Climate forcing: marine fish responses

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<u>Outline: sketches of four topics</u>

1.) Climate forcing via NAO—altering oceanographic contexts

2.) An oceanographic/climate data source

3.) NAO influence on fish assemblages—hypothesis testing at large spatial scales

4.) Testing climate's influence relative to others—methods and an example

1.) Winter North Atlantic Oscillation (NAO) index

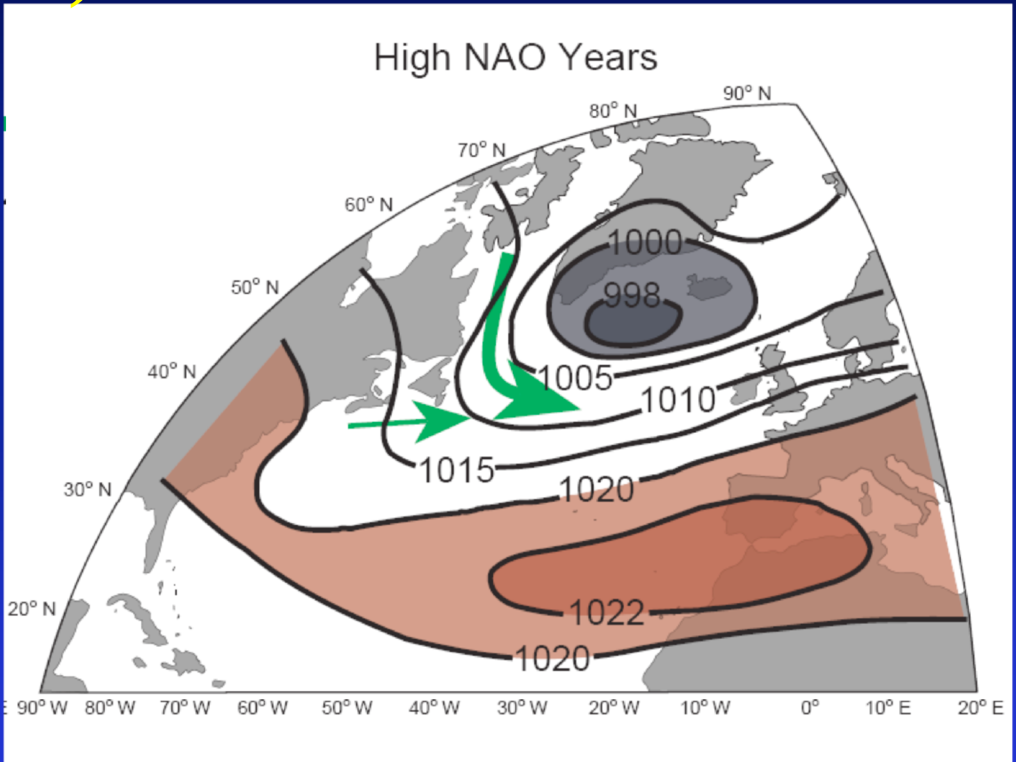
<u>High/Positive NAO years</u>:

Strong Iceland Low; strong Azores High

Warm, wet conditions in eastern US

Cool, stormy conditions in northeast Canada and Greenland

Decreased transport of cold Labrador slope water to southwest

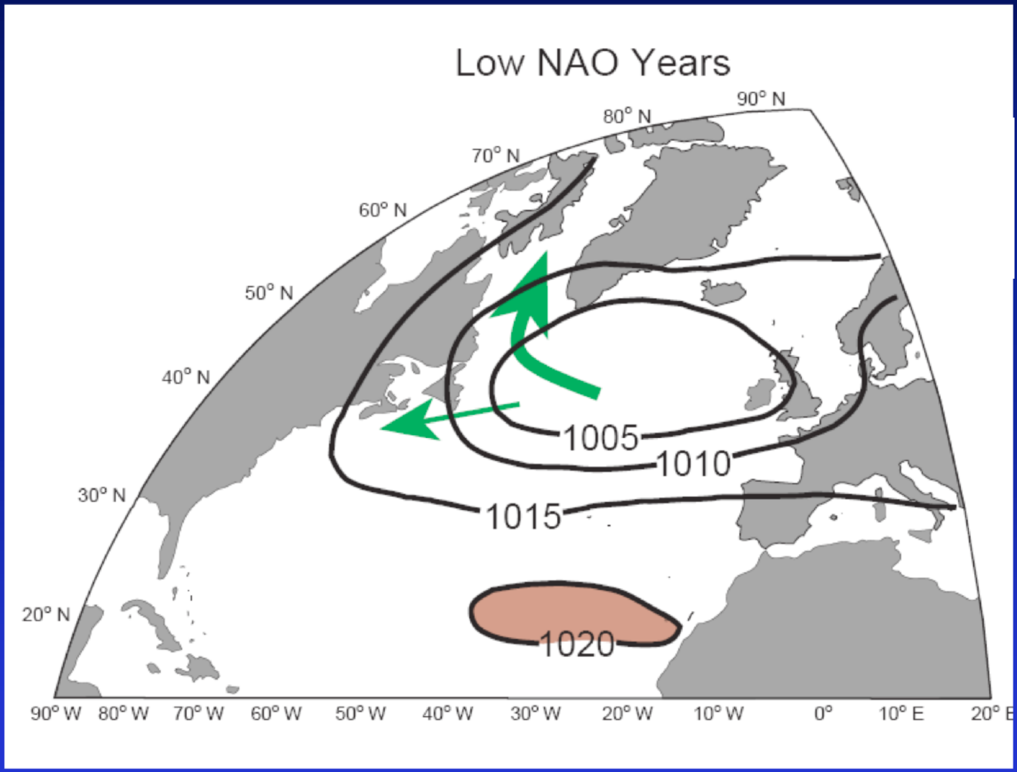


Winter surface air pressure shown as labelled lines

Wind anomalies shown as green arrows

from: K. Drinkwater (2000) AGU Chapman Conf...

Witner North Atlantic Oscillation (NAO) index



Winter surface air pressure shown as labelled lines

Wind anomalies shown as green arrows

<u>Low/Negative NAO years</u>:

Weak Iceland Low; weak Azores High

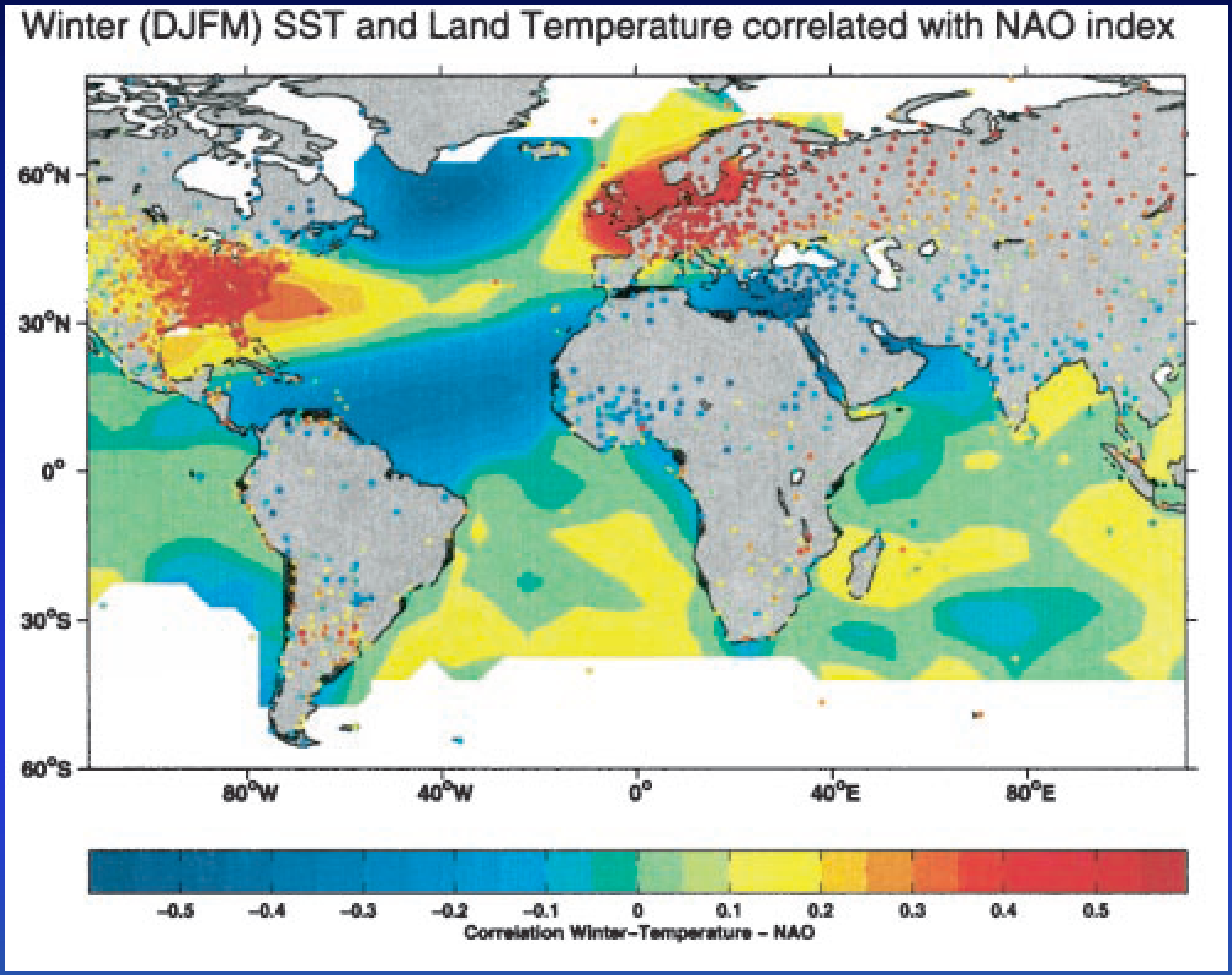
Cool, dry conditions in eastern US

Warm, calm conditions in northeast Canada and Greenland

Increased transport of cold Labrador slope water to southwest

from: K. Drinkwater (2000) AGU Chapman Conference

Correlation between NAO and SST



Salmon –NAO-SST relationships are well developed...focus on testing hypotheses

Visbeck et al. (2001) *PNAS*

How does the Gulf of Maine (and adjacent areas) respond to NAO forcing on a fine spatial scale?

