Indicators of ocean conditions and salmon survival in the Northern California Current

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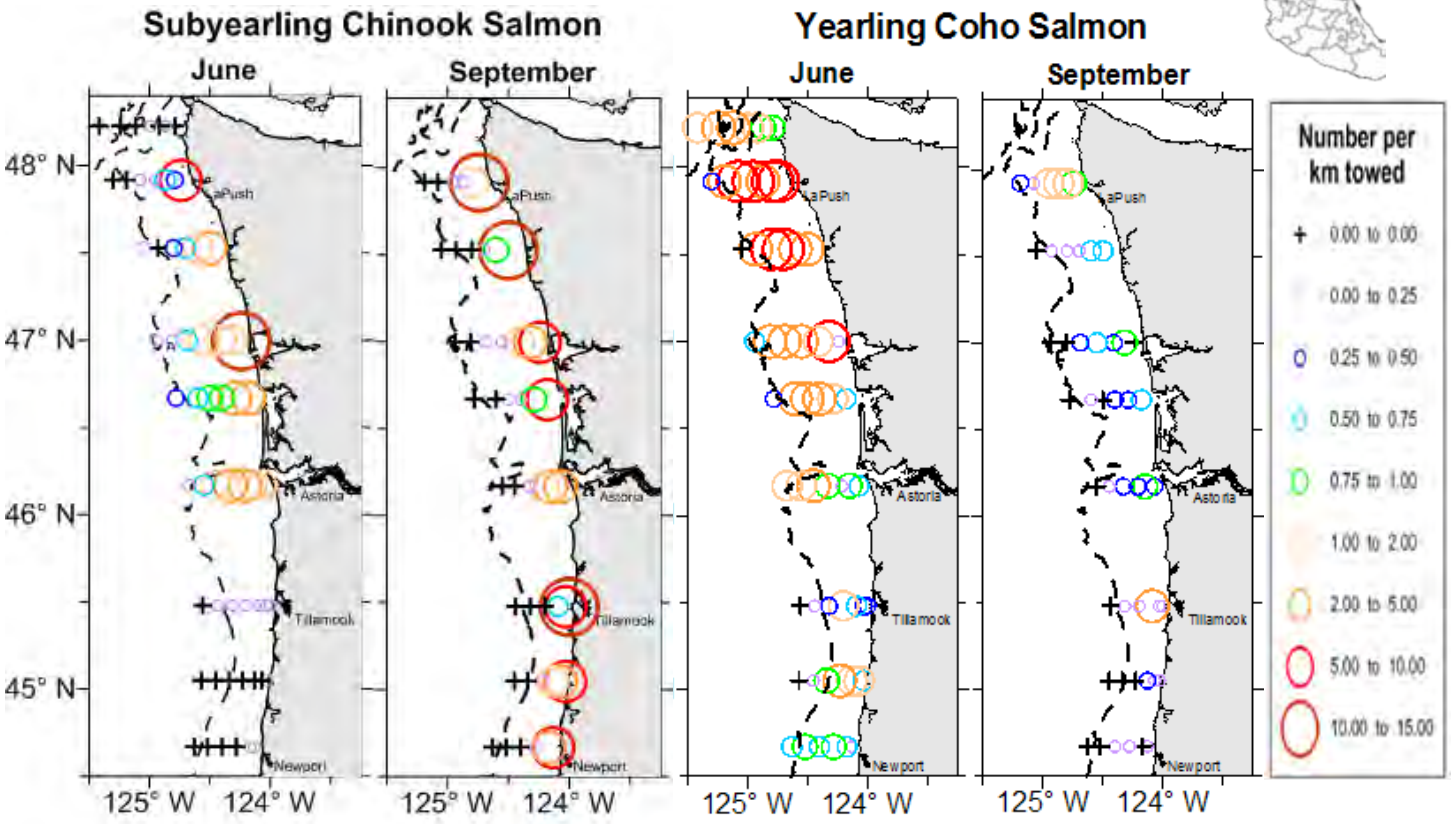
Salmon

•commercially and culturally very important in the NE Pacific.

•Closely managed
•Interest in what factors influence salmon success (e.g. dams, ocean habitat)

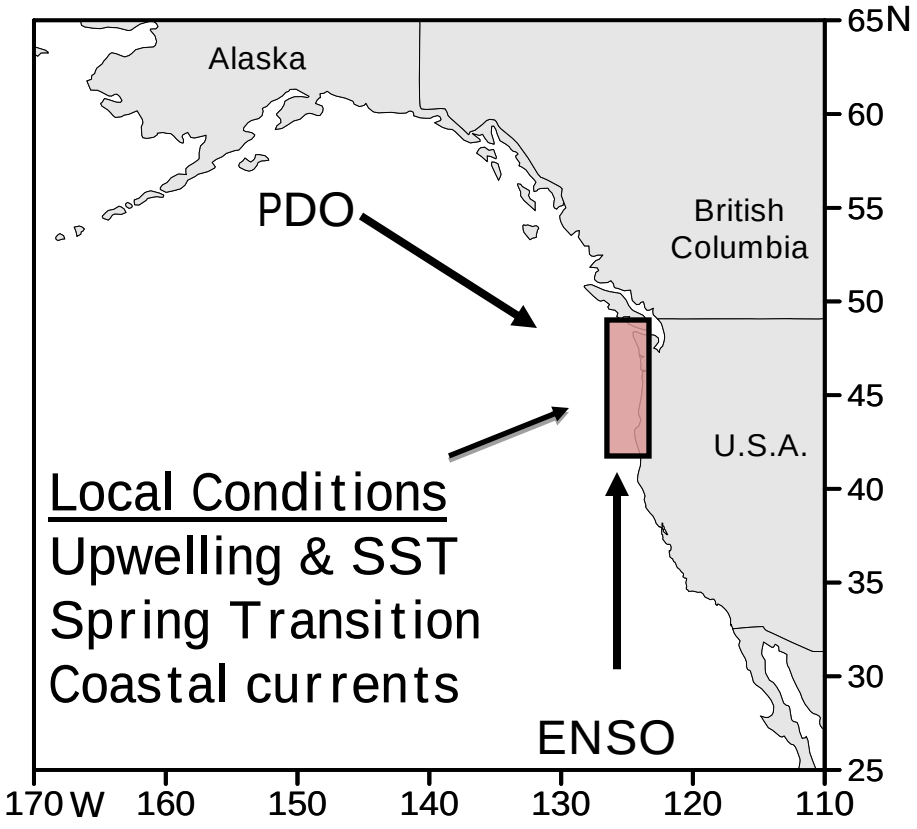
13 year time-series shows juvenile salmon occupy the shelf.

Variability between stocks.



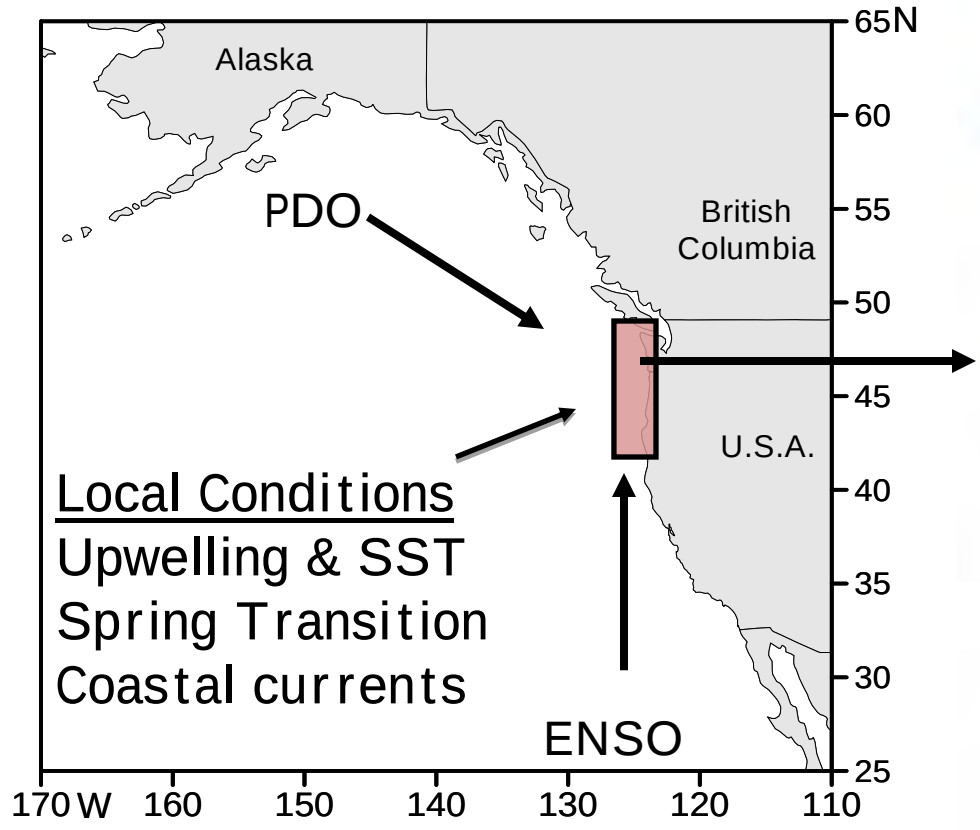
We study the ocean phase of salmon life history and develop management advice based on a suite of indicators

