

Winter and summer upwelling modes and their biological relevance in the California Current

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Seven time series



yelloweye rockfish
piscivorous

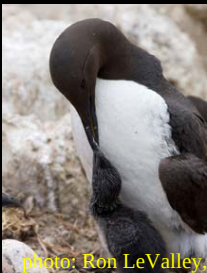


splitnose rockfish
planktivorous



Chinook salmon
piscivorous

**growth-increment
chronology**



common murre
piscivorous

egg lay date

and



Cassin's auklet
planktivorous

fledgling success

Splitnose rockfish

Splitnose rockfish (*Sebastes diploproa*)

80+ yrs old

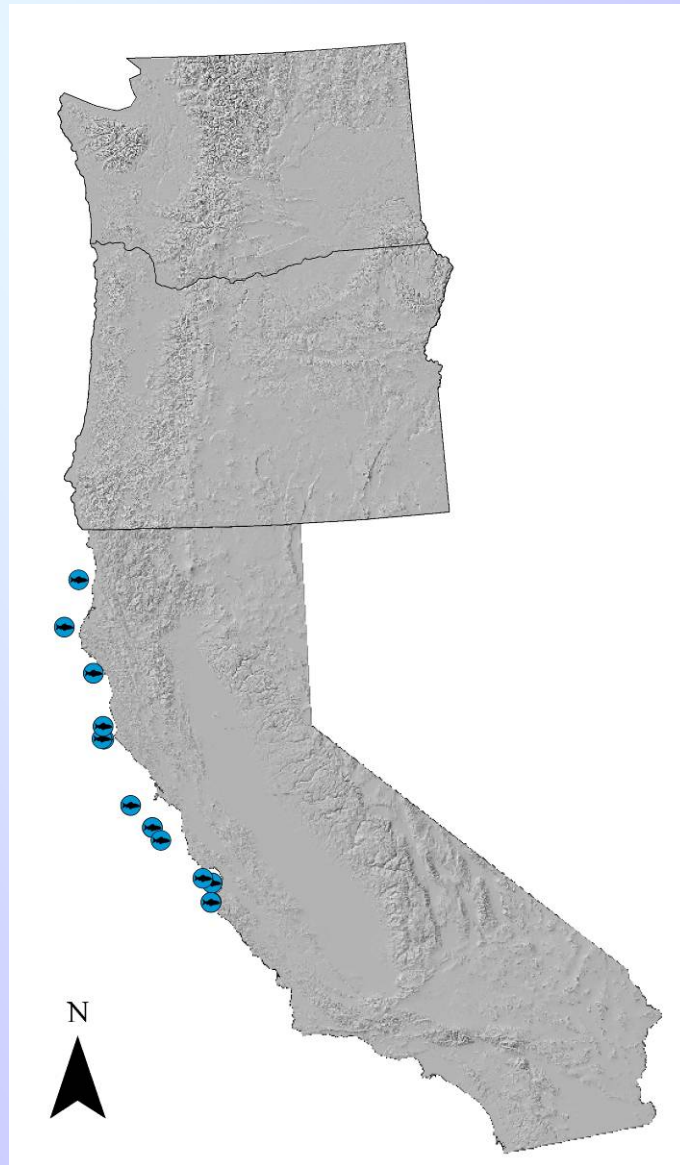
300 m depth; live on shelf floor

collected 1980, 1989, 1995, 2008

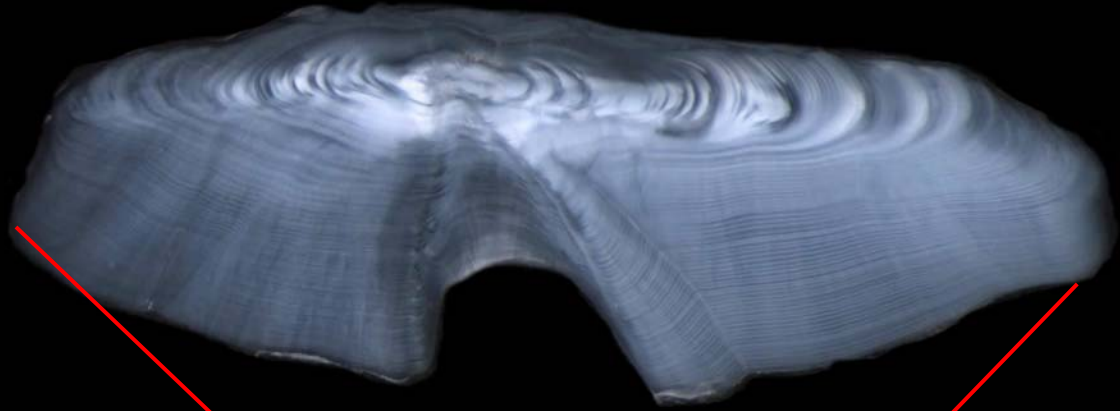


Photo credit:Lifted from M. Love's webpage

Splitnose rockfish sampling locations



Otolith thin sectioning

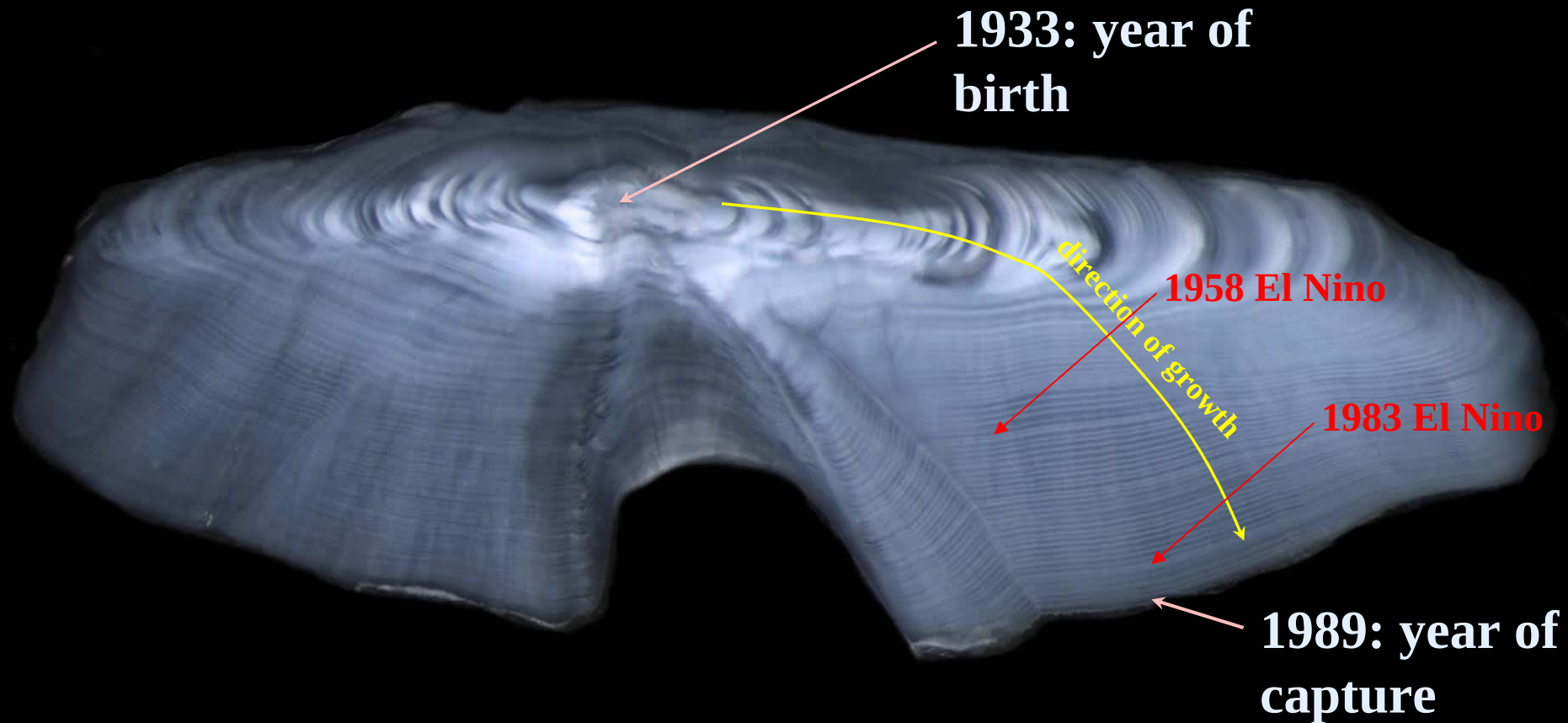


cut here

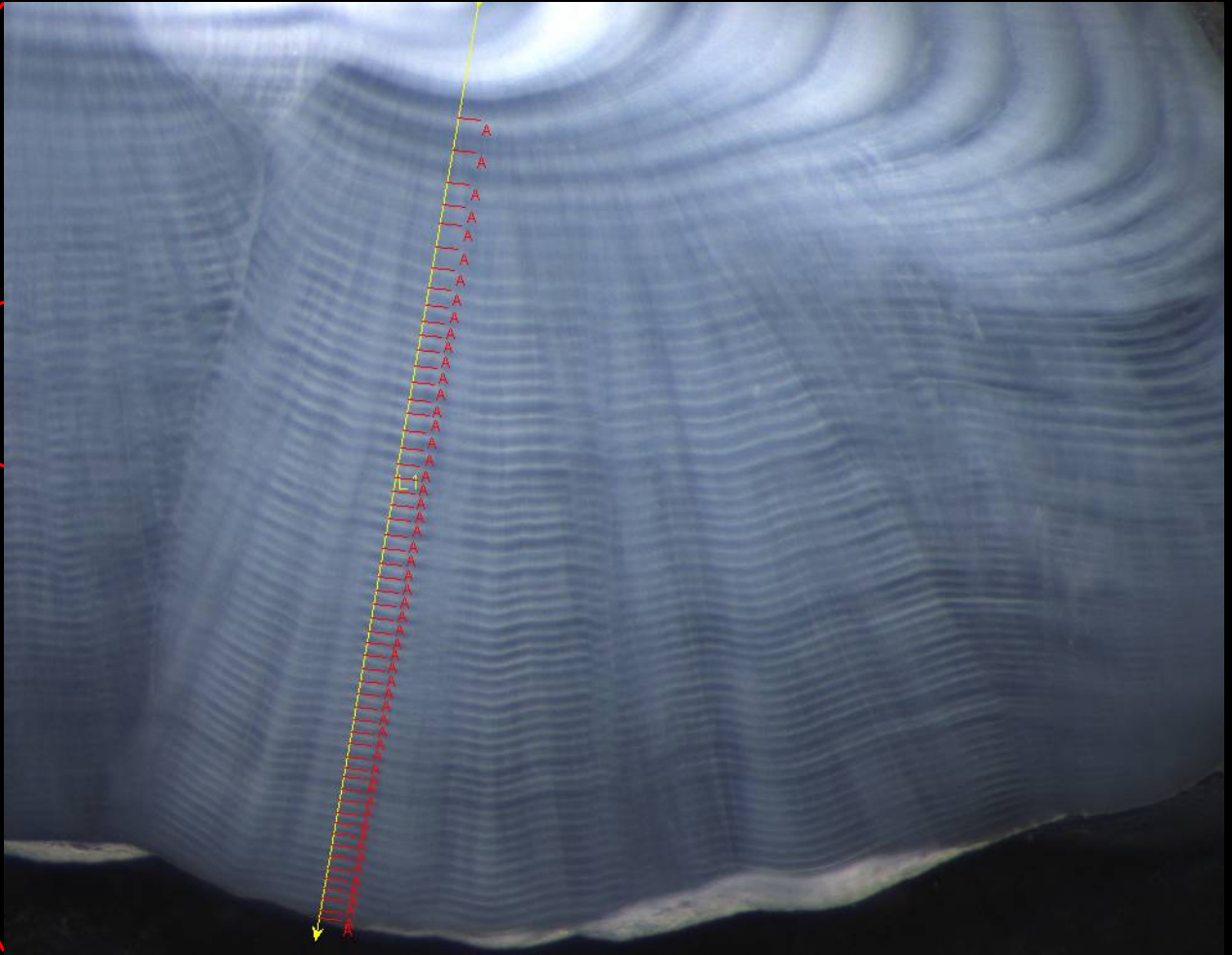
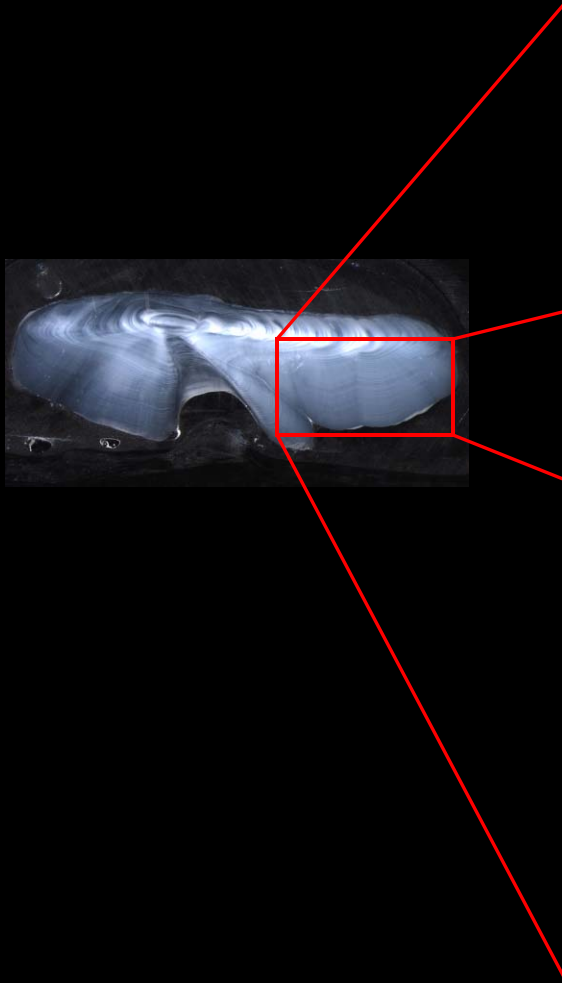


