# Abundance and diversity of coastal fish larvae as indicators of recent changes in ocean and climate conditions in the Oregon upwelling zone

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# Motivation

- Survival of larvae may directly influence future abundances of adult fish stocks

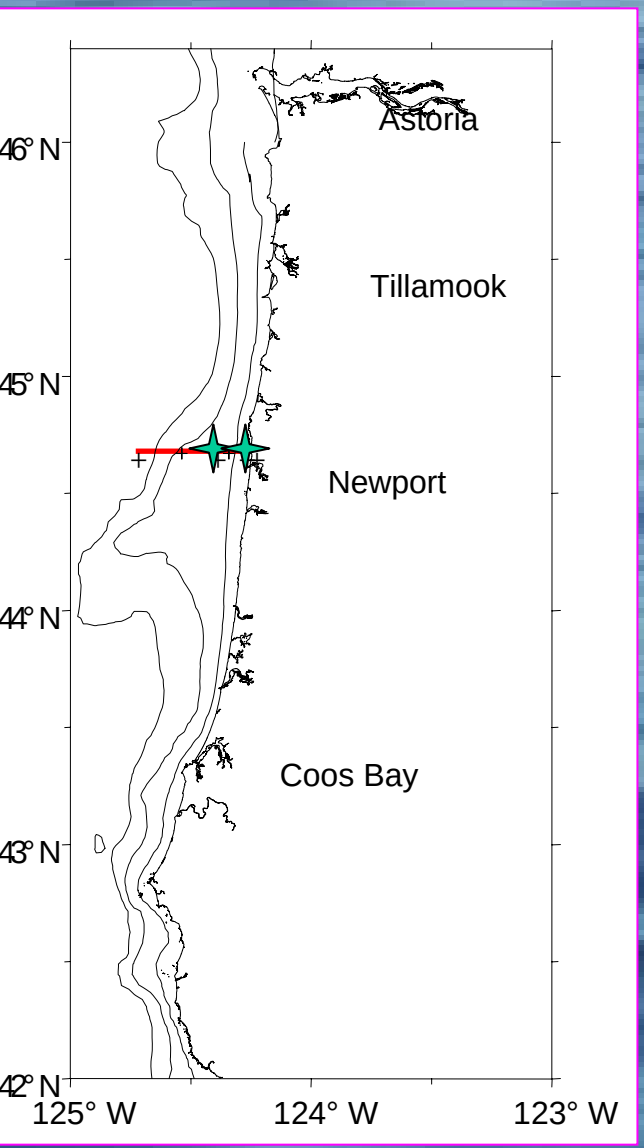
- The distribution and abundance of fish larvae can provide clues to the spawning locations, success, and environmental requirements of important fish species

- Ichthyoplankton can serve as an indicator of changing ocean conditions

# Objectives

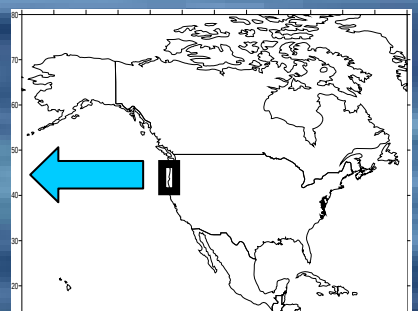
- Examine larval fish in plankton collections from 1996 to 2005 from collections at two stations off Newport Oregon
- Compare larval communities with historical sampling in the 1970s - 1980s off Newport
- Examine long-term trends in ichthyoplankton abundance and relate these to basin-wide and regional environmental conditions