Physical/Hydrographic

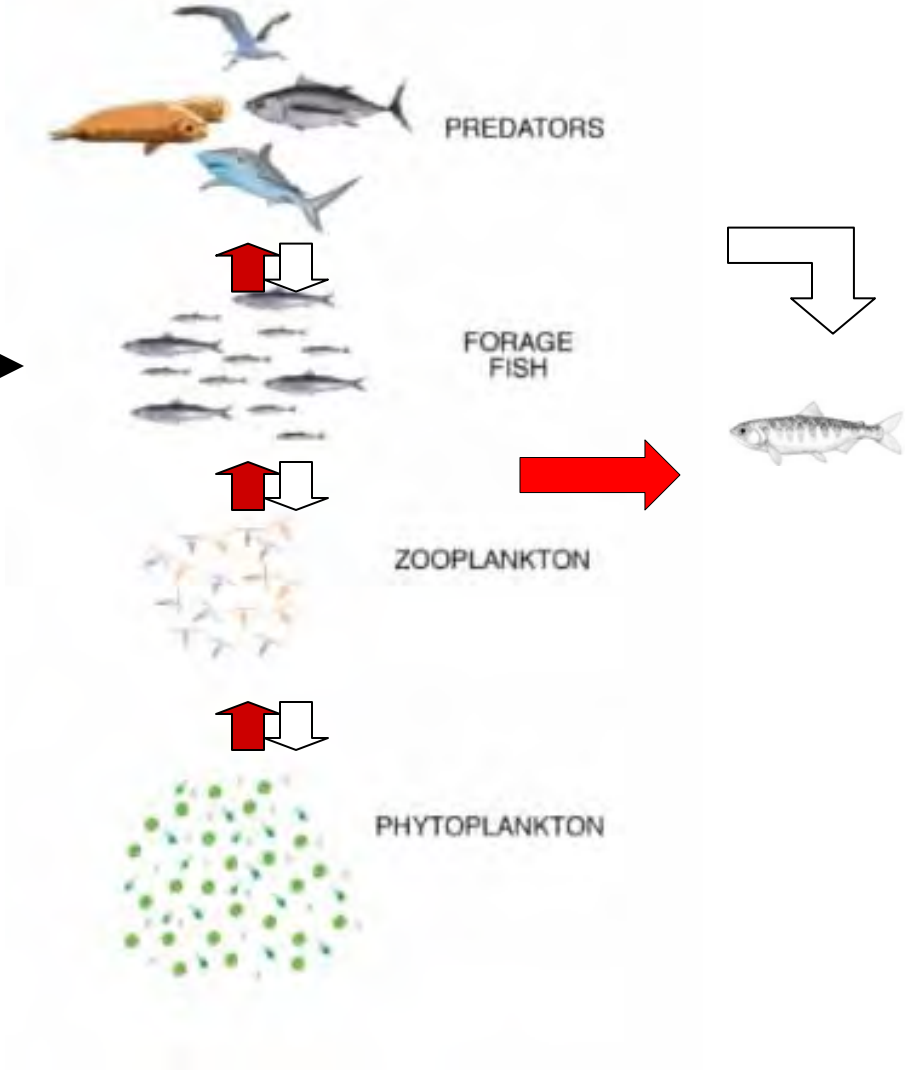


Basin and local scale forces influence biological process important for salmon

Physical/Hydrographic



Local Biological Conditions



Our work is an example of an ecosystem approach to management

Data Sources

SHELF SAMPLING - Newport

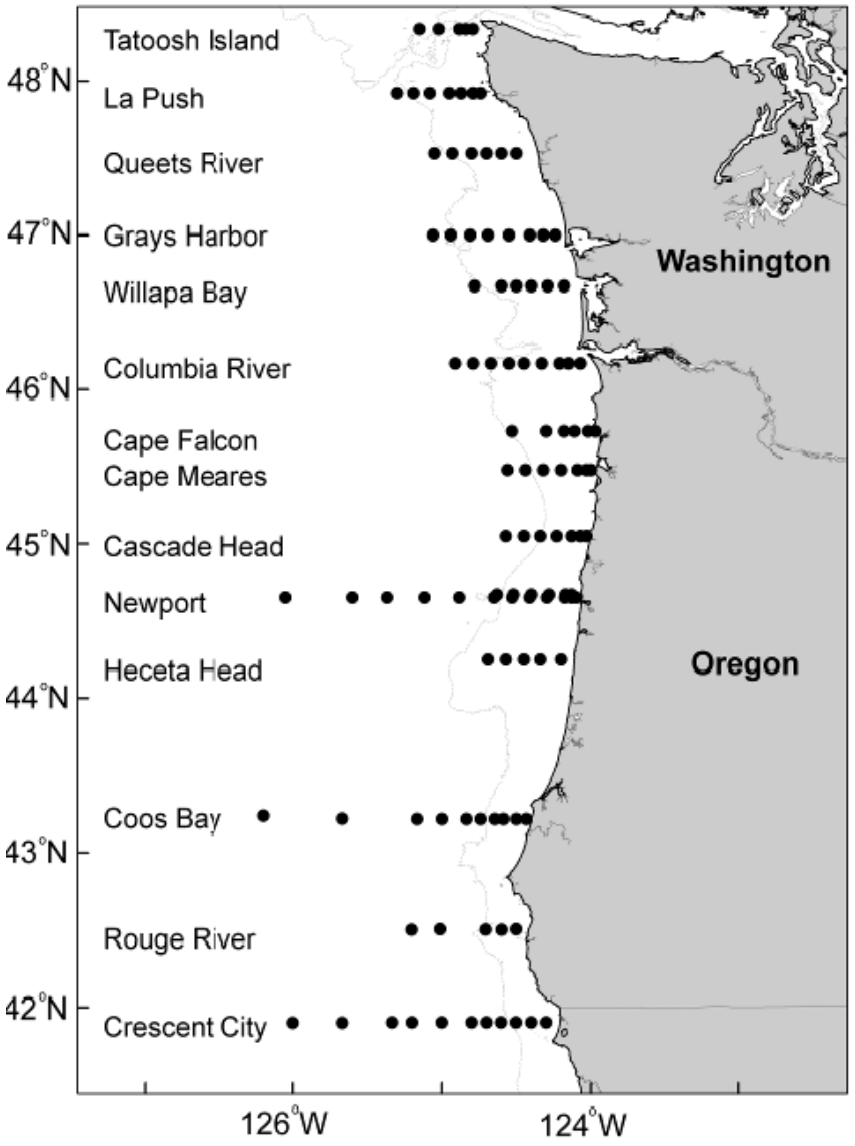
- Historical Hydrographic and plankton data at Newport Hydrographic Line (NH) – 1960s and 1970s, 1983, 1990-1992
- NH Line 1996-present

SHELF SAMPLING – Newport north to tip of Washington State

- Historical sampling of salmon and pelagic fish (1979, 1981-1985)
- BPA-hydrography, plankton, pelagic fish and juv. salmon (1998-present)
- PaCOOS-CCLME Cruises (2004 – present)

BLUE WATER SAMPLING – Newport south to northern California

- GLOBEC –LTOP and Mesoscale hydrography and plankton 1998-2003
- PaCOOS-CCLME (partially funded by SAIP) 2004-present; sampling LTOP grid



Ecosystem Data Available

Year-around data from Newport Line (bi-weekly):

- Hydrography: CTD casts 1997-present; Secchi depths
- Chlorophyll: fluorometer and filter extractions
- Hypoxia (SBE-43 sensor since summer 2006)
- Phytoplankton species; 2000-present
  - Harmful Algal Blooms (MERHAB funding)
- Zooplankton and krill biomass and species composition; copepod egg production; krill egg production and moulting rates; ichthyoplankton
- Seabirds (on some cruises)

Spring-Summer Spatial surveys (BPA and LTOP)

- Hydrography (T-S), oxygen, pH, chlorophyll, zooplankton, krill, fish eggs and larvae
- Pelagic fishes; seabirds; whales

Satellite Data – color, SST, SSH

http://www.nwfsc.noaa.gov

Northwest Fisheries Science Center

NOAA Fisheries Service

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- Programs/Projects/Teams
- Staff Profiles
- Monster Seminar Jam
- Calendar

Awards and Honors

Congratulations Tim Beechie and George Pess, winners of the 2010 Bronze Award.

All other awards

In the Region

Northwest Salmon Recovery-- a portal to publications, software and data on listed species of West Coast salmon and steelhead.

Sound Science -- a collaborative report summarizing what we know about the Puget Sound ecosystem and gaps in our knowledge.

