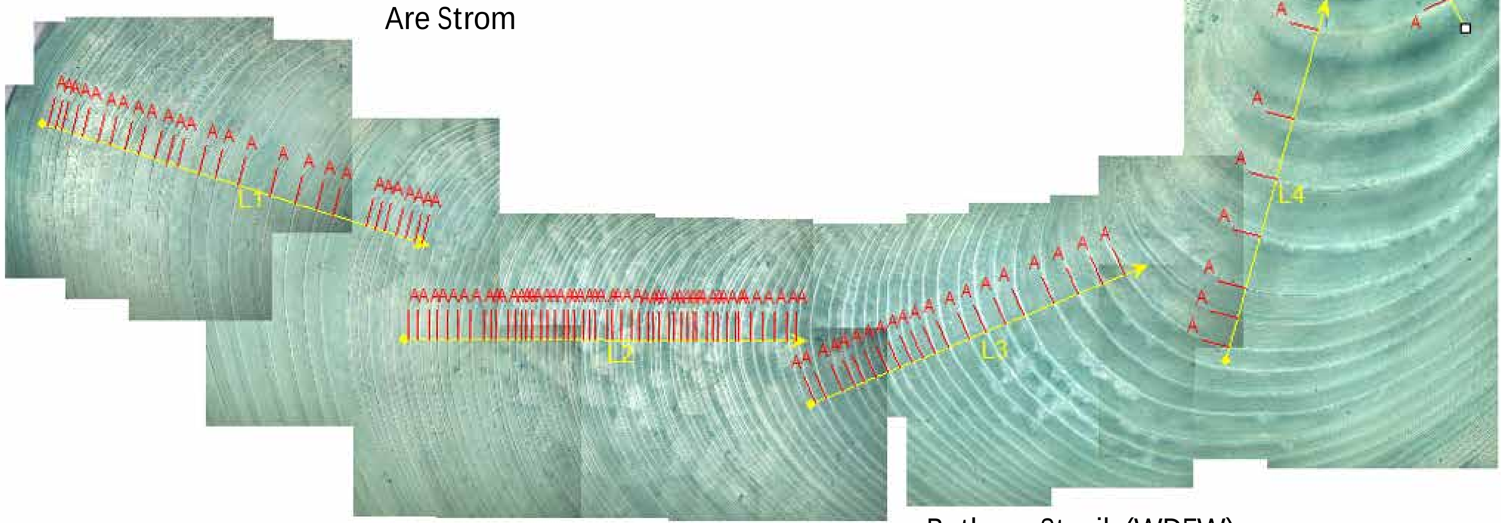
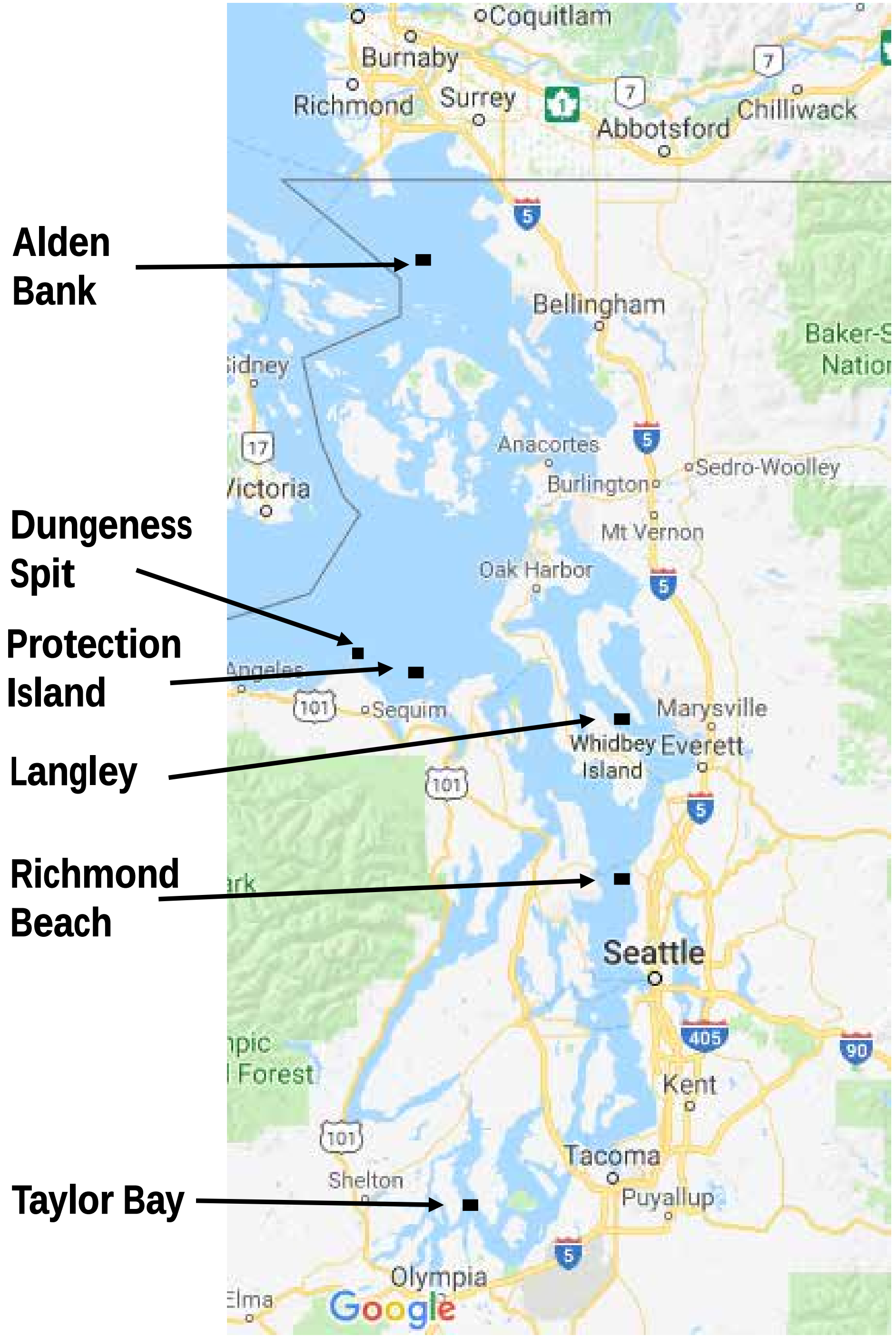