# Newport Line
# Long-term Sampling

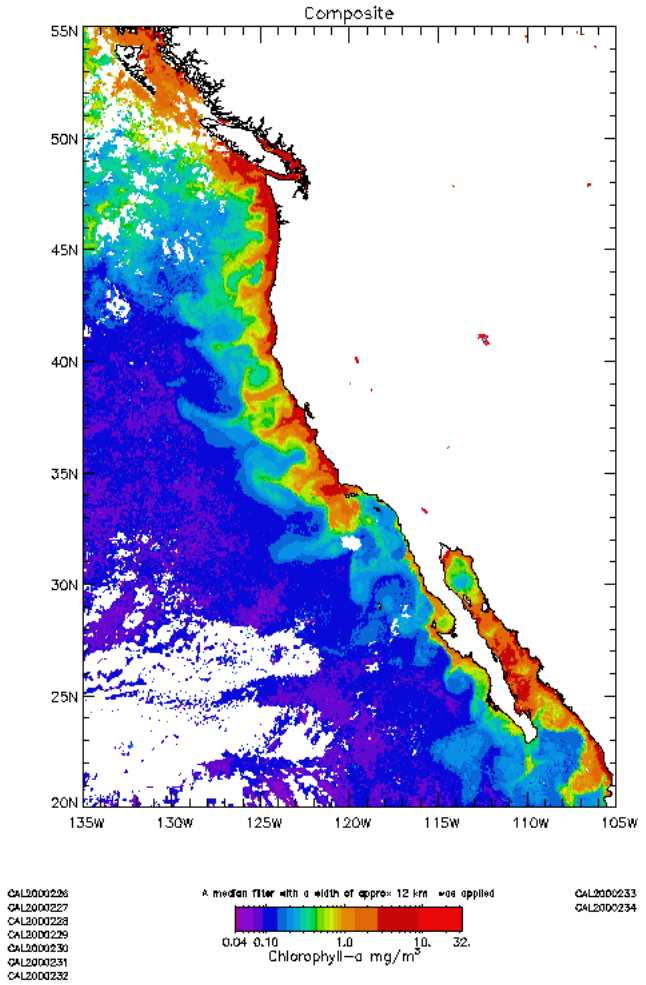



*Bi-weekly Sampling:*

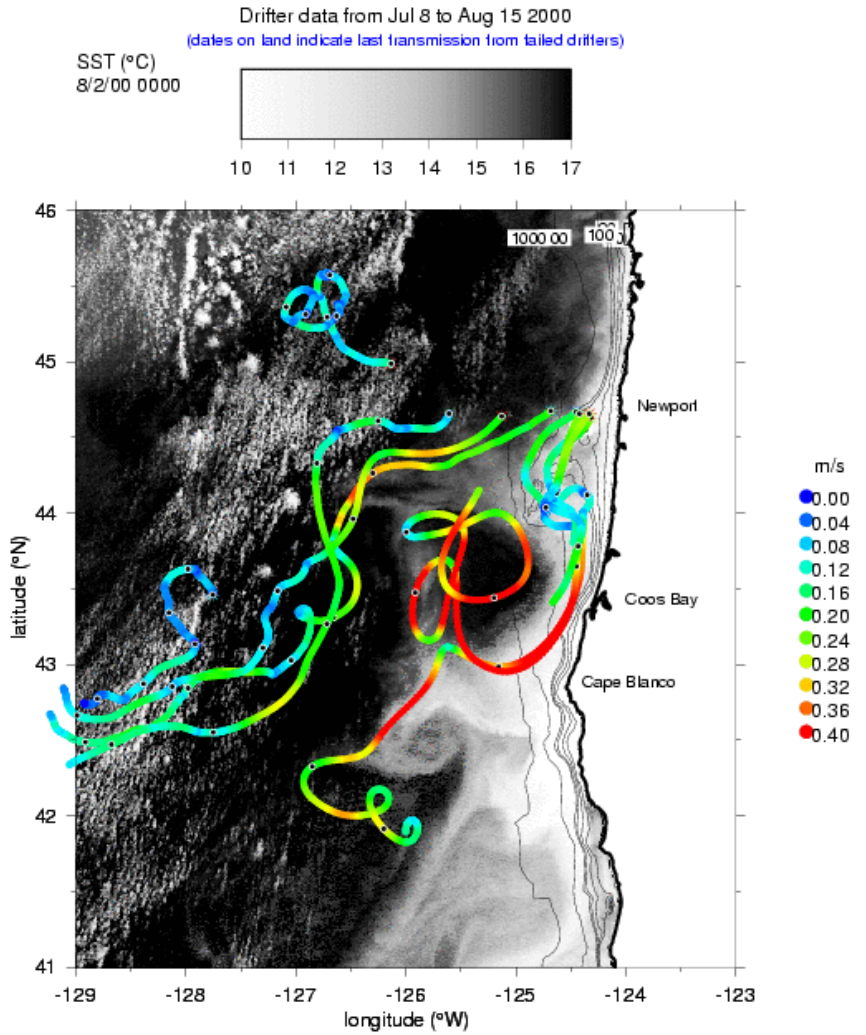
- **1972 – 1973** (Miller, Peterson)
- **1977 – 1978** (Richardson, Laroche)
- **1983** (Miller, Brodeur, Batchelder)
- **1996 – 2005** (Peterson et al.)



