Chemical feeding ecology and heavy metal contaminants in Steller sea lions

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Division of Wildlife Conservation

And a host of collaborators:

ALASKA DEPARTMENT OF FISH AND GAME

UAF UNIVERSITY OF ALASKA FAIRBANKS

NOAA

University of Colorado Denver

USGS science for a changing world

Chemical feeding ecology

Using naturally occurring stable isotopes of carbon and nitrogen

Profiles of $\delta^{13}C$ and $\delta^{15}N$ in the whiskers

1) Identify weaning
2) Identify the trophic level of feeding
3) Model the composition of the diet

Nitrogen Ratios:

The ratio of heavy (^{15}N) to light (^{14}N) isotopes of nitrogen in tissues increases by ~ 1 to 3 ‰ with each successive trophic level

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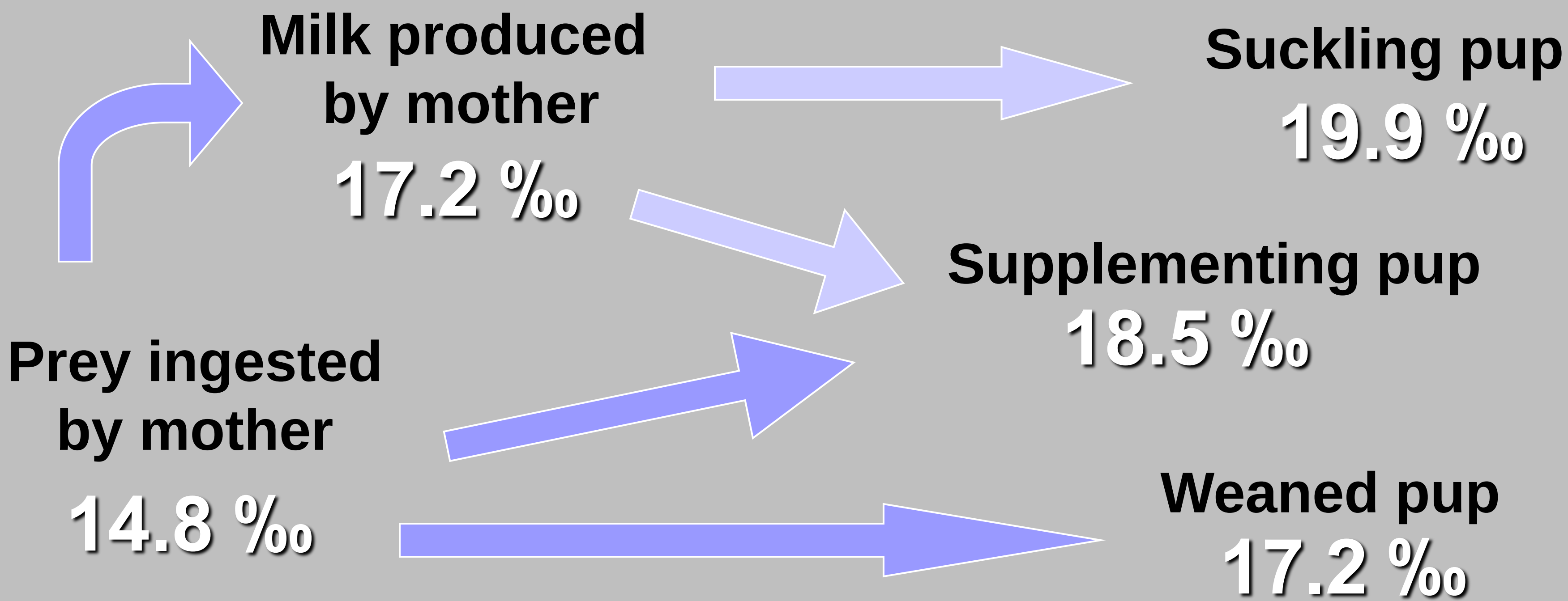


Carbon Ratios:

Can indicate the habitat in which the animal is feeding (i.e. geographical differences).

Latitude

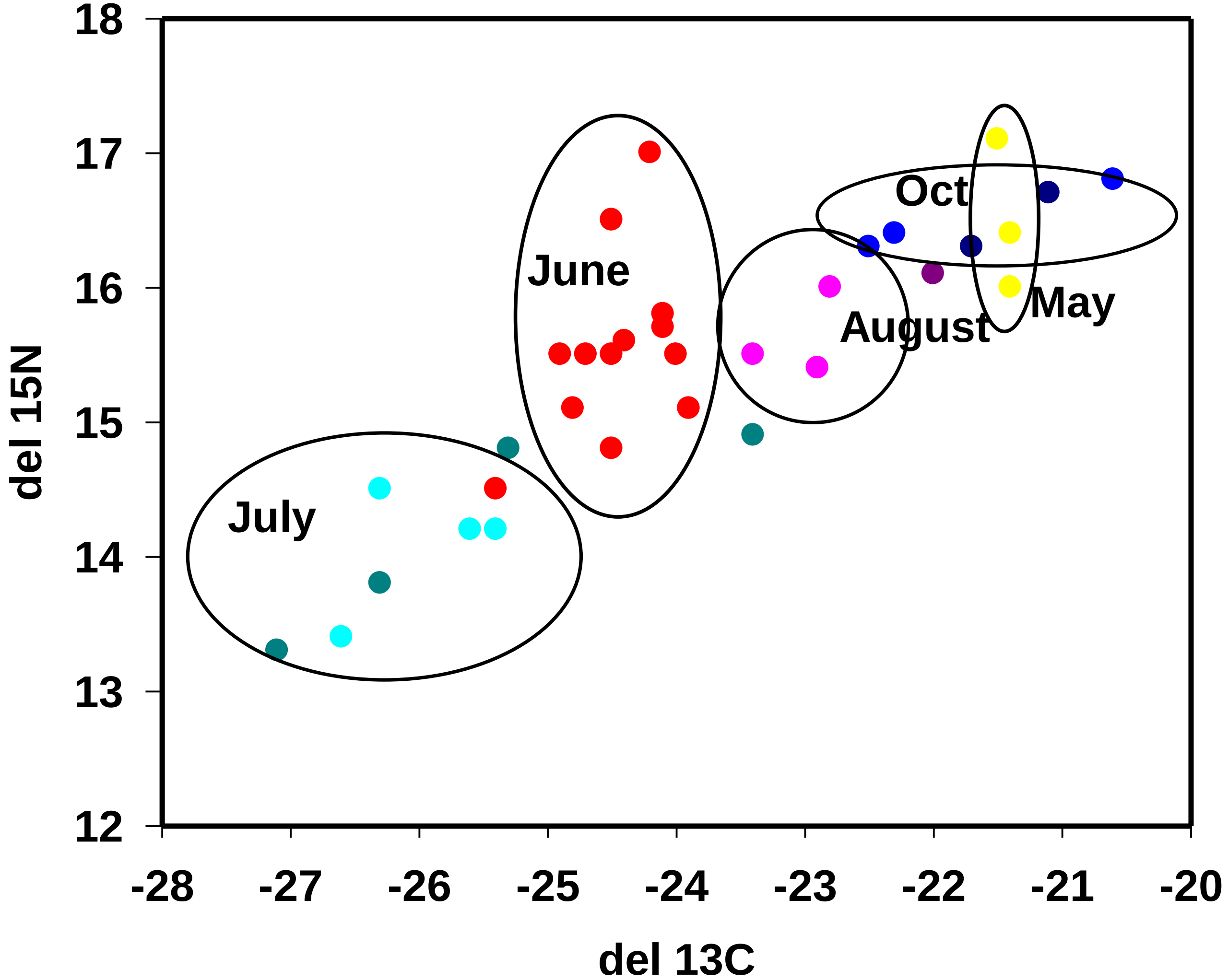
Middle = ↑ $\delta^{13}C$ **High = ↓ $\delta^{13}C$**

Marine Food Webs

Near-shore or Benthic = ↑ $\delta^{13}C$

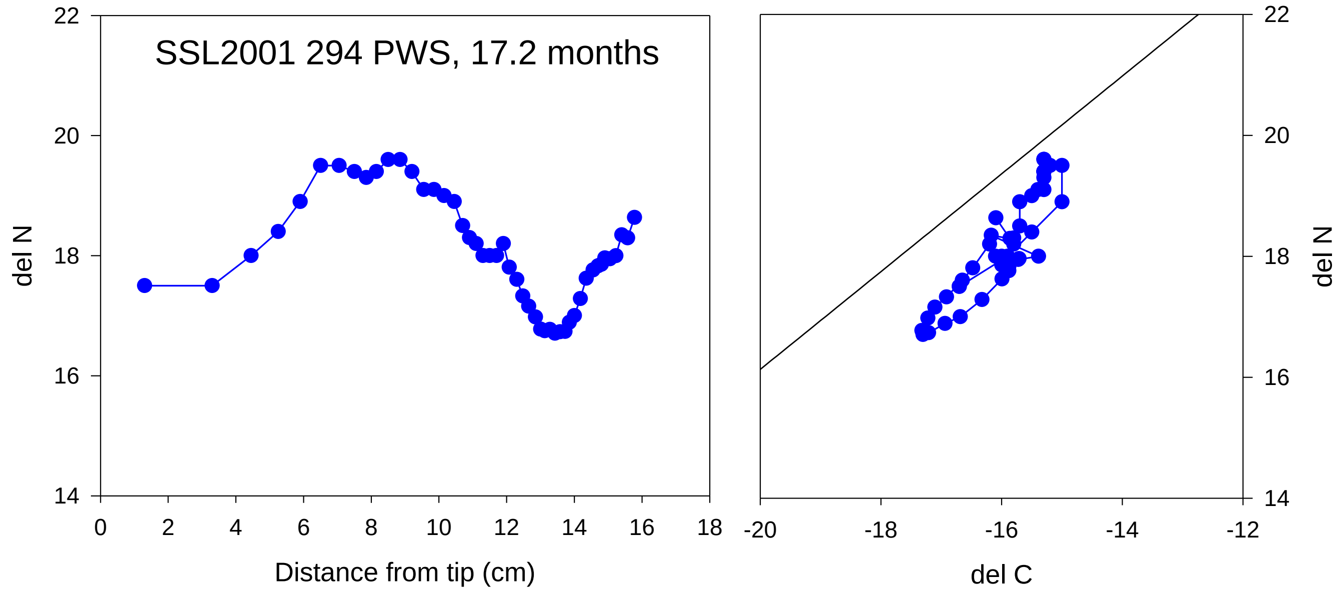
Off-shore = ↓ $\delta^{13}C$

Milk isotopes change seasonally in SEA reflecting changes in feeding area



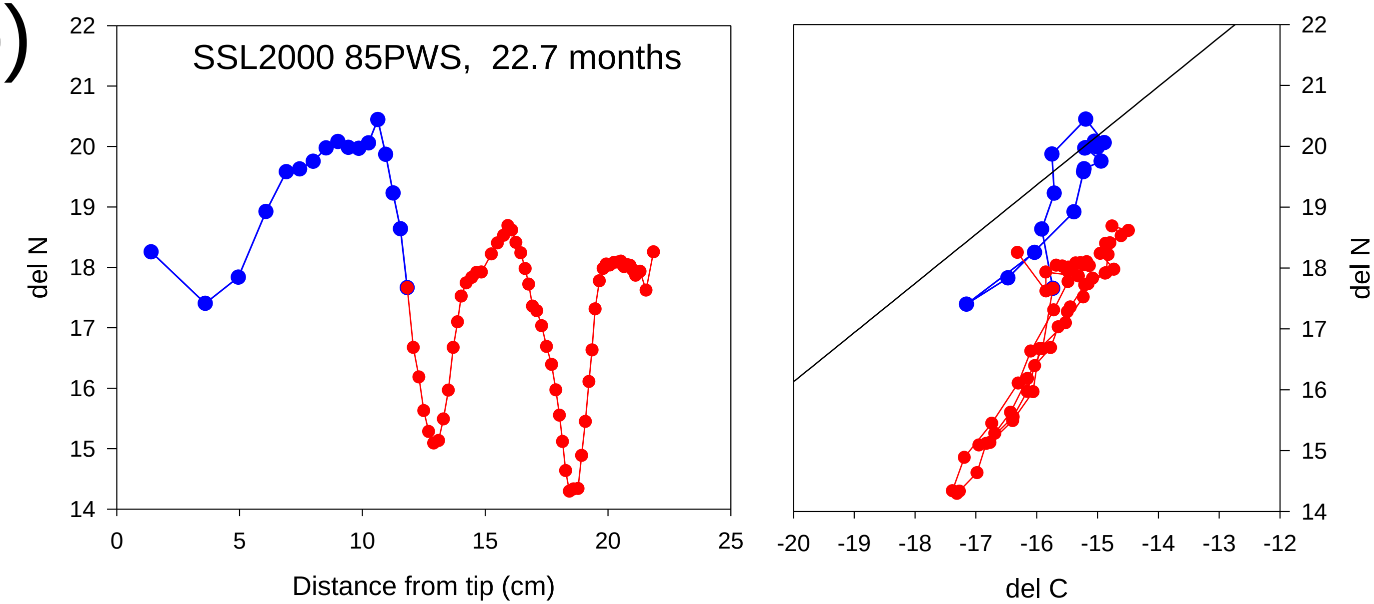
a)

nursing



b)

weaned



Proportion of Steller sea lions weaned by region

Age class	Aleutians Islands		Gulf of Alaska		PWS		Southeast Alaska	
	n	%	n	%	n	%	n	%
Pup	60	0%	31	3%	88	1%	60	0%
Yearling	6	67%	1	0%	29	62%	54	41%
Juvenile	1	100%	1	100%	7	71%	14	79%

n= 354 Rea et al. 2011

Next step:

Using calculated growth rates of whiskers we can "back-calculate" when weaning events occur

Age Class	Growth rate (cm/mo)	Sample size
Nursing pup (5-10 mo)	0.86 ± 0.28	n= 30
Yearlings/ 2 yr (TJs)	0.72 ± 0.29	n=27
Subadults (2-4 yr)	0.55 ± 0.03	n= 22
Adults (4+ yrs)	0.48 ± 0.18	n=11

Estimate diet composition using stable isotope modeling:

Advantages over scat analysis:

1) Relative diet contribution (importance to growth)
2) Seasonal history of diet
3) Potential for individual information

But:

-Probability distributions

-Some diet items not distinguished well

Adult female Steller sea lion “=24” at Petrel Point, Semisopochnoi Island on 18 March 2012 (138 days post-capture), and *Argos* locations for March 10-19, 2012.