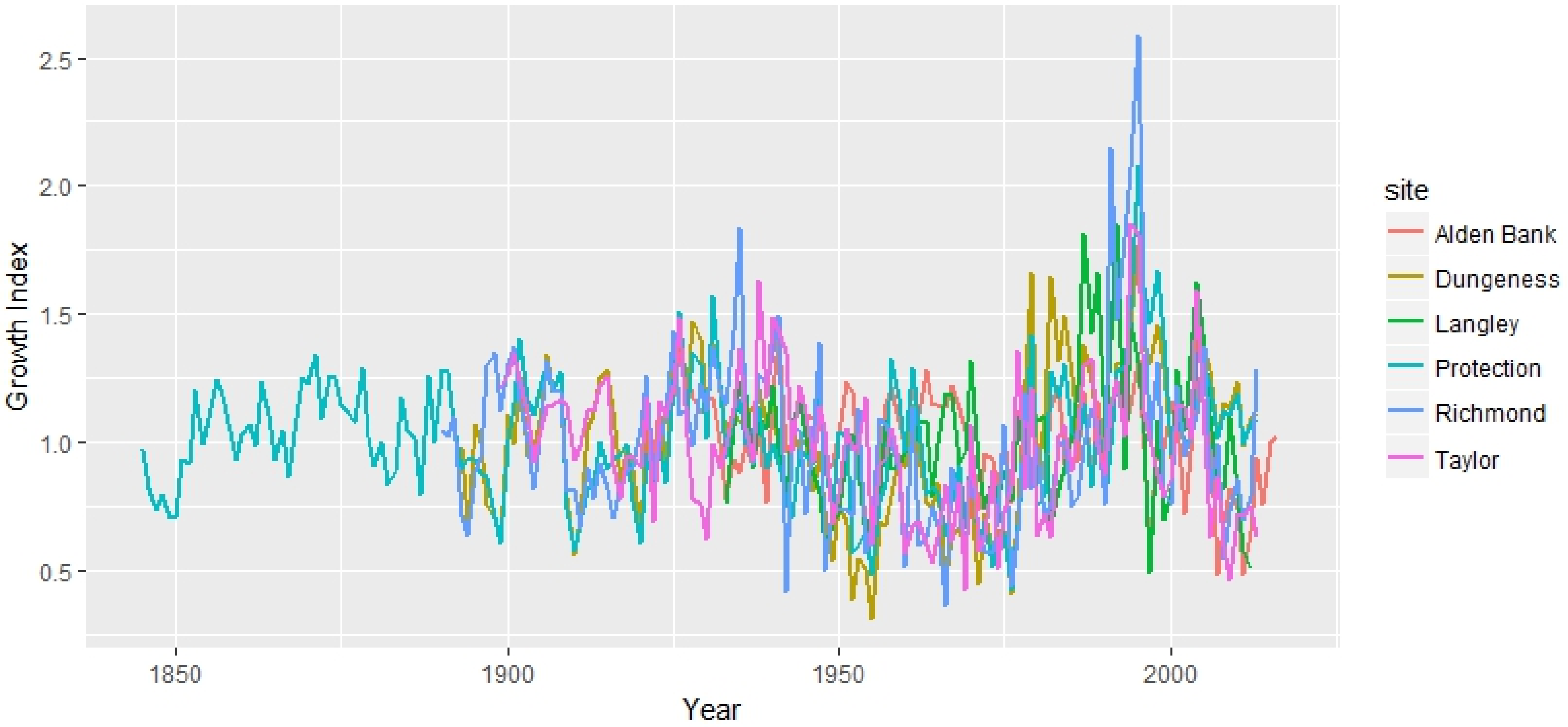