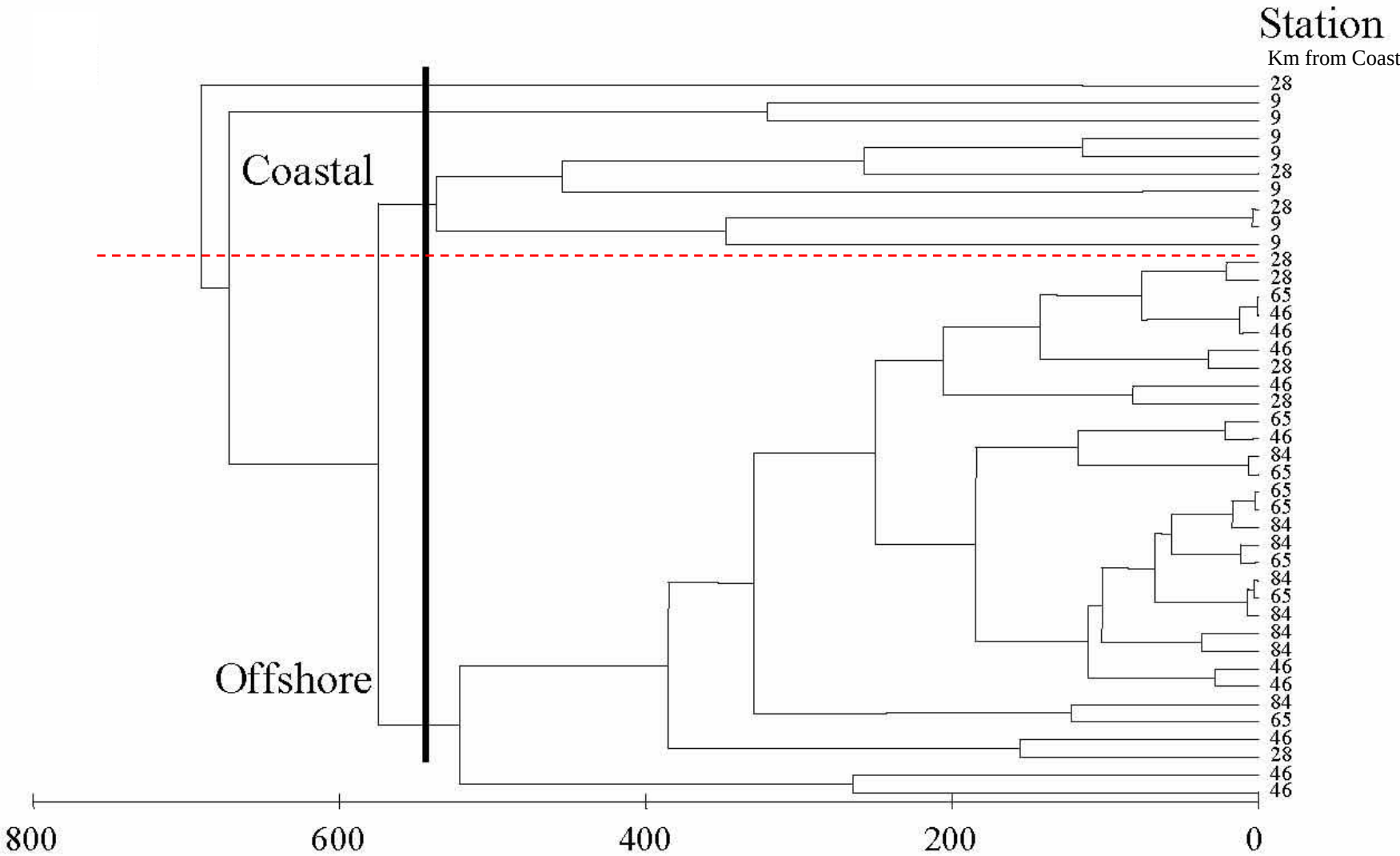
# Oceanography



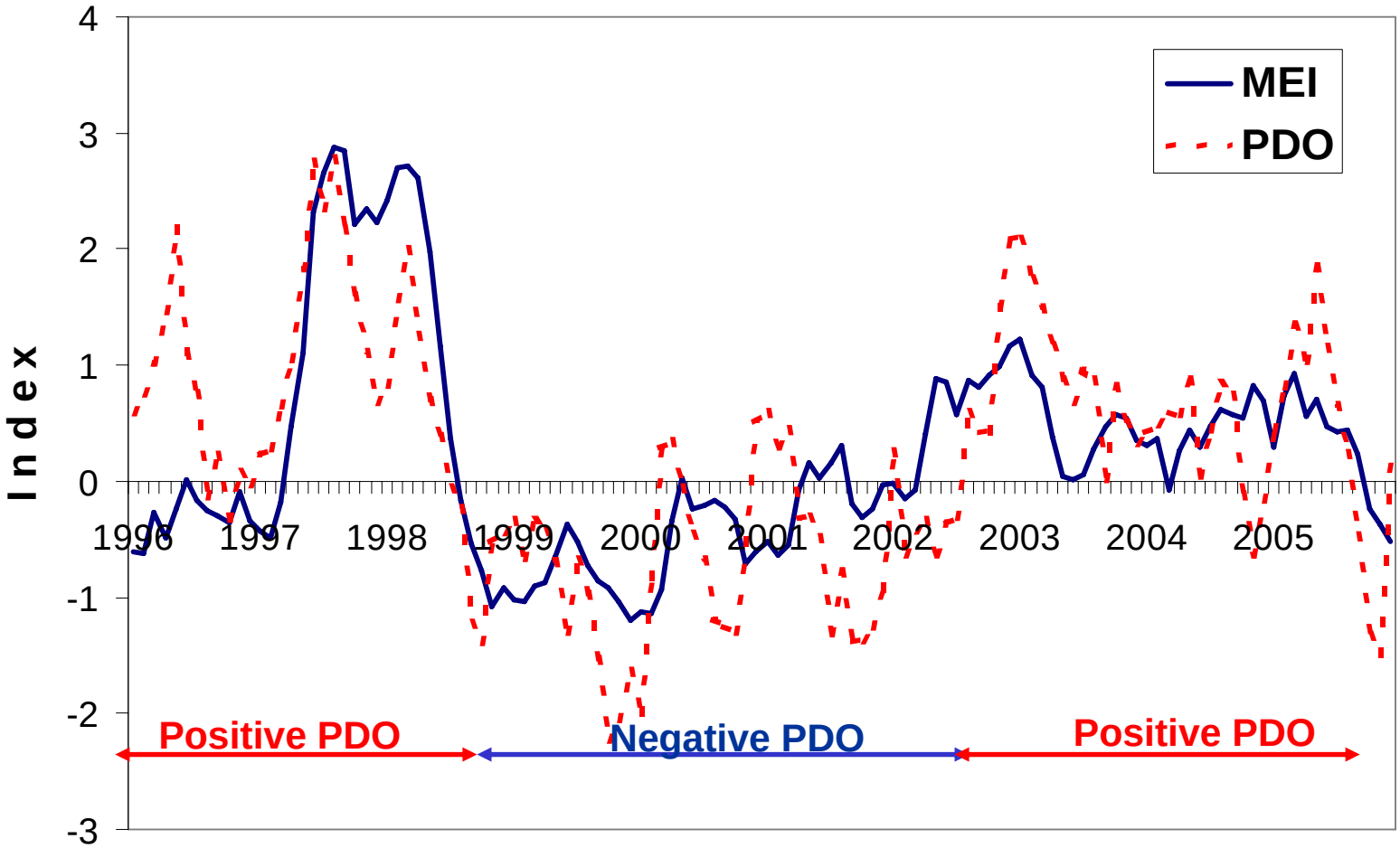

(A. Thomas, UM)

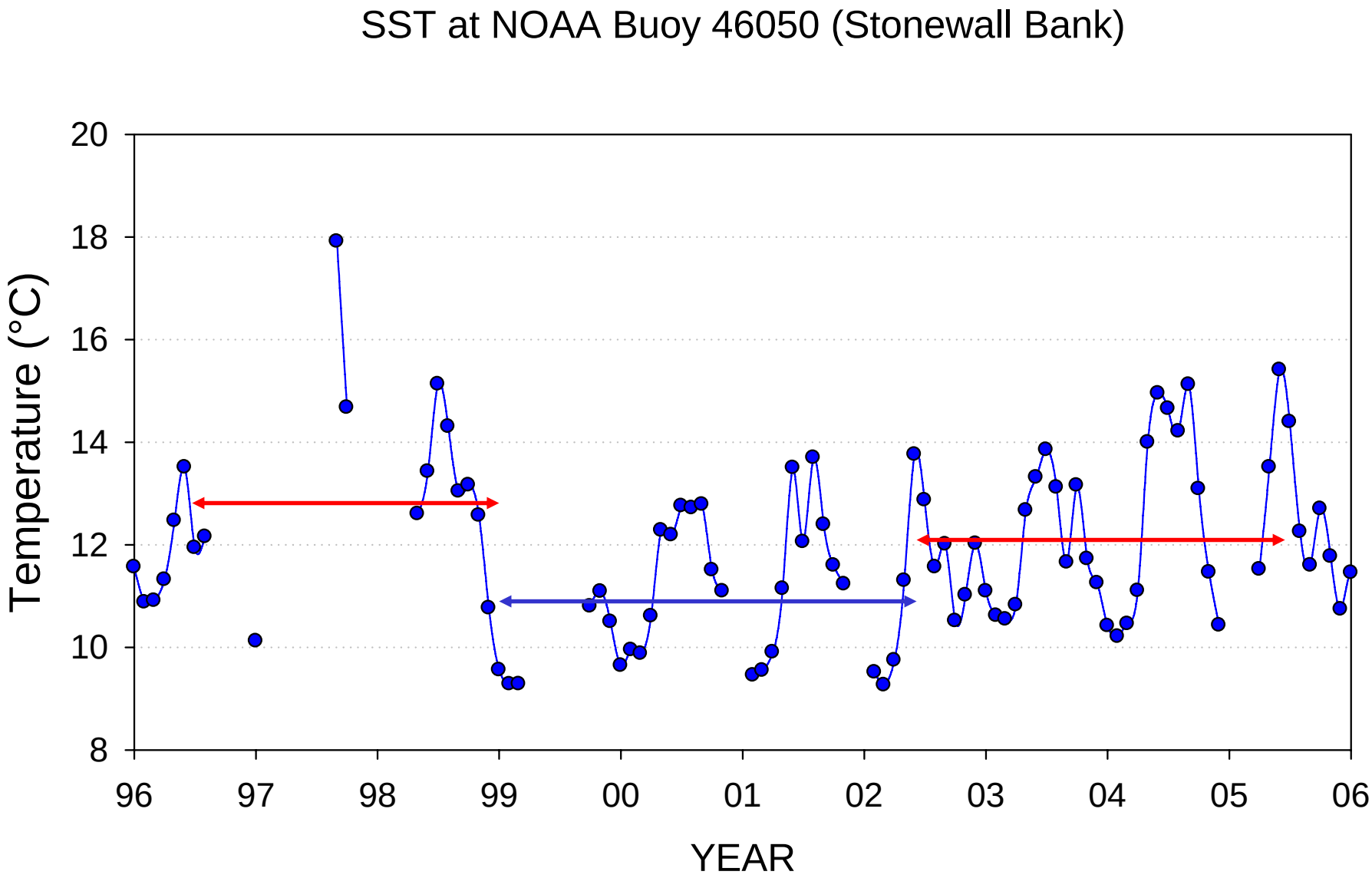



(Barth et al. 2005)