Splitnose otolith

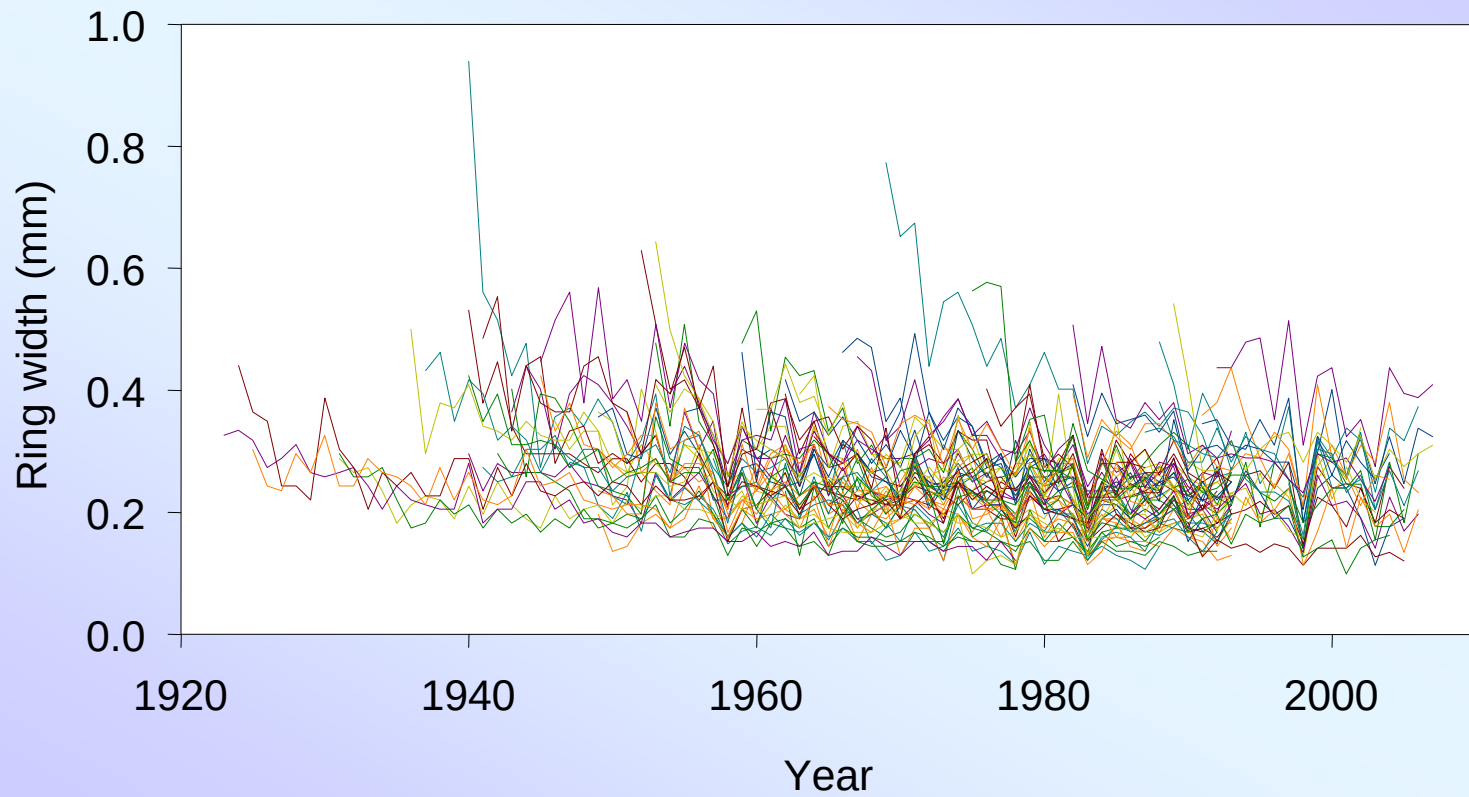
Annual growth increments analogous to trees