2.) An oceanographic and climate data source

http://www.mar.dfo-mpo.gc.ca/science/ocean/sci/sci-e.html

MARINE ECOSYSTEMS
- » Ecosystem Modelling
- » Operational Remote Sensing
- » Organic Chemistry
- » Particle Dynamics
- » Sampling & Monitoring Equipment
- » The Gully Marine Protected Area
- » Deep Sea Corals Atlantic Canada

CLIMATE AND VARIABILITY
- » Deep Ocean Studies
- » Turbulent Mixing
- » Sea Ice Studies
- » Computer Atlas of the NW Atlantic

SHELF OCEANOGRAPHY
- » Coastal Hydrodynamics
- » Classification of Maritime Inlets
- » GLOBEC Canada
- » Ice / Ocean Forecast
- » Minas Basin Sea Level
- » SeaHorse Moored Profiler

MONITORING
- » Atlantic Zone Monitoring Program
- » Bedford Basin Plankton Monitoring

CENTRES OF EXPERTISE
- » Offshore Oil and Gas (COOGER)
- » Ocean Model Development/Application (COMDA)
- » Centre for Ocean Satellite Salinity (VCOSS)

DATA
- » BioChem
- » CHS Tide, Current & Water Levels
- » Coastal Temperature Climate
- » Contaminants (NCIS)
- » Near Bottom Currents
- » Oceanographic Databases
- » Offshore Oceanographic Climate
- » Subsurface Drifter Velocities Database (SDVD)
- » WebDrogue Drift Prediction Model
- » WebTide Tidal Prediction Model

SEMINARS
- » OES Seminar Series
- » Bedford Institute Seminar Series

GENERAL
- » Department Links & Partnerships
- » OES Contacts
- » OES Publications
- » OES Staff Directories
- » ERD Home, OSD Home

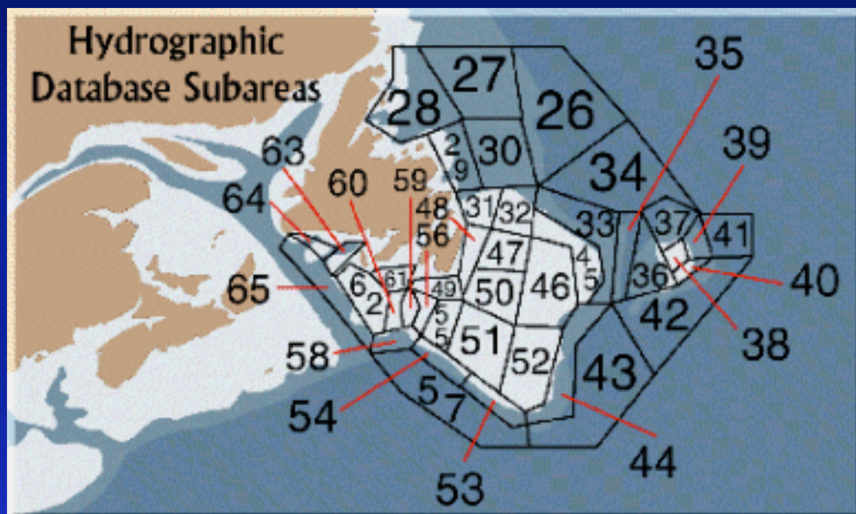
AZMP (20 time series)

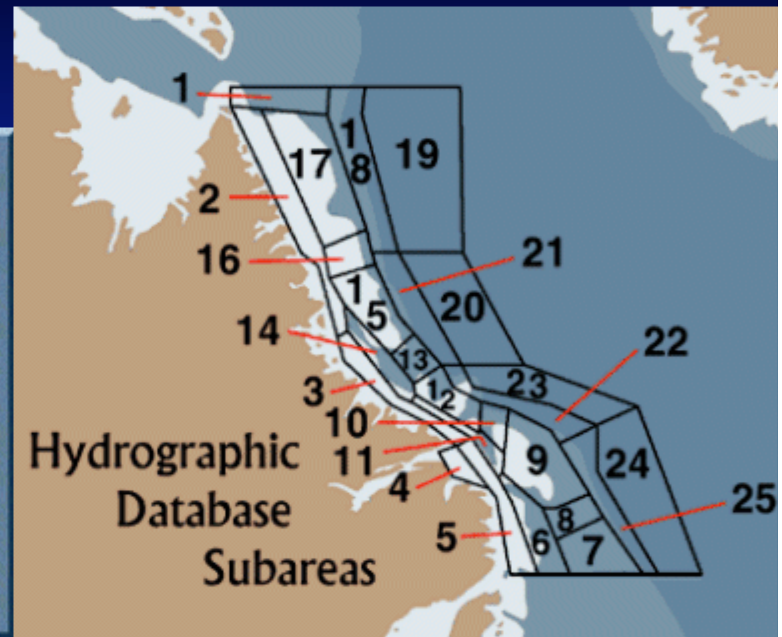
BIOCHEM (1575 research missions;
92 560 sampling events;
2 224 000 discrete measurements;
522 500 plankton measurements)

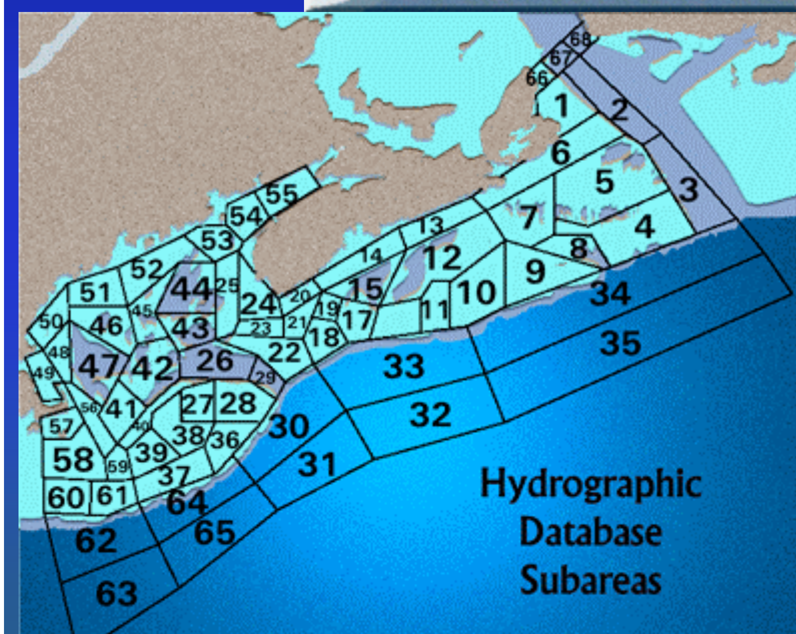
Oceanographic Databases
(Climate-Hydrography ~850000 T,S profiles to 1920;
Ocean Colour (1997-2004)

Provide data that may compliment/expand available US Sources (U. Maine chl., etc.)

Some data sources include the Gulf of Maine

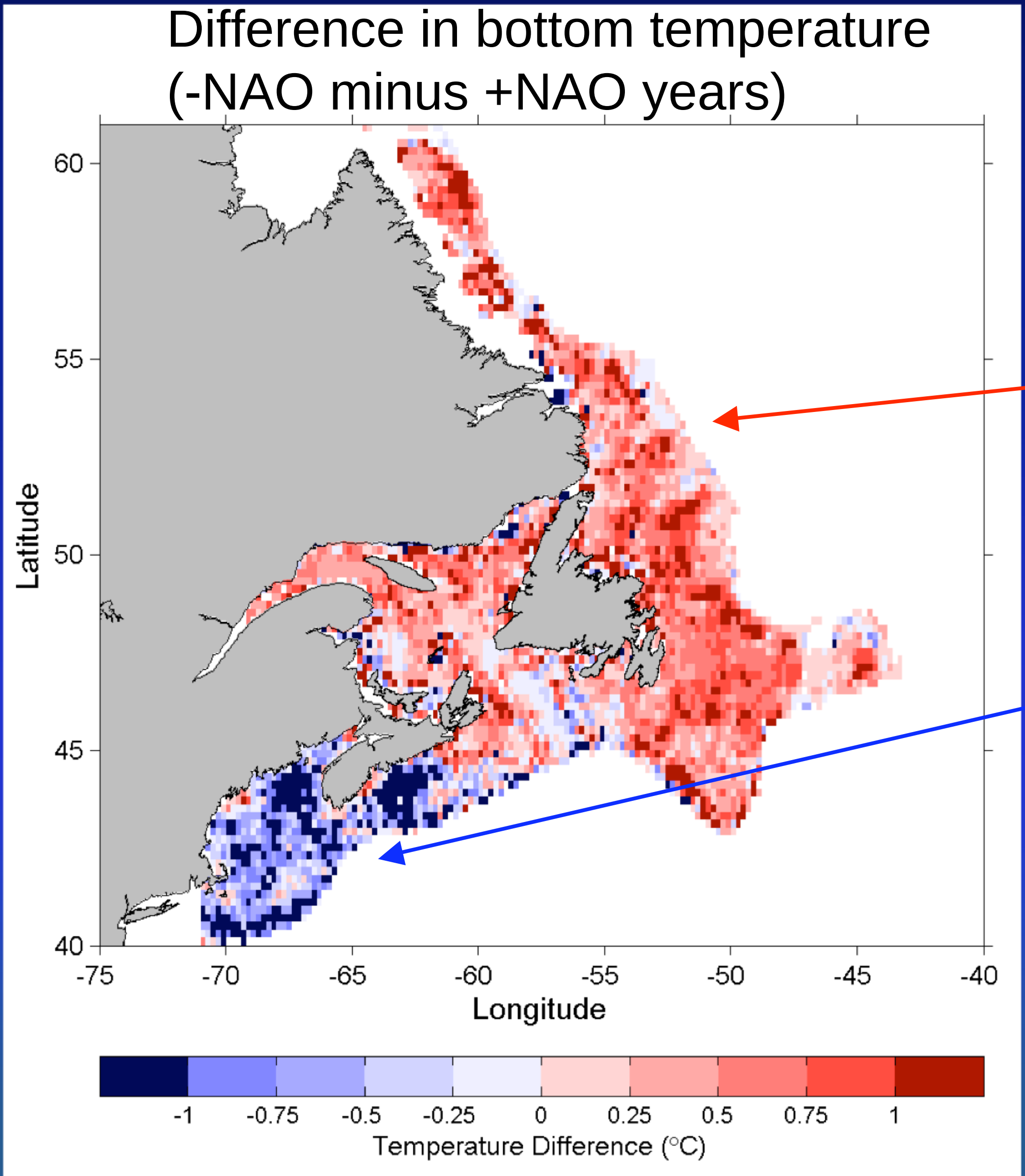






How does the Gulf of Maine (and adjacent areas) respond to NAO forcing at a fine spatial scale?

Shelf bottom water responses to NAO anomalies



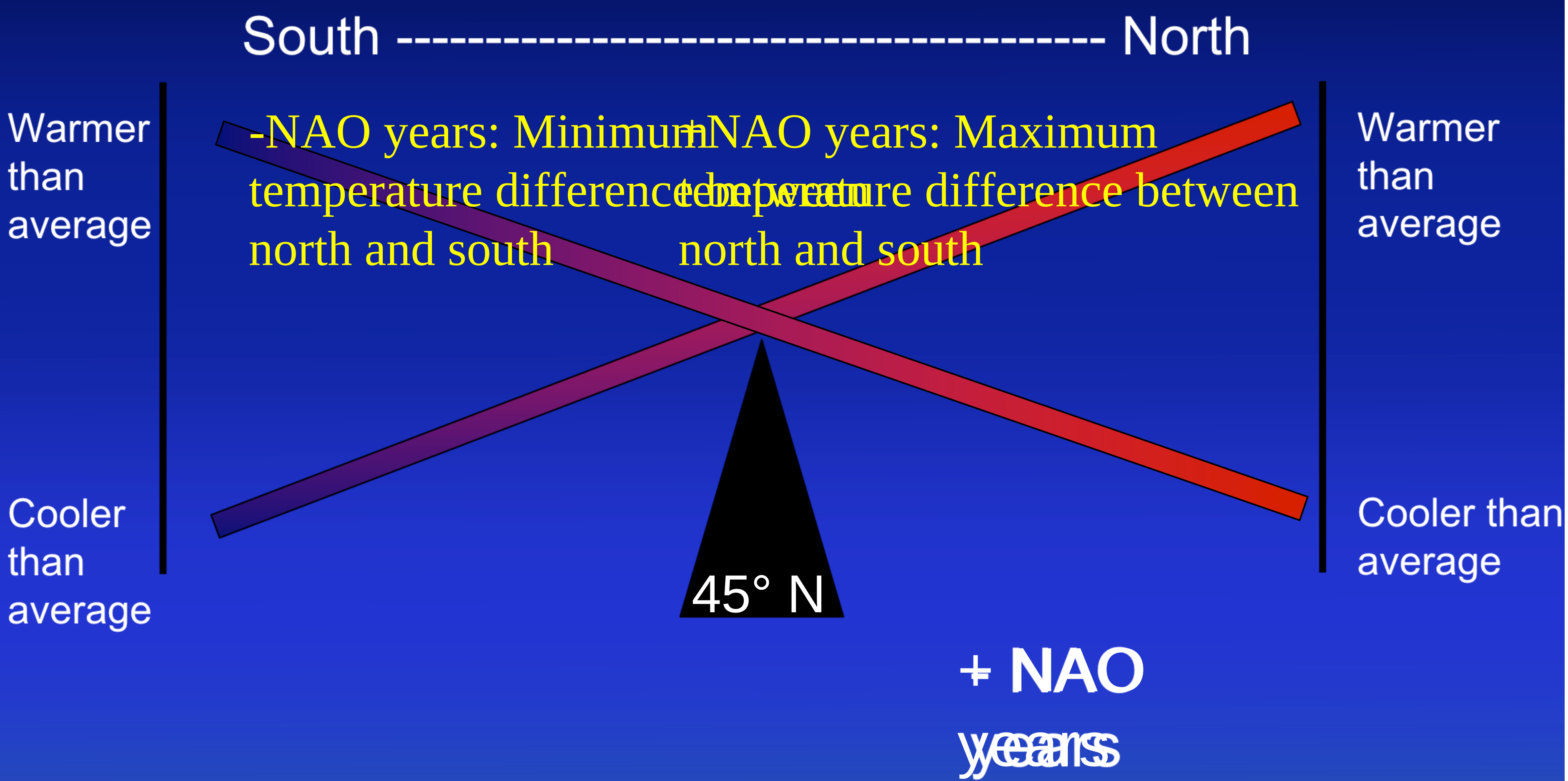
NAO ‘run years’ T, S from Climate database