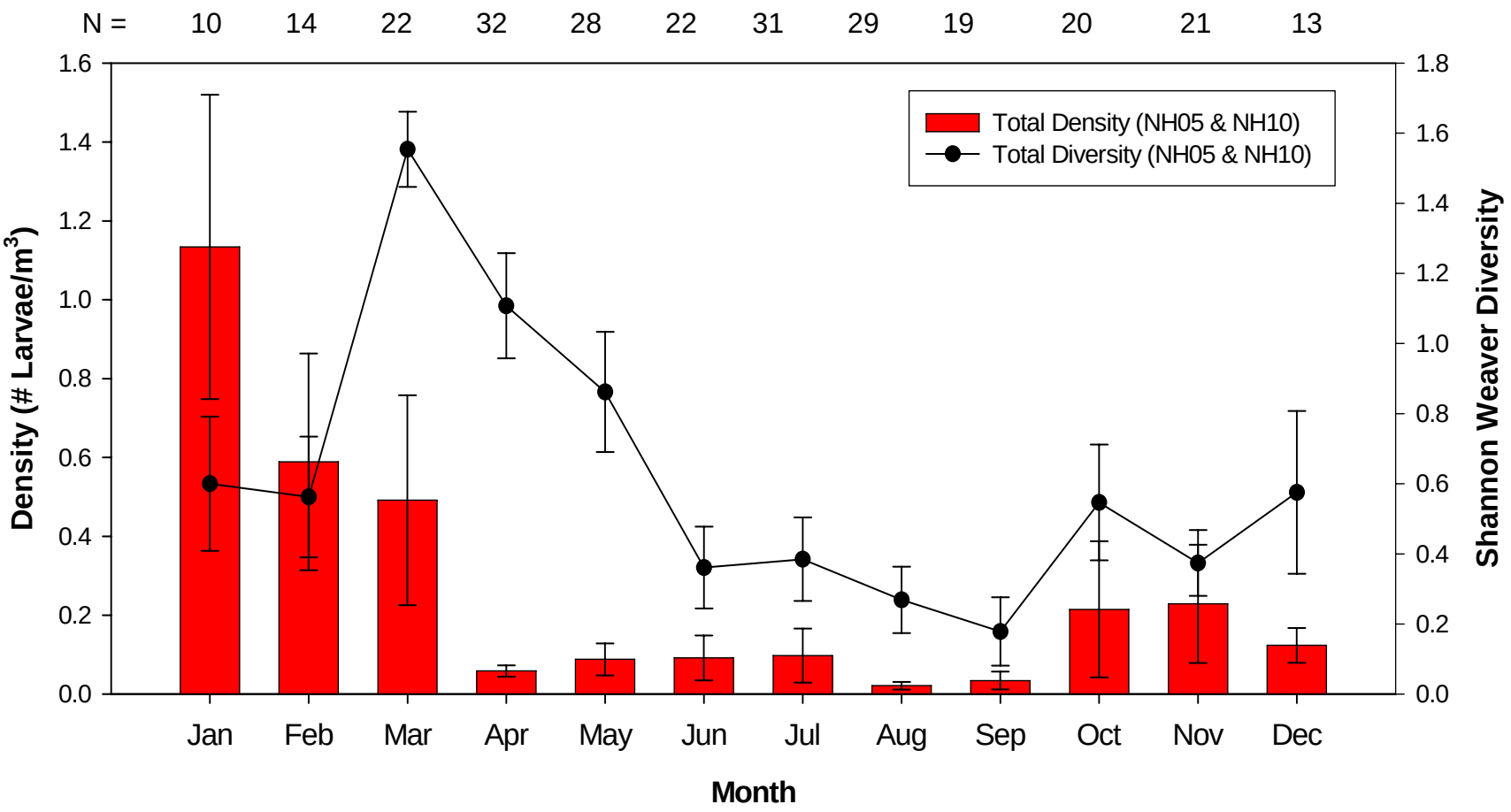



(Auth and Brodeur 2006 MEPS)


MEI
PDO
Index
4
3
2
1
0
-1
-2
-3
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
Positive PDO
Negative PDO
Positive PDO


SST at NOAA Buoy 46050 (Stonewall Bank)
Temperature (°C)
20
18
16
14
12
10
8
96
97
98
99
00
01
02
03
04
05
06
YEAR