In the News: Lamprey Decline

Posted: April 15, 2011

Pacific lamprey are making the climb toward recovery. Declining populations in the Columbia River Basin have spurred the development of specialized, lamprey-friendly, fish ladders to take advantage of this species' unique climbing ability. Watch as Center scientist Mary Moser describes NOAA's efforts to understand and halt lamprey decline in the latest episode of Oregon Field Guide. more...

Public Invited to Meet NOAA Scientists at the Mukilteo Research Station

What makes Puget Sound unique and how will human activities affect this critical ecosystem? Will Puget Sound's endangered species ever recover? What tools do researchers use to answer ecosystem and management questions? Find out the answers and more during a free public lecture series with NOAA's Mukilteo researchers on April 20 from 5:30-8:30pm at the Rosehill Community Center. More event information...

Director's Corner

Highlights 2010

2011 Annual Priorities

Data Products and Tools

West Coast Habitat Server -- interactive web applications and mapping tools to investigate the California Current Large Marine Ecosystem's fisheries and habitat data.

Ocean Conditions and Salmon Forecasting -- Explore biological and physical indicators of the California Current ecosystem and how these data help scientists forecast salmon survival.

Scientific Data and Tools -- A portal for resource managers, collaborators, and other scientific data users. Note: some databases are password-protected.

Home
- [illegible] Annual Update
- Forecast as of January 2011
- [illegible] Return Data
- 2009 Annual Report (PDF)

Large–scale Ocean and Atmospheric Indicators
- Pacific Decadal Oscillation
- Multivariate El Niño Southern Oscillation Index

Local and Regional Physical Indicators
- Sea surface temperature anomalies
- Coastal upwelling
- Physical spring transition
- Deep–water temperature and salinity

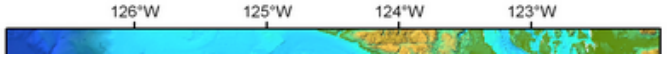
Local Biological Indicators
- Copepod biodiversity
- Northern copepod anomalies
- Copepod community structure
- Biological spring transition
- Winter Ichthyoplankton
- June spring Chinook

Ocean Ecosystem Indicators of Salmon Marine Survival in the Northern California Current

As many scientists and salmon managers have noted, variations in marine survival of salmon often correspond with periods of alternating cold and warm ocean conditions. For example, cold conditions are generally good for Chinook and coho salmon, whereas warm conditions are not.

These pages are based on our annual report of how physical and biological ocean conditions may affect the growth and survival of juvenile salmon in the northern California Current off Oregon and Washington. We present a number of physical, biological, and ecosystem indicators to specifically define the term "ocean conditions." More importantly, these metrics can be used to forecast the survival of salmon 1–2 years in advance, as shown in Table 1. This information is presented for the non–specialist; additional detail is provided via links when possible.

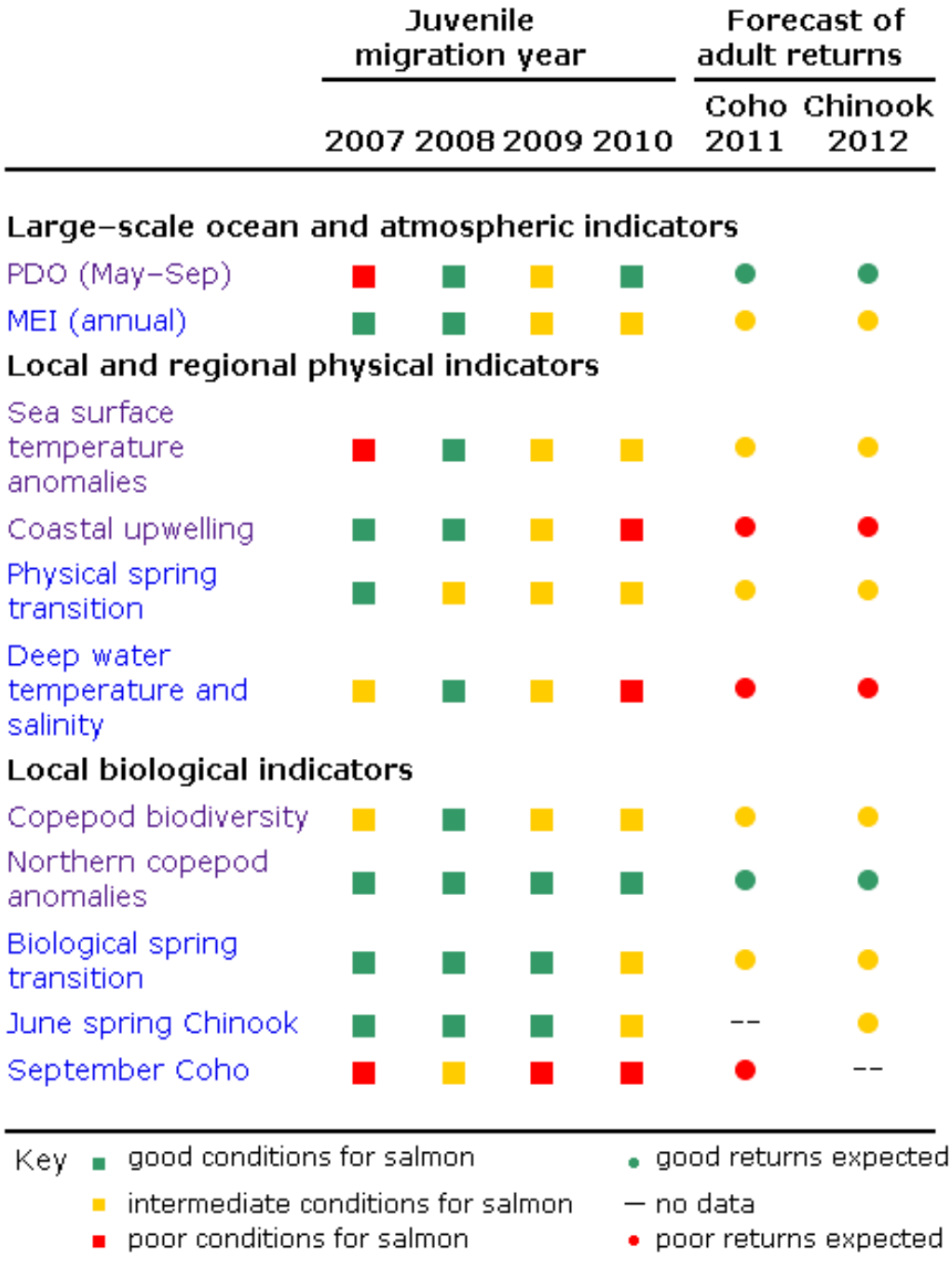
BPA Plume Study Target Station Locations



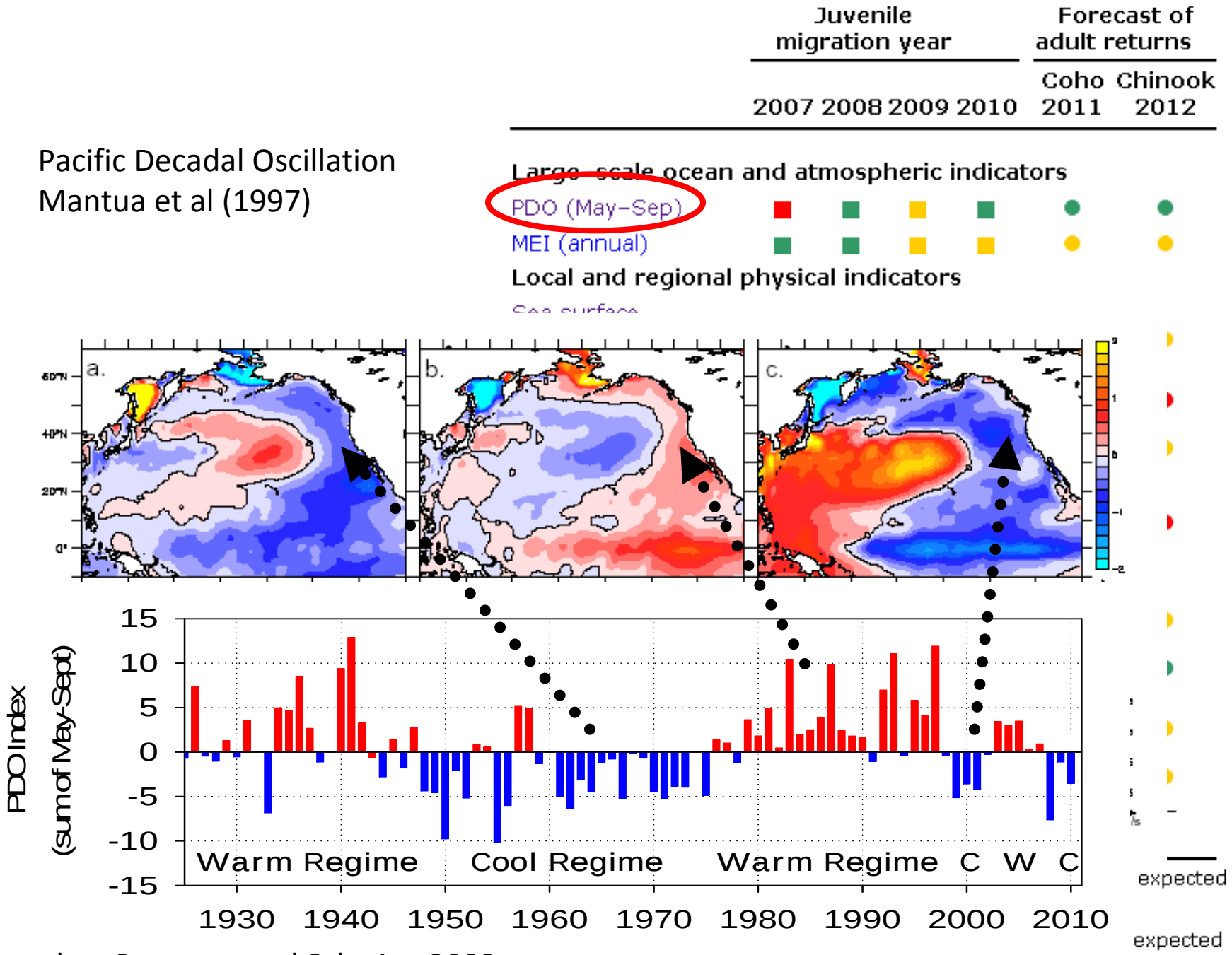
Broad array of indicators spanning a range of spatial scales and processes.