Axis of measurements

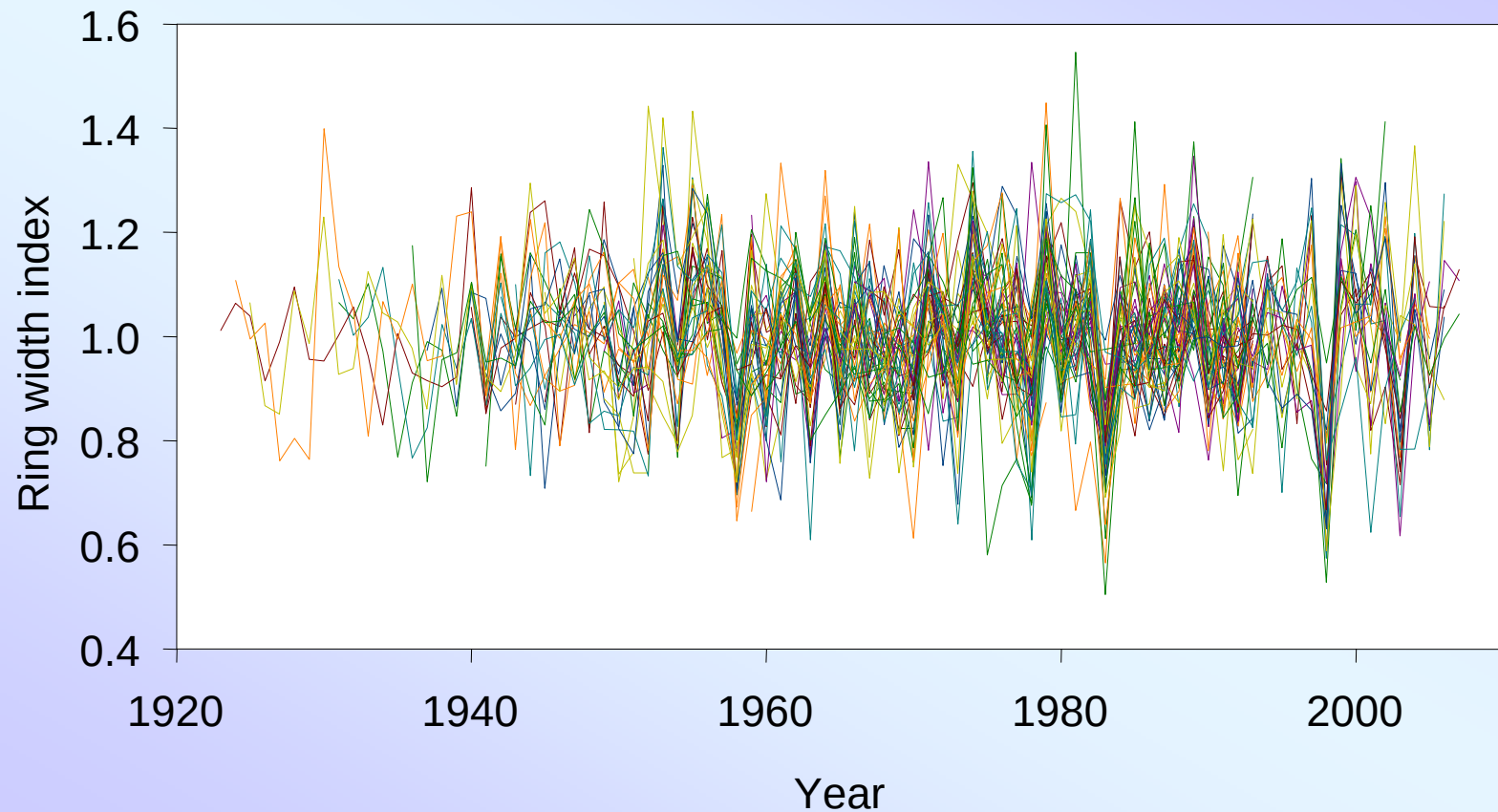


Measurements



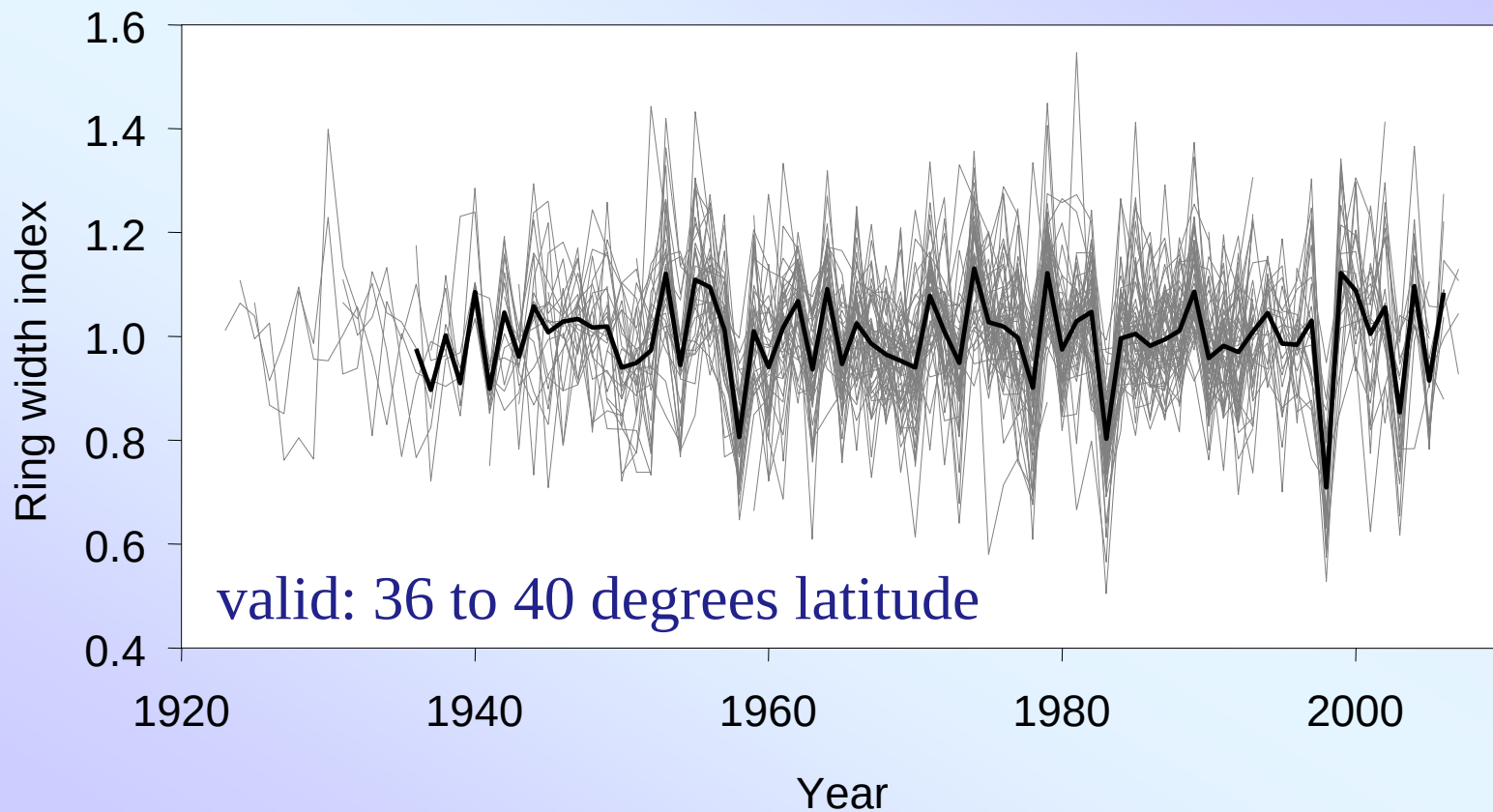
Detrended measurements

detrended splitnose otolith measurements

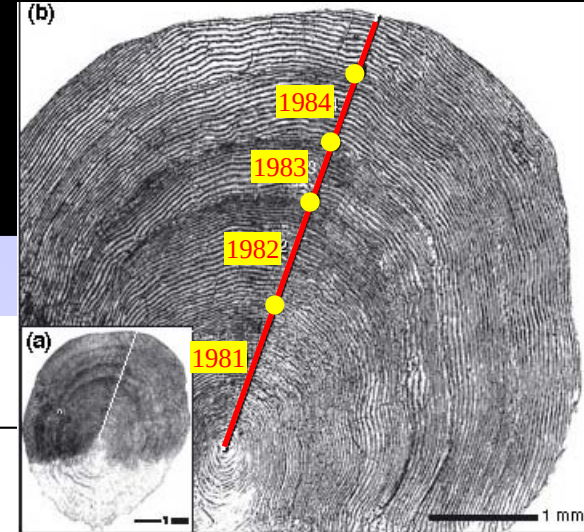
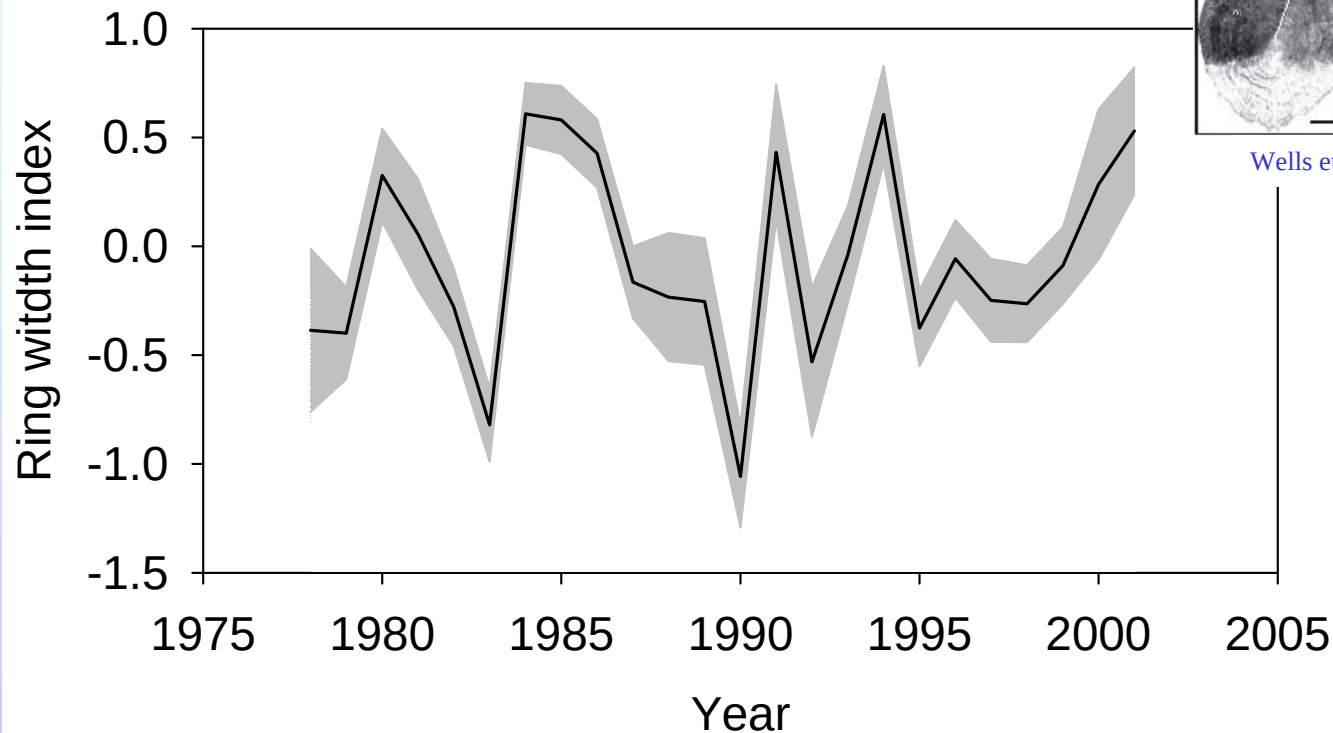


Splitnose chronology: 72 otoliths

Master chronology

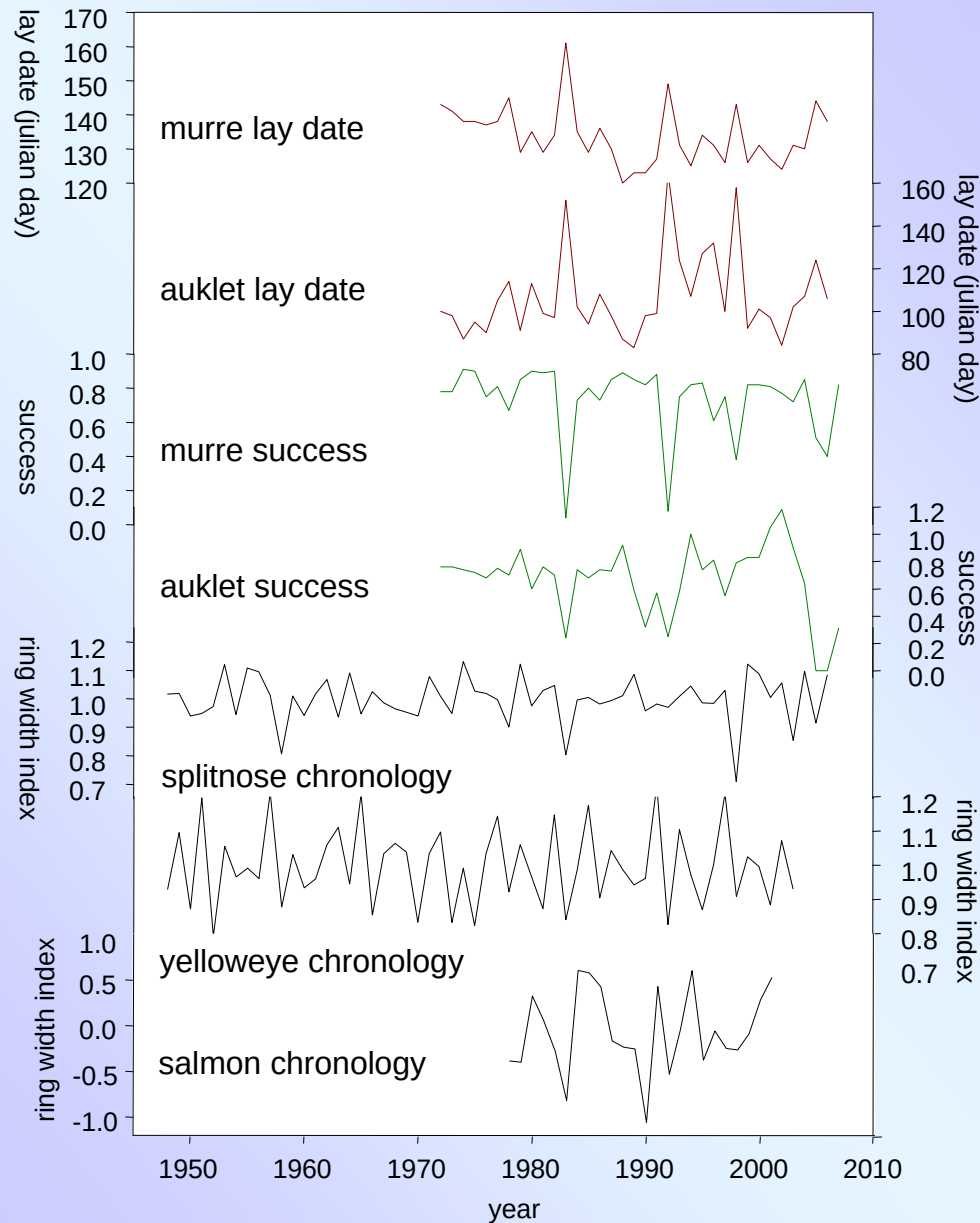


Salmon chronology: 613 fish (scales)



Wells et al. 2007 Fish Oceanog 16:363-382

Biological time series



lay date

fledgling success

growth-increment chronology

Upwelling index

**Upwelling: deep, cold, nutrient-rich water
very productive!**

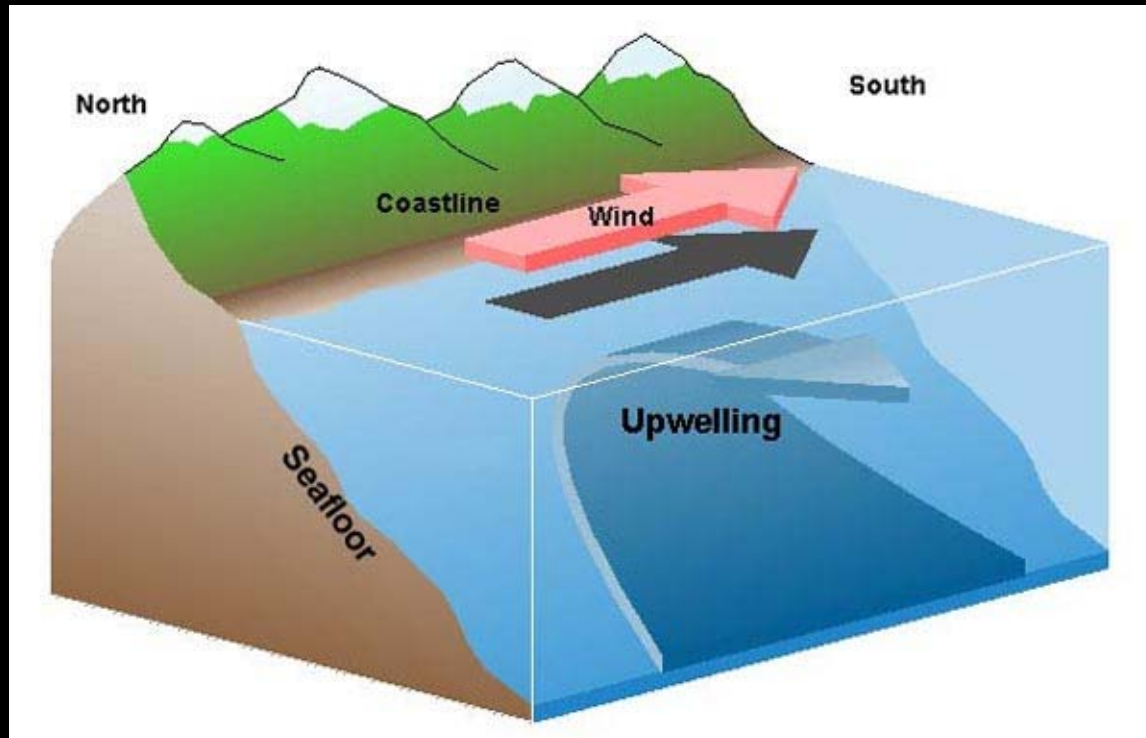
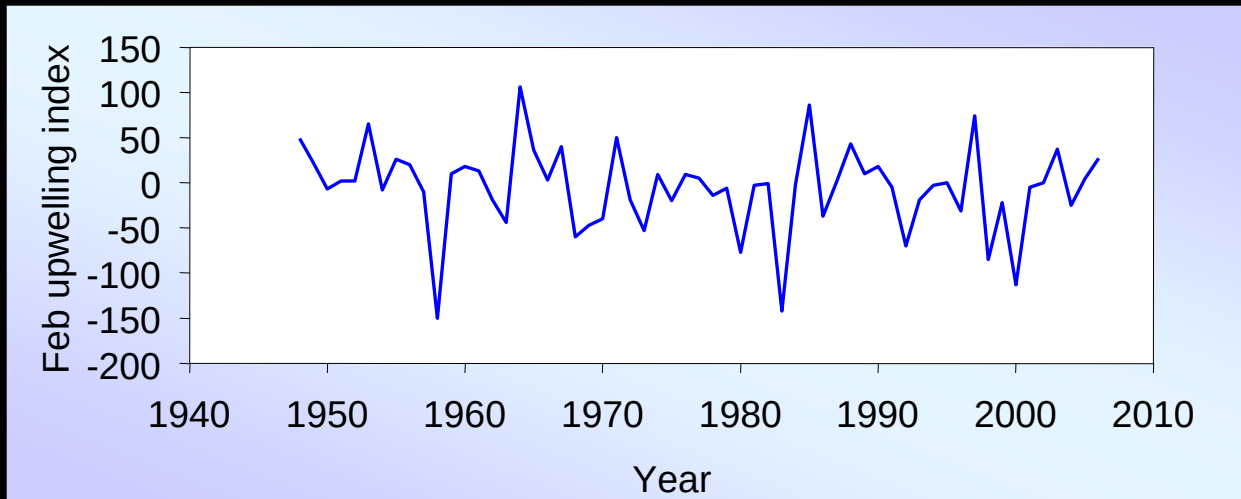


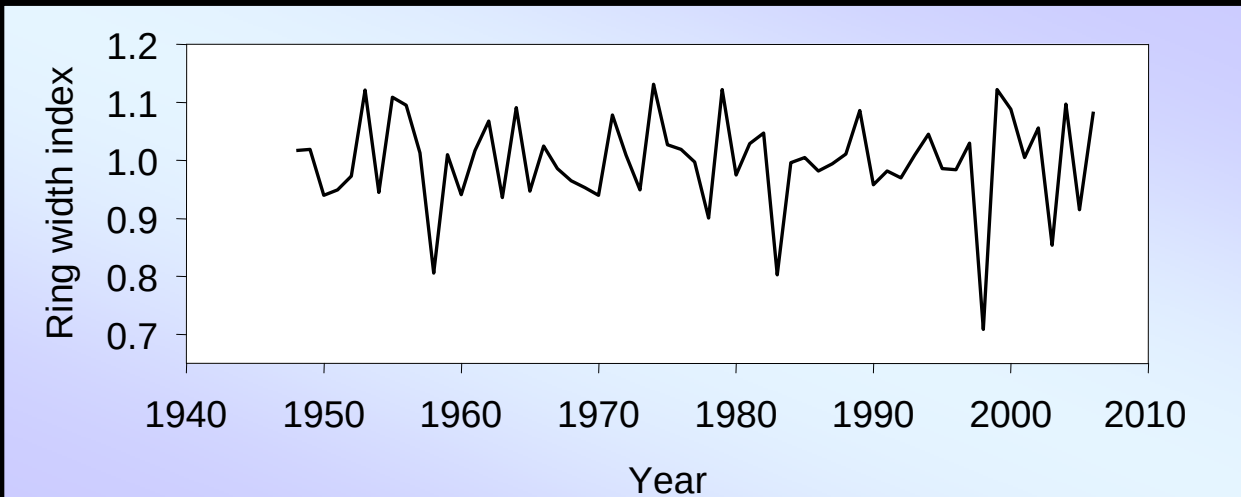
Figure credit: D. Reed and Pacific Marine Environmental Lab