# Density and Diversity

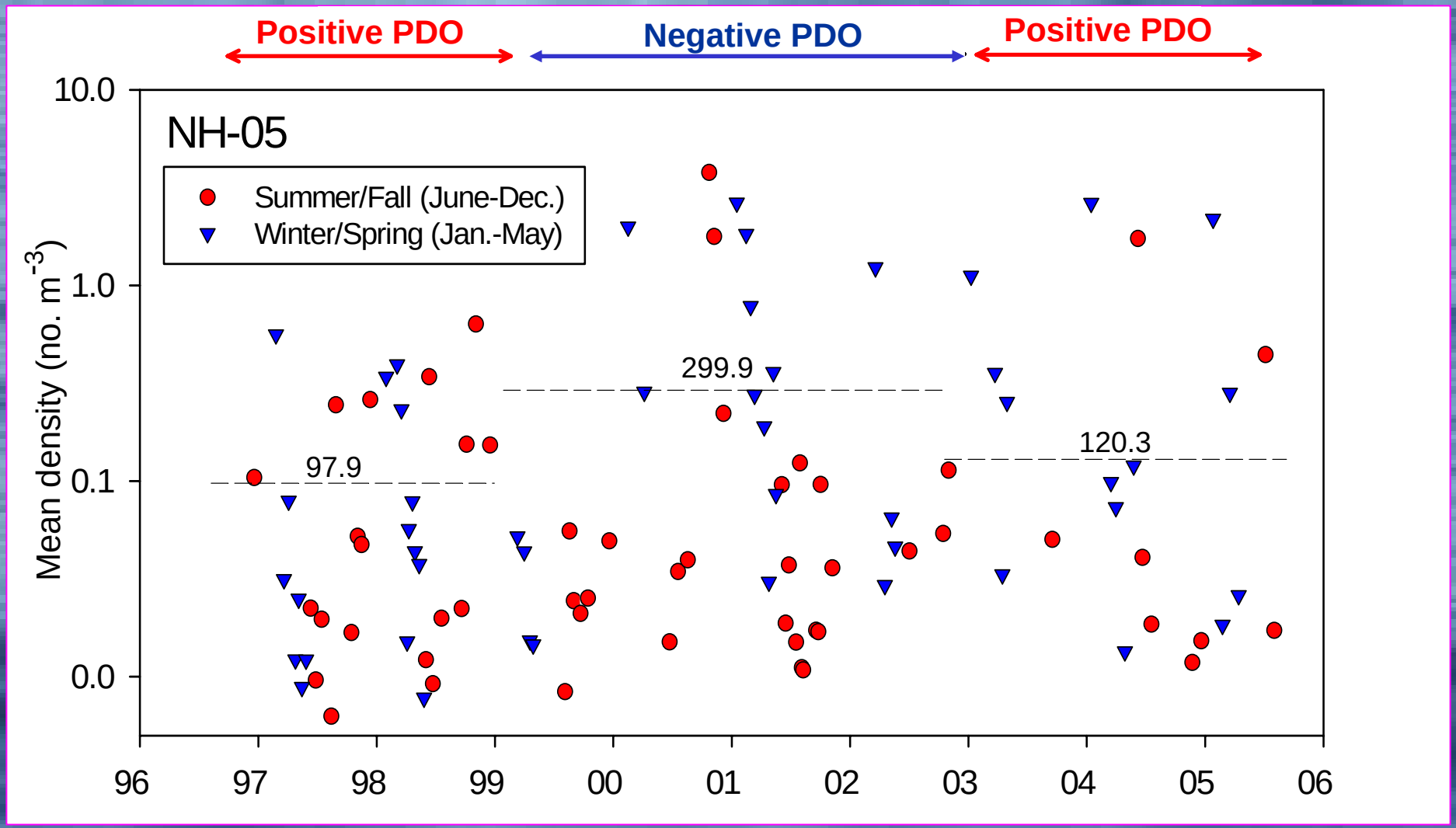



*Most larvae found during winter months*

Means and standard errors

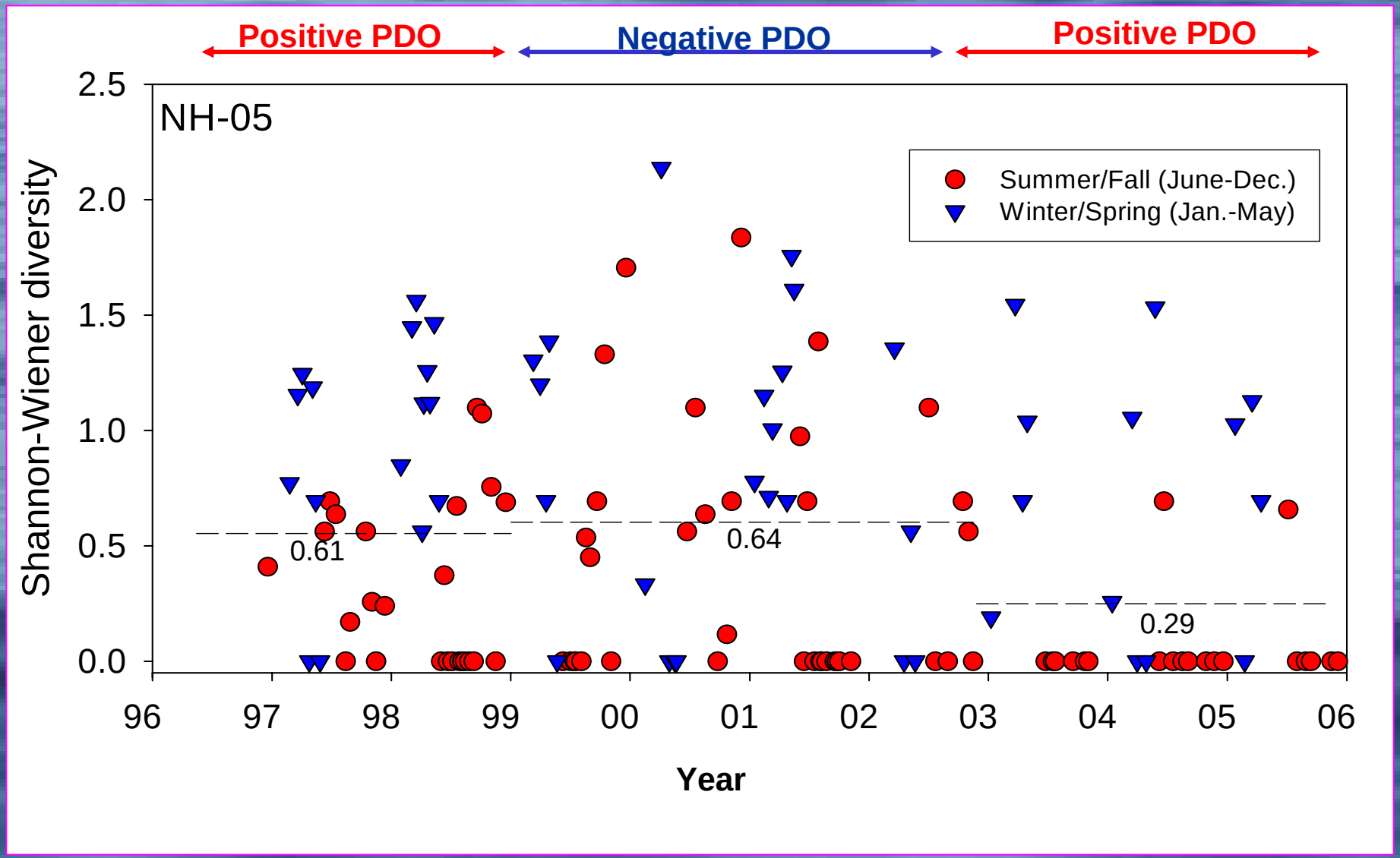
# Monthly Densities

**Copepod Biomass (Jan.-May): 7.5 12.6 11.0**

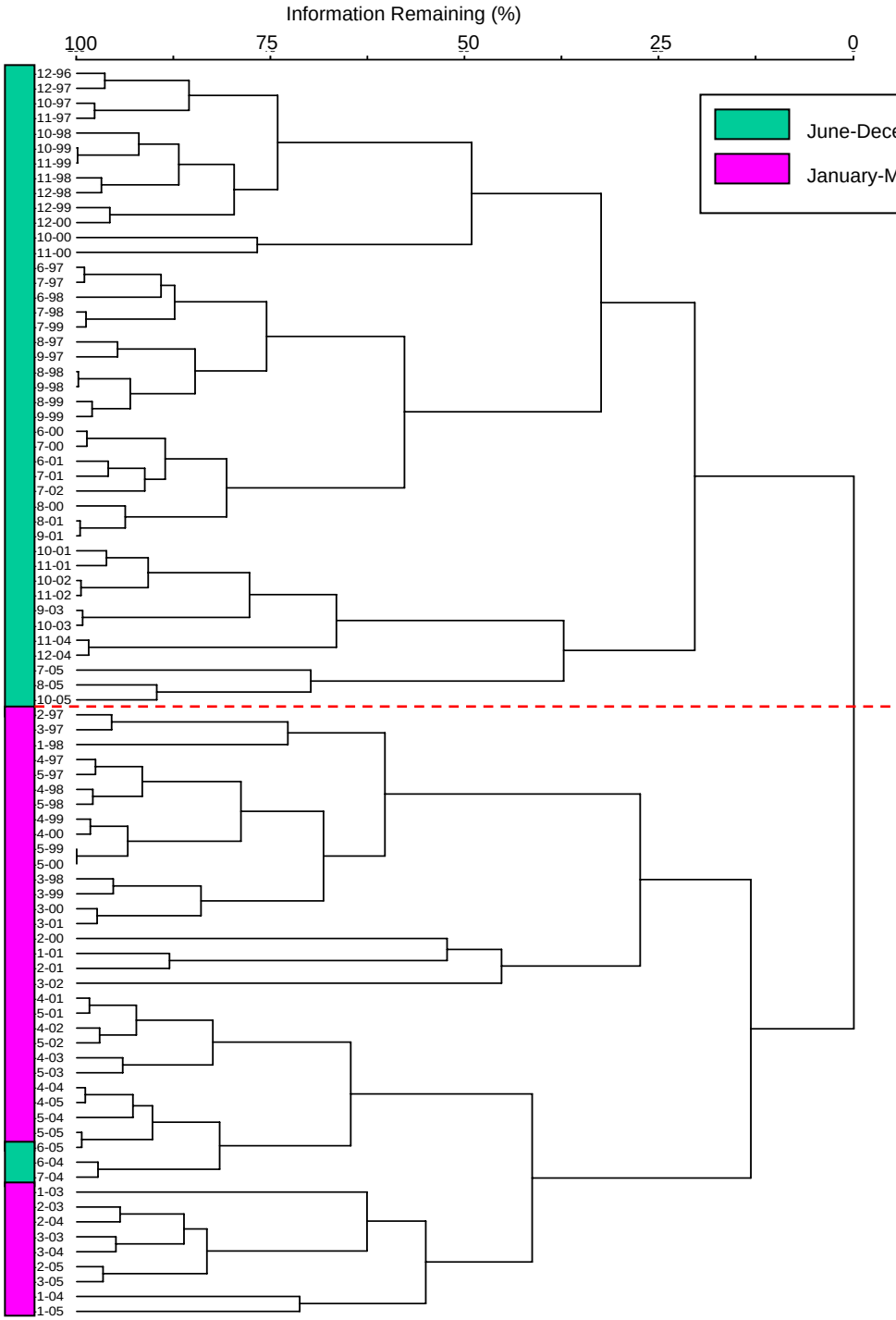



(Brodeur et al. In revision)

