Phenology of zooplankton species in the Oregon upwelling zone

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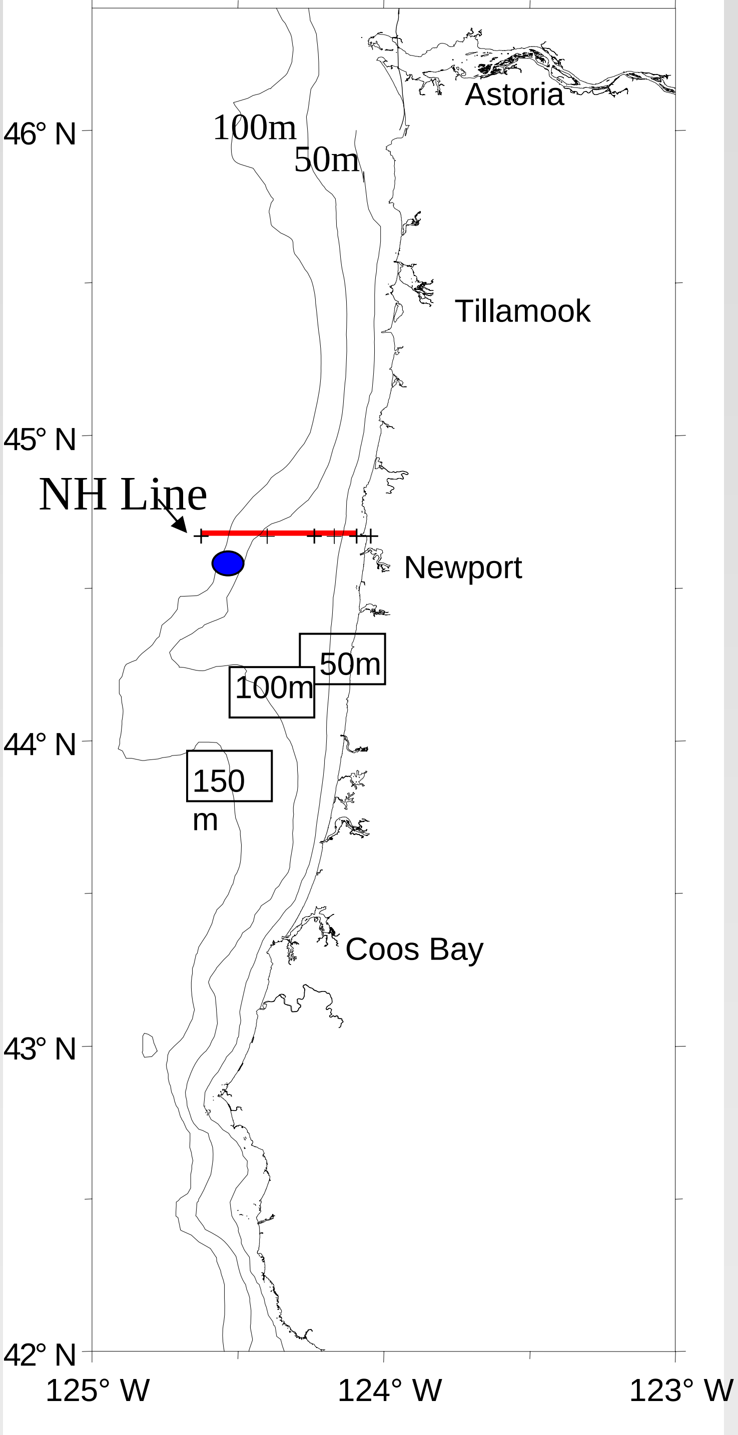


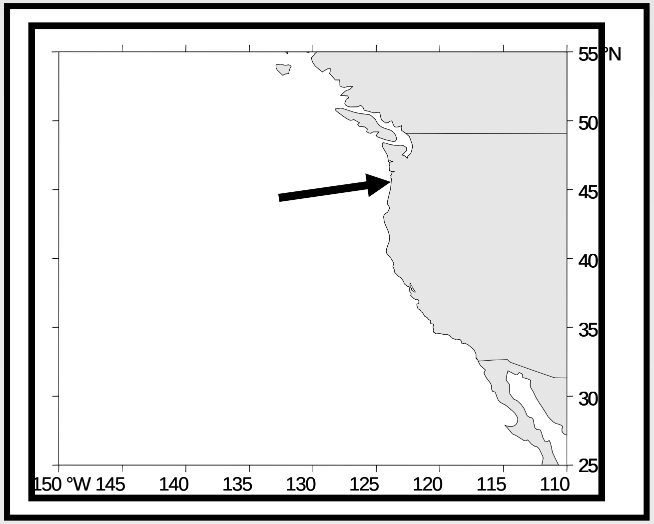
NH-Line Hydrographic and Zooplankton Time Series

Bi-weekly Sampling:

- **1969-1973**
- **1983**
- **1996 – present** (Peterson et al.)

N = 363 visits to NH 05

= NOAA Weather Buoy



Seasonal Cycles in Northern California Current Upwelling zone difficult to define clearly

- Regular and tidy seasonal cycle seen only in climatology

- Phytoplankton blooms can occur almost anytime between February and November depending on the weather.

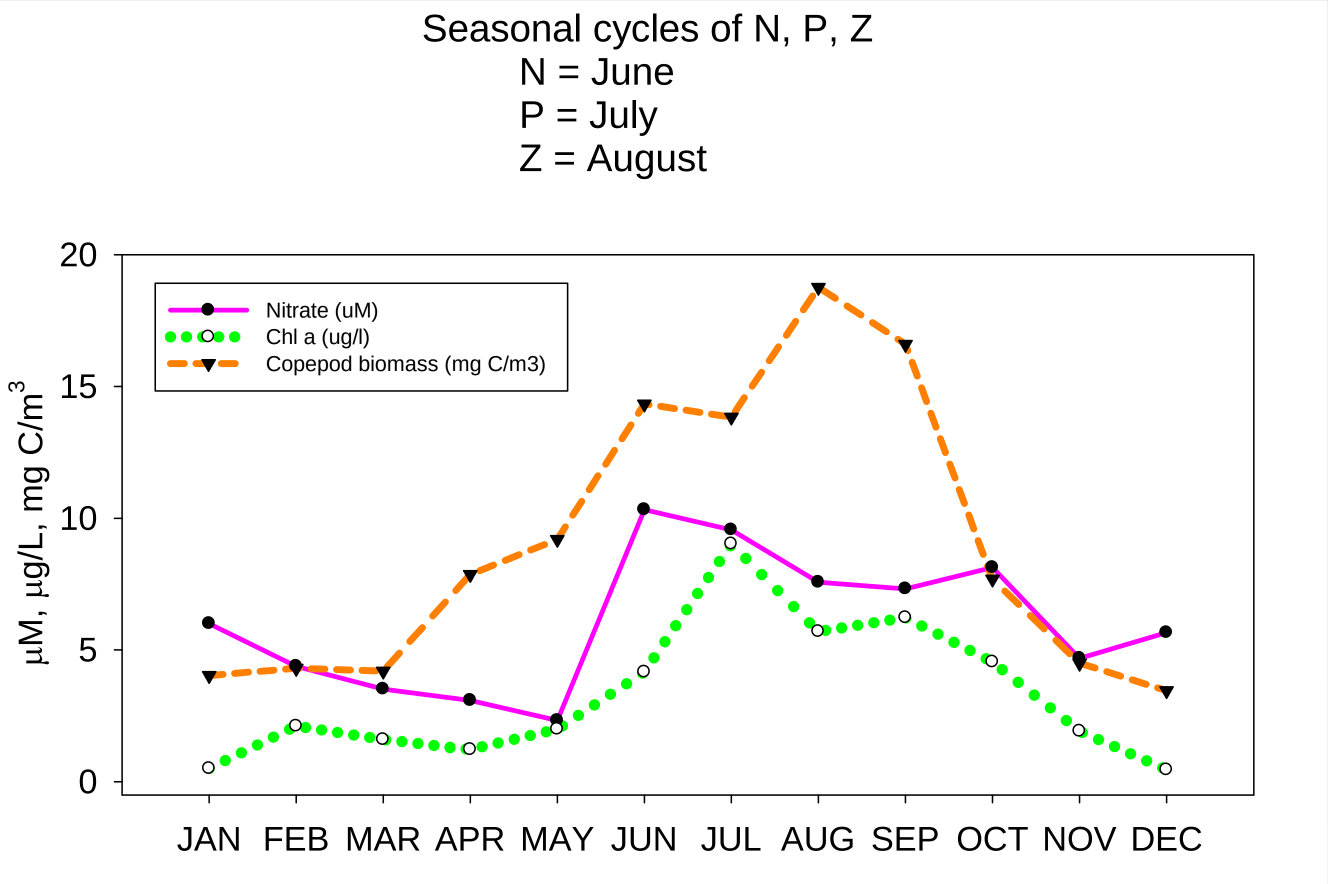
- Recently there have been disruptions to the normal upwelling-production cycles....and there have been modifications to seasonal cycles

- Length of the upwelling season and the spring and fall transition dates of interest to salmon and seabirds and other LMRs... but how do we define these dates?