Correlations with upwelling

February upwelling



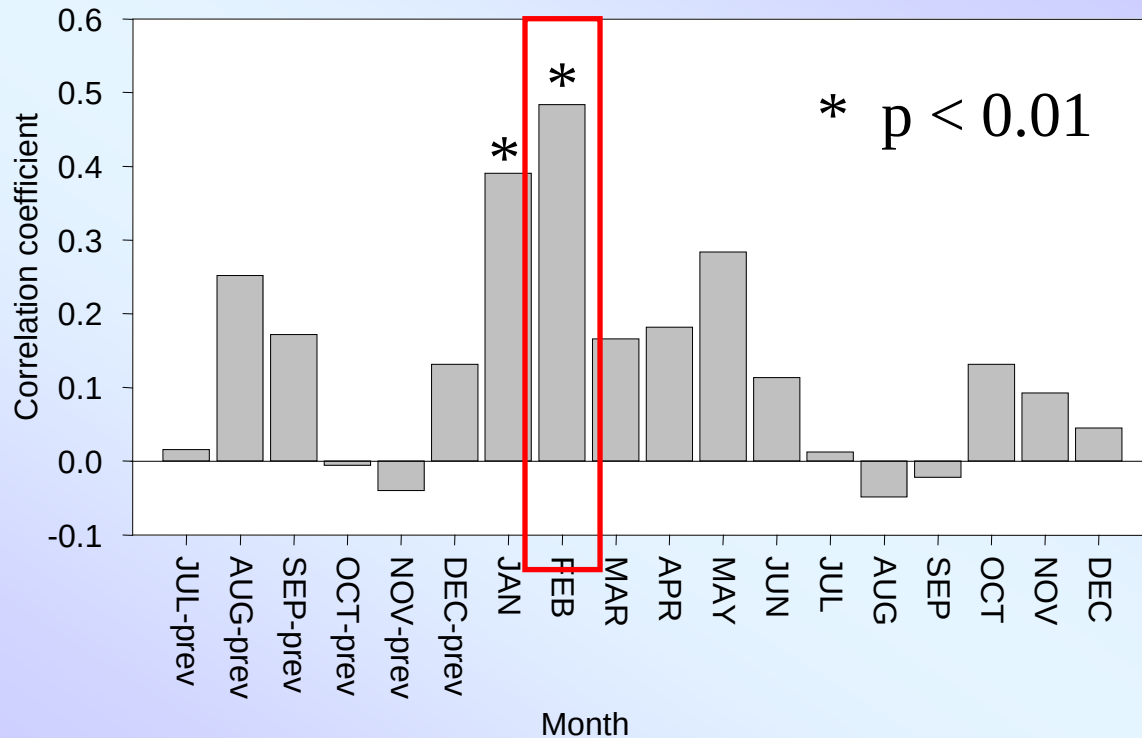
$$r = 0.54$$
$$p < 0.01$$



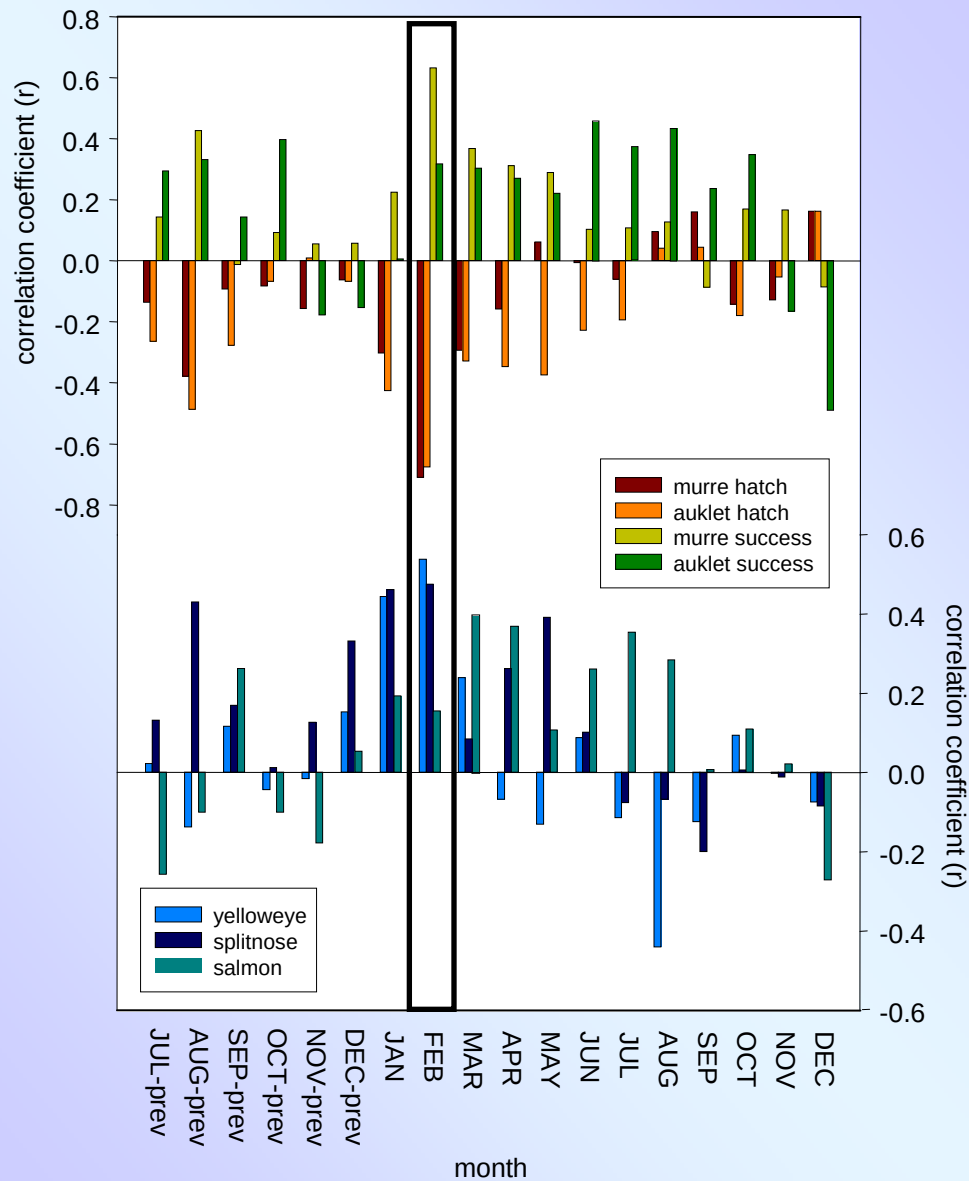
splitnose
chronology

Correlations with upwelling

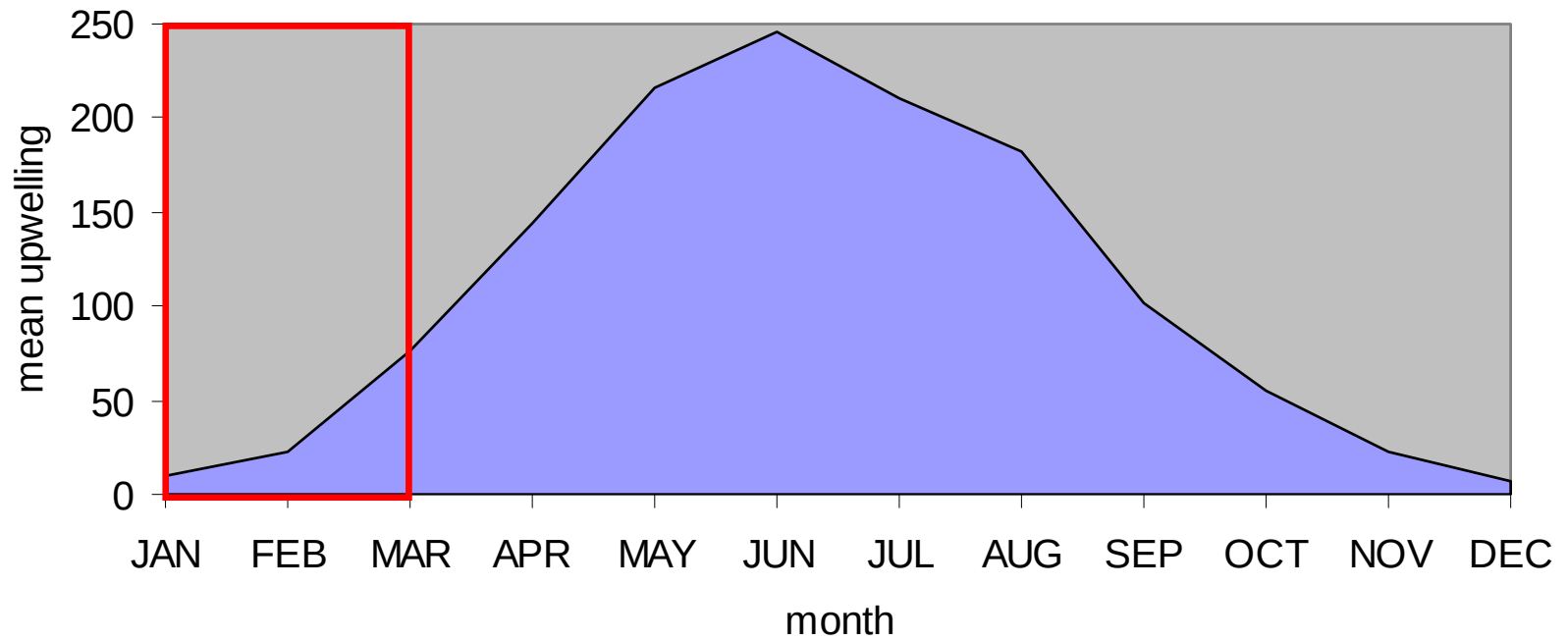
Splitnose rockfish chronology and monthly upwelling (51 yr overlap)



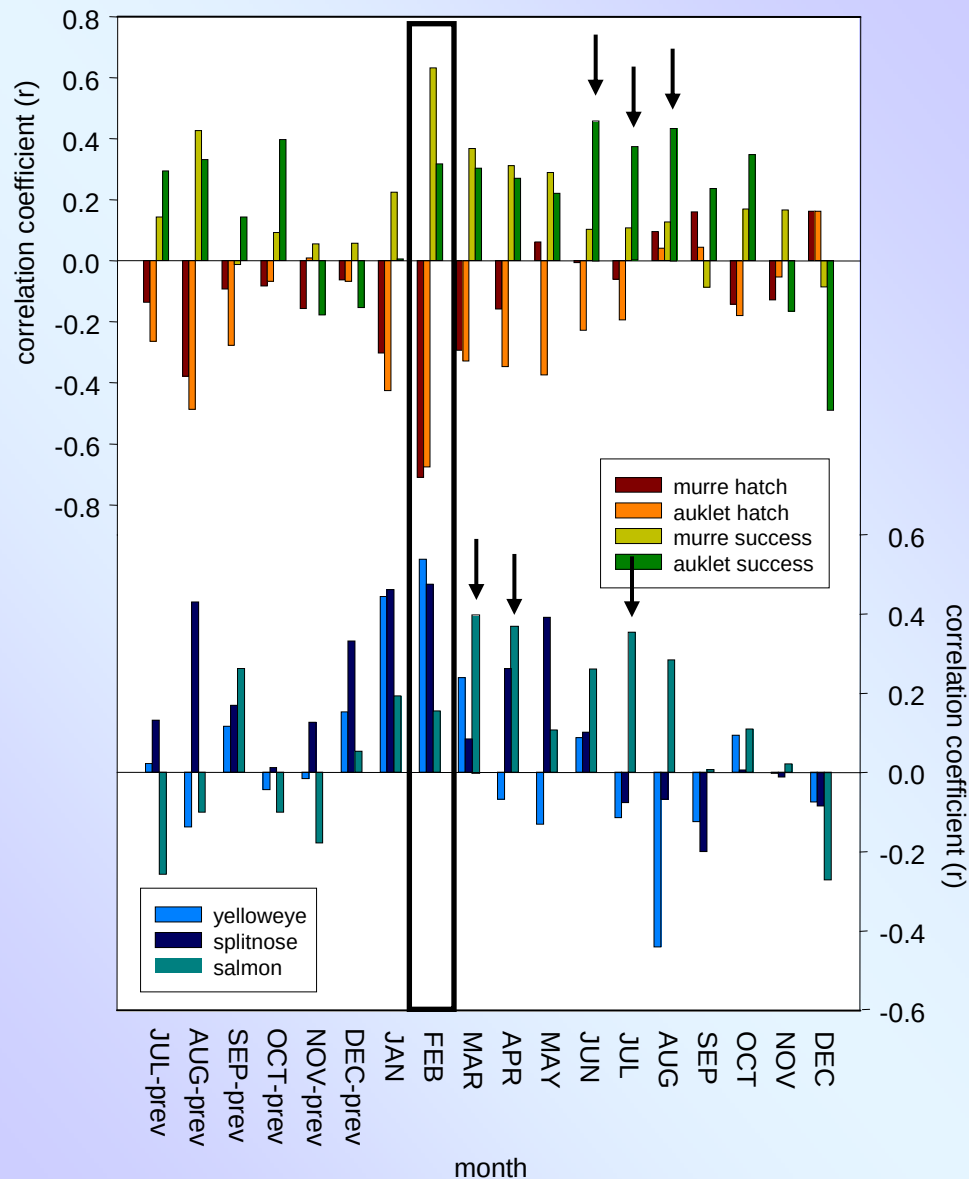
Biological time series: Feb UW correlations