# Monthly Diversities




(Brodeur et al. In revision)

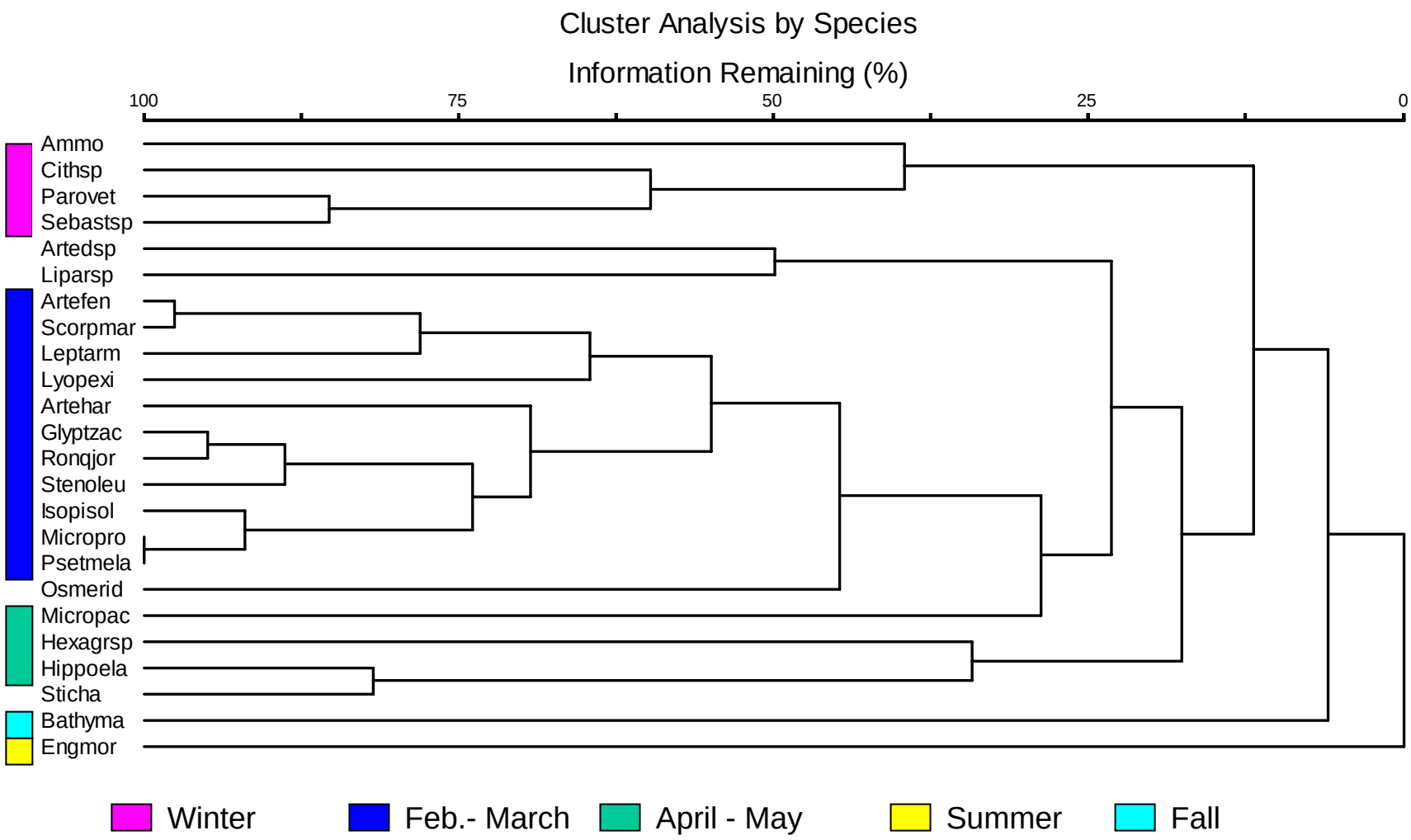



# Cluster Analysis of Monthly Catches

84 Months by 24 Species

- *Different larval fish communities found during winter/spring than the rest of the year*

- *Exceptions were June and July of 2004 and June of 2005*


Cluster Analysis by Species
Information Remaining (%)
100
75
50
25
0
Ammo
Cithsp
Parovet
Sebastsp
Artedsp
Liparsp
Artefen
Scorpmar
Leptarm
Lyopexi
Artehar
Glyptzac
Ronqjor
Stenoleu
Isopisol
Micropro
Psetmela
Osmerid
Micropac
Hexagrsp
Hippoela
Sticha
Bathyma
Engmor
Winter
Feb.- March
April - May
Summer
Fall

## Multiresponse Permutation Procedure (MRPP)

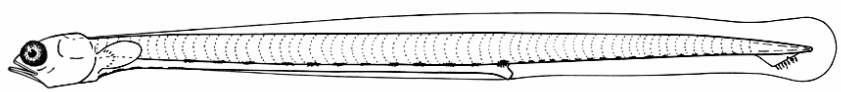
## Test for Differences in Community Structure

| Factor | p value | Significant indicator species ($p < 0.05$) |
|---|---|---|
| Regime | < 0.001 | *E. mordax*, *P. vetulus*, and *Sebastes* spp. (warm); *A. hexapterus*, *Citharichthys* spp., and Osmeridae (cold) |
| Year | 0.449 | None significant |
| Season | < 0.001 | *G. zachirus*, *M. pacificus*, *I. isolepis*, *P. vetulus*, *P. melanostictus*, *R. jordani*, *S. marmoratus*, *Sebastes* spp., *S. leucopsarus*, Osmeridae, and Stichaeidae (winter-spring); *E. mordax* (summer-fall) |
| Month | < 0.001 | Osmeridae, *P. vetulus*, and *Sebastes* spp. (January); *G. zachirus* and *S. leucopsarus* (March); *E. mordax* (July) |