- physical, biological

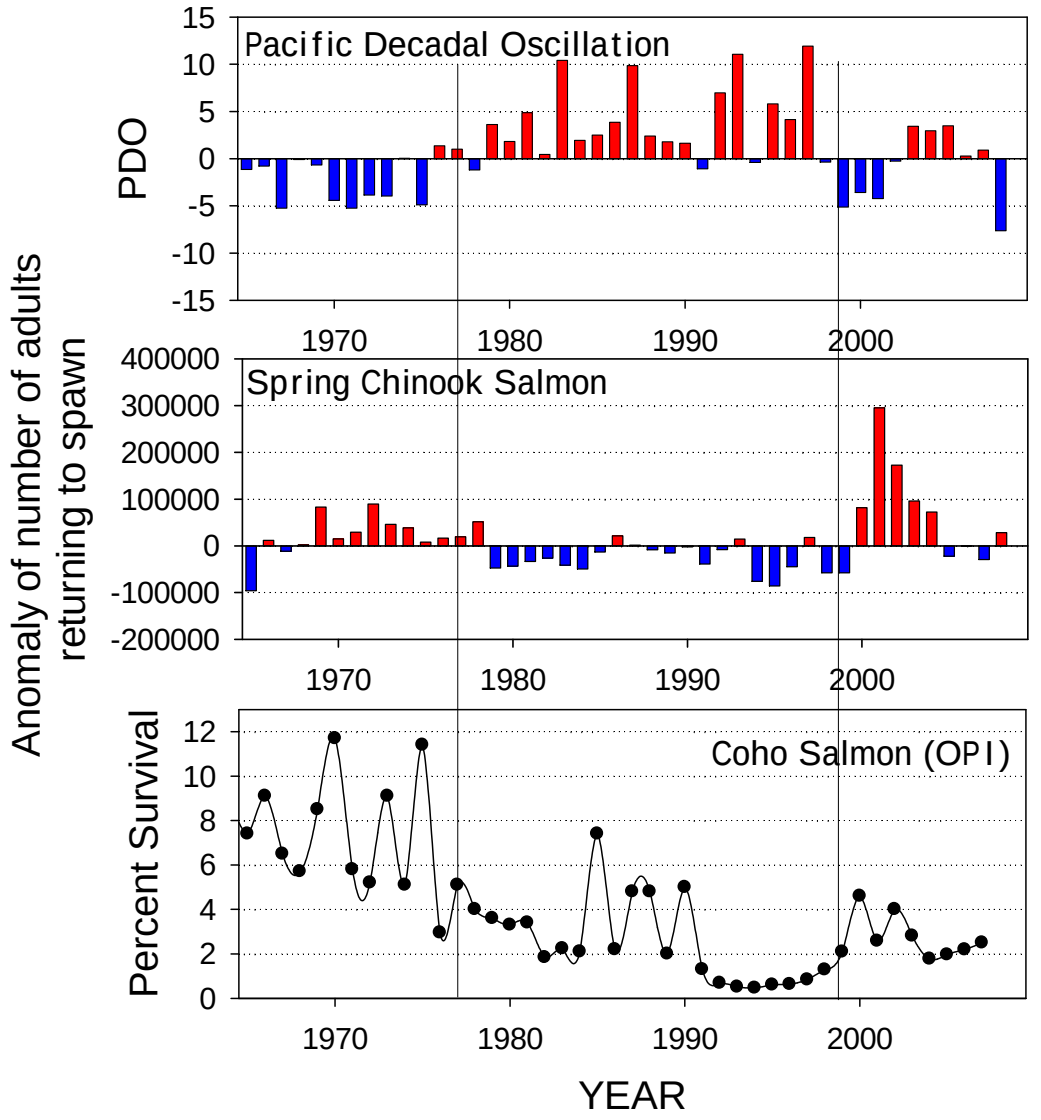
Indicators related to ocean conditions for salmon species (coho and Chinook) in the NCC.



Pacific Decadal Oscillation
Mantua et al (1997)

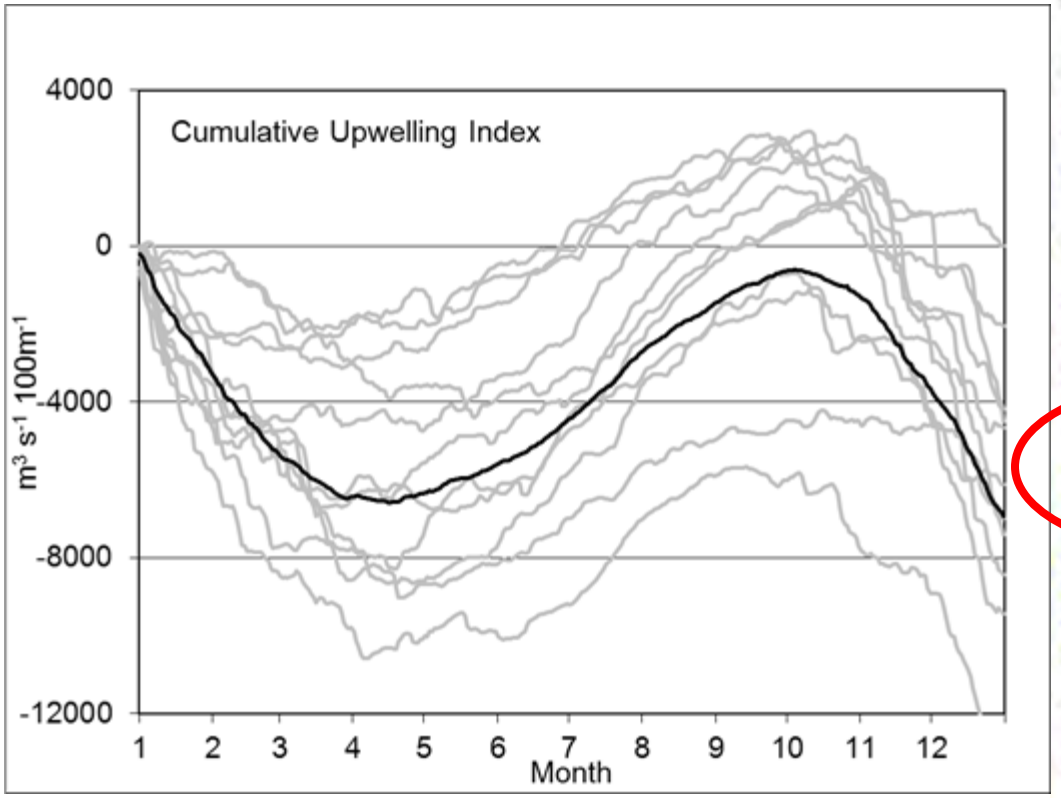


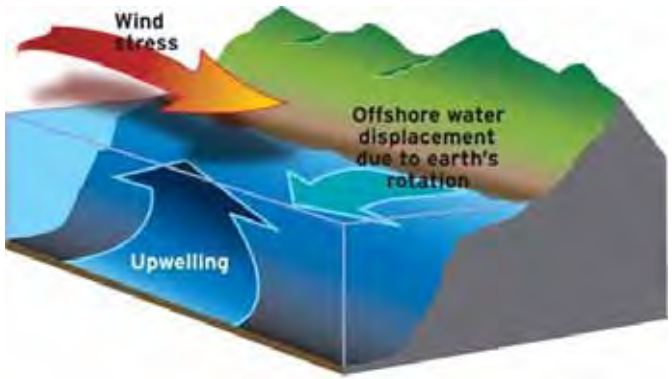
Based on Peterson and Schwing 2003



	Juvenile migration year			
	2006	2007	2008	2009
Large-scale ocean and atmospheric indicator				
PDO (May–Sep)				
MEI (annual)				
Local and regional physical indicators				
Sea surface temperature anomalies				
Coastal upwelling				
Physical spring transition				
Deep water temperature and salinity				
Local biological indicators				
Copepod biodiversity				
Northern copepod anomalies				
Biological spring transition				
June spring Chinook				
September Coho				