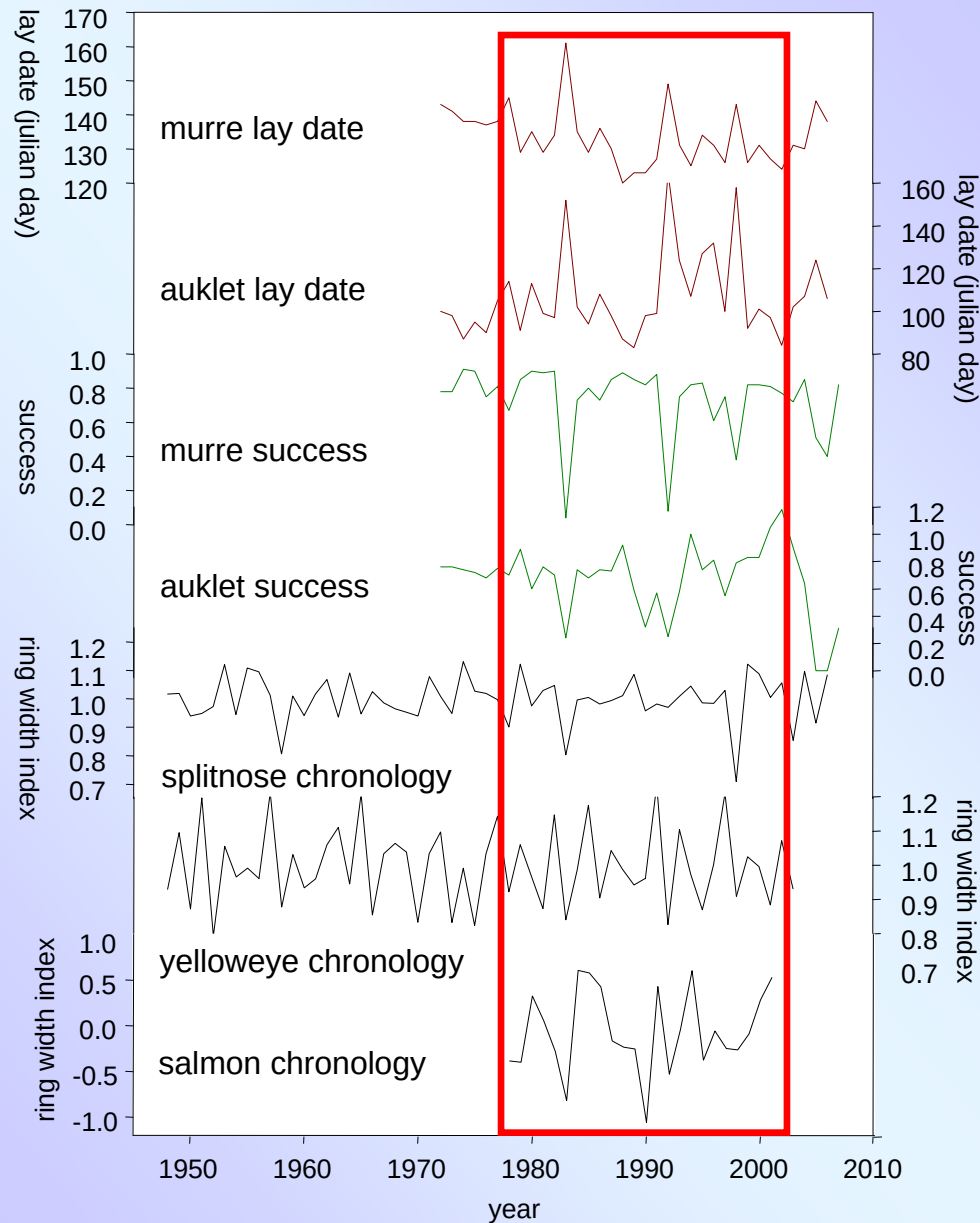
Upwelling



Biological time series: Feb UW correlations



Biological time series



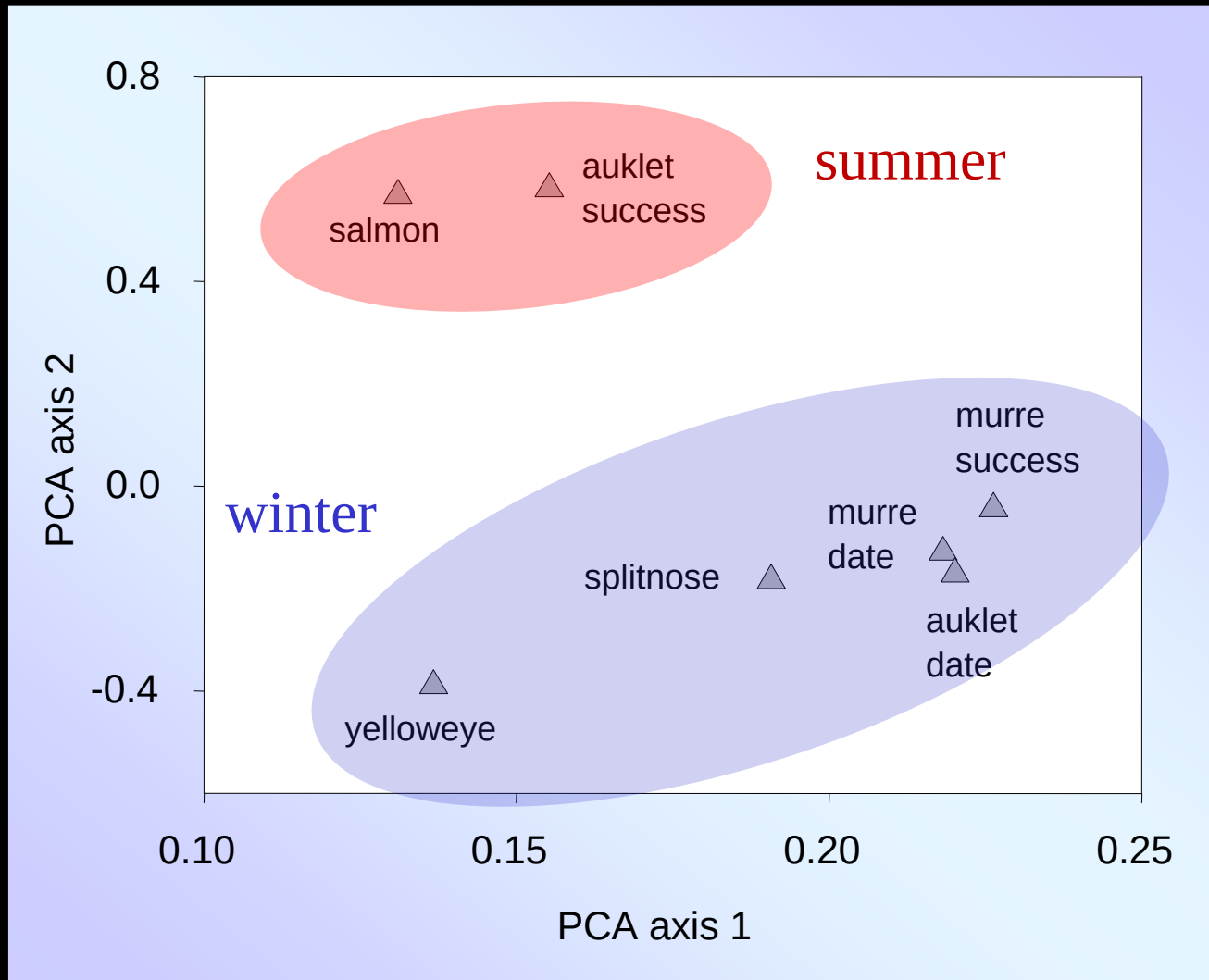
**common interval:
1978 - 2001**

**lay date
(seabirds)**

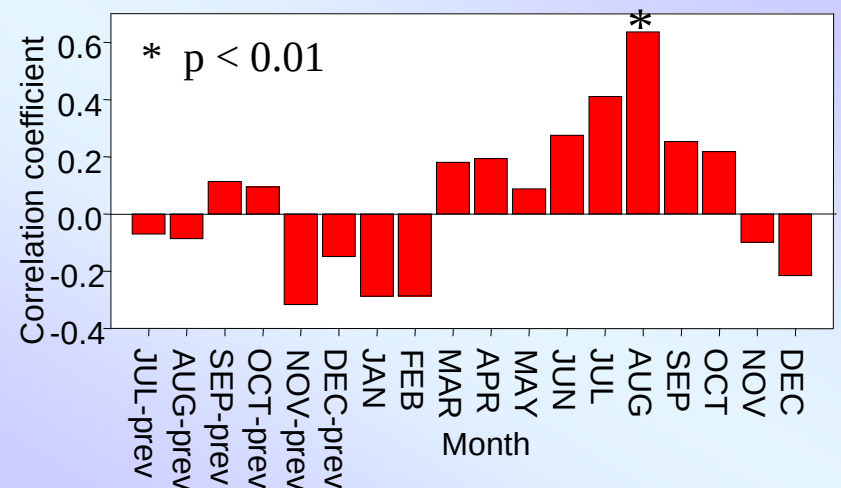
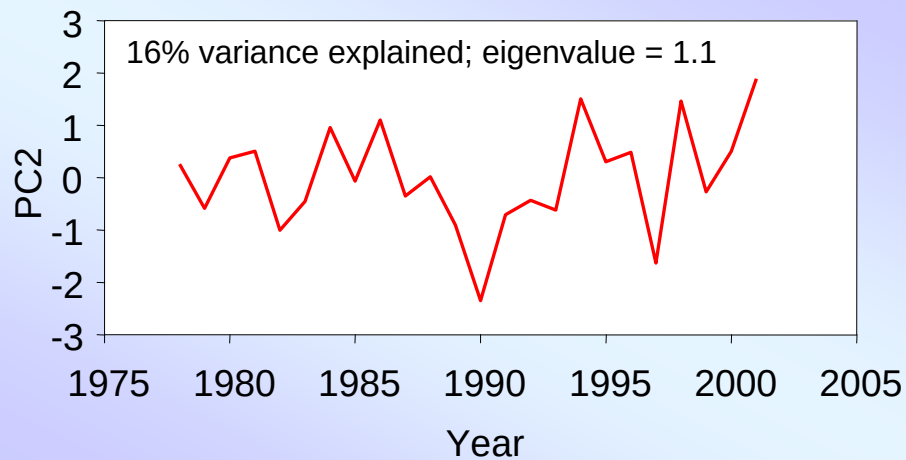
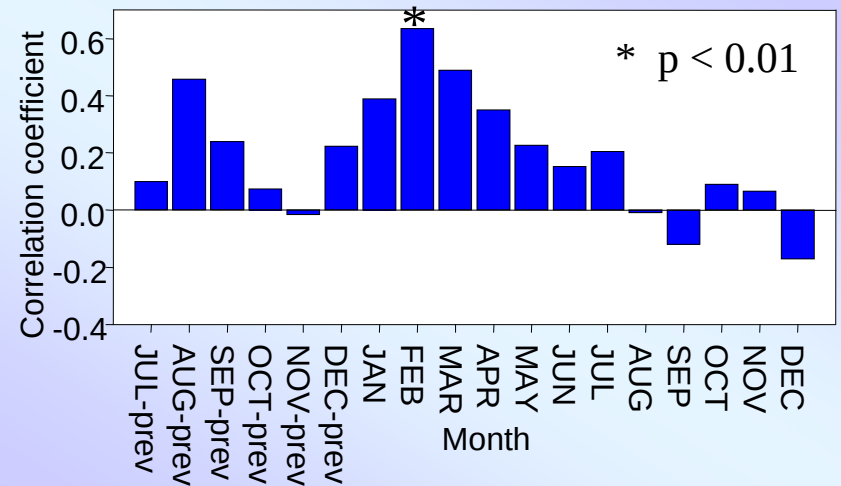
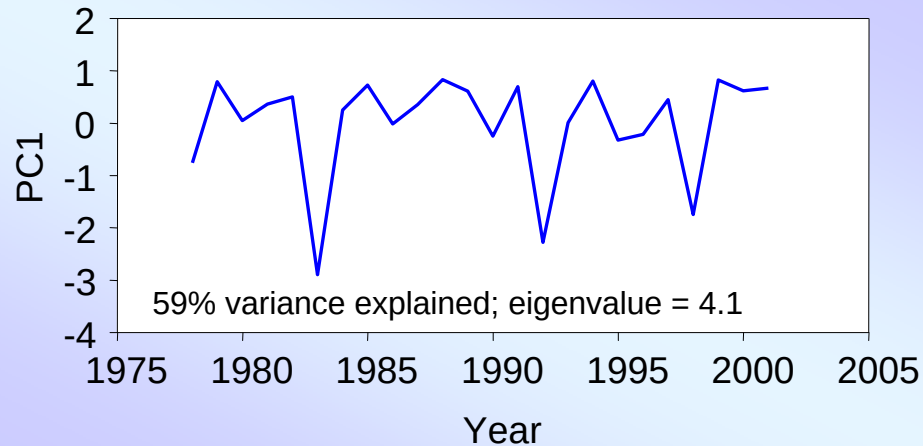
**fledgling success
(seabirds)**

