An ecosystem approach to Steller sea lion trophic ecology: the prey

- Sustainable Fisheries Program
- Gulf Apex Predator Prey Program

Robert J. Foy and *many* others (post docs, students, technicians and others)

School of Fisheries and Ocean Sciences
University of Alaska Fairbanks
Kodiak, Alaska

Kodiak Vessels
FV Peggy Jo
FV Alaska Beauty
FV Millennium
FV Laura
FV Alaskan
FV Mythos

Funding Sources
NOAA/NMFS
NPRB
NPMR
CIFAR
PCCRC
SSLIR
Rasmuson
UAF
CSREES/USDA

Sustainable Fisheries Program

Sustainability~ecosystem and trophodynamic interactions

- Distribution & abundance
  - Prey availability
- Predator vs commercial removals
- Environmental forcing
  - Physiological response
- Assess limiting currency
  - Energy density and lipid biochemistry

Gulf Apex Predator Prey Program

PIs: Kate Wynne, Robert Foy, and Loren Buck

Multidisciplinary effort to assess the status, environment, prey, and potential competitors of Steller sea lions in waters near Kodiak, Alaska.

Gulf Apex Predator Prey Program

Prey and fisheries oceanography

- Distribution, ecology and physiology of fish and zooplankton that make up the "prey" of Steller sea lions and their competitors.

2000-2005 Objectives

- Species composition, distribution, abundance, and quality of prey available to sea lions within 10 and 20 nm of Long Island haulout
- monitor oceanographic conditions associated with fish species distribution
- determine the feasibility of describing and quantifying prey fields upon which Steller sea lions, whales, and seabirds are observed actively foraging

An ecosystem approach to Steller sea lion trophic ecology: the prey

Hypotheses

1. Prey availability hypothesis
   - 6 projects
2. Competition hypothesis
   - 3 projects
3. Environmental variability hypothesis
   - 4 projects

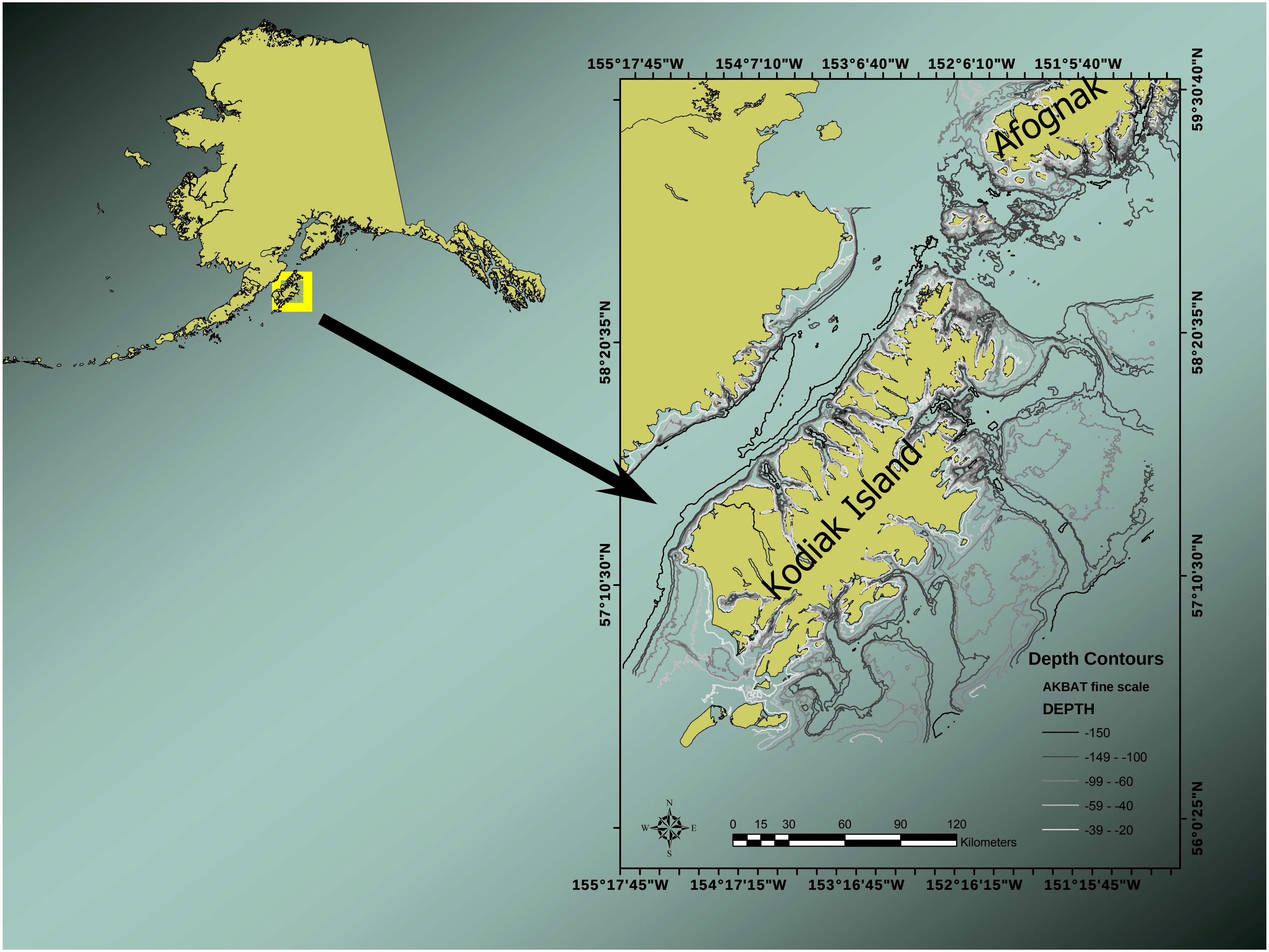
Prey Availability: So how much food is there?

- Sub-hypothesis: The seasonal and interannual availability of prey inside critical habitat is not sufficient to sustain Long Island SSL population.
  1. Does pelagic and demersal fish biomass fluctuate seasonally or interannually within SSL critical habitat?
  2. Are pelagic and demersal fish predictably distributed wrt bathymetry or hydrography?
  3. Is there enough energy available to sustain local SSL population?

Prey Availability: So how much food is there?

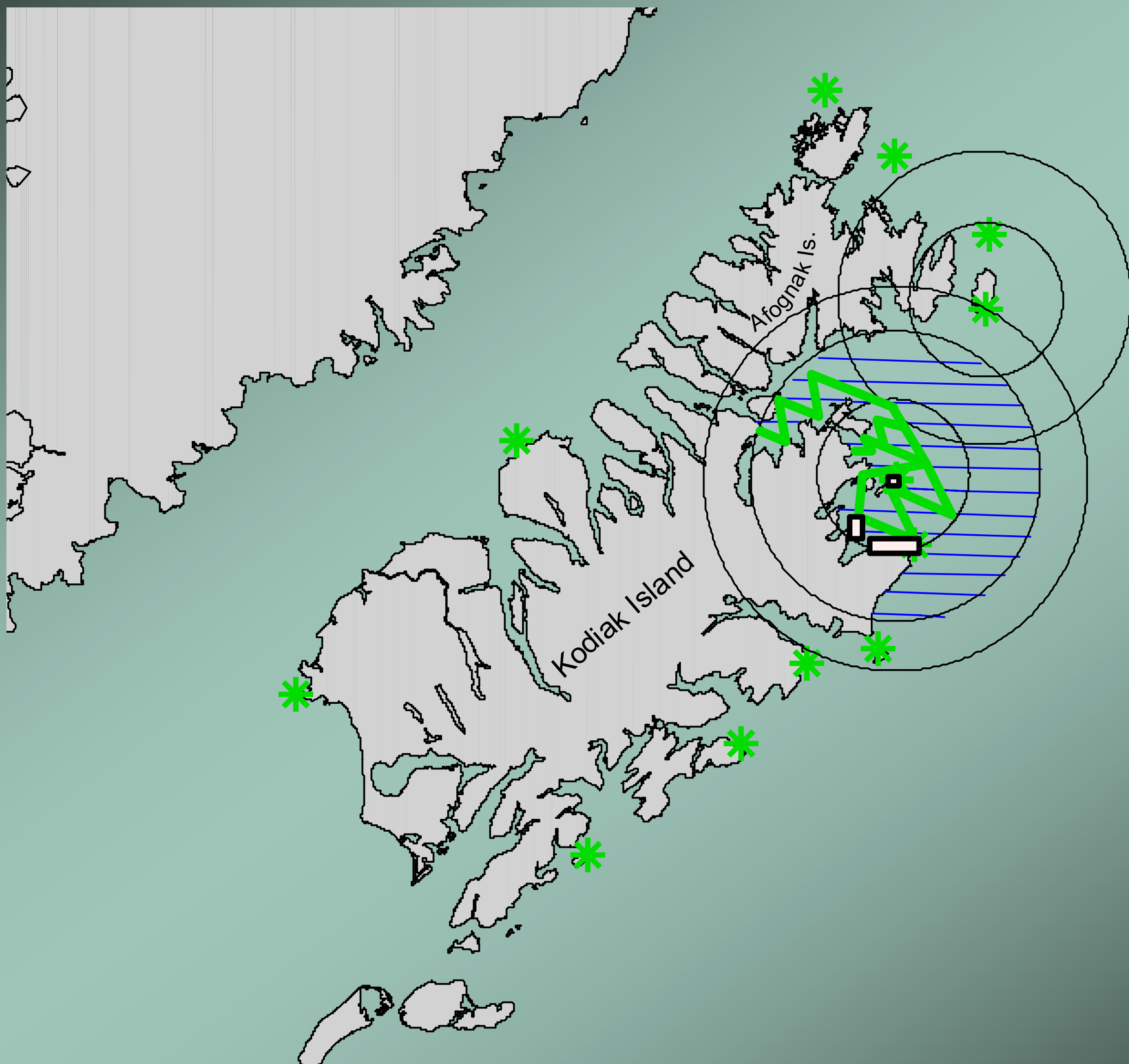
- Sub-hypothesis: The seasonal and interannual availability of prey inside critical habitat is not sufficient to sustain Long Island SSL population.

4. What is the relative availability of fish species directly next to a haulout?
5. Is pelagic prey availability different at a rookery versus a haulout in the same region?
6. How does the energy density of potential prey (pollock) fluctuate between haulout sites (regions?)



155°17'45"W
154°7'10"W
153°6'40"W
152°6'10"W
151°5'40"W
59°30'40"N
58°20'35"N
57°10'30"N
56°0'25"N
Afognak
Kodiak Island
Depth Contours
AKBAT fine scale
DEPTH
-150
-149 - -100
-99 - -60
-59 - -40
-39 - -20
N
S
E
W
0 15 30 60 90 120
Kilometers
155°17'45"W
154°17'15"W
153°16'45"W
152°16'15"W
151°15'45"W

Study areas in Kodiak Archipelago



"Portable" Fisheries Oceanography

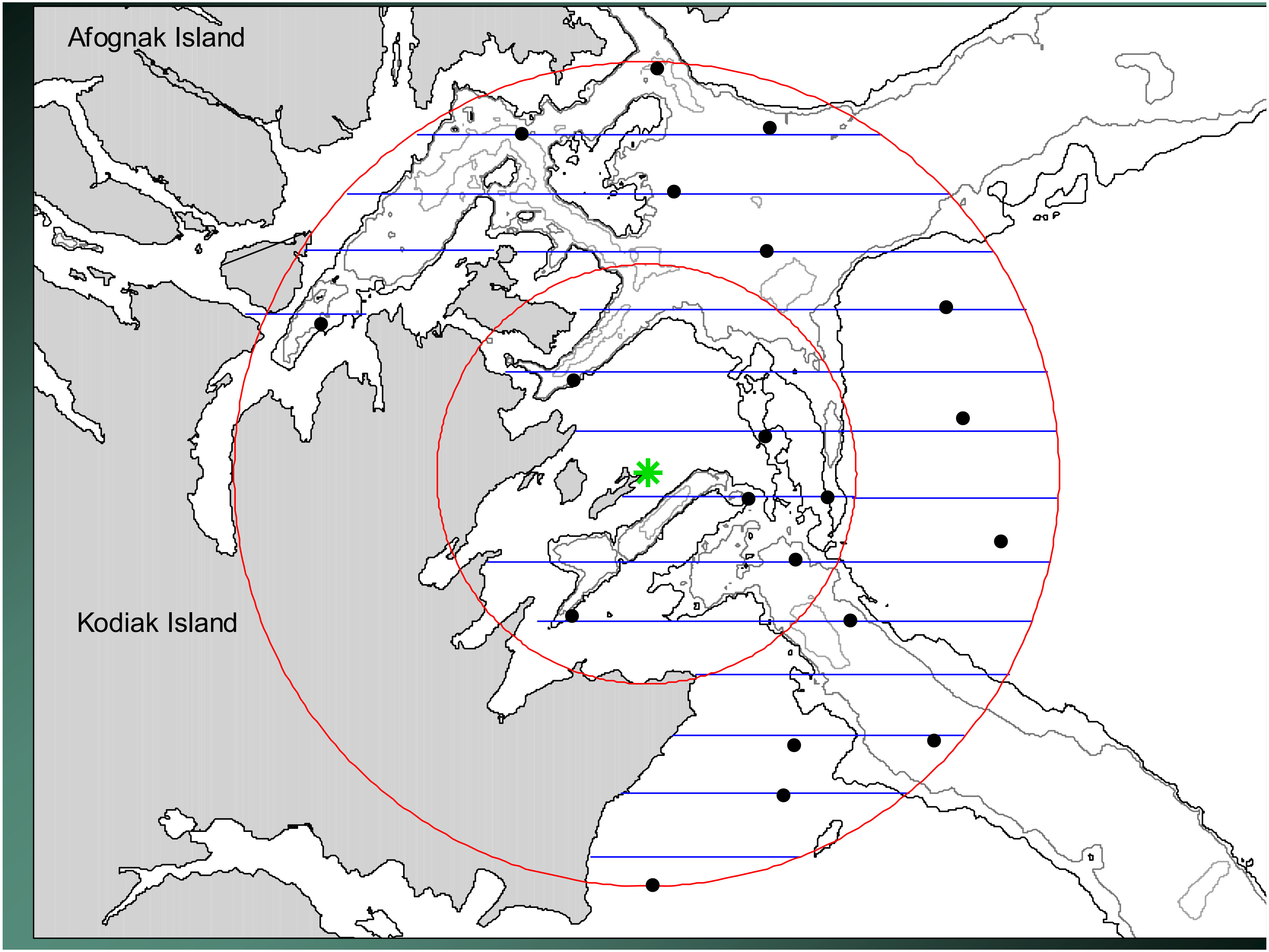
Acoustics

Oceanography

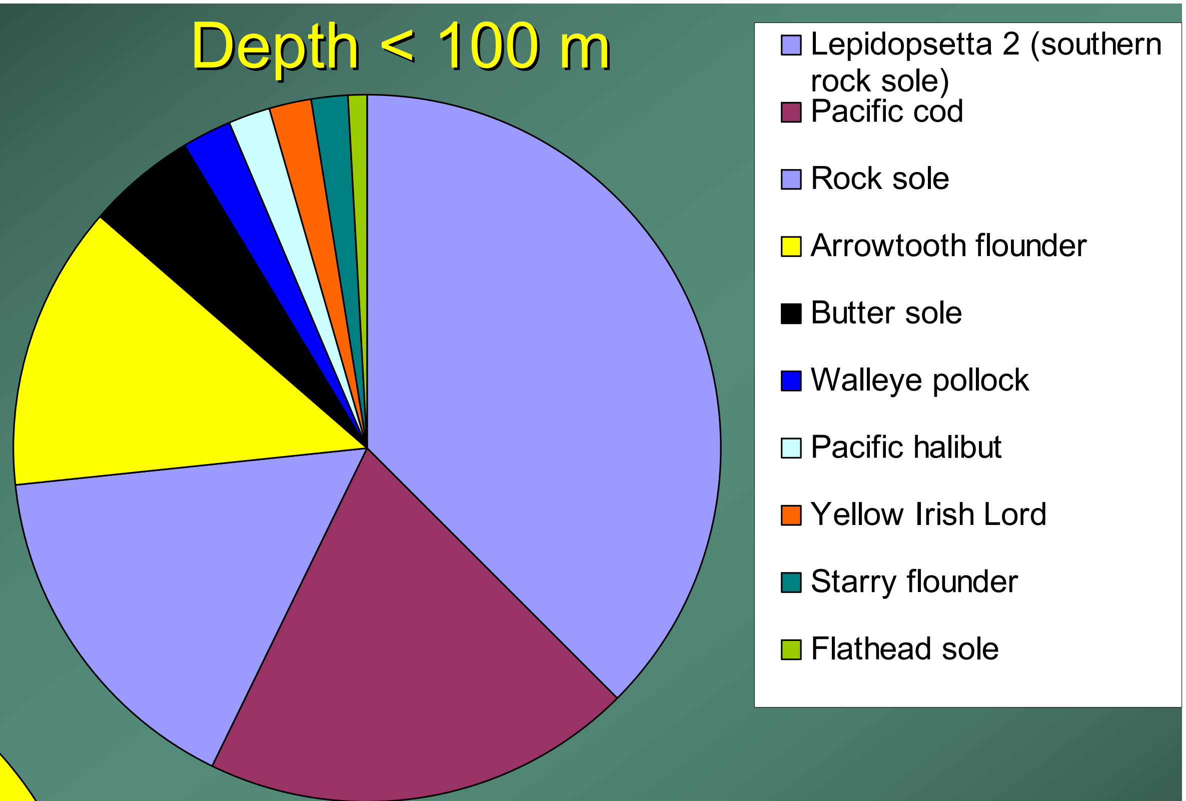
Commercial size nets

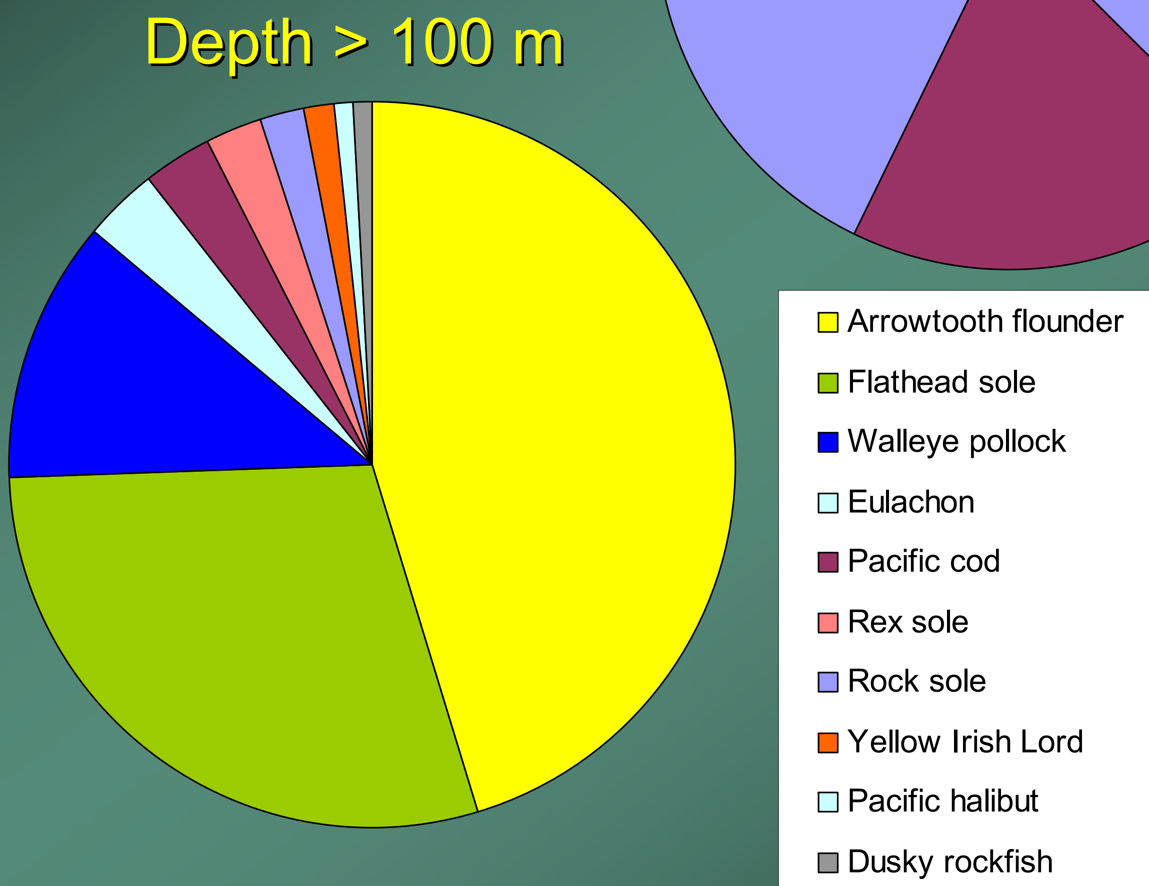
Pelagic and demersal fish distribution inside Steller Sea Lion critical habitat

