Science, Service, Stewardship

Climate change impacts on fish distributions in the Bering Sea

NOAA FISHERIES SERVICE

Presentation Outline

Physical description of the Bering Sea

Recent climate observations, indices and patterns

Nutrients, phytoplankton and zooplankton

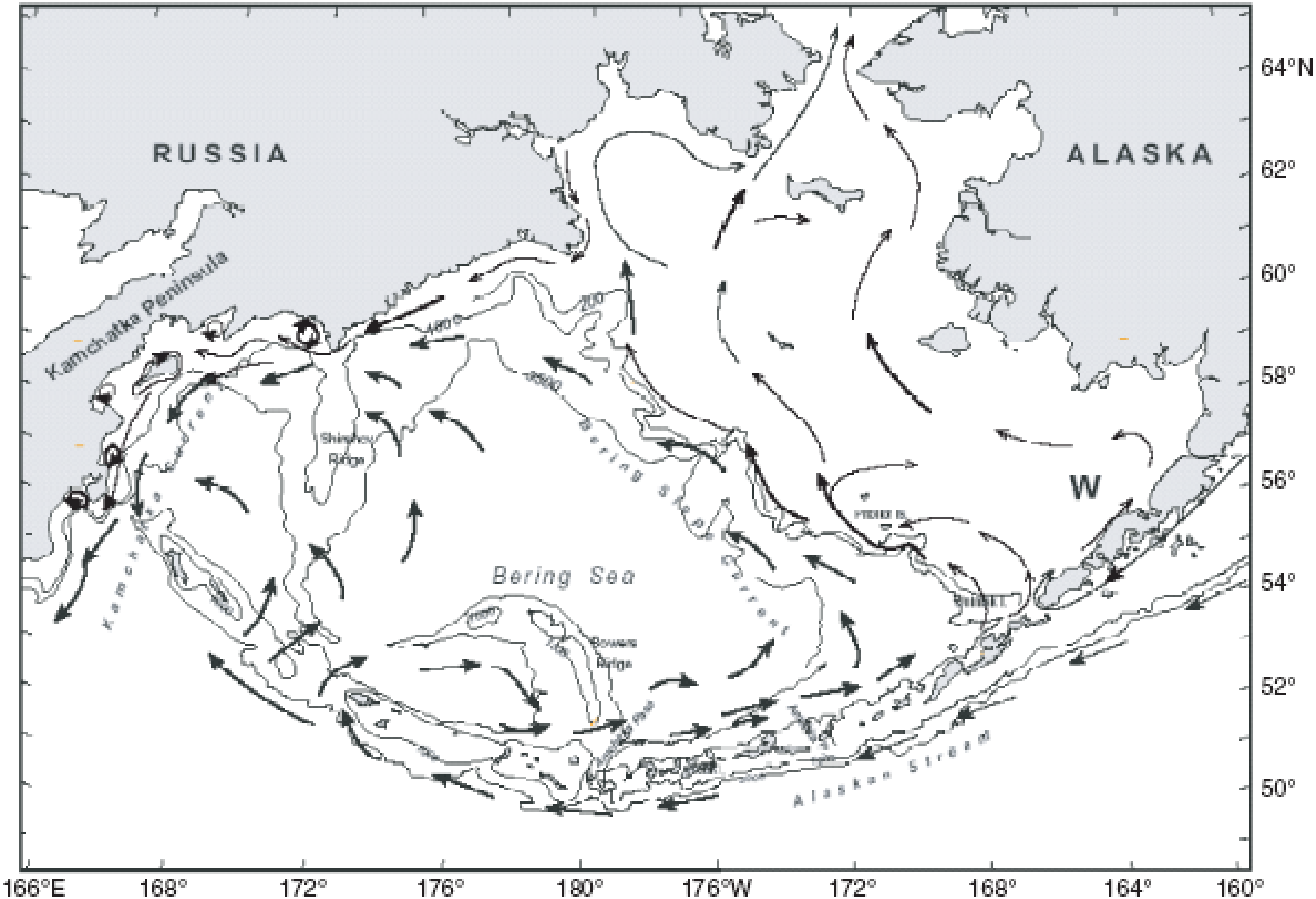
Effects of climate on fish distributions

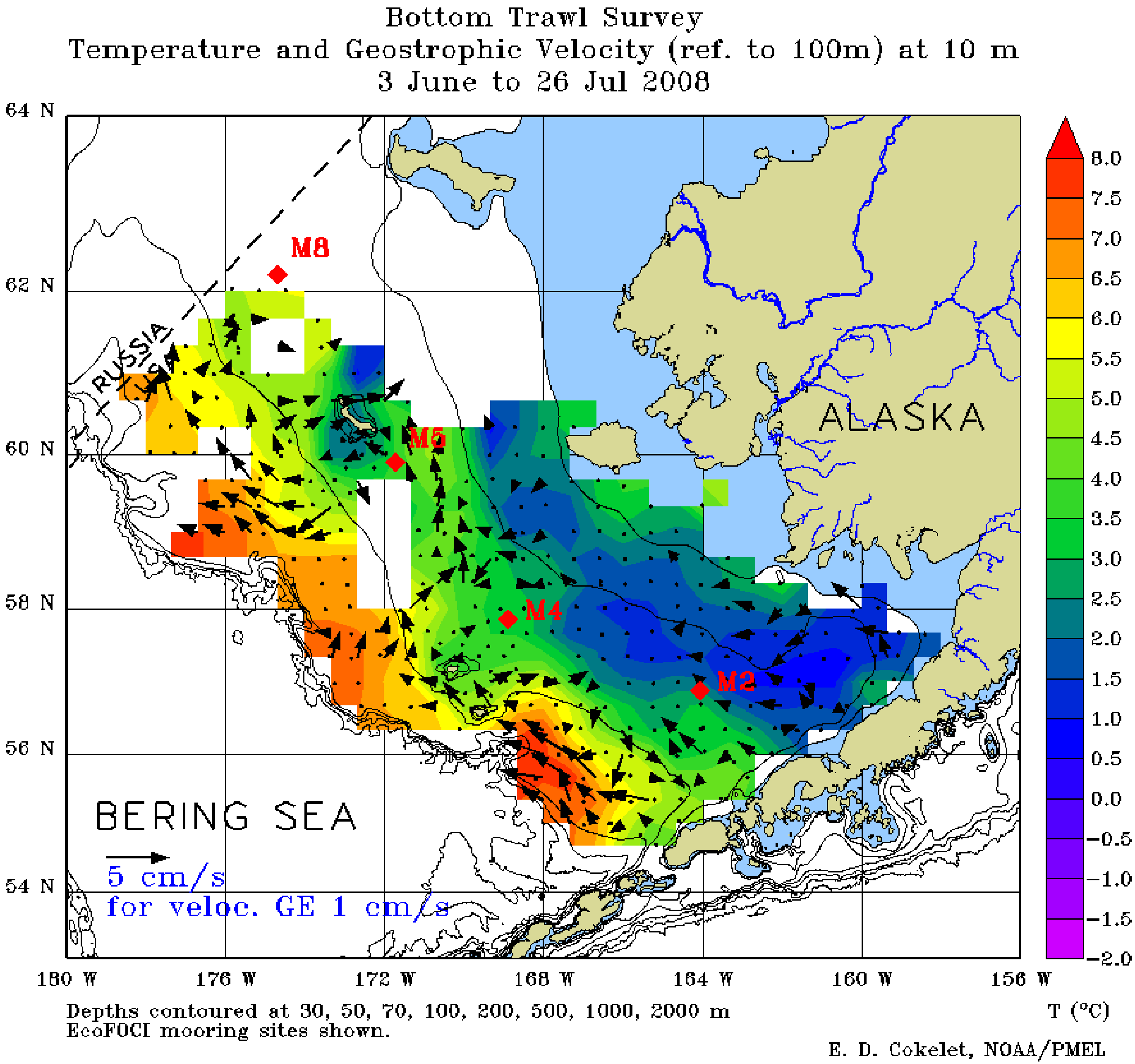
Effects of climate on community structure

Key indicators and ecosystem trends


Beaufort Sea
Chukchi Sea
Brooks Range
Koryakskoye Nagor'ye
Kuskokwim Mountains
Alaska Range
RUSSIA
USA
Bering Sea
St. Lawrence Island
Norton Sound
St. Paul Island
St. George Island
Bristol Bay

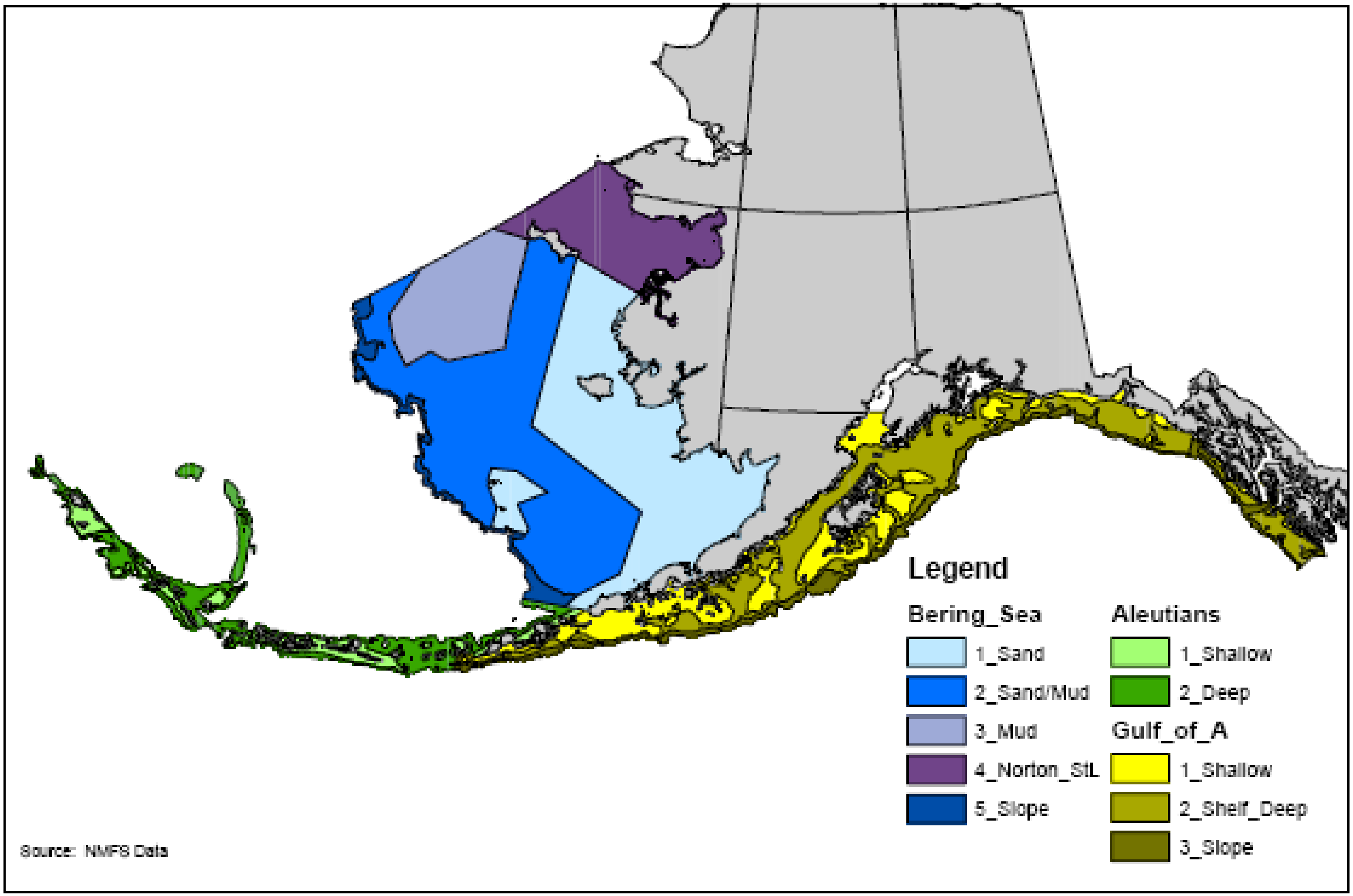
Circulation





Bottom Trawl Survey
Temperature and Geostrophic Velocity (ref. to 100m) at 10 m
3 June to 26 Jul 2008
64 N
62 N
60 N
58 N
56 N
54 N
180 W
176 W
172 W
168 W
164 W
160 W
156 W
M8
M5
M4
M2
RUSSIA
USA
ALASKA
BERING SEA
5 cm/s
for veloc. GE 1 cm/s
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
−0.5
−1.0
−1.5
−2.0
T (°C)
Depths contoured at 30, 50, 70, 100, 200, 500, 1000, 2000 m
EcoFOCI mooring sites shown.
E. D. Cokelet, NOAA/PMEL

Seafloor sediments



Bering Sea Biota

Moderately high productivity (150-300g Carbon/m^3)

450 species of fish and over 500 species of invertebrates

50 species of seabirds

25 species of marine mammals

Largest single-species fishery in the U.S. (pollock)

Largest flatfish fishery in the U.S.