Data and image collected under authority of Permit #14326.
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Steller sea lion pups are born with developed vibrissae, thus the tip of the vibrissae represents tissue grown *in utero*, and reflects the maternal diet during this period of fetal development.

This allows us to use the whiskers collected from young rookery pups to inform about diet of their mothers during gestation prior to birth. Knowing growth rates we can isolate sections of the in utero whisker growth to identify seasonal changes in diet of the adult females.

We can now show regional and seasonal differences in isotope ratios. Next we want to be able to translate that to what prey species contribute to the diet in different regions and seasons…..

To model diet composition from stable isotopes we need:

Carbon and nitrogen isotope ratios from whiskers

Discrimination factors for diet to tissue deposition

Discrimination factors from mother to pup whiskers

Growth rates of whiskers for all age classes

Scat hard parts data from one season to validate

Carbon and nitrogen isotope ratios for prey species

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Discrimination factors from mother to pup whiskers

Growth rates of whiskers for all age classes

Scat hard parts data from one season to validate

Carbon and nitrogen isotope ratios for prey species

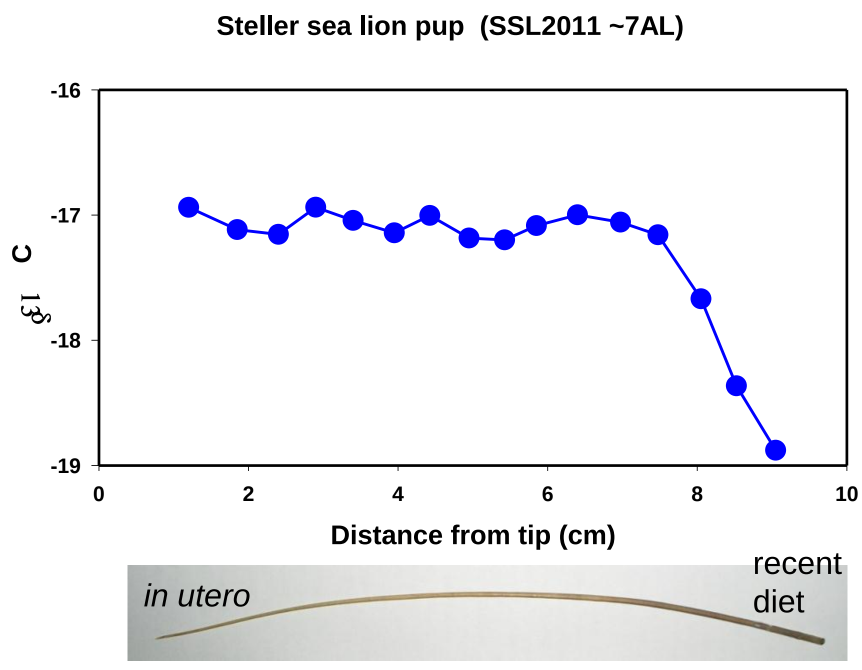
- Ongoing: still compiling and testing models

Methods:

•Analyzed the isotope ratios of carbon ($\delta^{13}C$) and nitrogen ($\delta^{15}N$) in pup vibrissae sections ranging from 0.2 to 0.5 mg

•Continuous flow isotope ratio mass spectrometry at the UAF Stable Isotope Facility.

•Segments of approximately 0.1 cm were selected every 0.5 cm along the length of the vibrissae from the tip (earliest *in utero*) to the root (representing current nursing signature at capture)



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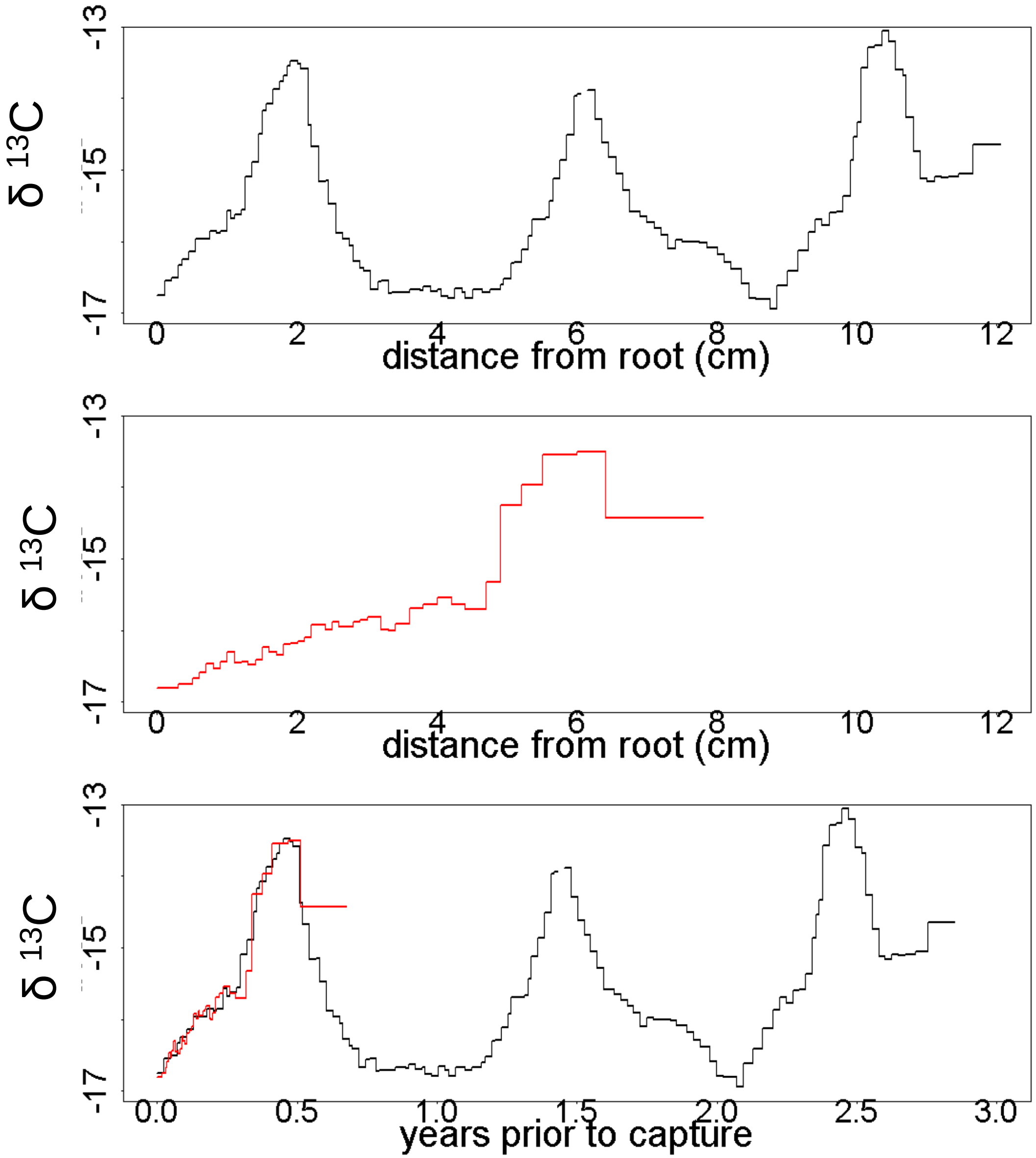
Isotope Diet Modeling – Part 1

Discrimination factors for $\delta^{13}C$ and $\delta^{15}N$ profiles of vibrissae from adult Steller sea lion females and their pups *in utero* and post parturition

Christ AM, Rea LD, Waite JN,Stricker CA, Wunder M, Scherer RD For IsoEcol August 2012

"Five matched mother-pup vibrissae pairs were collected at the Lovushki Island rookery in the Kuril Islands, Russia in June 2008. Seasonal oscillations in the $\delta^{13}C$ and $\delta^{15}N$ profiles along adult female vibrissae were presumed to reflect annual cycles of prey availability. Timing of these diet shifts were used to estimate an average vibrissae growth rate for each of the adult females. Similar features mirrored in the associated pup vibrissae profiles allowed us to align the two vibrissae over specific time spans. Future modelling of adult female diet using pup vibrissae as a proxy will need to account for the appropriate DF at the different times of fetal or pup development."

Paired vibrissae
Mother and pup



The δ ^{13}C profile along the vibrissae of an adult female

… and her pup

… adjusted for different vibrissae growth rates

Christ et al. 2012

Isotope Diet Modeling – Part 2

Carbon and nitrogen isotope discrimination factors for Steller sea lion vibrissae on milk and fish/squid diets
Stricker CA, Rea LD, Rosen, DAS, Tollit, DJ, Farley, SD for IsoEcol August 2012

"Diet reconstruction using isotopic techniques requires a priori knowledge of tissue-diet discrimination factors (DFs), which can vary as a function of diet quality. We refined vibrissa DFs for free ranging nursing pups and provide new estimates for captive sub-adults maintained on complex fish/squid diets. "

Discrimination factors for Steller sea lions

$\delta^{13}C$ & $\delta^{15}N$
Pups' vibrissae

$\Delta\delta^{13}C = -0.40\ (0.05)$
$\Delta\delta^{15}N = 0.90\ (0.03)$

$\delta^{13}C$ & $\delta^{15}N$
Moms' vibrissae

$\Delta\delta^{13}C = 2.90\ (0.40)$
$\Delta\delta^{15}N = 4.60\ (0.50)$

$\Delta\delta^{13}C = 3.30\ (0.40)$
$\Delta\delta^{15}N = 3.70\ (0.50)$

$\delta^{13}C$ & $\delta^{15}N$
Moms' diet

Fig. 2: Schematic with estimates of discrimination factors for $\delta^{13}C$ and $\delta^{15}N$ (± 1 SD) from (i) the vibrissae of pups to the vibrissae of their mothers, (ii) the vibrissae of mothers to their diets, and (iii) the vibrissae of pups to the diets of their mothers.