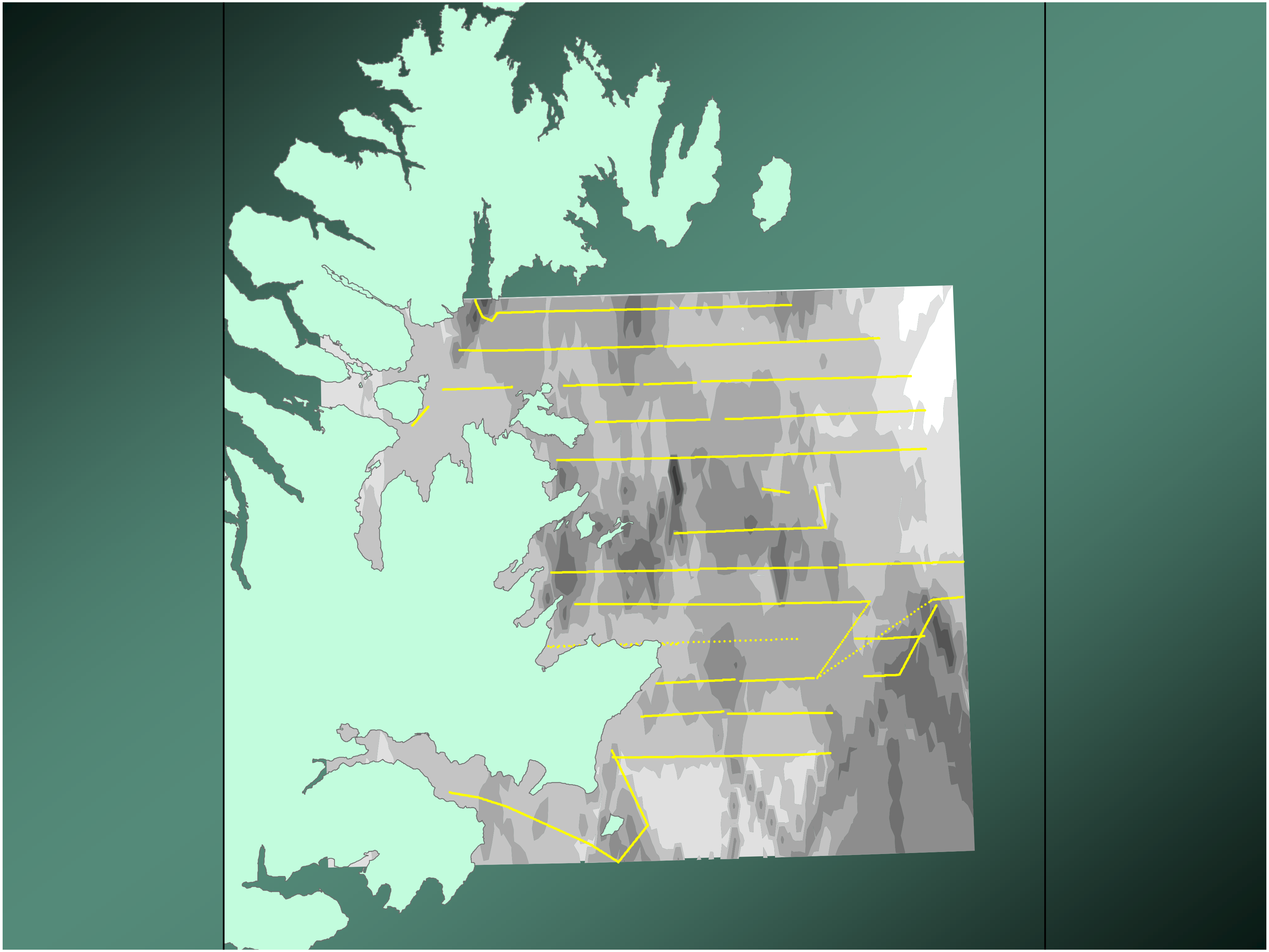
Robert Foy and Andreas Winter

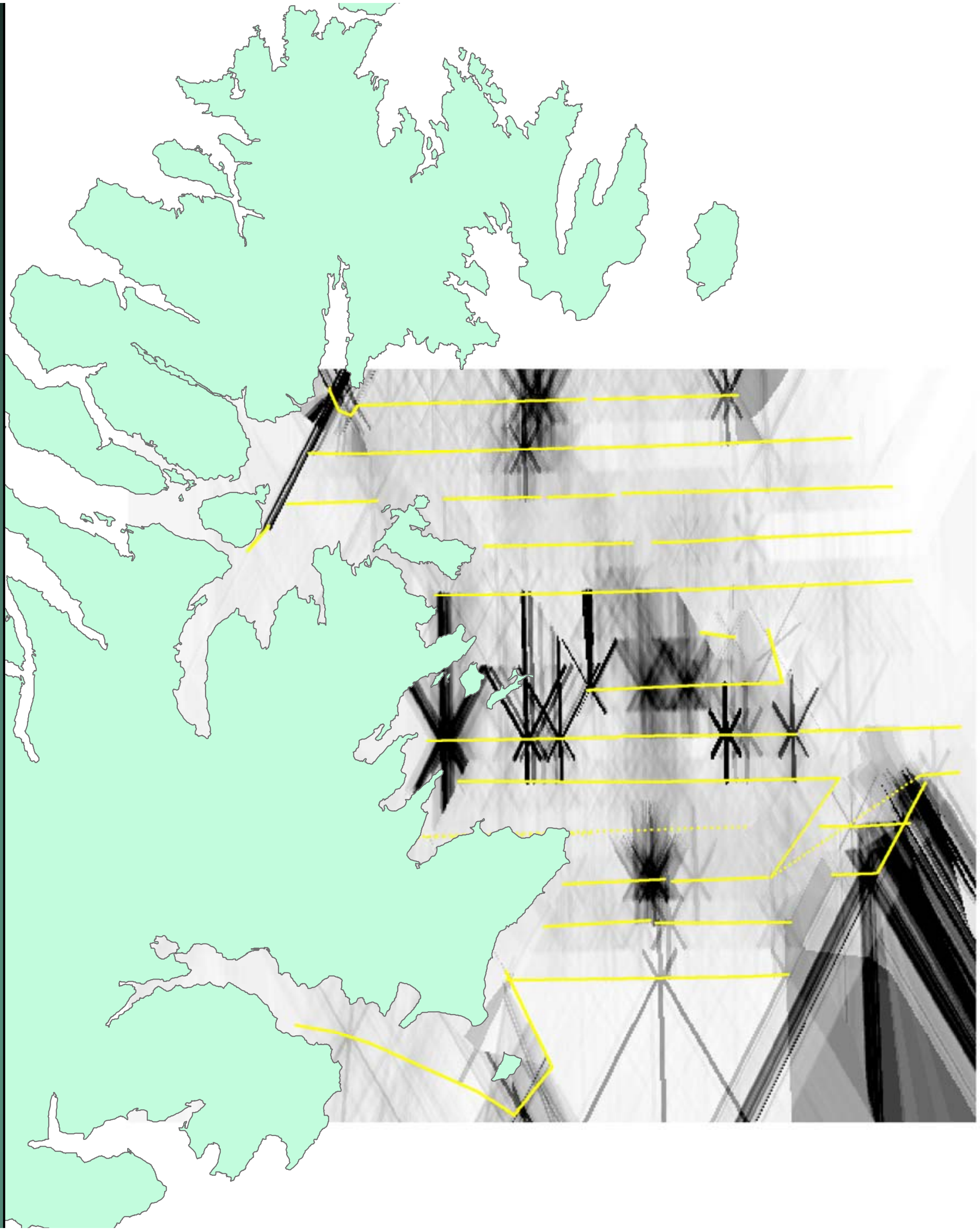

Afognak Island
Kodiak Island

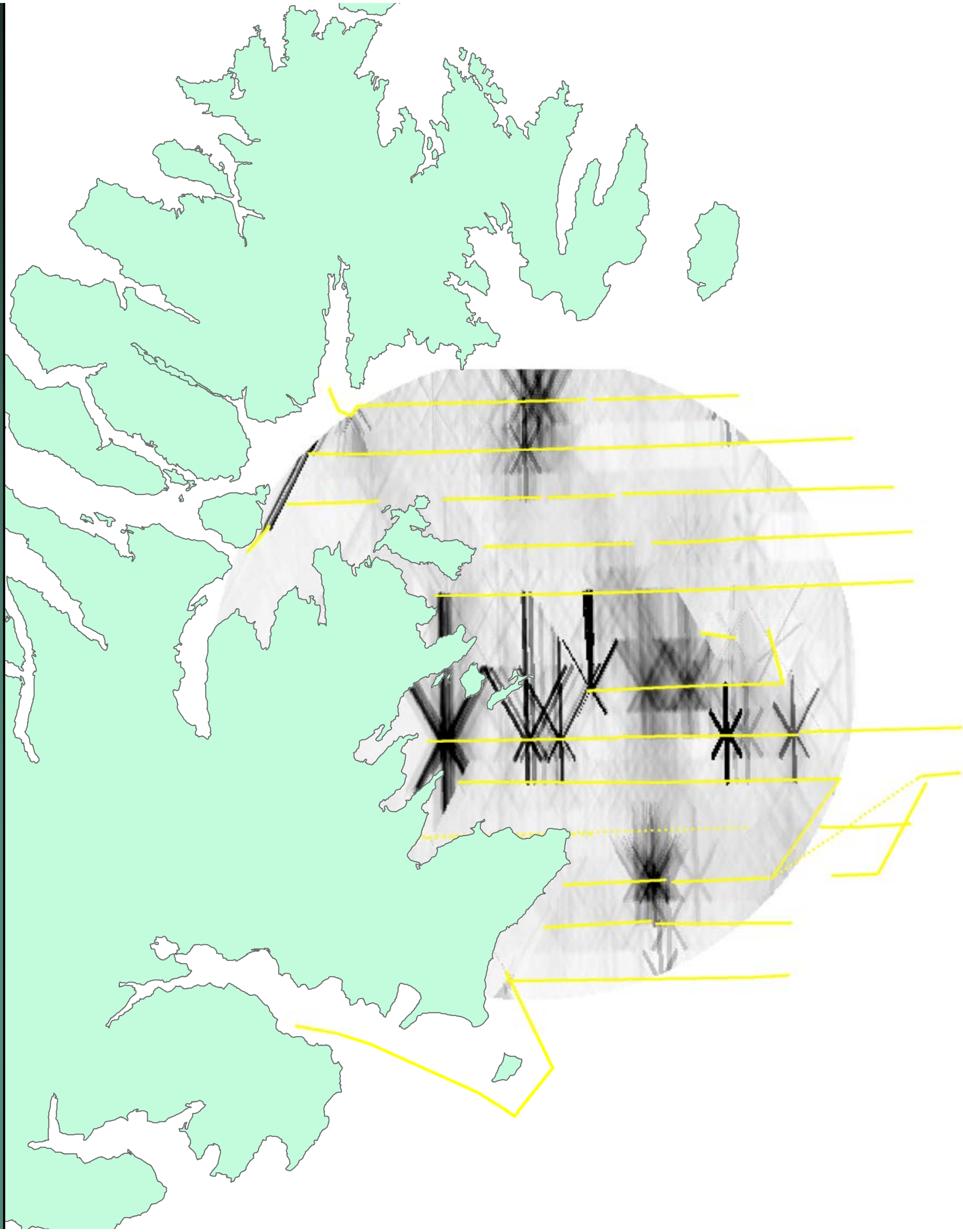
Bottom Trawl Species Composition

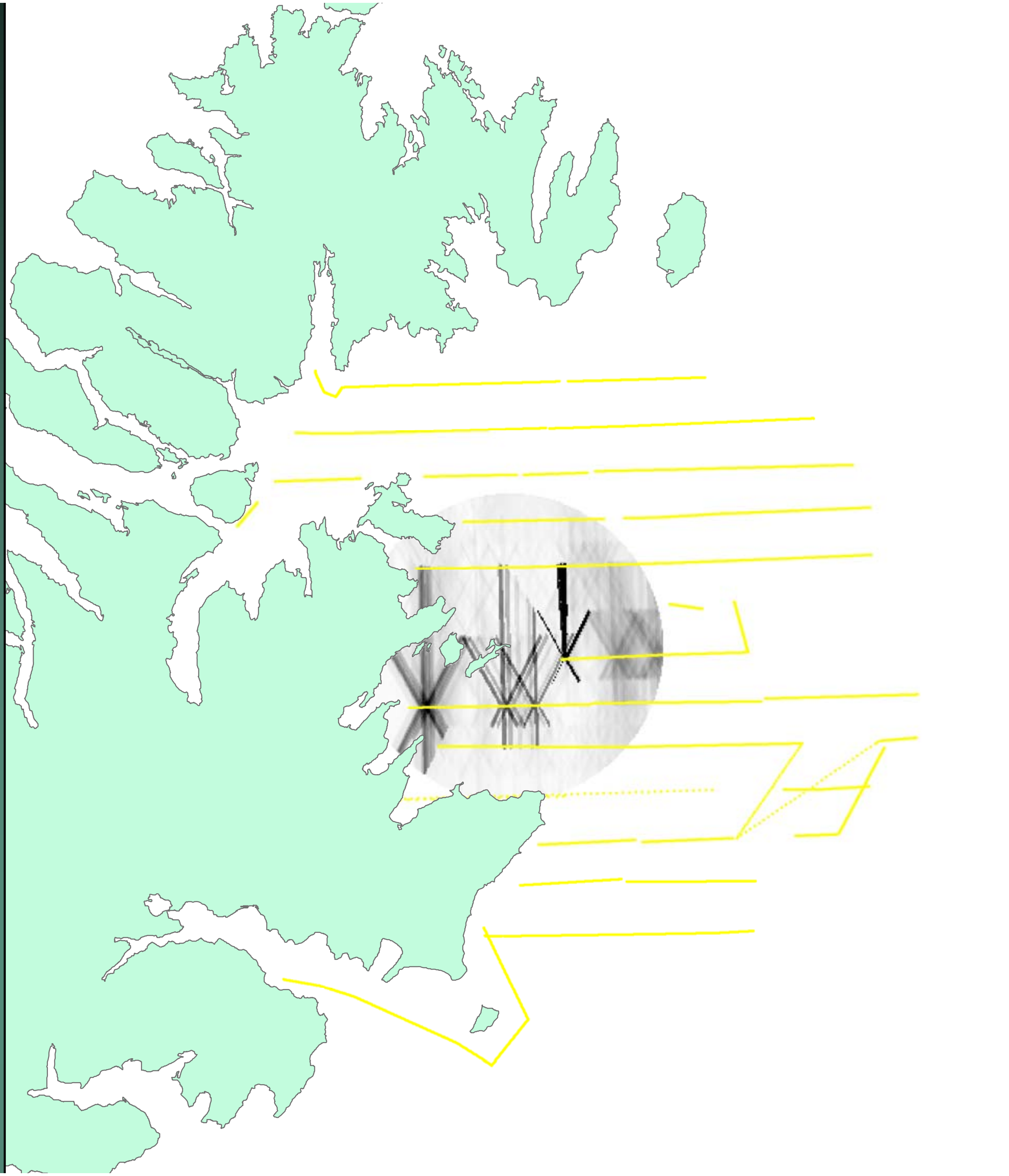


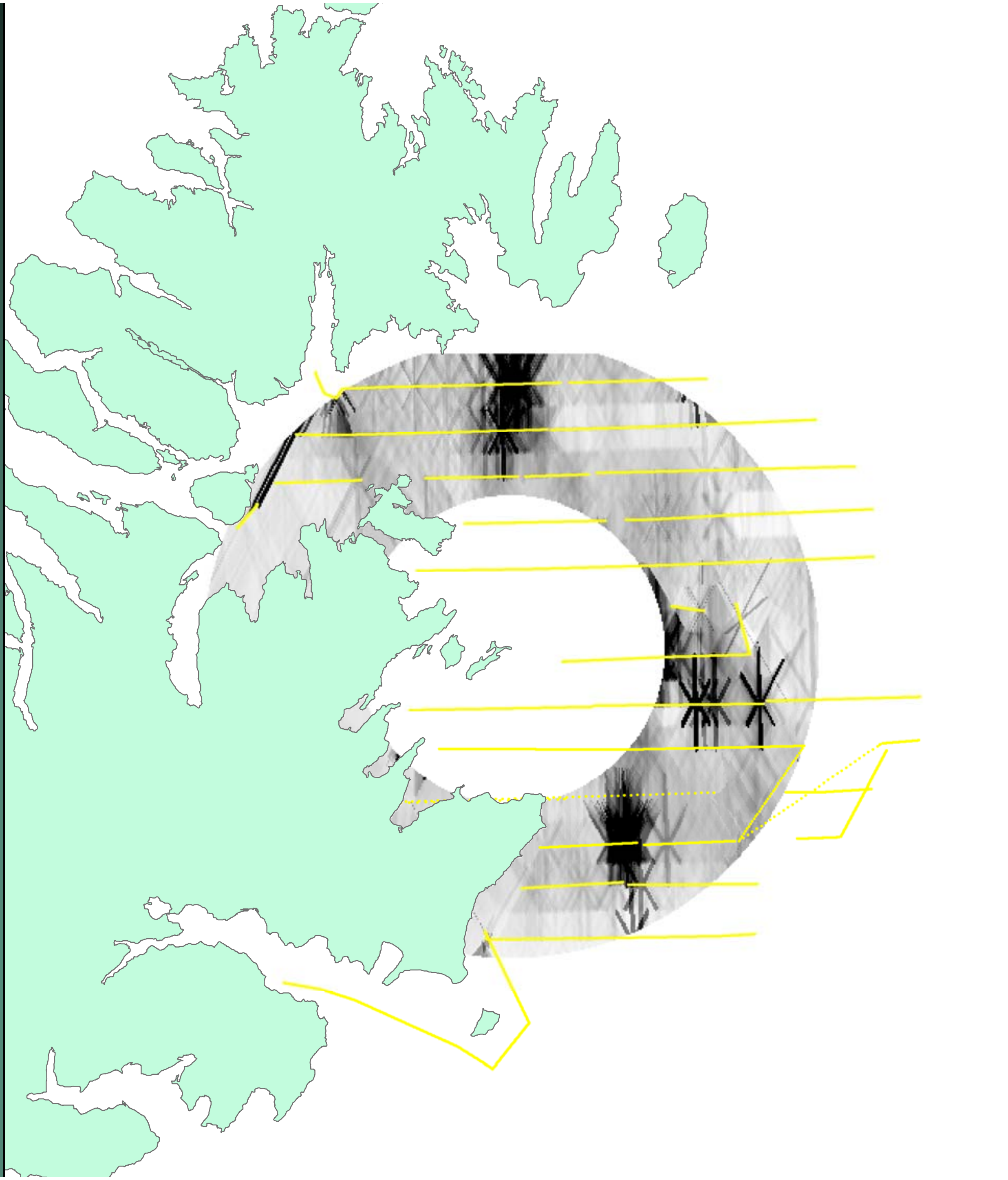






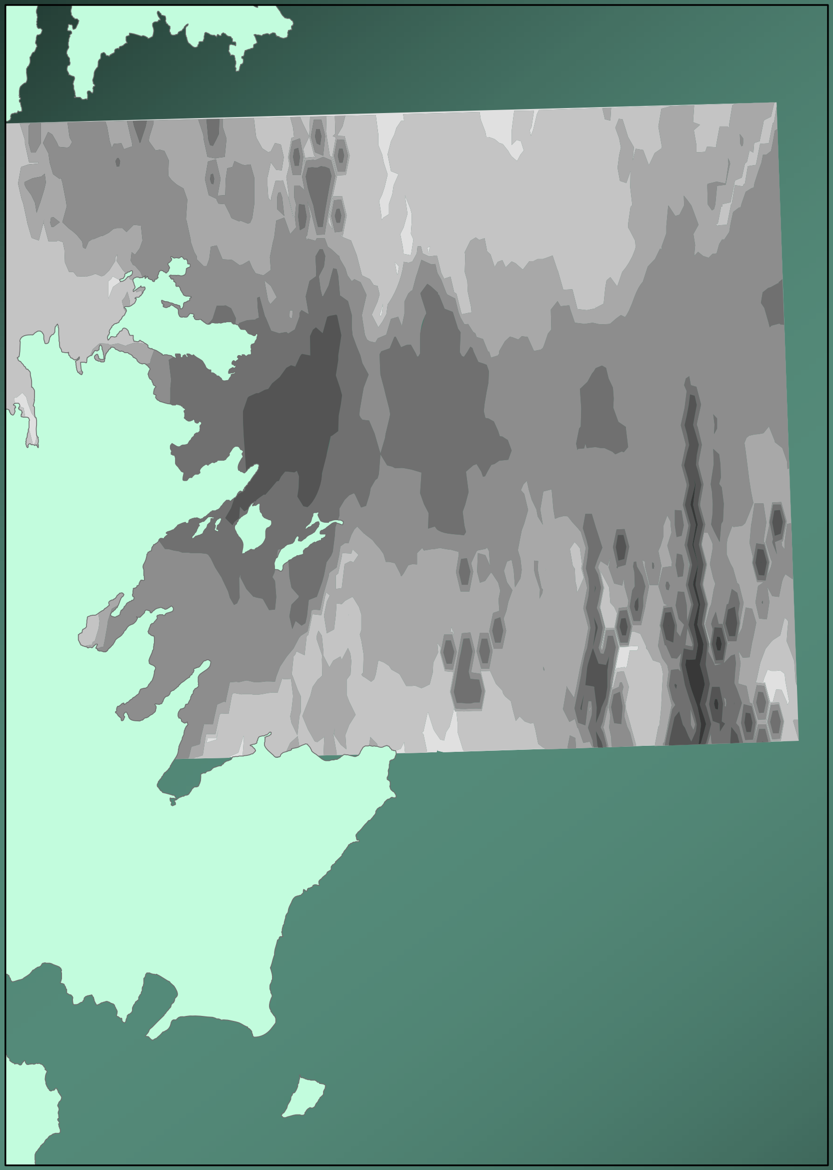




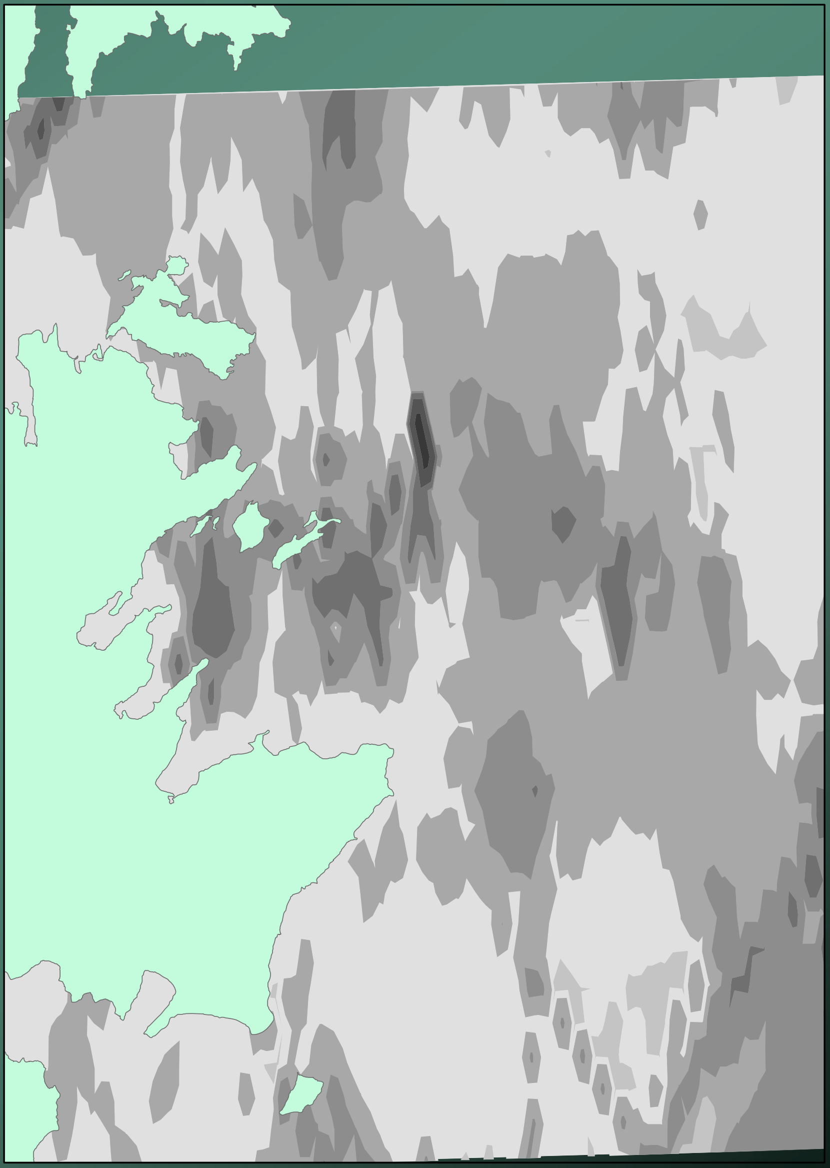


Pelagic biomass (kg/km^2)

May 2000

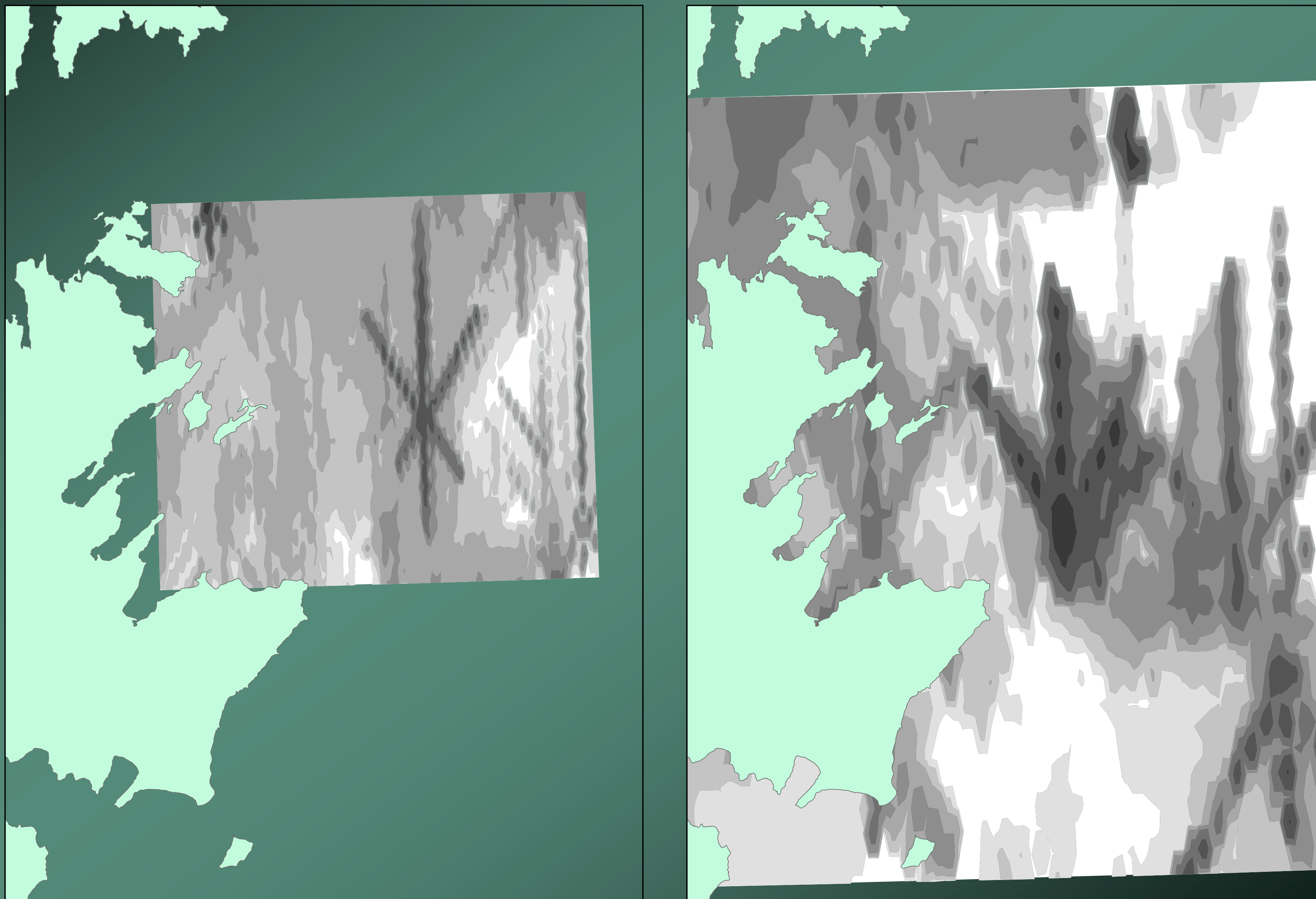


May 2001



Pelagic biomass (kg/km^2)

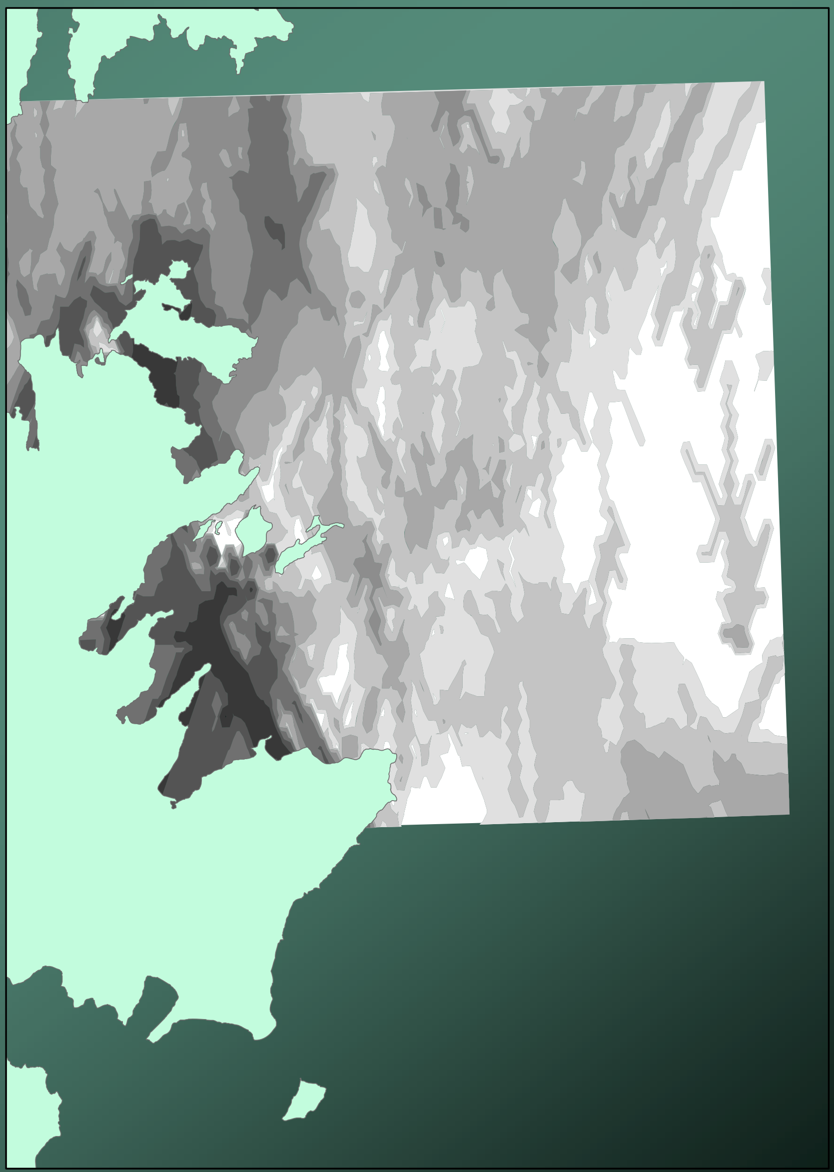
November 2000 | November 2001



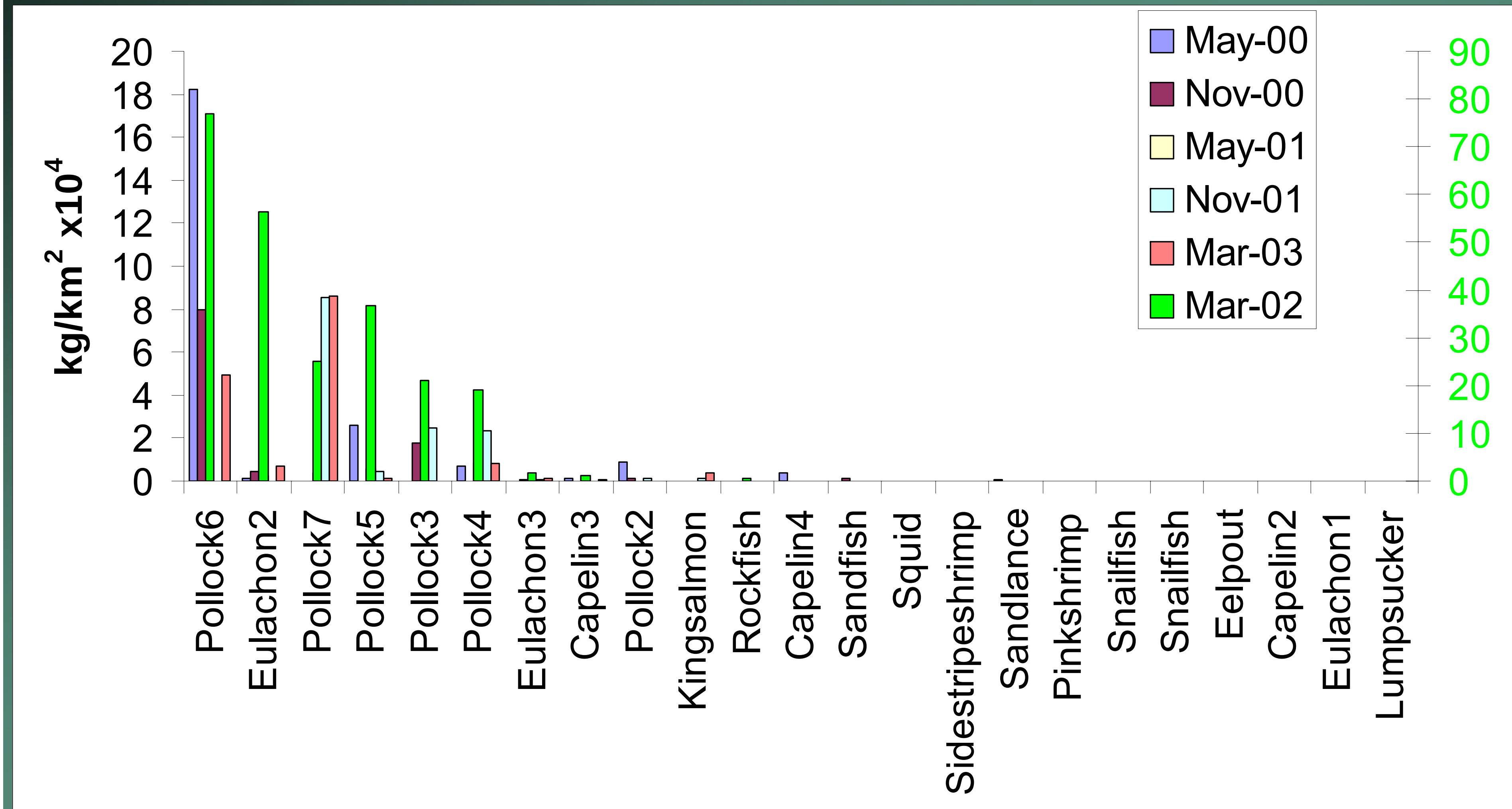
Pelagic biomass (kg/km^2)

March 2002

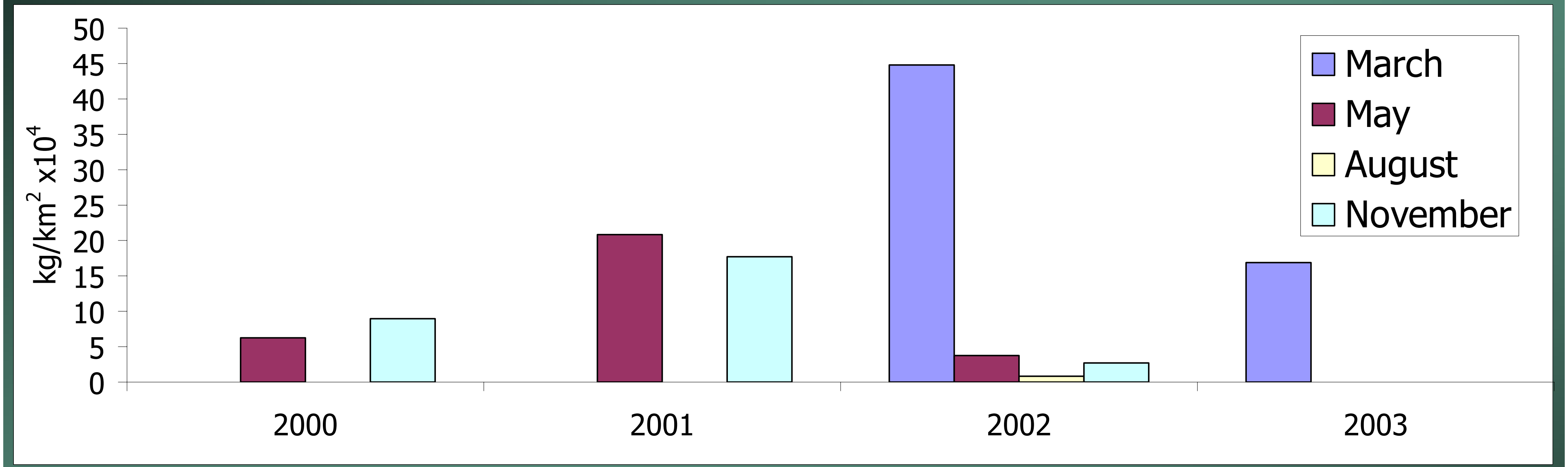
March 2003



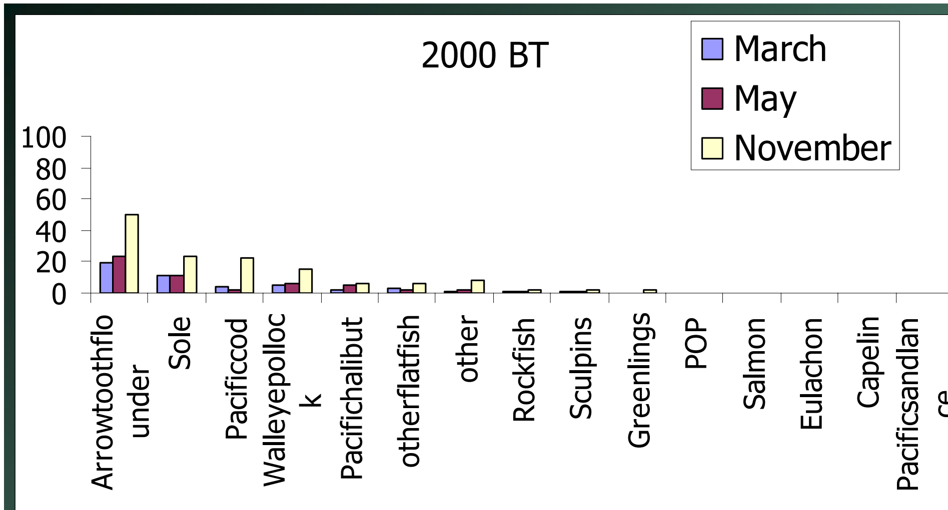
Pelagic biomass (kg/km^2)

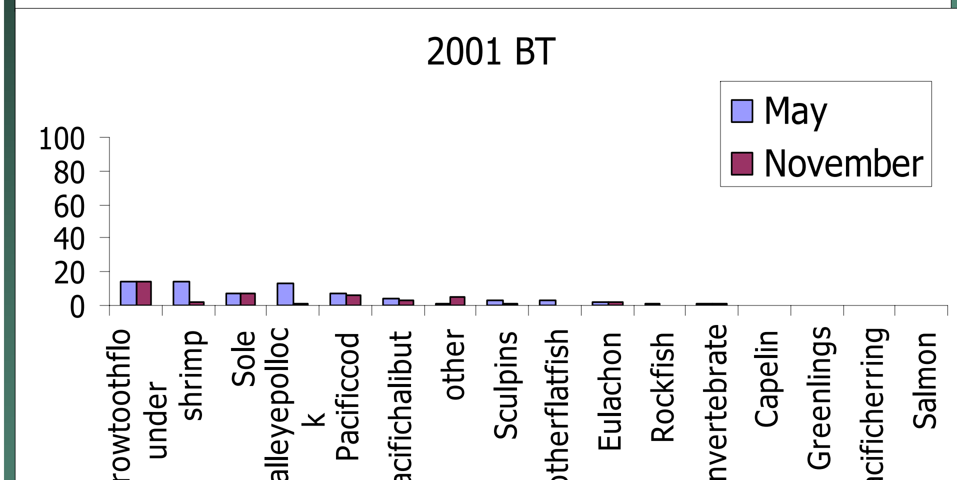


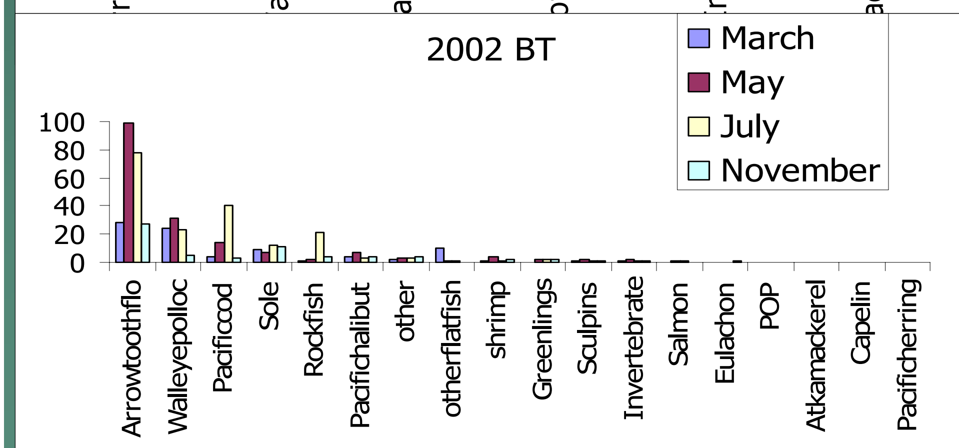
Pelagic biomass (kg/km^2)

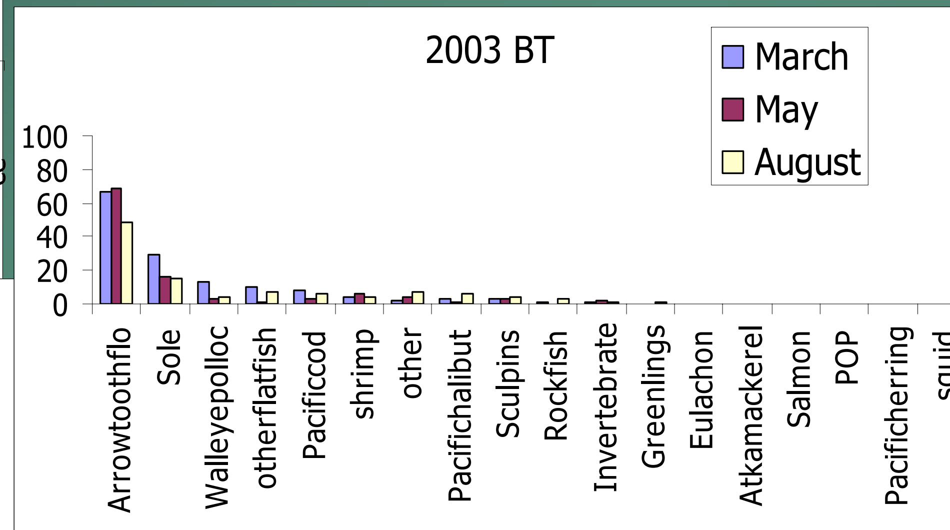


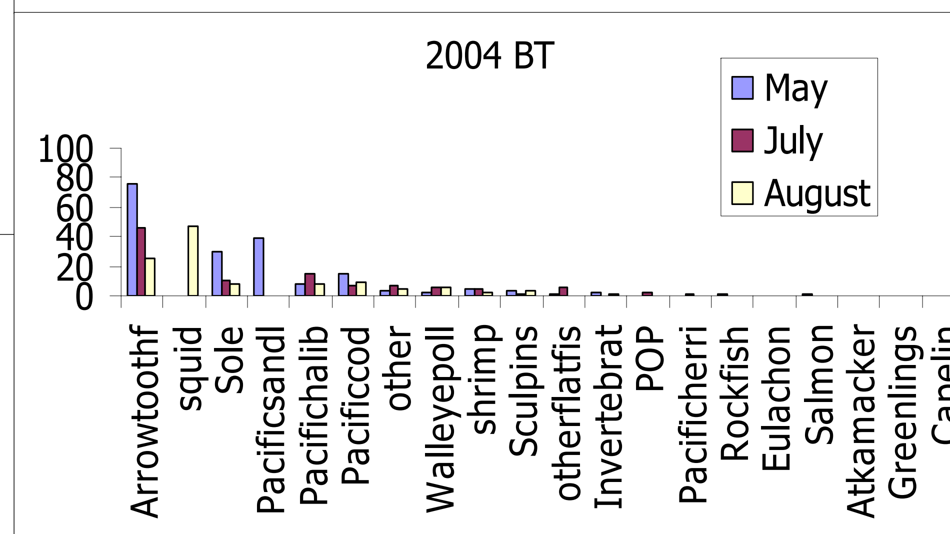
Spp	minlength	maxlength	Potential age-class
Pollock1	0	10	0,1
Pollock2	11	20	1,2
Pollock3	21	30	2,3
Pollock4	31	40	2,3,4
Pollock5	41	50	4,5
Pollock6	51	60	6,7
Pollock7	61	70	7
Capelin1	0	4.0	mixed male and females
Capelin2	4.1	8.0	mixed male and females
Capelin3	8.1	12.0	mixed male and females
Capelin4	12.1	16.0	mixed male and females
Capelin5	16.1	20.0	mixed male and females


2000 BT
March
May
November
100
80
60
40
20
0
Arrowtoothflo under
Sole
Pacificcod
Walleyepolloc k
Pacifichalibut
otherflatfish
other
Rockfish
Sculpins
Greenlings
POP
Salmon
Eulachon
Capelin
Pacificsandlan ce


2001 BT
May
November
100
80
60
40
20
0
rowtoothflo under
shrimp
Sole
alleyepolloc k
Pacificcod
acifichalibut
other
Sculpins
otherflatfish
Eulachon
Rockfish
nvertebrate
Capelin
Greenlings
acificherring
Salmon


2002 BT
March
May
July
November
100
80
60
40
20
0
Arrowtoothflo
Walleyepolloc
Pacificcod
Sole
Rockfish
Pacifichalibut
other
otherflatfish
shrimp
Greenlings
Sculpins
Invertebrate
Salmon
Eulachon
POP
Atkamackerel
Capelin
Pacificherring


2003 BT
March
May
August
100
80
60
40
20
0
Arrowtoothflo
Sole
Walleyepolloc
otherflatfish
Pacificcod
shrimp
other
Pacifichalibut
Sculpins
Rockfish
Invertebrate
Greenlings
Eulachon
Atkamackerel
Salmon
POP
Pacificherring
squid

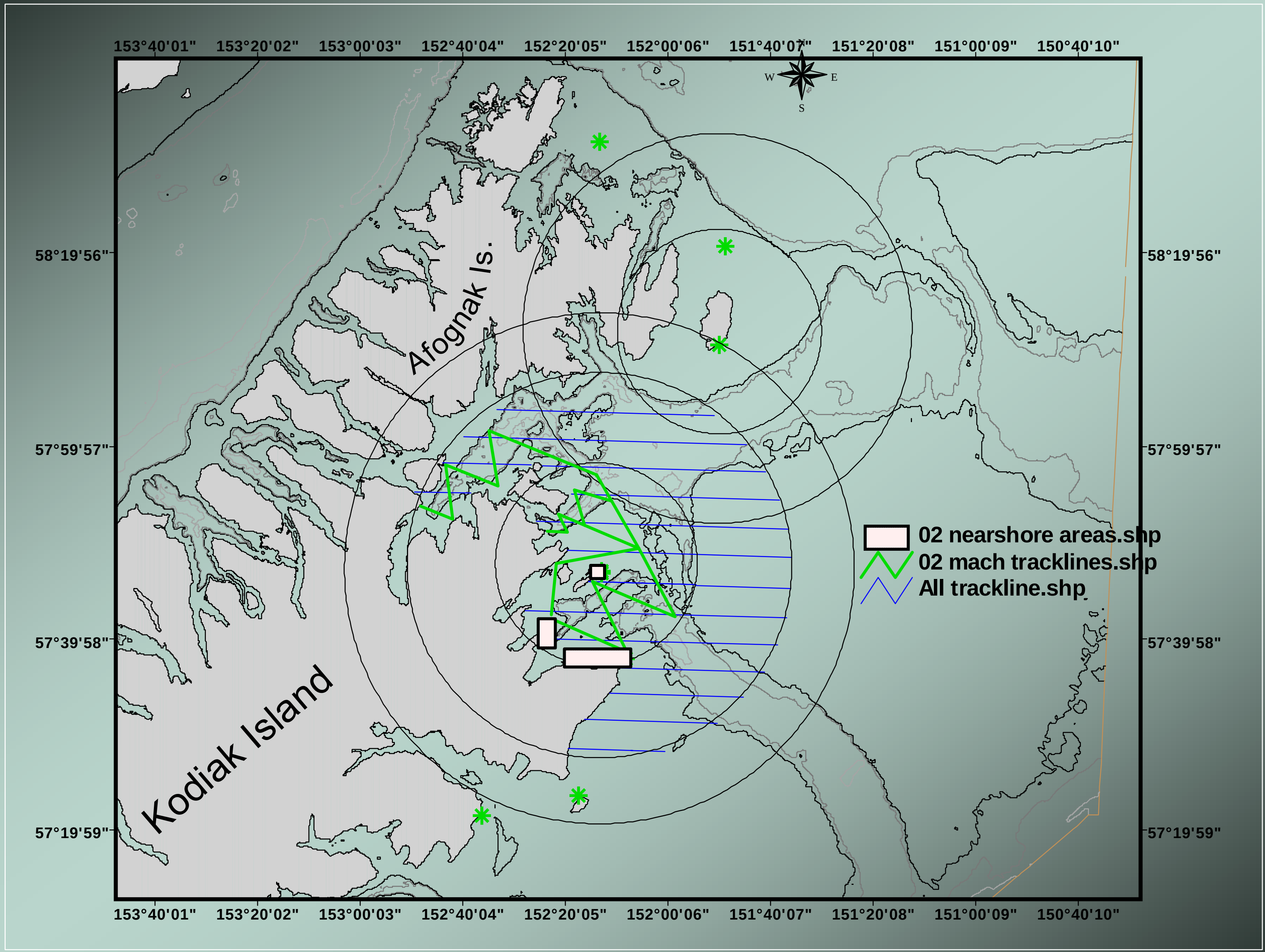

2004 BT
May
July
August
100
80
60
40
20
0
Arrowtoothf
squid
Sole
Pacificsandl
Pacifichalib
Pacificcod
other
Walleyepoll
shrimp
Sculpins
otherflatfis
Invertebrat
POP
Pacificherri
Rockfish
Eulachon
Salmon
Atkamacker
Greenlings
Capelin

So What to a SSL?