Warmer during –NAO years than +NAO years

Cooler during –NAO years than +NAO years

From: Petrie, B. (2007). Does the North Atlantic Oscillation affect hydrographic properties on the Canadian Atlantic continental shelf? *Atmosphere-Ocean*

Shelf bottom water responses to the NAO



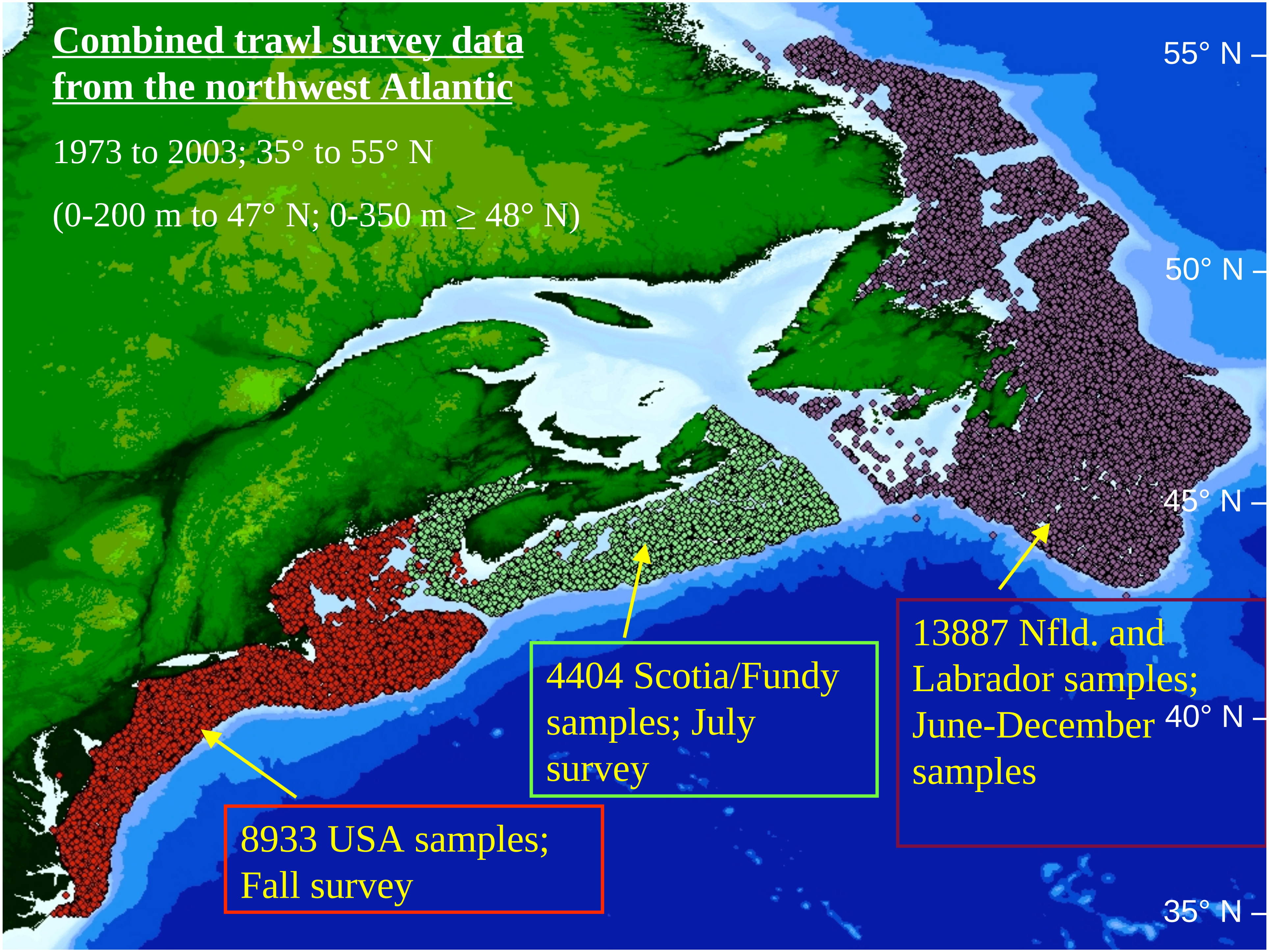
Simplified from: Petrie, B. (2007). *Atmosphere-Ocean*

3.) NAO influence on fish assemblages—hypothesis testing at large spatial scales

e.g. How does marine species richness respond to the NAO?

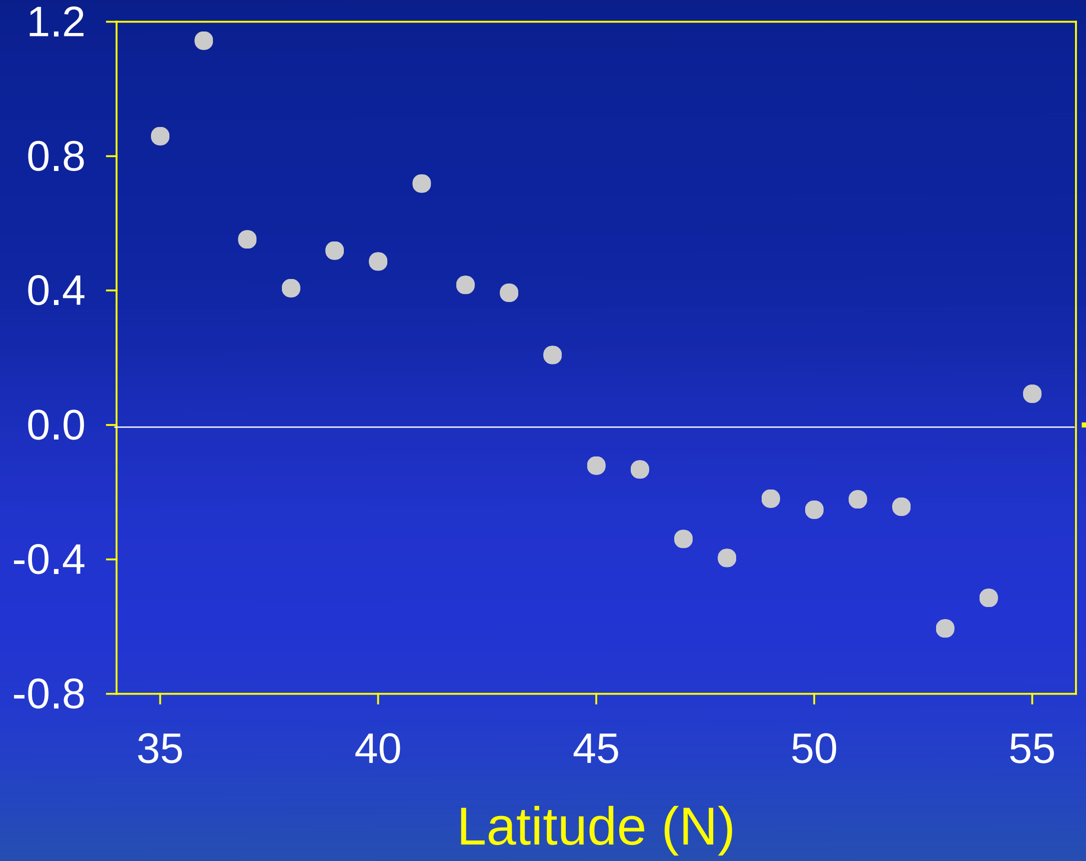
What is the mechanism driving interannual variability?

Fisher *et al*. (2008) Ecology Letters 11:883-897



Combined trawl survey data from the northwest Atlantic
1973 to 2003; 35° to 55° N
(0-200 m to 47° N; 0-350 m ≥ 48° N)
55° N
50° N
45° N
40° N
35° N
13887 Nfld. and Labrador samples; June-December samples
4404 Scotia/Fundy samples; July survey
8933 USA samples; Fall survey