# Dominant Ichthyoplankton

## Top 10 Taxa (all years, months combined)

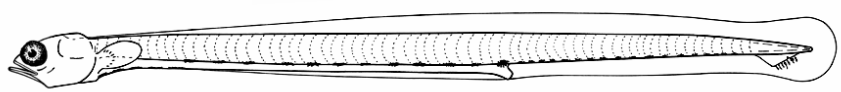
| Species | Overall Total # | Percent of Total | 1996-2005 |
|---|---|---|---|
| *Ammodytes hexapterus* | 1549 | 29.22 | 1 |
| *Parophrys vetulus* | 1289 | 24.32 | 2 |
| *Citharichthys* sp. | 655 | 12.36 | 3 |
| *Engraulis mordax* | 235 | 4.43 | 4 |
| *Sebastes* spp. | 204 | 3.85 | 5 |
| *Liparis* sp. | 170 | 3.21 | 6 |
| *Psettichthys melanostictus* | 150 | 2.83 | 7 |
| Osmeridae | 139 | 2.62 | 8 |
| *Isopsetta isolepis* | 132 | 2.49 | 9 |
| *Artedius harringtoni* | 104 | 1.96 | 10 |
| **Total (top 10)** | **4627** | **87.29** | |



# Dominant Ichthyoplankton

## Top 10 Taxa (all years, months combined)

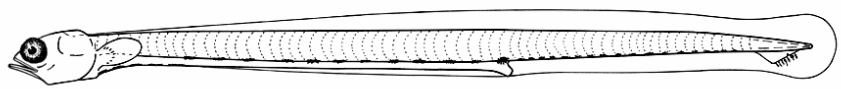
| Species | Overall Total # | Percent of Total | 1996-2005 | 1971-1972 |
|---|---|---|---|---|
| *Ammodytes hexapterus* | 1549 | 29.22 | 1 | 7 |
| *Parophrys vetulus* | 1289 | 24.32 | 2 | 2 |
| *Citharichthys* sp. | 655 | 12.36 | 3 | 27 |
| *Engraulis mordax* | 235 | 4.43 | 4 | 30 |
| *Sebastes* spp. | 204 | 3.85 | 5 | 9 |
| *Liparis* sp. | 170 | 3.21 | 6 | 15 |
| *Psettichthys melanostictus* | 150 | 2.83 | 7 | 5 |
| Osmeridae | 139 | 2.62 | 8 | 1 |
| *Isopsetta isolepis* | 132 | 2.49 | 9 | 3 |
| *Artedius harringtoni* | 104 | 1.96 | 10 | 6 |
| **Total (top 10)** | **4627** | **87.29** | | |



# Dominant Ichthyoplankton

## Top 10 Taxa (all years, months combined)

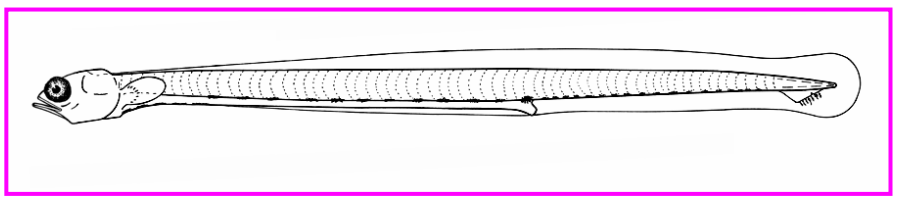
| Species | Overall Total # | Percent of Total | 1996-2005 | 1971-1972 | 1977-1978 |
|---|---|---|---|---|---|
| *Ammodytes hexapterus* | 1549 | 29.22 | 1 | 7 | 14 |
| *Parophrys vetulus* | 1289 | 24.32 | 2 | 2 | 1 |
| *Citharichthys* sp. | 655 | 12.36 | 3 | 27 | 8 |
| *Engraulis mordax* | 235 | 4.43 | 4 | 30 | 10 |
| *Sebastes* spp. | 204 | 3.85 | 5 | 9 | 3 |
| *Liparis* sp. | 170 | 3.21 | 6 | 15 | 16 |
| *Psettichthys melanostictus* | 150 | 2.83 | 7 | 5 | 4 |
| Osmeridae | 139 | 2.62 | 8 | 1 | 2 |
| *Isopsetta isolepis* | 132 | 2.49 | 9 | 3 | 5 |
| *Artedius harringtoni* | 104 | 1.96 | 10 | 6 | 12 |
| **Total (top 10)** | **4627** | **87.29** | | | |