Bethany Stevik (WDFW)

Geoduck Growth Indices

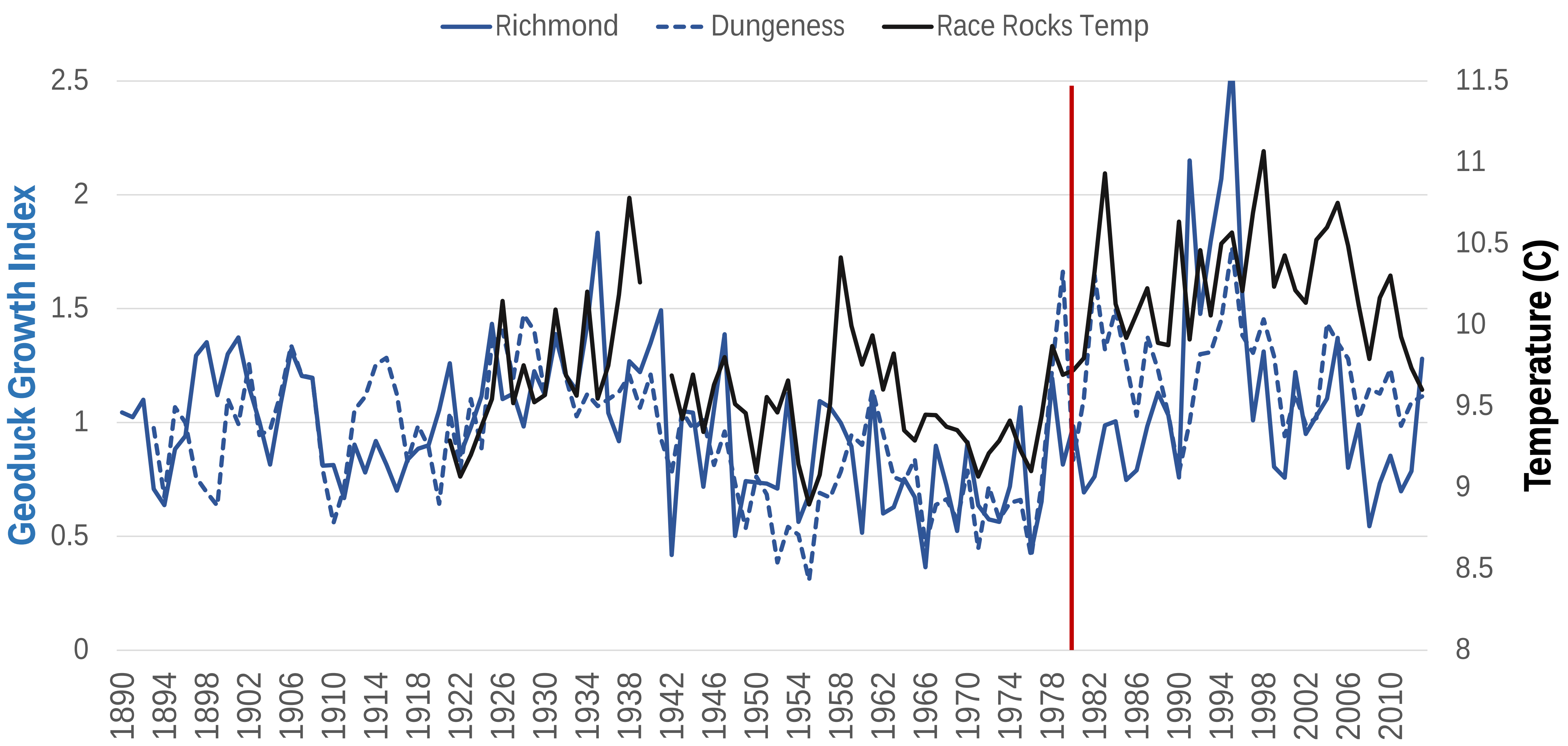
- Geoduck from a particular site are aged and a growth index is calculated
  - Growth index is a metric for the population for a given year.
- Indices from six sites are being utilized
- The growth index is variable across all sites, and some sites are more similar than others.