Four Topics

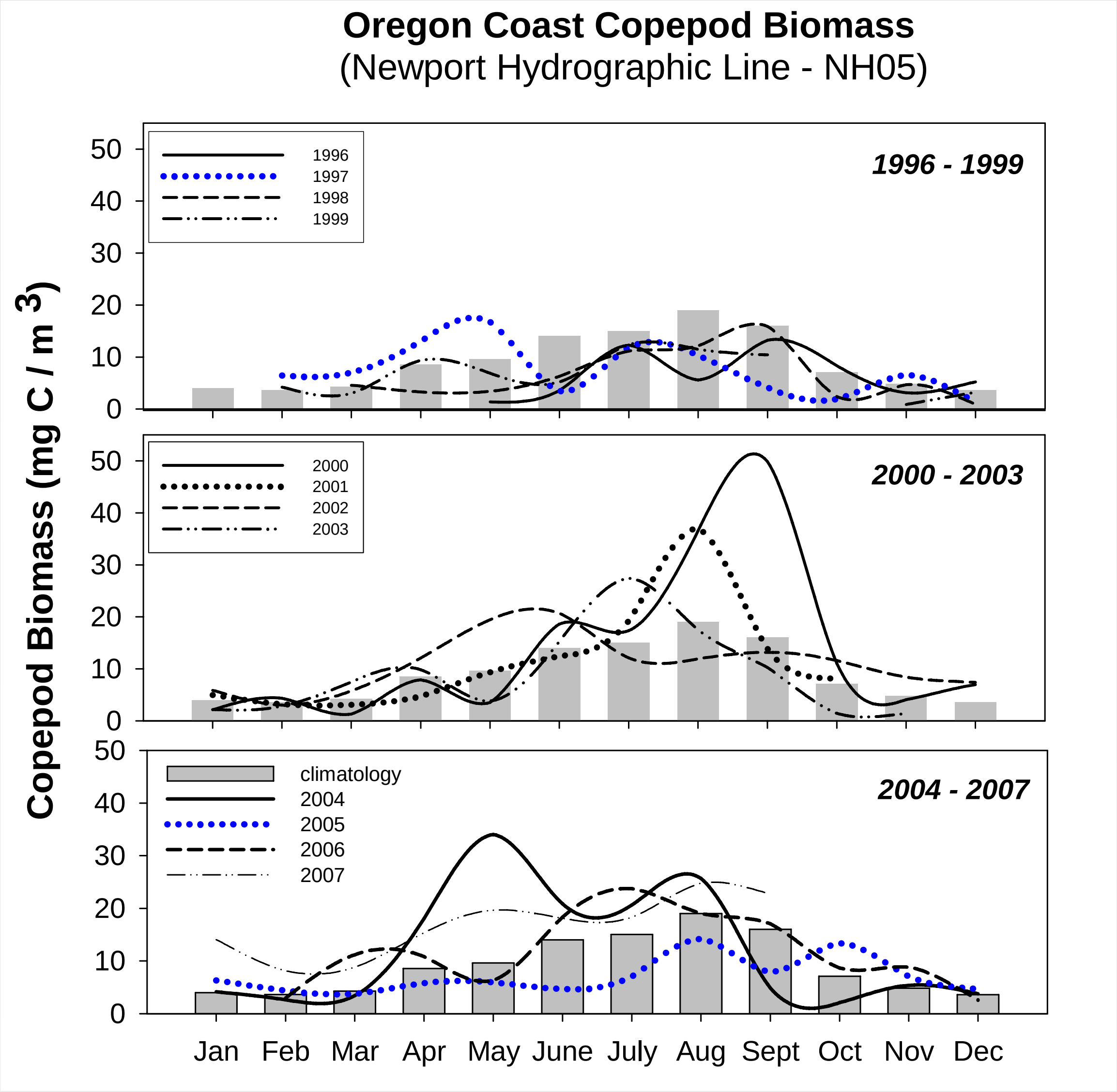
- The "seasonal cycle" is somewhat regular in phytoplankton, but not so for copepod biomass
- Winter bloom in February results in a burst in egg production by the euphausiid *Thysanoessa spinifera*
- Spring Transition
- Length of Upwelling Season

1. Seasonal Cycles



- 12-year climatology from biweekly sampling
- Seasonal cycles of nitrate, chlorophyll and copepods shows nice progression of peaks each with a one-month lag = the perfect world!

Copepod seasonal cycles



PDO negative (1999-2002)

PDO positive (97-98, 03-06,

PDO neutral 2007

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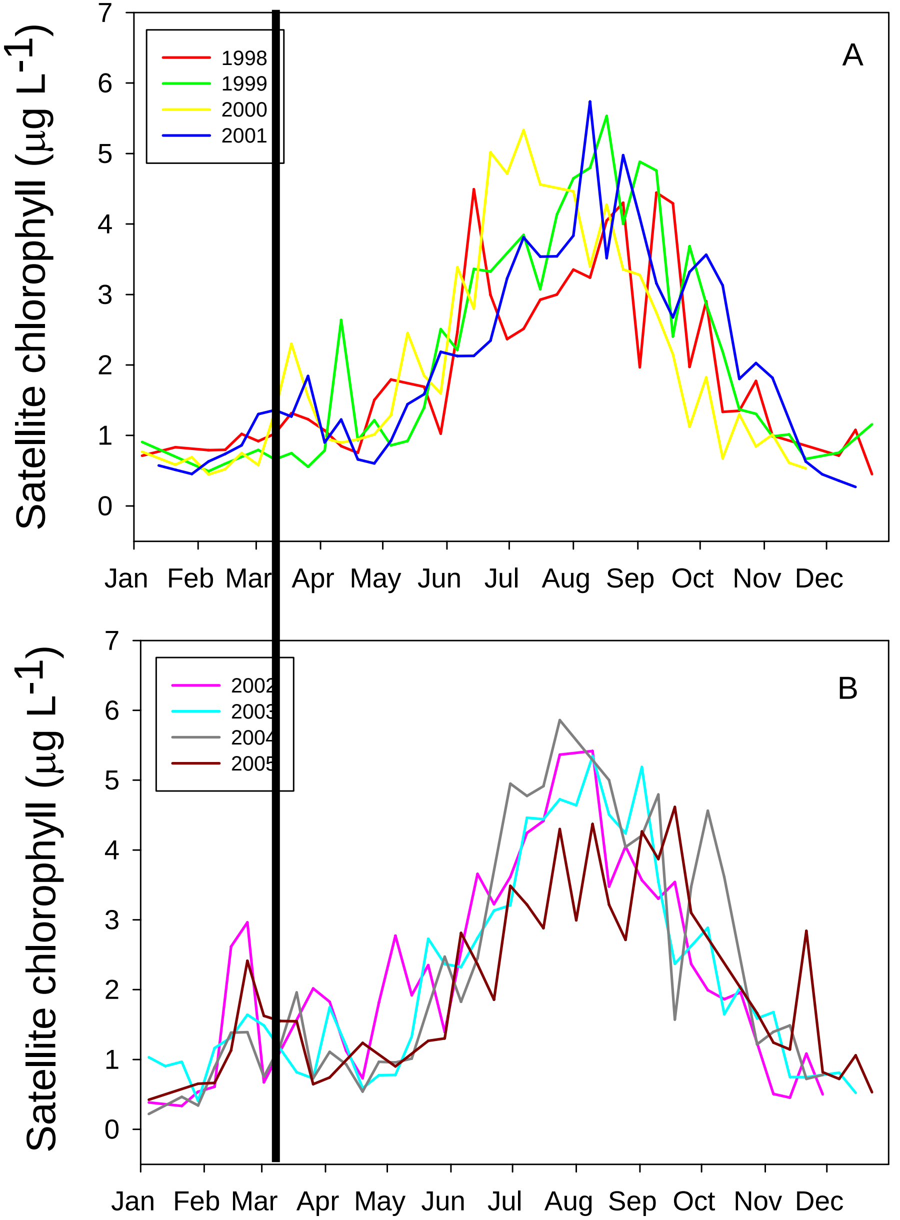
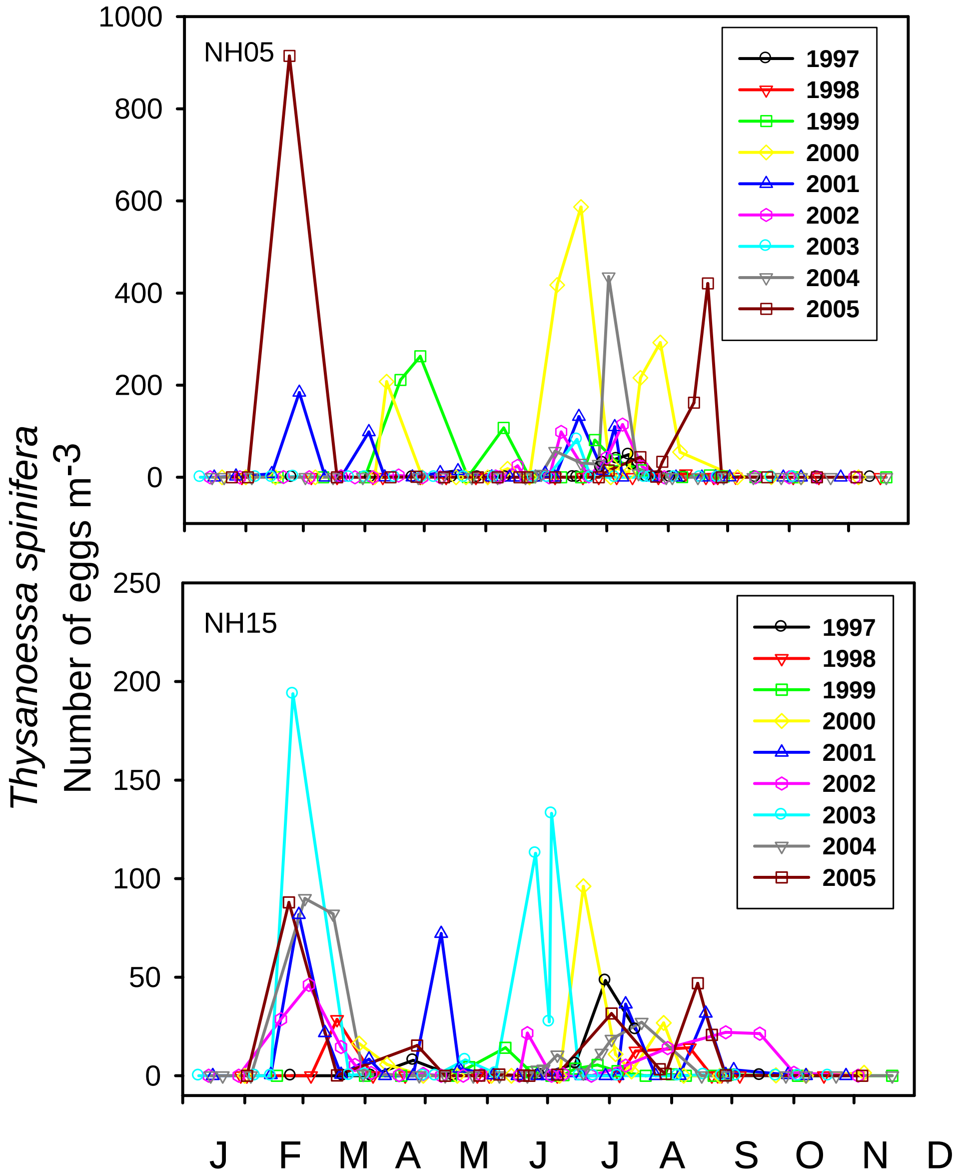
- 1996-1999 Below average
- 2000 Sept
- 2001 Aug
- 2002 June
- 2003 July
- 2004 May + Aug
- 2005 Very Low
- 2006 March + July
- 2007 High all year