Bering Sea climate indices

North Pacific Index/Aleutian low (1900-2011)

Arctic Oscillation

El Nino/Southern Oscillation

East Pacific Index

Pacific Decadal Oscillation

Pribilof Island May SST (1948-2011)

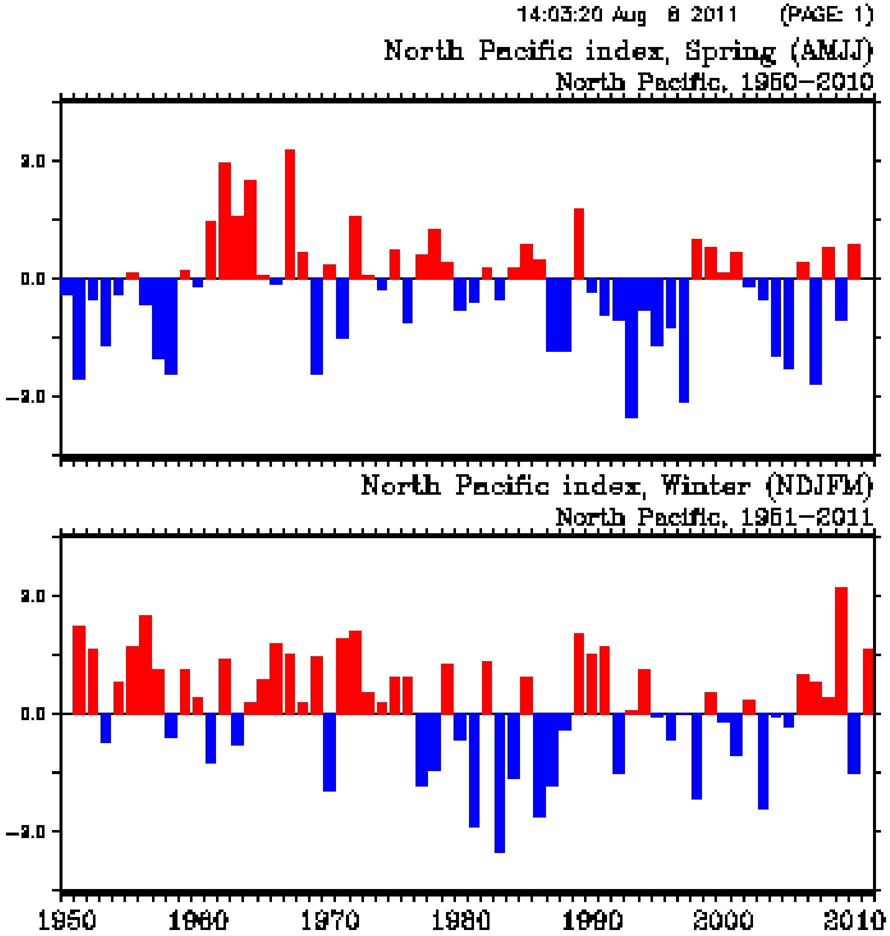
Pribilof Island winter SST (1950-2011)

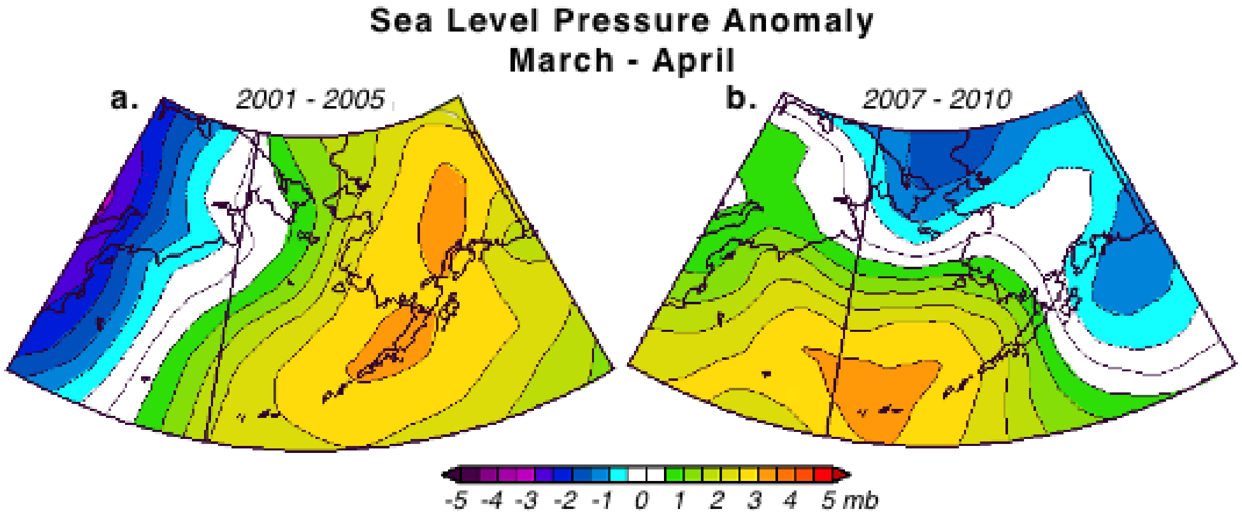
Ice cover/retreat

Summer bottom temperature trawl survey

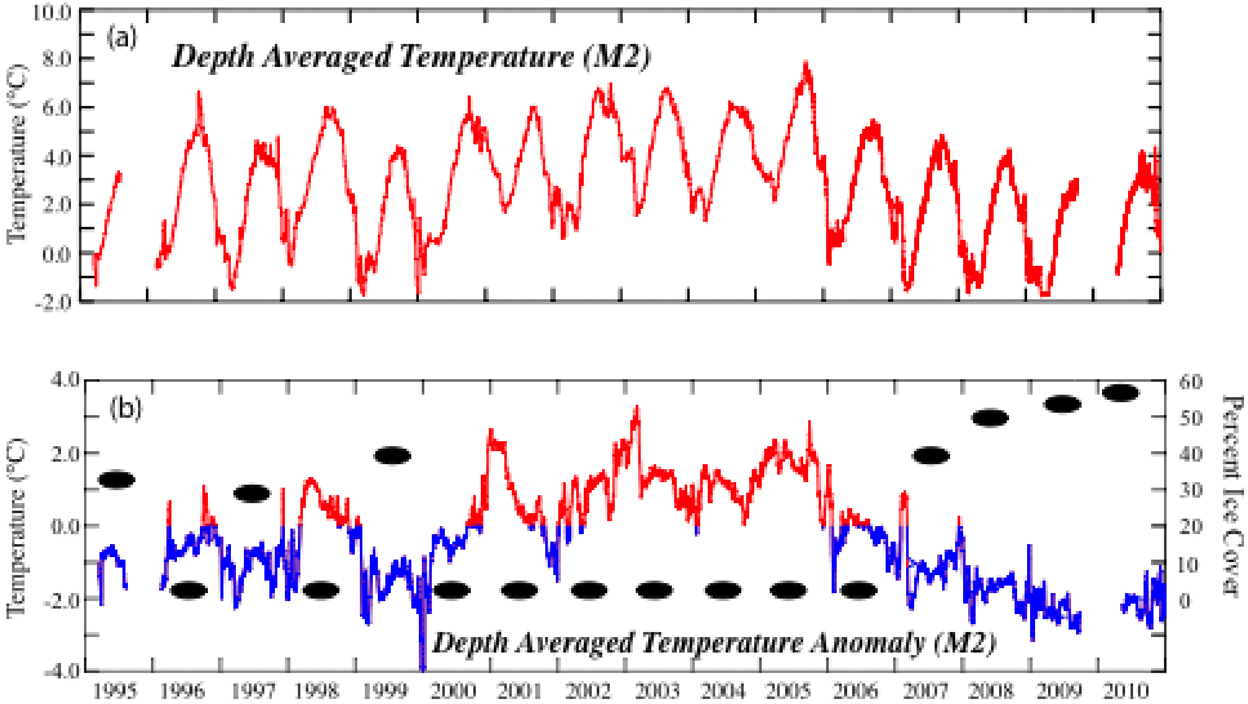
Pacific North American Index (1949-2011)

North Pacific Index

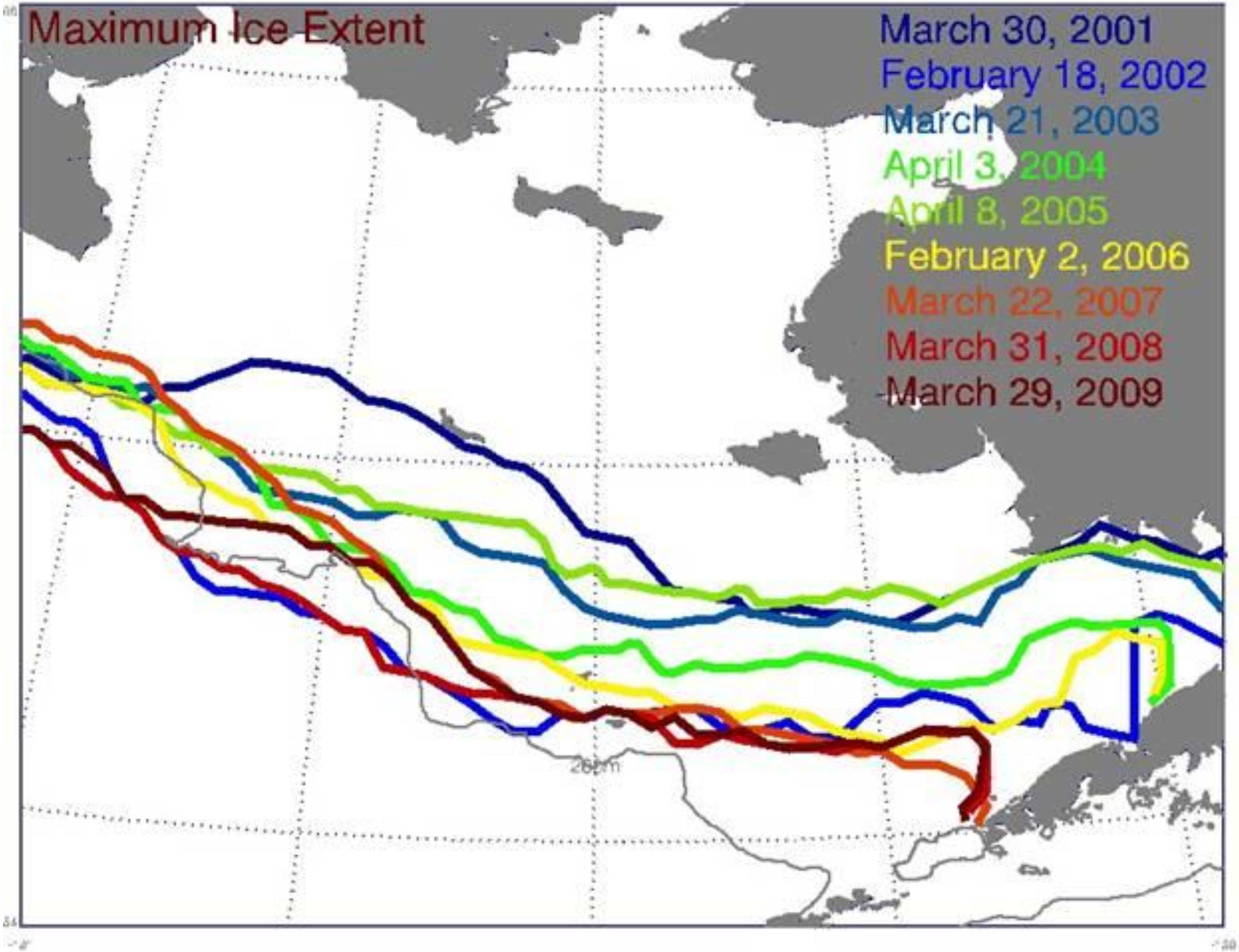




Sea Level Pressure Anomaly
March - April
a.
2001 - 2005
b.
2007 - 2010
-5 -4 -3 -2 -1 0 1 2 3 4 5 mb