Trawl survey data—shelf bottom water temperatures

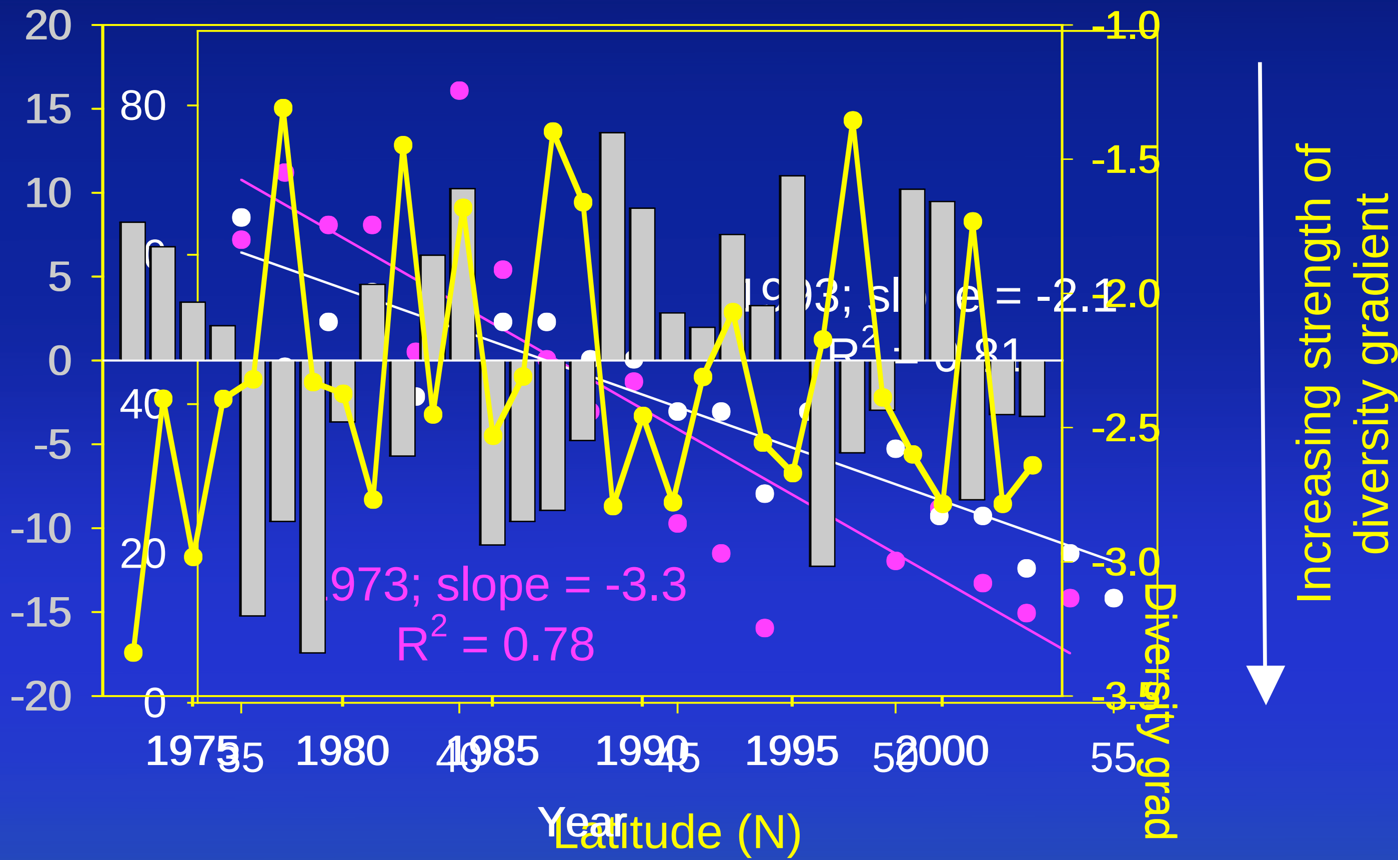


(+NA

Warmer than average during +NAO years

Warmer than average during –NAO years

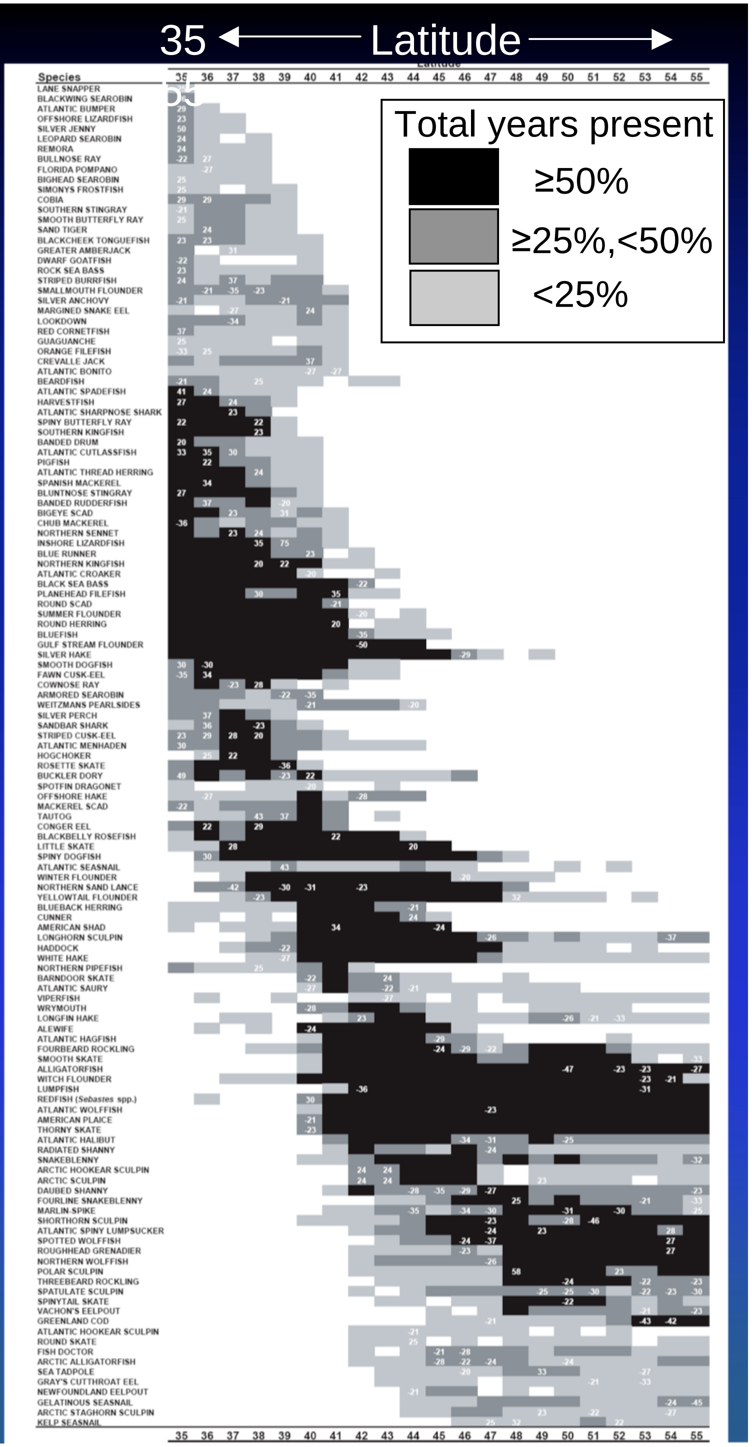
Are the yearly changes in the species diversity gradient related to the strength of the NAO?



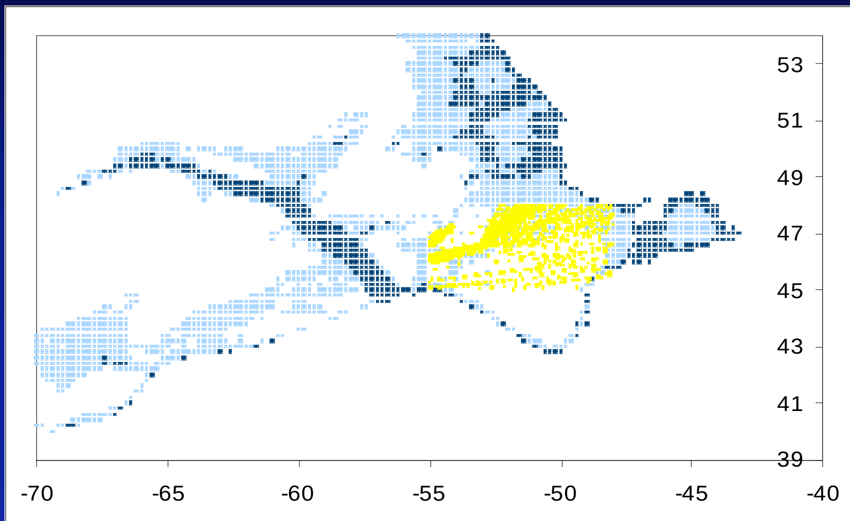
Annual NAO strengths and diversity gradients are significantly negatively related (r = -0.41, n = 31 years, *P* = 0.01).

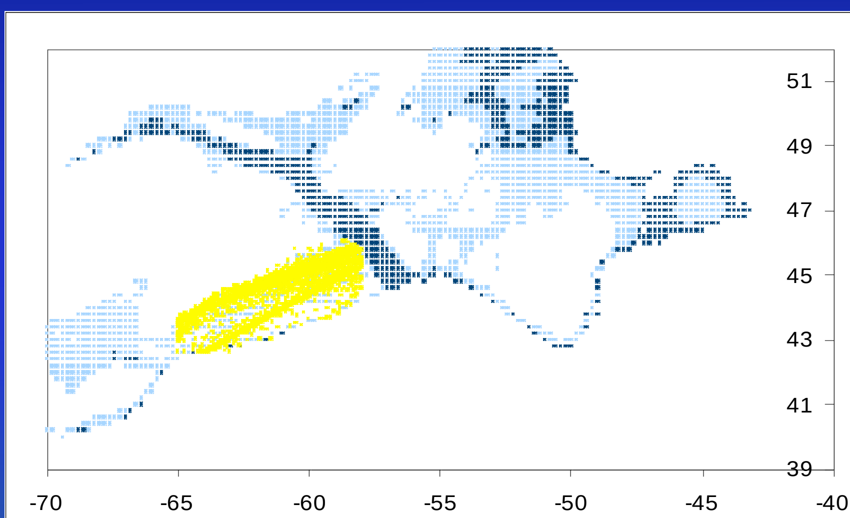
Patterns not simply due to changes in the distribution of few species

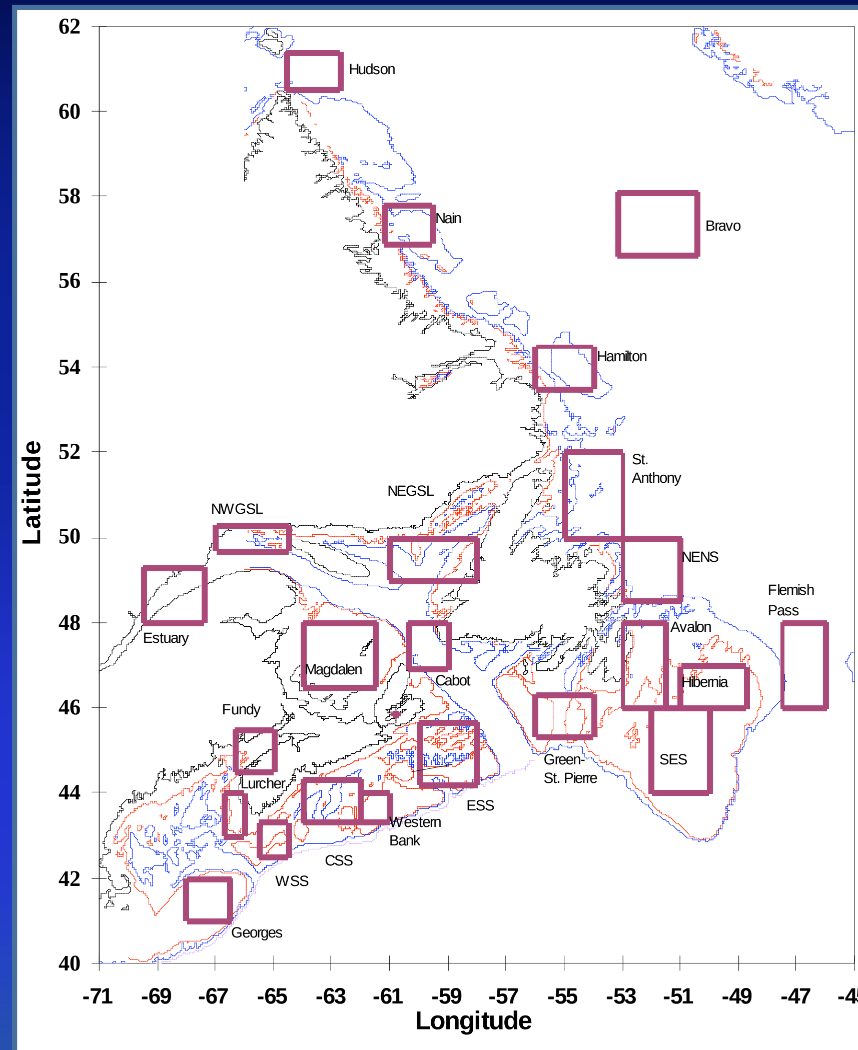
- 133 species had ≥20% difference in frequency of occurrence between +NAO and –NAO years (26 in GOM)
- As expected, at southern latitudes, more species were observed during +NAO; more northern species observed during –NAO (r = -0.54)
- Gulf of Maine changes were influenced by both southern and northern species



H_a: NAO influence on shelf productivity?