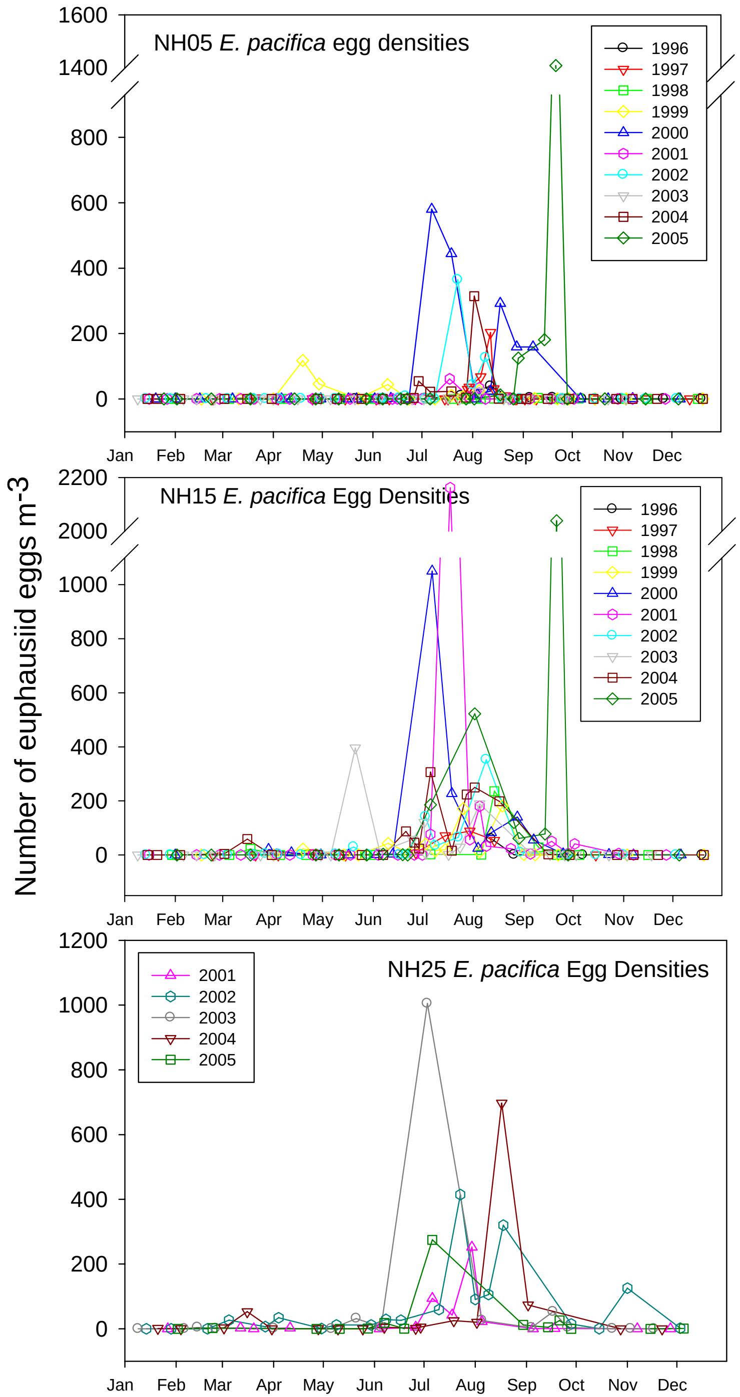
2. Chlorophyll (SeaWiFS)

- 1998-2001 Spring Bloom in March-April
- 2002-2005 Spring Bloom in February
- 2006 no Feb bloom
- 2007 Feb bloom

Thysanoessa spinifera



- Peaks seen in 2001-2005 and 2007 in February
- No peaks until April/May in all other years
- Summer peaks in July-August (but September 2005)
- Implications: reach juvenile stage in 58 d in the lab (two months) and adult in 4 months. Thus the July spawning peaks likely are the product of females born in February



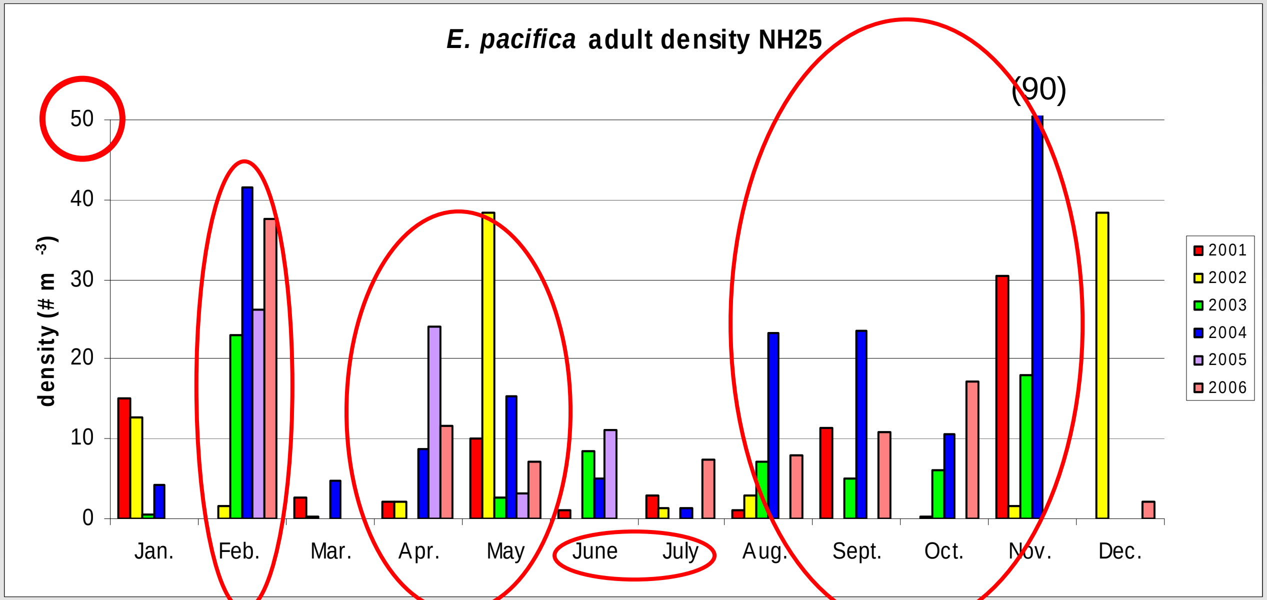
Euphausia pacifica

- Never spawn in winter
- Seldom spawn in spring
- Always spawn in July/August

Density of adult euphausiids

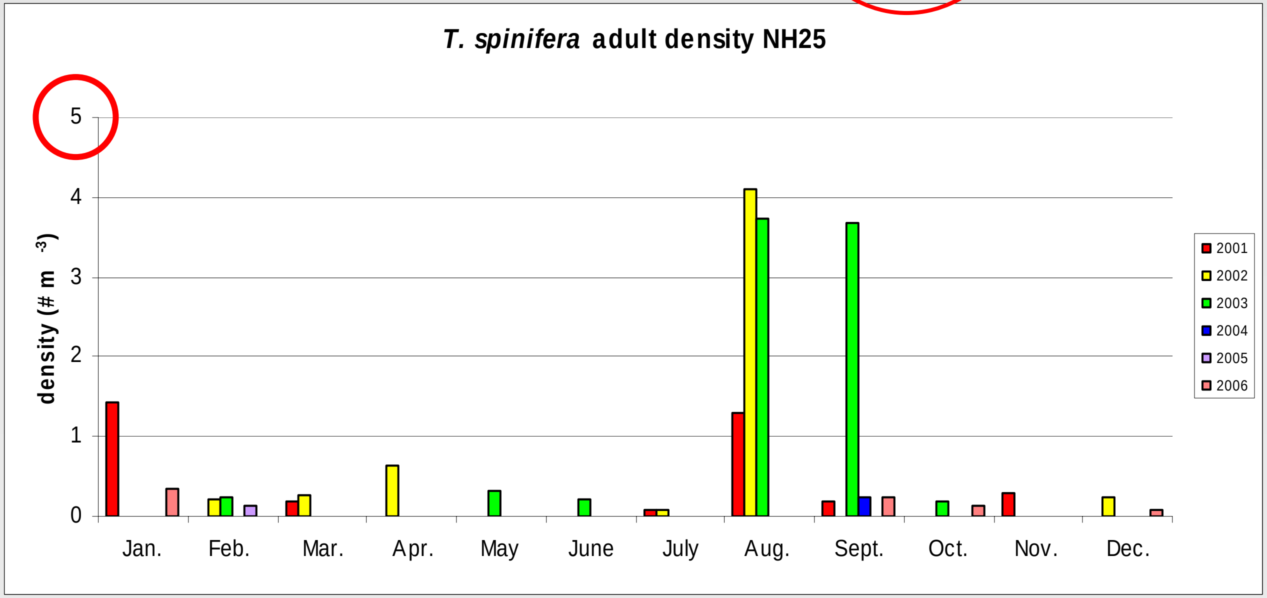
E. pacifica adults

- Abundant in Feb, April-May
- Low density June-July
- Higher Aug-Nov
- Dec inconclusive due to few samples