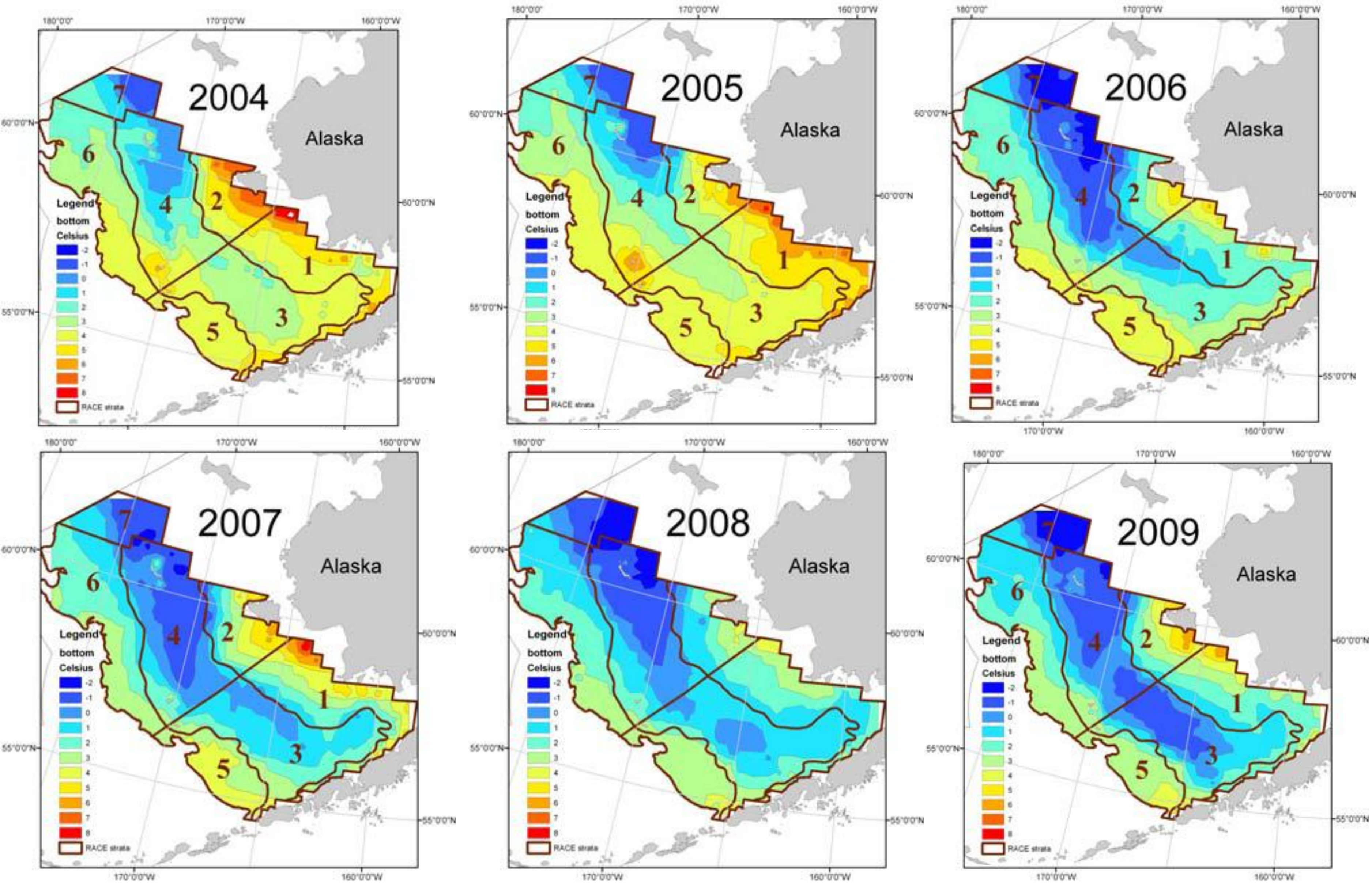


(a)
Depth Averaged Temperature (M2)
Temperature (°C)
10.0
8.0
6.0
4.0
2.0
0.0
-2.0
(b)
Depth Averaged Temperature Anomaly (M2)
Temperature (°C)
4.0
2.0
0.0
-2.0
-4.0
Percent Ice Cover
60
50
40
30
20
10
0
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010

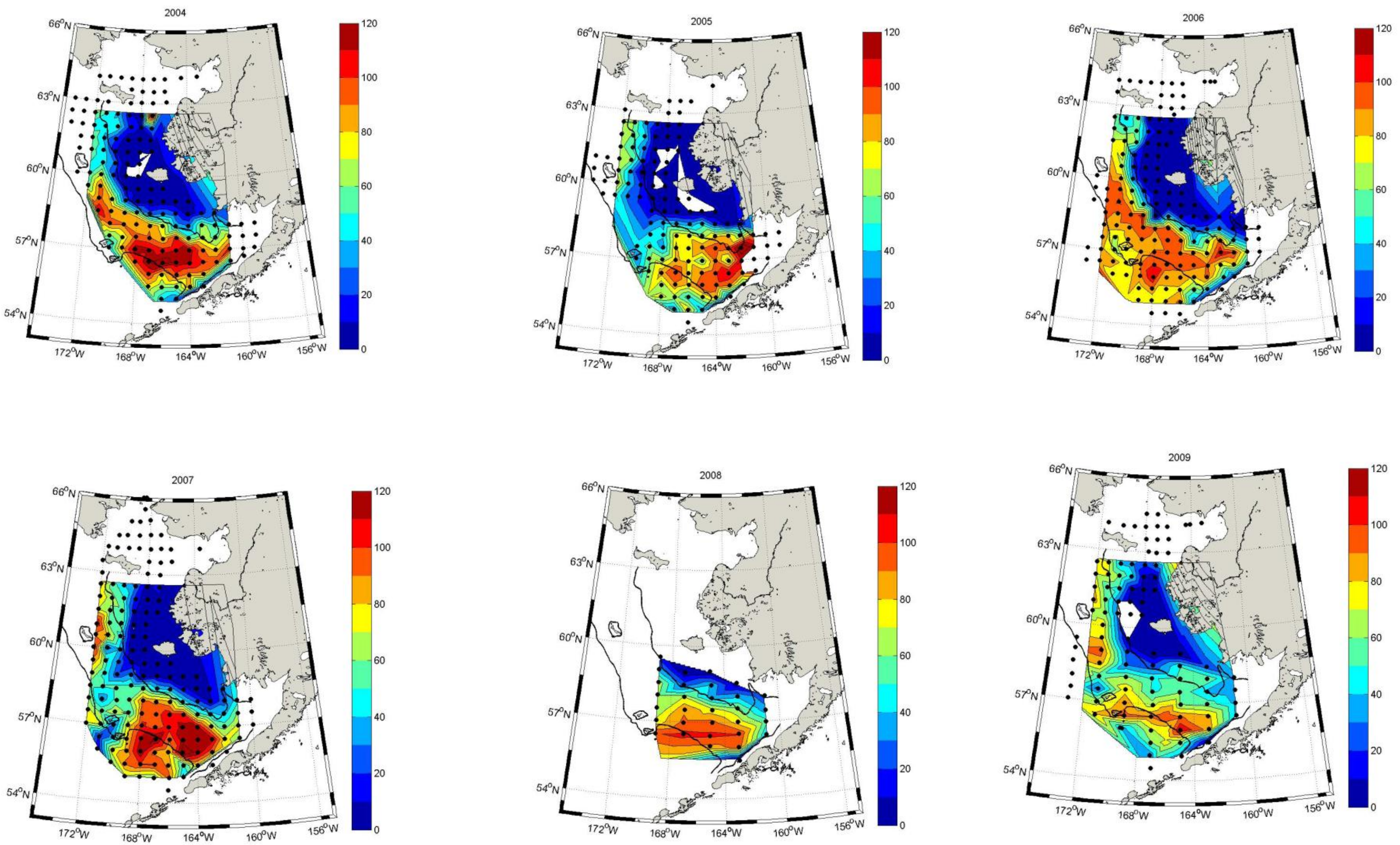


Maximum Ice Extent
March 30, 2001
February 18, 2002
March 21, 2003
April 3, 2004
April 8, 2005
February 2, 2006
March 22, 2007
March 31, 2008
March 29, 2009

EBS bottom temperature



Water column stratification



Effect of climate differences from 2001-2005 and 2006-2010 on the biota

Zooplankton

Forage fish

Adult pollock

Arrowtooth flounder

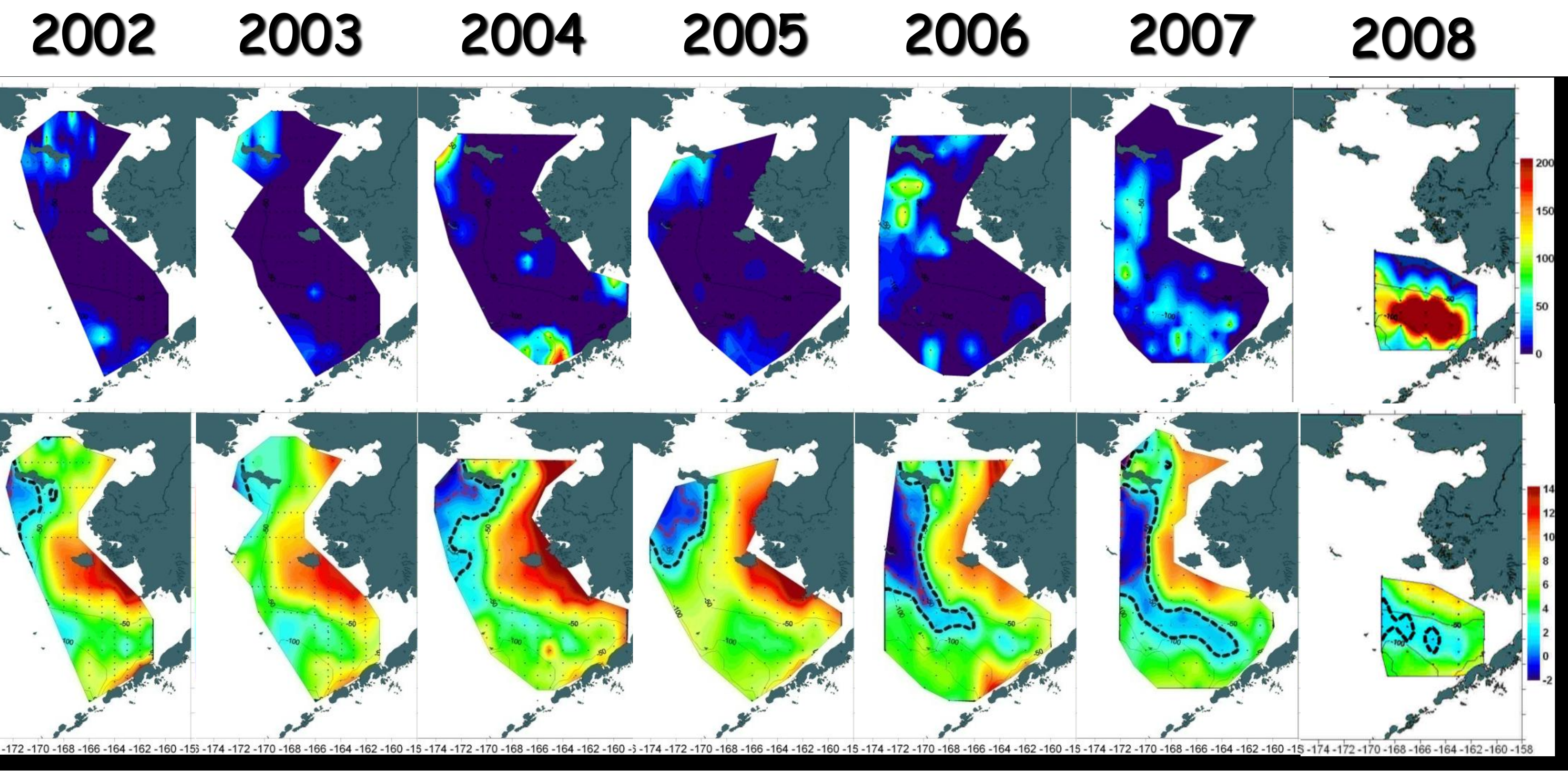
Flatfish recruitment

Snow crab

Biodiversity

Fish Growth (weight-at-age)

Calanus Marshallae (large copepod) abundance (# per m^3), Bongo Tow, 505 μm mesh net