To model diet composition from stable isotopes we now have:

Carbon and nitrogen isotope ratios from whiskers

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Discrimination factors from mother to pup whiskers

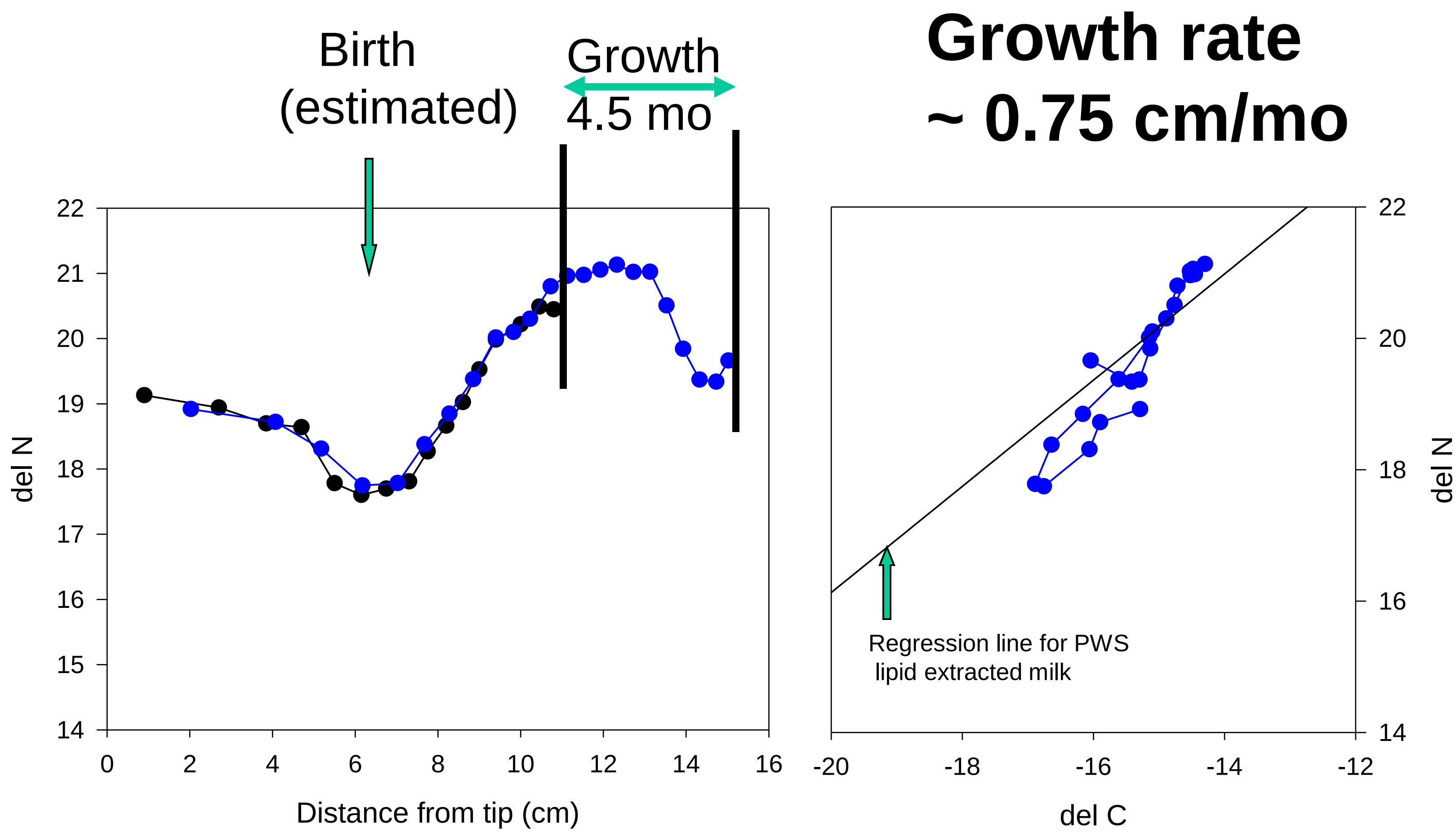
Growth rates of whiskers for all age classes

Scat hard parts data from one season to validate

Carbon and nitrogen isotope ratios for prey species

- Ongoing: still compiling and testing models

Stable Isotopes – Part 3: Calculating whisker growth rates for young of the year using stable isotopes



Black symbols SSL619PWS captured at 5 mo
Blue symbols SSL619PWS recaptured at 9.5 mo

Knowing growth rates of whiskers we can then estimate ages at which animals have changes in isotope ratios caused by changes in diet or natural history events such as weaning

We now have evidence that growth rates of whiskers vary by age, and we have estimates for young of the year, juveniles and adults (manuscript in progress)

Growth rates of vibrissae in Steller sea lions

Age Class	**Growth rate (cm/mo)**	**Sample size**
Nursing pup (5-10 mo)	0.86 ± 0.28	n= 30
Yearlings/ 2 yr (TJs)	0.72 ± 0.29	n=27
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- Ongoing: still compiling and testing models

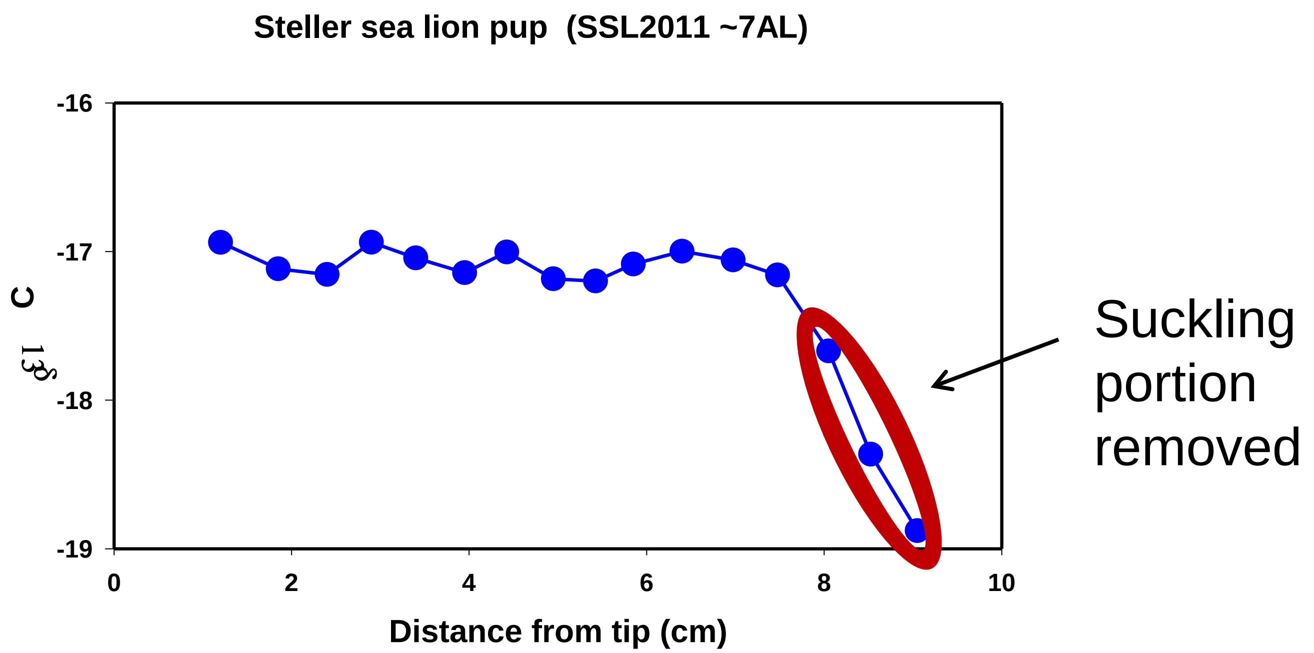
Isotope Diet Modeling – Part 4 Ongoing….

Spatial variation in the diets of female Steller sea lions inferred from ^{13}C and ^{15}N values of vibrissae from pups
<u>Scherer RD</u>, Rea LD, Christ AM, Wunder M, Stricker CA
For IsoEcol August 2012

"Vibrissae segments from westernmost subpopulation, the Central Aleutians, are depleted in $\delta^{13}C$ and $\delta^{15}N$ relative to subpopulations to the east. On average, $\delta^{13}C$ values are depleted by 1.3 $\pm$ 0.5‰, and $\delta^{15}N$ are depleted by 3.0 $\pm$ 0.3‰. These results are consistent with the patterns inferred from the spatially and temporally limited scat data. We are compiling a database of $\delta^{13}C$ and $\delta^{15}N$ values of putative prey species in the region and have estimated discrimination factors for both nursing pups and developing fetuses. We will use stable isotope mixing models to estimate the composition of prey in Steller sea lion subpopulations and compare the estimates to frequency of occurrence of prey from scat data."

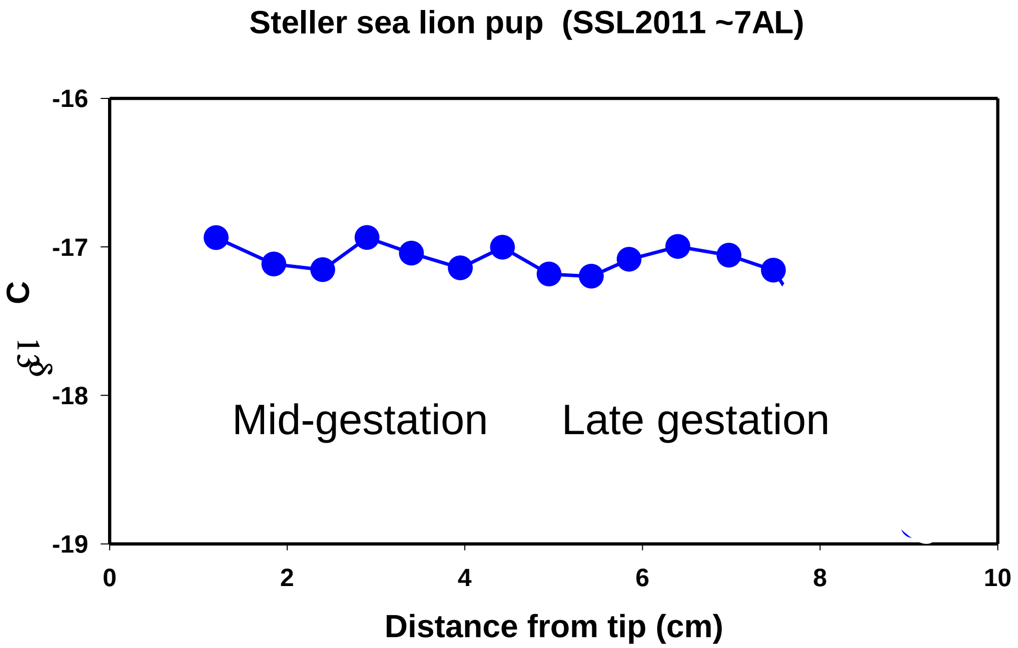
Methods:

•The suckling portion of this vibrissae was identified by the depleted carbon signature seen when feeding on high fat diets



Methods:

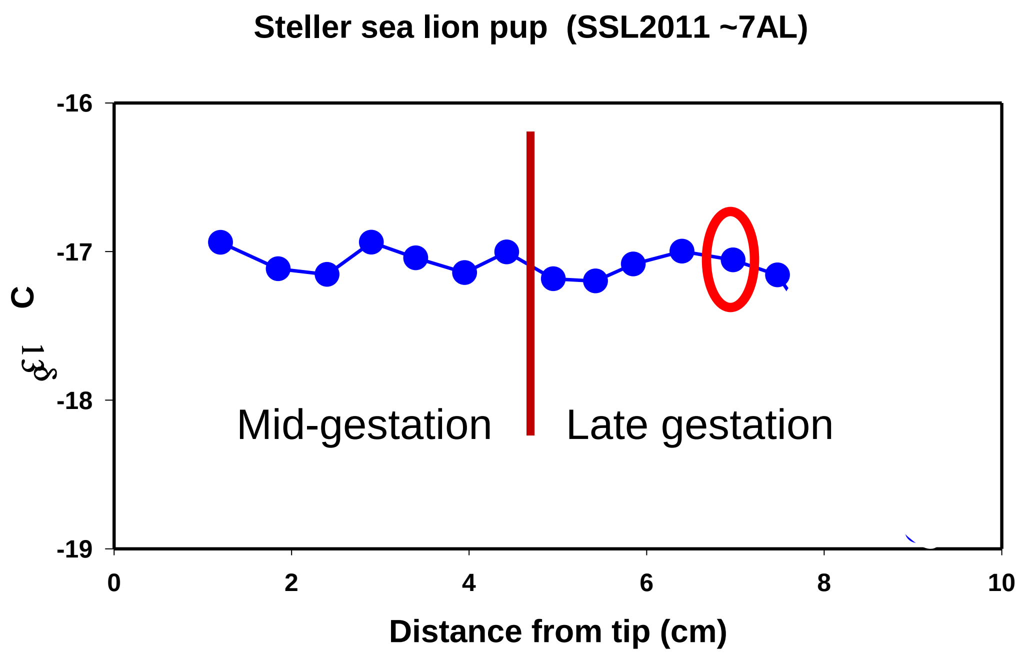
•The suckling portion of this vibrissae was identified by the depleted carbon signature seen when feeding on high fat diets - removed



Methods:

•The suckling portion of this vibrissae was identified by the depleted carbon signature seen when feeding on high fat diets - removed

•One segment representing late-gestation whisker growth was selected per pup to represent spring/summer diet



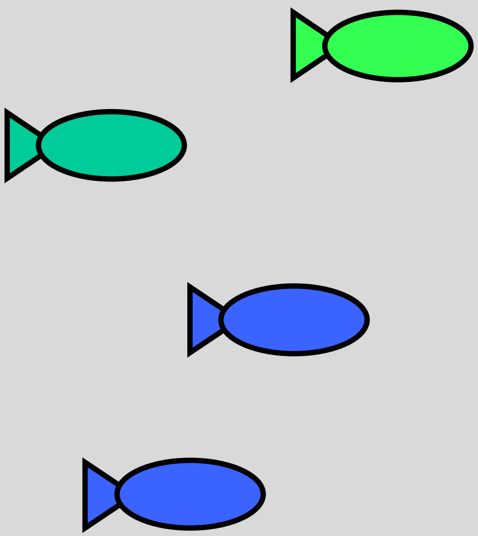
Proportion of Steller sea lion diet by species modeled from stable isotopes

Subpopulation	Proportion Atka mackerel	Proportion walleye pollock*
Central Aleutians	0.87 (0.69 – 0.98)	0.07 (0.00 – 0.20)
Eastern Aleutians	0.27 (0.06 – 0.46)	0.08 (0.00 – 0.22)
Central Gulf of Alaska	0.27 (0.10 – 0.44)	0.30 (0.04 – 0.57)
Eastern Gulf of Alaska	0.19 (0.01 – 0.33)	0.09 (0.00 – 0.25)
Southeast Alaska	0.16 (0.07 – 0.25)	0.74 (0.56 – 0.88)