Geoduck Growth Across Sites

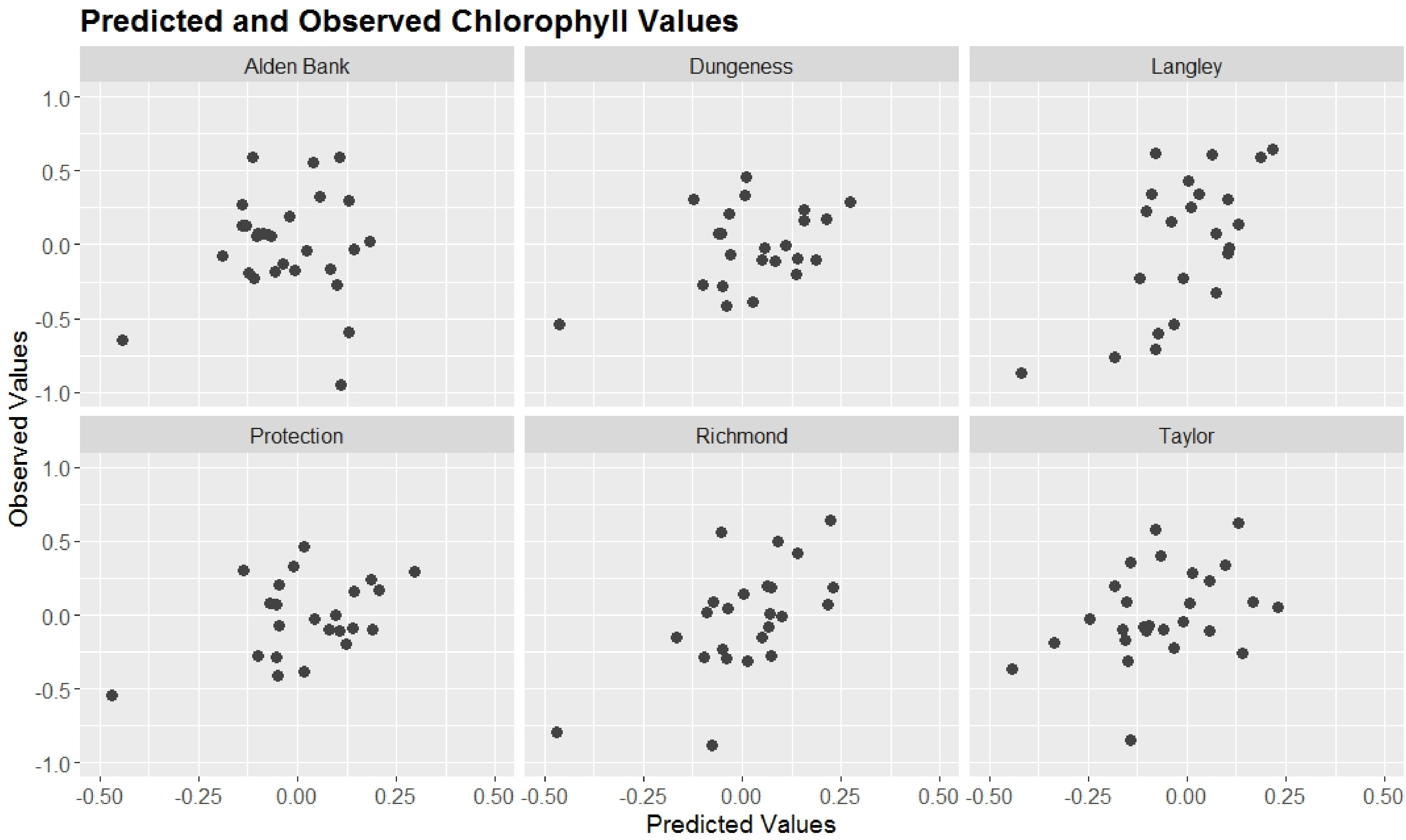


Geoduck Growth and Temperature

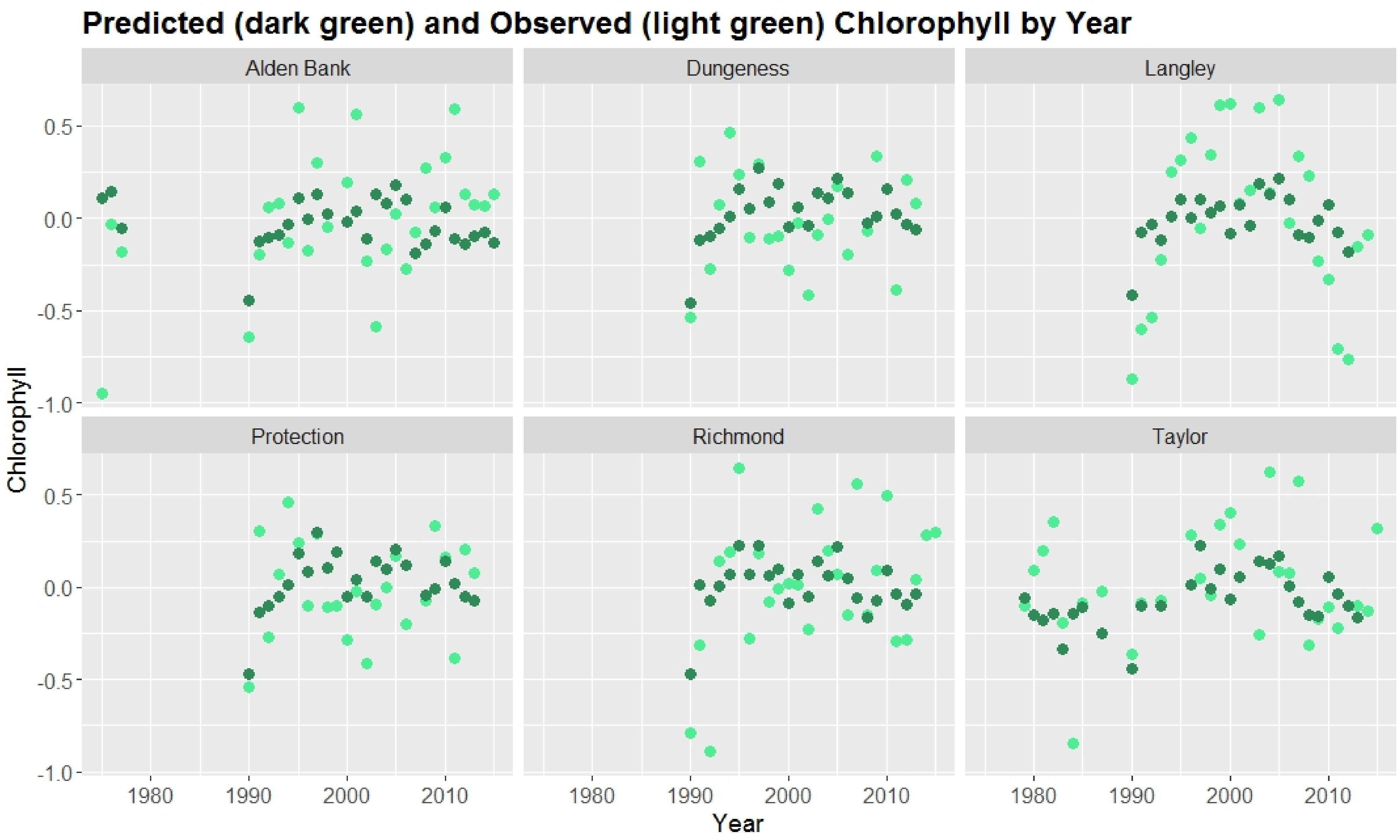


Methods for Predicting Historical Primary Production

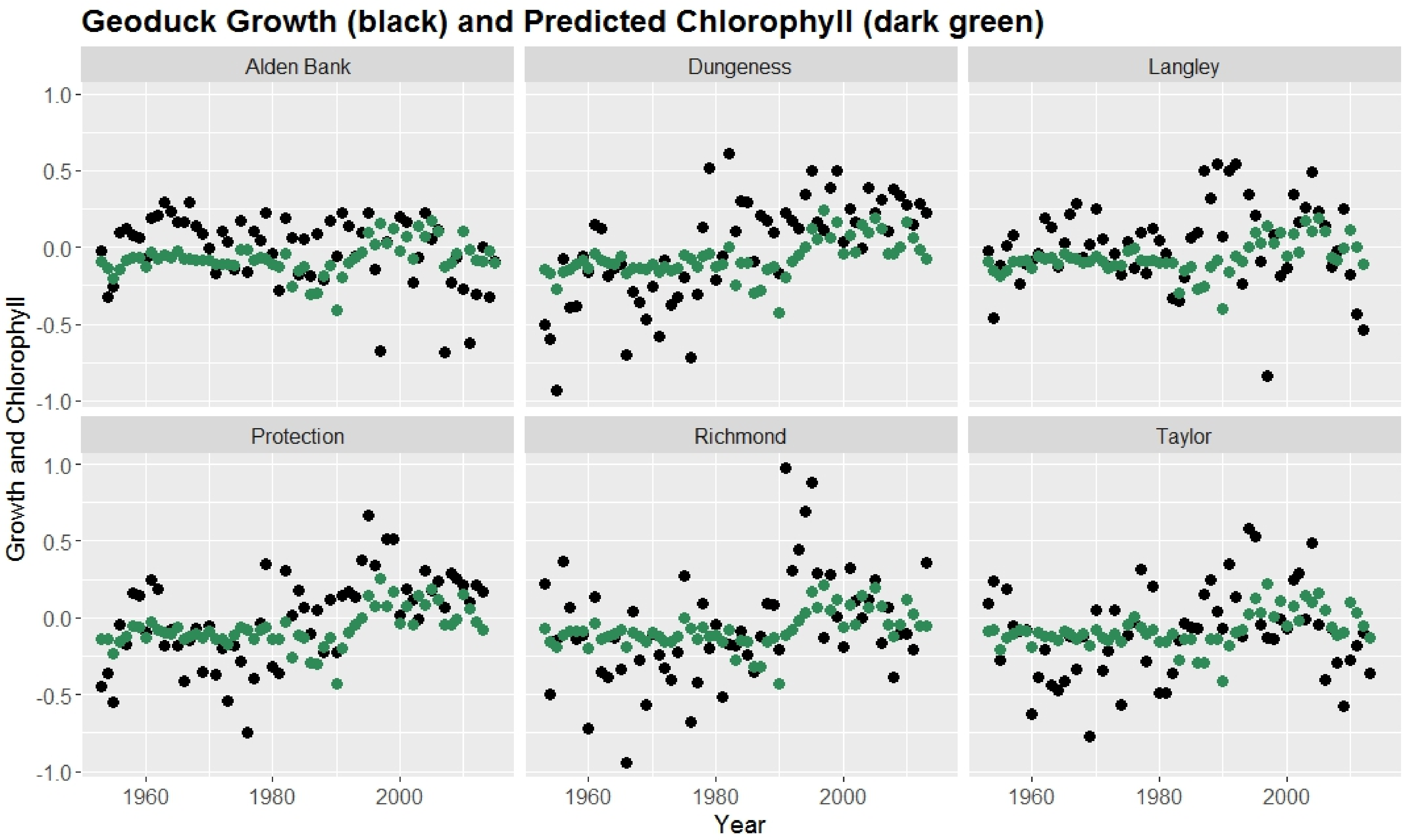
- Construct a model to explain patterns in chlorophyll using geoduck growth and other long term variables.
- Controlled for temperature in chlorophyll and growth
- Best mixed effects model includes
  - Geoduck growth
  - Stratification metric
  - Wind Speed
  - Interaction between stratification and windspeed
  - Site used as a blocking factor and temporal auto correlation is included
  - Overall variation explained is 17%



Predicted and Observed Chlorophyll Values
Alden Bank
Dungeness
Langley
Protection
Richmond
Taylor
1.0
0.5
0.0
-0.5
-1.0
-0.50
-0.25
0.00
0.25
0.50
Observed Values
Predicted Values



Predicted (dark green) and Observed (light green) Chlorophyll by Year
Alden Bank
Dungeness
Langley
Protection
Richmond
Taylor
Chlorophyll
0.5
0.0
-0.5
-1.0
1980
1990
2000
2010
Year



Geoduck Growth (black) and Predicted Chlorophyll (dark green)
Alden Bank
Dungeness
Langley
Protection
Richmond
Taylor
1.0
0.5
0.0
-0.5
-1.0
Growth and Chlorophyll
1960
1980
2000
Year

Summary For Predicting Primary Production

- Geoduck growth can be used together with other variables to predict historical chlorophyll levels.
- Temporal autocorrelation is very important
- There is an important pattern despite the chlorophyll observation error.
- Production appears affected by winds and stratification, as has been hypothesized previously for optimal chlorophyll production windows.