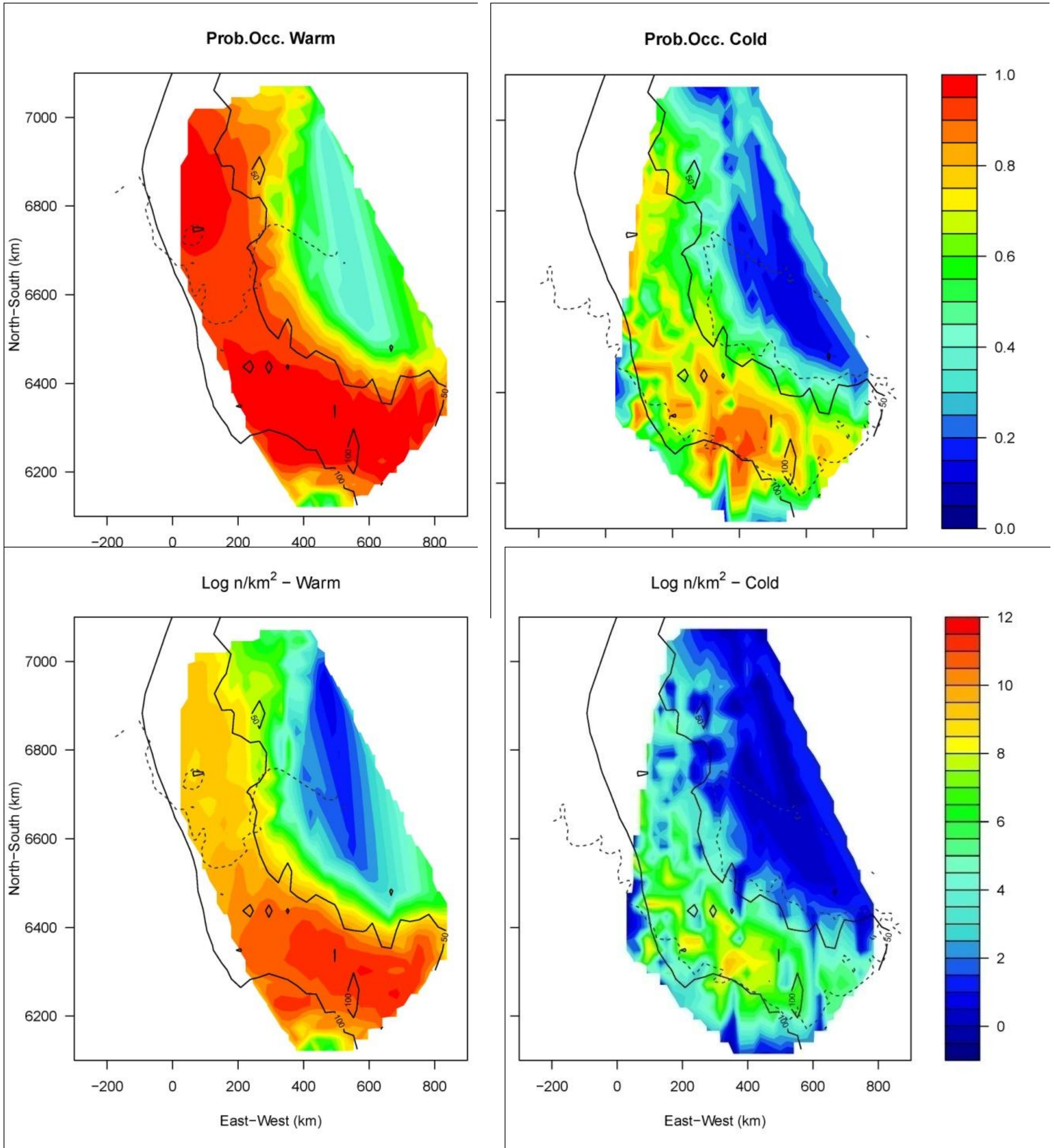
Bottom panel: Mean Temperature Below MLD

Cold pool (< 2°C) indicated by dashed black line.

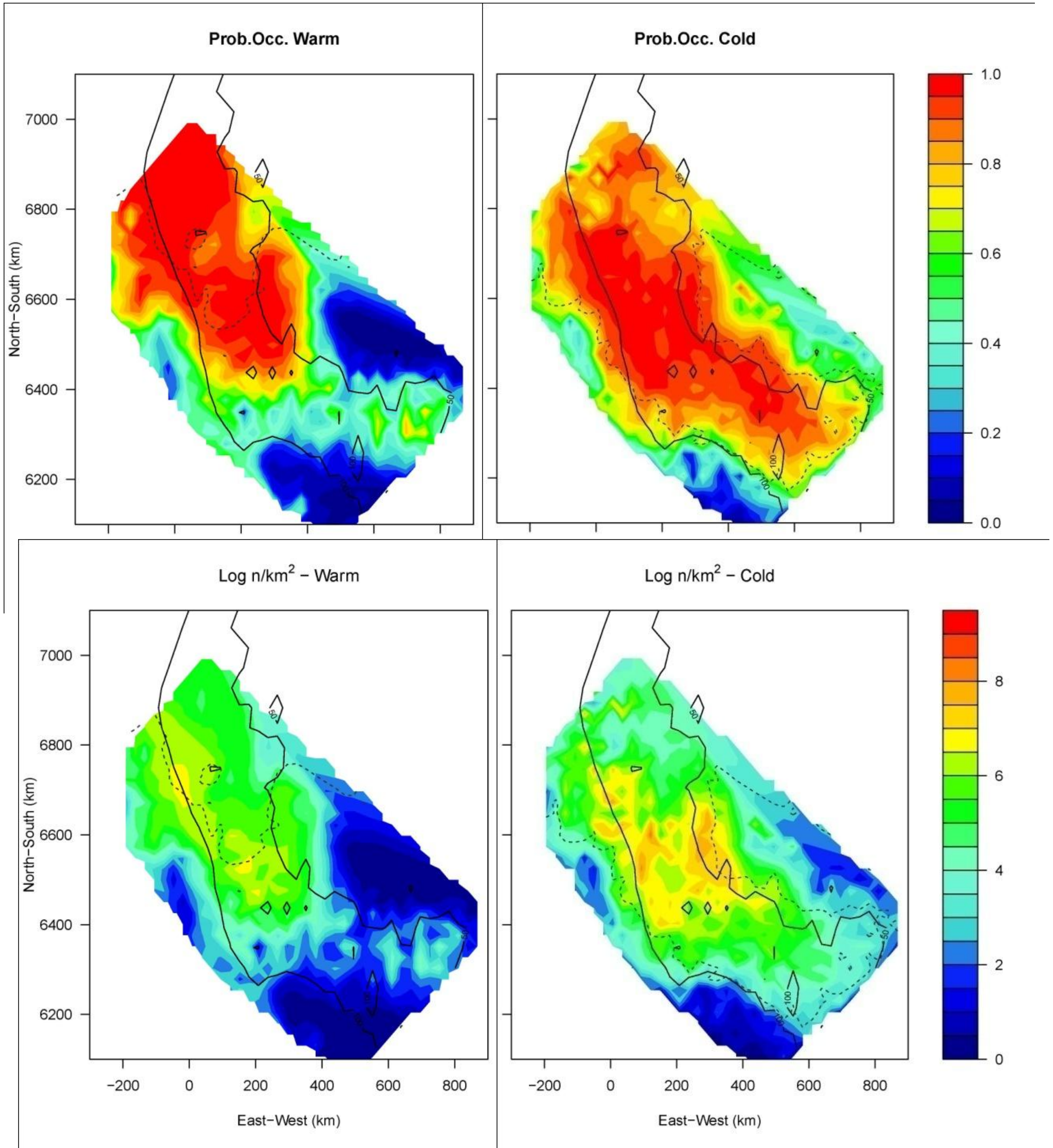
0°C indicted by dashed red line.