T. spinifera adults

- Never very abundant at NH25
- Highest abundance Aug-Sept, 3-4 animals m^{-3}



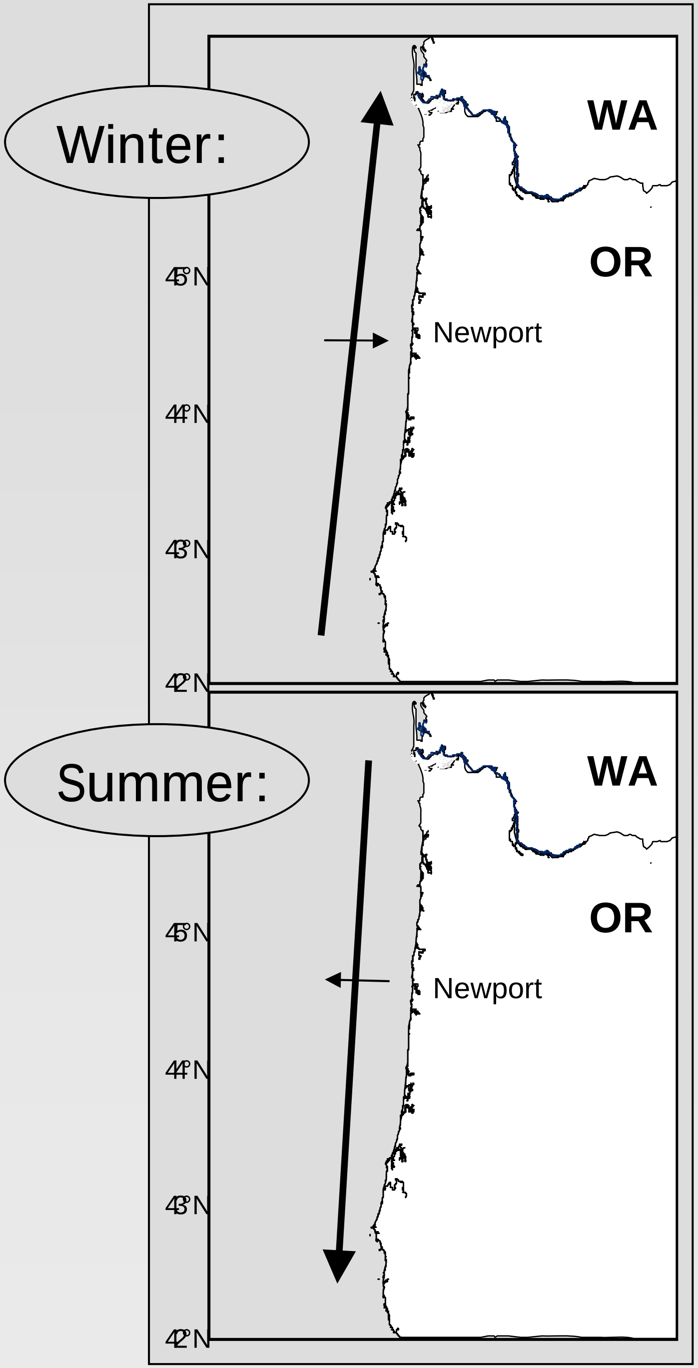
3. Seasonal cycles of winds and current structure off coastal Oregon:

- Winter:
  - Winds from the South
  - Downwelling
  - Poleward-flowing Davidson Current
  - Subtropical/southern species transported northward & onshore

- **Spring Transition in April/May**

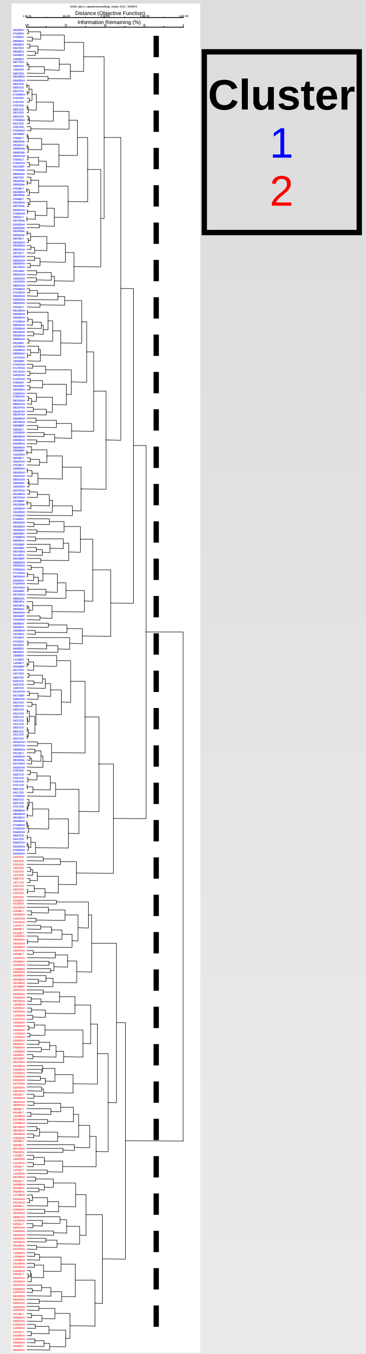
- Summer:
  - Strong winds from the North
  - Coastal upwelling
  - Equatorward alongshore transport
  - Boreal/northern species transported southward

- **Fall Transition in October**



Cluster analysis

Results of processing of 363 samples



Two patterns:

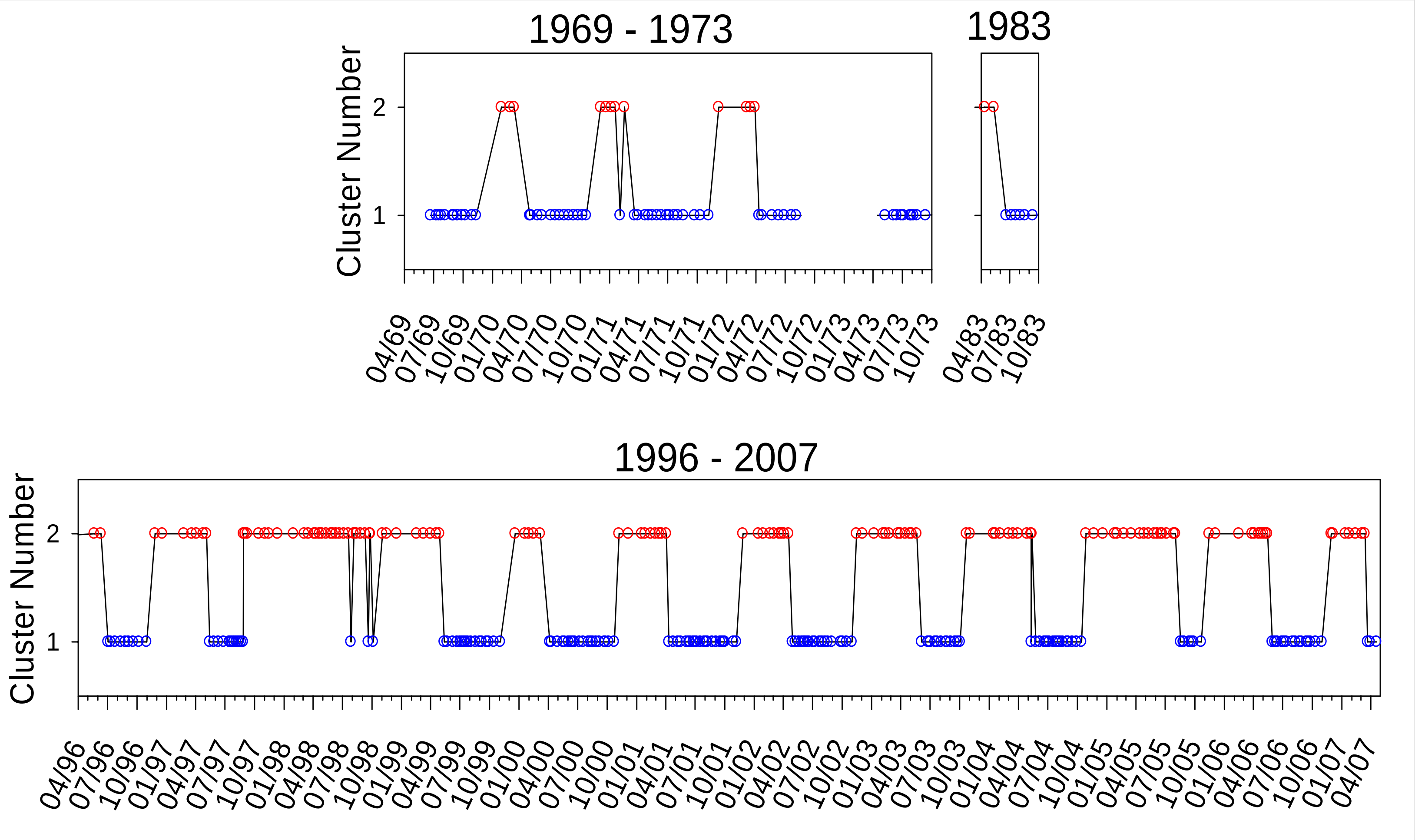
- Clusters **1** and **2** capture seasonal variations.

- Clusters 3-5 capture warm vs. cold ocean and El Niño events.

Cluster analysis defines seasonal changes in community structure and can be used to define transition dates.

Following Peterson And Keister 2003

Summer (cold water) and Winter (warm water) Clusters



Apart from the 1998 El Niño, cluster fidelity was stunning!