* May represent a combination of pollock and herring   Scherer et al. 2012

QFASA:
Quantitative Fatty Acid Signature Analysis

"You are what you eat"



Metabolism

Accumulation

Synthesis

Rosen and Tollit 2012

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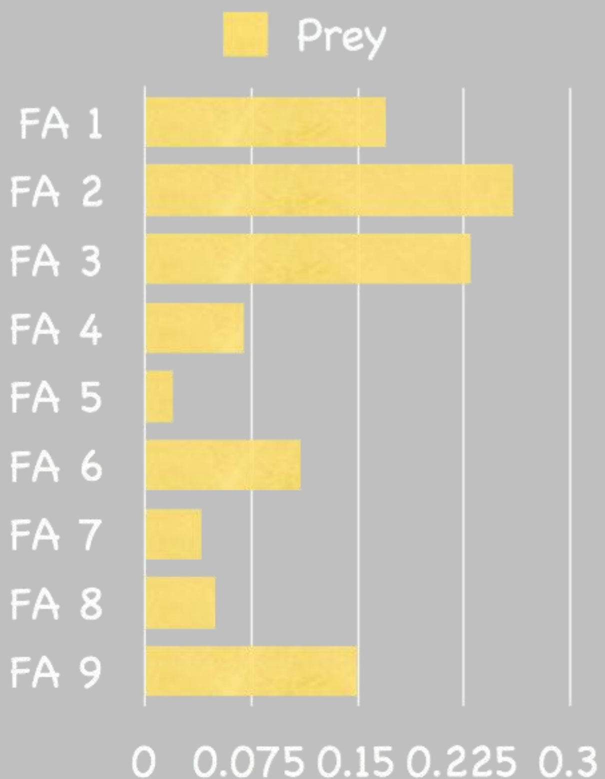
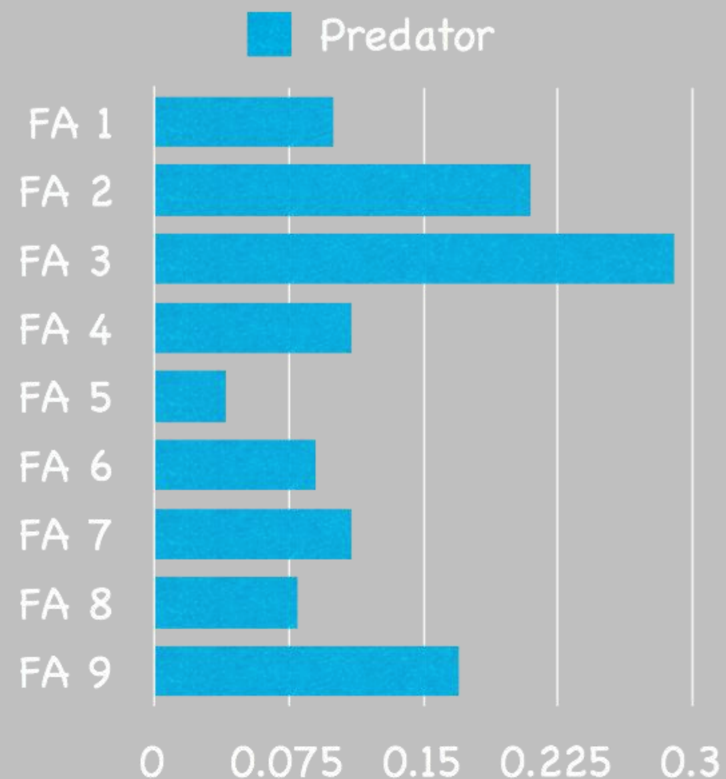


C.C.
0.59
0.81
1.26
1.57
2.00
0.82
2.75
1.60
1.13



Rosen and Tollit 2012

Quantitative Fatty Acid Signature Analysis

Steller sea lion

Northern fur seal

Harbour seal

Otariid	Otariid	Phocid	Family
Sea lion	Fur seal		Species

Herring

Prey

Eulachon

Quantitative Fatty Acid Signature Analysis

Steller sea lion

Northern fur seal

Harbour seal

41% differed by predator Family

58% differed by Predator

64% differed by Prey

32% of FAs not comparable

Family

Species

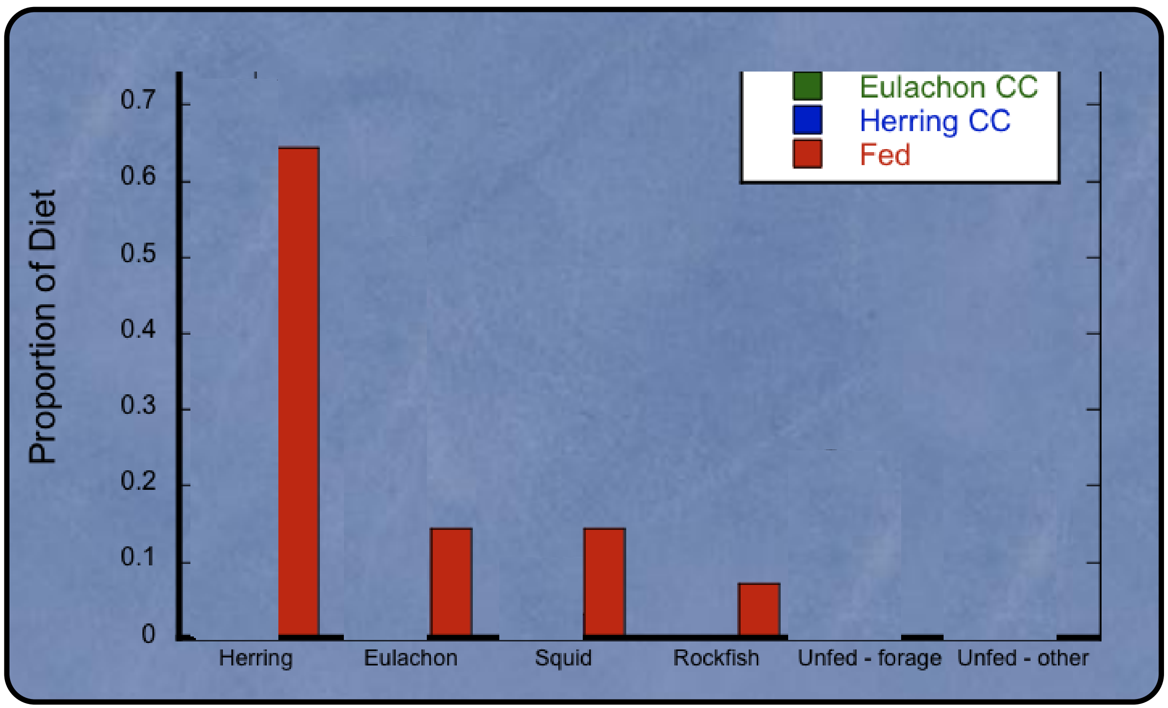
Prey

Rosen and Tollit *in press*

Quantitative Fatty Acid Signature Analysis

Maintained on 4-species diet for 160 d

Herring, eulachon, squid, rockfish



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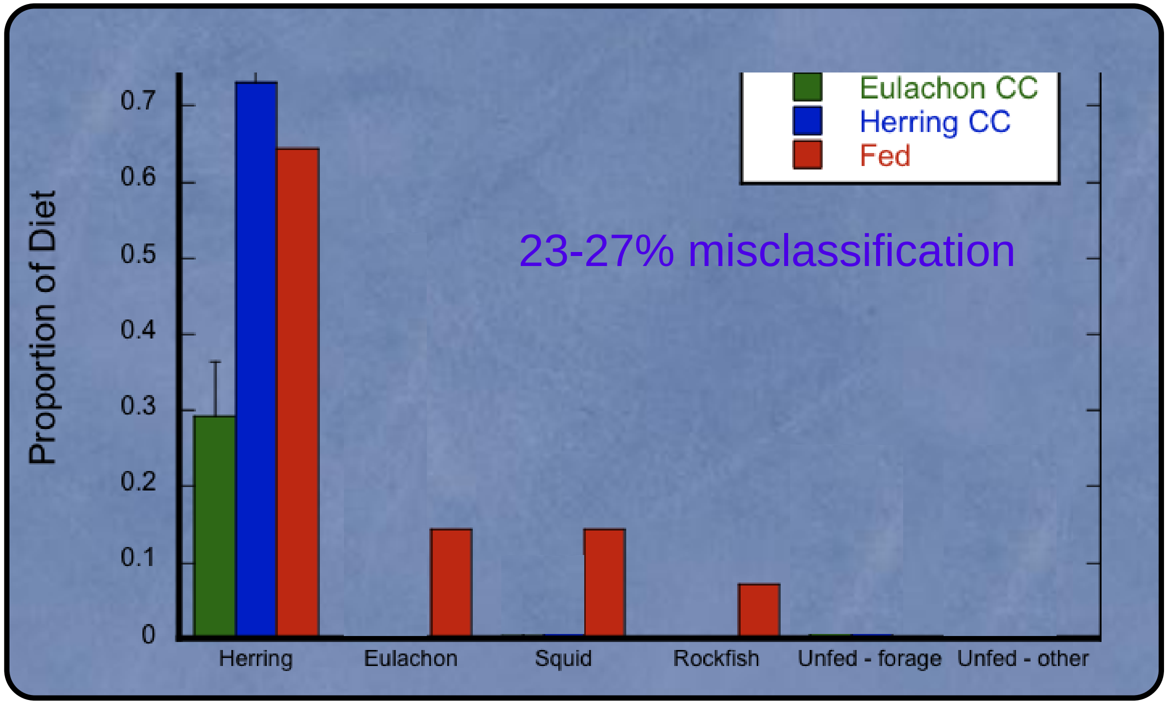


Chemical feeding ecology predicts concentration of mercury contamination in the hair of Steller sea lions.

Lorrie Rea
Maggie Castellini
Lucero Correa
Brian Fadely
Todd O'Hara

Investigating heavy metal contaminants as a possible contributor to lack of recovery

Mercury (Hg) has been shown to:

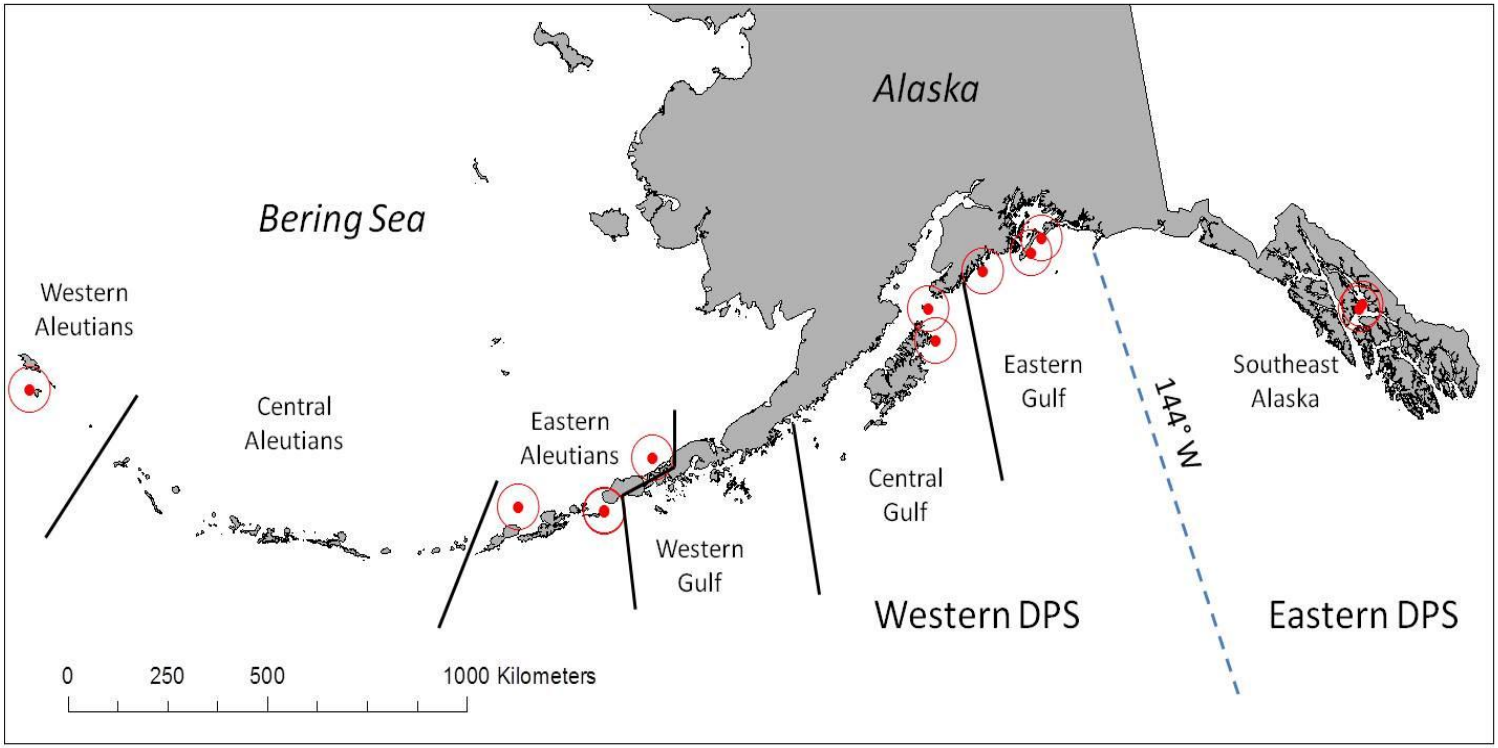
- Bioaccumulate and biomagnify
- Be neurotoxic to humans and other fish-eating mammals
- Cause neurochemical changes that impact mammalian health and survival
- Lower reproductive rates in mink
- Be transferred transplacentally to expose fetus