EISNER 2010

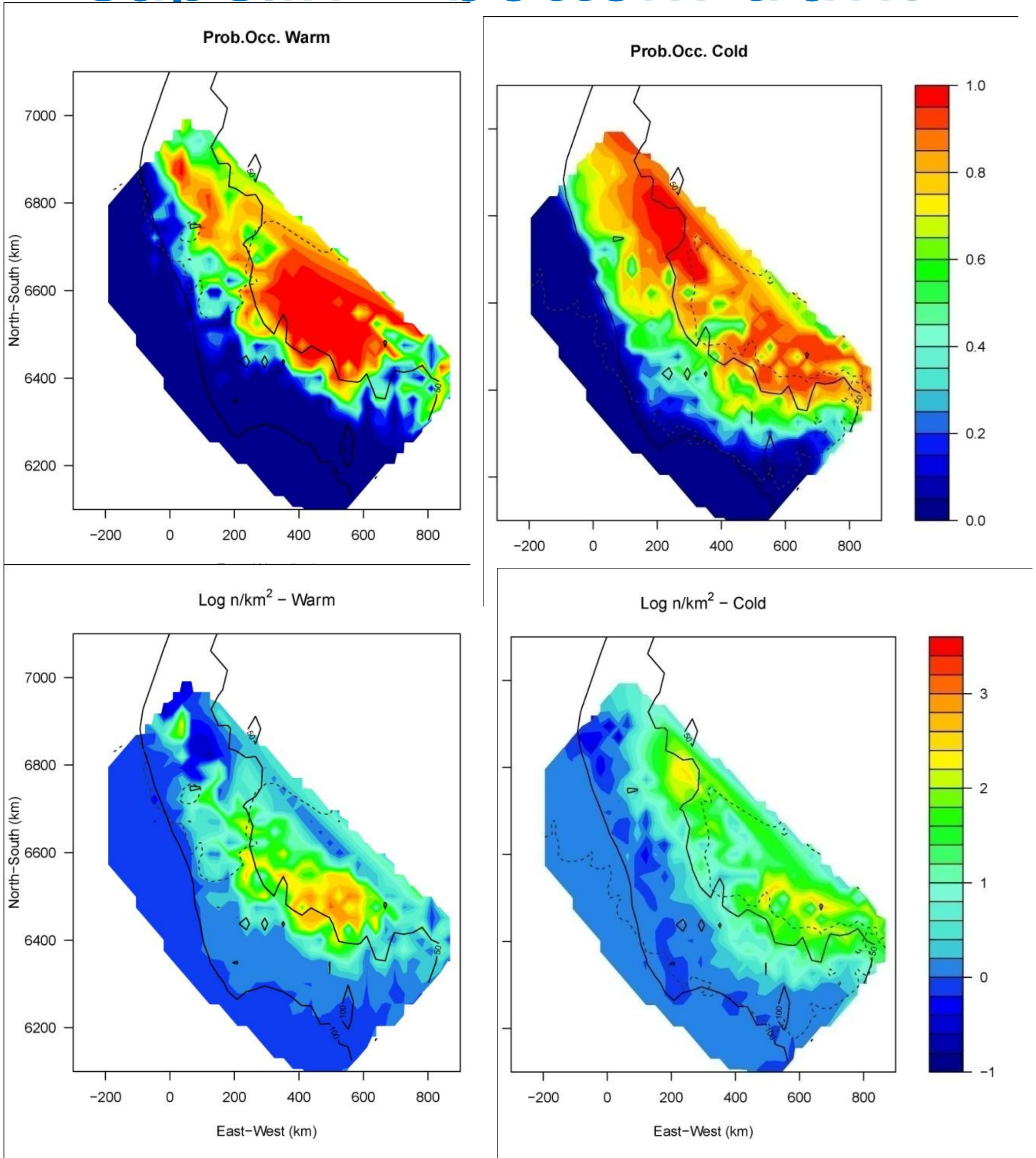
Age-0 pollock



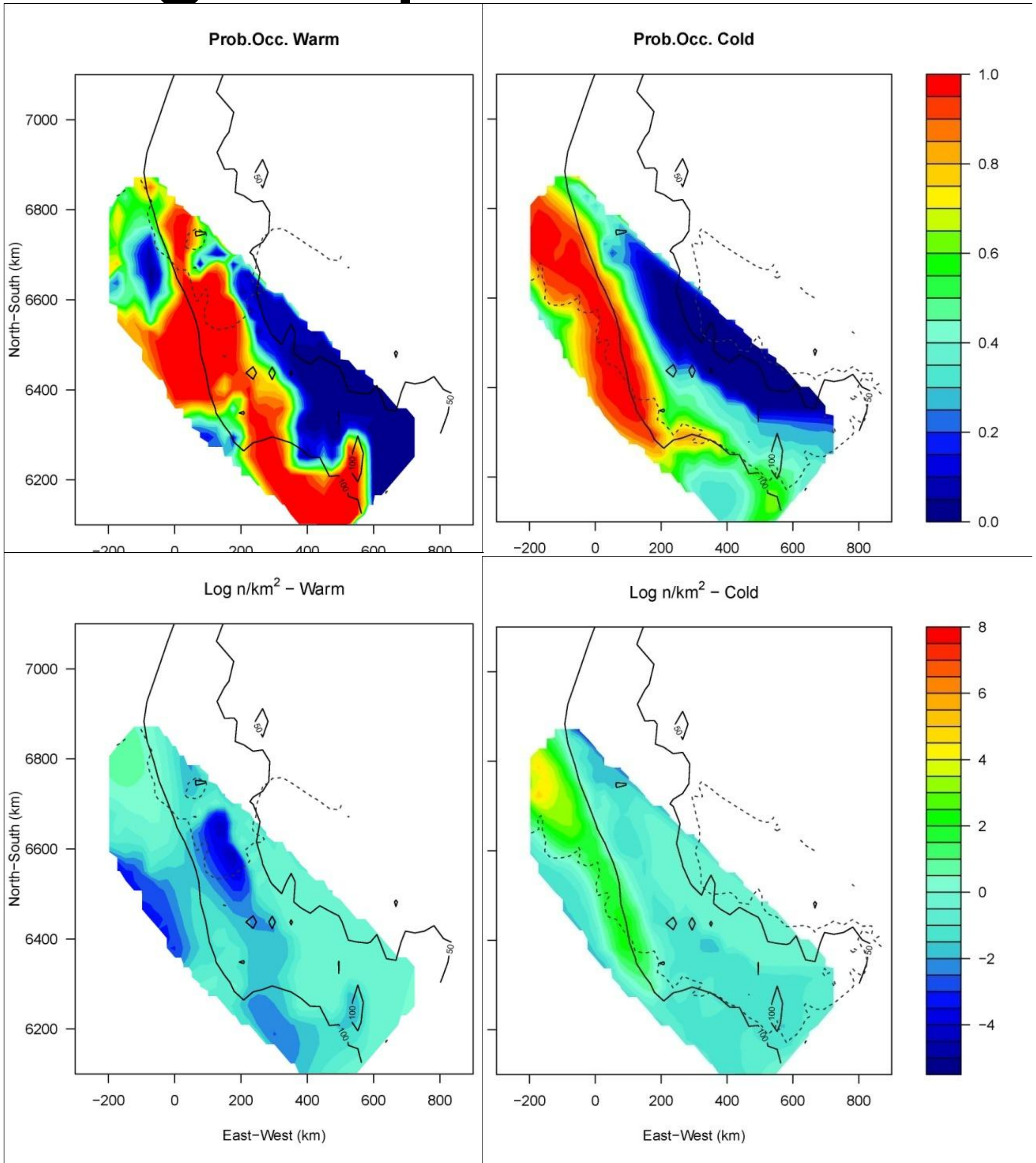
Age-1 pollock – Bottom trawl



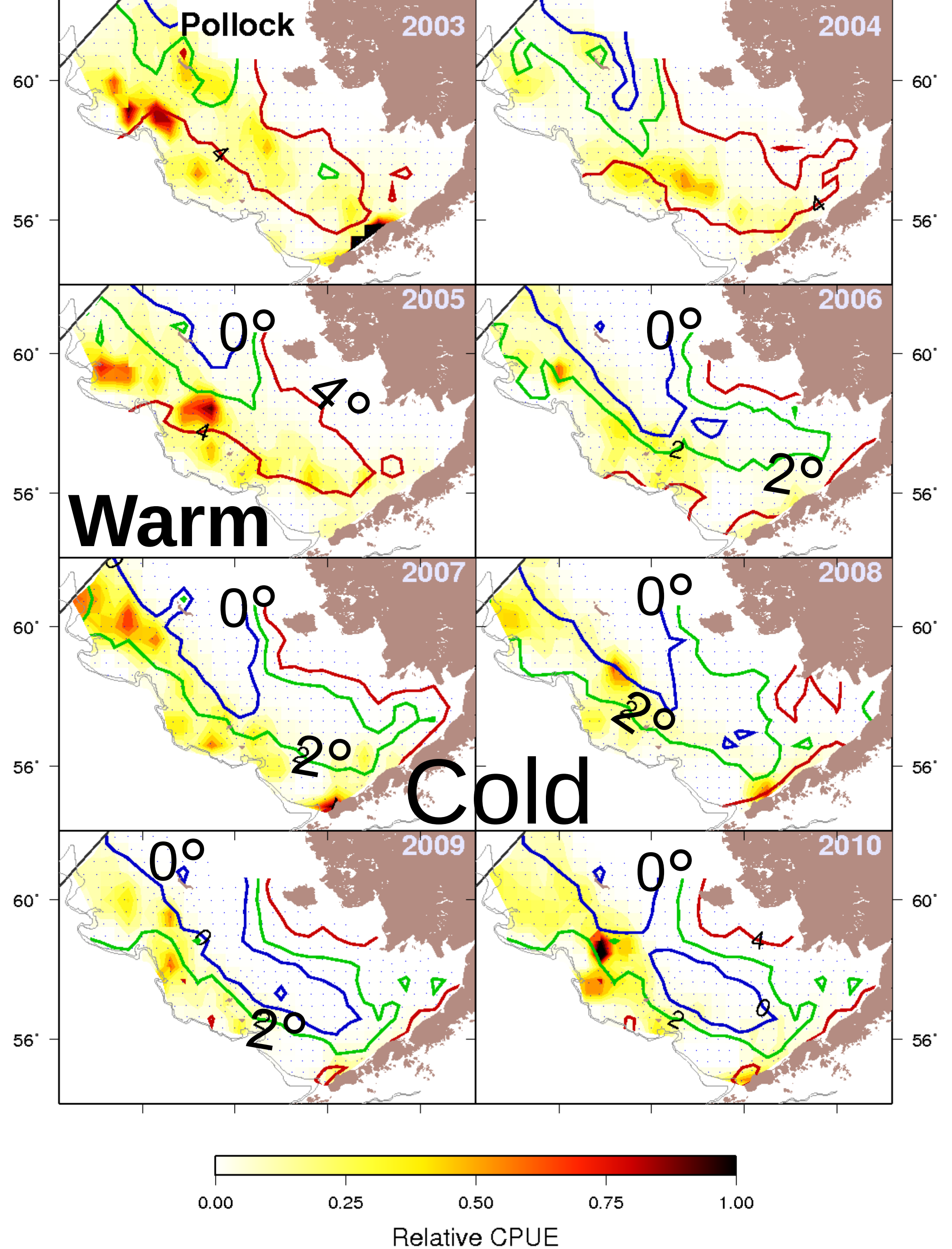
Capelin – bottom trawl



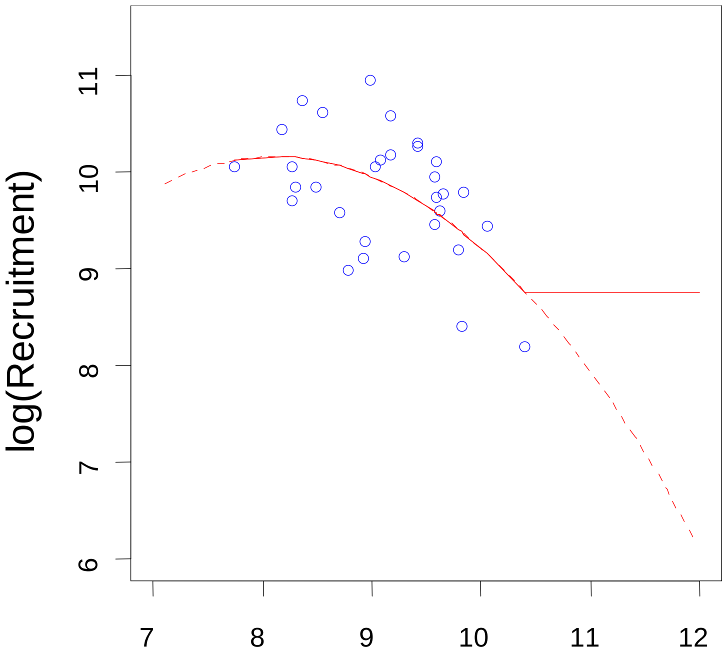
Age-1 pollock acoustic



Adult pollock survey densities and temperature



Pollock recruitment (Mueter et al. 2011)