**growth-increment crn
(rockfish, salmon)**

Biological time series



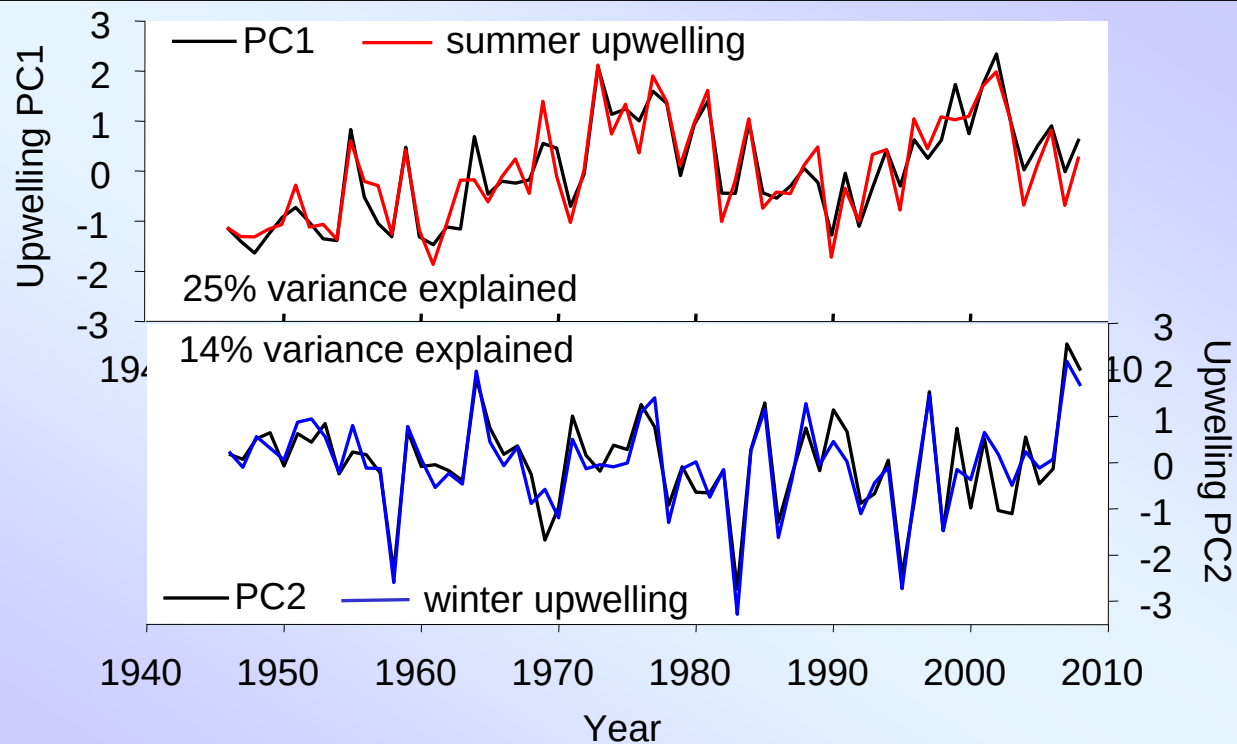
PC1 and PC2 for fish and bird time series



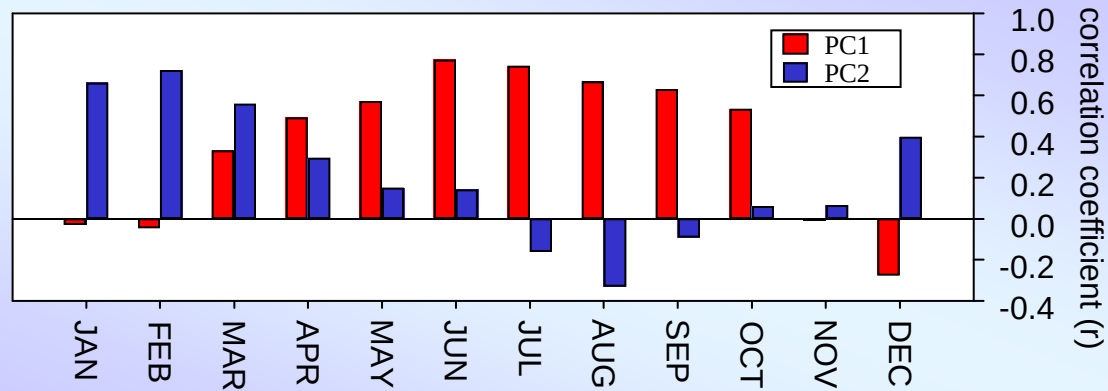
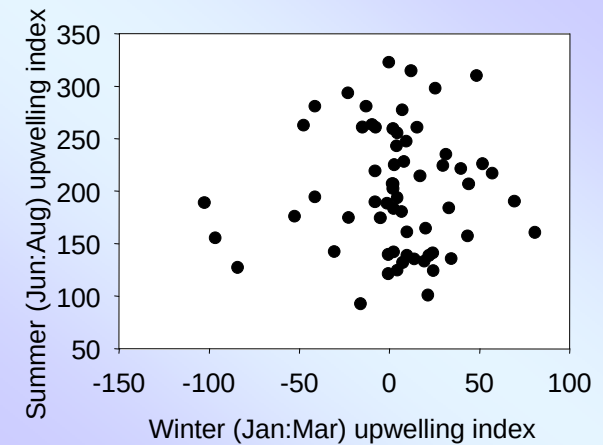
Upwelling at 39N

year	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1946	6	-10	45	36	85	111	140	155	35	59	5	-5
1947	14	-3	2	60	68	122	83	169	81	9	44	1
1948	-4	49	28	7	47	108	148	117	54	12	7	7
1949	40	22	-4	44	67	165	160	74	41	65	-35	11
1950	24	-7	12	72	210	121	205	90	48	-6	0	-58
1951	7	2	90	66	87	170	203	179	33	12	-18	4
1952	-3	2	104	45	100	137	144	126	52	0	0	-45
1953	-39	65	40	42	74	189	174	53	33	20	-23	8
.	.	.	.	.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.	.	.	.	.
2000	-21	-113	105	21	116	216	302	272	115	64	14	-5
2001	-5	-5	86	127	256	326	365	203	106	91	-12	-18
2002	3	0	33	117	202	388	271	285	130	129	-2	-175
2003	-102	37	20	18	221	302	327	154	140	51	-6	-95
2004	-38	-25	92	73	149	241	145	97	173	45	78	3
2005	-17	4	18	80	64	196	216	209	194	82	40	-37
2006	1	27	0	30	170	202	297	243	170	116	29	4
2007	107	23	112	146	239	228	116	138	105	37	56	26
2008	-1	39	133	150	231	287	170	194	87	65	11	34

Upwelling 39N



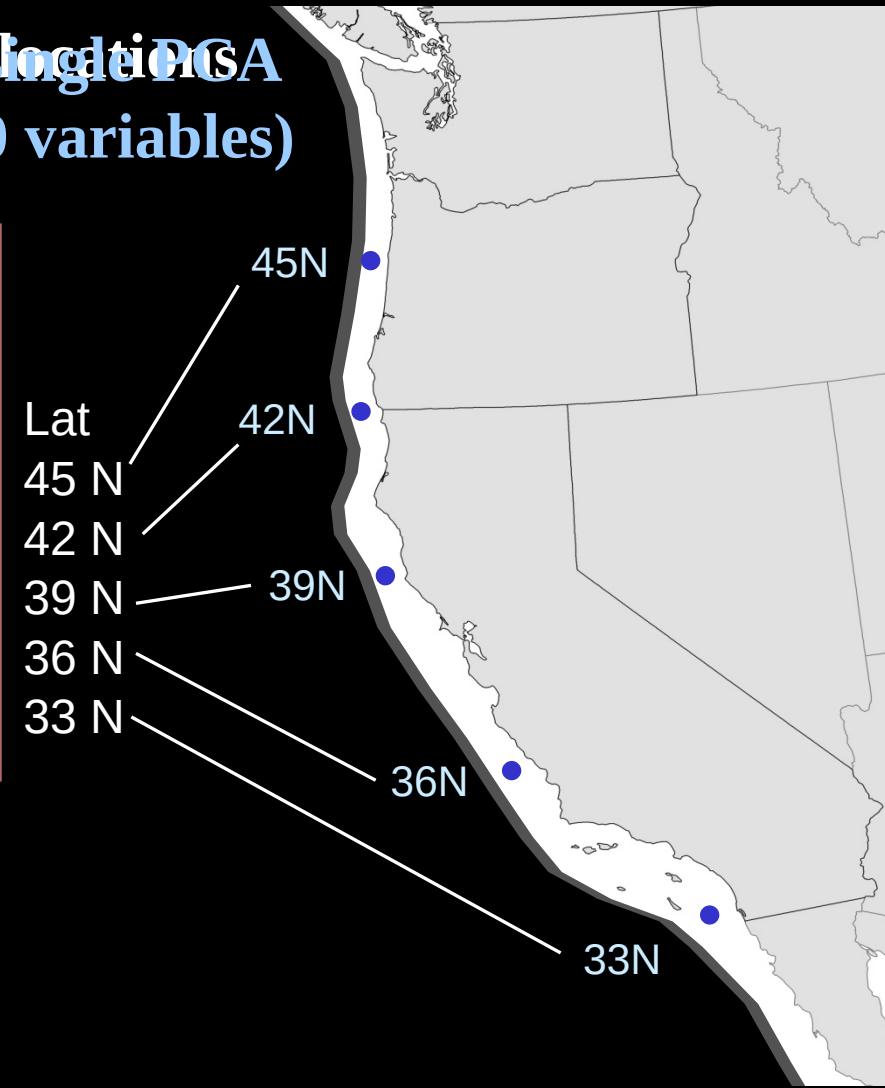
winter vs. summer UW



Upwelling stations

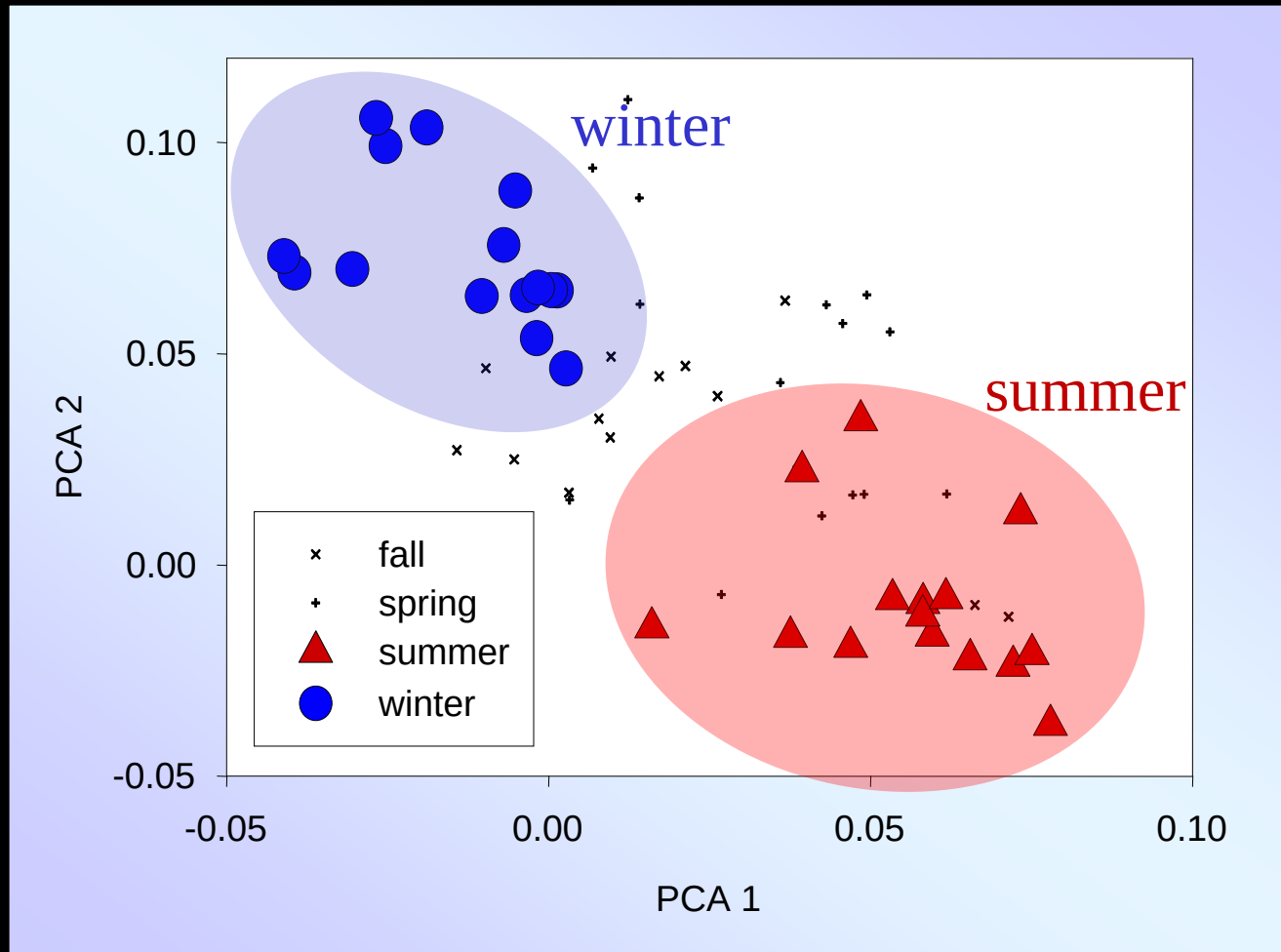
Principal components analysis (PCA)
Principal 60 monthly variables reduced into 5 single PCA
(12 months at 5 latitudes = 60 variables)

winter vs. summer	winter mode		summer mode	
Correl.	EV	% var	EV	% var
-0.01	1.68	14	1.74	15
-0.01	1.87	16	2.88	24
0.02	1.71	14	3.03	25
-0.08	2.24	19	3.61	30
-0.02	2.22	19	4.08	34