4. Length of upwelling season and the PDO

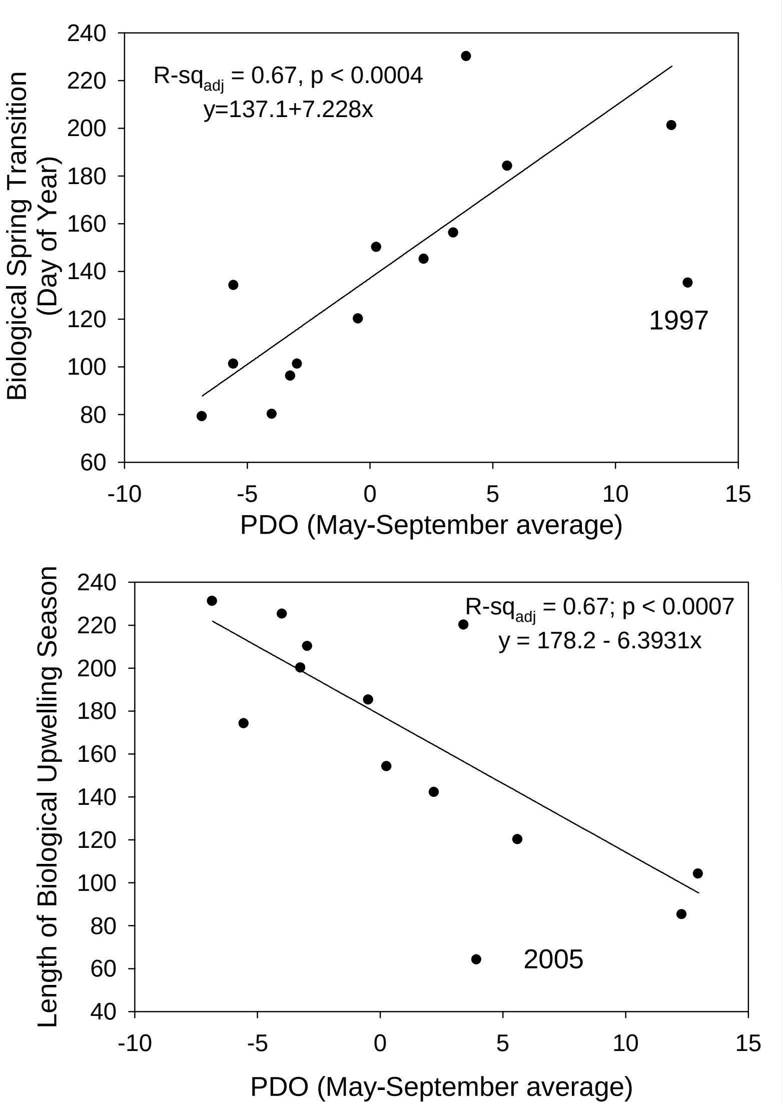
	Upwelling Season Start Date	End Date	Length Days	PDO
1970	~ 20 Mar	20 Oct	225	neg
1971	20 Mar	6 Nov	231	neg
1983	20 Jun	13 Sep	85	pos
1996	3 Jul	31 Oct	120	pos
1997	15 May	27 Aug	104	pos
1998	never	never	0	pos
1999	14 May	4 Nov	174	neg
2000	6 Apr	23 Oct	200	neg
2001	11 Apr	7 Nov	210	neg
2002	30 Apr	1 Nov	185	neg
2003	5 June	3 Oct	220	pos
2004	25 May	14 Oct	142	pos
2005	18 Aug	21 Oct	64	pos
2006	30 May	31 Oct	154	pos
2007	22 Mar			neg

Length of upwelling season:

174-231 d

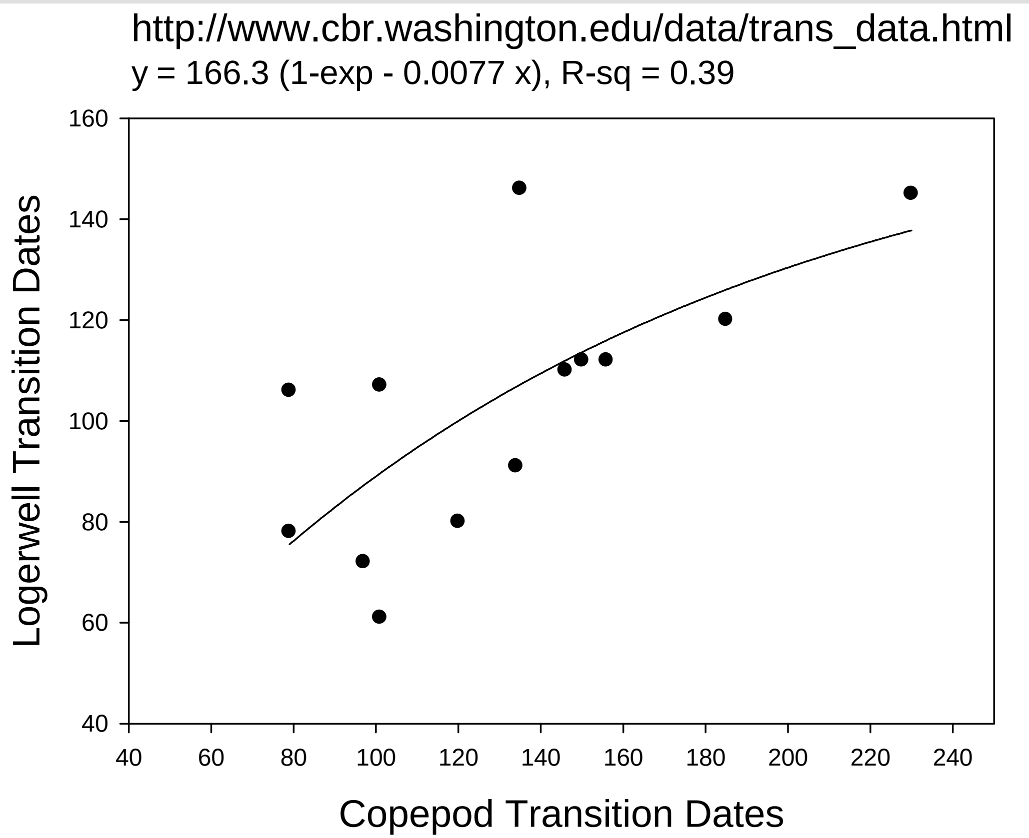
64-134 d

PDO vs date of 'biological spring transition' (UPPER) and number of days that a cold water community persisted in a given year (LOWER)



- The more negative the PDO, the **earlier** the date of "biological spring"
  - 'Zero' point is day 10 April
- The more negative the PDO the **longer** a cold water community persists.
  - 64-154 d when PDO positive
  - 174-231 d when PDO negative

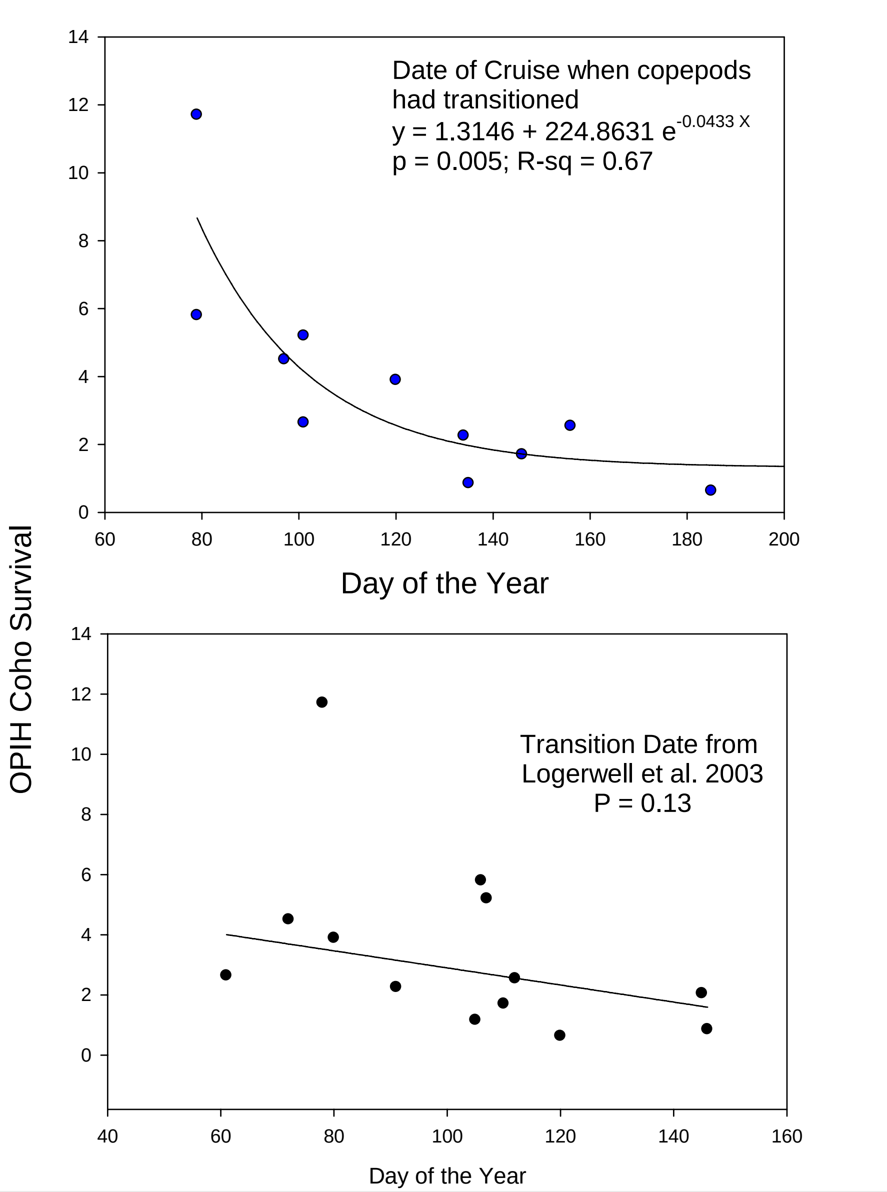
Logerwell vs Peterson Transition Dates



	Peterson	Logerwell
1996	185	120
1997	135	146
1998	---	105
1999	134	91
2000	97	72
2001	101	61
2002	120	80
2003	156	112
2004	146	110
2005	230	145
2006	150	112
2007	81	
1970	79	78
1971	79	106
1972	101	107