Seasonal upwelling in the NCC
Using the CUI (Bakun 1973)





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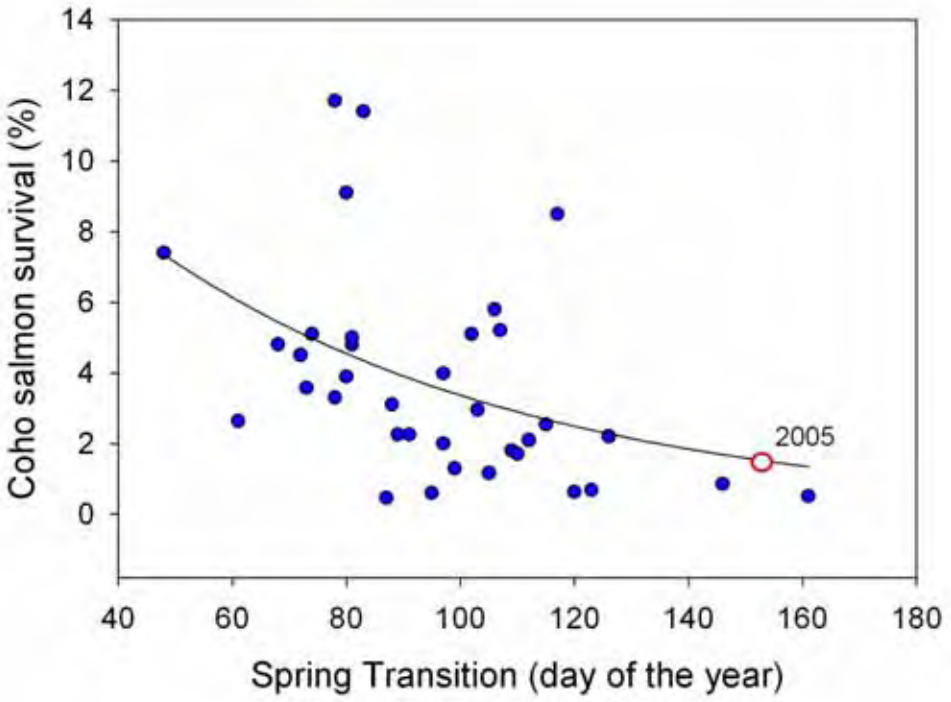
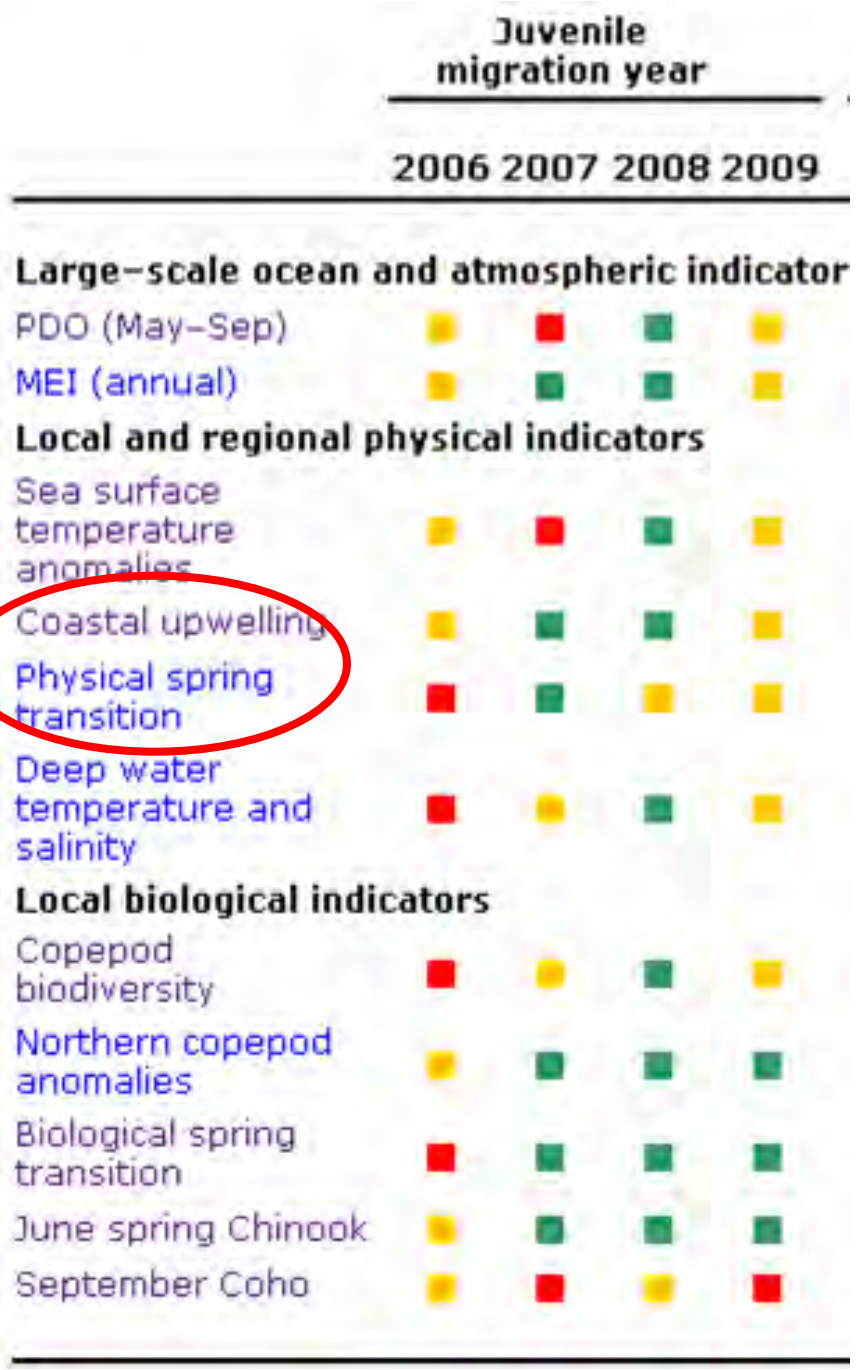
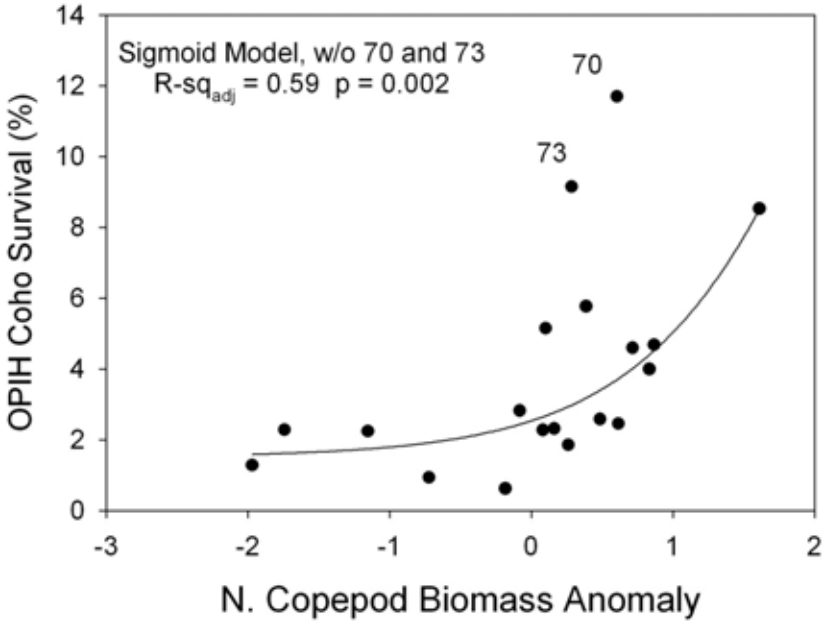
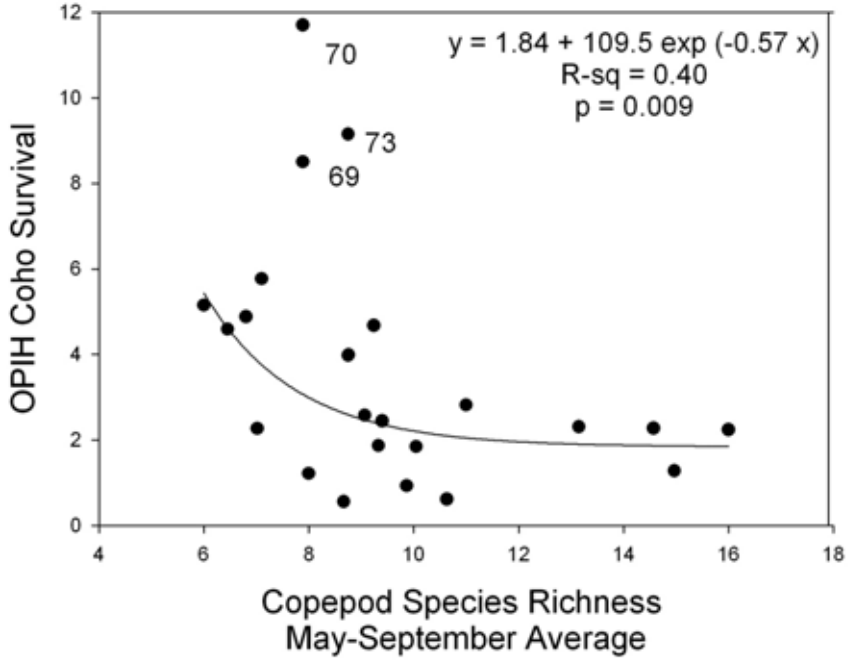