Total mercury concentrations in Alaska Steller sea lions – previous studies

Beckmen et al. 2002 – young of the year < 3.5 µg/g in hair
juveniles <7 µg/g in hair
western DPS > eastern DPS

Holmes et al. 2008 - young pups < 10 µg/g in liver
western DPS > eastern DPS

Castellini et al. 2012– young pups > older age classes
young pups < 21.5 µg/g in hair
western DPS > eastern DPS



Castellini et al. 2012

Southeast AK to Amak Island

Total Mercury Concentrations ([THg]) in Steller sea lion hair (young pups highest)

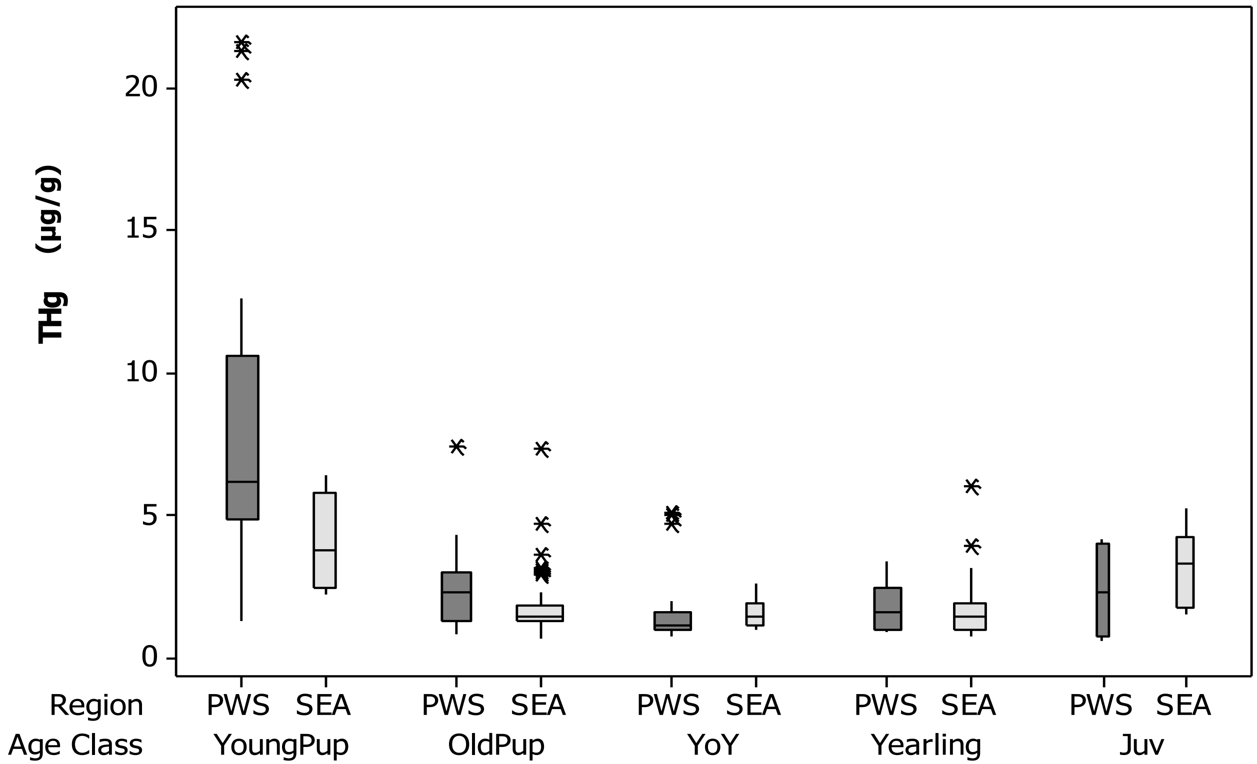


Figure 2: Box and whisker plot of hair [THg] for all age groups from SEA and PWS. Horizontal line represents median, boxes represent the mid 50% distribution, whiskers represent the upper and lower 25% and individual points represent outliers. The width of each bar is proportional to the sample size which is also listed in Table 1.

Castellini et al. *2012*

Total Mercury Concentrations ([THg]) in Steller sea lion hair (west > east)

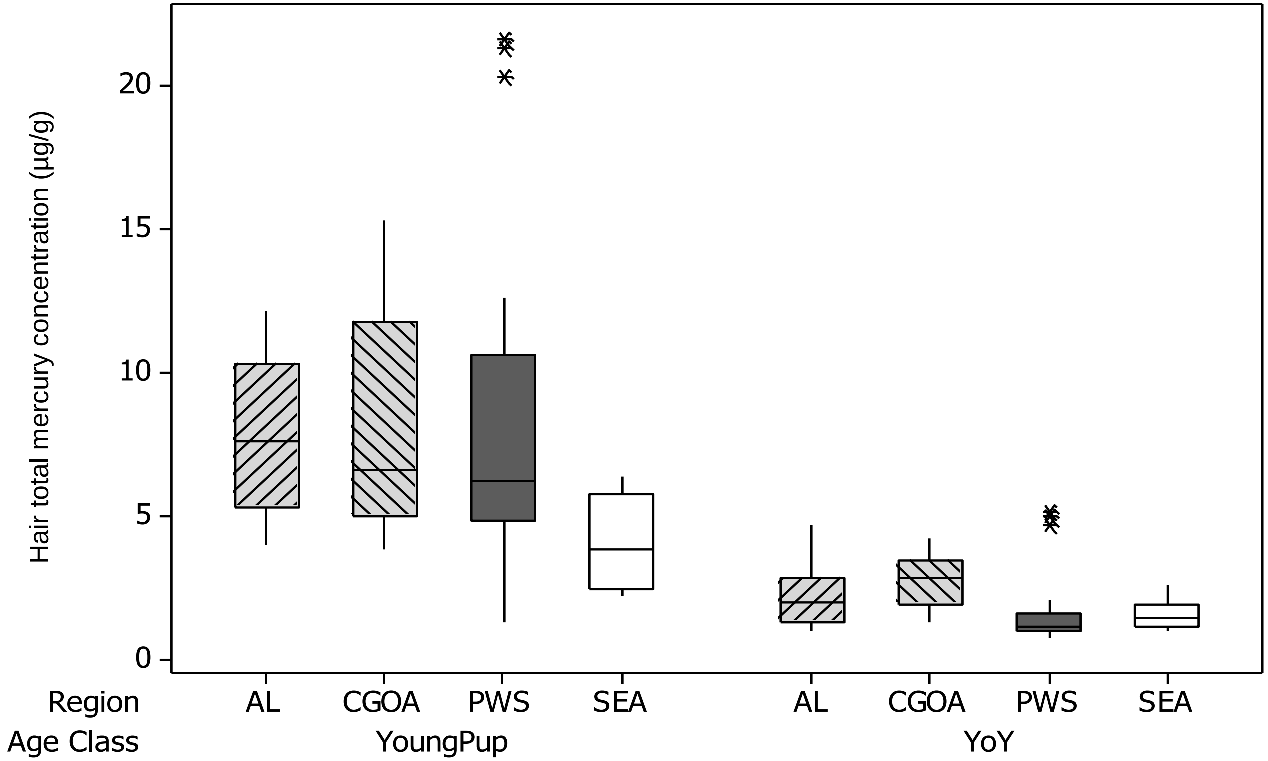


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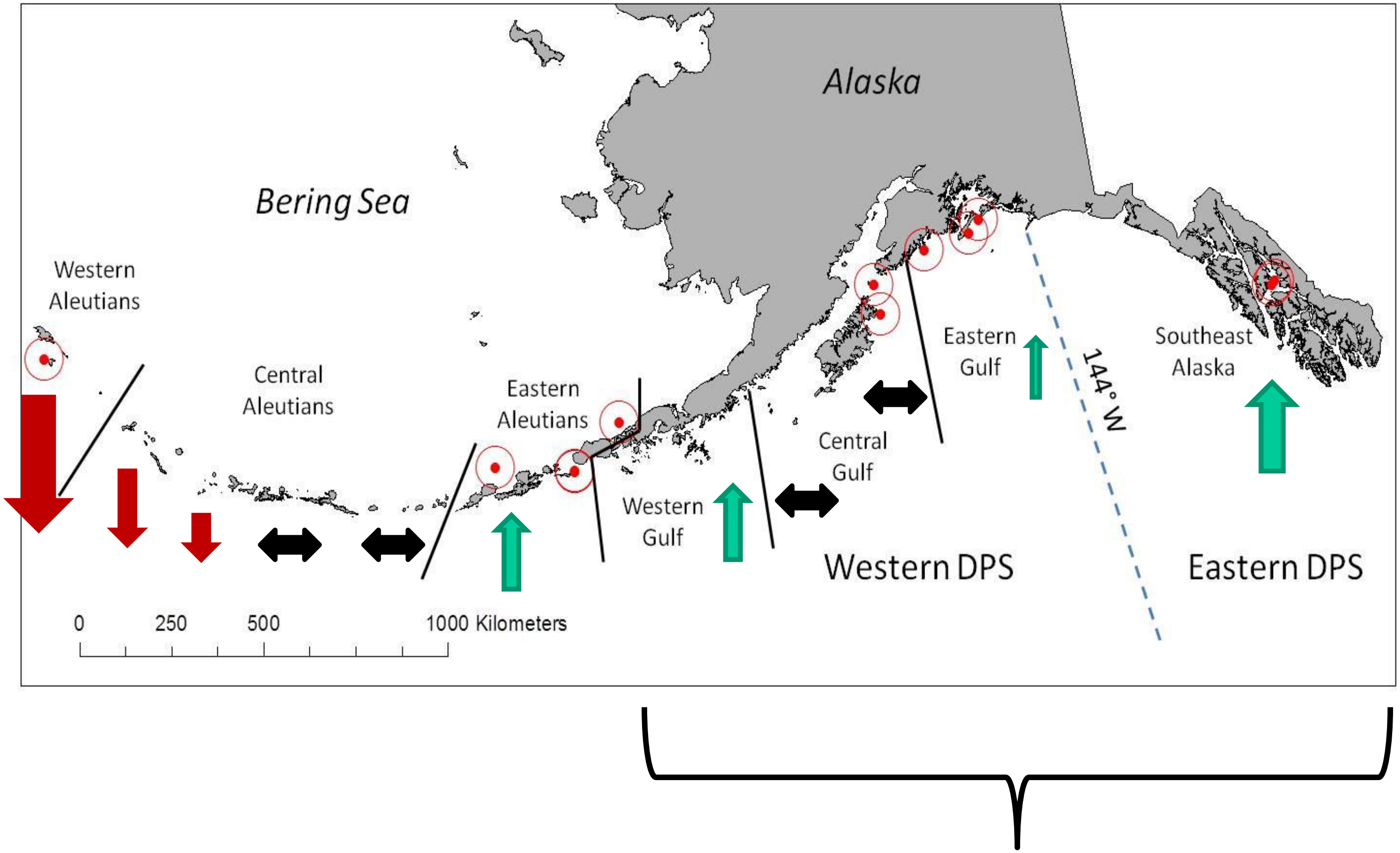
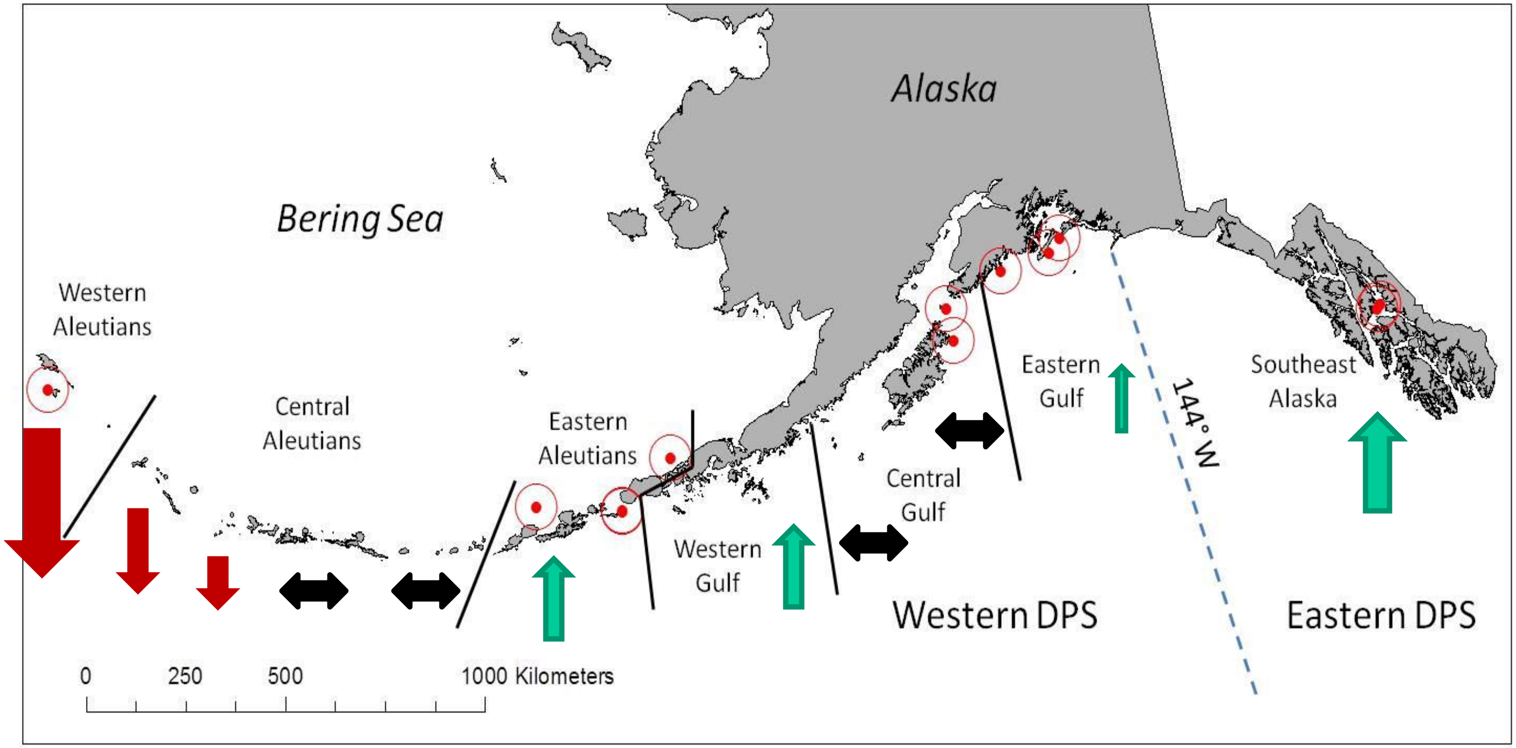
Figure 3. in Castellini et al 2012