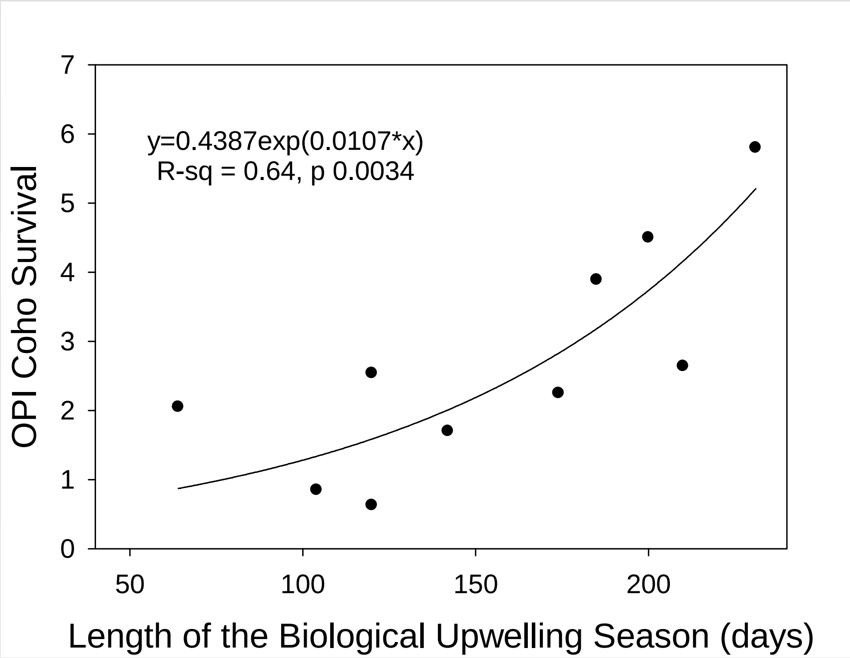
Mean = 128 (Copepods) v 103 (Sea Level)

Coho salmon survival vs. spring transition Dates



- Early transition yields better coho survival
- "Biological" transition dates better correlated with coho than "physical" transition dates

Length of upwelling season vs. coho survival



- Length of upwelling season equal fall date – spring date
- Longer upwelling seasons (as indexed by summer copepod communities) result in higher coho salmon survival

Summary

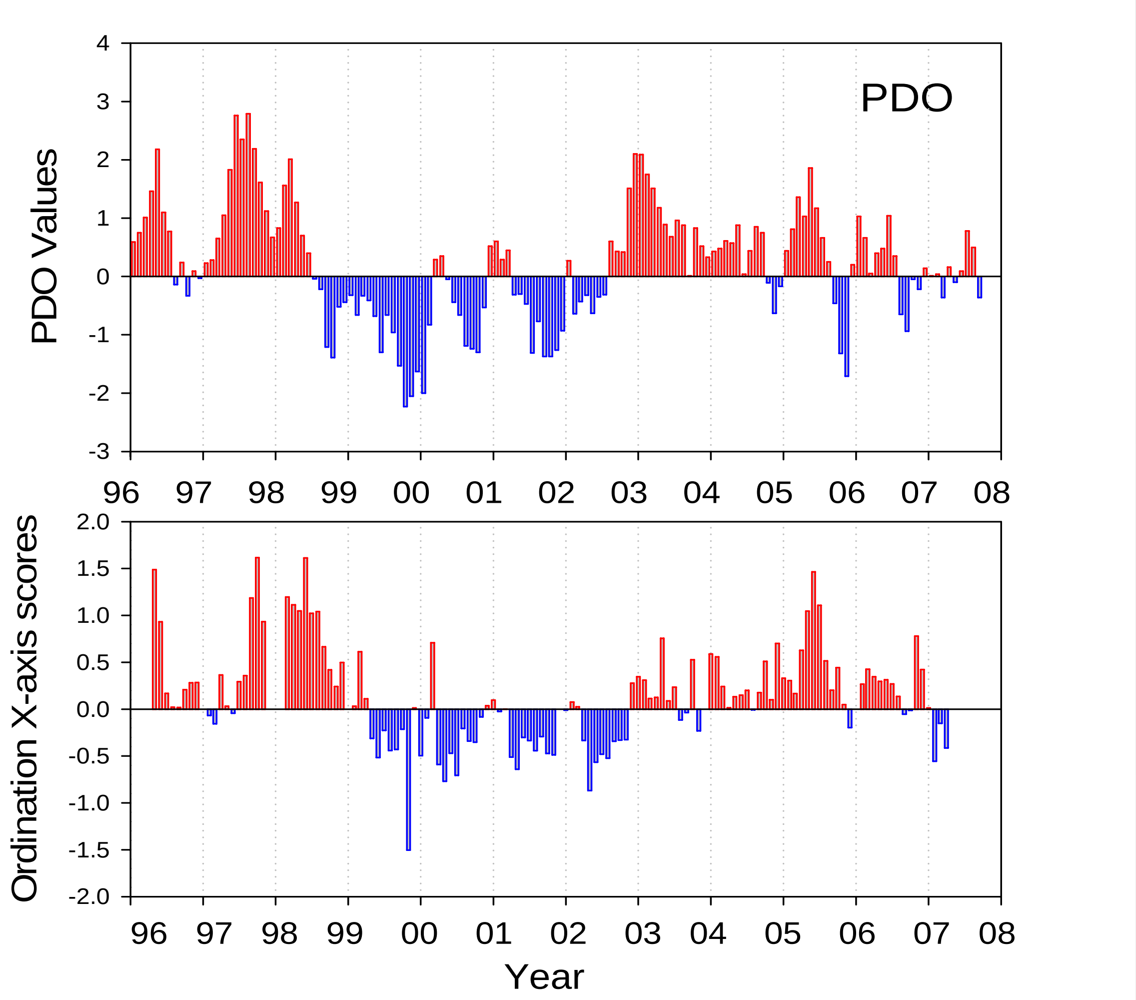
- Seasonal cycles of copepods highly variable among years;
- Late winter spawning by the euphausiid *Thysanoessa spinifera* appears to be dependent on presence of a late-winter phytoplankton bloom; perhaps results in more/less juveniles and adults 4-6 months later (this is a new discovery -- we have not looked at stock-recruit relationships);
- A highly variable date of spring transition should affect reproduction and feeding by those animals that depend upon production resulting from the spring transition;
- Length of the upwelling season is a new variable that we may want to examine more closely

Acknowledgements

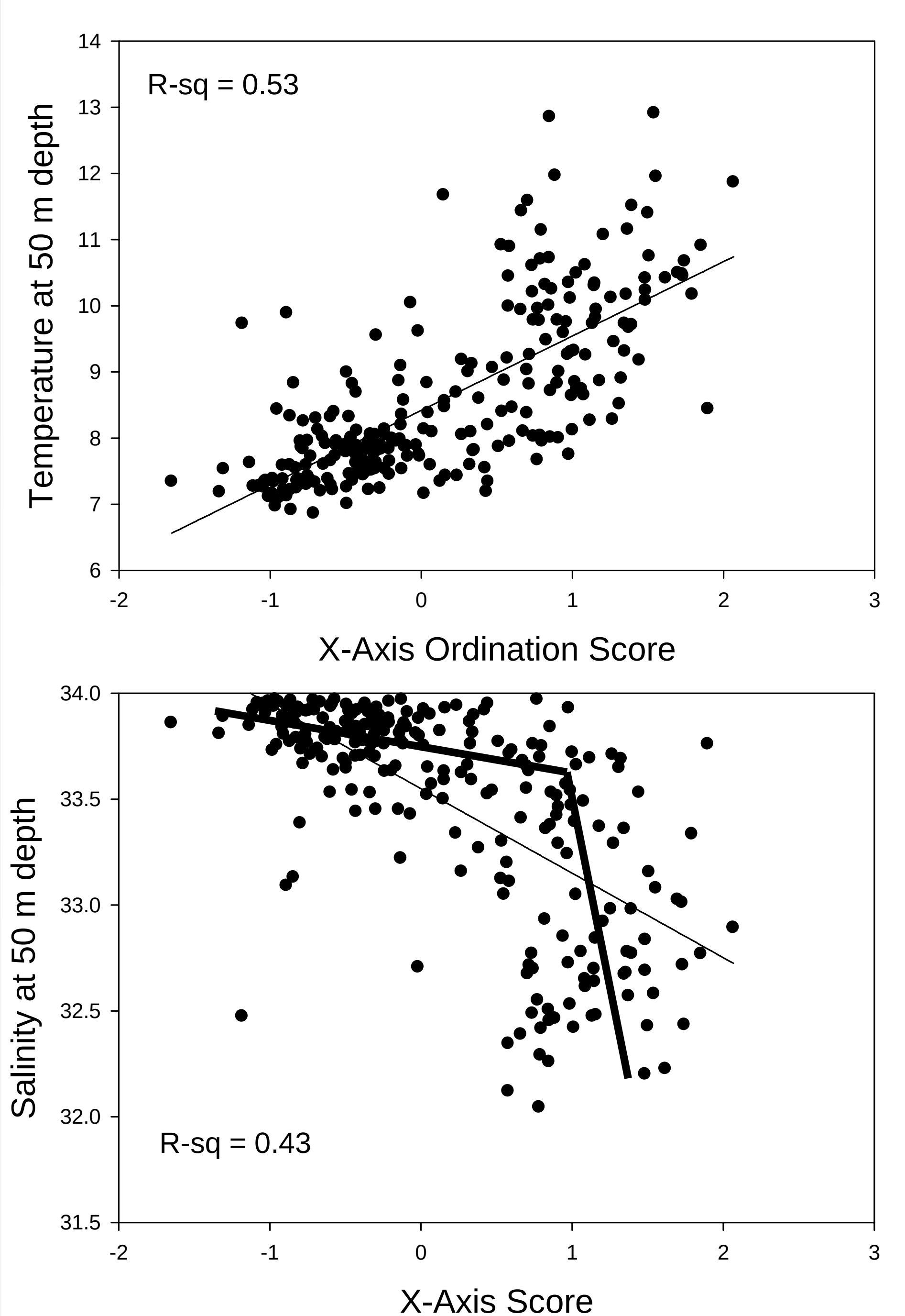
- U.S.GLOBEC Program (NOAA/NSF)
- PaCOOS Program (NOAA)
- NSF CoOP Programs (COAST, RISE)
- ONR-NOPP