Logerwell et al. 2003 Fish. Ocean. 23



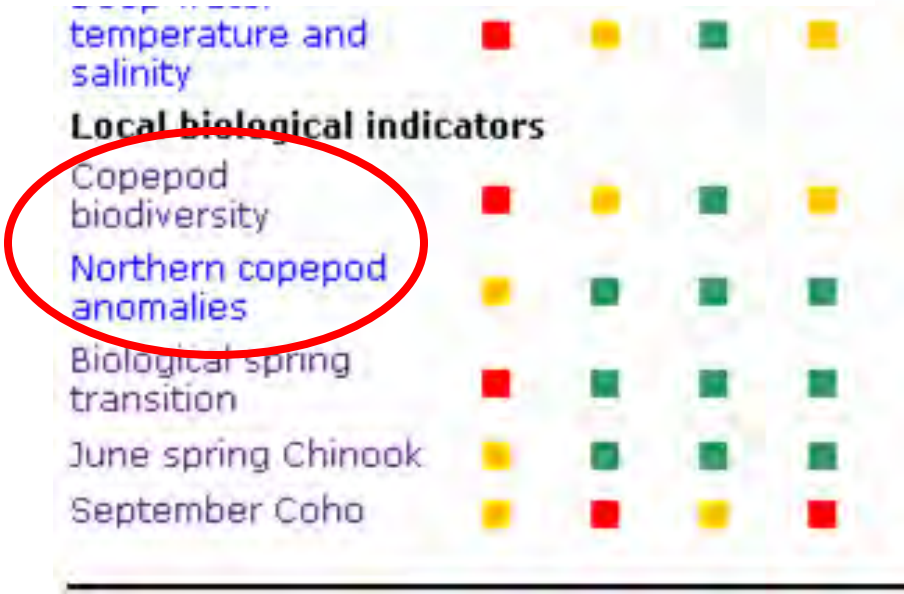




← Boreal Sub-tropical →

Importance of the food source:
Zooplankton assemblage is dependent on source waters.

- Boreal (northern) zooplankton may ultimately be a better food source for salmon (high in lipids).
- Sub-tropical zooplankton are lower in quality.



Original data available on the website
Different levels of simplification used to help with interpretation

		1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
PDO (December-March)		5.07	-1.75	-4.17	1.86	-1.73	7.45	1.85	2.44	1.94	-0.17	-3.06	-5.41	2.17
PDO (Sum May-September)		-0.37	-5.13	-3.58	-4.22	-0.26	3.42	2.96	3.48	0.28	0.91	-7.63	-1.11	-3.53
MEI Annual		0.80	-0.89	-0.53	-0.18	0.58	0.45	0.43	0.29	0.31	-0.33	-0.67	0.38	-0.42
MEI Jan-June		2.22	-0.85	-0.67	-0.30	0.31	0.57	0.26	0.62	-0.27	0.25	-0.84	-0.17	0.84
SST 46050	deg C	13.66	13.00	12.54	12.56	12.30	12.92	14.59	13.56	12.77	13.87	12.39	13.02	12.92
SST NH 05 Summer	deg C	11.26	10.79	10.64	11.08	10.73	10.91	13.11	12.00	11.11	12.08	10.74	12.00	11.50
SST NH 05 Winter Before (No	deg C	12.00	10.80	9.96	10.04	10.11	10.78	11.02	10.74	10.47	9.84	9.36	10.03	11.28
Physical Spring Trans UI Bas	Day of Yea	83	88	134	120	84	109	113	142	109	70	87	82	95
Upwelling Anomaly (April-May)		-14	19	-36	2	-12	-34	-27	-55	-14	9	0	-5	-35
Length of upwelling season (I	days	191	205	151	173	218	168	177	129	195	201	179	201	161
NH 05 Deep T	deg C	8.58	7.51	7.64	7.50	7.38	7.75	7.88	7.91	7.92	7.55	7.46	7.70	7.67
NH 05 Deep S		33.51	33.87	33.83	33.87	33.86	33.70	33.66	33.79	33.82	33.88	33.87	33.73	33.71
Copepod richness anomaly	no. of spec	5.49	-2.46	-3.03	-0.41	-0.72	1.52	0.57	5.02	3.67	-0.39	-0.53	-0.35	3.70
Northern Copepod Biomass	log biomas	-1.97	0.08	0.72	0.49	0.83	-0.08	0.26	-1.74	0.16	0.62	0.87	0.66	0.68
Biological Transition	Day of Yea	365	134	97	79	108	156	146	230	150	81	64	65	135
Copepod Community structur	X-axis ordi	0.75	-0.84	-0.83	-0.78	-0.98	-0.18	-0.11	0.57	0.00	-0.66	-0.93	-0.81	-0.19
Winter Ichthyoplankton	log biomas	0.16	0.90	1.80	1.25	1.05	0.63	0.58	0.83	0.59	0.60	1.84	0.89	1.65
June-Chinook Catches	fish per km	0.26	1.27	1.04	0.44	0.85	0.63	0.42	0.13	0.69	0.86	2.56	0.97	0.89
Sept-Coho Catches	fish per km	0.11	1.12	1.27	0.47	0.98	0.29	0.07	0.03	0.16	0.15	0.27	0.01	0.03

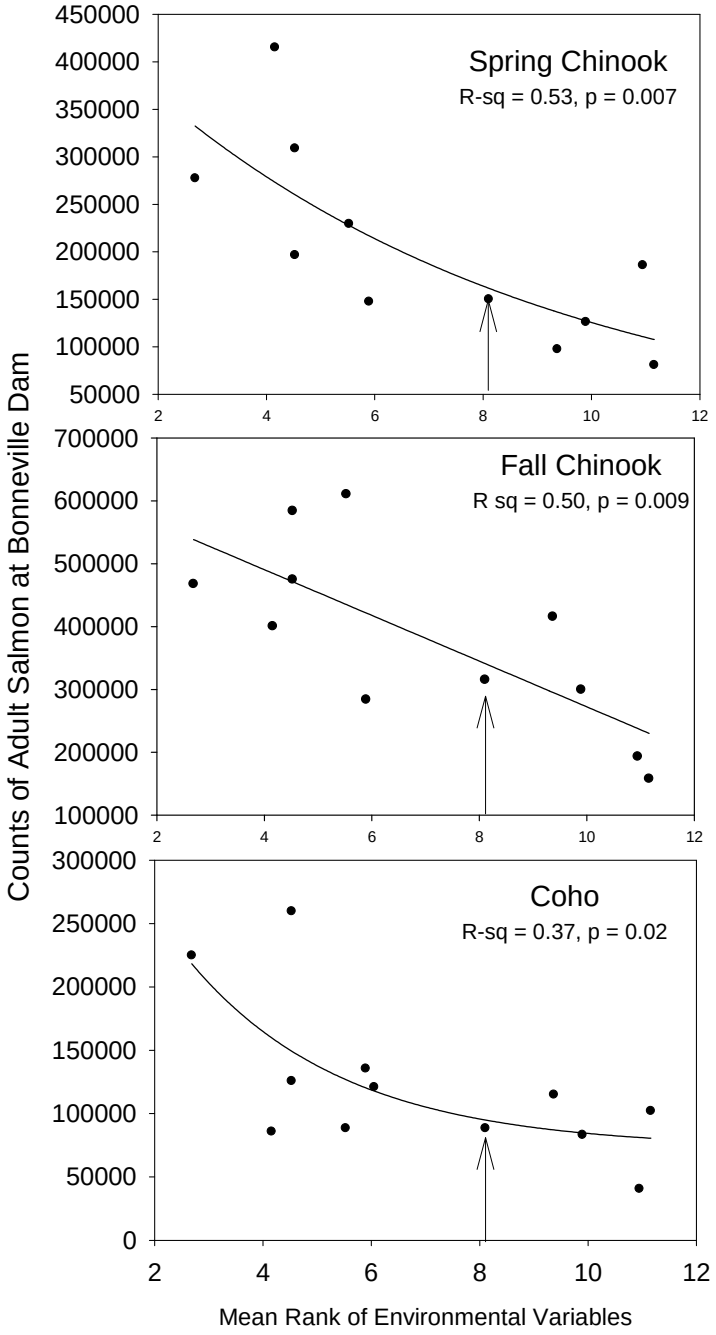
Original data available on the website
Different levels of simplification used to help with interpretation