1. Does pelagic and demersal fish biomass fluctuate seasonally or interannually within SSL critical habitat? Yes
2. Are pelagic and demersal fish predictably distributed wrt bathymetry or hydrography? Yes

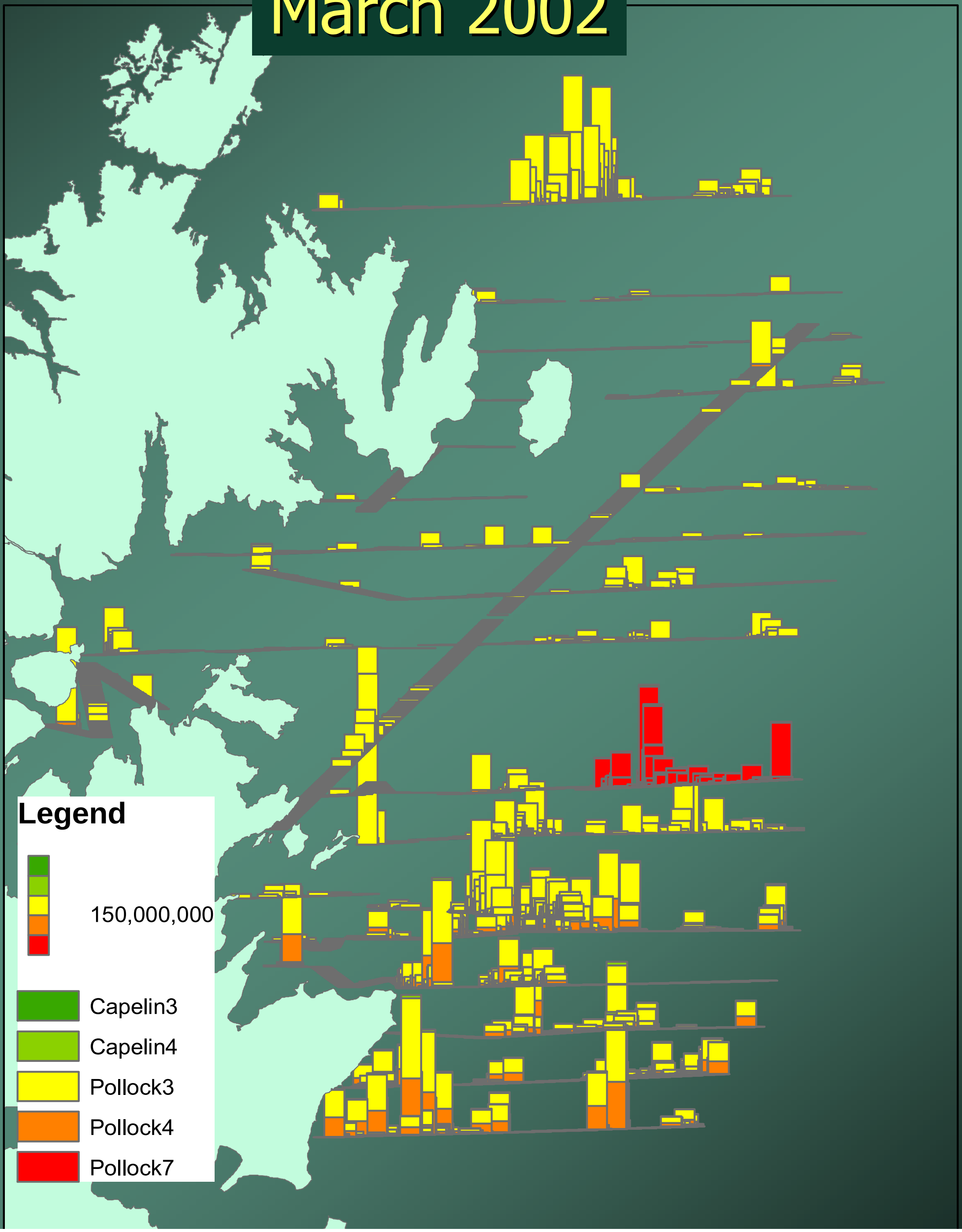
Pelagic fish distribution compared between a Steller Sea Lion haulout and rookery

Robert Foy and Andreas Winter

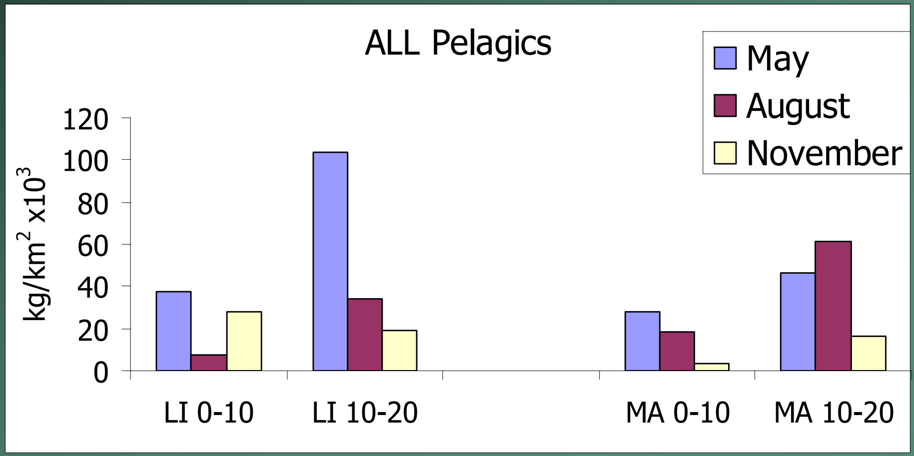


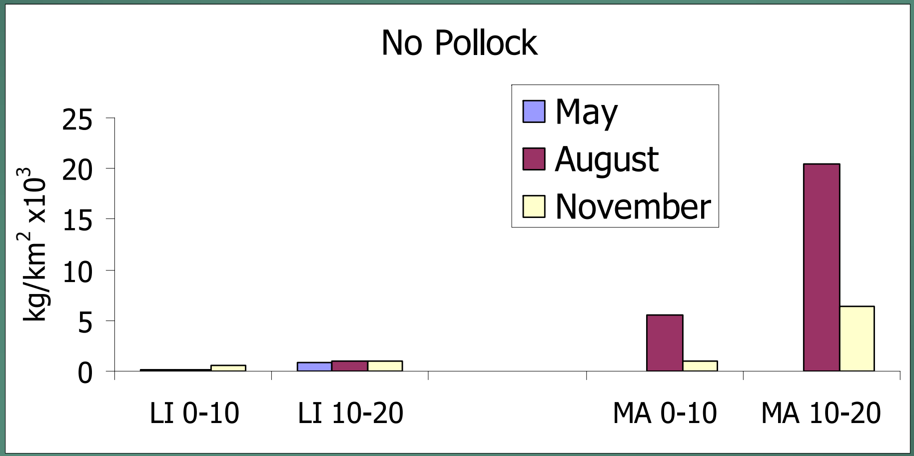
153°40'01"
153°20'02"
153°00'03"
152°40'04"
152°20'05"
152°00'06"
151°40'07"
151°20'08"
151°00'09"
150°40'10"
58°19'56"
57°59'57"
57°39'58"
57°19'59"
W
E
S
Afognak Is.
Kodiak Island
02 nearshore areas.shp
02 mach tracklines.shp
All trackline.shp

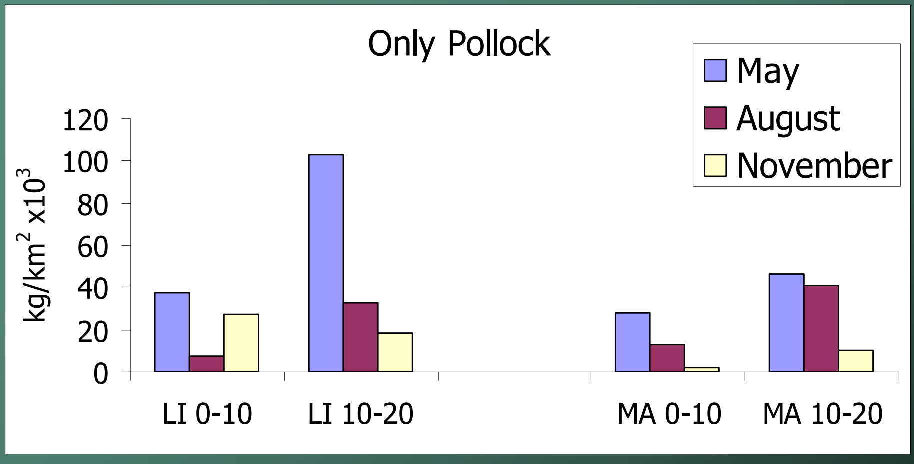
March 2002



Legend
150,000,000
Capelin3
Capelin4
Pollock3
Pollock4
Pollock7


ALL Pelagics
May
August
November
kg/km² x10³
120
100
80
60
40
20
0
LI 0-10
LI 10-20
MA 0-10
MA 10-20


No Pollock
May
August
November
kg/km² x10³
25
20
15
10
5
0
LI 0-10
LI 10-20
MA 0-10
MA 10-20

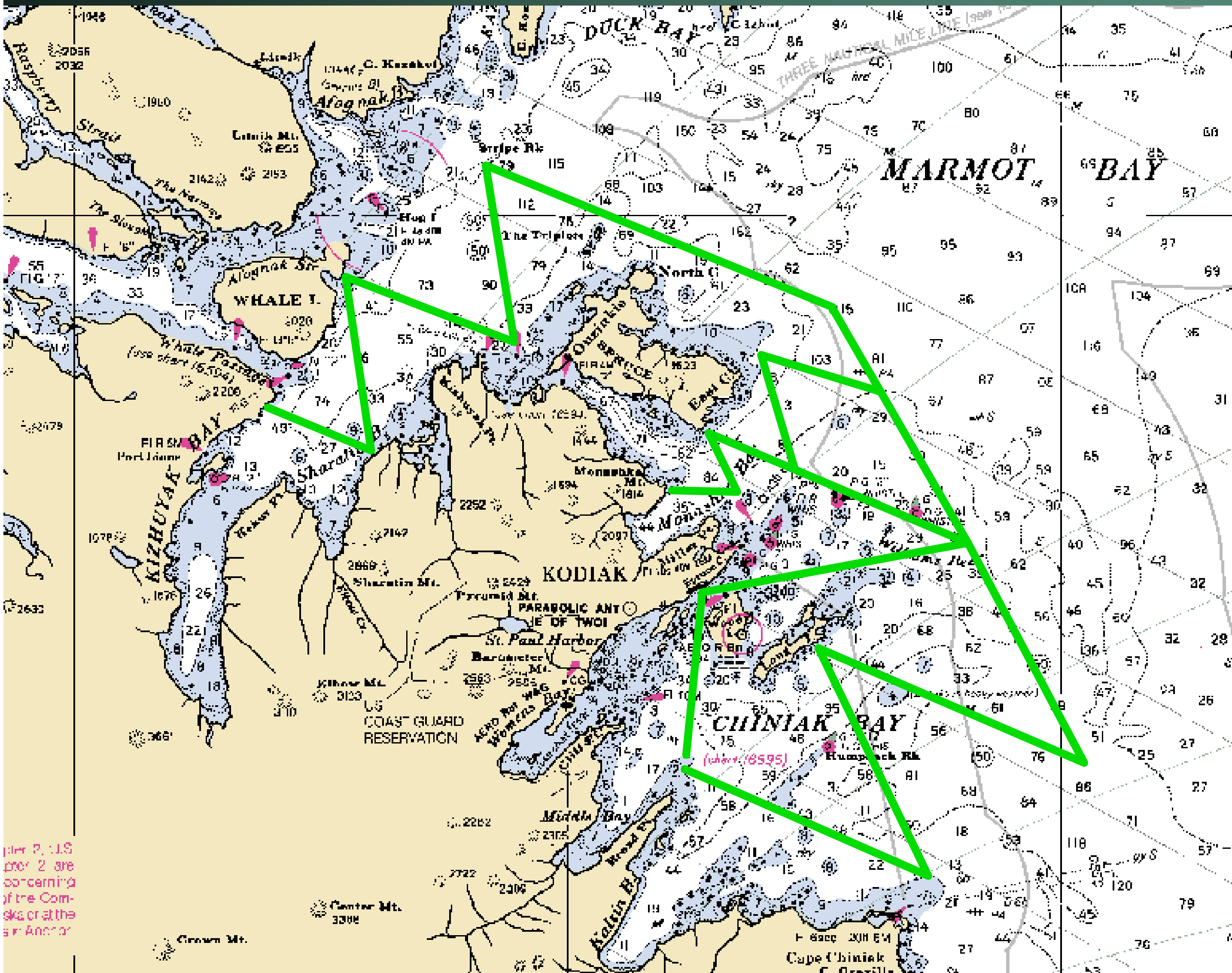

Only Pollock
May
August
November
kg/km² x10³
120
100
80
60
40
20
0
LI 0-10
LI 10-20
MA 0-10
MA 10-20

So What to a SSL?

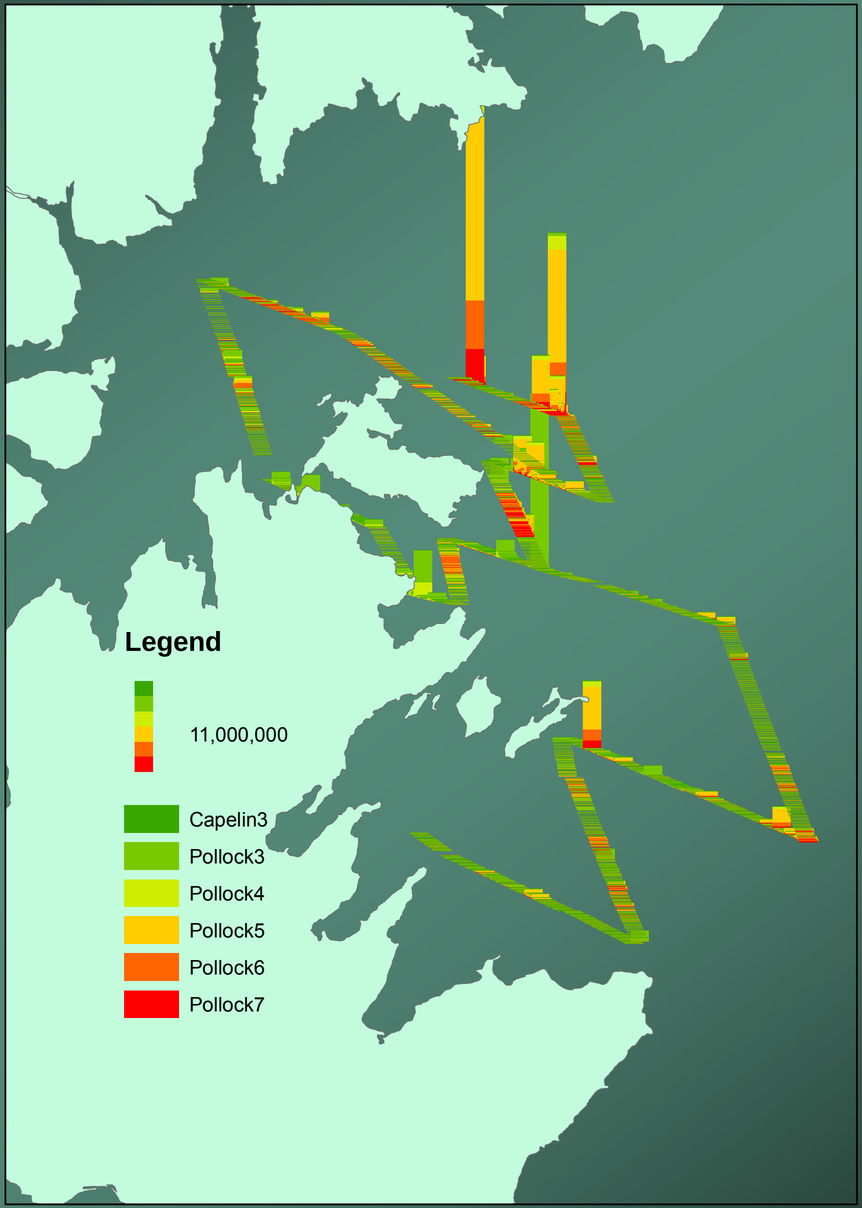
4. Is pelagic prey availability different at a rookery versus a haulout in the same region? Yes, consistent with SSL movements

Monthly pelagic fish distribution inside 10 nm

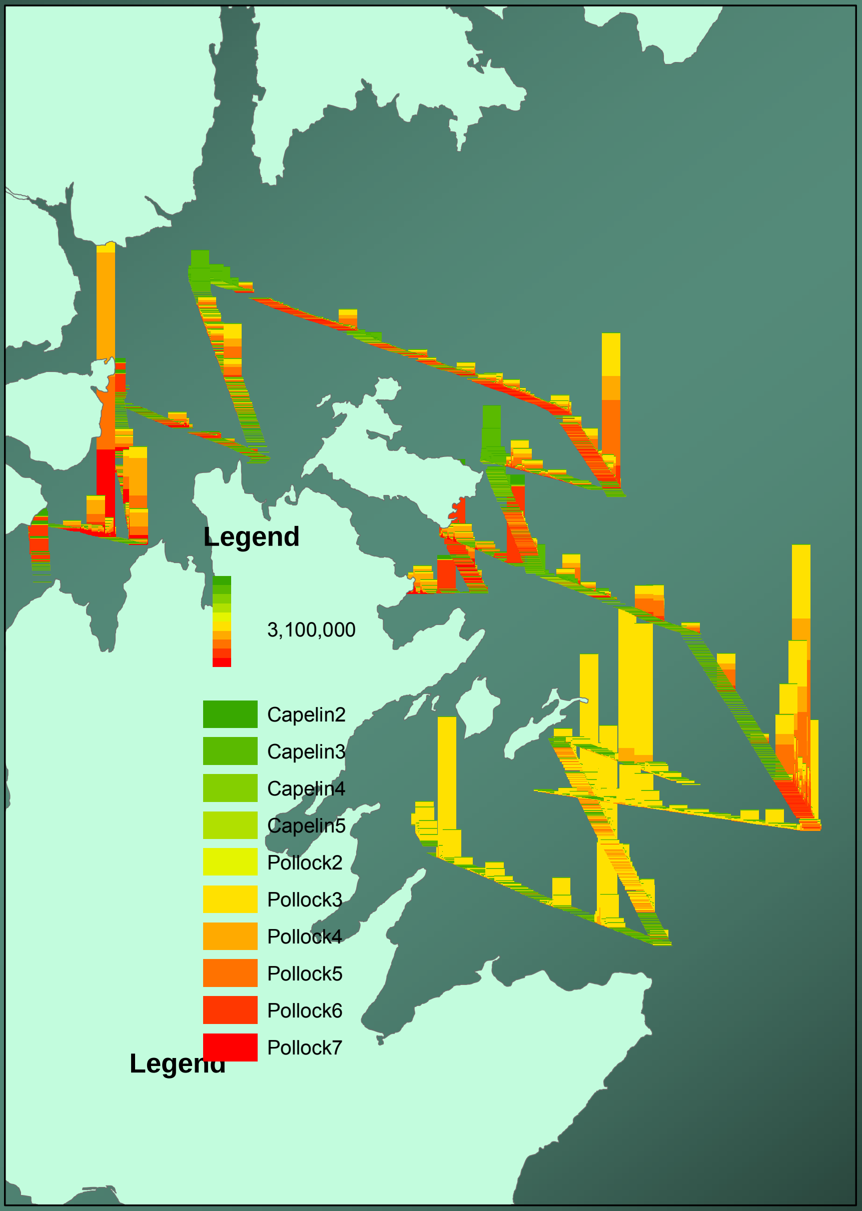
Robert Foy and Andreas Winter


DUCK BAY
MARMOT
BAY
THREE NAUTICAL MILE LINE
Afognak
Strait
WHALE I.
Whale Passage
KIZHUYAK
BAY
KODIAK
Pyramid Mt.
St. Paul Harbor
Barometer Mt.
US COAST GUARD RESERVATION
CHINIAK BAY
Middle Bay
Center Mt.
Crown Mt.
Cape Chiniak