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Next Steps

- See if there are any minor adjustments that can improve model performance.
- Cross check the different methods of chlorophyll collection in overlapping time periods
- Investigate the relationship between salmon survival data and modeled chlorophyll
- Consider the correlations between geoduck growth and salmon survival

Salmonography.com

Thank You

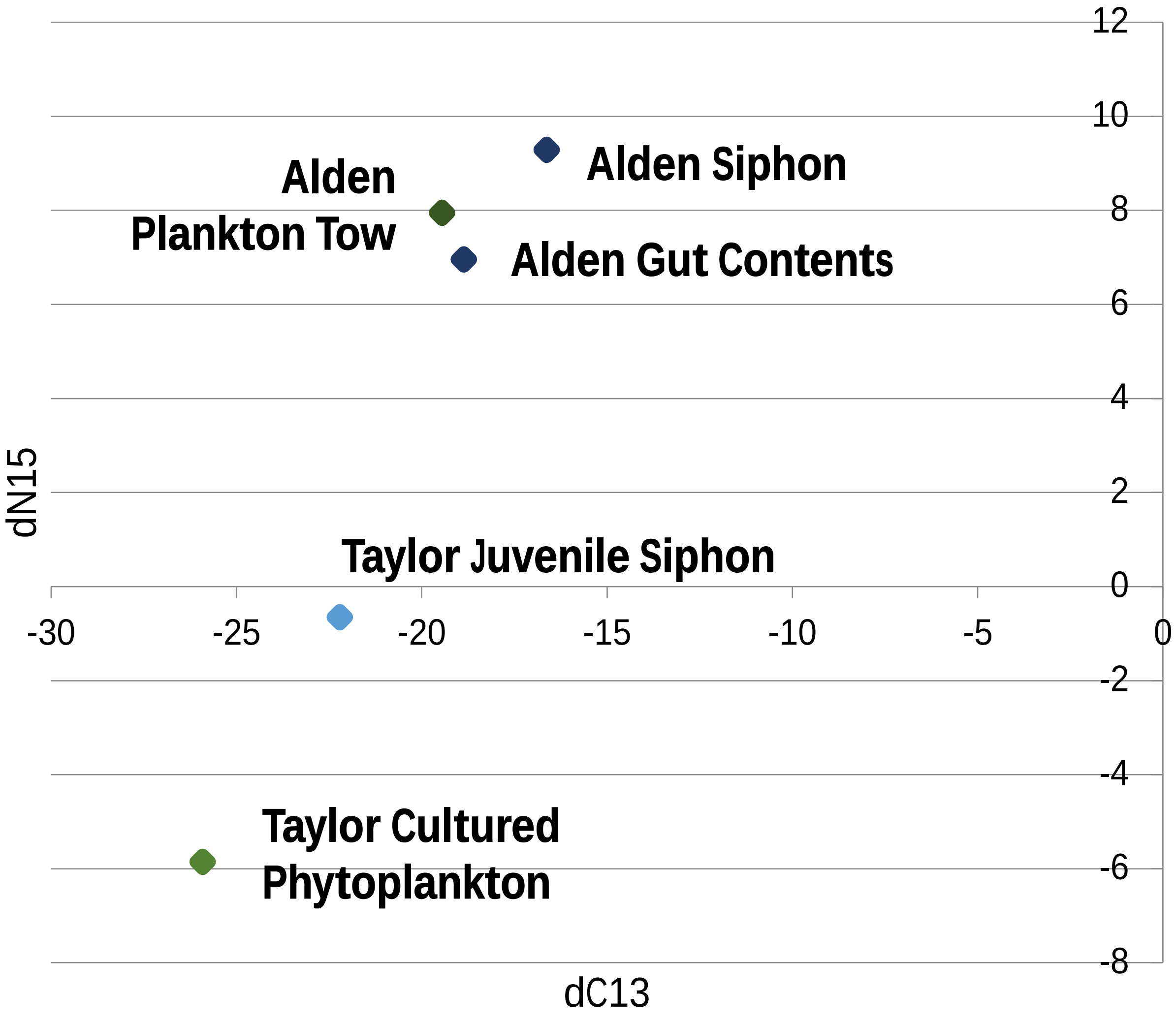
- ***Funding***
  - Salish Sea Marine Survival Project (Long Live the Kings)
- ***Growth Indices***
  - Bethany Stevik (WDFW)
  - Are Strom
  - Brian Black
- ***Geoduck and algae samples***
  - WDFW Shellfish Dive Team
  - Taylor Shellfish
  - Tulalip Tribes
- ***Data***
  - Department of Ecology
  - WDFW
  - Fisheries and Oceans Canada
  - University of Washington Oceanography
- ***Data Analysis and other help***
  - Iris Kemp
  - Lance Campbell
  - Jan Newton