	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
PDO (December-March)	12	4	2	8	5	13	7	11	9	6	3	1	10
PDO (May-September)	7	2	4	3	8	12	11	13	9	10	1	6	5
MEI Annual	13	1	3	6	12	11	10	7	8	5	2	9	4
MEI Jan-June	13	1	3	4	9	10	8	11	5	7	2	6	12
SST at 46050 (May-Sept)	11	8	3	4	1	7	13	10	5	12	2	9	6
SST at NH 05 (May-Sept)	8	4	1	6	2	5	13	10	7	12	3	11	9
SST winter before (Nov-Mar)	13	10	3	5	6	9	11	8	7	2	1	4	12
Physical Spring Trans (UI Based)	3	6	12	11	4	8	10	13	8	1	5	2	7
Upwelling Anomaly (Apr-May)	7	1	12	3	6	10	9	13	7	2	4	5	11
Length of upwelling season (UI Based)	6	2	12	9	1	10	8	13	5	3	7	3	11
Deep Temperature at NH 05	13	4	6	3	1	9	10	11	12	5	2	8	7
Deep Salinity at NH05	13	3	6	2	5	11	12	8	7	1	4	9	10
Copepod Richness Anomaly	13	2	1	5	3	9	8	12	10	6	4	7	11
N.Copepod Anomaly	13	10	3	7	2	11	8	12	9	6	1	5	4
Biological Transition	13	7	5	3	6	11	9	12	10	4	1	2	8
Copepod Community structure	13	3	4	6	1	9	10	12	11	7	2	5	8
Winter Ichthyoplankton	13	6	2	4	5	9	12	8	11	10	1	7	3
June-Chinook Catches	12	2	3	10	7	9	11	13	8	6	1	4	5
Sept-Coho Catches	9	2	1	4	3	5	10	12	7	8	6	13	11
Mean of Ranks of Environmental Data	10.8	4.1	4.5	5.4	4.6	9.4	10.0	11.0	8.2	5.9	2.7	6.1	8.1
RANK of the mean rank	12	2	3	5	4	10	11	13	9	6	1	7	8

Quantitative assessment

Initially using a simple mean-rank to forecast salmon returns.

Surprisingly good results, especially for Chinook.



What's New?

Determine 'weights' for the different indicators (Brian Burke)

- Maximum Covariance Analysis [MCA]
- Partial Least Squares Regression [PLSR]

> "Multivariate regression methods like PLSR have been designed to confront the situation that there are many, possibly correlated, predictor variables, and relatively few samples."
>
> -Mevik and Wehrens, Journal of Statistical Software 18(2):1-24.

Indicators

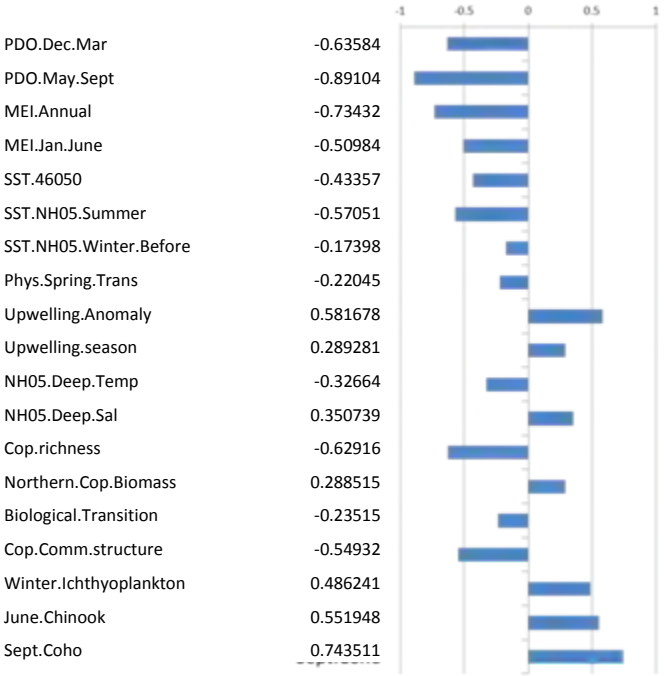
	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
PDO.Dec.Mar	5.07	-1.75	-4.17	1.86	-1.73	7.45	1.85	2.44	1.94	-0.17	-3.06	-5.41	2.23
PDO.May.Sept	0.9	-5.54	-3.23	-2.95	-0.47	3.42	2.21	3.94	0.28	0.18	-6.08	-1.11	-3.53
MEI.Annual	0.87	-0.85	-0.51	-0.18	0.59	0.46	0.38	0.40	0.22	-0.20	-0.65	0.32	-0.31
MEI.Jan.June	2.28	-0.8	-0.62	-0.26	0.32	0.55	0.27	0.62	-0.25	0.28	-0.85	-0.19	0.84
SST.46050	13.66	13.00	12.54	12.56	12.30	12.92	14.59	13.56	12.77	13.87	12.4	13.02	12.92
SST.NH05.Summer	11.3	10.8	10.6	11.1	10.7	10.9	13.1	12	11.1	12.1	10.7	12	11.5
SST.NH05.Winter.Before	12	10.8	9.96	10	10.1	10.8	11	10.7	10.5	9.84	9.36	10	11.3
Phys.Spring.Trans	83	88	134	120	84	109	113	142	109	70	87	82	95
Upwelling.Anomaly	-14	19	-36	2	-12	-34	-27	-55	-14	9	0	-5	-35
Upwelling.season	191	205	151	173	218	168	177	129	195	201	179	201	161
NH05.Deep.Temp	8.58	7.51	7.64	7.5	7.38	7.75	7.88	7.91	7.92	7.55	7.46	7.7	7.67
NH05.Deep.Sal	33.5	33.9	33.8	33.9	33.9	33.7	33.7	33.8	33.8	33.9	33.9	33.7	33.7
Cop.richness	5.49	-2.46	-3.03	-0.41	-0.72	1.52	0.57	5.02	3.67	-0.39	-0.53	-0.35	3.7
Northern.Cop.Biomass	-1.97	0.08	0.72	0.49	0.83	-0.08	0.26	-1.74	0.16	0.62	0.87	0.66	0.68
Biological.Transition	365	134	97	79	108	156	146	230	150	81	64	65	135
Cop.Comm.structure	0.75	-0.84	-0.83	-0.78	-0.98	-0.18	-0.11	0.57	0.00	-0.66	-0.93	-0.81	-0.19
Winter.Ichthyoplankton	0.16	0.9	1.8	1.25	1.05	0.63	0.58	0.83	0.59	0.6	1.84	0.89	1.65
June.Chinook	0.26	1.27	1.04	0.44	0.85	0.63	0.42	0.13	0.69	0.86	2.56	0.97	0.89
Sept.Coho	0.11	1.12	1.27	0.47	0.98	0.29	0.07	0.03	0.16	0.15	0.27	0.01	0.03