Based on rather informal analyses (correlation): No strong evidence from long-term CPR greeness time series or 1997-2004 satellite chl

Potential implications for salmon

Demonstrated NAO influence via physiological tolerance is a direct and *simple* mechanism (no species interactions, no population dynamics, single TL)

Oceanographic (productivity) allowed testing competing hypothesis

Potential salmon predators/prey shift distributions quickly (annually) with no apparent lag in NAO-temperature (shallow shelf) or NAO-species response

Positive temperature anomalies in GOM contrast high latitude—salmon climb steeper gradient (NAO+)

Additional (e.g. NMFS spring trawl) survey data are available

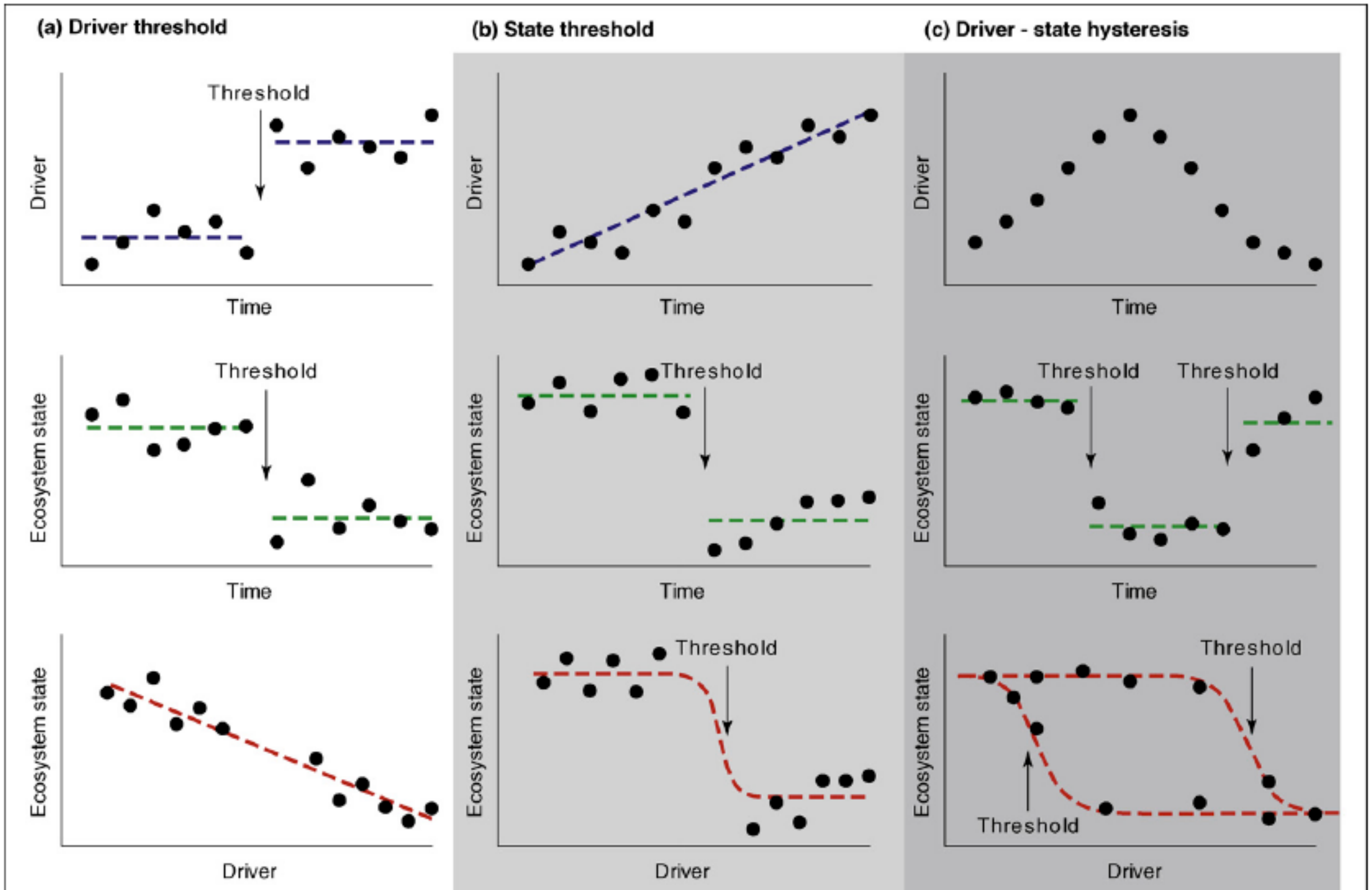
4.) Testing climate's influence relative to others—methods and an example

Review

Ecological thresholds and regime shifts: approaches to identification

Tom Andersen[1], Jacob Carstensen[2], Emilio Hernández-García[3] and Carlos M. Duarte[4]

Trends in Ecology and Evolution (2008)



TRENDS in Ecology & Evolution

Review

Ecological thresholds and regime shifts: approaches to identification

Tom Andersen[1], Jacob Carstensen[2], Emilio Hernández-García[3] and Carlos M. Duarte[4]

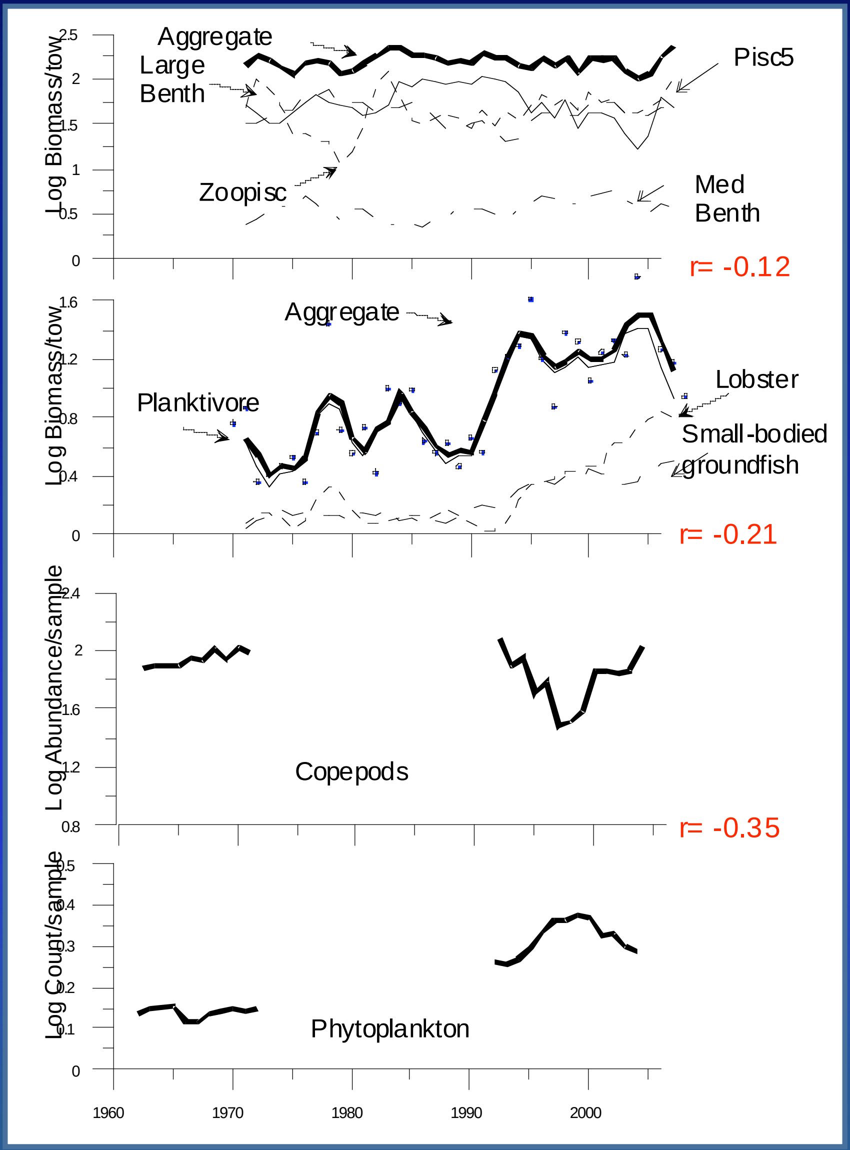
Trends in Ecology and Evolution (2008)

Table 1. Software for regime shift detection[a]

Program	Methods	Approach	Availability	Authors	URL
Brodgar	Chronological clustering, dynamical factor analysis, min/max autocorrelation factor analysis, etc.	Inferential	Commercial, stand-alone with R interface, Windows	A.F. Zuur [30]	http://www.brodgar.com/brodgar.htm
Caterpillar-SSA	Singular spectrum analysis, structural change detection	Exploratory	Commercial, stand-alone, Windows	N. Golyandina, V. Nekrutkin, A. Zhigljavsky	http://www.gistatgroup.com/cat/index.html
Change-point analyzer	CUSUM charts, bootstrap tests	Inferential	Shareware, stand-alone + Excel add-in, Windows	W. Taylor	http://www.variation.com/cpa
DCPC	Detection of changes using a penalized contrast	Inferential	Freeware, Matlab scripts, multiple OS	M. Lavielle	http://www.math.u-psud.fr/~lavielle/programs
Dimensionality reduction toolbox	Linear (PCA, etc.) and nonlinear dimensionality reduction methods	Exploratory	Freeware, Matlab scripts, multiple OS	L.J.P. van der Maaten [32]	http://www.cs.unimaas.nl/l.vandermaaten/Laurens_van_der_Maaten/Matlab_Toolbox_for_Dimensionality_Reduction.html
Palaeo	Chronological clustering	Exploratory	Freeware, R package, multiple OS	S. Juggins	http://www.staff.ncl.ac.uk/staff/stephen.juggins/analysis.htm
Regime shift detection	Sequential t tests, prewhitening option for autocorrelated data	Inferential	Freeware, Excel add-in, Windows	S.N. Rodionov [42]	http://www.beringclimate.noaa.gov/regimes
STSA: statistical time series analysis toolbox	Dynamical linear models, TAR models, singular spectrum analysis, etc.	Inferential	Commercial, O-matrix toolbox, Windows	D.D. Thomakos	http://www.omatrix.com/stsa.html
Strucchange	Multiple change-points, F tests, empirical fluctuation processes, etc.	Inferential	Freeware, R package, multiple OS	A. Zeileis *et al.* [39]	http://cran.r-project.org/web/packages/strucchange/index.html
ThEnhancer	Nonlinear diffusion filtering	Exploratory	Freeware, stand-alone, multiple OS	A. Jacobo, P. Colet, E. Hernandez-Garcia	http://ifisc.uib.es/ThEnhancer

[a]A selection of available software products with relevance to detection of thresholds and regime shifts in ecological data sets.

How do extrinsic and intrinsic factors contribute to trophic structuring?