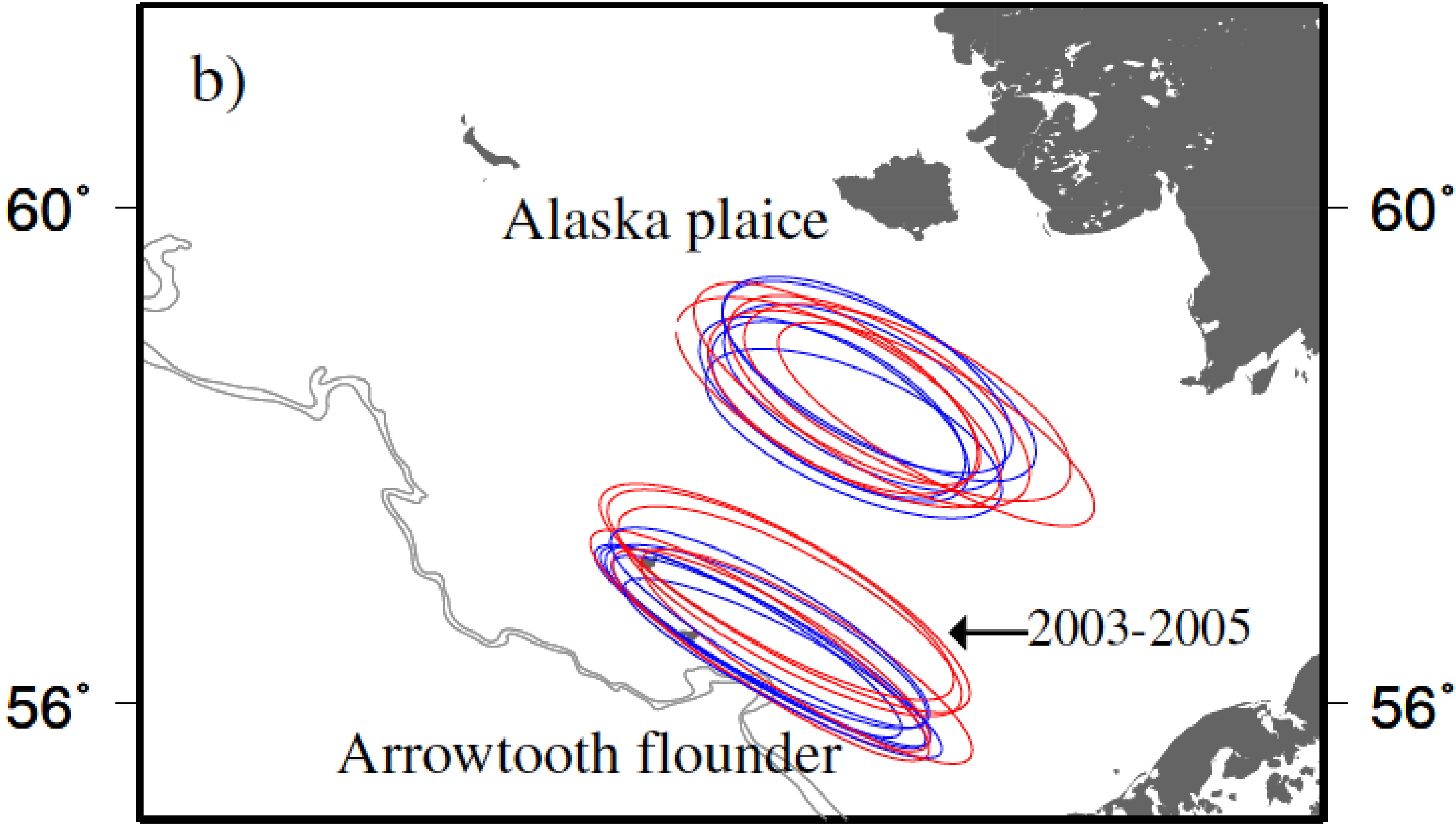
Summer SST

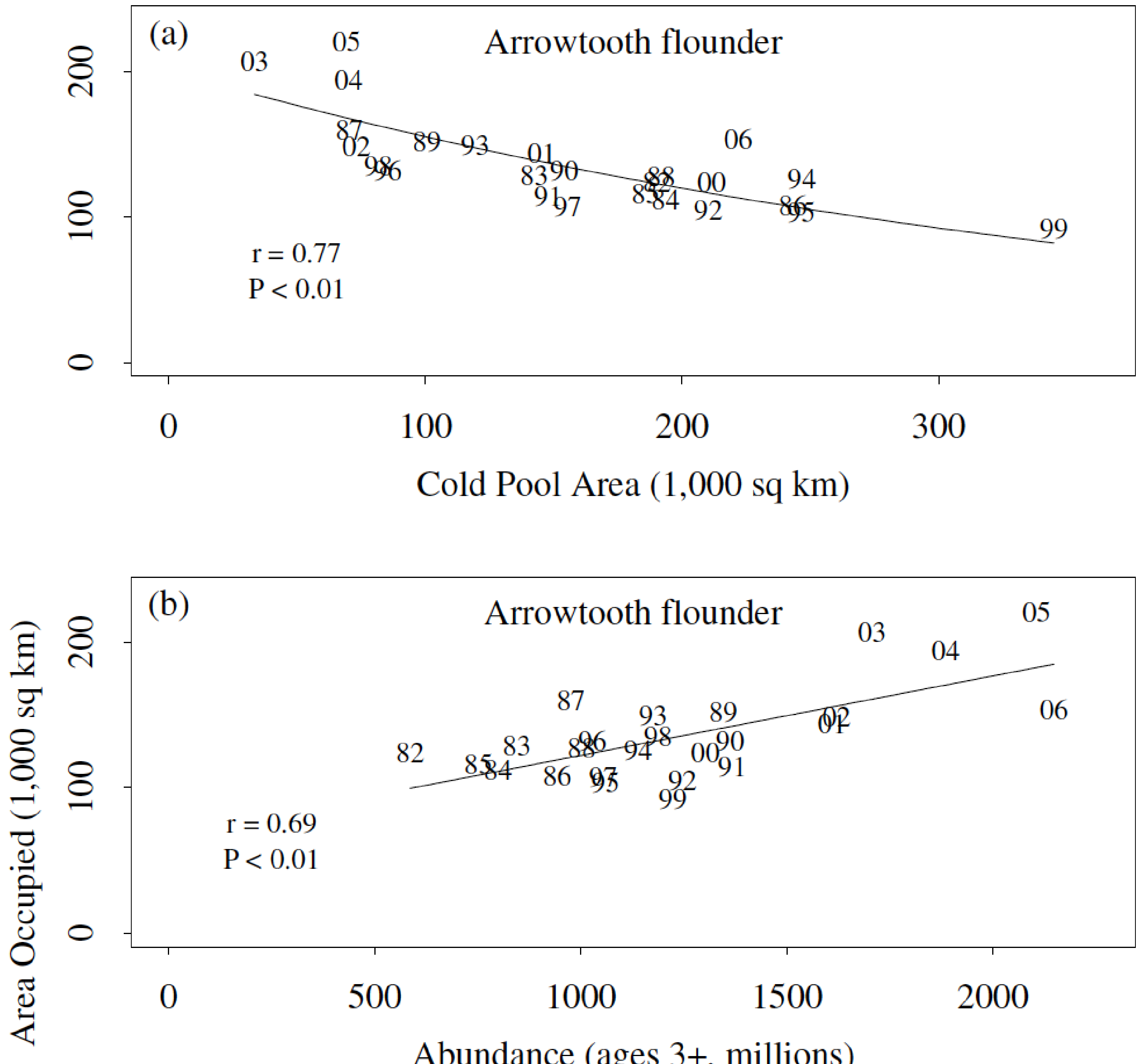
Is an indicator of

Prey quality &

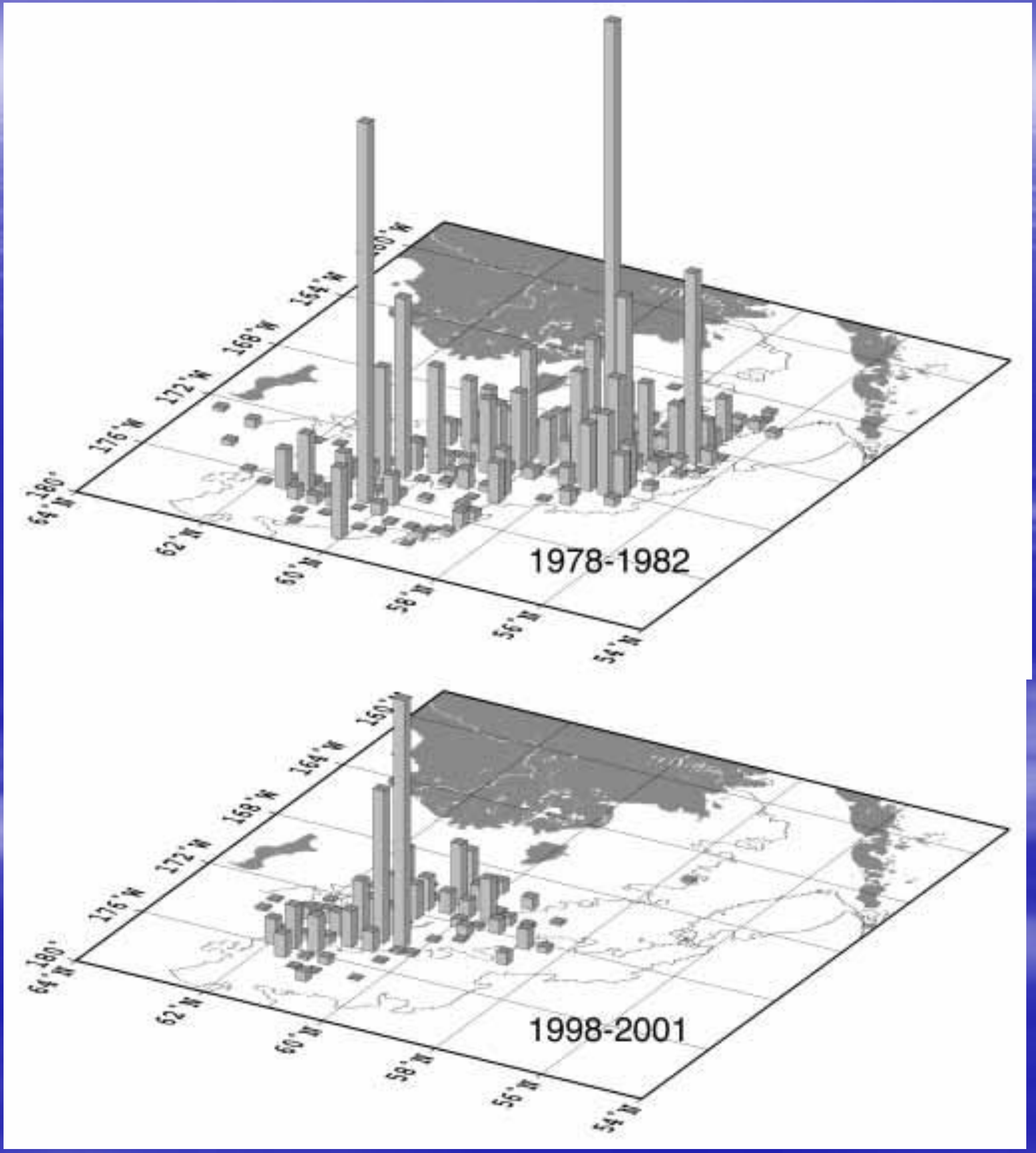
Predator exposure

Spencer (2008)




(a)
Arrowtooth flounder
r = 0.77
P < 0.01
Cold Pool Area (1,000 sq km)
(b)
Arrowtooth flounder
r = 0.69
P < 0.01
Area Occupied (1,000 sq km)
Abundance (ages 3+, millions)

Snow Crab Population Has Diminished and Contracted North



Orensanz, J. L., B. Ernst, D. Armstrong, P. Stabeno, and P. Livingston. 2004. Contraction of the geographic range of distribution of snow crab (*Chionoecetes opilio*) in the eastern Bering Sea: An environmental ratchet? CalCOFI Rep. 45: 65-79.