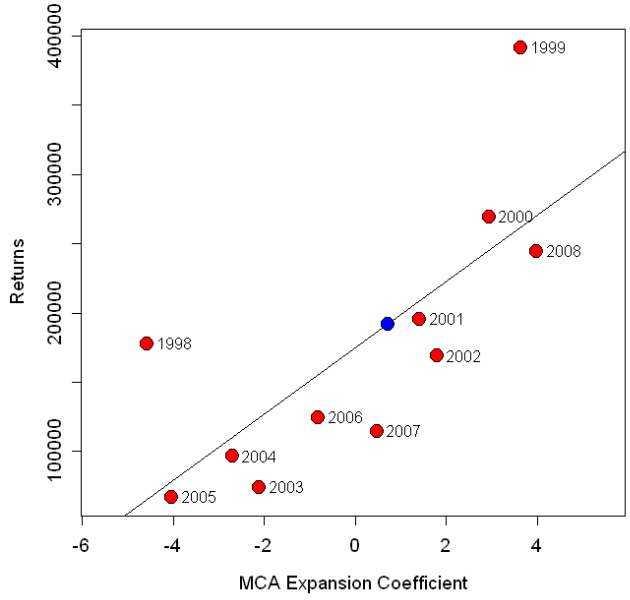
X

Spring Chinook Returns

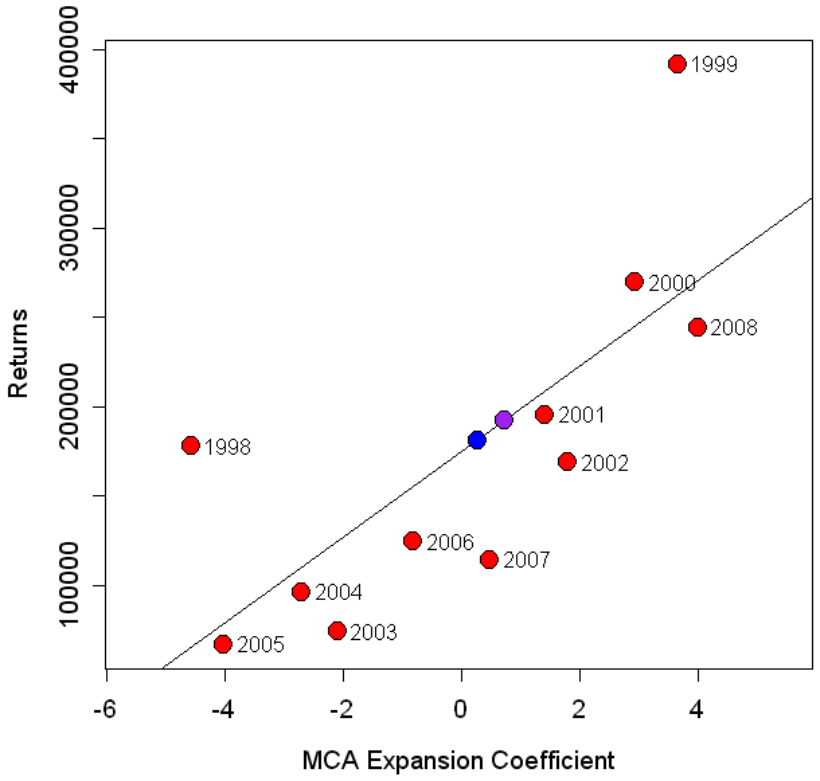
1998	177774
1999	391818
2000	269428
2001	195671
2002	168779
2003	74053
2004	96457
2005	66644
2006	124369
2007	114548
2008	244418

Covariance

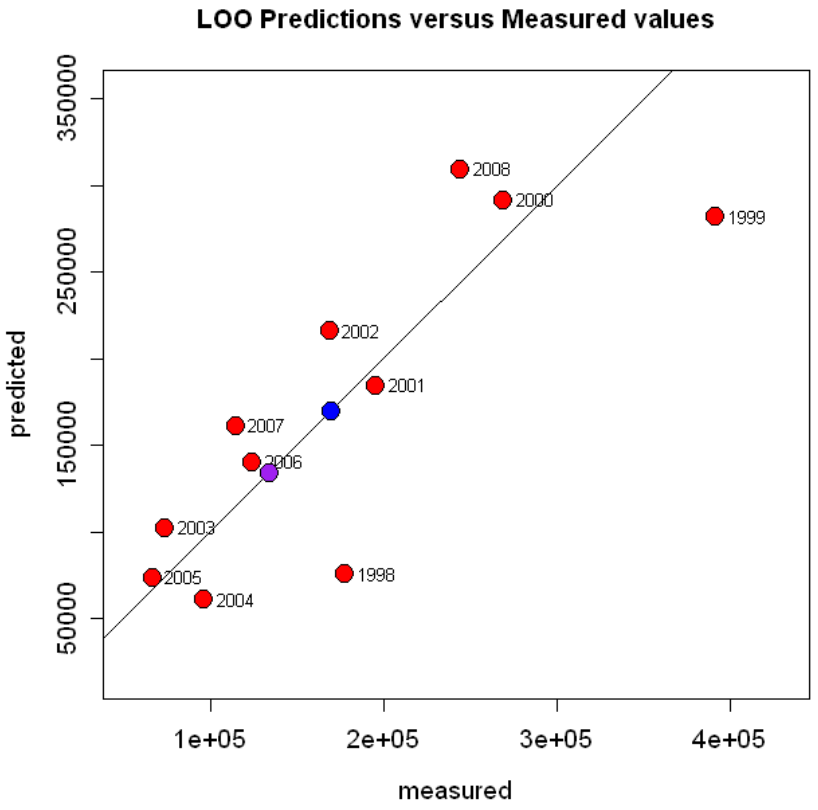




MCA



PLSR

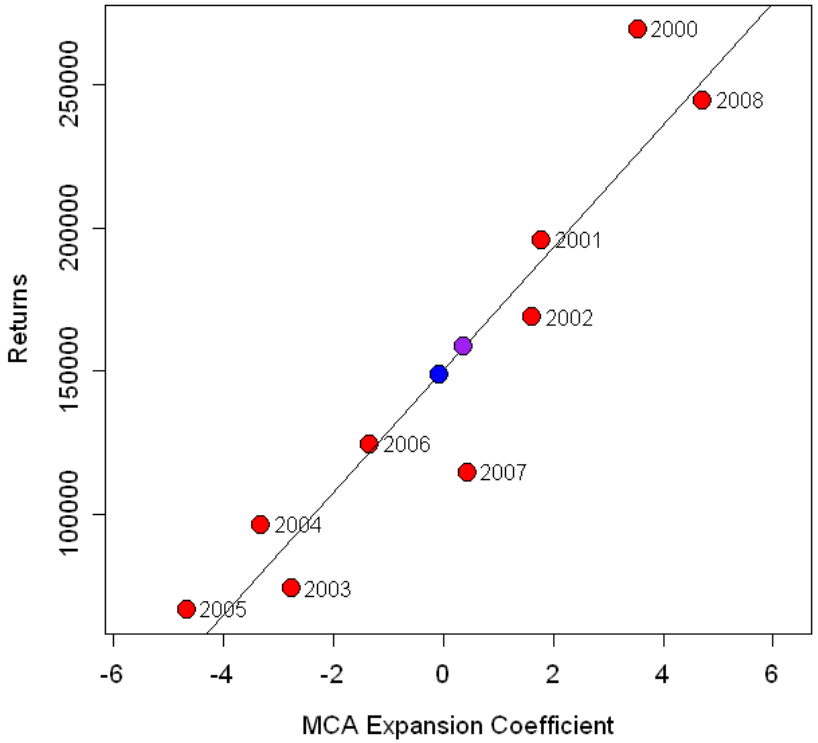


Predicted returns
(from outmigration year)

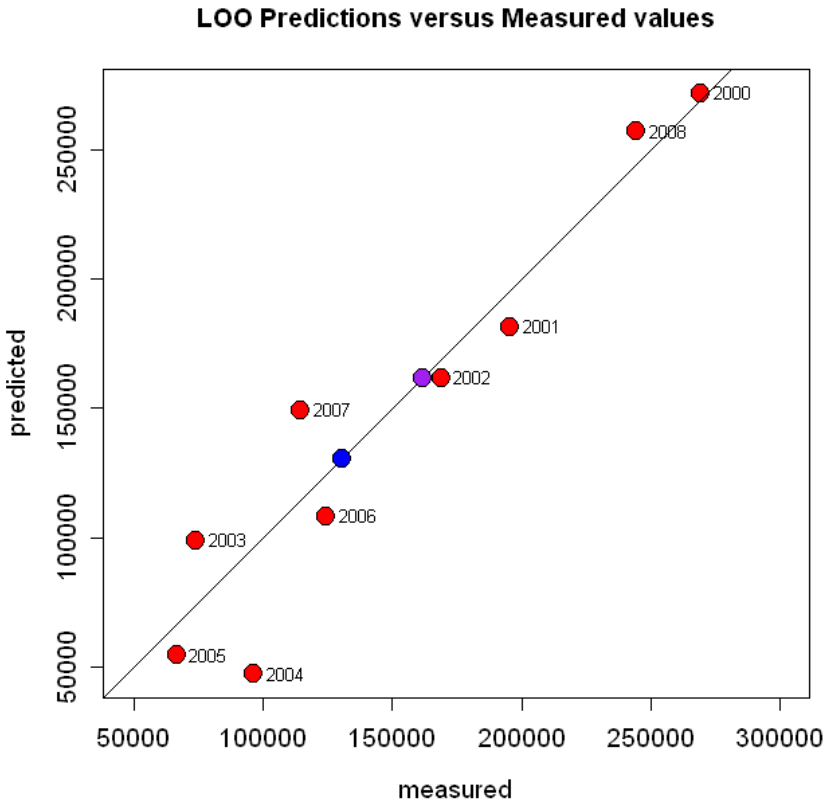
	MCA	PLSR
2009	192	134
2010	181	170

Without 1998 and 1999

MCA



PLSR



Predicted returns
(from outmigration year)

	MCA	PLSR
2009	159	162
2010	149	130

How do the predictions compare?

Spring Chinook					
		Actual			
Outmigration	Return	Return	Burke	Peterson	TAC
Year	Year	Mar - June	Forecas	Forecast	Managers
2008	2010	278	296	325	470
2009	2011	~5	134	100	~250

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