- Lots of people have contributed to the success of the 363 cruises off Newport:
  - since 1997: Leah Feinberg, Tracy Shaw, Julie Keister, Jen Menkel, Rian Hooff, Jay Peterson, Jesse Lamb, Karen Hunter
  - in the 1970s and 1980s: Peter Rothlisberg, Greg Lough, Charlie Miller, Hal Batchelder

PDO vs Copepod Community Structure



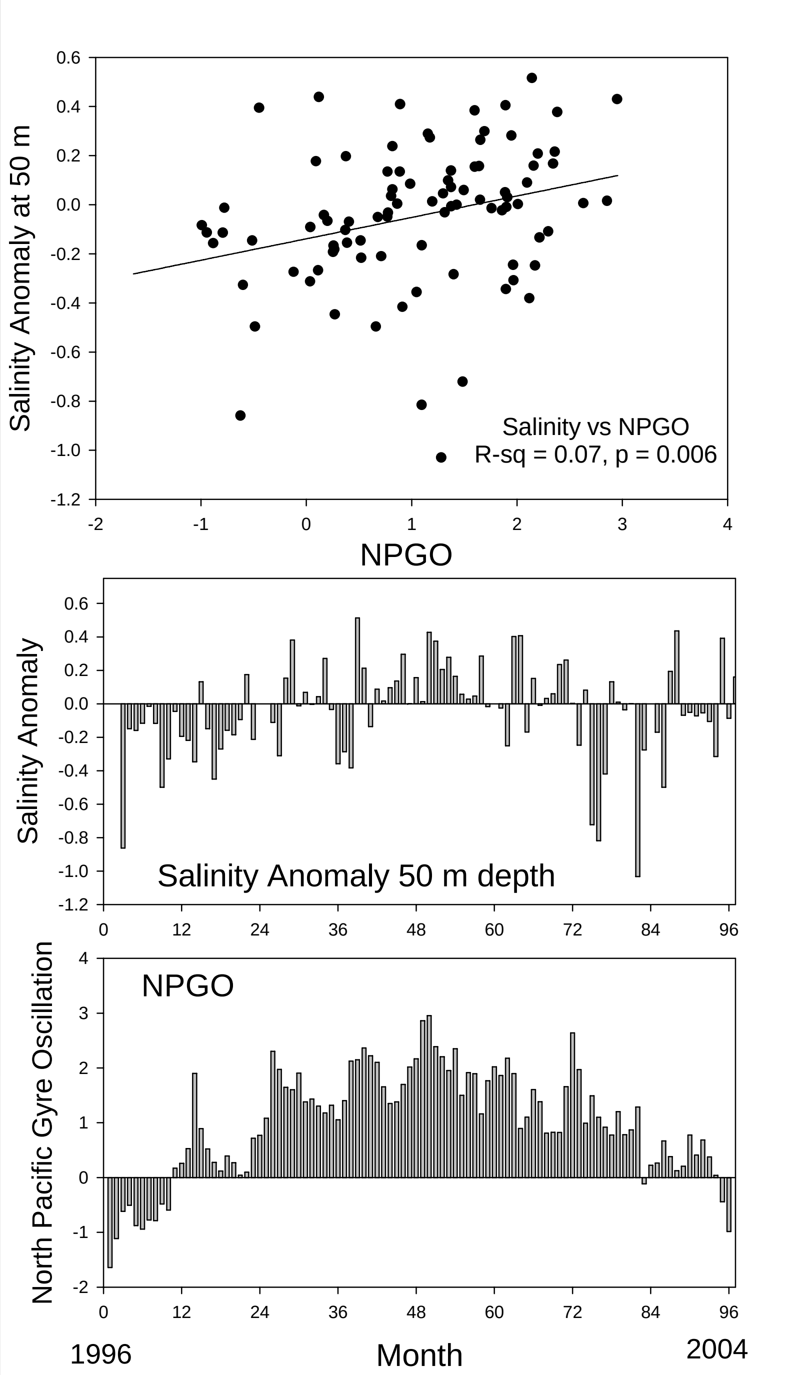
- As with SST and copepod species richness, copepod community structure also tracks the PDO



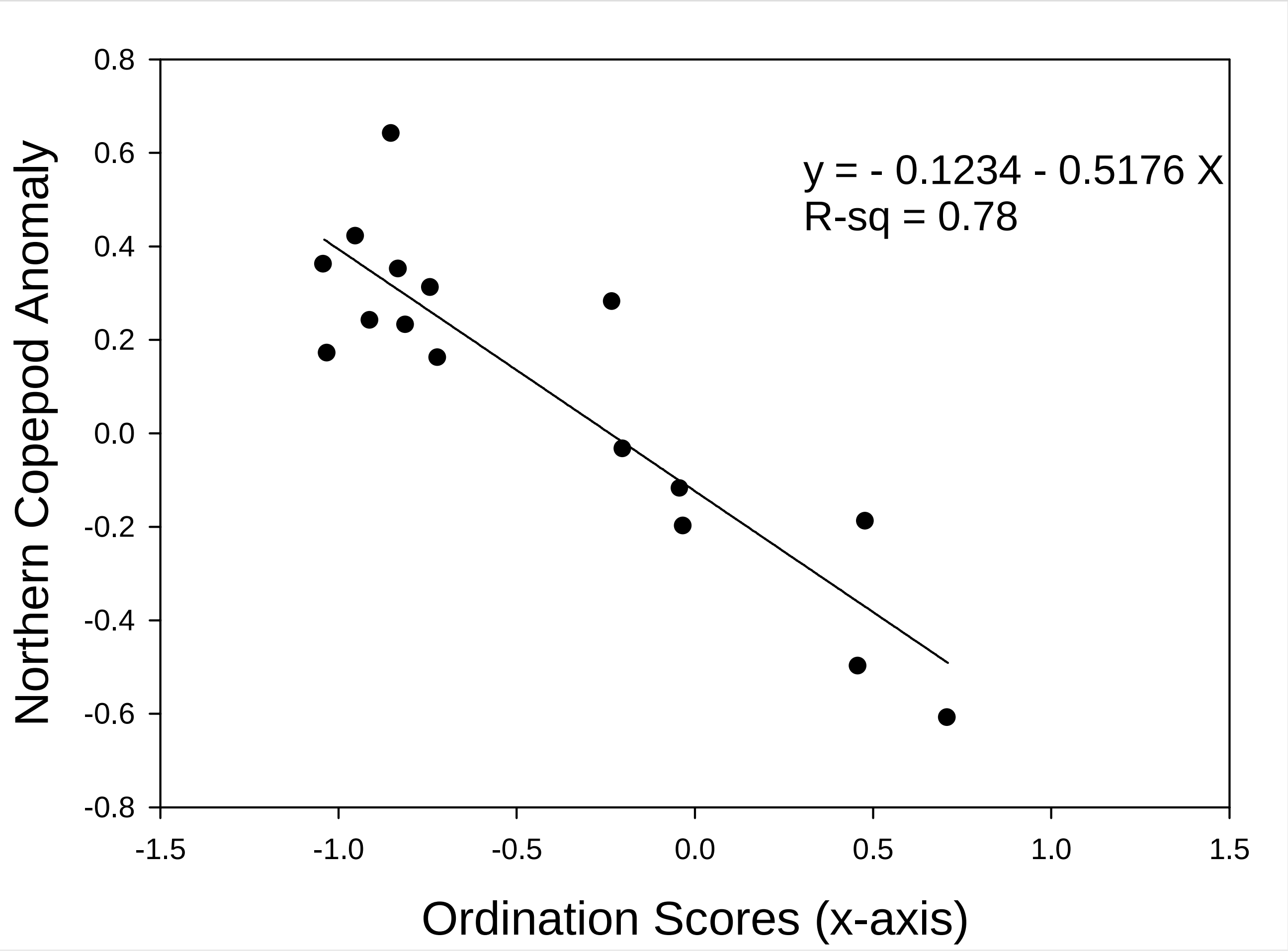
Community Structure vs. temperature and salinity measured at Newport (depth of 50 m) at the same time the plankton tows were taken

- Correlations are better with T than S
- Perhaps salinity will correlate better with the NPGO as shown for the Southern California current?