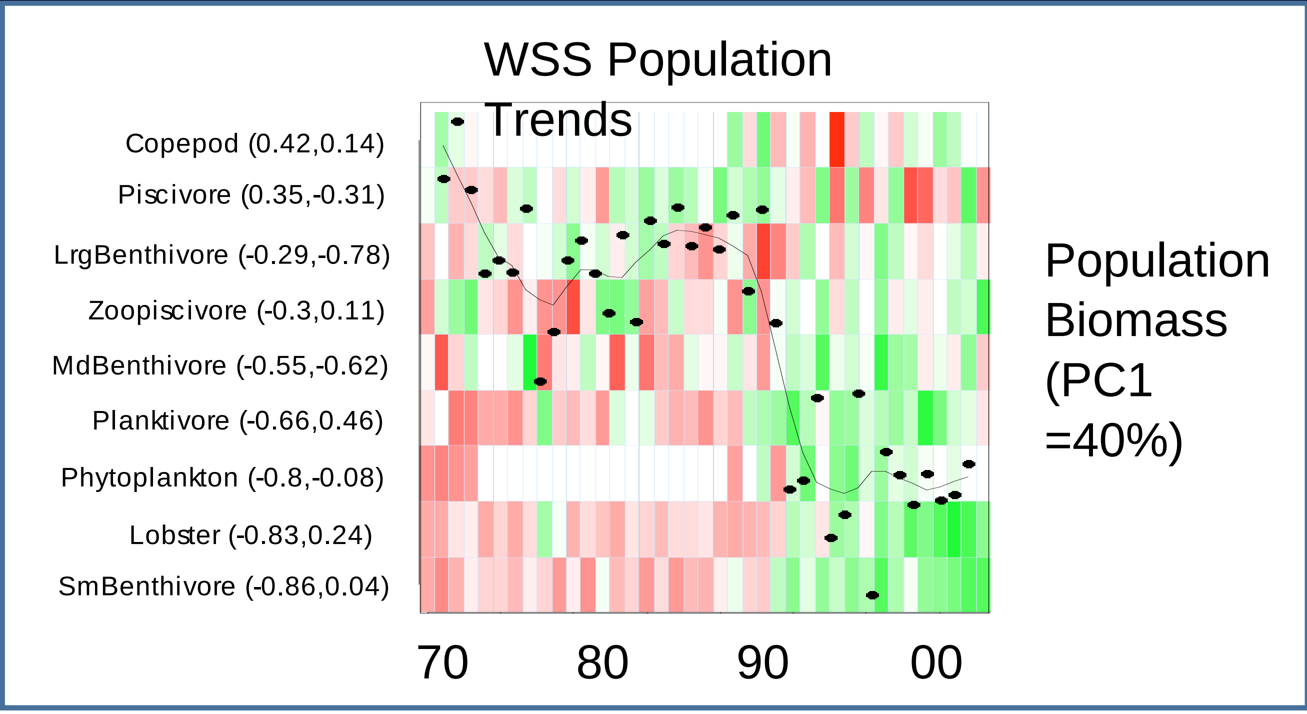


Western Scotian Shelf
4 trophic level system

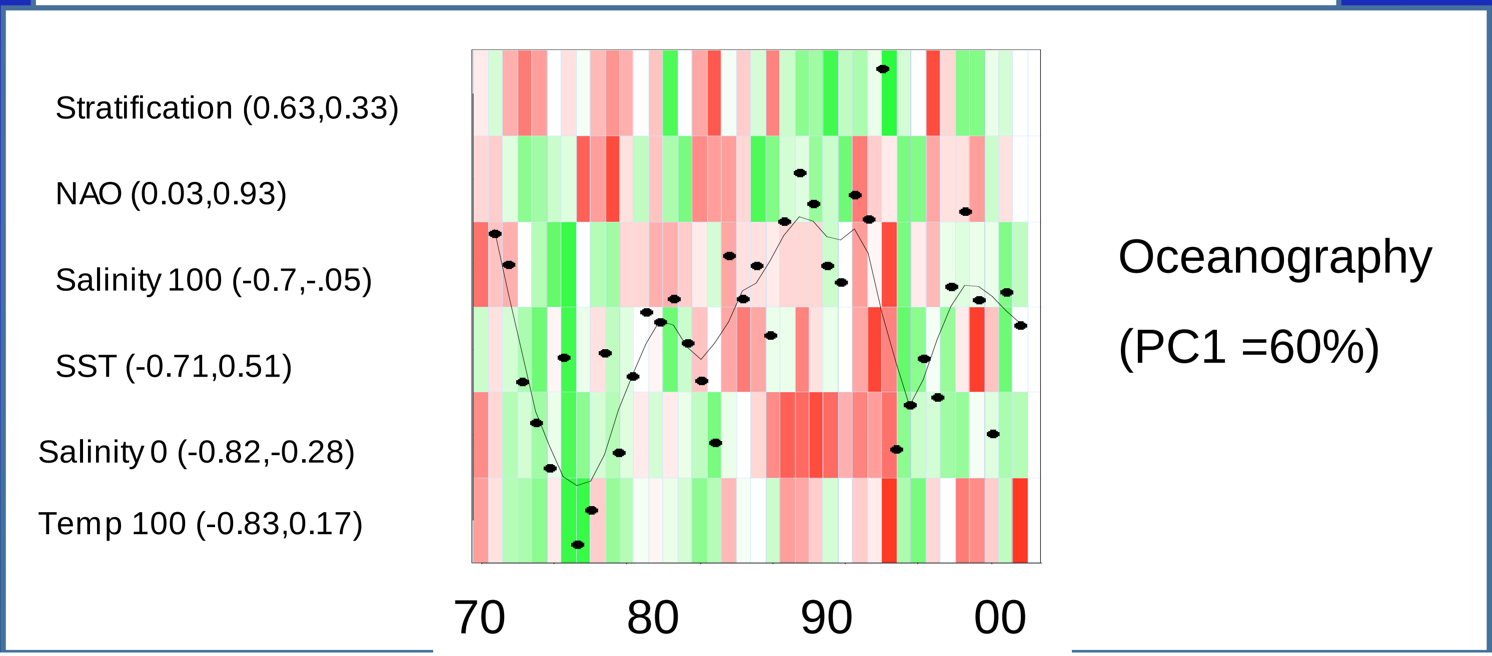
Why does top-predator biomass remain stable despite increasing potential prey biomass and other changes at low trophic levels?

Consistent with bottom-up effects or trait changes in predators affecting lower levels?

From: N.L. Shackell et al. (in prep.)

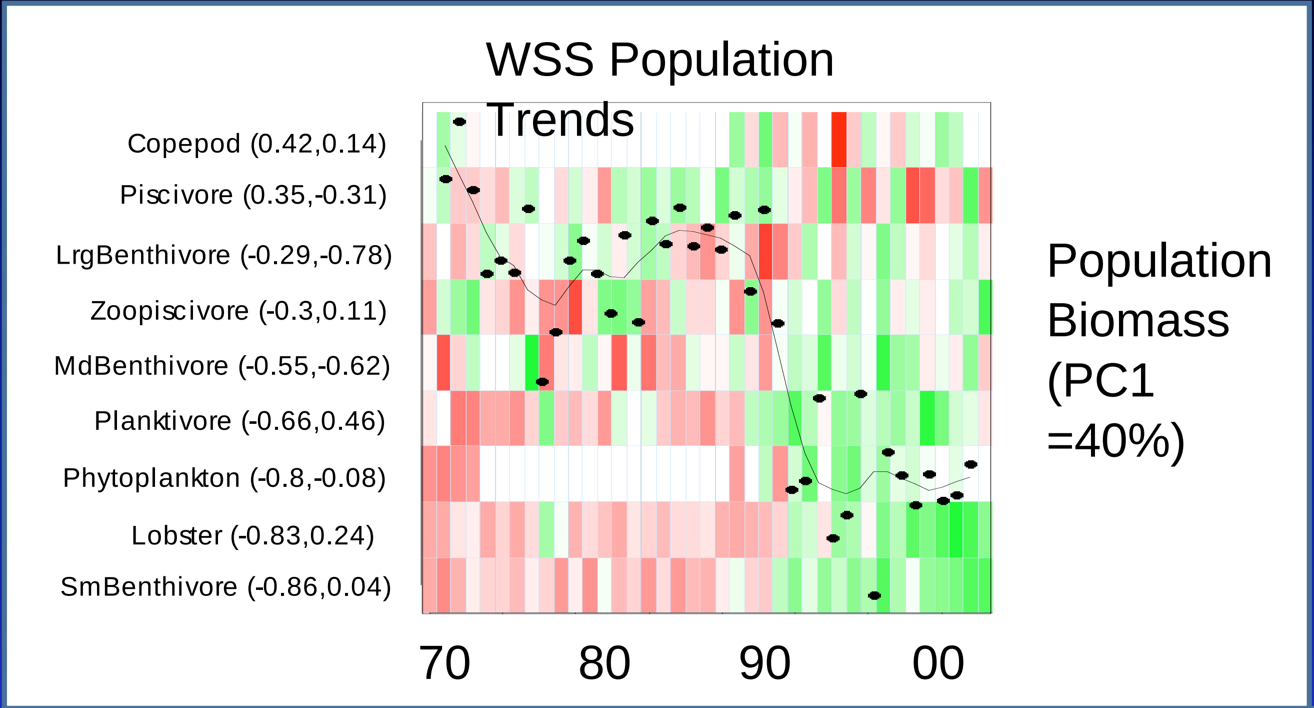


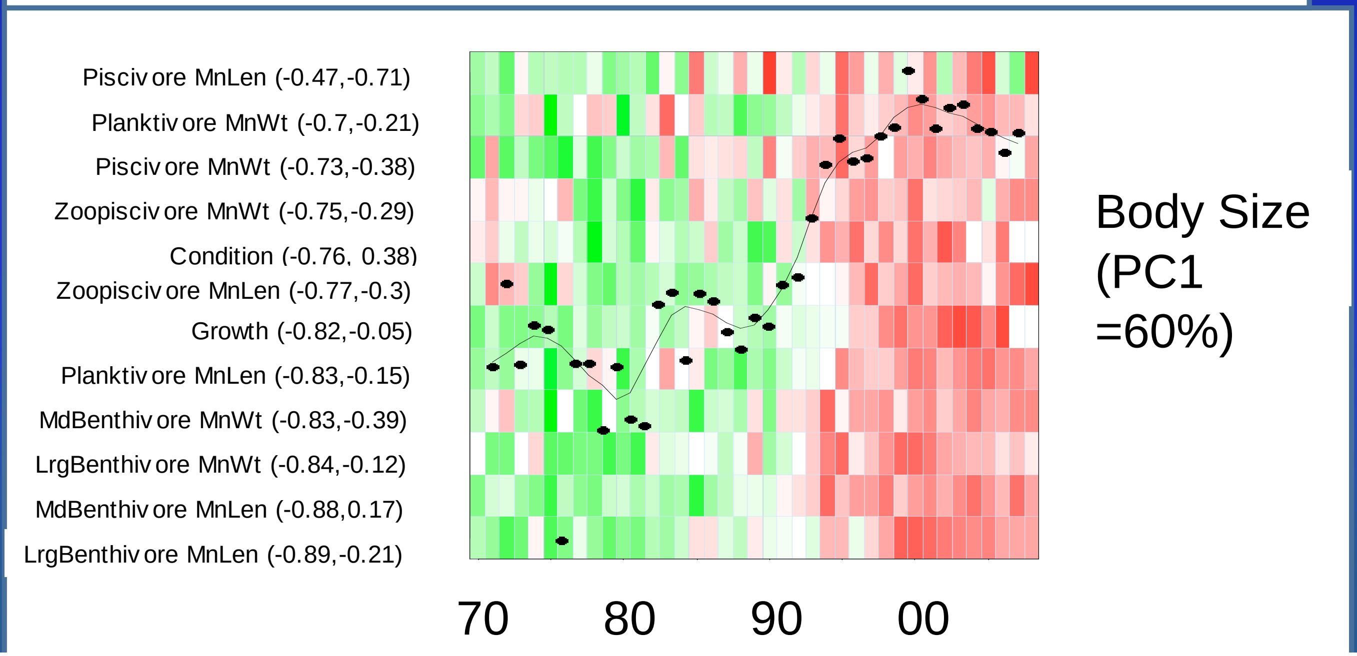
Does multivariate oceanographic or traits information provide more explanatory power?