Significant Northward Displacement within the southeastern Bering Sea

Greenland halibut 98 km

Snow crab 89 km

Bering flounder 76 km

Arrowtooth flounder 46 km

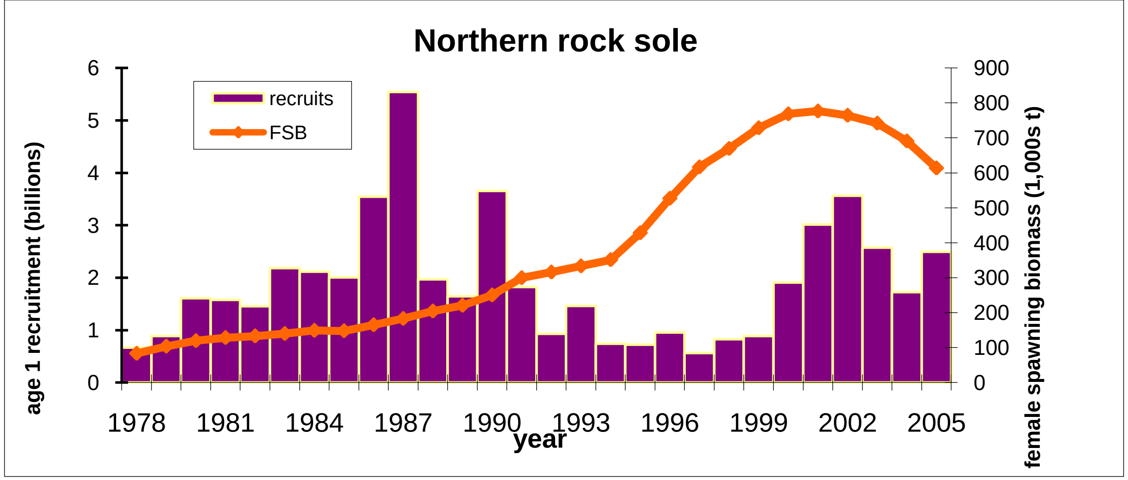
Eulachon 34 km

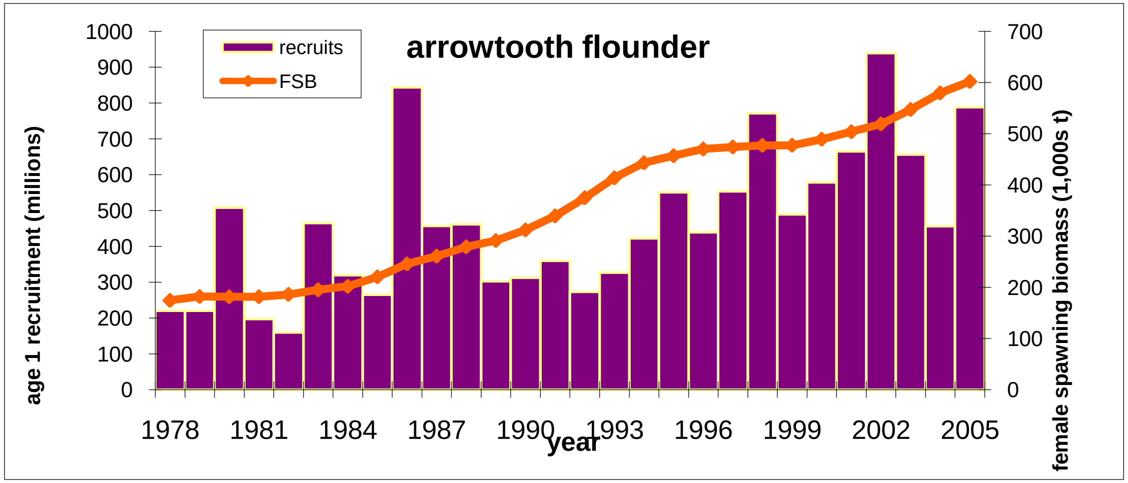
Flathead sole 57 km

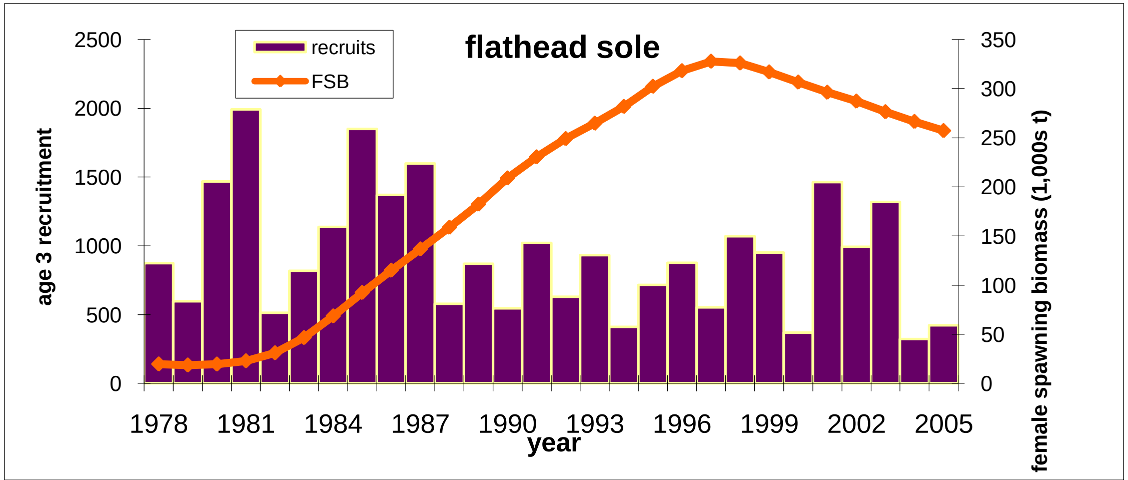
Pacific halibut 55 km

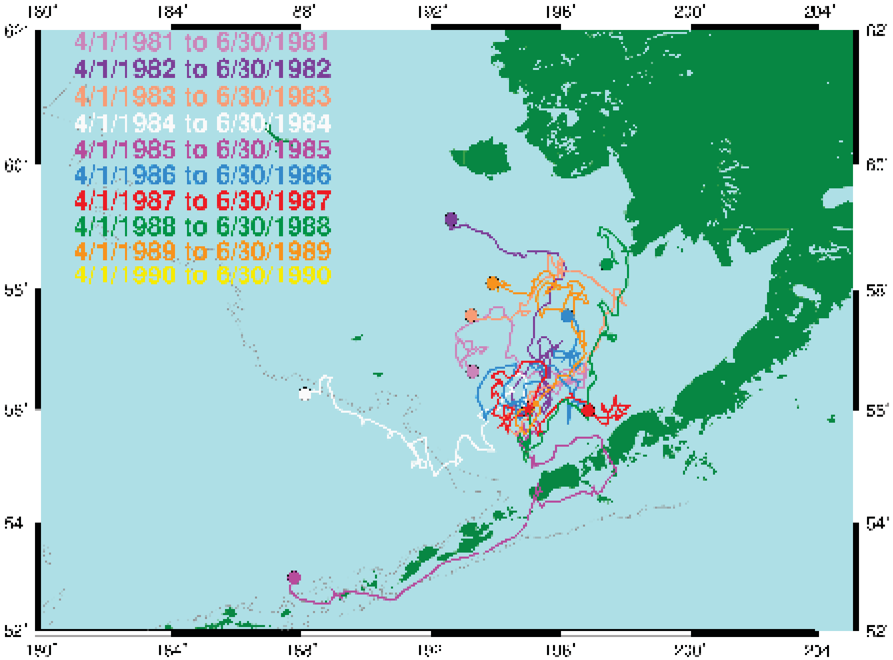
Plus 8 other species

Mueter, F.J. and M.A. Litzow. 2008. Sea ice retreat alters the biogeography of the Bering Sea continental shelf. Ecol. Appl. 18: 309-320. Significant defined as $p < 0.05$. 1982-2006 Bering Sea bottom trawl surveys.
Also see: Spencer, P.D. 2008. Density-independent and density-dependent factors affecting temporal changes in spatial distributions of eastern Bering Sea flatfish. Fish. Oceanogr.17: 396-410.

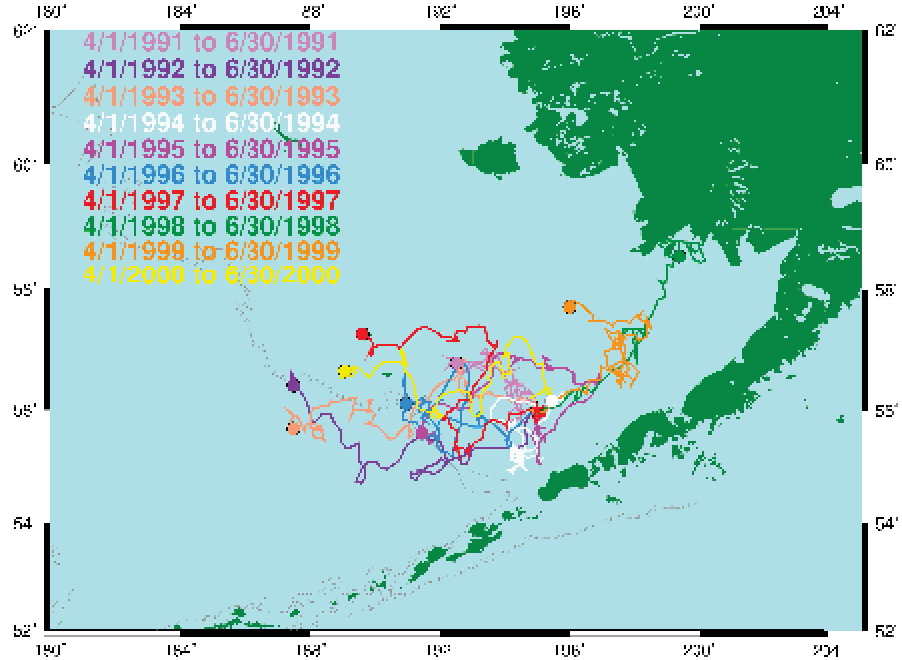

Northern rock sole
recruits
FSB
age 1 recruitment (billions)
female spawning biomass (1,000s t)
year
0
1
2
3
4
5
6
0
100
200
300
400
500
600
700
800
900
1978
1981
1984
1987
1990
1993
1996
1999
2002
2005


arrowtooth flounder
recruits
FSB
age 1 recruitment (millions)
female spawning biomass (1,000s t)
year
0
100
200
300
400
500
600
700
800
900
1000
0
100
200
300
400
500
600
700
1978
1981
1984
1987
1990
1993
1996
1999
2002
2005

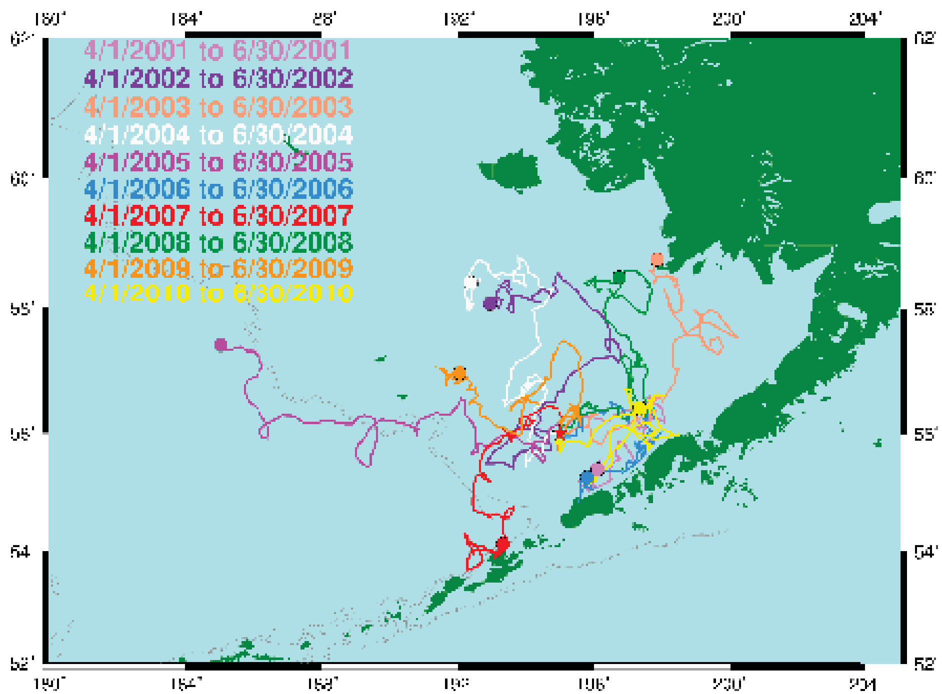

flathead sole
recruits
FSB
age 3 recruitment
female spawning biomass (1,000s t)
year
0
500
1000
1500
2000
2500
0
50
100
150
200
250
300
350
1978
1981
1984
1987
1990
1993
1996
1999
2002
2005



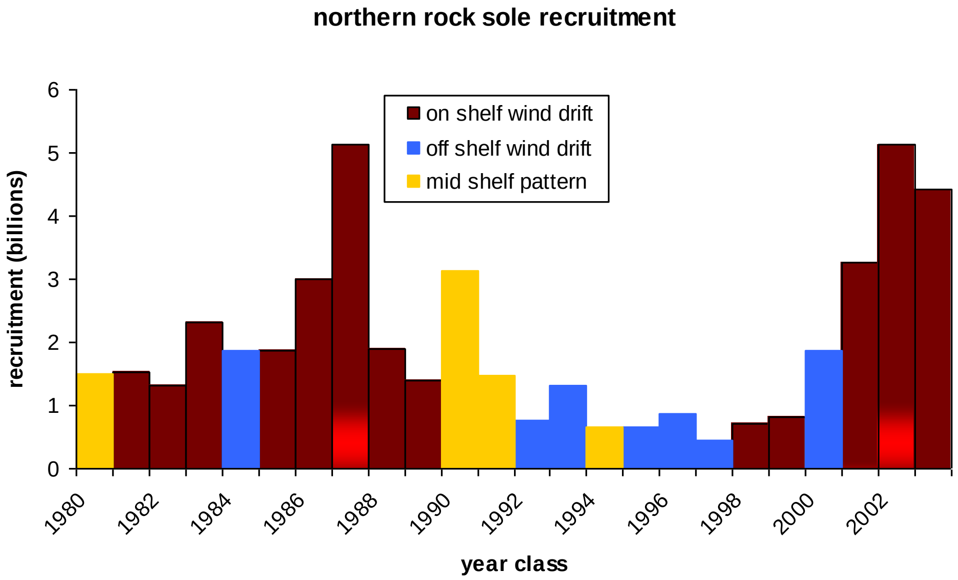
4/1/1981 to 6/30/1981
4/1/1982 to 6/30/1982
4/1/1983 to 6/30/1983
4/1/1984 to 6/30/1984
4/1/1985 to 6/30/1985
4/1/1986 to 6/30/1986
4/1/1987 to 6/30/1987
4/1/1988 to 6/30/1988
4/1/1989 to 6/30/1989
4/1/1990 to 6/30/1990



4/1/1991 to 6/30/1991
4/1/1992 to 6/30/1992
4/1/1993 to 6/30/1993
4/1/1994 to 6/30/1994
4/1/1995 to 6/30/1995
4/1/1996 to 6/30/1996
4/1/1997 to 6/30/1997
4/1/1998 to 6/30/1998
4/1/1999 to 6/30/1999
4/1/2000 to 6/30/2000