Castellini et al. 2012

Southeast AK to Amak Island



Current study
Ugamak to Agattu Islands

Castellini et al. 2012
Southeast AK to Amak Island

In 2011 ADF&G joined NMML to sample young pups at:

Agattu Island (WAI) n= 32

Bogoslof Island (EAI) n=18

Ugamak Island (EAI) n=47

In 2012 ADF&G joined NMML to sample young pups at:

Agattu Island (WAI) n=49

Ulak Island (CAI) n=51

Seguam Island (EAI) n=50

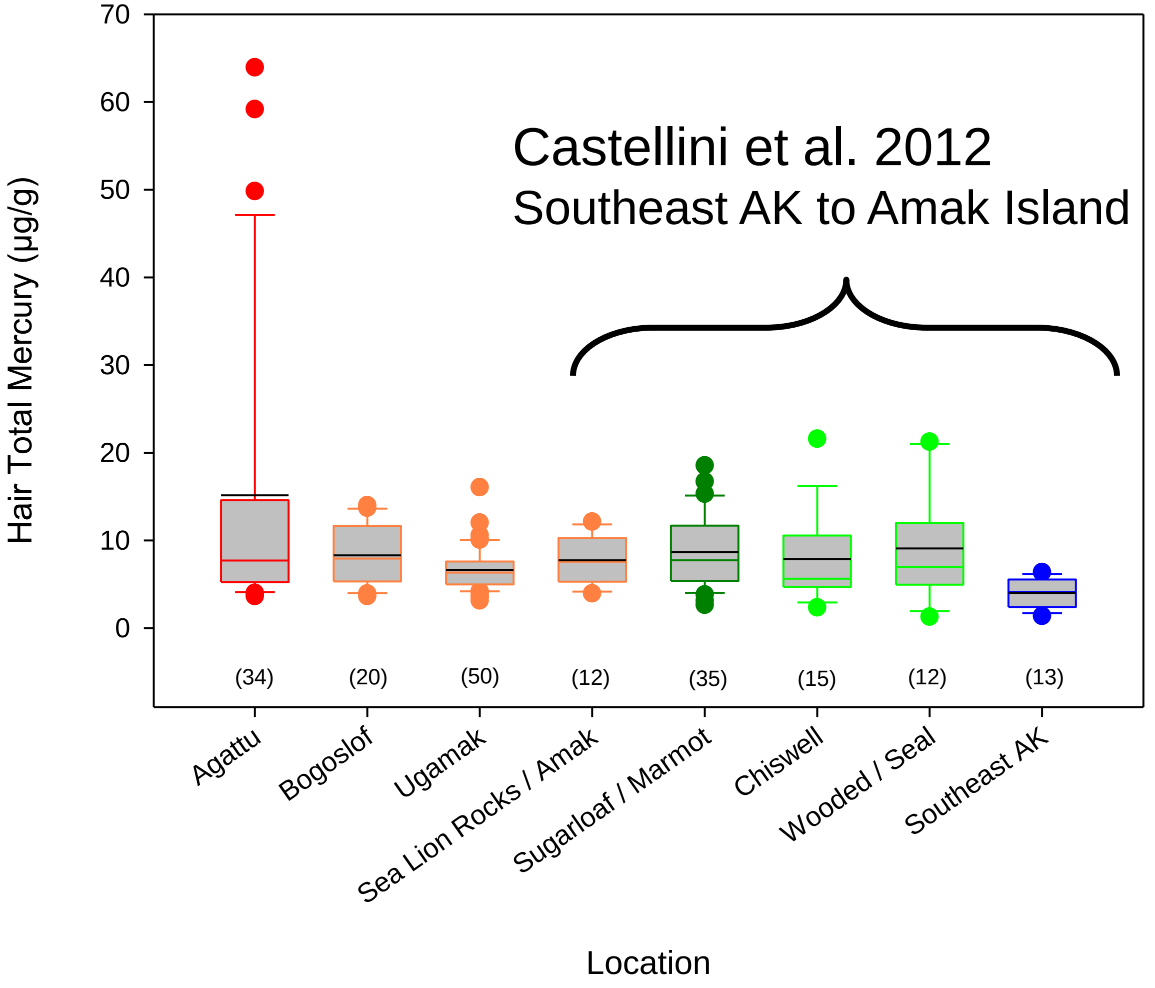
ADF&G collected samples for:

Total mercury analysis in hair and blood
Stable isotopes of C and N in whiskers
Stress protein analysis (haptoglobin in blood)
Organochlorine (OC) contaminants
Samples for Calicivirus analysis

NMML collected:

Body morphometrics
Scats for food habits
Blood chemistry and hematology data
Swabs for Phocine Distemper Virus analysis
Branded pups at Agattu and Ugamak (2011)
Resights of branded animals (2011 and 2012)

Highest total mercury concentrations in Alaska Steller sea lions are in the western Aleutian Islands

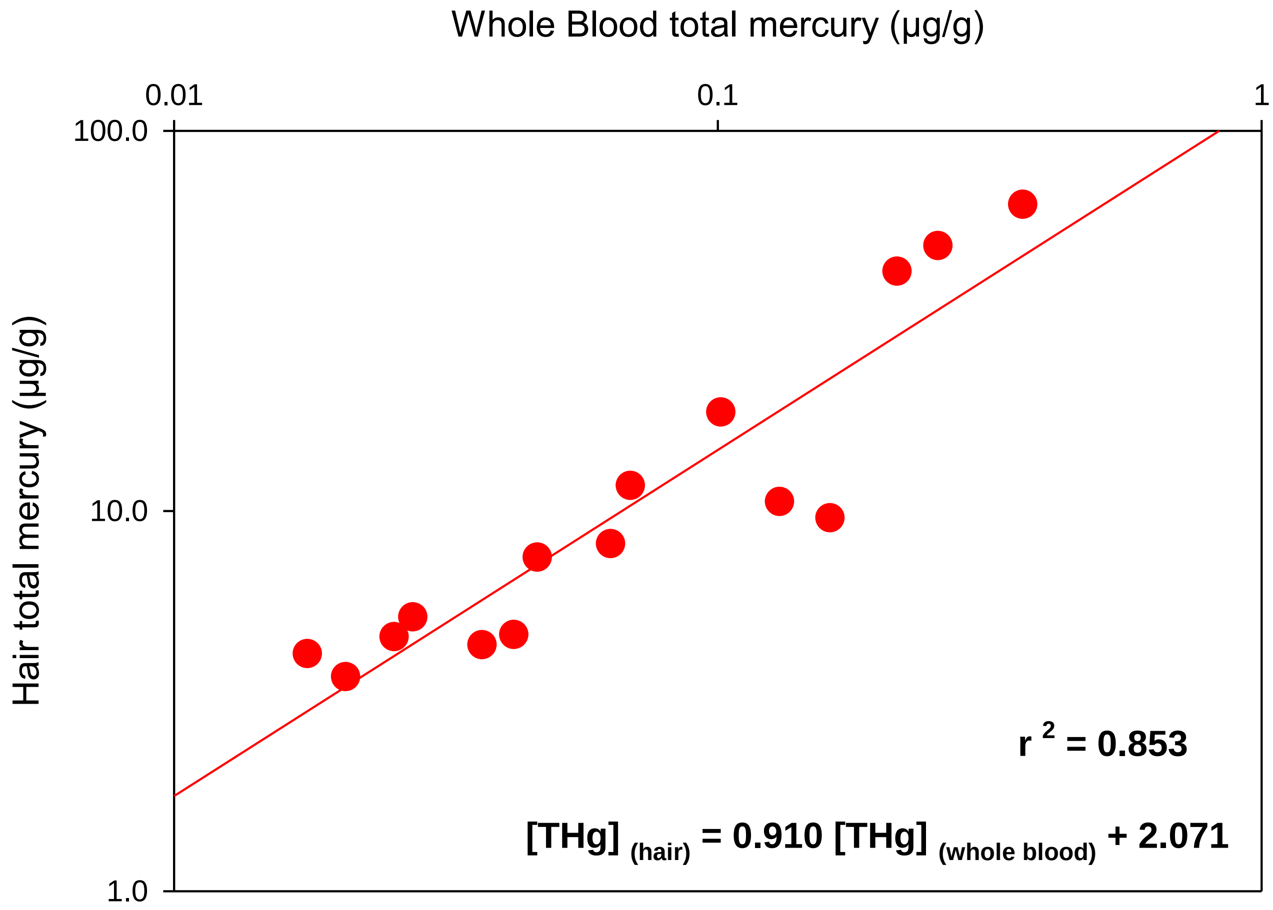


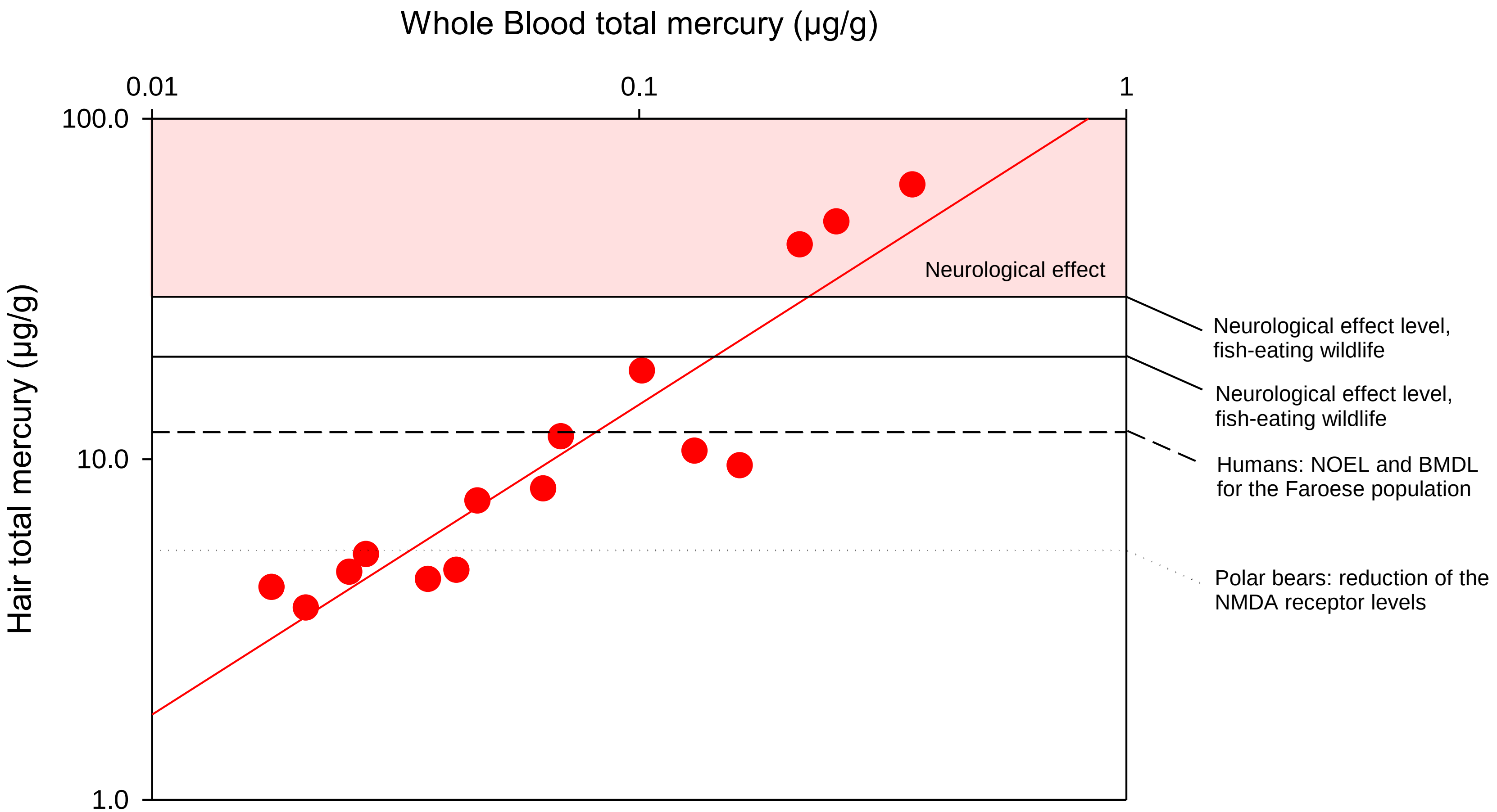
Total Mercury (THg) levels at Agattu Is.