Oceanographic data from BIOCHEM

From: N.L. Shackell et al. (in prep.)





Body size, not oceanographic conditions parallel WSS population trends and may explain lack of top-predator response

GAM tests confirm the apparent influence of size

From: N.L. Shackell et al. (in prep.)

Potential implications for salmon

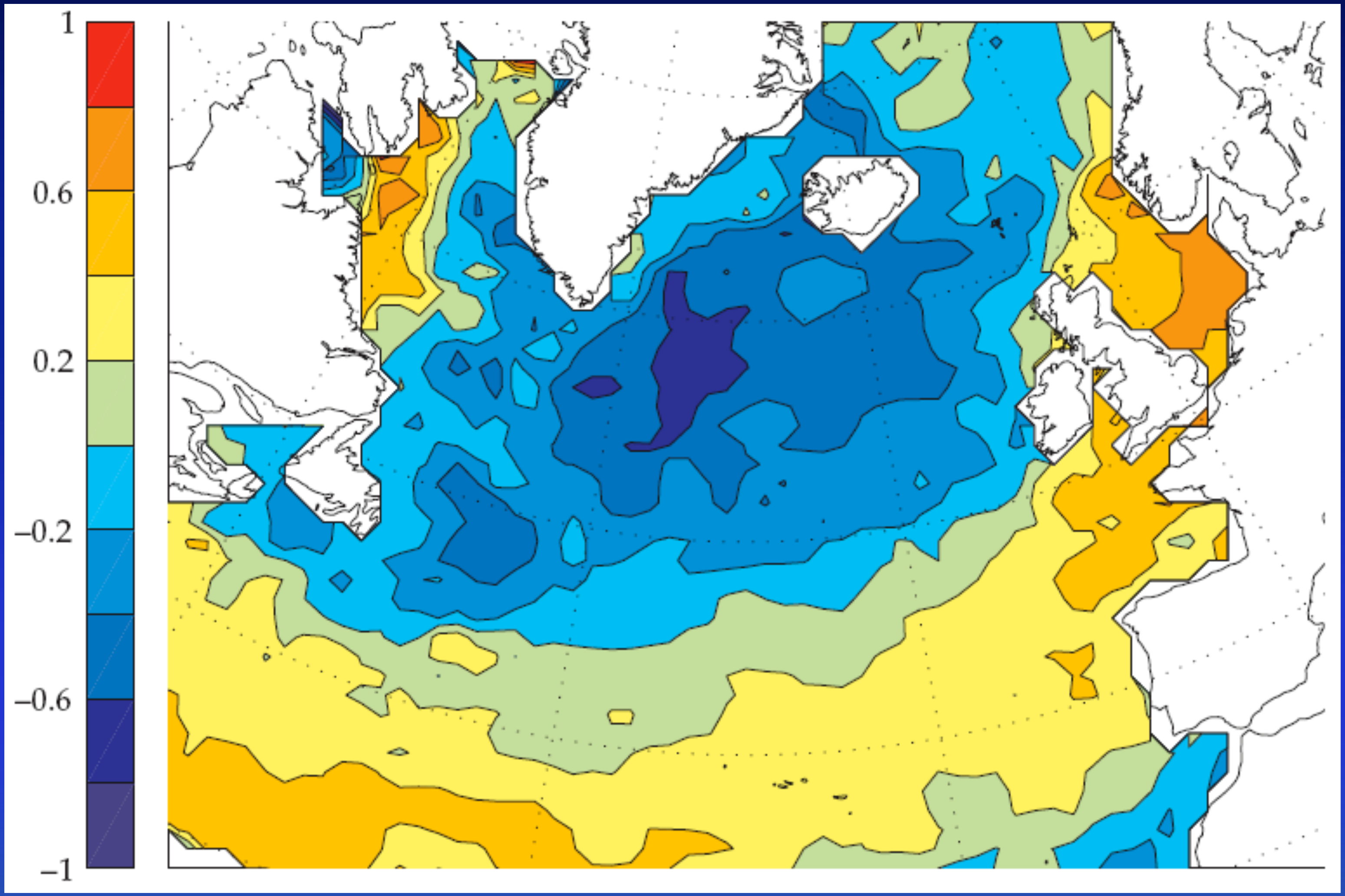
Diverse methods, software, and data are available to test specific hypotheses about regime change

Examining intrinsic (e.g., traits) vs. extrinsic (e.g., climate) influences on population time series may be useful

For salmon, returns provide population time series at multiple spatial scales and climate influences (and from different areas) could be tested against each other

End.

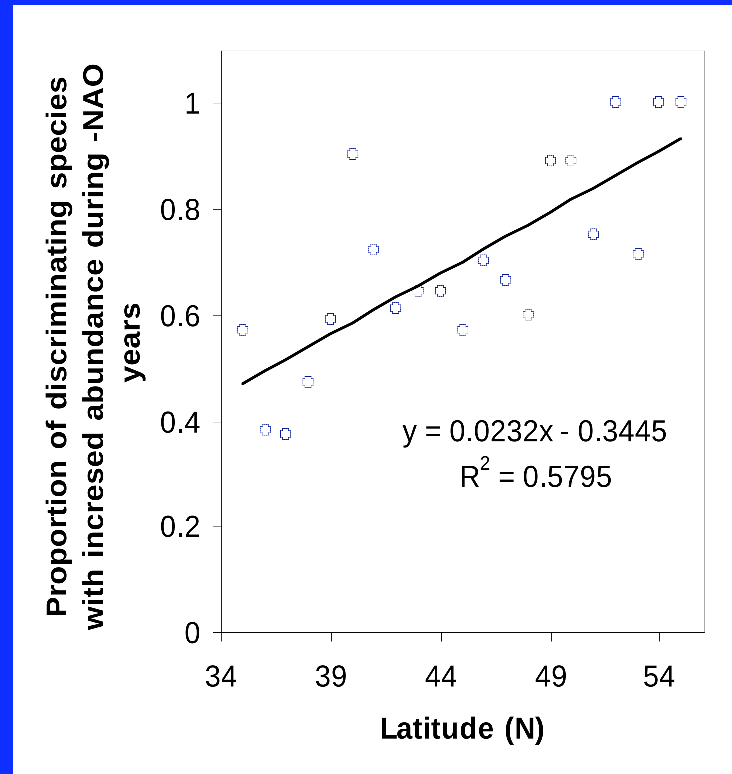
Correlation between NAO and SST



From: Hurrell and Dickson (2004) in
Marine Ecosystems and Climate Variation

Latitude

Species	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55
Pigfish	-1.18																				
Spanish sardine	-1.27																				
Planehead filefish	-0.99																				
Bigeye scad	-0.78																				
Round scad	-3.85																				
Rough scad	-0.62																				
Banded drum	1.21																				
Blue runner	-0.73	-0.41																			
Atl. Thread herring	0.74	0.81																			
Scup	-6.72	-2.99	-0.91																		
Striped anchovy	-10.45	14.44	-11.56	3.6	-1.76																
Northern searobin	0.74	-1.21	2.46	-2.82	-2.02																
Atl. Croaker	12.8	6.3	6.22	-6.03	-2.41																
Spot	12.43	10.05	10.19	4.35	1.12																
Bay anchovy	3.34	5.38	7.71	10.14	9.9	-6.27															
Spotted hake	-0.68	-5.67	-4.71	-7.86	-4.75	-1.86															
Bluefish	1.49	-1.46	1.73	1.68	-1.43	-0.95															
Weakfish	3.36	-2.31	6.33	5.07	2.47	-1.04															
Round herring	-1.47	-0.95	-1.34	-1.46	-1.55	-1.83															
Scup	-16.23	-19.43	12.51	5.03	4.23	-3.53	-1.2														
Butterfish	9.07	15.26	-21.06	31.55	28.67	-32.52	7.74	-1.26													
Southern kingfish		0.46																			
Harvestfish		0.4																			
Black sea bass		0.78																			
Clearnose skate		0.46																			
Summer flounder		0.71	1.27	1.28	1.39	-1.62															
Striped searobin		0.4	0.59	0.66	1.09	-0.85															
Silver hake		0.43		1.99	-8.75	-13.63	-18.38	-15.81	-17.57	-8.91											
Silver perch			0.63																		
Smooth dogfish			-0.48	-3.44	-4.39	-0.96															
Windowpane			0.54	-1.13	1.75	-2.41	2.13														
Gulf stream flounder				-0.77	-1.27	-1.8															
Fourspot flounder				-0.77	-3.26	-2.81	-1.22														
Little skate				-0.74	-2.87	-4.16	-4.4														
Fawn cusk eel					-0.92																
Red hake					1.38	2.36	-5.45	-4.27	-2.43												
Northern sand lance					-0.63		1.85		-1.32	-7.52	-15.85	-13.18									
Spiny dogfish					2.16	-7.6	-23.8	-10.42	-5.51	-2.06	-1.3										
Winter skate						-0.77	-4.48														
Haddock						-0.79	-5.01	-26.03	-18.48	-13.15	-1.82										
Winter flounder						-0.97	-2.28	-1.85			-0.59										
Yellowtail flounder						1.39	-2.61	-3.27	-7.25	-16.5	-6.54	-1.85									
Sea raven							-0.8	-0.75													
Longhorn sculpin							3.94	4.1	1.45	2.85	-0.61										
White hake							-1.91	1.32	2.62	2.49	0.93										
Thorny skate							0.69	1.91	-2.25	4.63	4.3	4.38	1.76	2.13			-1.75				
Atlantic cod							2.02	4.8	4.66	-10.73	-13.74	-16.09	-5.24	11.62	23.92	-9.47	-16.5	-15.43	19	-20.28	-22.53
Am. Plaice							-0.75	4.86	19.29	13.27	36.27	-47.28	-61.74	-37.24	-8.46	16.75	19.15	-16.64	-19.93	-11.42	-10.63
Atl. Argentine								1.05													
Alewife								-0.74			0.78										
Pollock								1.3	-1.36	-1.04											
Witch flounder								-1.05	-1.6	1.52	1.59	1.05			-7.8	-2.59					
Redfish (unseparated)								-5.2	5.21	-4.78	4.1	3.56	16.37	4.06	-19.83	-14.59	-10.48	-8.4	3.34		-1.99
Alligatorfish										-0.8	-1.25	-1.08									
Arctic eelpout											0.81	-1.24		-1.44							
Arctic cod												-1.31	-2.56	-14.35	-9.53	-18.22	15.47	-13.56	-26.24	-37.81	-37.93
Spatulate sculpin													-2.73								
Greenland halibut														-7.31	-7.81	-10.81	-8.73	-14.33	-8	-8.47	-5.52
Daubed shanny														-3.66	-1.75	-4.05	-7.52	-14.33	-11.29	-6.99	
Atlantic wolffish														1.77				-1.61			-2.12
Atl. Sea poacher														-7.59	-10.36	-11.92	-11.87	-6.86	-4.77	-5.95	-7.53
Northern wolffish																					-1.92
Vahl's eelpout															-1.9	-2.24					