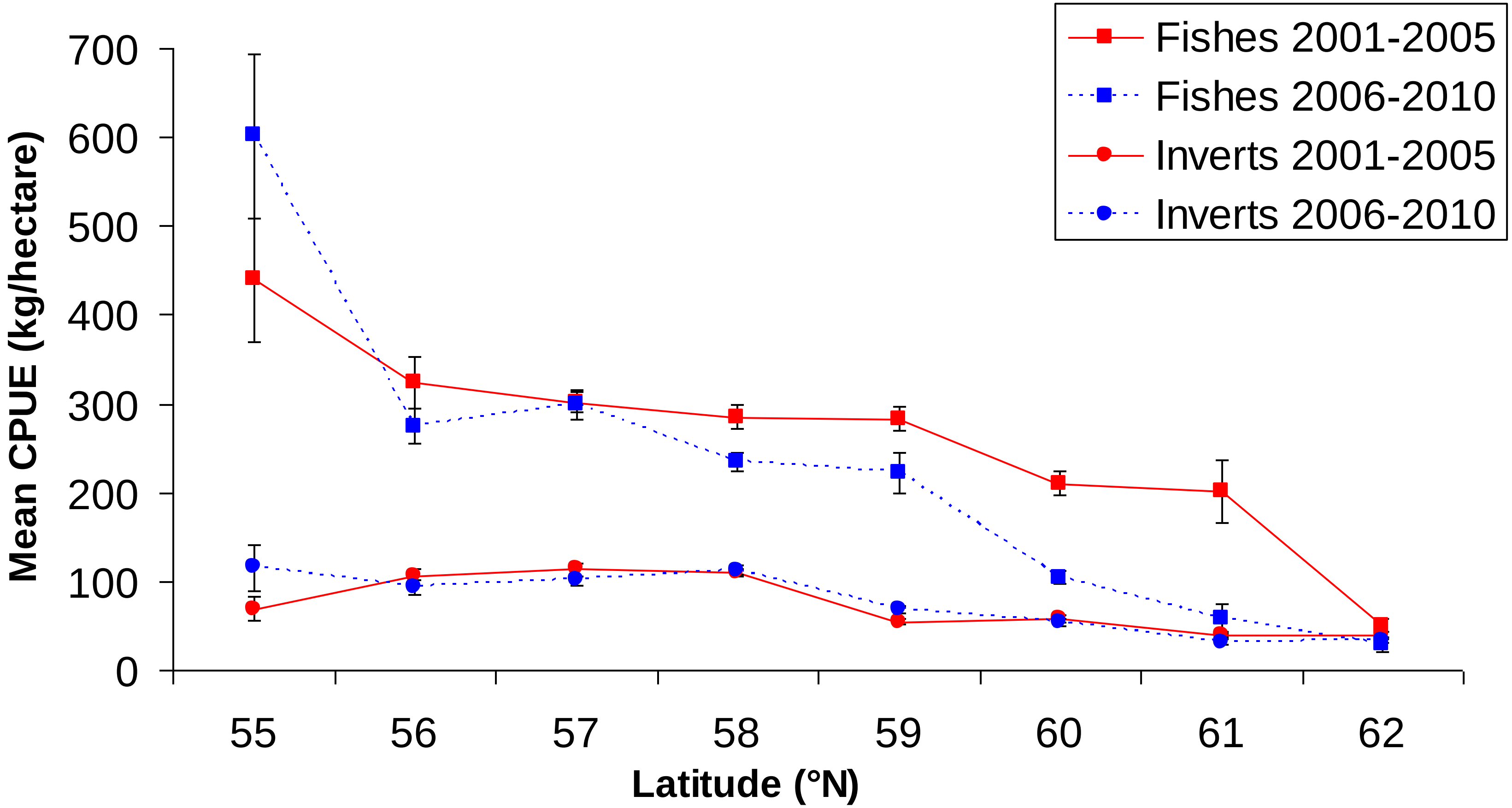


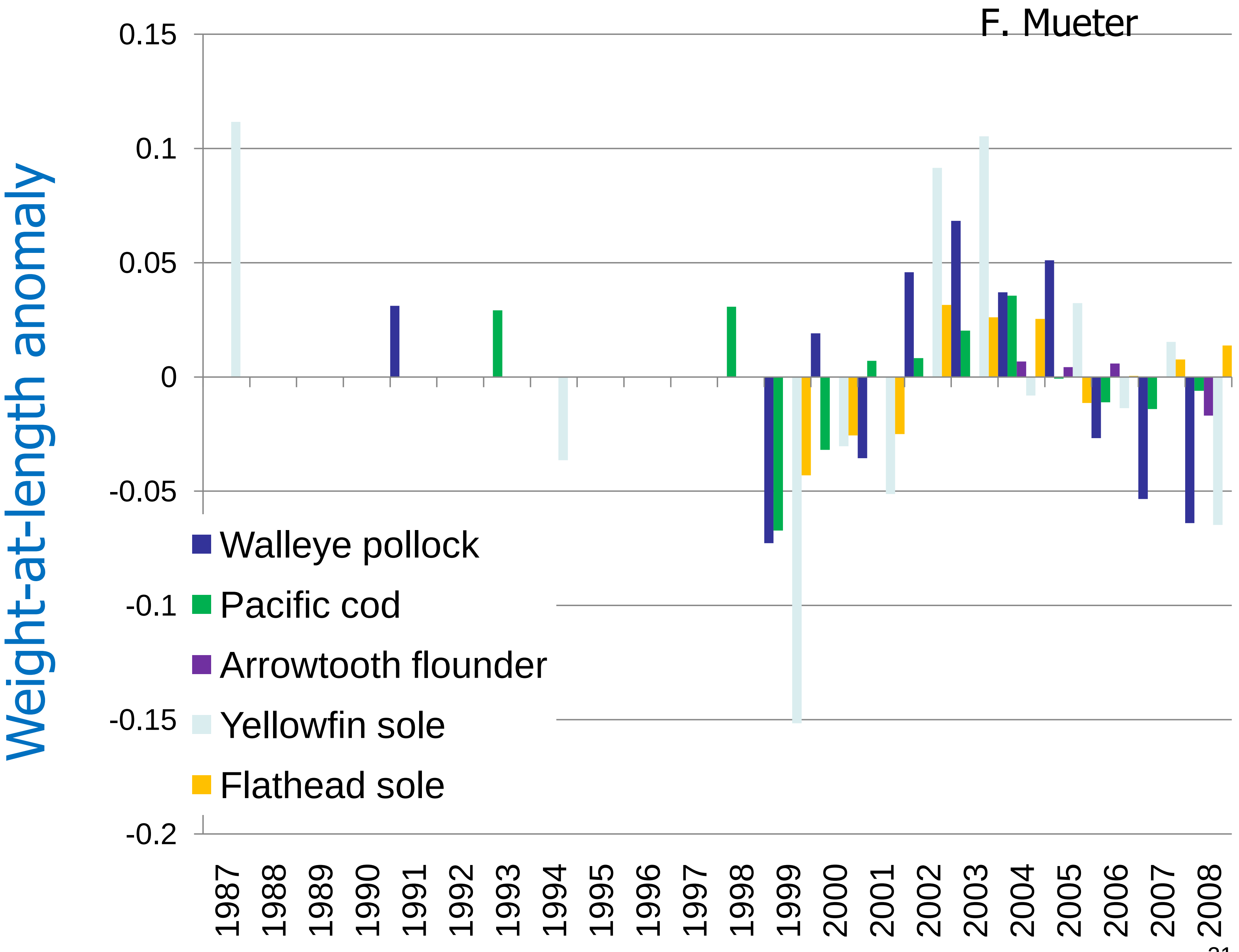
4/1/2001 to 6/30/2001
4/1/2002 to 6/30/2002
4/1/2003 to 6/30/2003
4/1/2004 to 6/30/2004
4/1/2005 to 6/30/2005
4/1/2006 to 6/30/2006
4/1/2007 to 6/30/2007
4/1/2008 to 6/30/2008
4/1/2009 to 6/30/2009
4/1/2010 to 6/30/2010



northern rock sole recruitment
on shelf wind drift
off shelf wind drift
mid shelf pattern
recruitment (billions)
0
1
2
3
4
5
6
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
year class

Trawl survey CPUE analysis for fish and invertebrate communities (D. Stevenson, AFSC)





F. Mueter
Weight-at-length anomaly
0.15
0.1
0.05
0
-0.05
-0.1
-0.15
-0.2
Walleye pollock
Pacific cod
Arrowtooth flounder
Yellowfin sole
Flathead sole
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008

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Summary - EBS

- Southern part of the Bering Sea shelf has more climate variability than the northern shelf. Winter ice extent determines summer cold pool.
- Hydrography and bathymetry contribute to spatial segregation of Age-1 pollock and capelin.
  - In the Bering Sea, the frontal boundary at 50m bottom depth partitioned age-1 pollock and capelin in most years.
- Age-0 and Age-1 pollock were both broadly distributed throughout the middle domain although they were partitioned vertically.
  - Age-0 were found in the upper mixed layer with higher concentrations in the south in cold years.
  - Age-1 pollock located along the bottom and were concentrated in the north in warm years.

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Summary Cont.

- Midwater Age – 1 pollock located in transition regions along frontal boundaries.
- Middle domain a region of high Calanus marshallae.
- Fronts – zones of production and aggregation of prey.
- Cold pool provides refuge for age-1 pollock from predation.
- Northward shift in spatial distribution for some flatfish and snow crab and other fish
- Warm years enhance growth in some major species

Ecosystem Assessments at the Alaska Fisheries Science Center

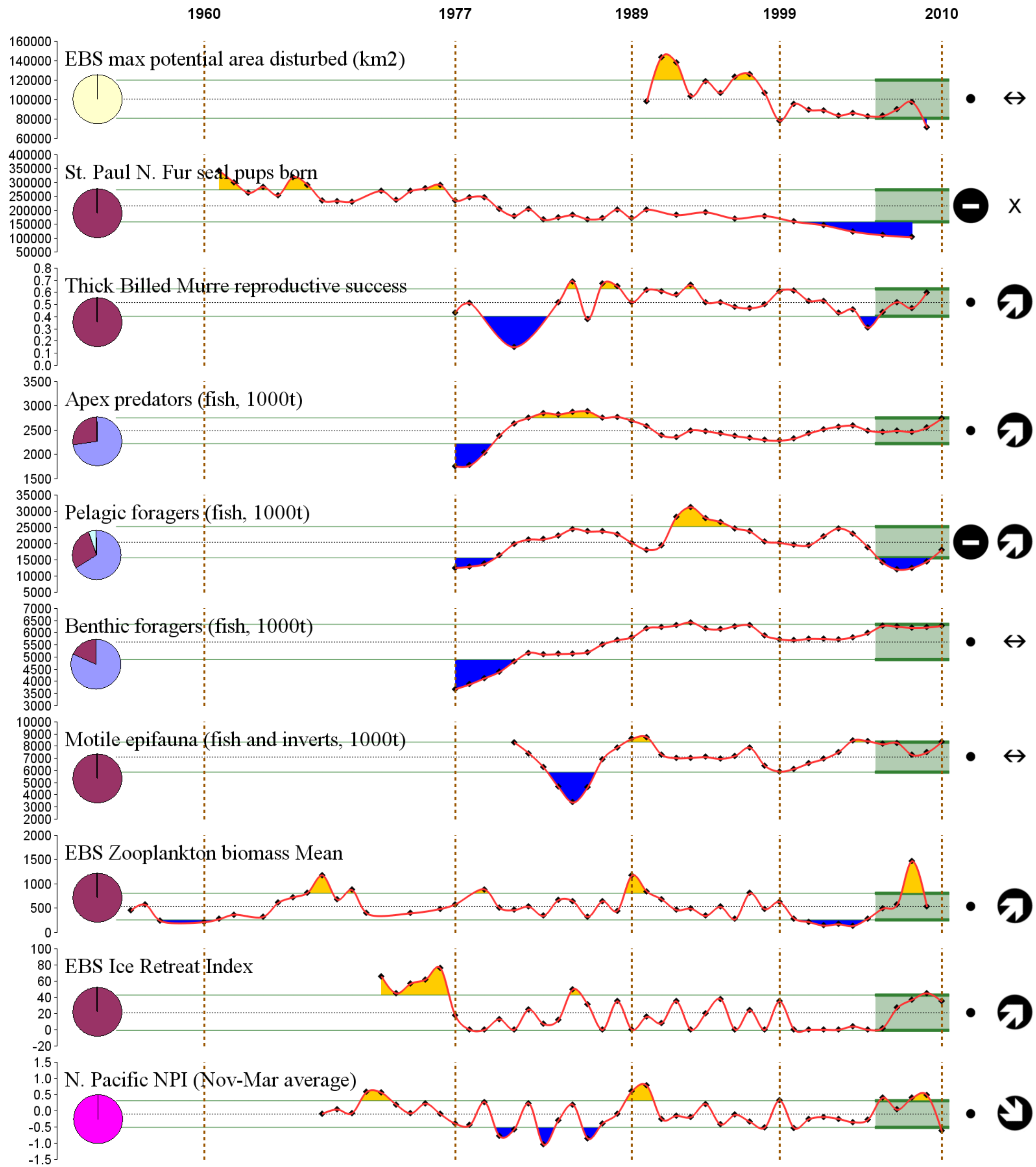
- Goal: to provide current and relevant scientific advice for fisheries managers
- Part of the annual Stock Assessment and Fishery Evaluation report
- In 2010, initiated a regional approach and presented an entirely new assessment for the eastern Bering Sea

http://access.afsc.noaa.gov/reem/ecoweb/index.cfm

Methods



- Assembled a team of Eastern Bering Sea experts
- Met in September and October 2010
- Developed list of hot topics and 10 indicators
- Focused on broad, community-level indicators of ecosystem-wide productivity, and those most informative for managers
- Stock-specific indicators discussed in workshop early April 2011


1960
1977
1989
1999
2010
EBS max potential area disturbed (km2)
160000
140000
120000
100000
80000
60000
St. Paul N. Fur seal pups born
400000
350000
300000
250000
200000
150000
100000
50000
X
Thick Billed Murre reproductive success
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
Apex predators (fish, 1000t)
3500
3000
2500
2000
1500
Pelagic foragers (fish, 1000t)
35000
30000
25000
20000
15000
10000
5000
Benthic foragers (fish, 1000t)
7000
6500
6000
5500
5000
4500
4000
3500
3000
Motile epifauna (fish and inverts, 1000t)
10000
9000
8000
7000
6000
5000
4000
3000
2000
EBS Zooplankton biomass Mean
2000
1500
1000
500
0
EBS Ice Retreat Index
100
80
60
40
20
0
-20
N. Pacific NPI (Nov-Mar average)
1.5
1.0
0.5
0.0
-0.5
-1.0
-1.5

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BEST-BSIERP Hypothesis

- "*Climate and ocean conditions influencing water temperature, circulation patterns and domain boundaries impact fish reproduction, survival and distribution, the intensity of predator-prey relationships and the location of zoogeographic provinces through bottom-up processes;*
- *Reduced cold pool extent will increase overlap of inner domain forage fish and outer domain piscivores;*
- *Strength of frontal boundaries will weaken due to absence of the summer cold pool, allowing expansion of the inner domain and juvenile and forage fish habitat there. Weaker winds will enhance this effect*". (http://bsierp.nprb.org/)"