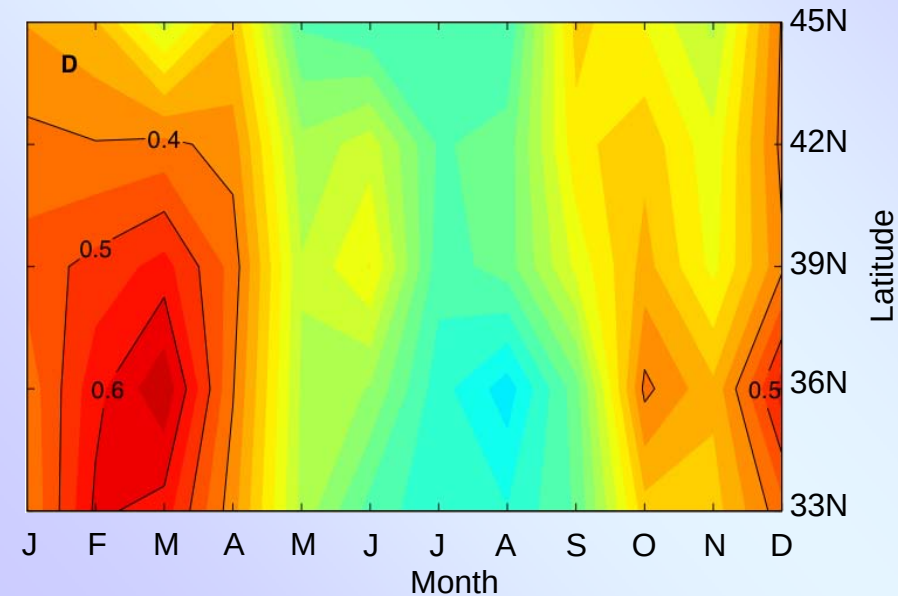
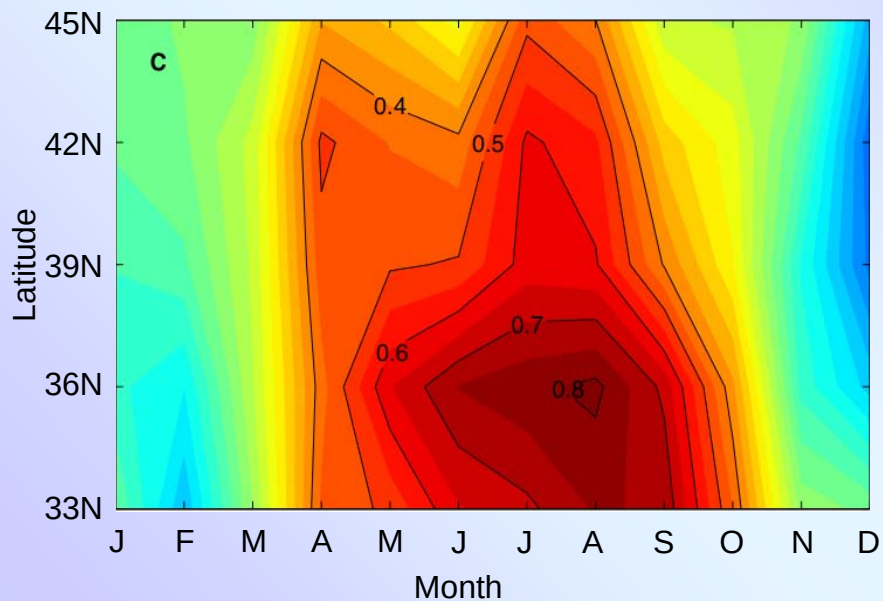
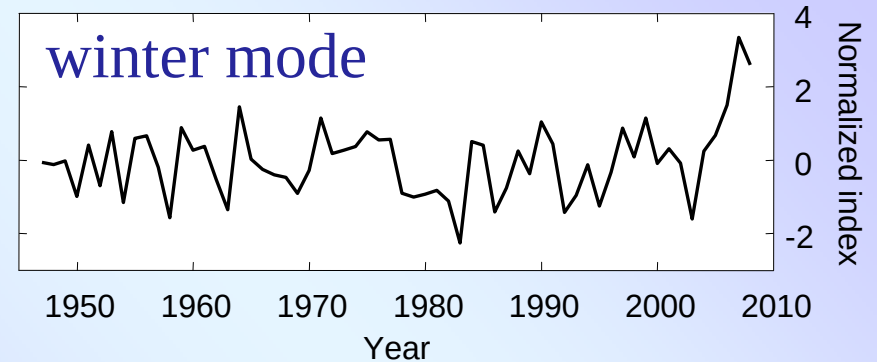
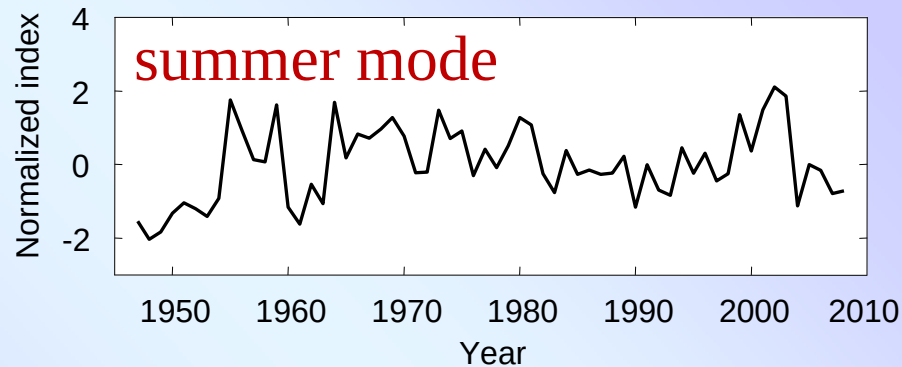
EV = eigenvalue
% var = percent variance explained

PCA of upwelling indices



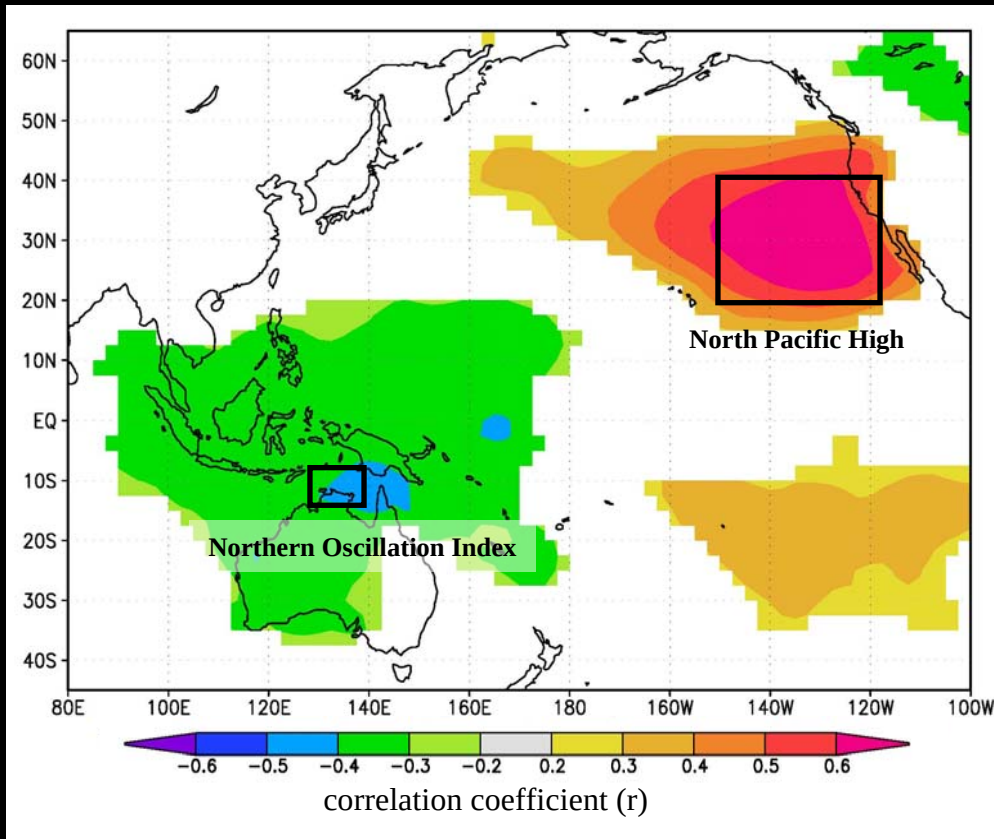
Upwelling index

“Coastwide” analysis (5 upwelling stations)