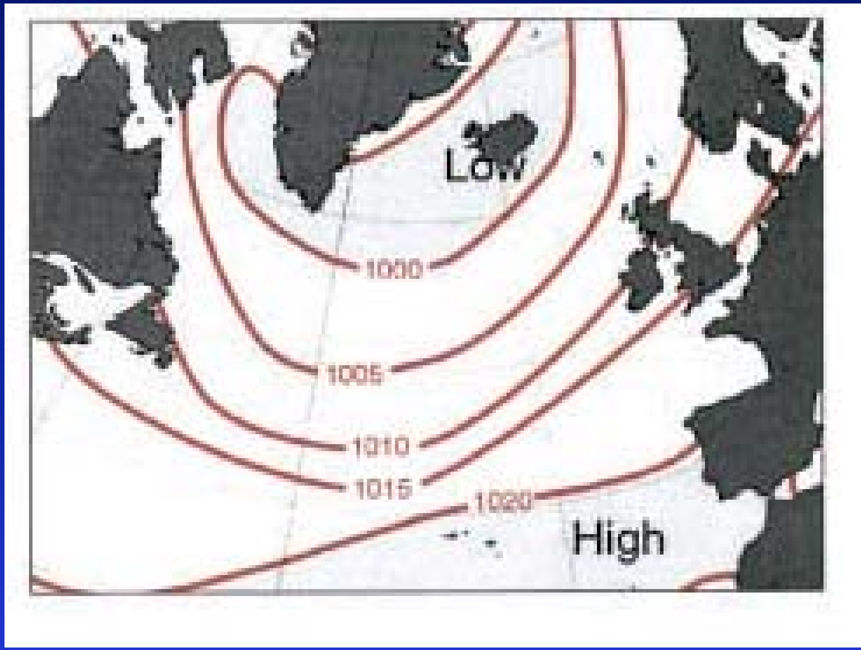
Values are species % contributions to dissimilarity between +NAO years and –NAO years

Red = higher avg. abundance during –NAO years

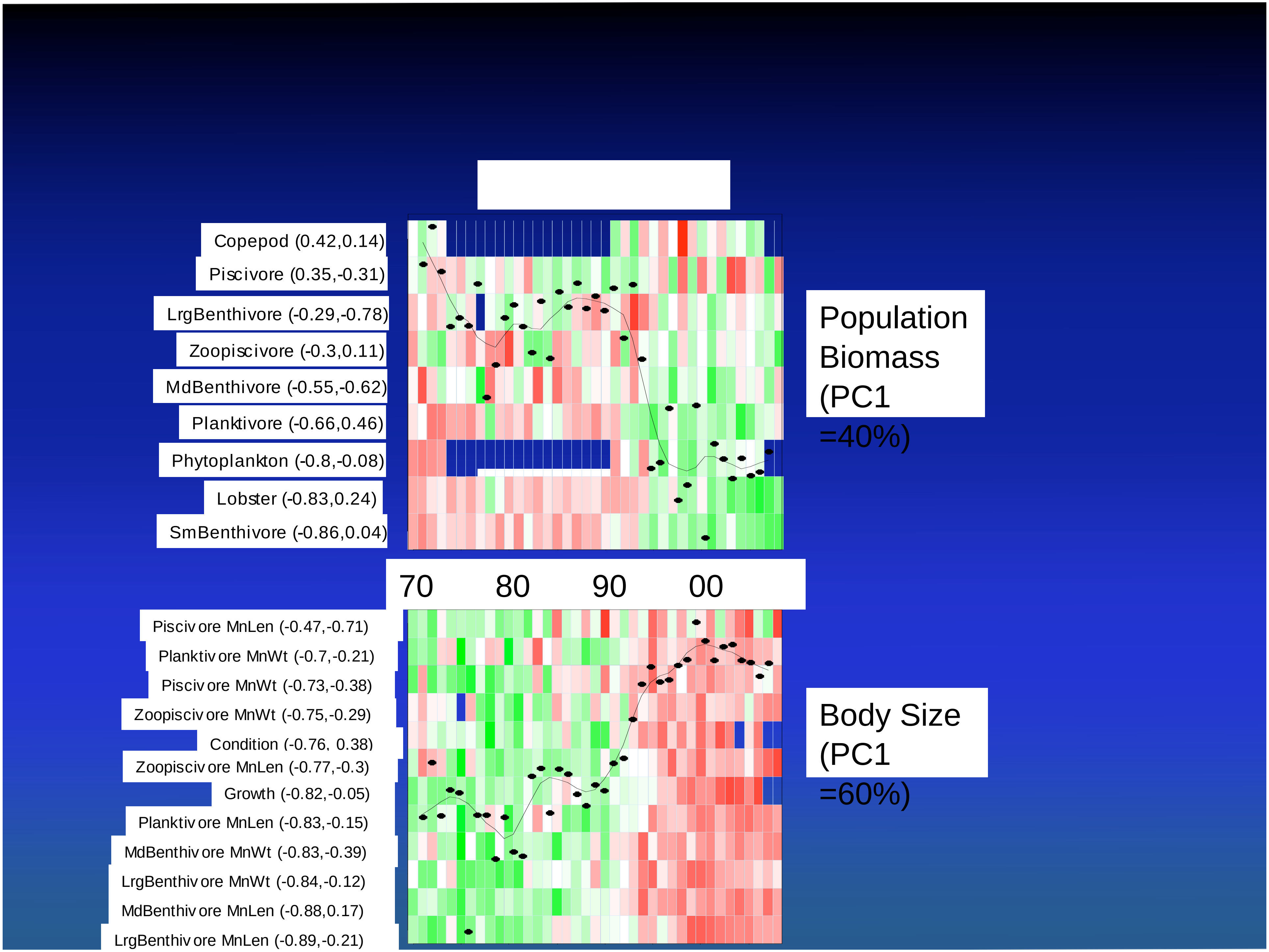
Green = higher avg. abundance during +NAO years

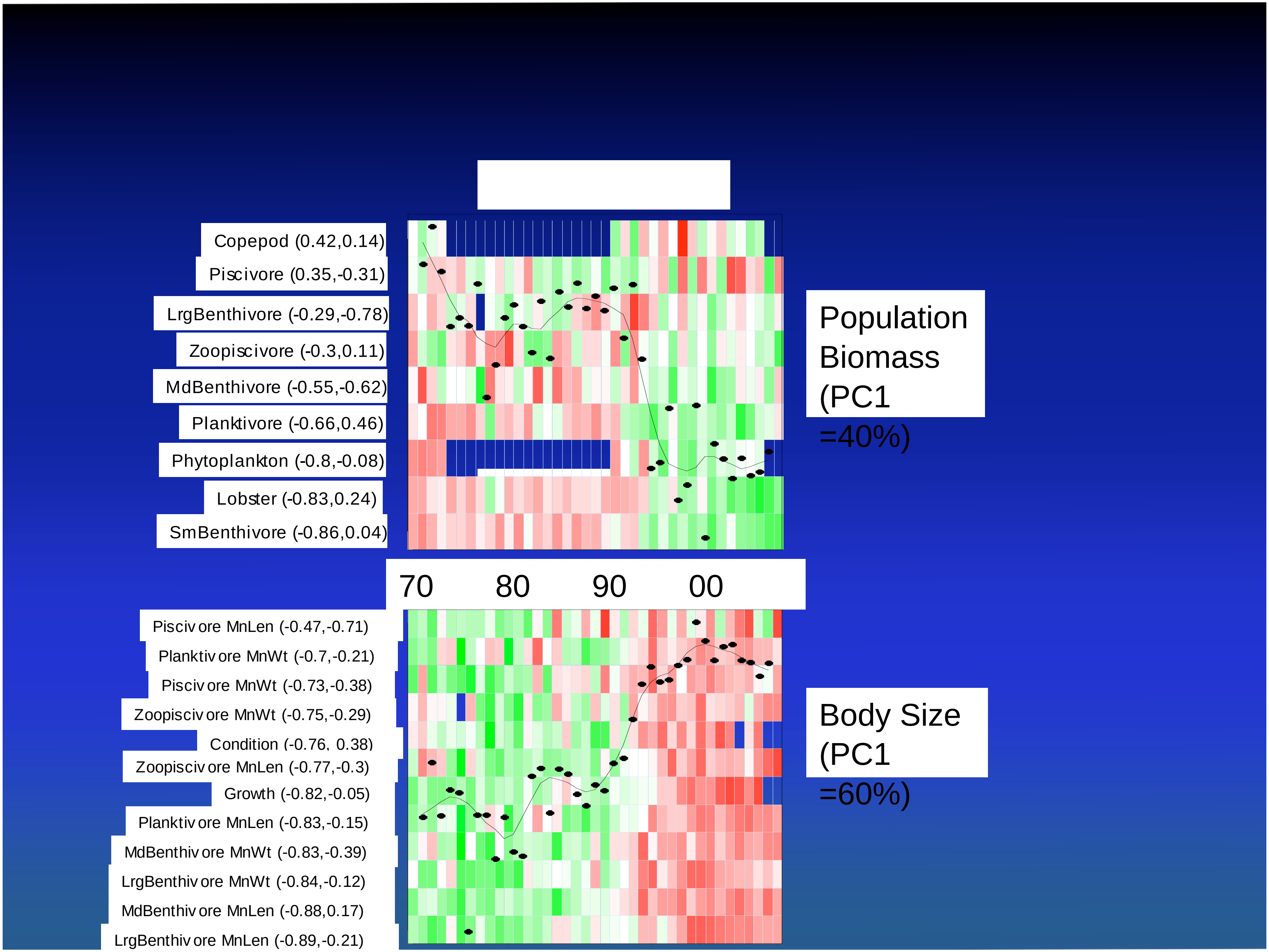
1.) The winter North Atlantic Oscillation (NAO) index

- Dec.-Feb. difference in sea level pressure between Iceland (low) and Azores (high)
- Dominant climate signal across the north Atlantic
- The NAO Influences climate from US east coast to Siberia via changing wind speeds and directions



Winter sea level pressure fields. (Ottersen et al. [2001] *Oecologia*)


Copepod (0.42,0.14)
Piscivore (0.35,-0.31)
LrgBenthivore (-0.29,-0.78)
Zoopiscivore (-0.3,0.11)
MdBenthivore (-0.55,-0.62)
Planktivore (-0.66,0.46)
Phytoplankton (-0.8,-0.08)
Lobster (-0.83,0.24)
SmBenthivore (-0.86,0.04)
Population Biomass (PC1 =40%)
70
80
90
00
Piscivore MnLen (-0.47,-0.71)
Planktivore MnWt (-0.7,-0.21)
Piscivore MnWt (-0.73,-0.38)
Zoopiscivore MnWt (-0.75,-0.29)
Condition (-0.76, 0.38)
Zoopiscivore MnLen (-0.77,-0.3)
Growth (-0.82,-0.05)
Planktivore MnLen (-0.83,-0.15)
MdBenthivore MnWt (-0.83,-0.39)
LrgBenthivore MnWt (-0.84,-0.12)
MdBenthivore MnLen (-0.88,0.17)
LrgBenthivore MnLen (-0.89,-0.21)
Body Size (PC1 =60%)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Lobster (-0.83,0.24)
SmBenthivore (-0.86,0.04)
Population Biomass (PC1 =40%)
70
80
90
00
Piscivore MnLen (-0.47,-0.71)
Planktivore MnWt (-0.7,-0.21)
Piscivore MnWt (-0.73,-0.38)
Zoopiscivore MnWt (-0.75,-0.29)
Condition (-0.76, 0.38)
Zoopiscivore MnLen (-0.77,-0.3)
Growth (-0.82,-0.05)
Planktivore MnLen (-0.83,-0.15)
MdBenthivore MnWt (-0.83,-0.39)
LrgBenthivore MnWt (-0.84,-0.12)
MdBenthivore MnLen (-0.88,0.17)
LrgBenthivore MnLen (-0.89,-0.21)
Body Size (PC1 =60%)