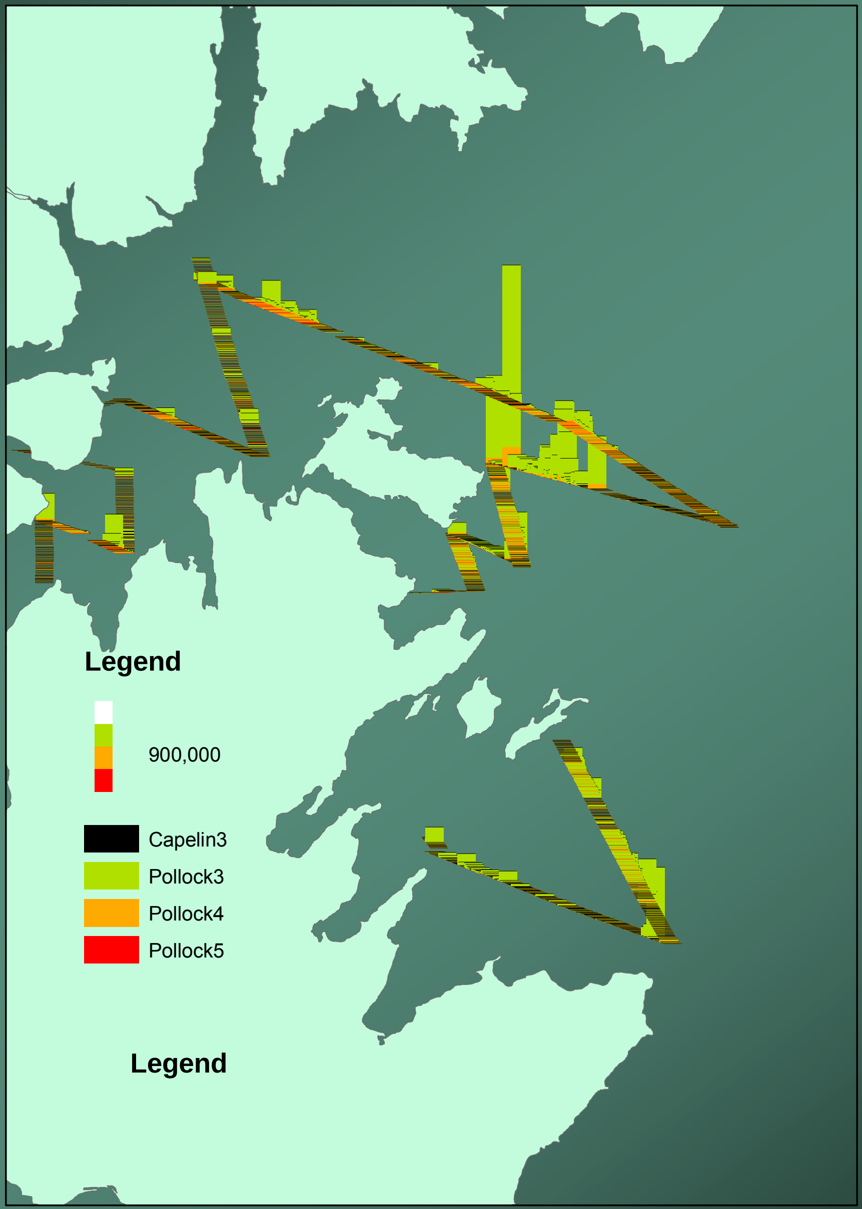
May 2002 pelagic



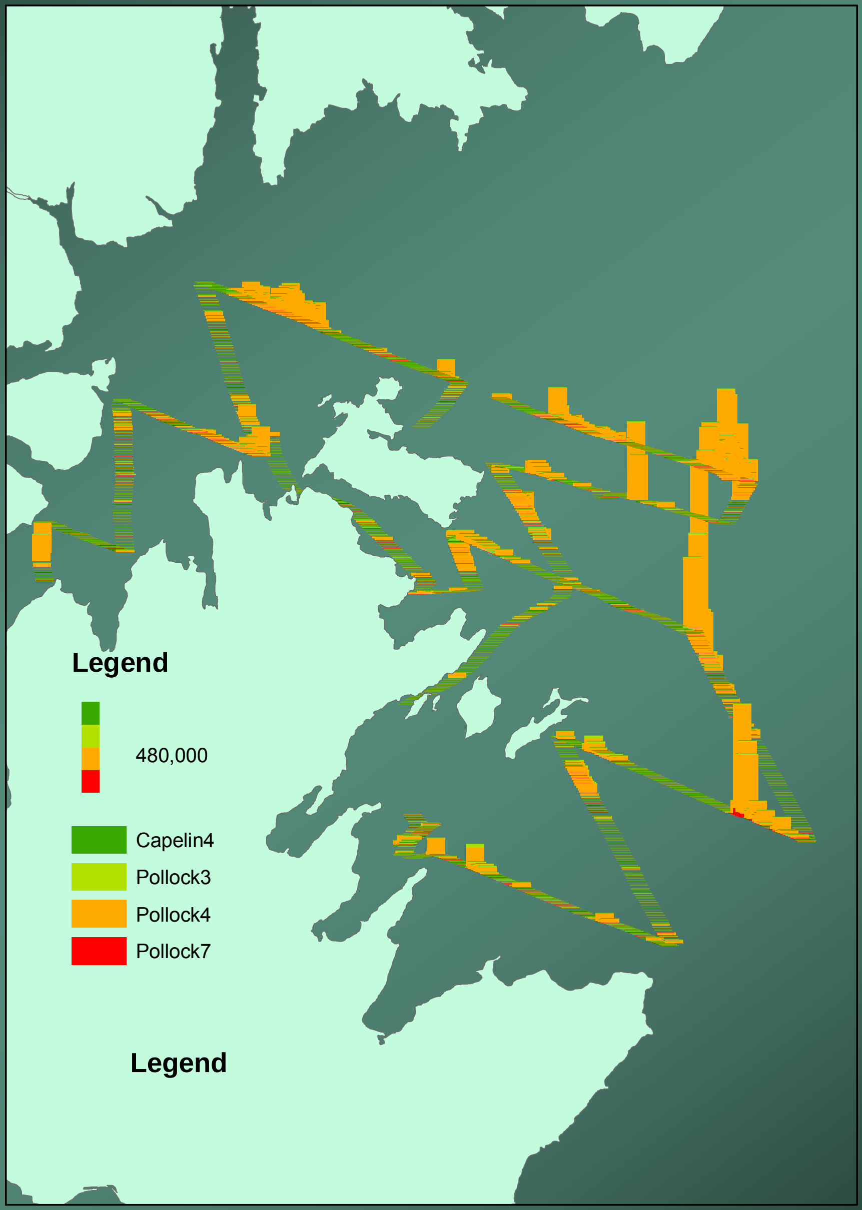
June 2002 pelagic



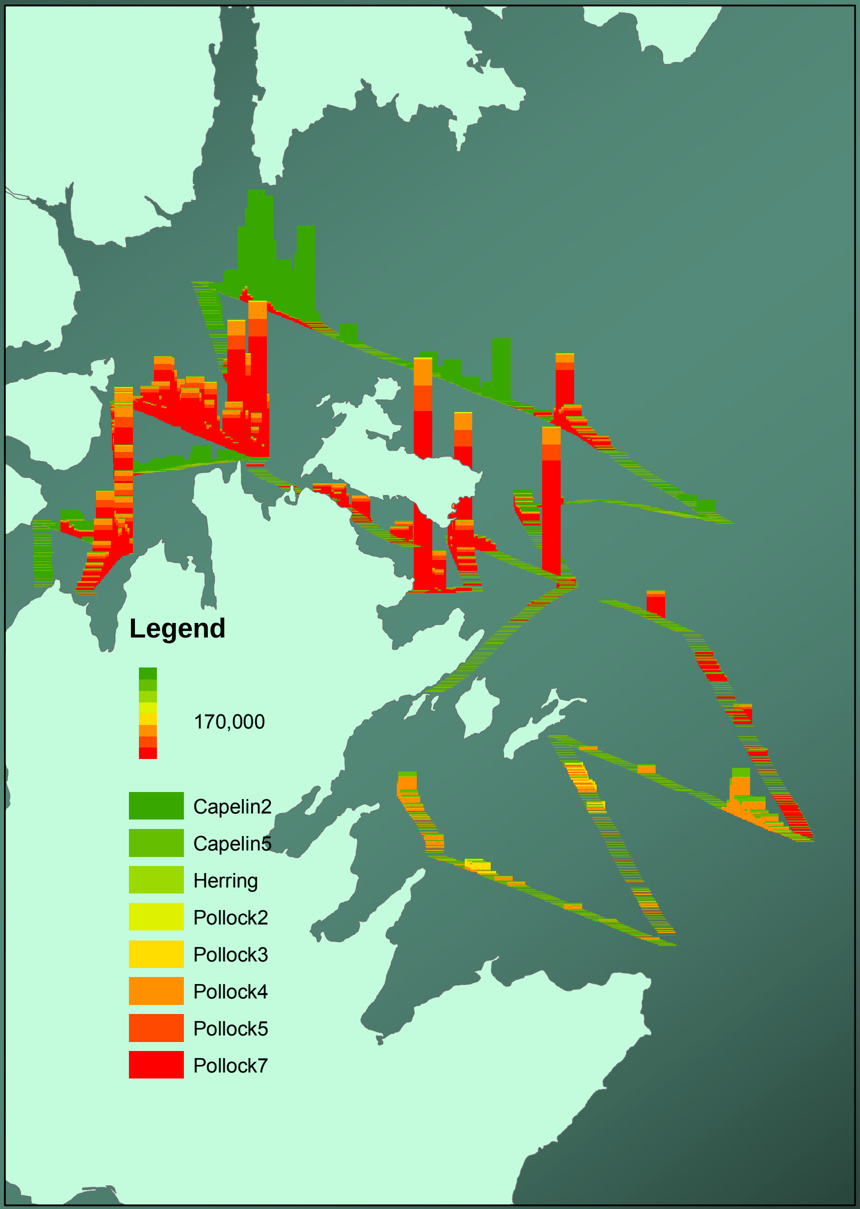
July 2002 pelagic



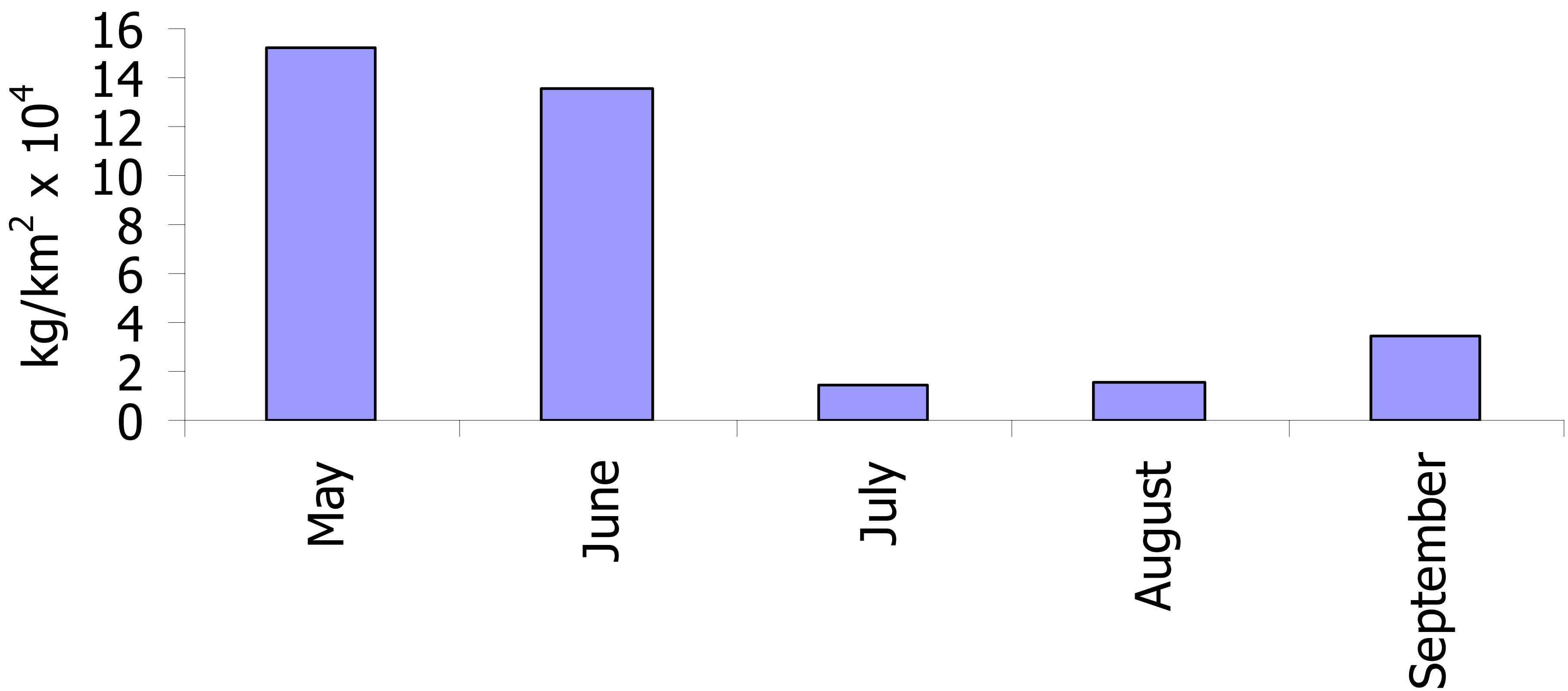
August 2002 pelagic

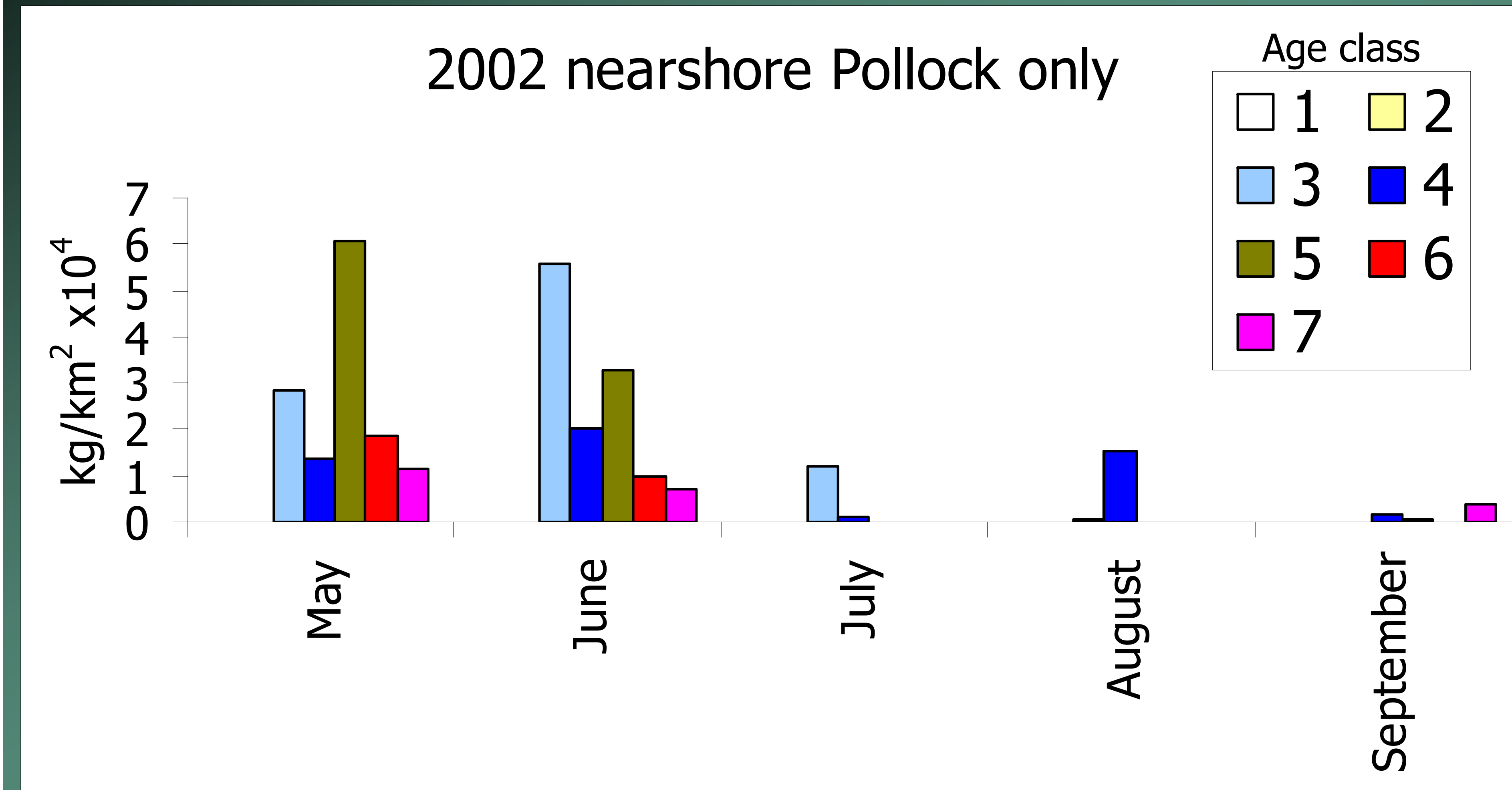


September 2002 pelagic



2002 nearshore all pelagics





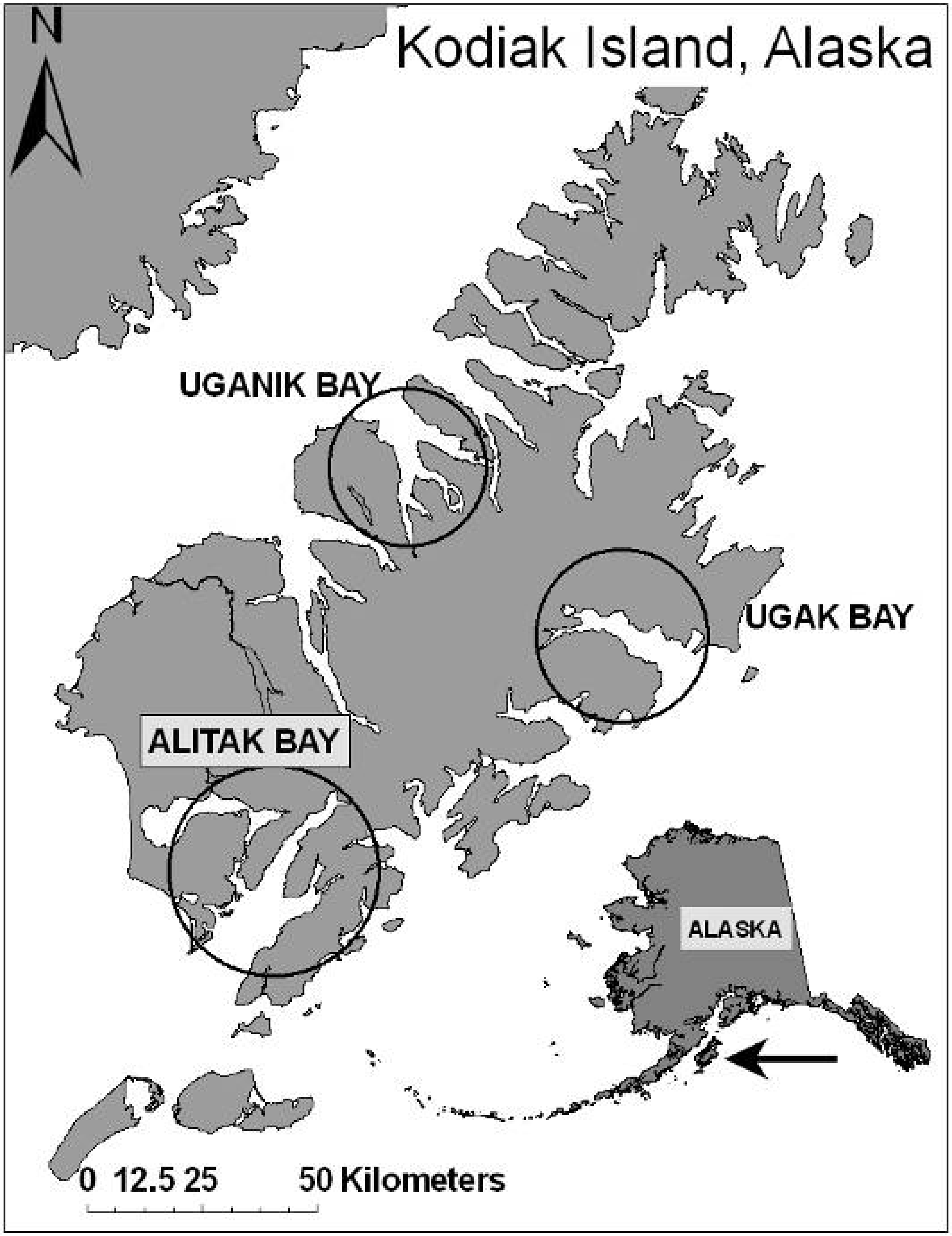
2002 nearshore Pollock only
Age class
1
2
3
4
5
6
7
kg/km2 x10^4
0
1
2
3
4
5
6
7
May
June
July
August
September

So What to a SSL?

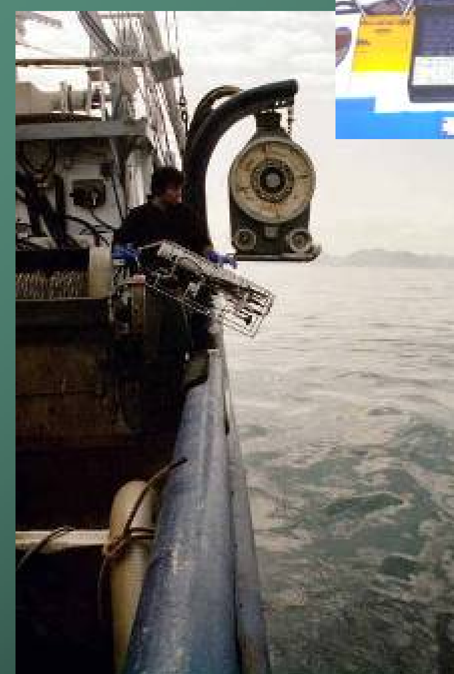
4. What is the relative availability of fish species directly next to a haulout?

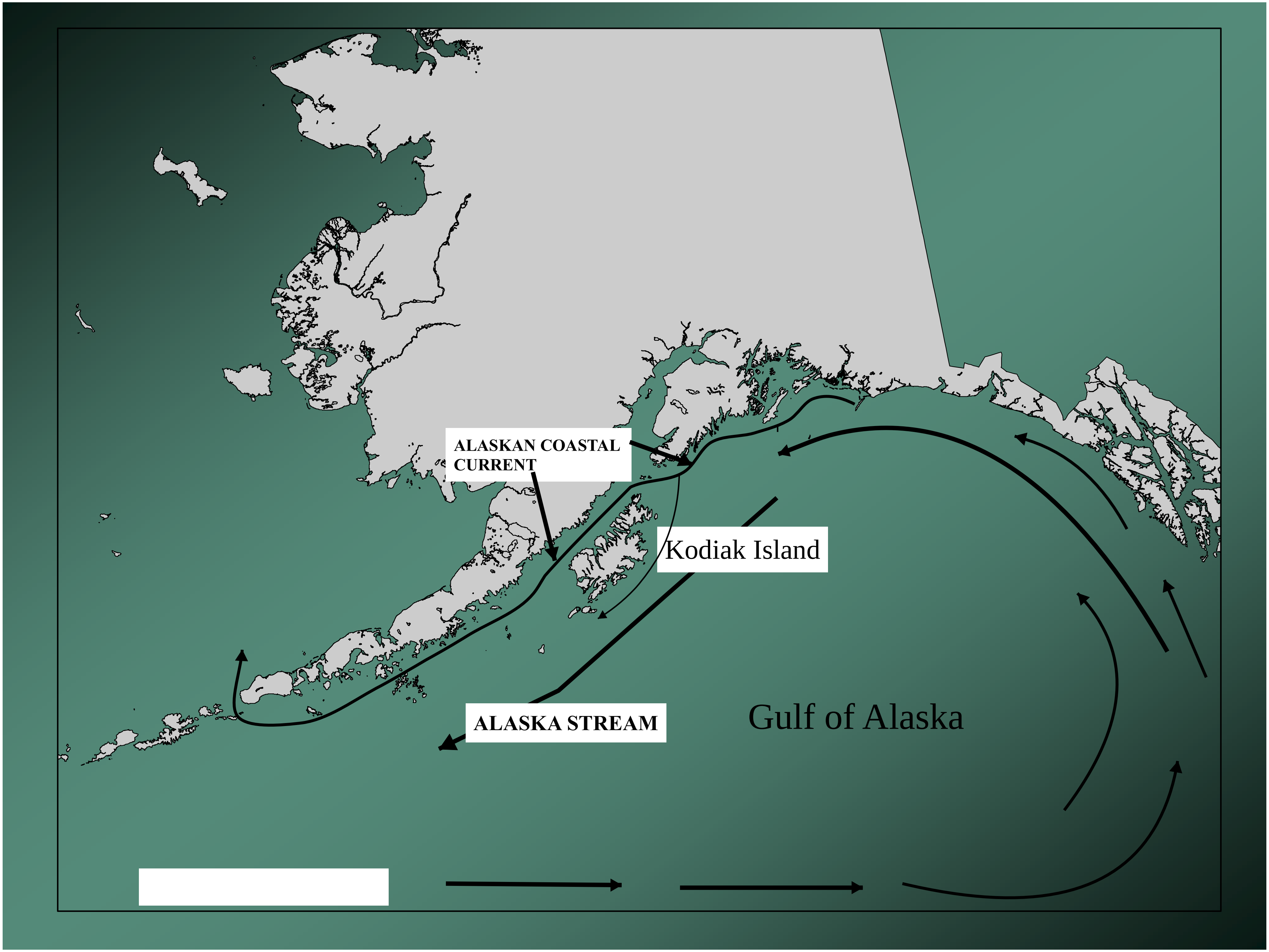
Abundance and distribution of herring and pollock inside 3 bays within the Kodiak Archipelago

Mary Beth Loewen and Robert Foy



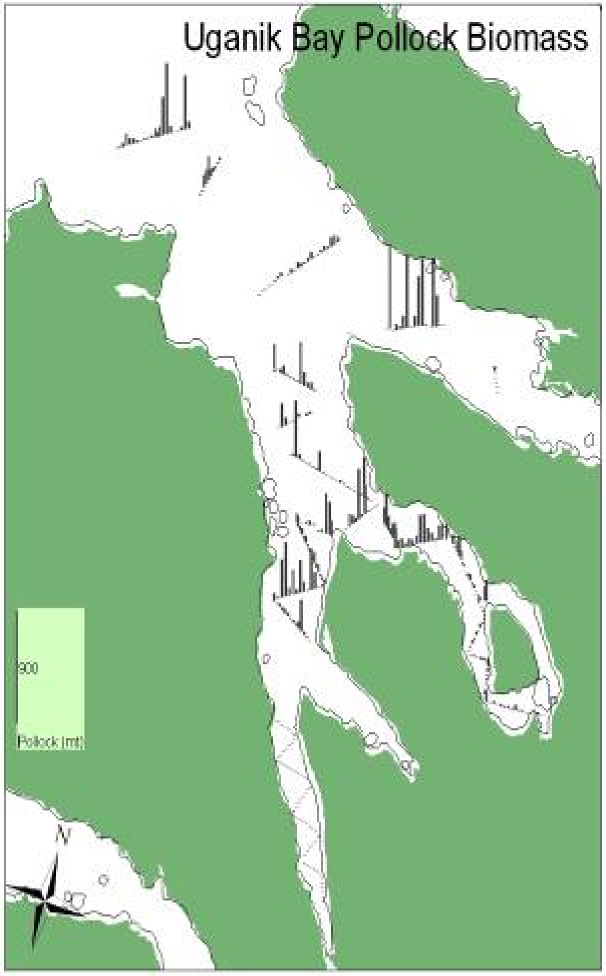
Acoustic and oceanography surveys



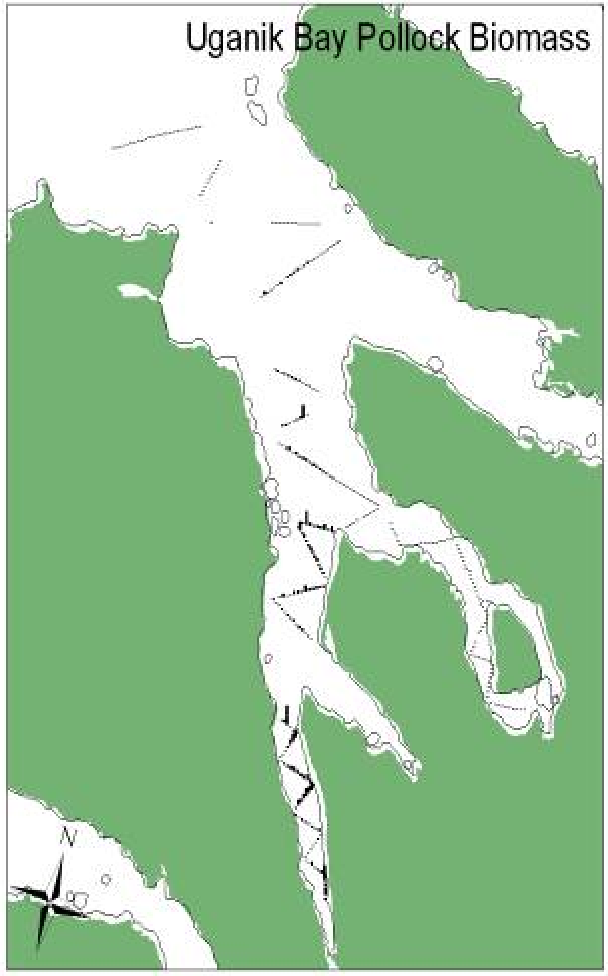

ALASKAN COASTAL CURRENT
Kodiak Island
ALASKA STREAM
Gulf of Alaska

Pollock Distribution 2003

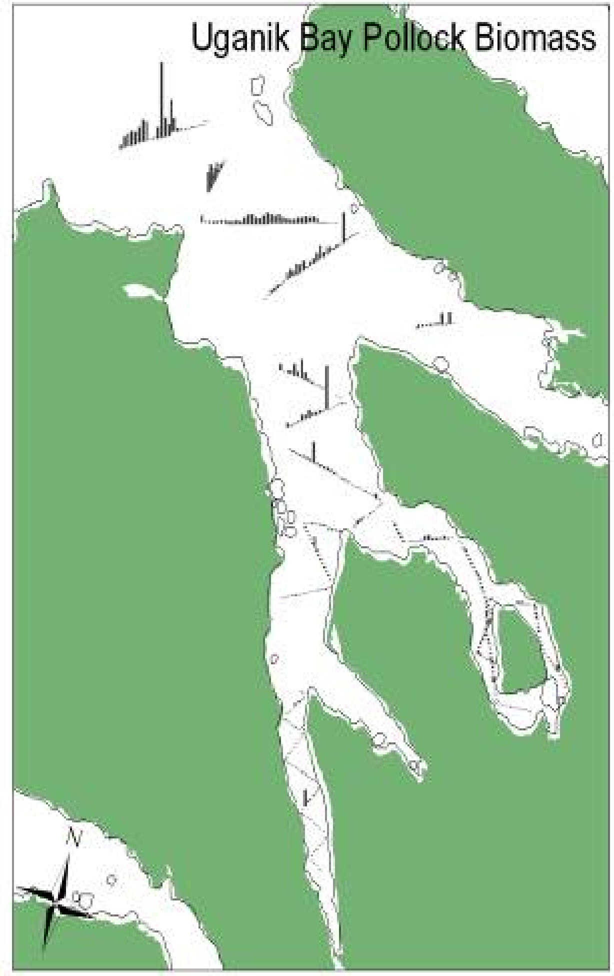
February



May



August



Pollock Distribution 2003

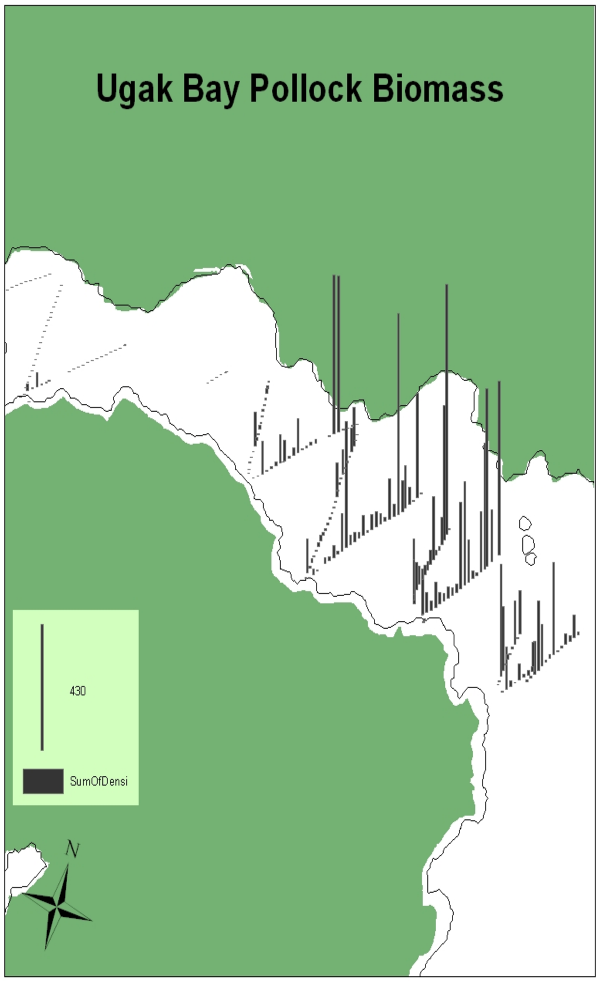
February

May

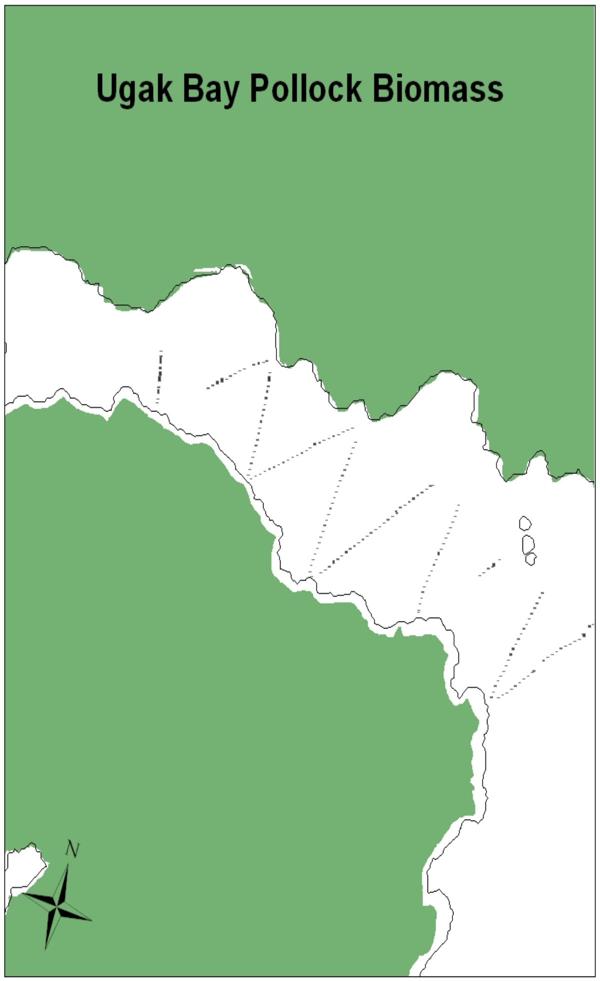
August

Pollock Distribution 2003

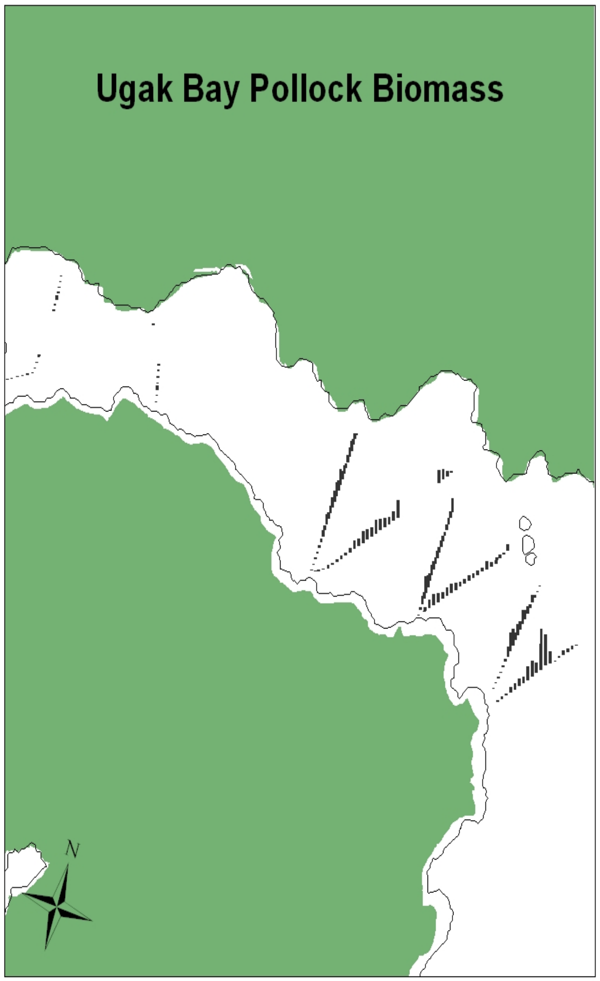
February



May



August



So What to a SSL?

- Seasonal availability of pollock coincides with SSL use of bays.

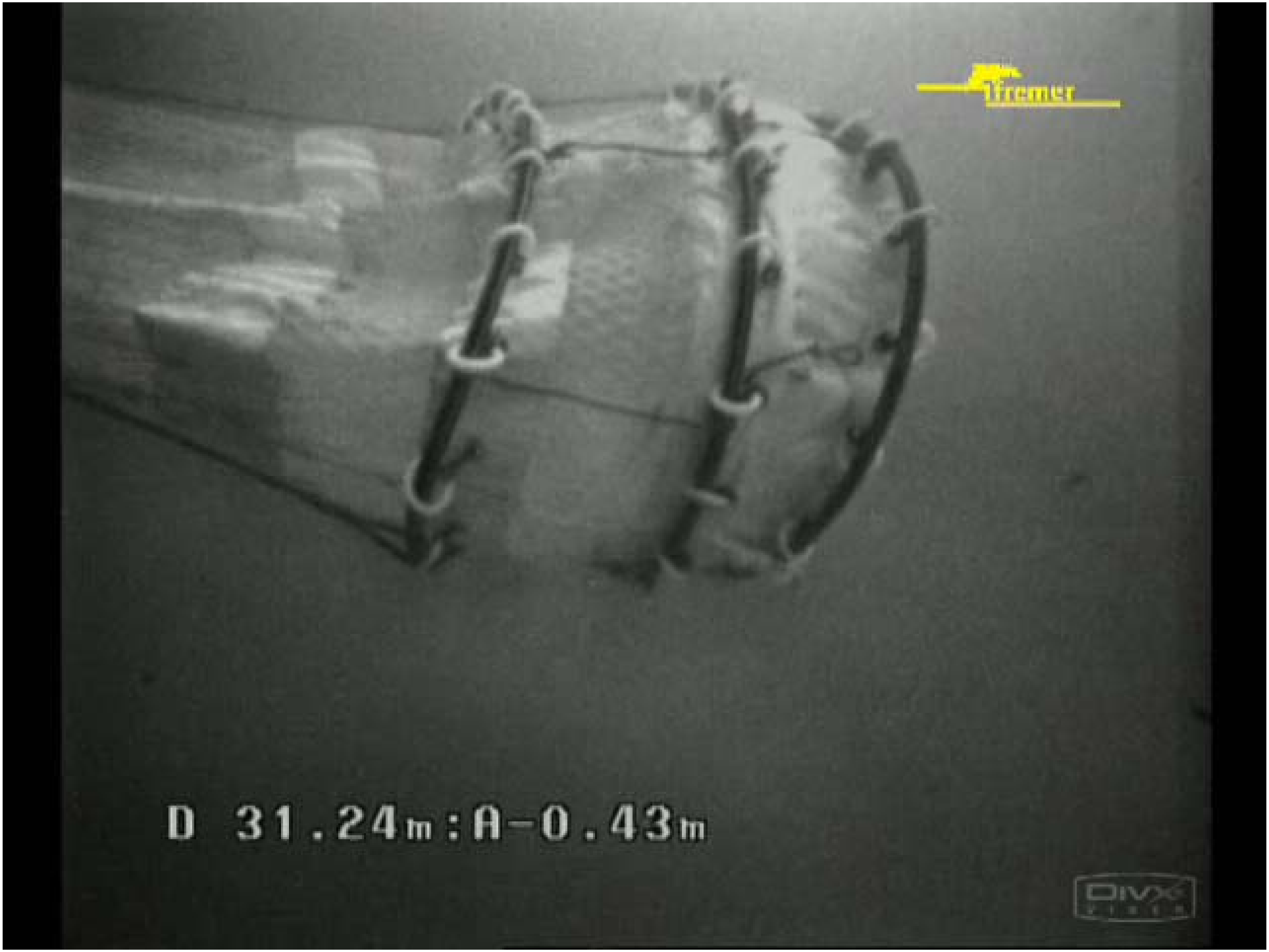
Factors influencing the mortality of tagged walleye pollock captured with a modified trawl net