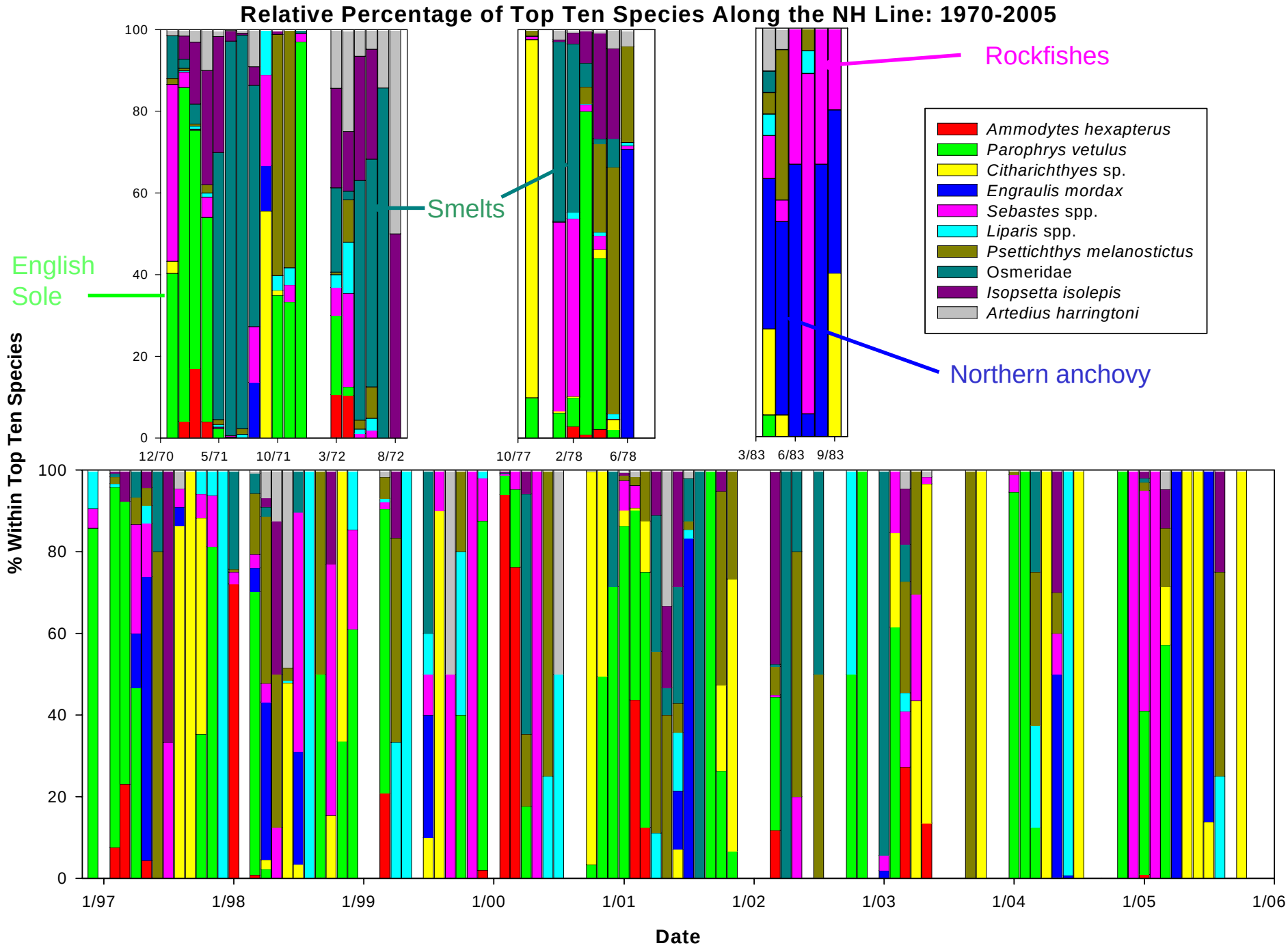


# Dominant Ichthyoplankton

## Top 10 Taxa (all years, months combined)

| Species | Overall Total # | Percent of Total | 1996-2005 | 1971-1972 | 1977-1978 | 1983 |
|---|---|---|---|---|---|---|
| *Ammodytes hexapterus* | 1549 | 29.22 | 1 | 7 | 14 | -- |
| *Parophrys vetulus* | 1289 | 24.32 | 2 | 2 | 1 | 11 |
| *Citharichthys* sp. | 655 | 12.36 | 3 | 27 | 8 | 7 |
| *Engraulis mordax* | 235 | 4.43 | 4 | 30 | 10 | 1 |
| *Sebastes* spp. | 204 | 3.85 | 5 | 9 | 3 | 3 |
| *Liparis* sp. | 170 | 3.21 | 6 | 15 | 16 | 16 |
| *Psettichthys melanostictus* | 150 | 2.83 | 7 | 5 | 4 | 5 |
| Osmeridae | 139 | 2.62 | 8 | 1 | 2 | 13 |
| *Isopsetta isolepis* | 132 | 2.49 | 9 | 3 | 5 | -- |
| *Artedius harringtoni* | 104 | 1.96 | 10 | 6 | 12 | 10 |
| **Total (top 10)** | **4627** | **87.29** | | | | |




Relative Percentage of Top Ten Species Along the NH Line: 1970-2005
Rockfishes
Smelts
English Sole
Northern anchovy
Ammodytes hexapterus
Parophrys vetulus
Citharichthyes sp.
Engraulis mordax
Sebastes spp.
Liparis spp.
Psettichthys melanostictus
Osmeridae
Isopsetta isolepis
Artedius harringtoni
% Within Top Ten Species
Date
12/70
5/71
10/71
3/72
8/72
10/77
2/78
6/78
3/83
6/83
9/83
1/97
1/98
1/99
1/00
1/01
1/02
1/03
1/04
1/05
1/06

## Species/Environmental Relationships using General Additive Models

- Both large-scale and regional scale environmental variables were examined
- Correlations (Spearman's Rho) of environmental variables were conducted to eliminate highly correlated variables from inclusion in GAM
- GAMs were run using both abundance (Gaussian) and pres./abs. (binomial) for 5 most dominant species and total fish density and diversity
- stepwise model selection dropping variables to minimize GCV score
- used various lag periods in the models (0-3 months)

| NAME | SOURCE LOCATION URL | WEB SITE AUTHOR |
|---|---|---|
| **Basin Scale Indicies** | | |
| Pacific Decadal Oscillation (PDO) | http://jisao.washington.edu/pdo/PDO.latest | Nathan Mantua |
| Multivariate ENSO Index (MEI) | http://www.cdc.noaa.gov/ENSO/enso.mei_index.html | Klaus Wolter |
| Northern Oscillation Index (NOI) | http://www.pfeg.noaa.gov/products/PFEL/indices/NOIx/noix/html | Frank Schwing |
| **Regional Scale Indices** | | |
| Curl of the Wind Stress (CWS) | http://www.pfeg.noaa.gov/products/las.html | PFEL |
| E-W Ekman Transport (EET) | http://www.pfeg.noaa.gov/products/las.html | PFEL |
| Upwelling Index (UPW) | http://www.pfeg.noaa.gov/products/PFEL/modeled/indices/upwelling | PFEL |

# GAM Results: Abundance

| Taxa | Best Fit Model | Significant Variables | Dev Exp (%) |
|---|---|---|---|
| Osmerids | PDO***, MEI***, UPW | PDO***, UPW | 50.3 |
| *Parophrys vetulus* | PDO*, NOI*, CWS, EET | PDO*, NOI*, EET | 44.4 |
| *Ammodytes hexapterus* | PDO**, MEI**, NOI**, CWS, EET, UPW | PDO**, MEI**, NOI**, EET, UPW | 98.4 |
| *Sebastes* spp. | PDO**, MEI**, NOI**, EET | PDO**, MEI**, EET | 56.6 |
| *Isopsetta isolepis* | NOI***, UPW | NOI*** | 26.7 |

Lag periods: * = 1 month, ** = 2 months, *** = 3 months

# Conclusions

- Overall mean density and diversity are highest winter and early spring
- Overall density tracks changes in PDO and temperature
- Sharp delineation between the winter summer spawning communities perhaps related to spring transition period
- Dramatic changes in dominant species by regime: osmerids, sanddabs, sand lance dominant in cold regimes and anchovy, rockfish and English sole in warm regimes
- Abundance of species seem to be affected when there are lags in large scale environmental indices (i.e. PDO, MEI, NOI)
- Abundance of species seems to be affected when there is at least two large scale and one small scale environmental indices

# Applications

- Shown that ichthyoplankton diversity and abundance are indicators of ocean conditions
- Relate changes in abundance of early life stages to adult spawners and subsequent year class strength
- Develop indices of coastal conditions related to the survival of early life stages
- Provide managers early indications of strong year classes that may recruit into fisheries

# Acknowledgements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Oregon State University

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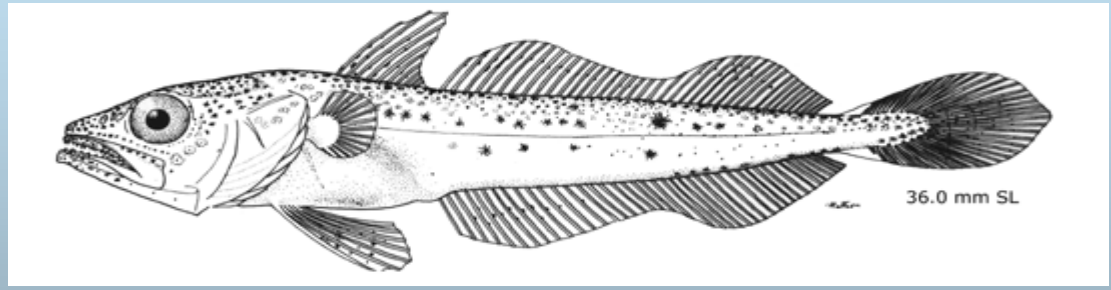
Jim Colbert for assistance with environmental data
Lorenzo Ciannelli for statistical advice


# Northern Shift in the Location of Spawning and Recruitment of Pacific Hake (*Merluccius productus*) in the Northern California Current

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2 NOAA Fisheries, Hatfield Marine Science Center, Newport, OR
3 NOAA Fisheries, SWFSC Santa Cruz, Santa Cruz, CA
4 Pacific Whiting Conservation Cooperative, Seattle, WA