References

1. Strom, A., et al. 2004. North pacific climate recorded in growth rings of geoduck clams: A new tool for paleoenvironmental reconstruction. Geophysical Research Letters, 31, L06206
2. Zimmerman, M.S., et al. 2015. Spatial and temporal patterns in smolt survival of wild and hatchery coho salmon in the Salish Sea. Marine and Coastal Fisheries, 7, 116-134

Geoduck Stable Isotopes

- Adult geoduck samples were taken from Alden Bank
- Vertical and horizontal tows were conducted at each site to capture plankton
- Taylor Shellfish provided 15mm juvenile geoduck and samples of their diet.
- dN of other species
  - Salmon[2]: dN >10
  - Marine algae[2]: dN = 4-7
  - Estuarine-marine phytoplankton[3]: dN = 6-10
  - SOG zooplankton[4]: 7-14



Geoduck Coho Correlations

- The EXP growth index correlates more often with coho marine survival

		Central Sound		*Whidbey Basin*		*South Sound*			*Hood Canal*			*Rosario*	*Juan de Fuca*		*Coast*	
		Green	**Puallup**	**Tulalip**	**Skykomish**	**Deschutes**	**Kalama**	**Minter**	**Quilcene**	**Skokomish**	**Big Beef**	**Nooksack**	**Snow**	**Dungeness**	**Carnation**	**PS wide**
EXP	**Richmond B.**	-0.35	-0.03	0.12	0.00	-0.36	0.09	-0.43	-0.19	-0.06	-0.04	-0.01	-0.18	-0.13	-0.36	-0.10
	Taylor B.	-0.10	0.33	0.35	0.37	-0.36	0.37	0.04	0.11	0.14	0.29	0.17	0.07	0.09	-0.16	0.19
	Alden B.	0.14	0.41	0.34	0.39	0.28	0.24	0.23	0.16	0.31	0.31	0.39	0.15	0.53	-0.29	0.35
	Langley	0.35	0.38	0.35	0.52	0.14	0.23	0.21	0.33	0.26	0.39	0.44	0.05	0.02	0.12	0.38
RCS	**Richmond B.**	0.07	0.19	0.14	0.37	0.13	0.46	0.01	-0.02	-0.17	-0.10	0.52	-0.55	0.00	0.21	0.12
	Taylor B.	-0.04	0.12	0.18	0.43	0.14	0.01	0.15	0.21	-0.13	0.13	0.36	-0.32	0.18	0.11	0.07
	Alden B.	-0.06	0.01	0.04	0.09	0.24	-0.22	0.23	0.10	-0.08	-0.04	0.32	0.23	-0.20	0.02	0.00
	Langley	-0.24	-0.06	-0.14	-0.11	0.05	0.28	-0.12	0.17	0.11	0.09	0.03	0.37	0.13	-0.17	0.06

> 0.3	> 0.4	> 0.5

Geoduck Chinook Correlations

- Fewer strong correlations with chinook, but the EXP geoduck index still performs better

		Strait of Georgia			Puget Sound							
		Northern	*Central*	*Southern*	*South*	*Central*	*Hood Canal*	*Whidbey Basin*	*Juan de Fuca*	*Coast*	*PS-wide*	*Salish Sea*
EXP	**Richmond B.**	-0.49	-0.43	-0.38	0.10	-0.07	-0.52	-0.28	-0.04	-0.42	-0.32	-0.40
	Taylor B.	-0.20	-0.31	-0.52	0.05	-0.07	-0.27	-0.02	0.08	-0.14	-0.22	-0.24
	Alden B.	0.15	0.02	0.02	0.23	0.20	-0.20	0.01	0.17	0.04	0.08	0.06
	Langley	-0.07	-0.08	-0.24	0.14	-0.05	0.01	0.03	0.18	0.14	-0.05	-0.10
RCS	**Richmond B.**	-0.24	0.06	0.01	0.32	0.03	-0.29	0.16	-0.11	0.12	-0.03	-0.10
	Taylor B.	-0.14	0.11	-0.19	0.05	-0.20	-0.23	0.18	-0.20	-0.07	-0.19	-0.20
	Alden B.	0.07	0.07	-0.13	-0.09	-0.09	-0.02	0.05	-0.01	0.09	-0.06	-0.05
	Langley	0.06	-0.23	-0.28	-0.18	-0.04	0.08	-0.26	0.18	-0.08	-0.16	-0.12

>0.3	>0.4	>0.5

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1. Strom, A., et al. 2004. North pacific climate recorded in growth rings of geoduck clams: A new tool for paleoenvironmental reconstruction. Geophysical Research Letters, 31, L06206
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