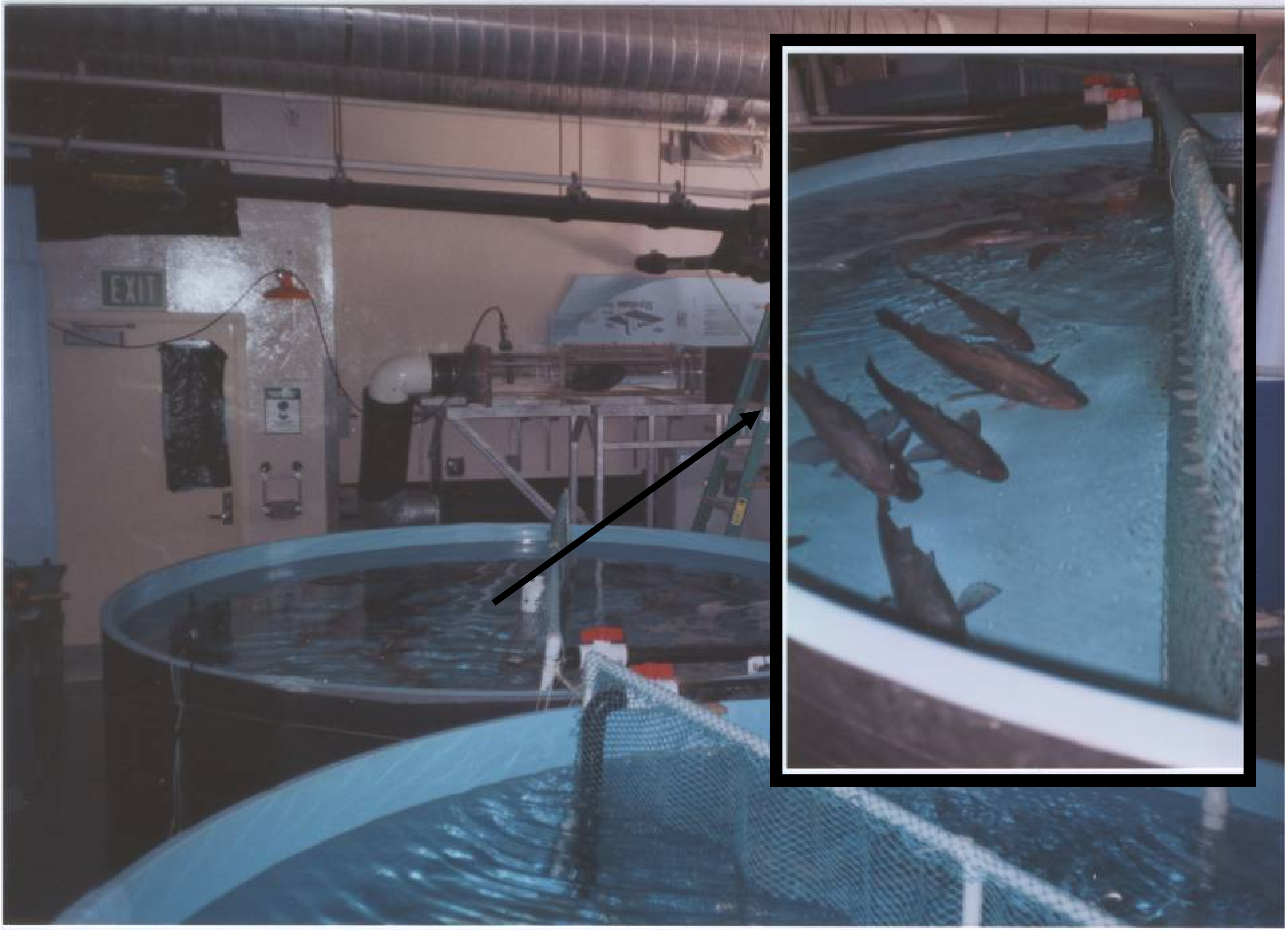
Robert J. Foy and Andreas Winter
School of Fisheries and Ocean Sciences, UAF

Martin Dorn and Anne Hollowed
Alaska Fisheries Science Center, NMFS, NOAA

Background

- Seasonal movements of walleye pollock (*Theragra chalcogramma*) are not well known
- Spatially explicit stock assessments would benefit from this information
- Pollock spawn in large aggregations relatively deep for methods of capture.
- Pollock are sensitive to trawl stress (Ryer 2002)


Ifremer
D 31.24m:A-0.43m
DIVX


EXIT

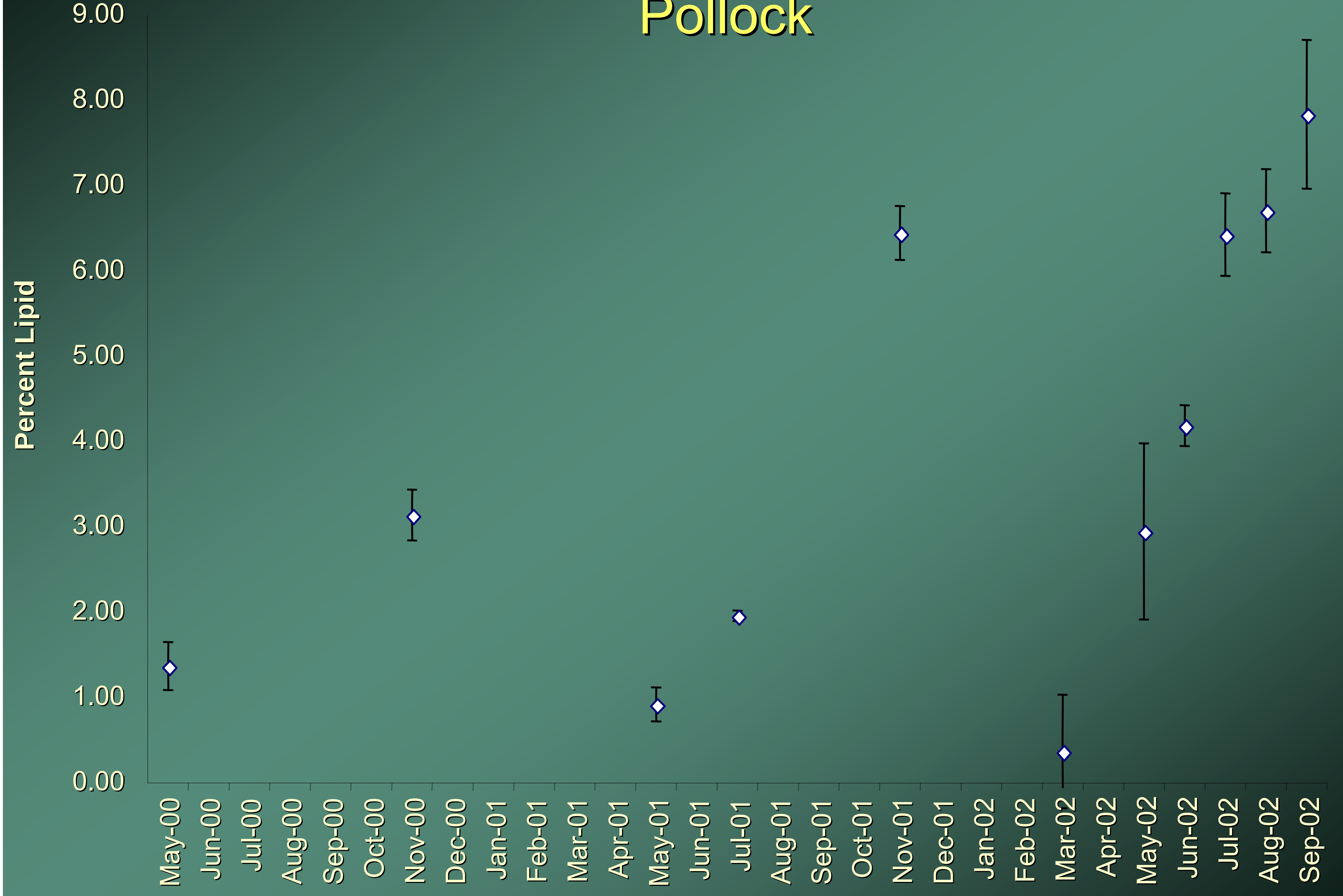
So What to a SSL?

- Do prey stocks fluctuate locally due to migration? Stay tuned
- Are spawning stocks of pollock discreet? Stay tuned

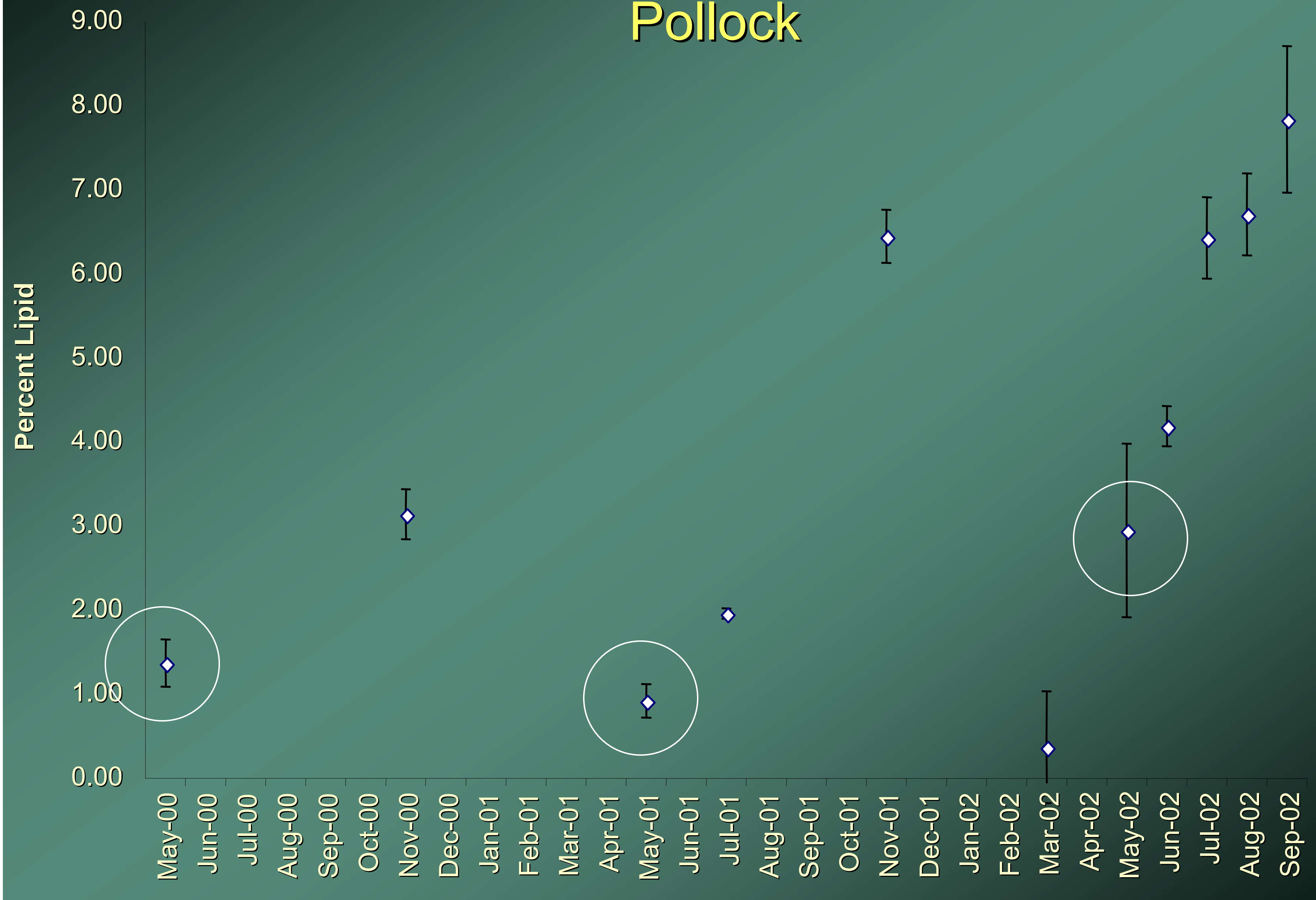
Proximate composition (energetic value) of important Steller sea lion prey

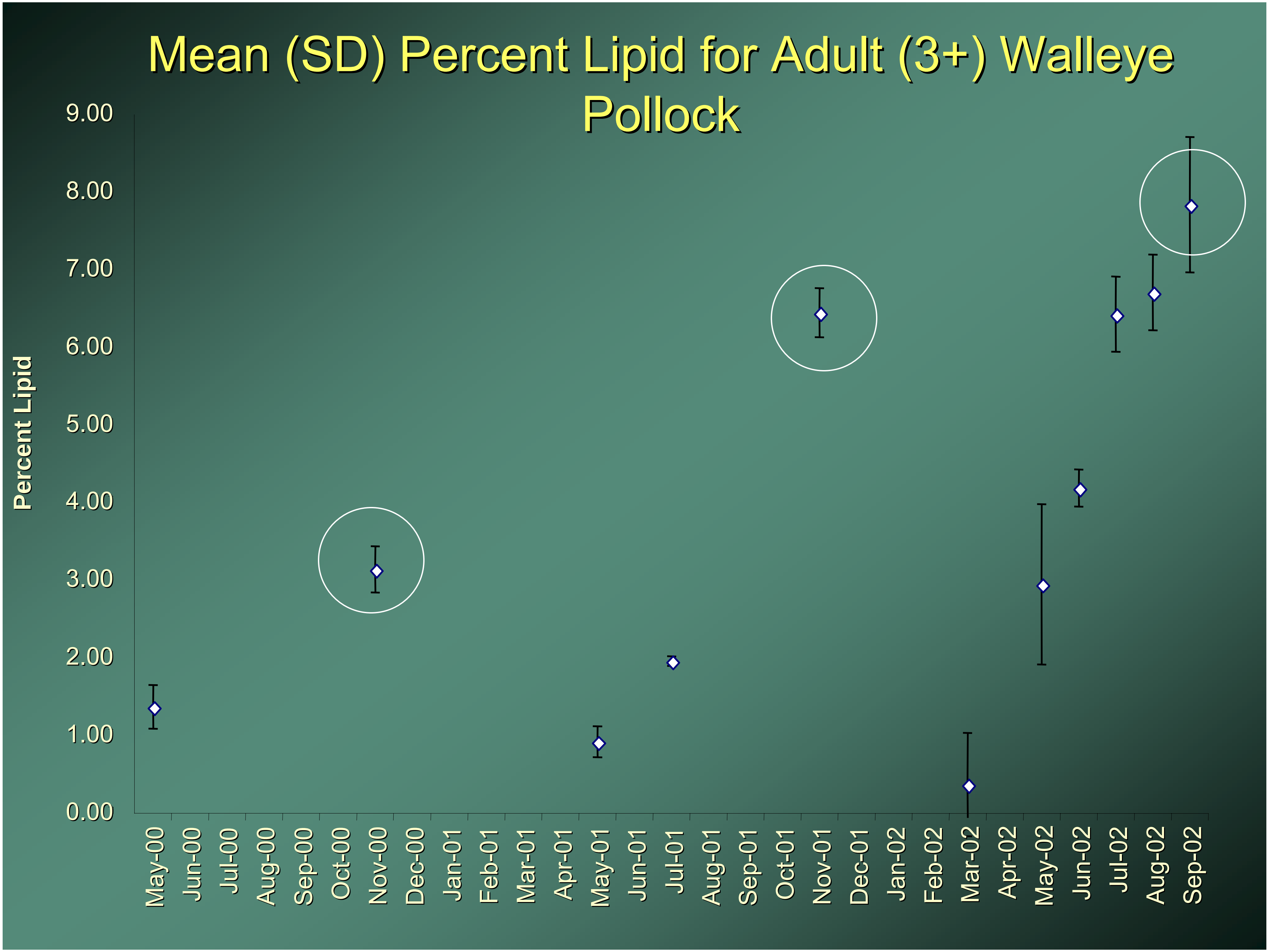
Robert Foy

Mean (SD) Percent Lipid for Adult (3+) Walleye Pollock

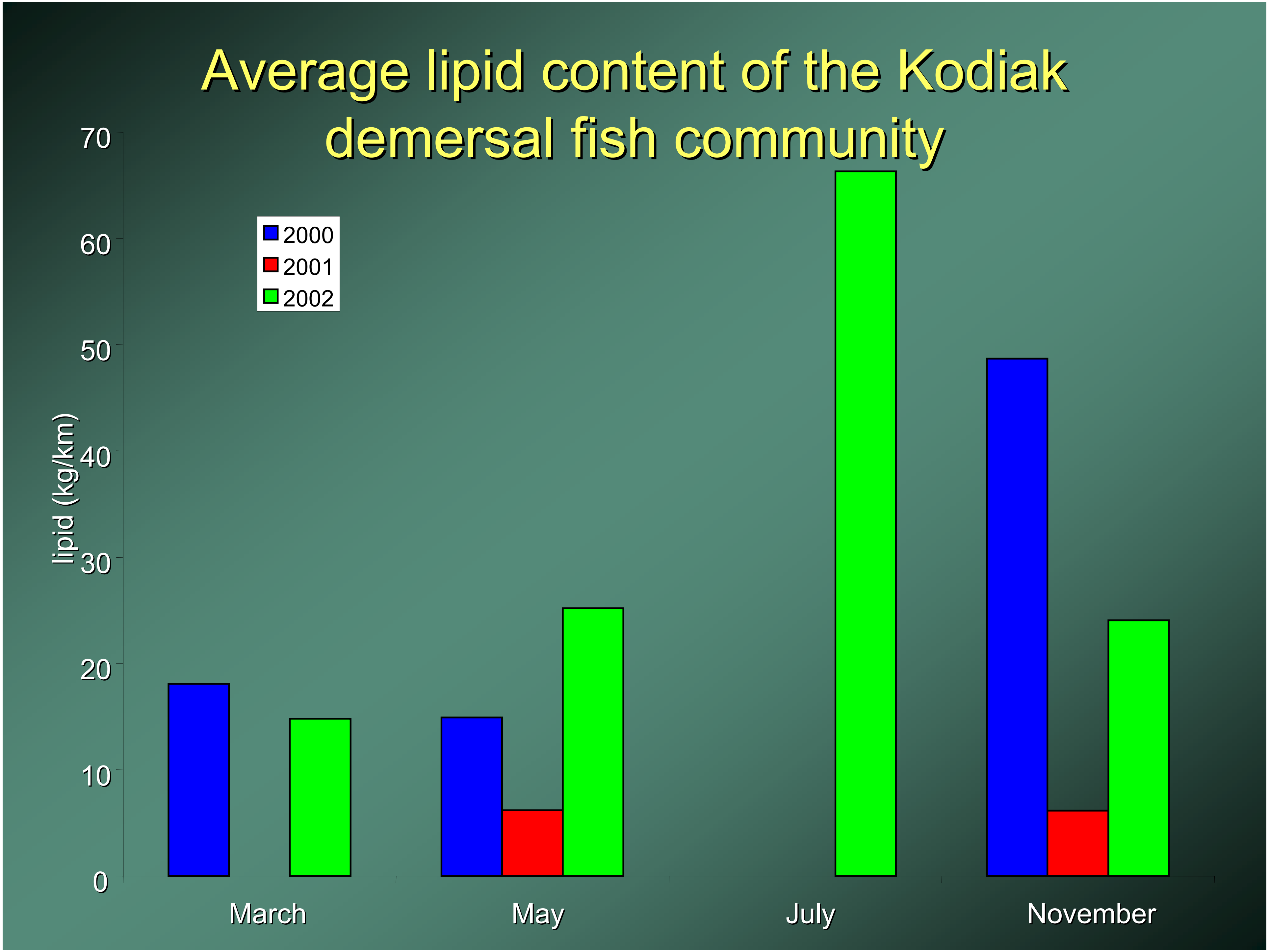


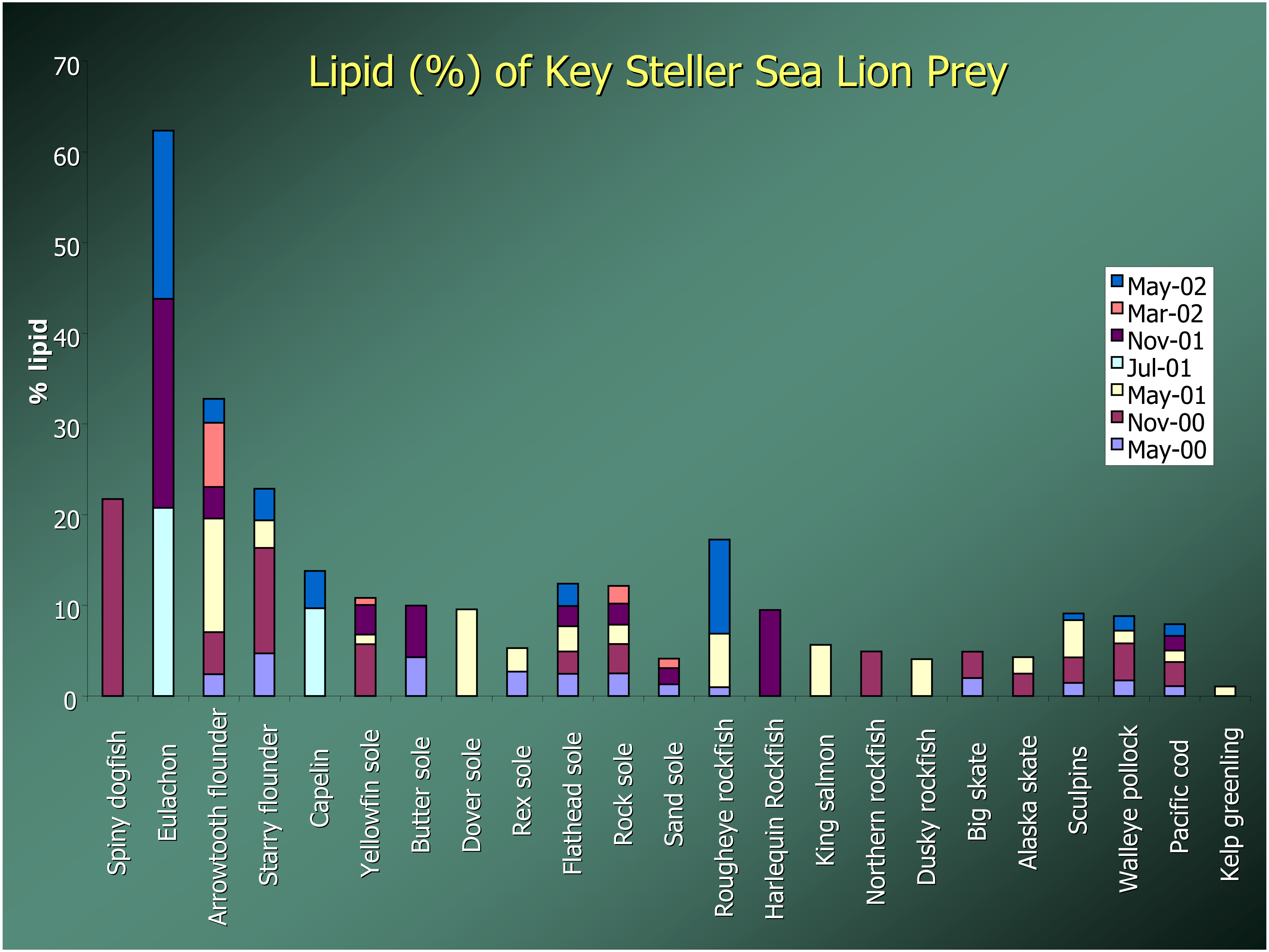
Mean (SD) Percent Lipid for Adult (3+) Walleye Pollock





Mean (SD) Percent Lipid for Adult (3+) Walleye Pollock
Percent Lipid
9.00
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
May-00
Jun-00
Jul-00
Aug-00
Sep-00
Oct-00
Nov-00
Dec-00
Jan-01
Feb-01
Mar-01
Apr-01
May-01
Jun-01
Jul-01
Aug-01
Sep-01
Oct-01
Nov-01
Dec-01
Jan-02
Feb-02
Mar-02
Apr-02
May-02
Jun-02
Jul-02
Aug-02
Sep-02


Average lipid content of the Kodiak demersal fish community
lipid (kg/km)
0
10
20
30
40
50
60
70
2000
2001
2002
March
May
July
November

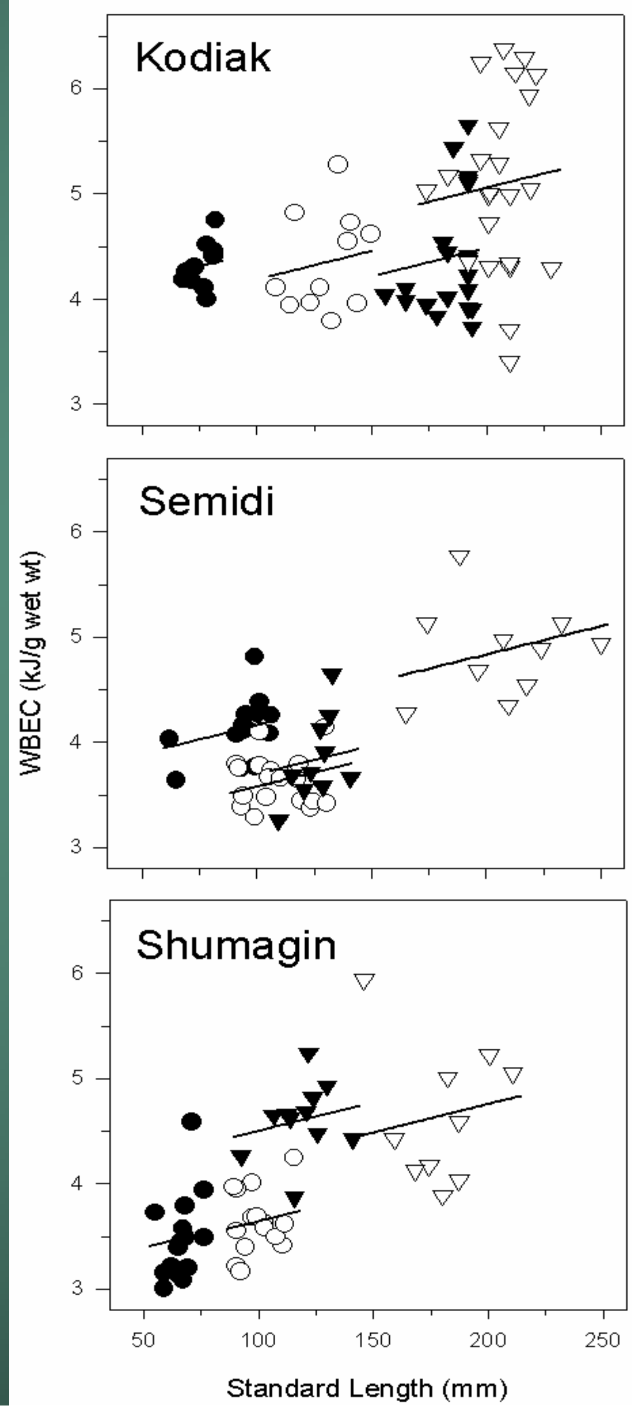

Lipid (%) of Key Steller Sea Lion Prey
% lipid
0
10
20
30
40
50
60
70
May-02
Mar-02
Nov-01
Jul-01
May-01
Nov-00
May-00
Spiny dogfish
Eulachon
Arrowtooth flounder
Starry flounder
Capelin
Yellowfin sole
Butter sole
Dover sole
Rex sole
Flathead sole
Rock sole
Sand sole
Rougheye rockfish
Harlequin Rockfish
King salmon
Northern rockfish
Dusky rockfish
Big skate
Alaska skate
Sculpins
Walleye pollock
Pacific cod
Kelp greenling

Pollock

Whole-body energy content versus standard length

Buchheister, A., M. T. Wilson, R. J. Foy, and D. A. Beauchamp. 2006. Seasonal and geographic variation in condition of juvenile walleye pollock in the Western Gulf of Alaska. Transactions of the American Fisheries Society. 135:897-907.

autumn 2000 (filled circles)
winter 2001 (open circles)
summer 2001 (filled triangles)
autumn 2001 (open triangles)

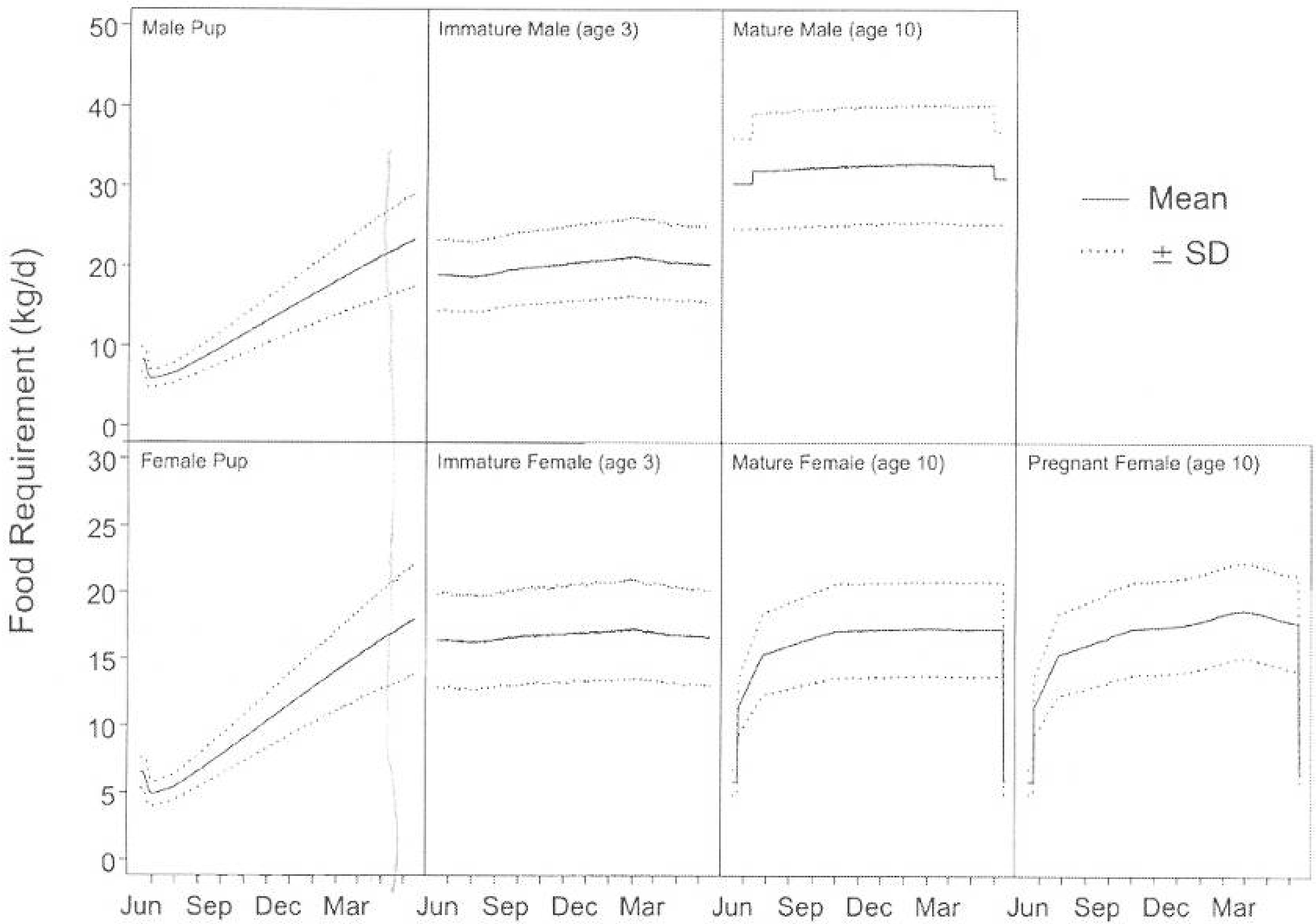


Bioenergetics

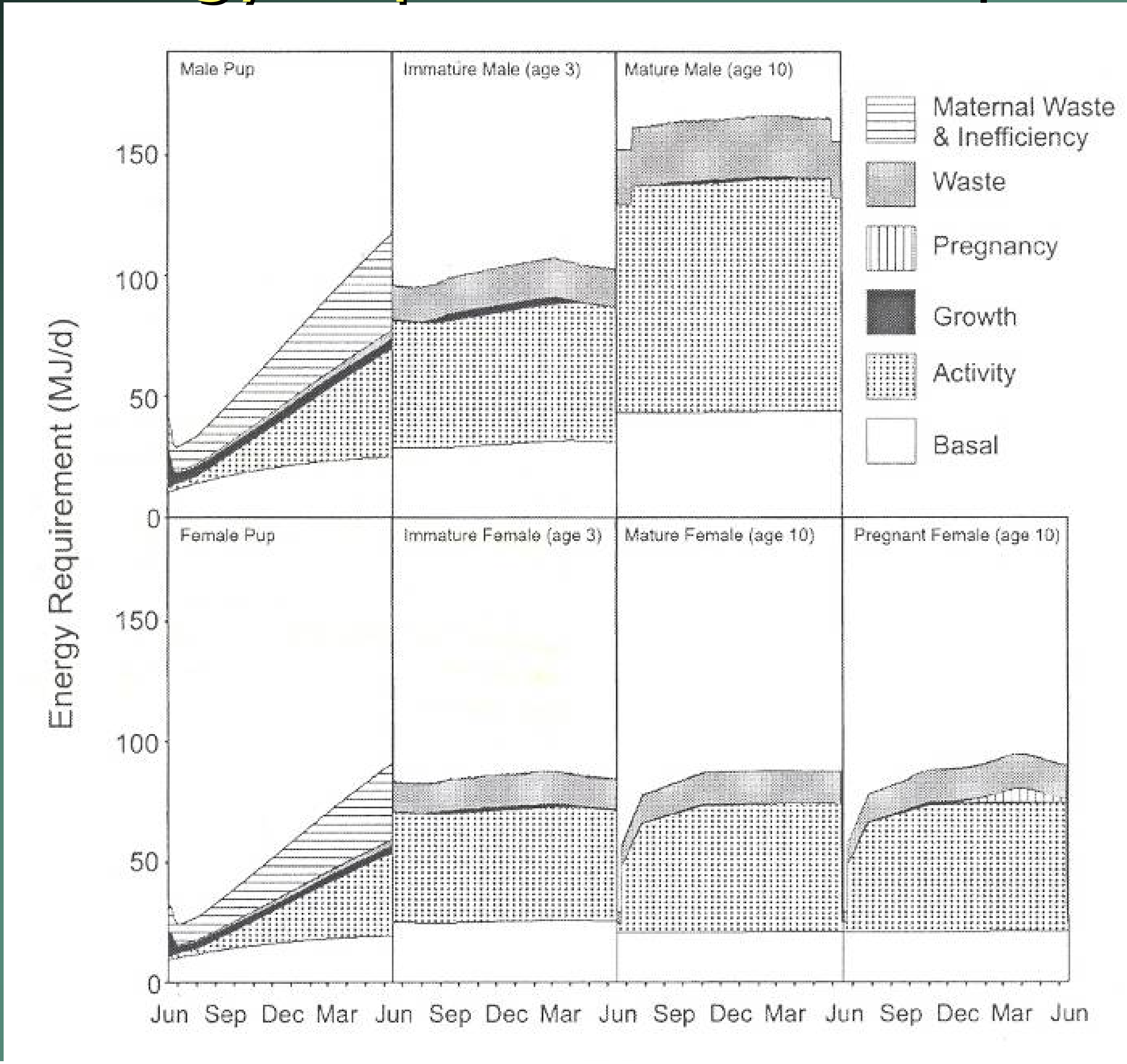
- Combine physiological data, environmental data for individual fish extrapolated tot eh entire population to estimate fish growth.
- Is there enough energy for specific life stages of SSL?
- Is it appropriate to rerun an existing bioenergetic model on SSL for a discreet region (Kodiak)

Robert Foy

SSL food requirements Winship et al. 2002



SSL energy requirements Winship et al. 2002



So What to a SSL?