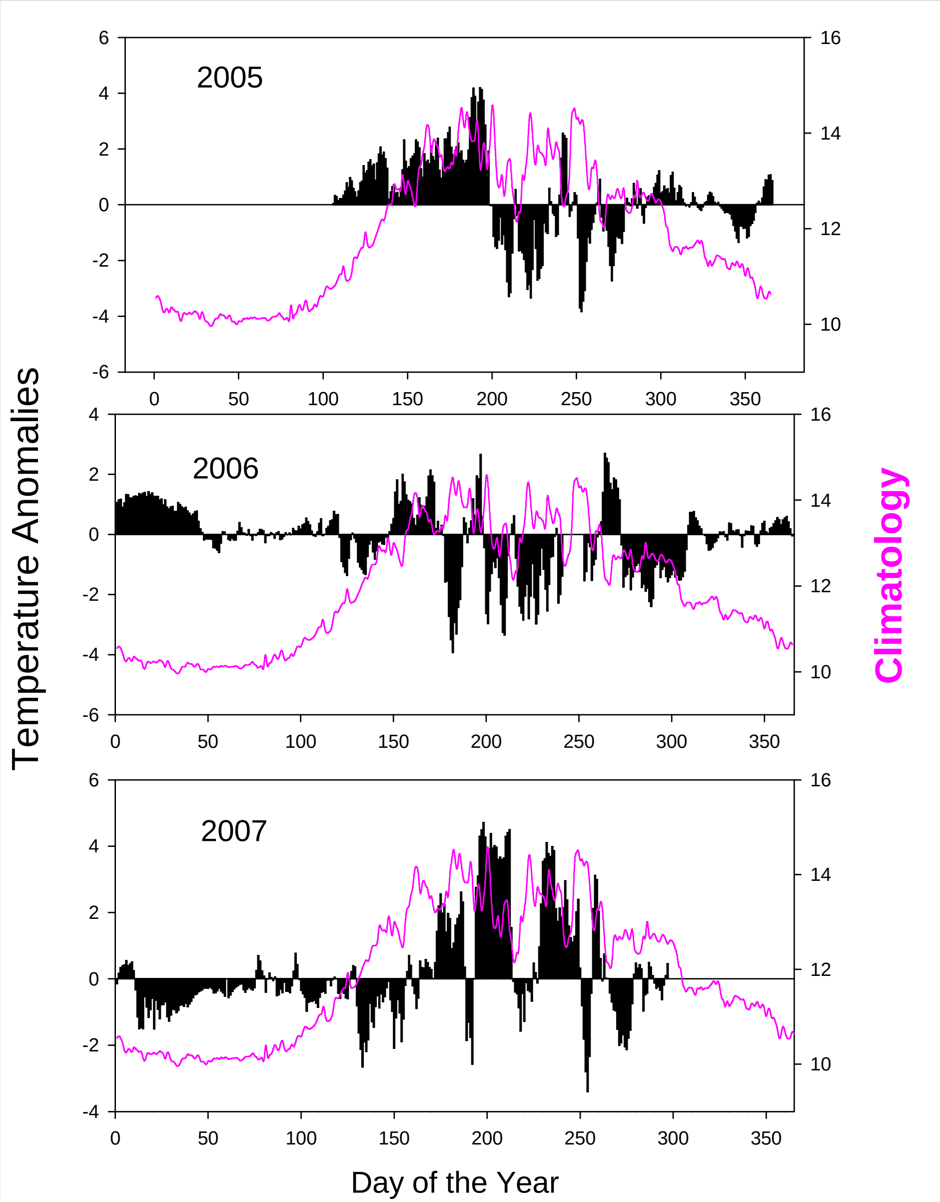
NPGO vs Salinity



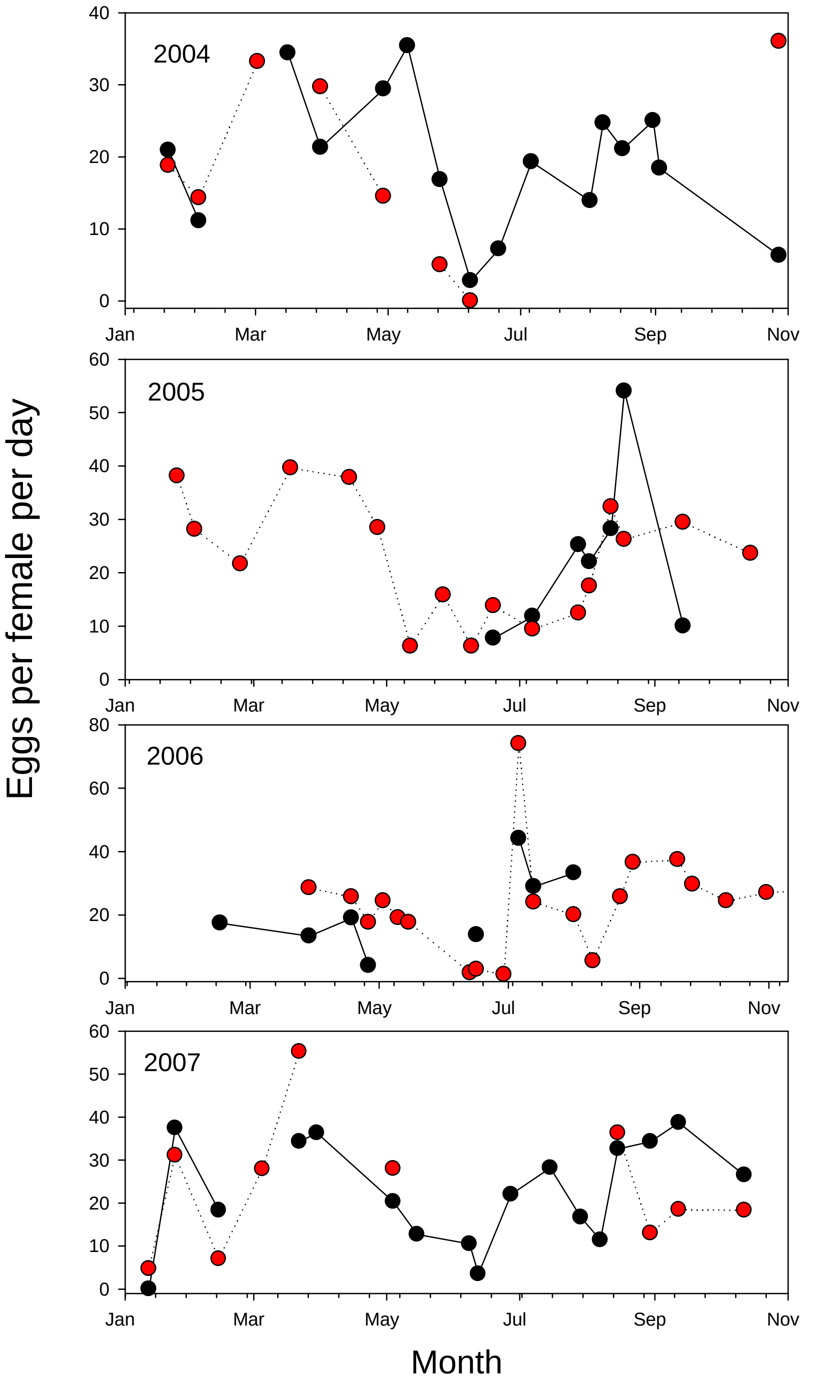
Northern Copepods and Ordination Scores highly correlated



NOAA Buoy 46050 20 miles offshore

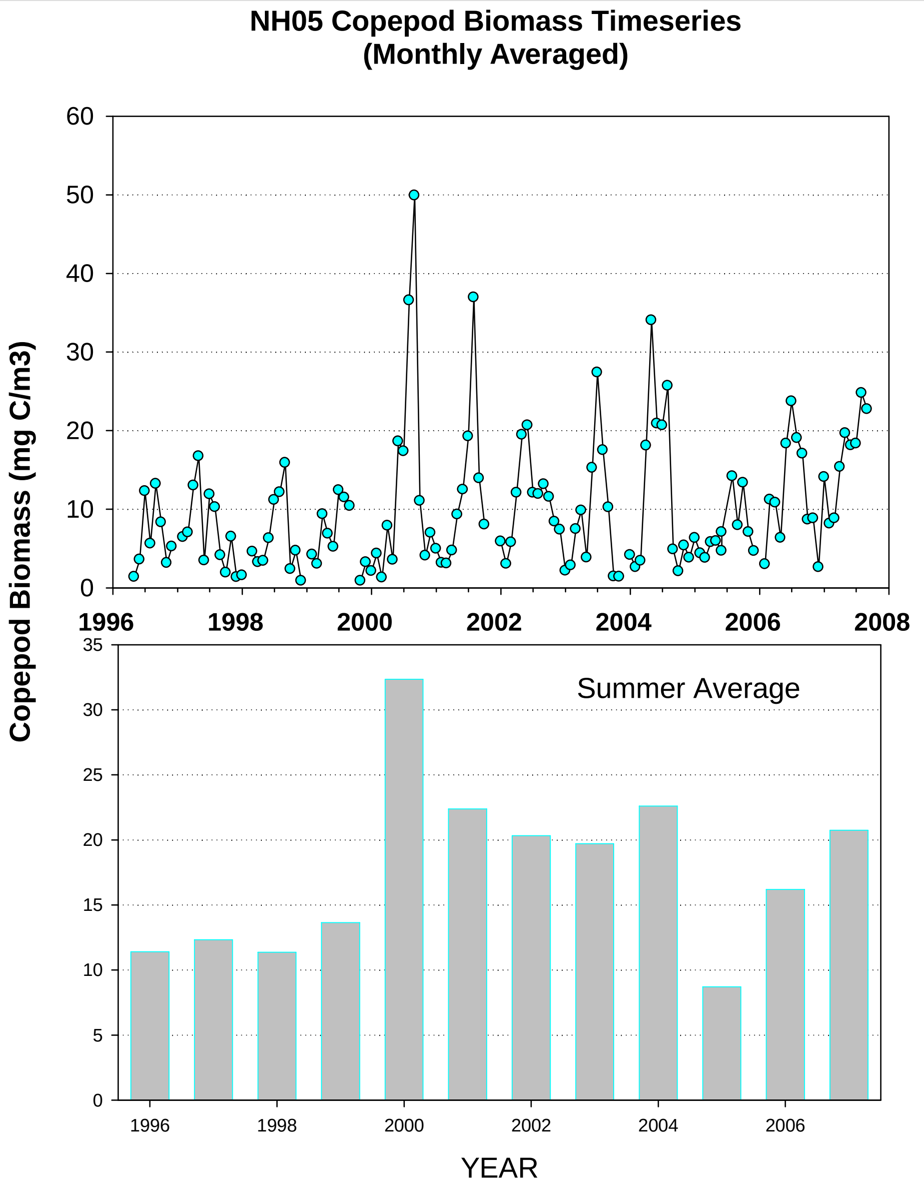


- Climatology: upwelling intense on day 202 (21 July)
- Past three years:



C. marshallae

C. pacificus



NH05 Copepod Biomass Timeseries
(Monthly Averaged)
Copepod Biomass (mg C/m3)
60
50
40
30
20
10
0
1996
1998
2000
2002
2004
2006
2008
35
30
25
20
15
10
5
0
Summer Average
1996
1998
2000
2002
2004
2006
YEAR