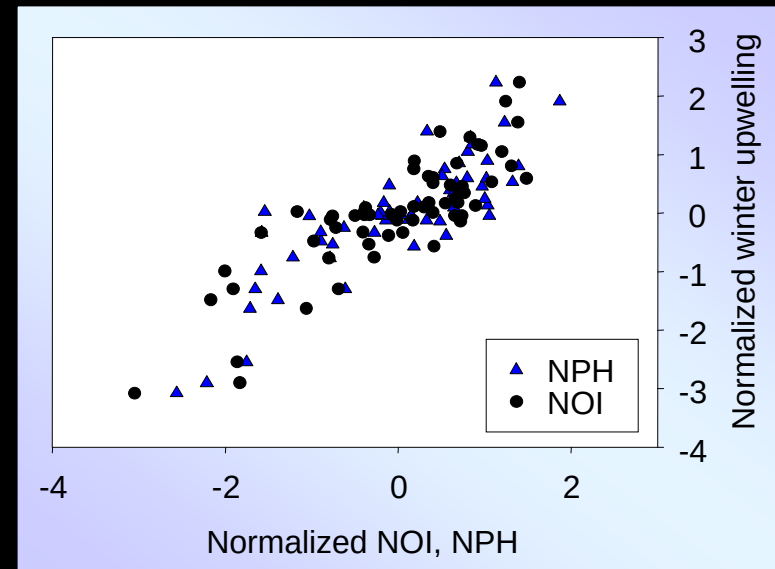


Winter mode and winter sea level pressure

Correlation with winter sea level pressure

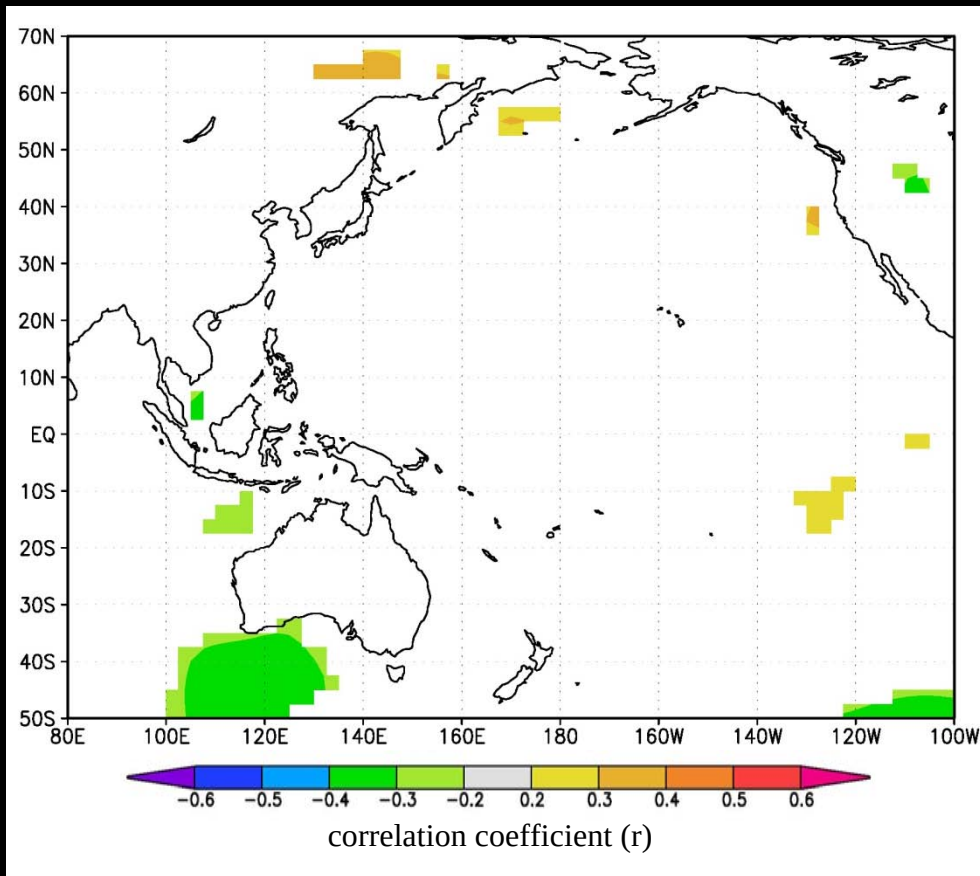


Winter mode vs. NOI and NPH

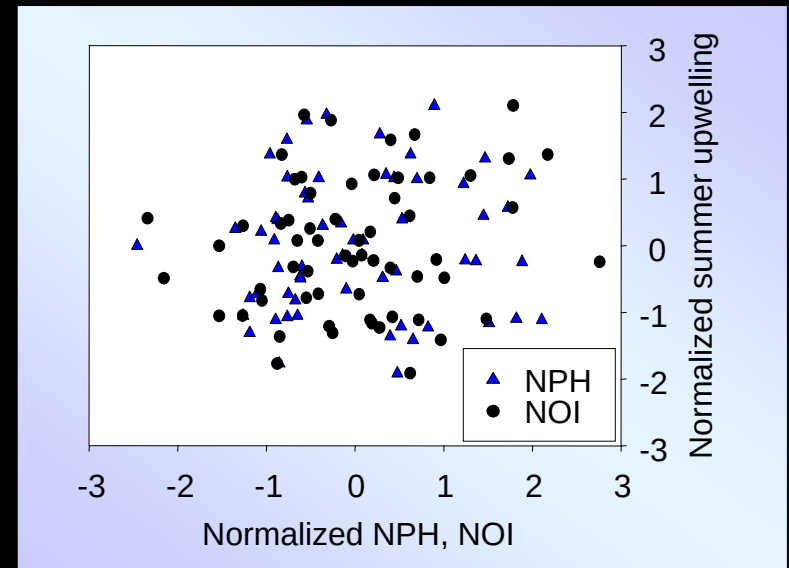


Summer mode and sea level pressure

Correlation with summer sea level pressure



Summer mode vs. NOI and NPH



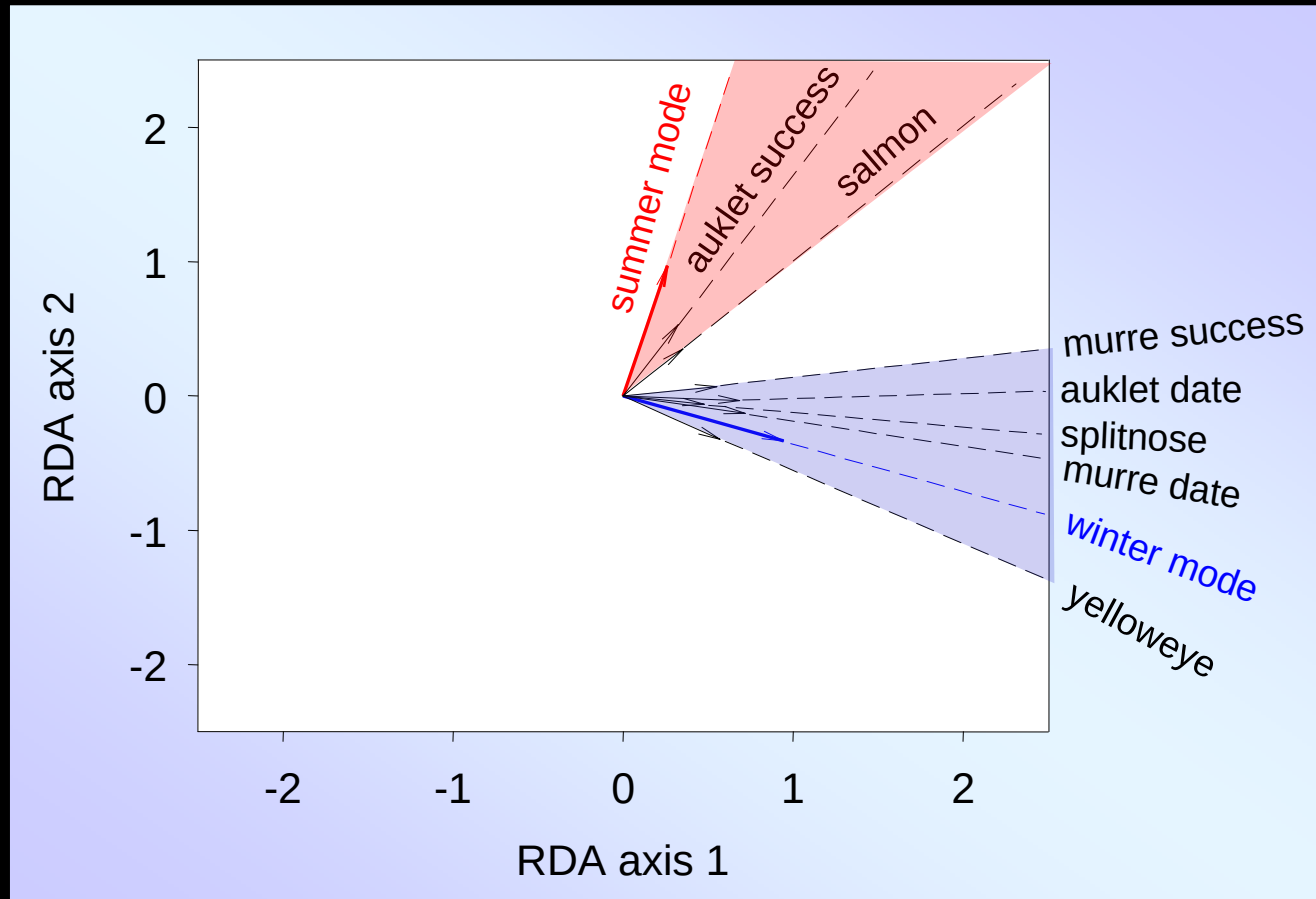
Biological responses at 39N

Biological Time series	Span (years)	Summer mode		Winter mode	
		Sp	p	Sp	p
Murre lay date	1972:2006	0.04	0.81	-0.39	0.02
Auklet lay date	1972:2006	-0.25	0.14	-0.55	0.001
Murre success	1972:2007	0.03	0.84	0.36	0.03
Auklet success	1972:2007	0.48	0.002	-0.14	0.41
Splitnose crn	1936:2006	0.17	0.19	0.44	0.001
Yelloweye crn	1946:2003	-0.08	0.58	0.34	0.01
Salmon crn	1978:2001	0.42	0.04	0.27	0.20

Sp = Spearman's correlation coefficient

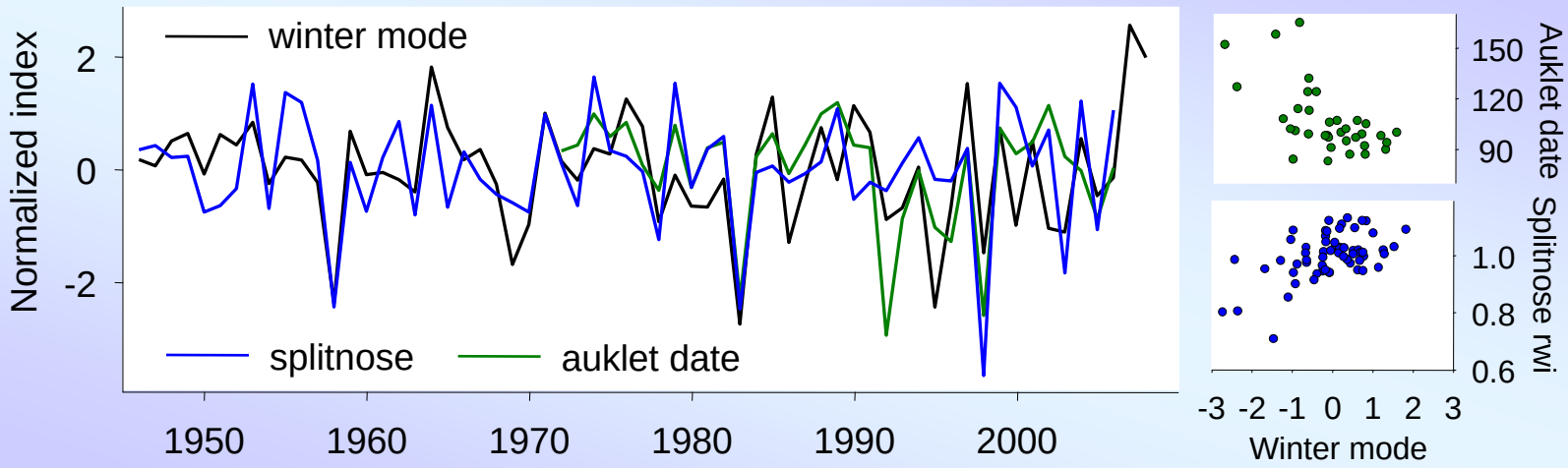
p = level of significance

Biological response at 39N

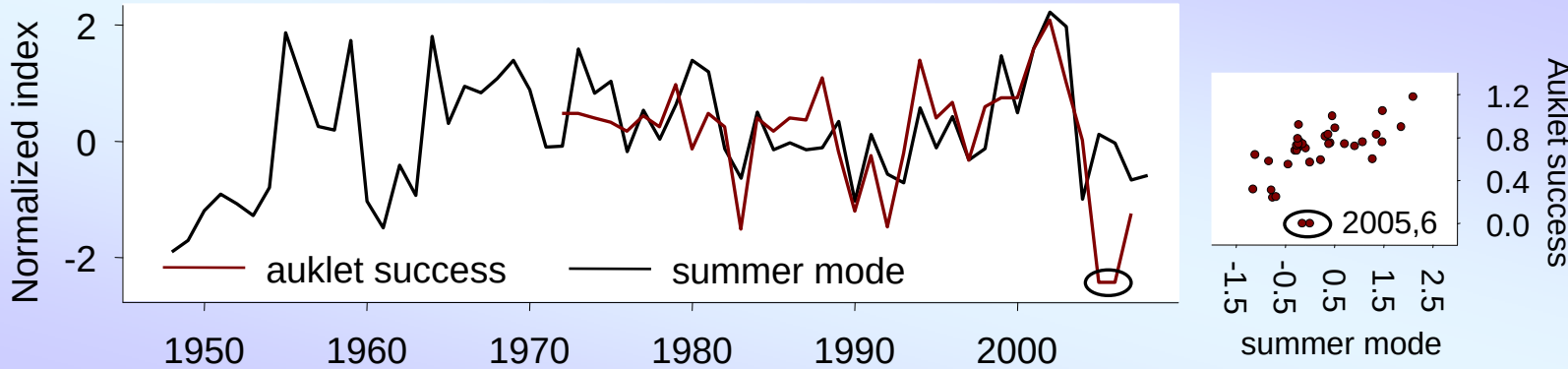


Biological response

winter mode

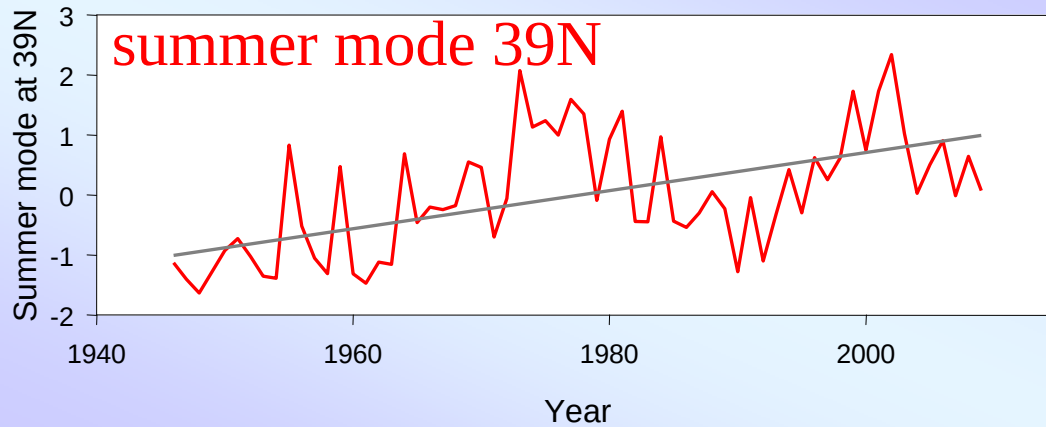


summer mode

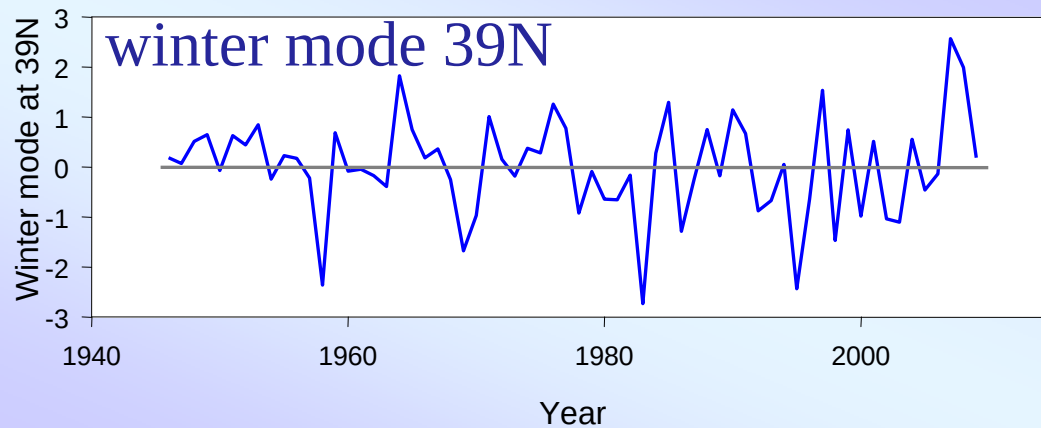


Biological response

summer sensitive



winter sensitive



Acknowledgements

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**PRBO Conservation Science and the US Fish
and Wildlife Service**

Otolith collections:

**Don Pearson, Mary Yoklavich, and the SW
Fisheries Science Center**

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