- Is there enough energy available to sustain local SSL population? Stay tuned

4. How does the energy density of potential prey (pollock) fluctuate between haulout sites (regions?) substantially

Competition hypothesis: So what is the competition for food?

- Sub-hypothesis: Competitors of SSL prey do not overlap in prey composition and/or require forage at different scale.

1. Do other apex predators feed at same trophic level as SSLs?
2. Do other apex predators remove similar biomass of prey?
3. How do these removals compare to commercial removals?

Humpback and Fin Whales: foraging habitat and prey removals

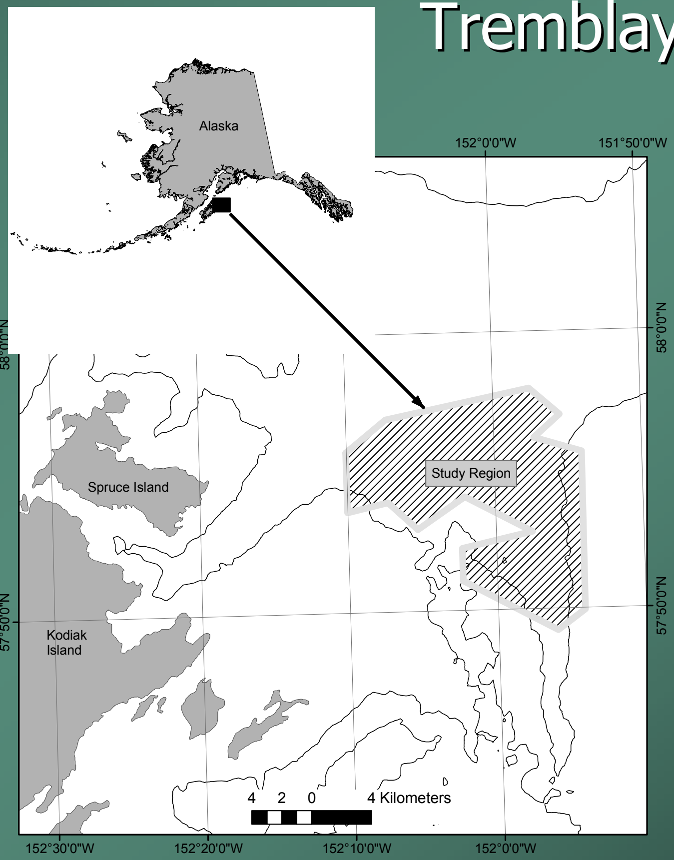
Baraff, L., K. Wynne, and R. J. Foy. MS thesis in prep. Describing physical and biological (zooplankton) habitat associated with humpback and fin whales.

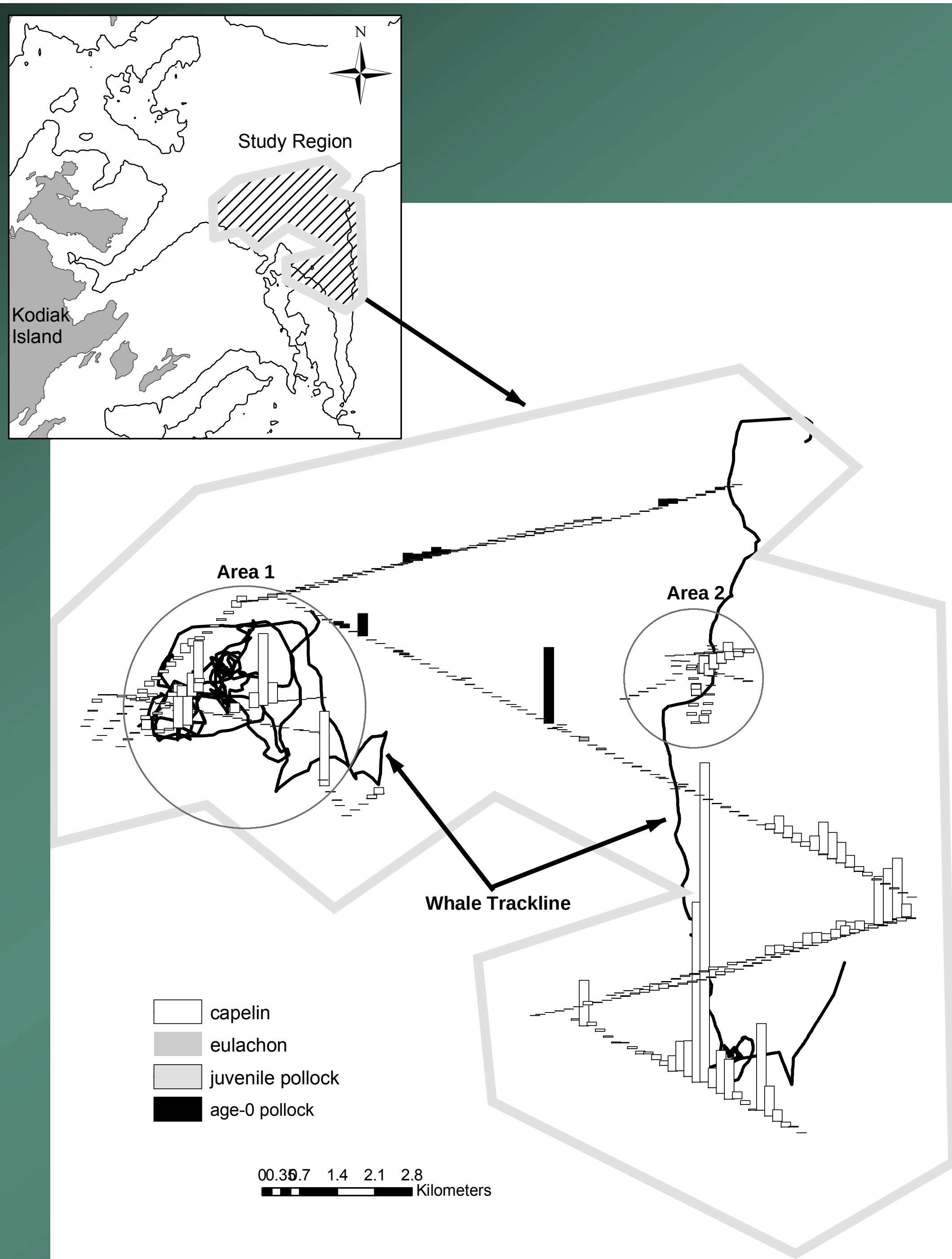
Witteveen, B., R. J. Foy, and K. Wynne. 2006. The effect of predation (current and historical) by humpback whales (*Megaptera novaeangliae*) on fish abundance near Kodiak Island, Alaska. Fishery Bulletin. 104: 10-20.

Witteveen, B., R. J. Foy, K. Wynne, and Yann Tremblay. In Review. Investigation of foraging habits and prey preference of humpback whales (*Megaptera novaeangliae)* near Kodiak Island, Alaska using acoustic tags. Marine Mammal Science.

Investigation of foraging habits and prey selection of humpback whales (*Megaptera novaeangliae)* using acoustic tags and concurrent fish surveys.

Briana H. Witteveen, Robert J. Foy, Kate M. Wynne, Yann Tremblay





N
Study Region
Kodiak Island
Area 1
Area 2
Whale Trackline
capelin
eulachon
juvenile pollock
age-0 pollock
00.350.7 1.4 2.1 2.8
Kilometers

So What to a SSL?

- Whale removals in a local region may be substantial.
- Prey switching in other apex predators may indicate change in prey availaility for SSL.

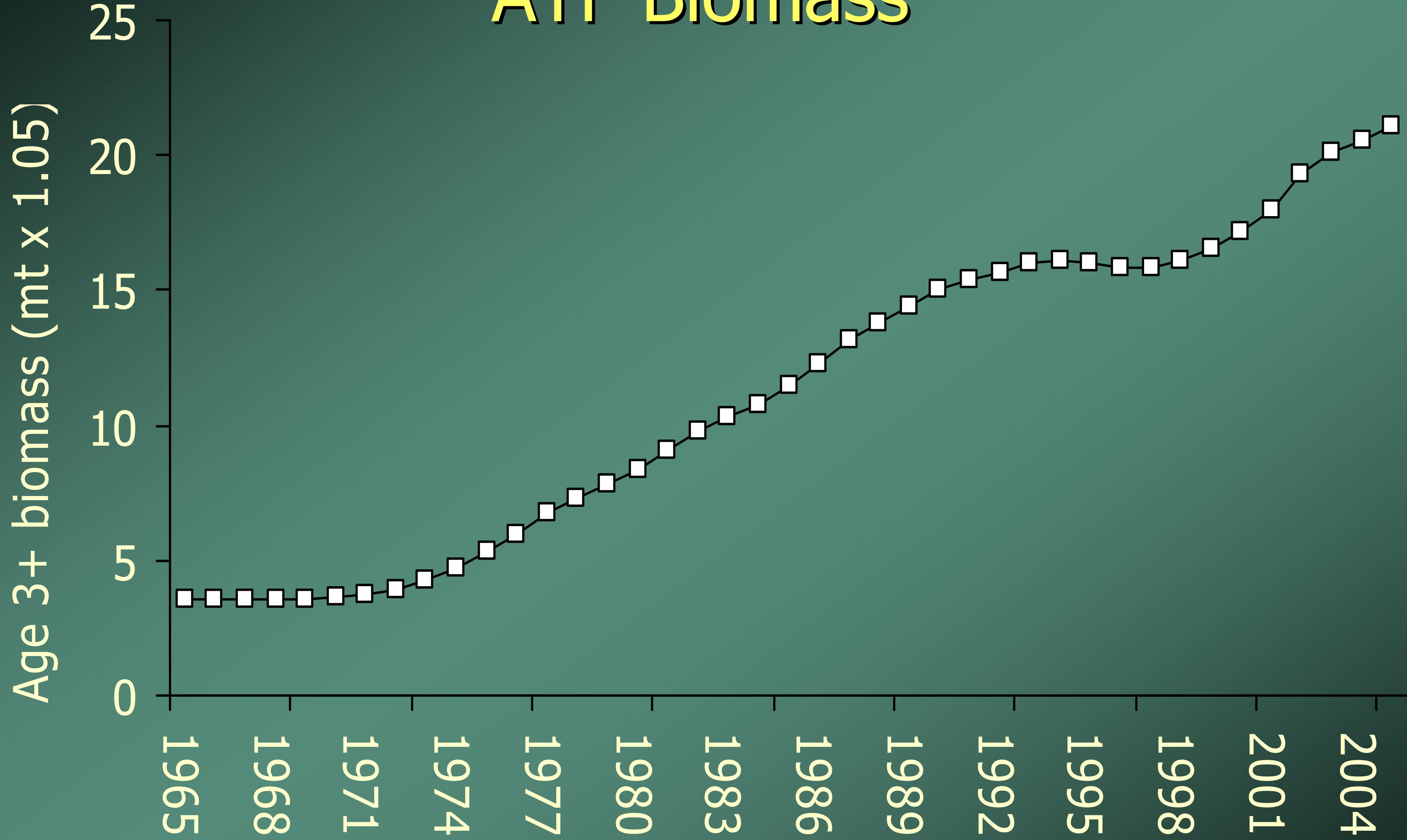
Arrowtooth flounder (*Atheresthes stomias)* diet and prey consumption near Kodiak Island, AK

Knoth, B.K. and R. J. Foy. In Prep. The seasonal and ontogenetic variability in the diets of arrowtooth flounder on the Gulf of Alaska shelf.

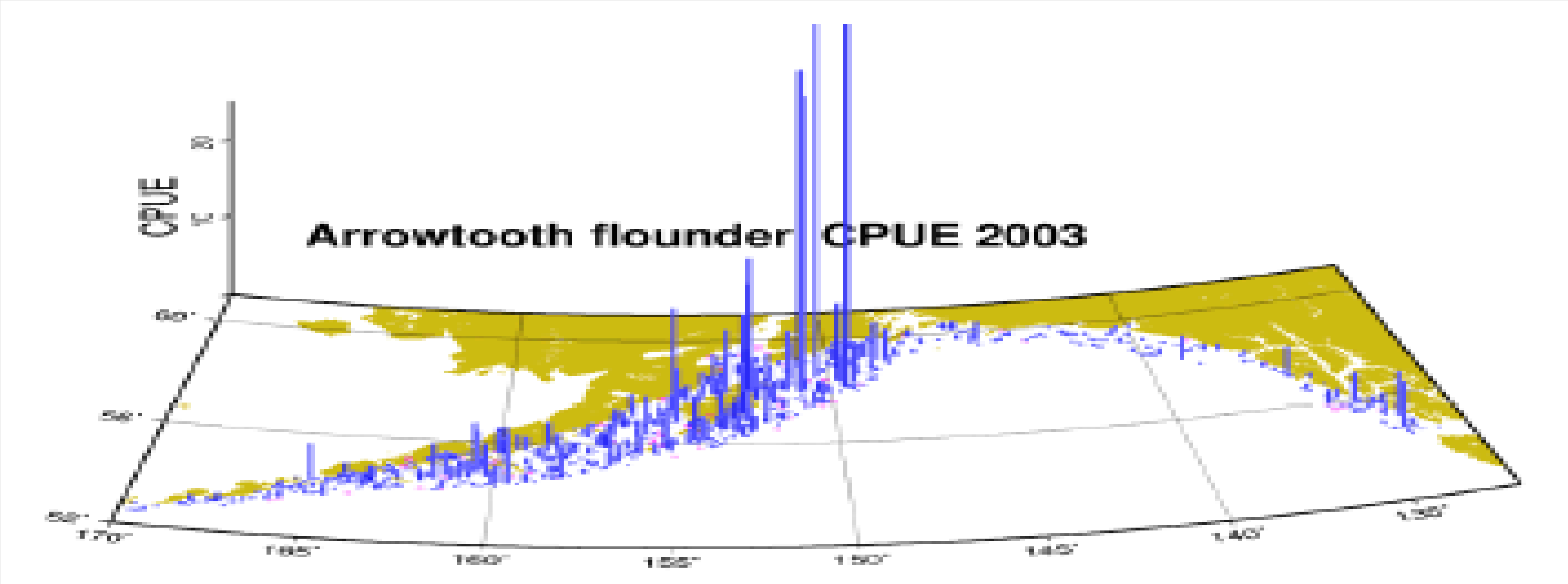
Knoth, B.K. and R. J. Foy. In Prep. The role of arrowtooth flounder as apex predators in the Gulf of Alaska: consumption of important commercial fish species.

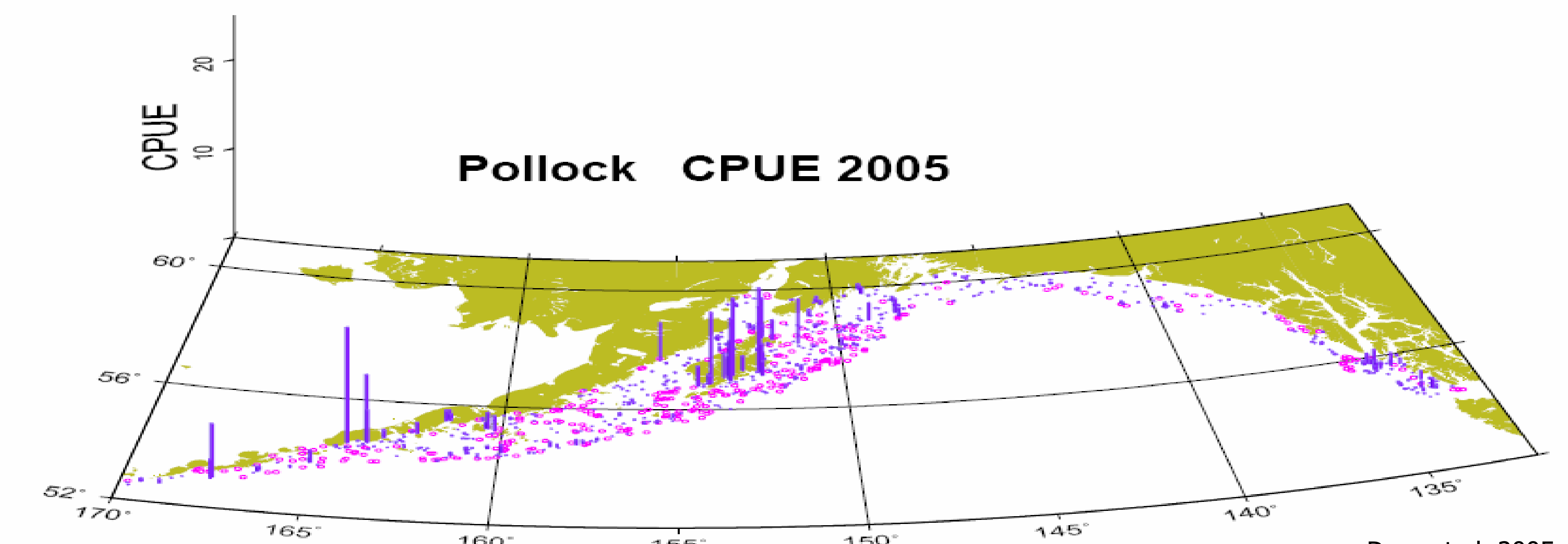
Gulf Apex Predator Prey program
Rasmuson Fisheries Research Center

ATF Biomass



Turnock et al. 2005



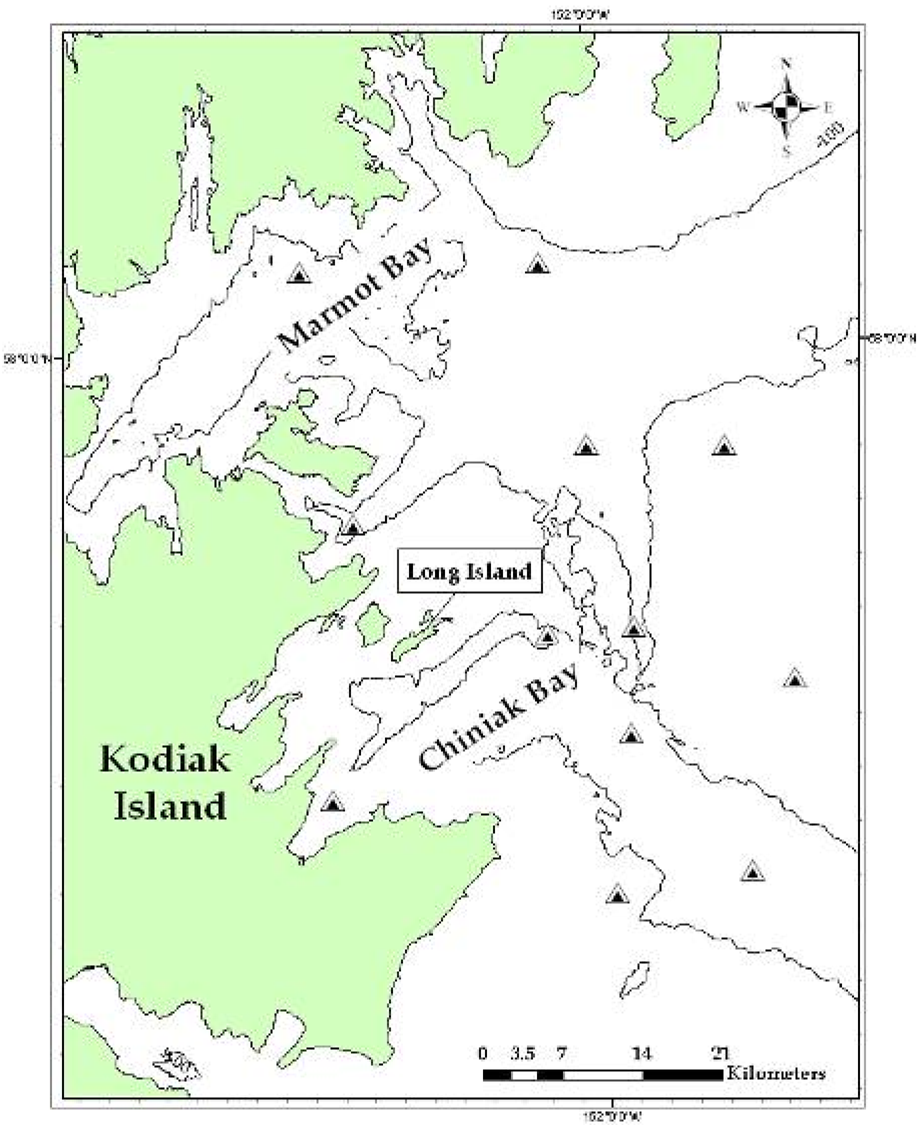


Dorn et al. 2005

ATF Diet

- Main prey: walleye pollock (*Theragra chalcogramma*), capelin (*Mallotus villosus*), and Pacific herring (*Clupea pallasii*) as well as shrimp and euphausiids.
- Ontogenetic dietary shifts
- Prey overlap with SSL

ATF bottom trawl sites



Surveys

- -May and August 2002, 2003, and 2004
- -Bottom trawls
- -Stomach contents

Summary of ATF diet variability

Interannual

- Pacific sand lance only found in significant proportions in 2004, however no strong within year trend
- Size and importance of walleye pollock in ATF diets was the lowest in 2004

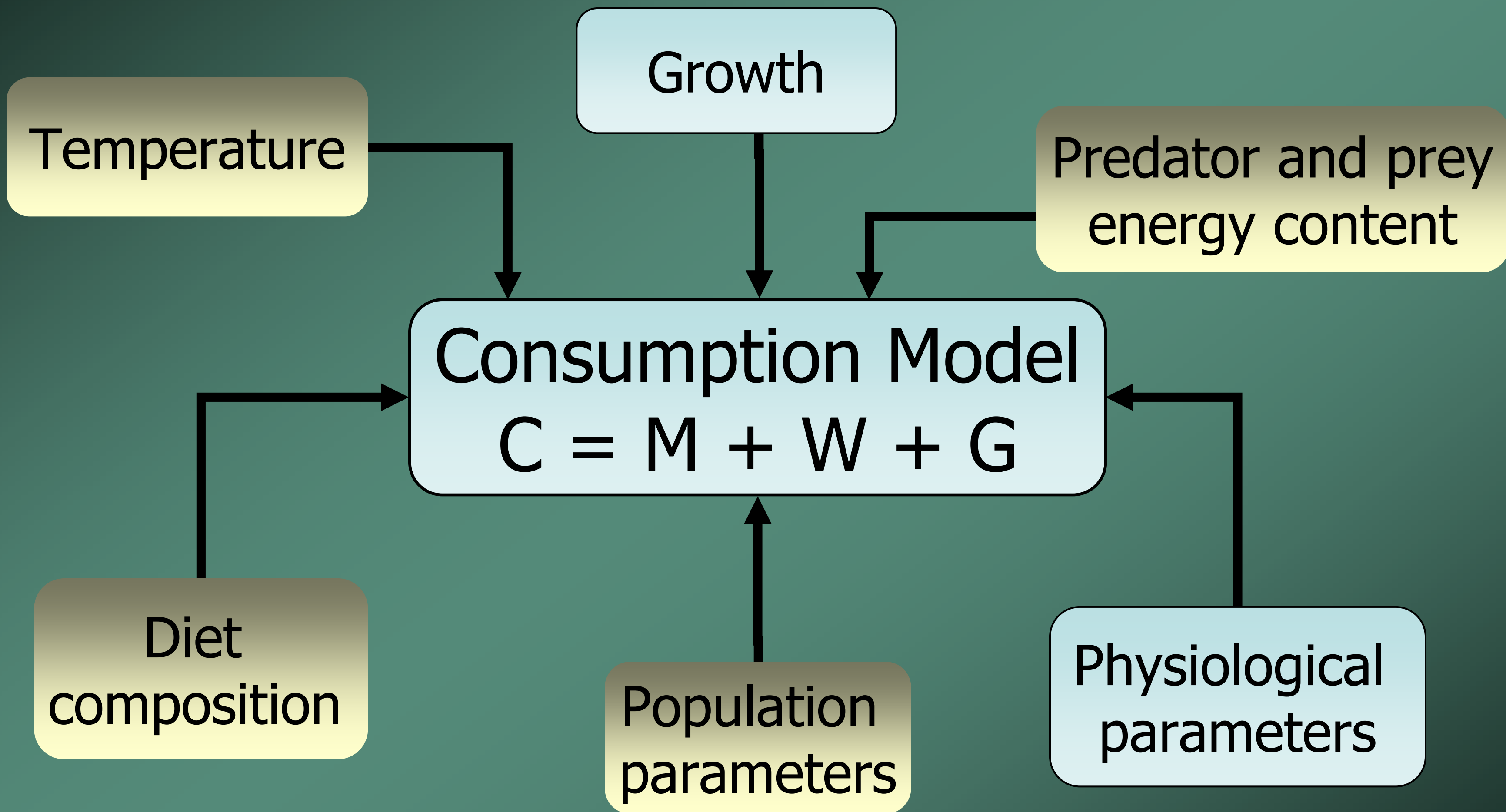
Within year

- Euphausiids more important in May, while capelin more important in August

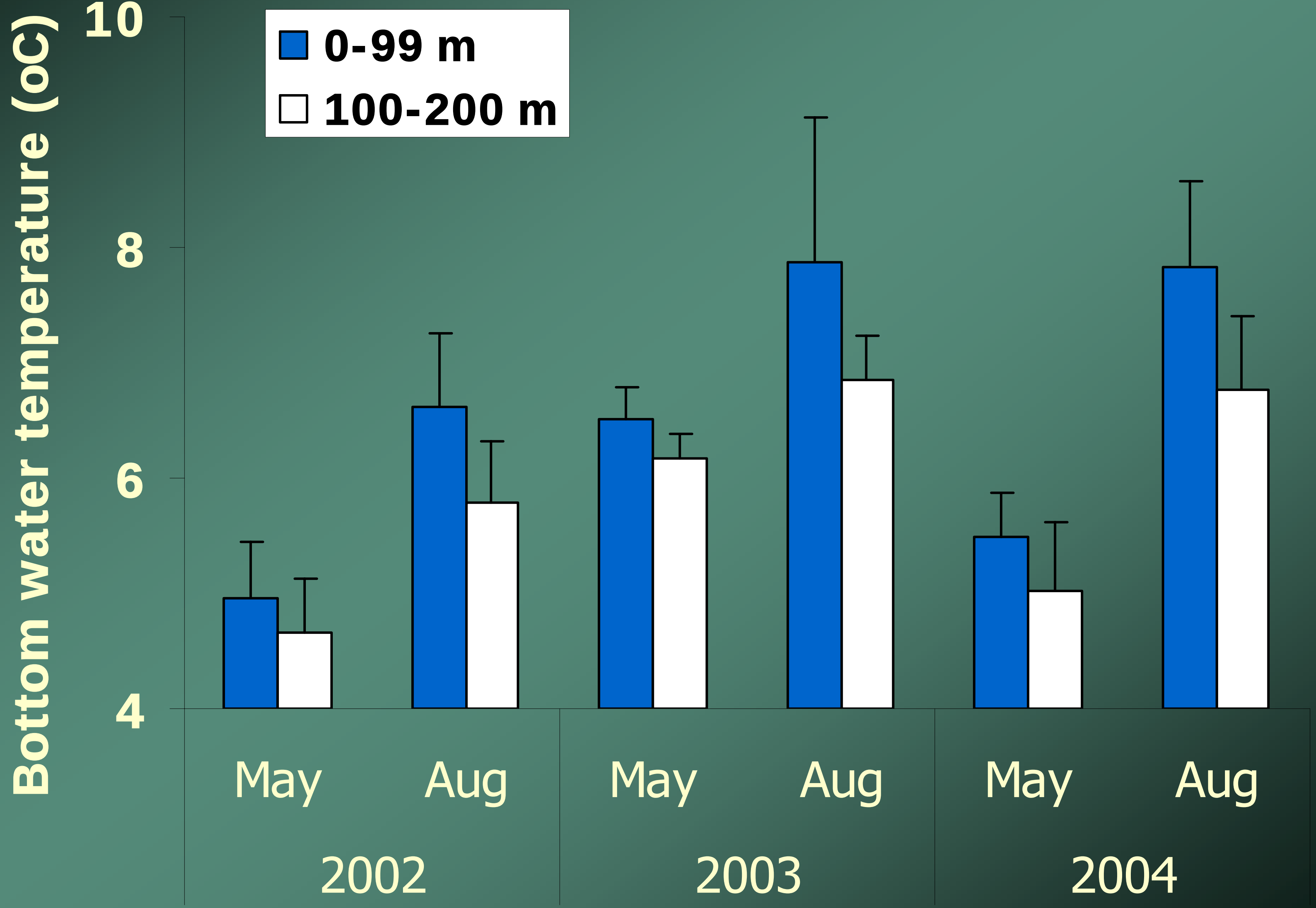
Ontogenetic

- Euphausiids more important for smaller ATF, while walleye pollock and Pacific sand lance more important for larger ATF

ATF consumption



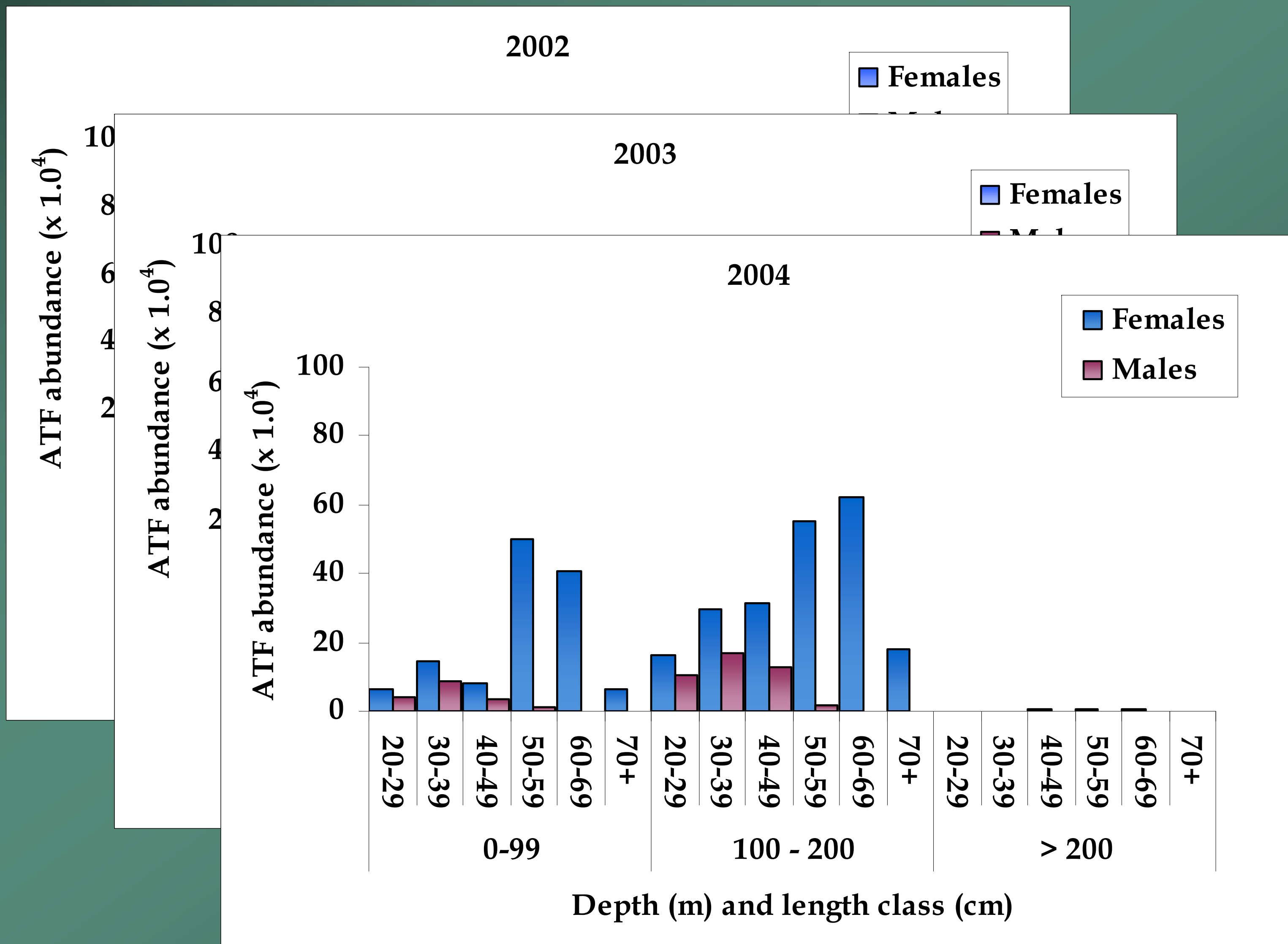
Bottom Temperature



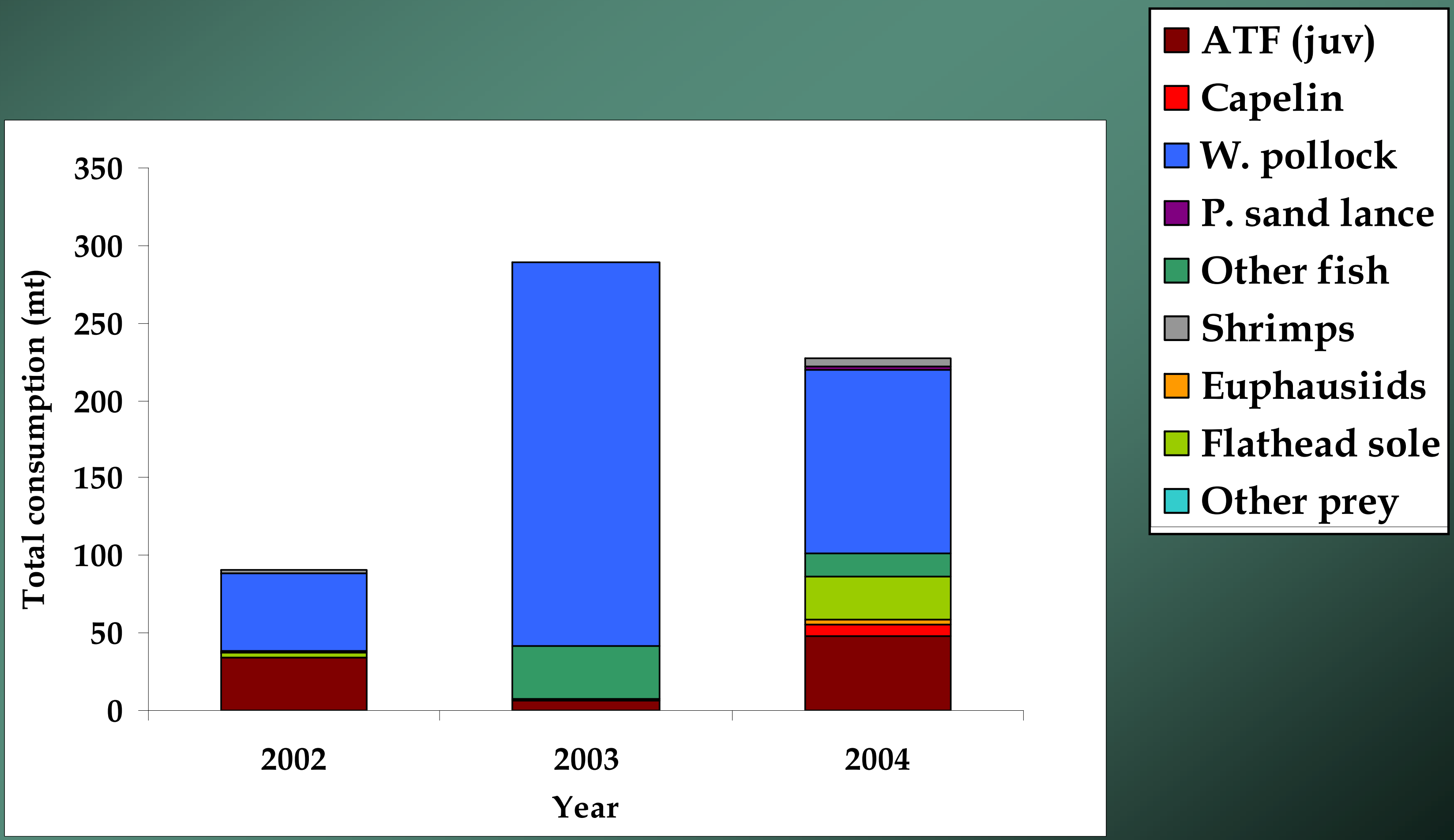
ATF population estimates

- Abundance estimates needed to expand consumption to ATF population in study area
- Used area-swept method (Alverson and Pereyra 1969) to estimate abundance for each depth interval (100 m) of study area
- Segregated into appropriate length and sex classes based on length class structure of ATF catch

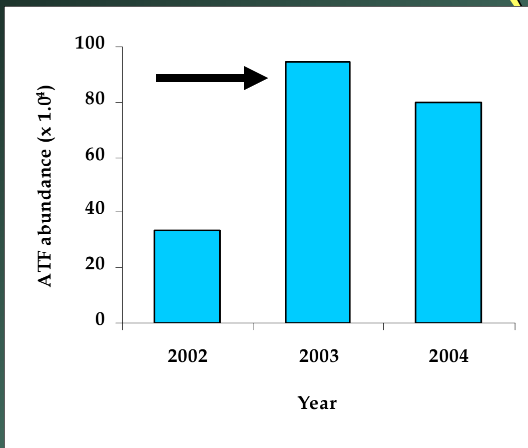
ATF population estimates

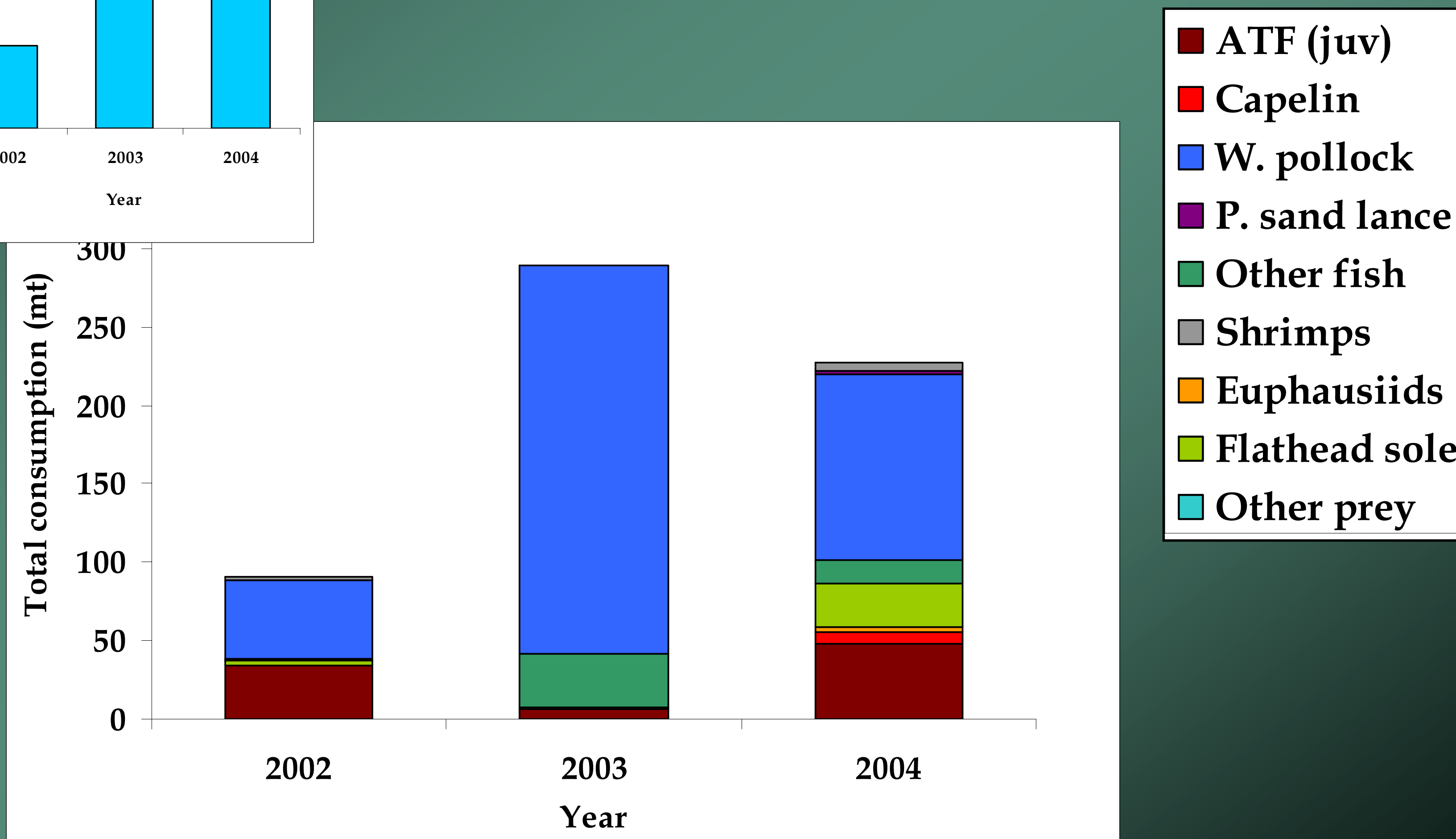


Results- Interannual variations in ATF (≥ 60 cm) consumption rates



Results- Interannual variations in ATF (≥ 60 cm) consumption rates

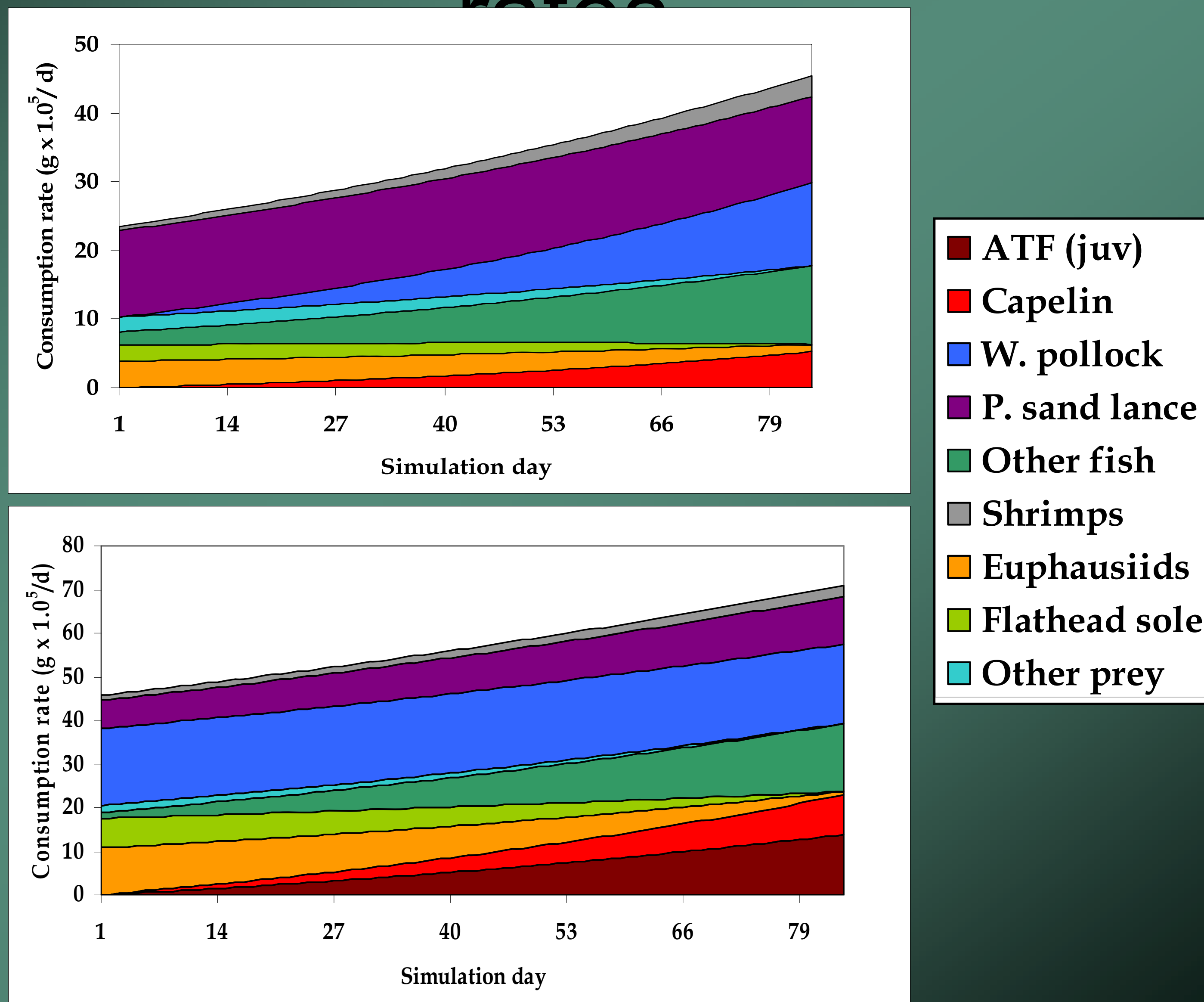




Results- Temporal variations in ATF population consumption rates

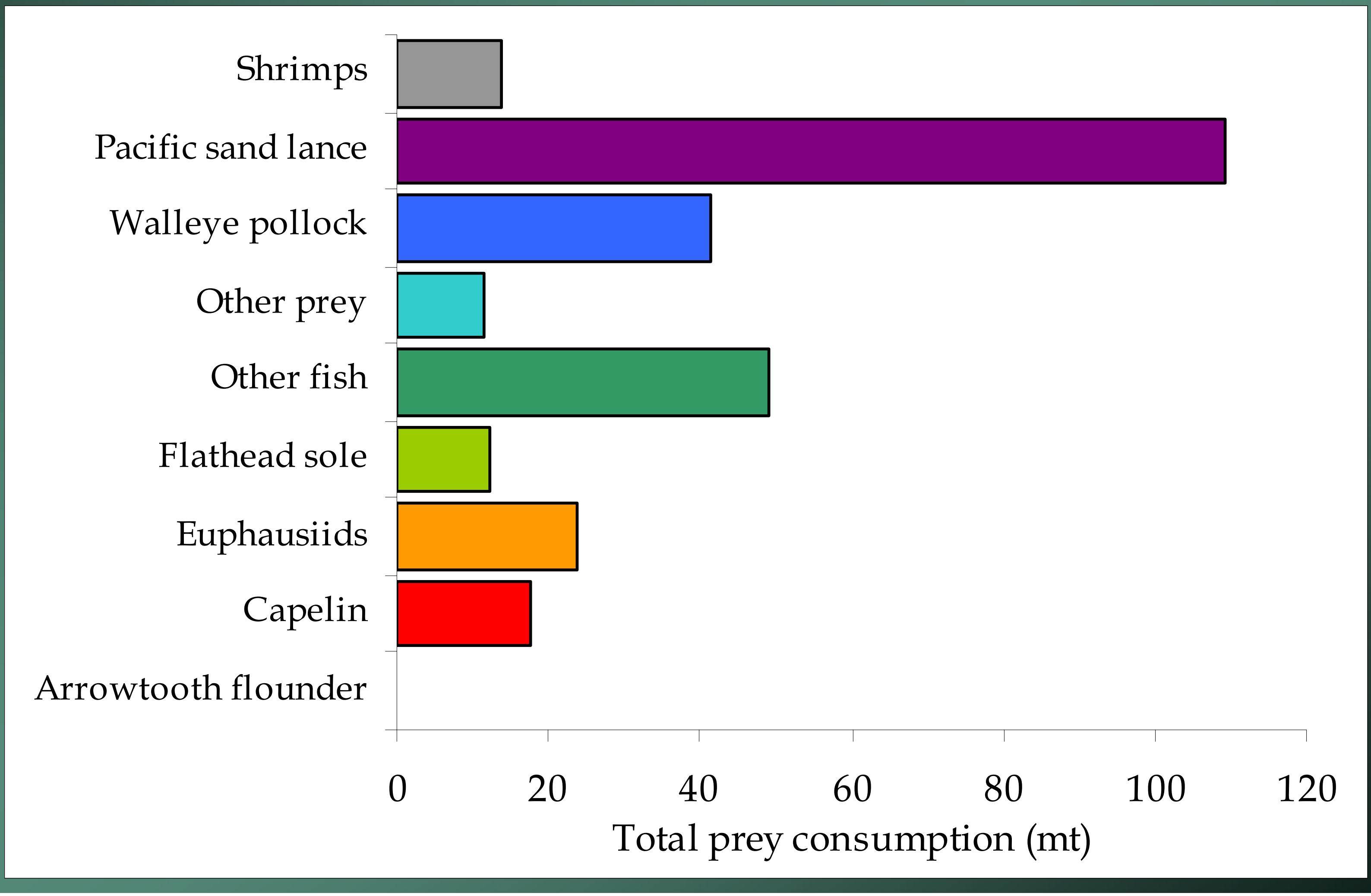
0-99 m

100-200 m



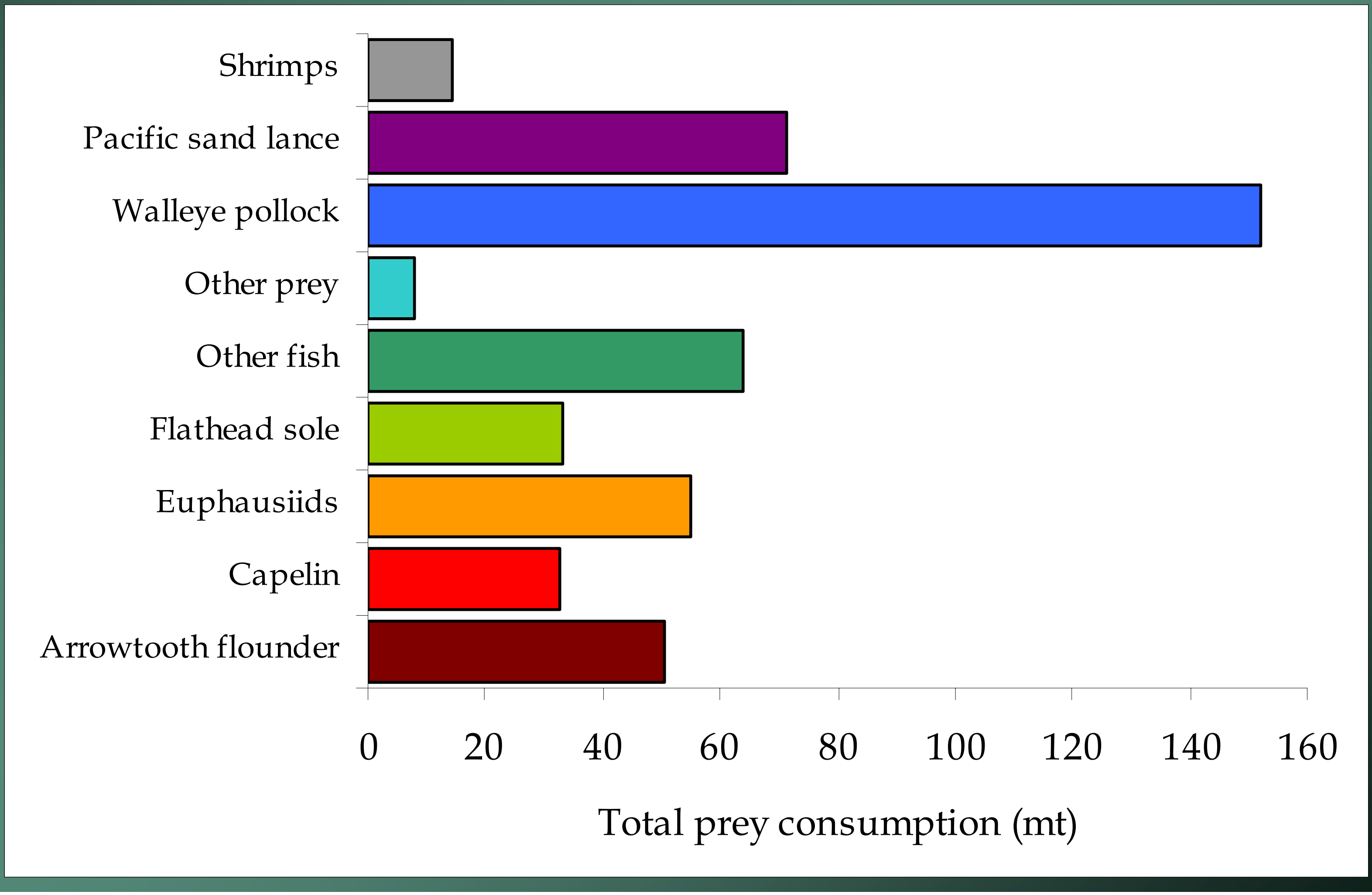
Results- ATF population cumulative prey biomass consumption in 2004

Depth: 0-99 m



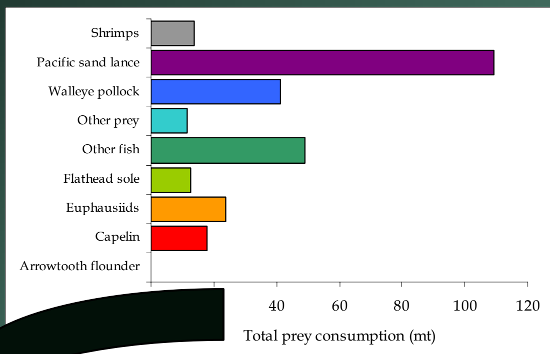
Results- ATF population cumulative prey biomass consumption in 2004

Depth: 100-200 m

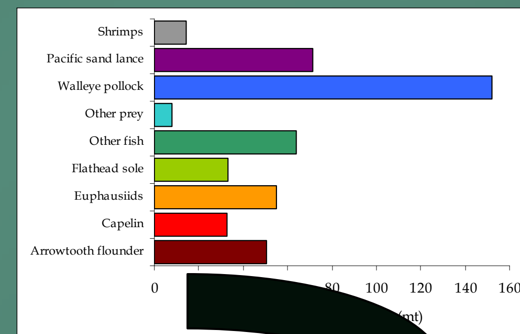


ATF population cumulative prey biomass consumption in 2004

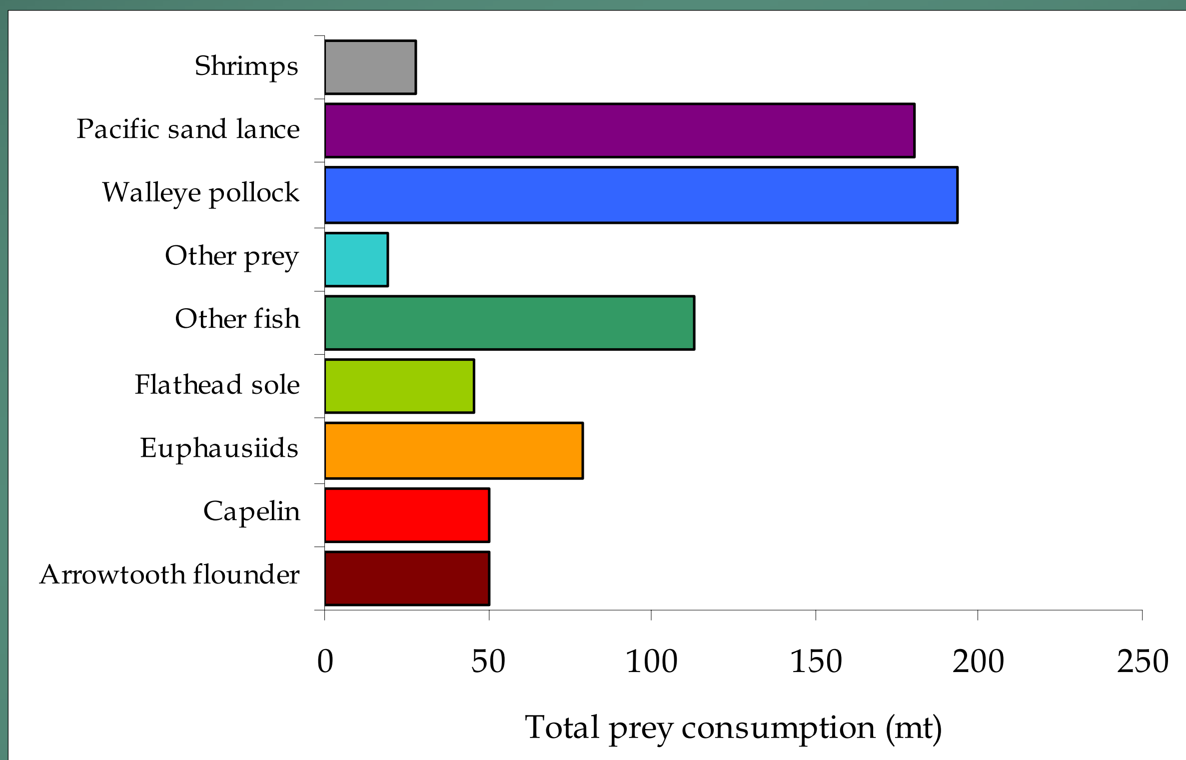
0-99 m



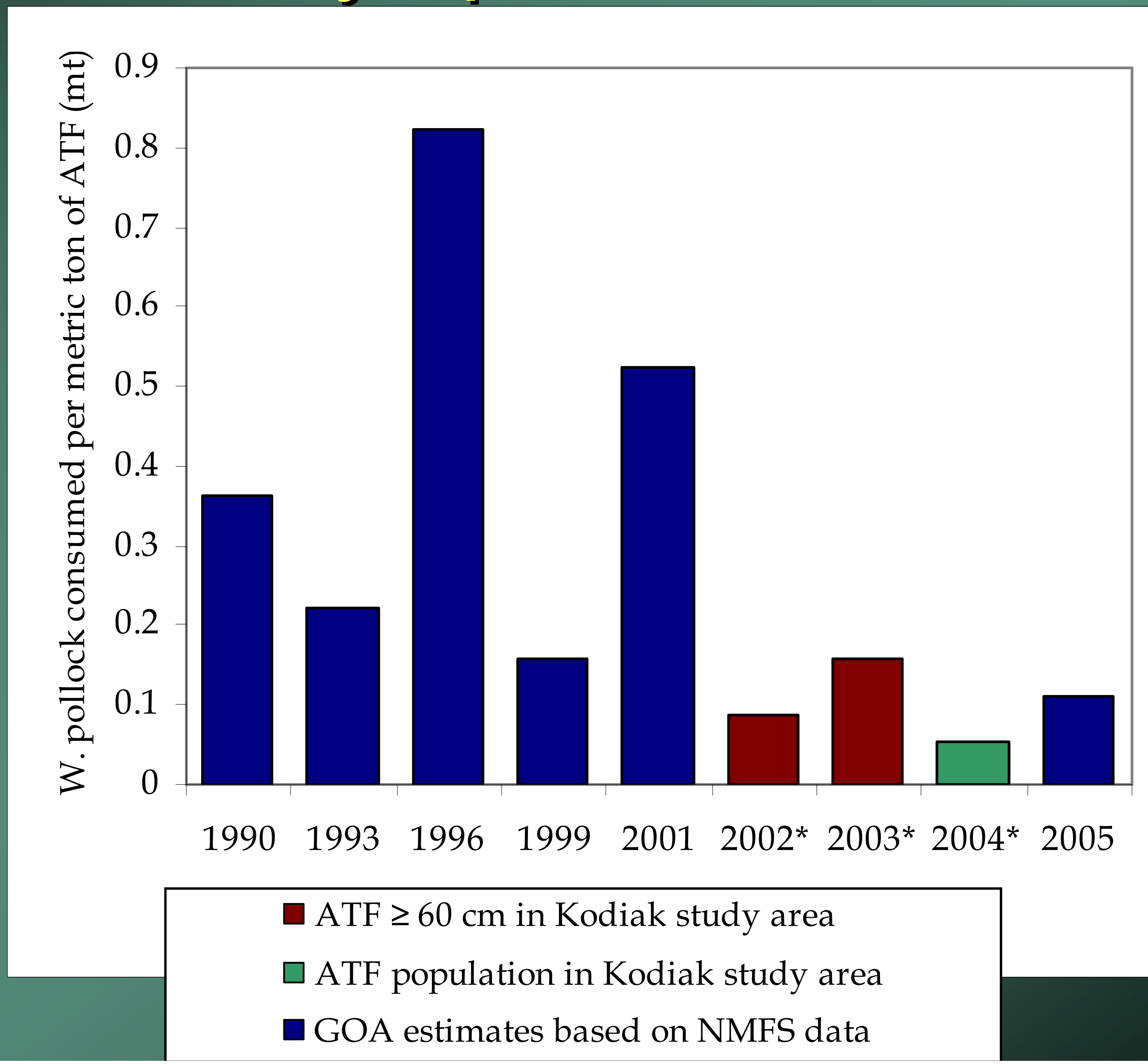
100-200 m



All waters ≤ 200 m



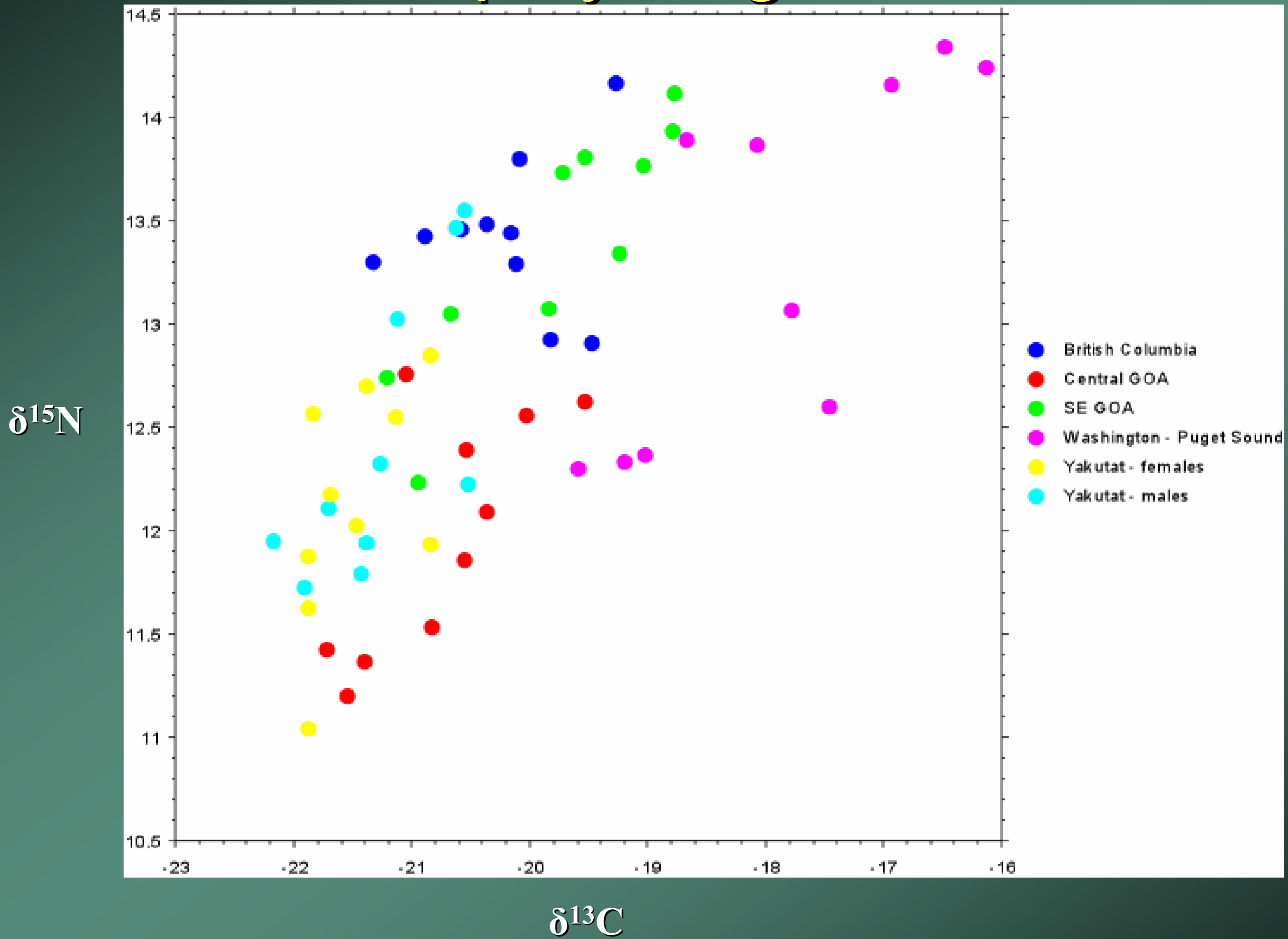
Why does a SSL care? Walleye pollock removals



So What to a SSL?

- ATF are both prey and competitor of SSL. Given the huge biomass of ATF in the GOA, prey removals and population structure is sure to affect all trophic levels.

Spiny Dogfish



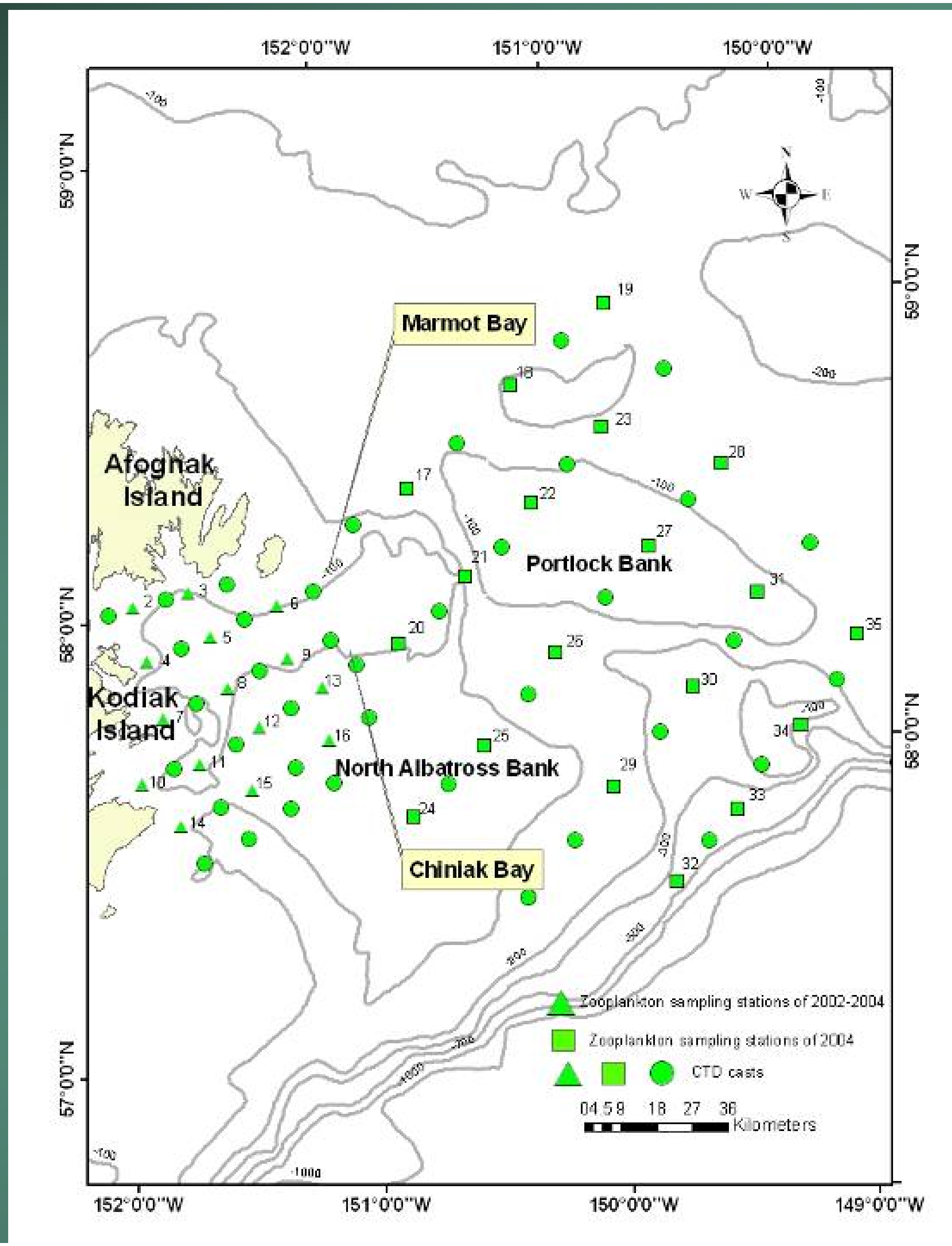
Alex Andrews and Robert Foy

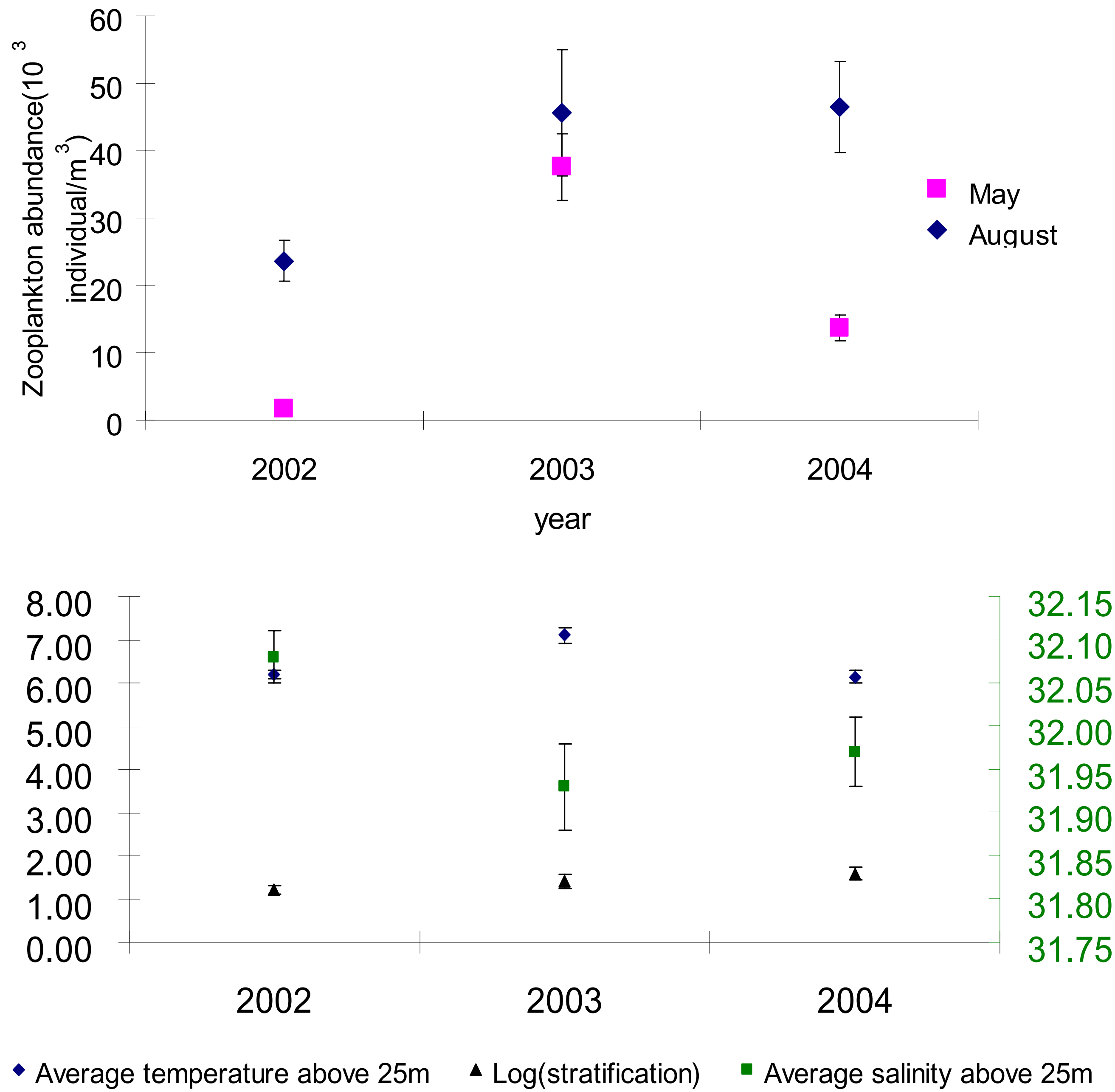
Environmental Variability: Do SSL prey fields respond?

- Sub-hypothesis: SSL prey are not affected by climate and oceanographic variability on a scale important for SLL feeding.
  1. How are primary producers and consumers affected by environmental fluctuation?
  2. What is the physiological response of important SSL prey species to long term environmental change?

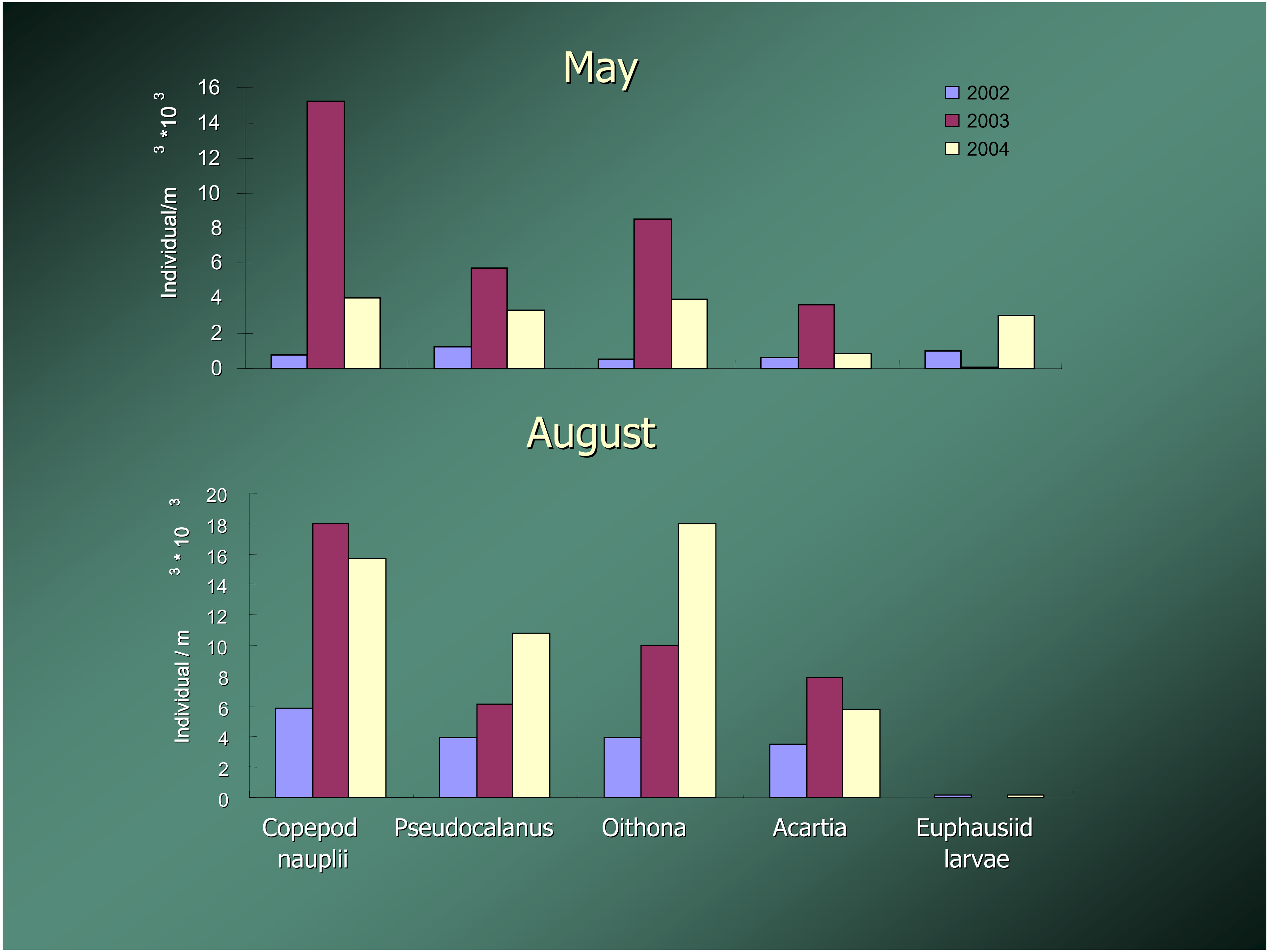
Seasonal mesozooplankton abundance and distribution in relation to hydrography on the Gulf of Alaska shelf

Xian Wang and Robert Foy

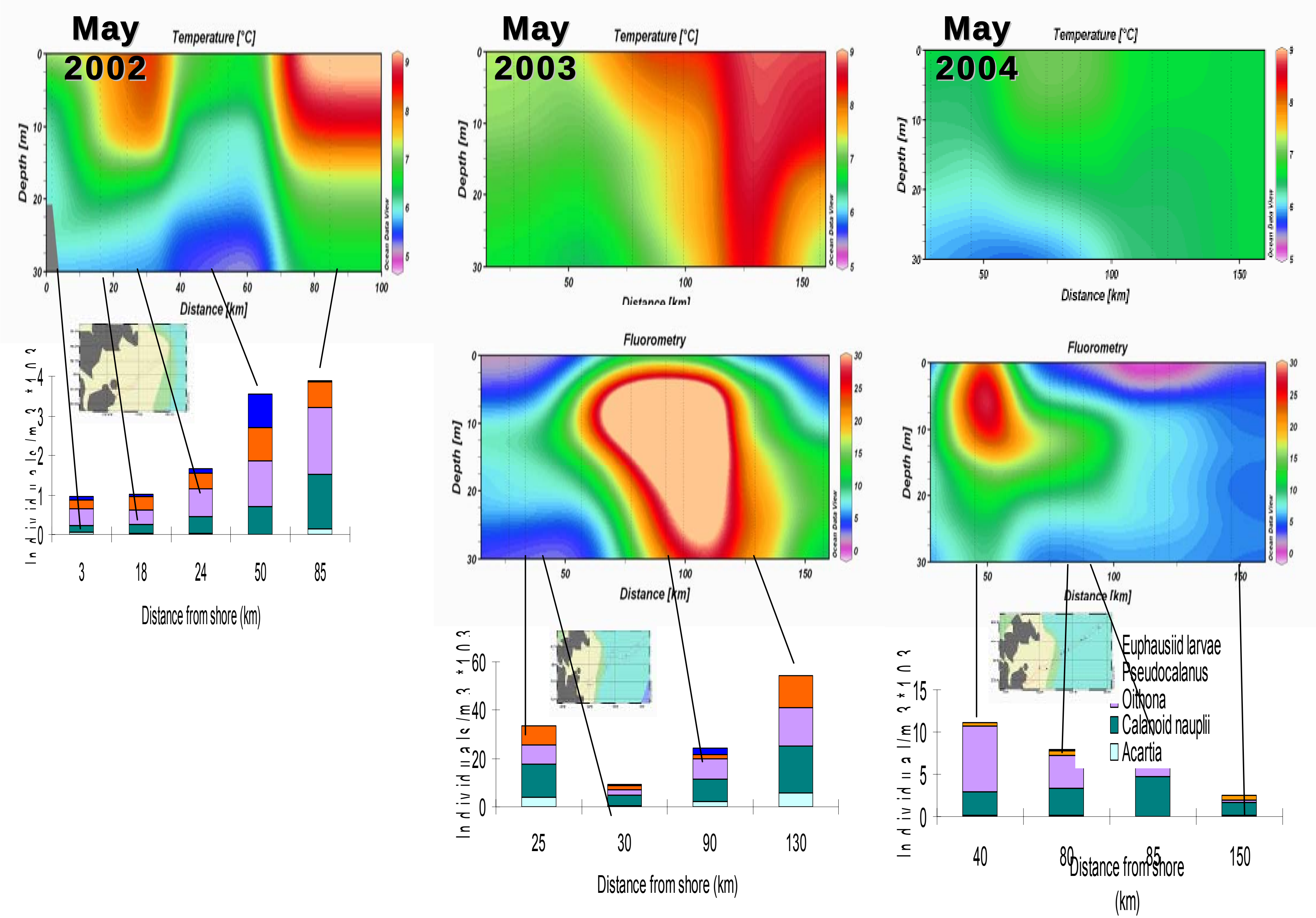

152°0'0"W
151°0'0"W
150°0'0"W
149°0'0"W
59°0'0"N
58°0'0"N
57°0'0"N
Marmot Bay
Afognak Island
Kodiak Island
Portlock Bank
North Albatross Bank
Chiniak Bay
Zooplankton sampling stations of 2002-2004
Zooplankton sampling stations of 2004
CTD casts
0 4.5 9 18 27 36
Kilometers



Zooplankton abundance(10 3 individual/m 3)
60
50
40
30
20
10
0
2002
2003
2004
year
May
August
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
32.15
32.10
32.05
32.00
31.95
31.90
31.85
31.80
31.75
2002
2003
2004
Average temperature above 25m
Log(stratification)
Average salinity above 25m



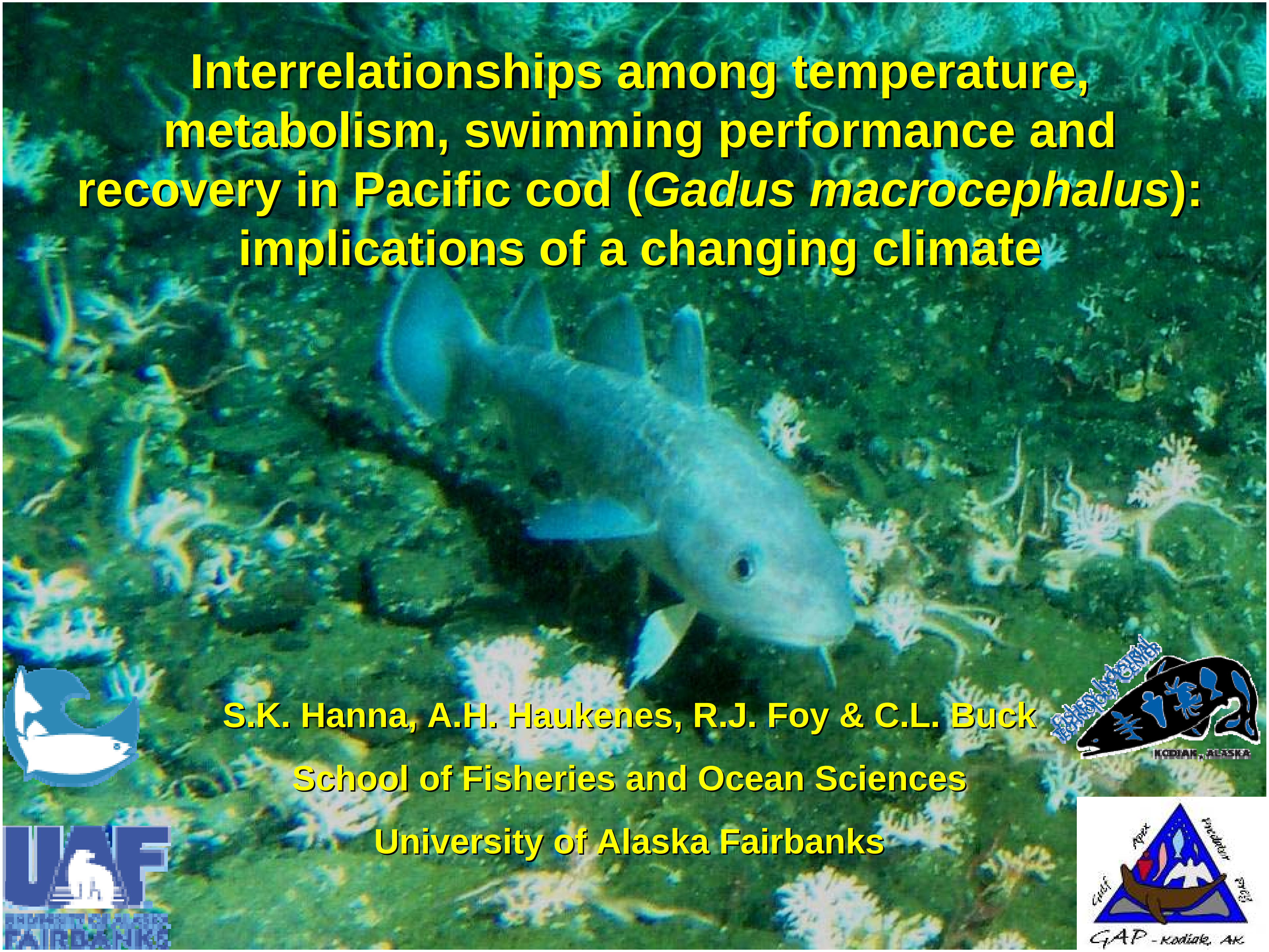
May
2002
2003
2004
Individual/m3 *10 3
0
2
4
6
8
10
12
14
16
August
Individual / m3 * 10 3
0
2
4
6
8
10
12
14
16
18
20
Copepod nauplii
Pseudocalanus
Oithona
Acartia
Euphausiid larvae


May 2002
Temperature [°C]
Depth [m]
Distance [km]
Individuals/m3 *103
3
18
24
50
85
Distance from shore (km)
May 2003
Temperature [°C]
Depth [m]
Distance [km]
Fluorometry
Individuals/m3 *103
25
30
90
130
Distance from shore (km)
May 2004
Temperature [°C]
Depth [m]
Distance [km]
Fluorometry
Euphausiid larvae
Pseudocalanus
Oithona
Calanoid nauplii
Acartia
Individuals/m3 *103
40
80
85
150
Distance from shore (km)

So What to a SSL?

- Do changes in secondary consumers represent potential bottom-up forcing on upper trophic levels?

Interrelationships among temperature, metabolism, swimming performance and recovery in Pacific cod (*Gadus macrocephalus*): implications of a changing climate

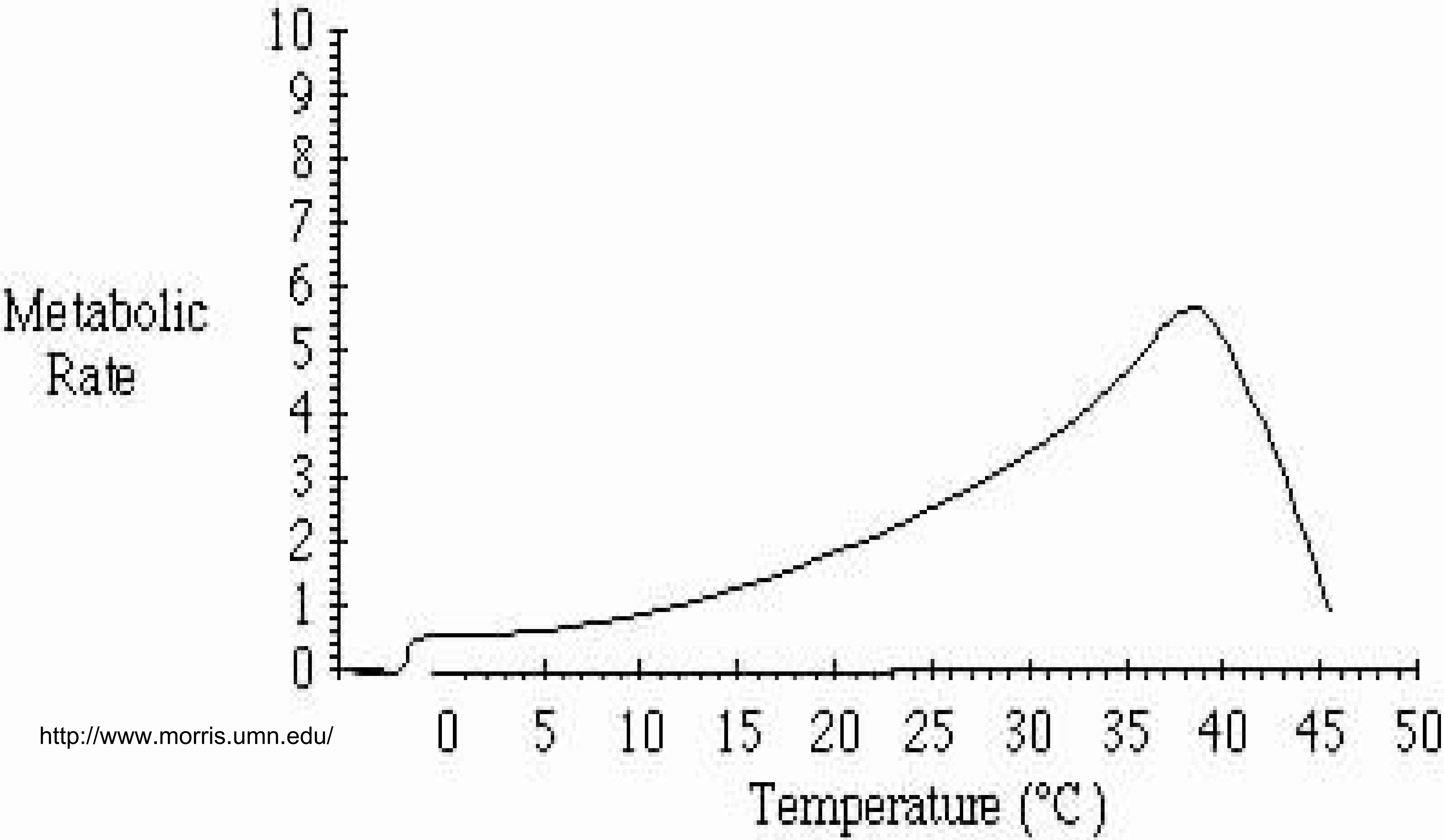


S.K. Hanna, A.H. Haukenes, R.J. Foy & C.L. Buck

School of Fisheries and Ocean Sciences

University of Alaska Fairbanks

Expected metabolic response to increased temperature



http://www.morris.umn.edu/

Collection

4ºC

11ºC

2 week acclimation

Bled

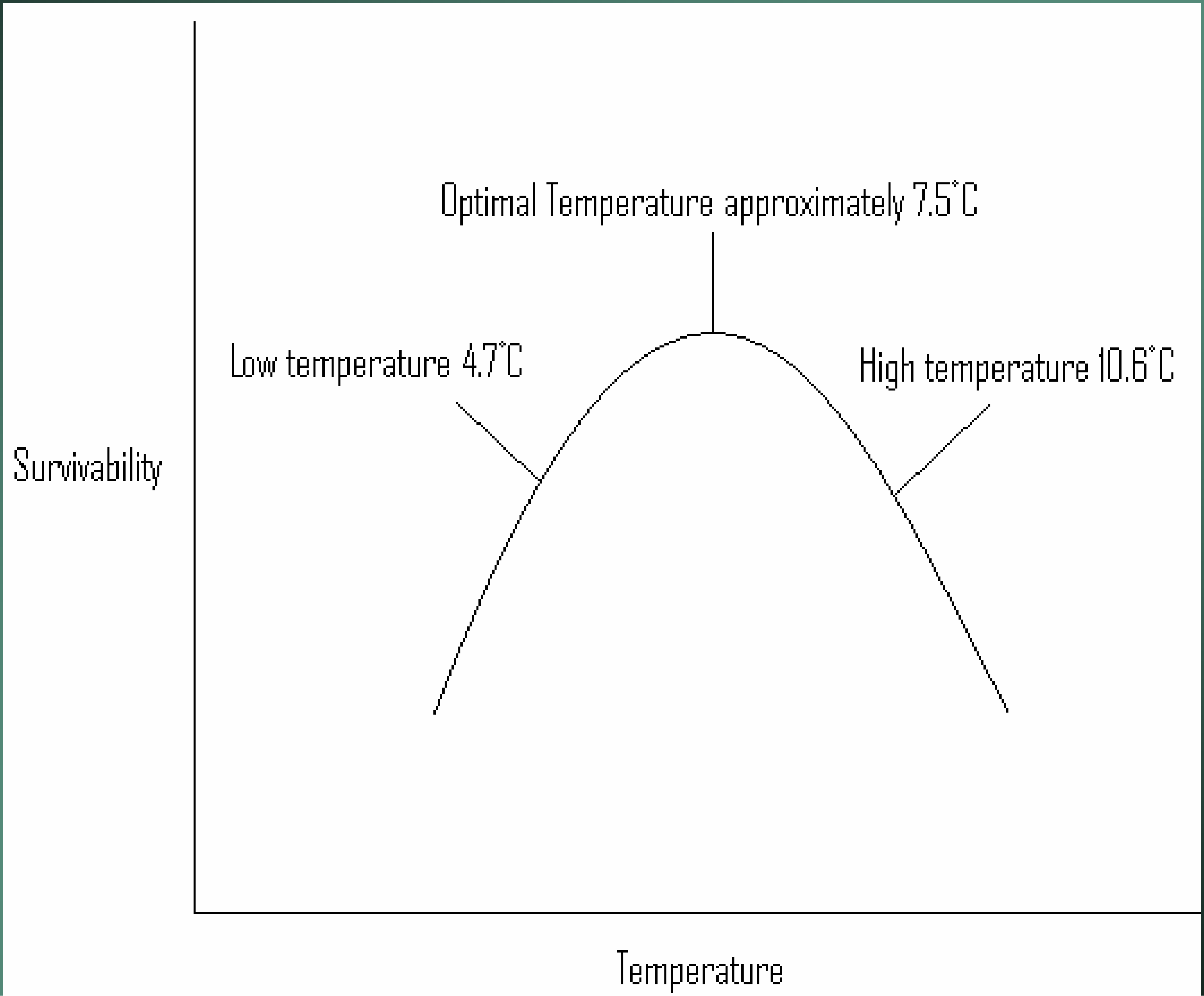
4ºC

11ºC

Swum to exhaustion

Bled

Pacific cod optimum survivability



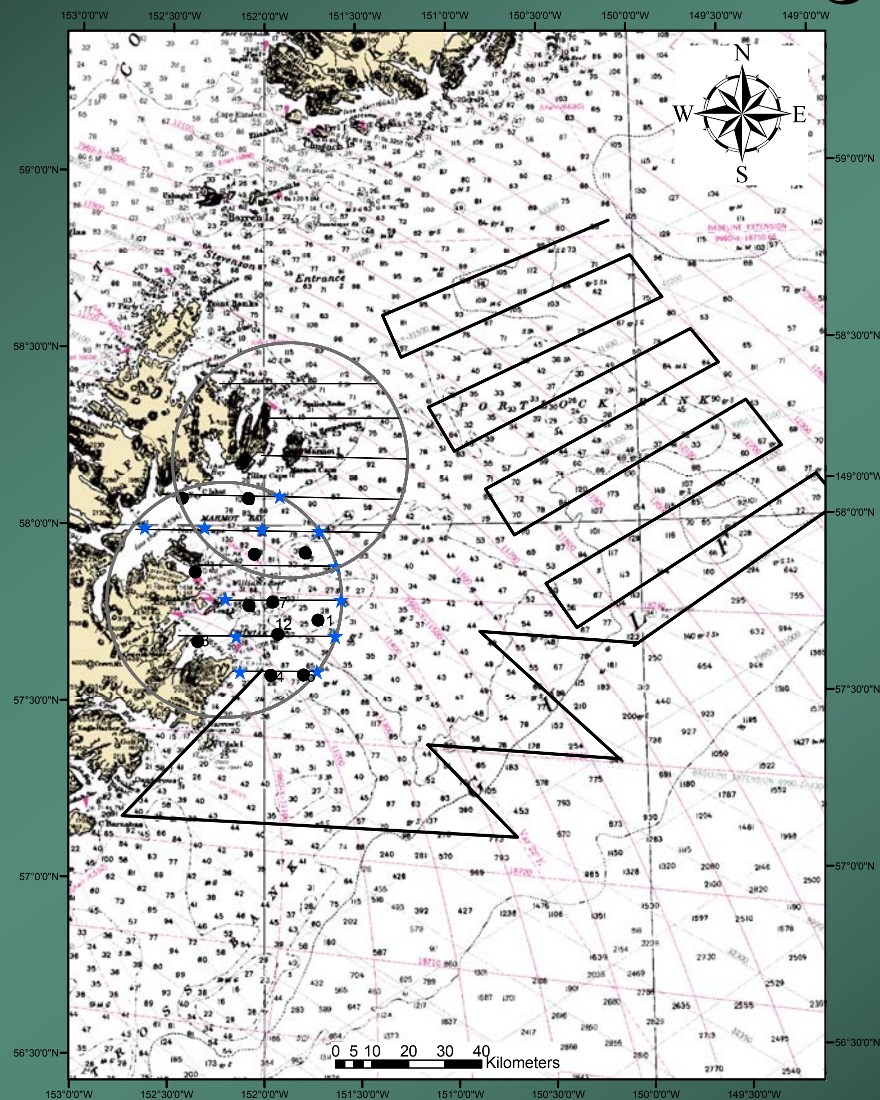
Pollock and cod bioenergetics models

- Previous models
- New data
  - Physiological tolerances related to temperature
  - Swimming activity constant
  - Diet and energy density on appropriate scales

So What to a SSL?

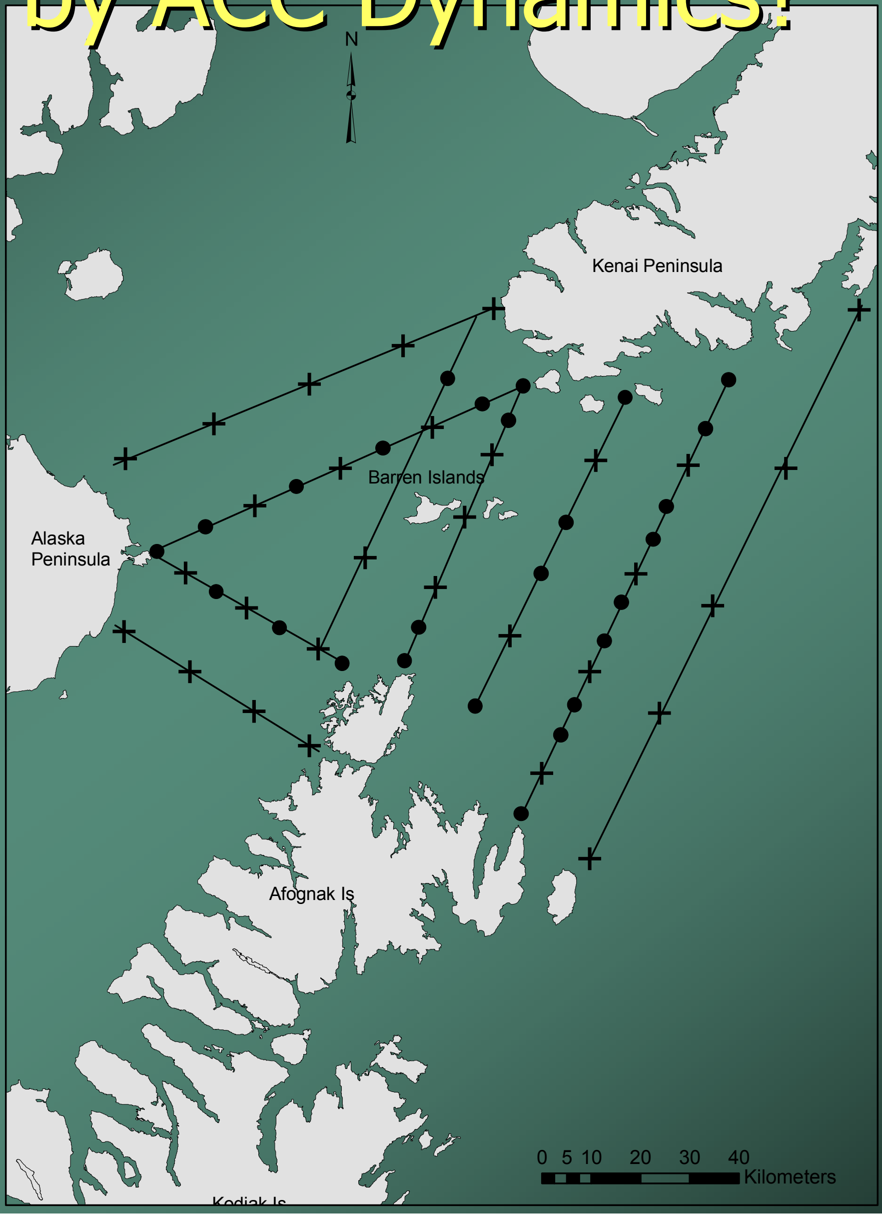
- Physiological tolerances of key prey and competitors may lend insight to future population structure in GOA.

Portlock Bank Oceanography



Robert Foy

Is Kodiak Archipelago Production Driven by ACC Dynamics?



Future Studies

- Fine tune bioenergetic models parameters on appropriate scale
- Trophic efficiencies between zooplankton and juvenile fish
- Continue to assess key forage spp distribution and abundance: new scales?
- Continue to assess predator prey overlap in space and time
- All in the context of a changing climate…