Mean THg: 15.15 ± 2.87 µg/g

Range THg: 3.66 to 63.95 µg/g

3 dead pups: 6.75, 7.86 and 59.17 µg/g


Whole Blood total mercury (µg/g)
0.01
0.1
1
100.0
10.0
1.0
Hair total mercury (µg/g)
r 2 = 0.853
[THg] (hair) = 0.910 [THg] (whole blood) + 2.071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10.0
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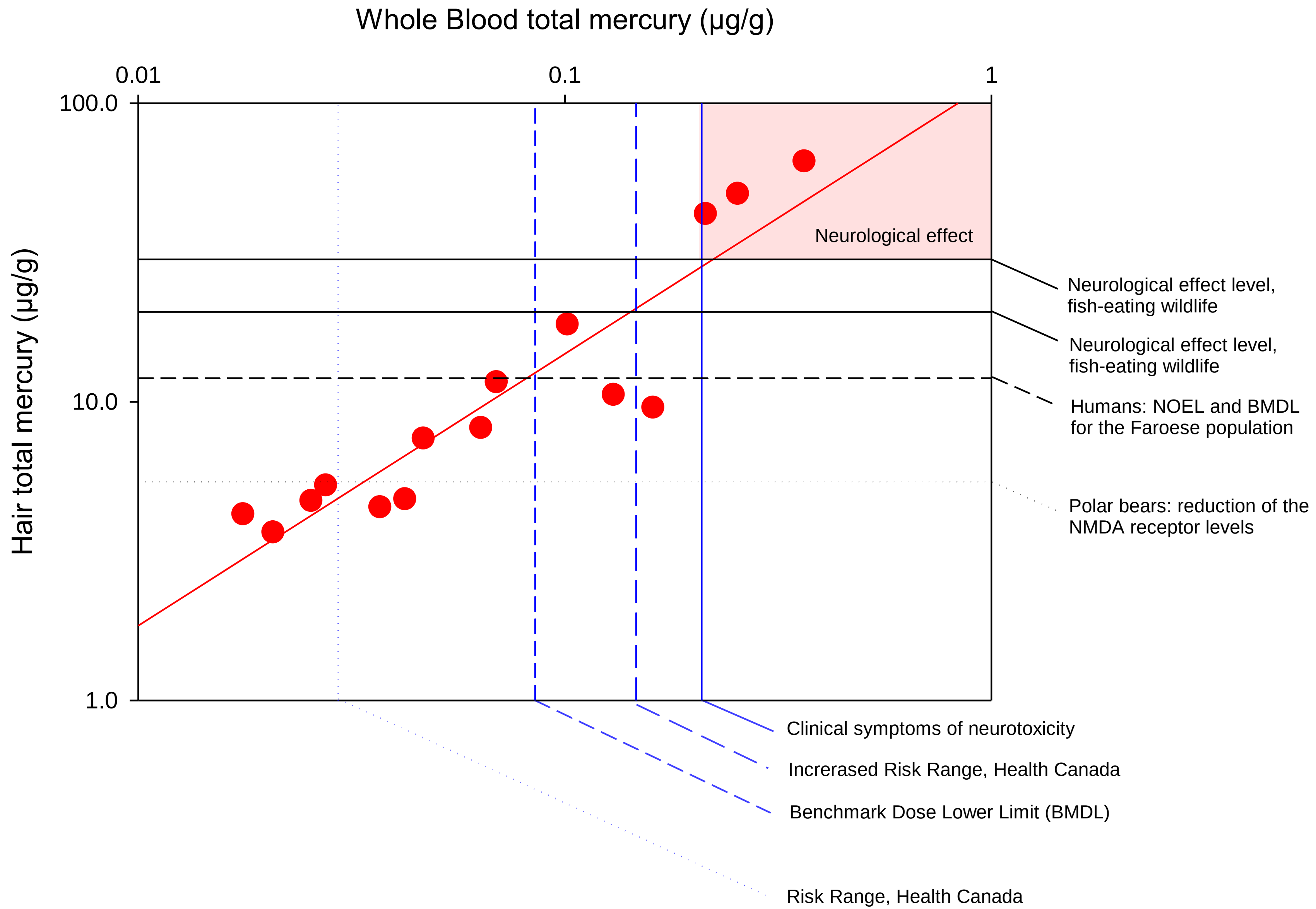
Neurological effect
Neurological effect level, fish-eating wildlife
Neurological effect level, fish-eating wildlife
Humans: NOEL and BMDL for the Faroese population
Polar bears: reduction of the NMDA receptor levels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Neurological effect
Neurological effect level, fish-eating wildlife
Neurological effect level, fish-eating wildlife
Humans: NOEL and BMDL for the Faroese population
Polar bears: reduction of the NMDA receptor levels
Clinical symptoms of neurotoxicity
Increrased Risk Range, Health Canada
Benchmark Dose Lower Limit (BMDL)
Risk Range, Health Canada

Where are they getting the mercury?

Most wildlife are exposed to methylmercury through their diet

The amount of methylmercury in prey items can vary by geographic location and by trophic position of the prey in the food web (biomagnification)

Adult female Steller sea lion “=24” at Petrel Point, Semisopochnoi Island on 18 March 2012 (138 days post-capture), and *Argos* locations for March 10-19, 2012.

Data and image collected under authority of Permit #14326.
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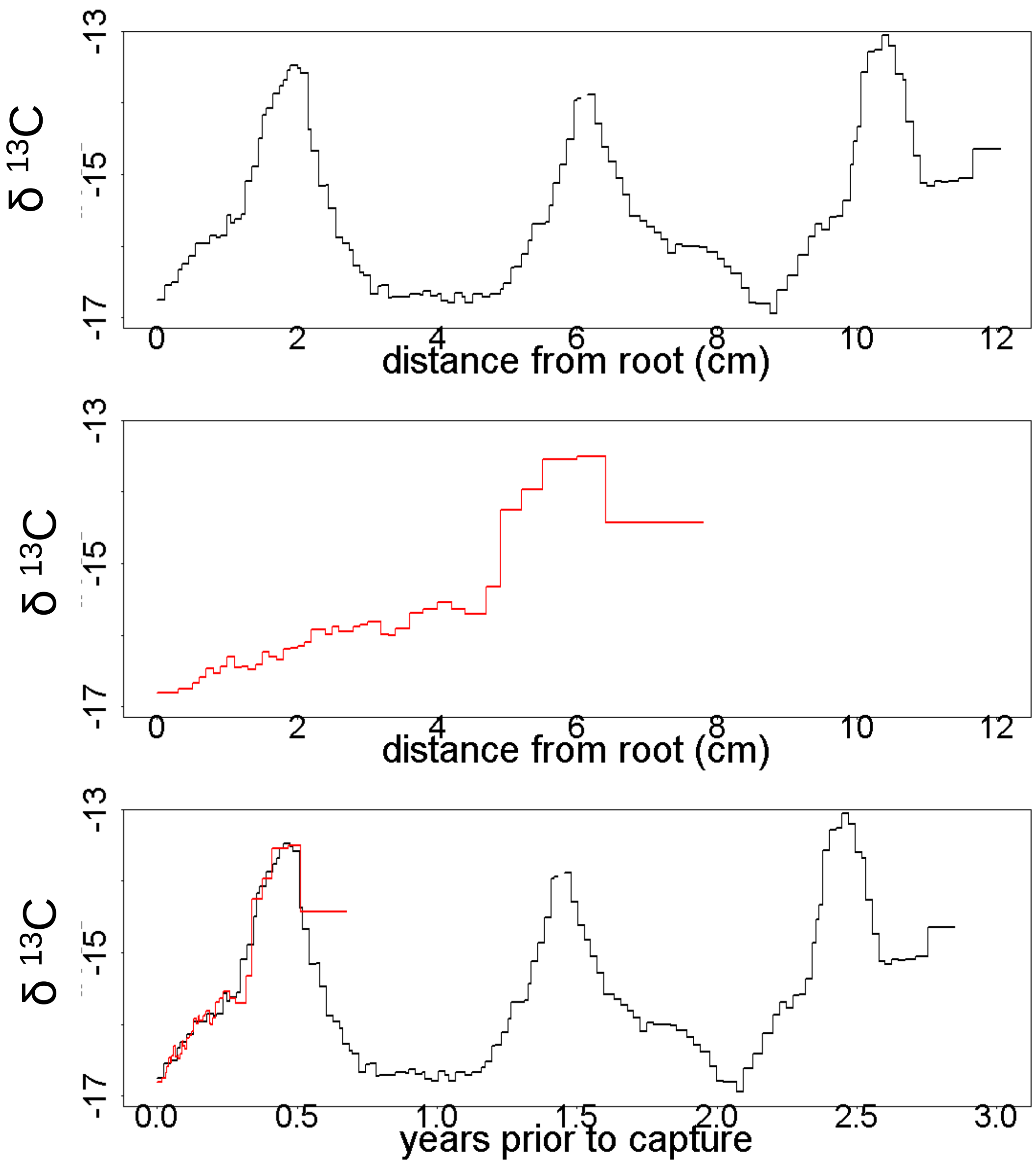
Utilize suckling pups to monitor changes in foraging ecology of their lactating mothers.

Paired vibrissae
Mother and pup



The δ ^{13}C profile along the vibrissae of an adult female

… and her pup

… adjusted for different vibrissae growth rates

Methods:

•Analyzed the isotope ratios of carbon ($\delta^{13}C$) and nitrogen ($\delta^{15}N$) in pup vibrissae sections ranging from 0.2 to 0.5 mg

•Continuous flow isotope ratio mass spectrometry at the UAF Stable Isotope Facility.

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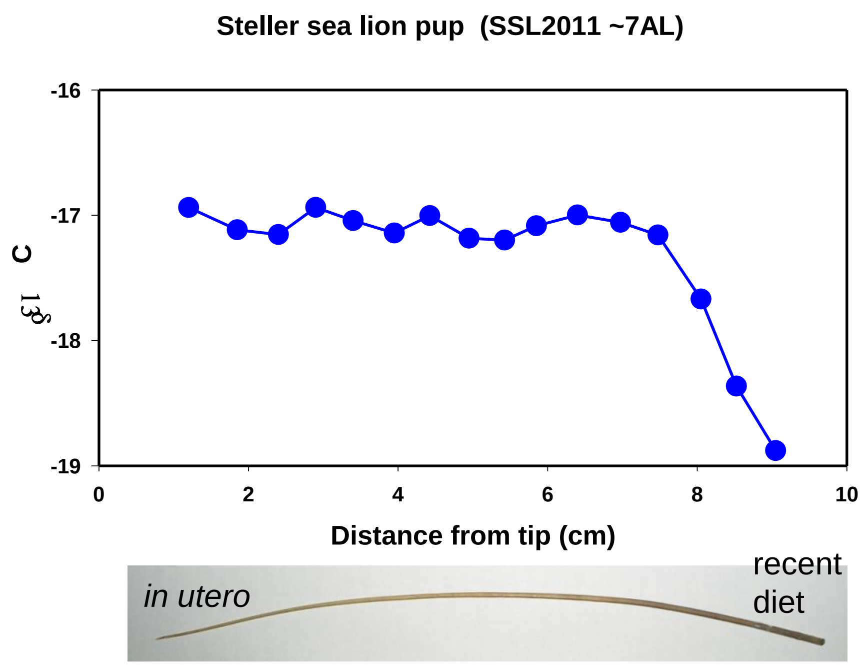

Methods:

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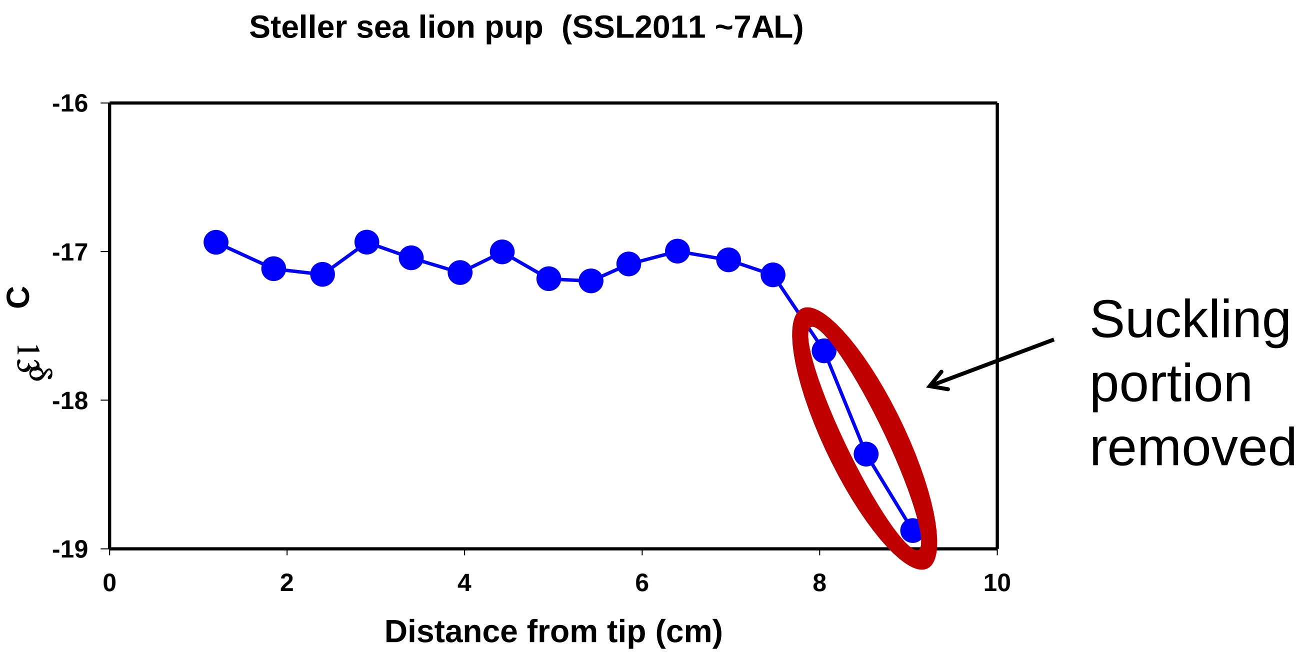
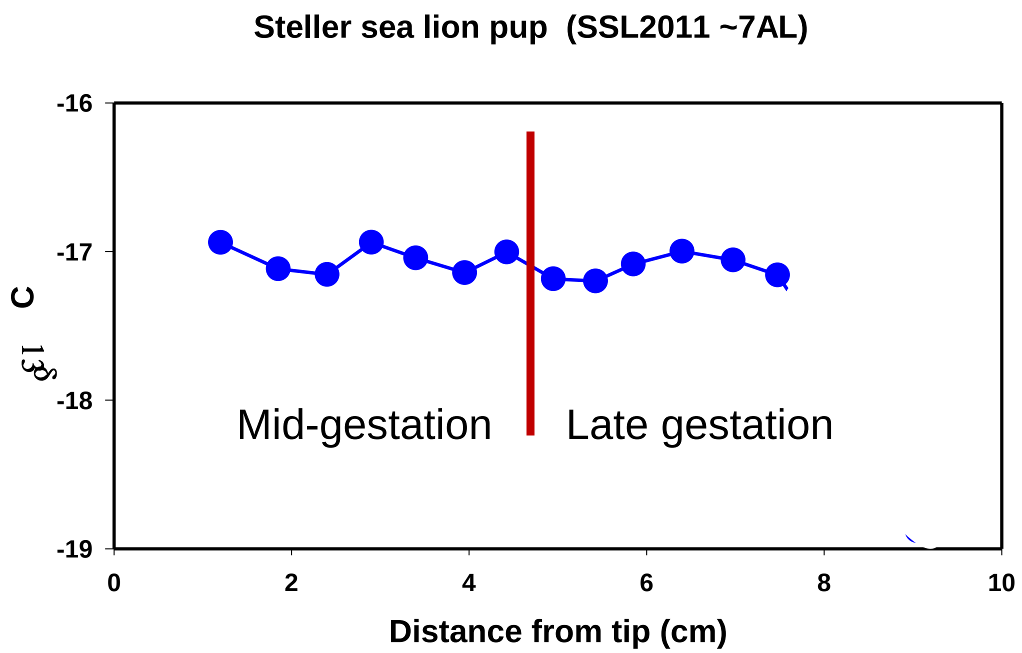


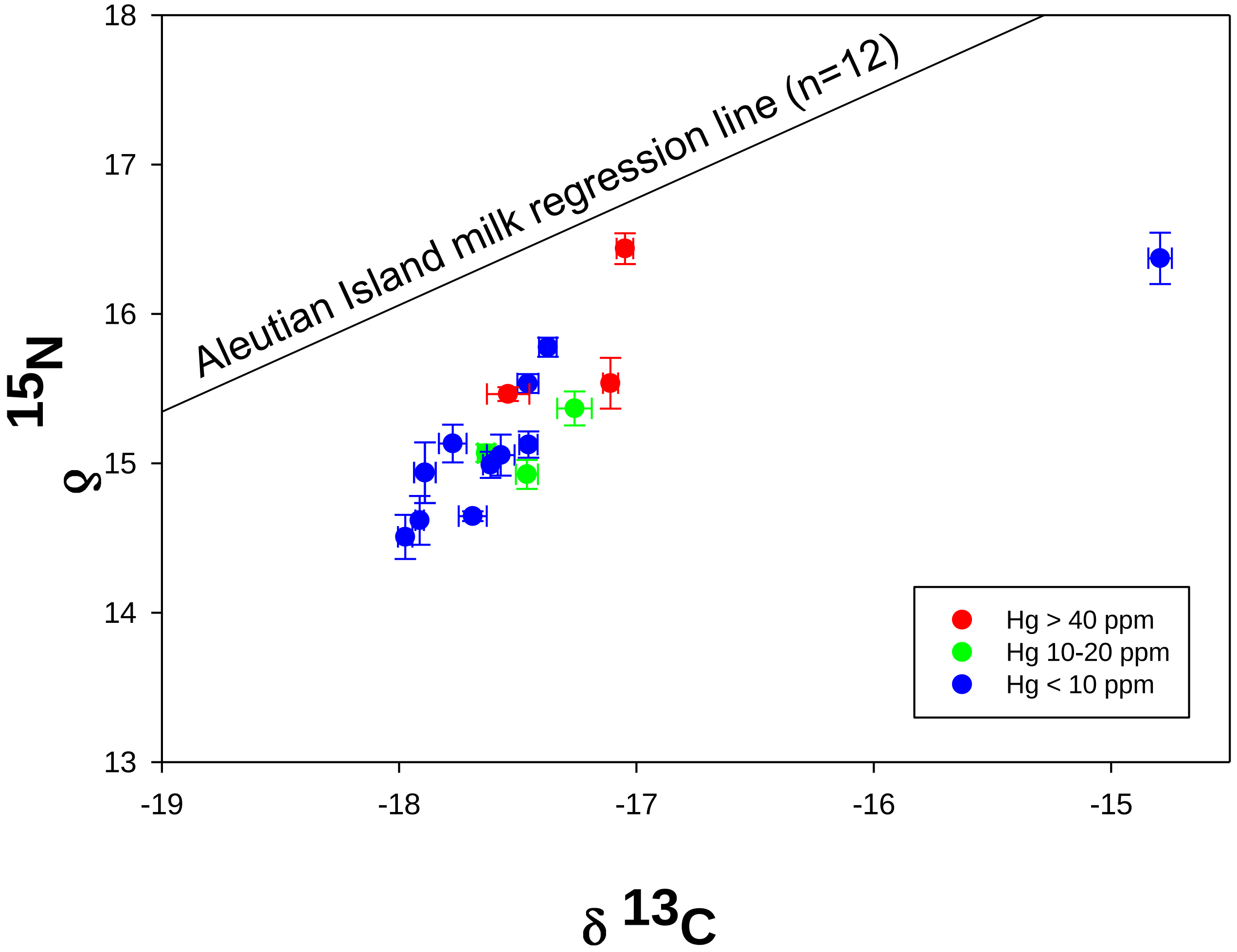
Methods:

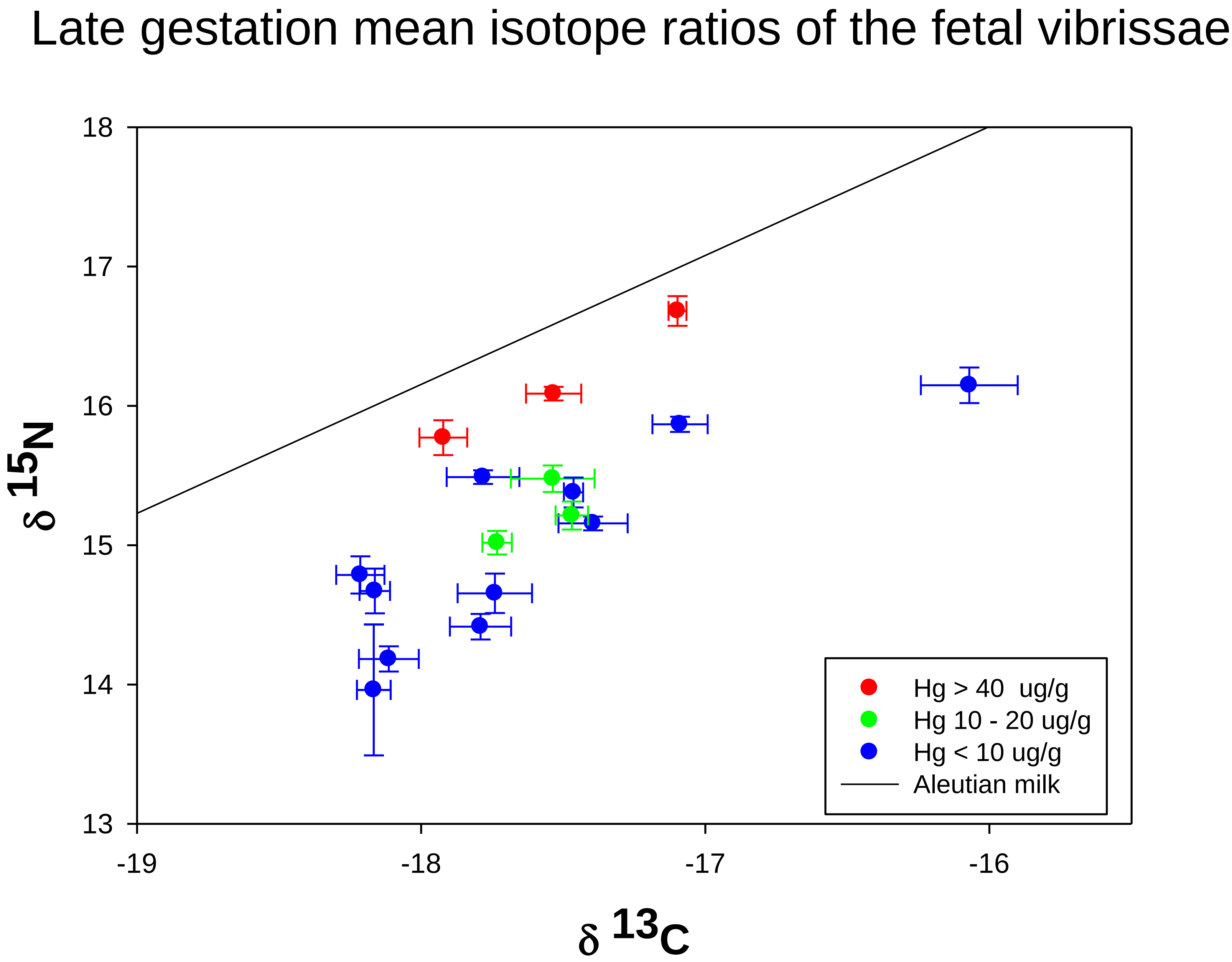
•The suckling portion of this vibrissae was identified by the depleted carbon signature seen when feeding on high fat diets - removed

•The remainder of the vibrissa was divided equally in two sections to represent mid- and late-gestation whisker growth



Mid-gestation mean isotope ratios of the fetal vibrissae





Late gestation mean isotope ratios of the fetal vibrissae
δ 15N
δ 13C
18
17
16
15
14
13
-19
-18
-17
-16
Hg > 40 ug/g
Hg 10 - 20 ug/g
Hg < 10 ug/g
Aleutian milk

We conclude:

We found a wide range of [THg] in the hair of young Steller sea lion pups suggesting some fetuses are exposed to high levels of mercury *in utero*

Stable isotope ratios of nitrogen and carbon measured along the length of the pup vibrissa reflects the trophic level of their mother's diet while they were developing *in utero*

Those pups with the highest hair [THg] also showed elevated $\delta^{15}N$, suggesting that their dams were feeding on higher trophic level prey than pups with low [THg]

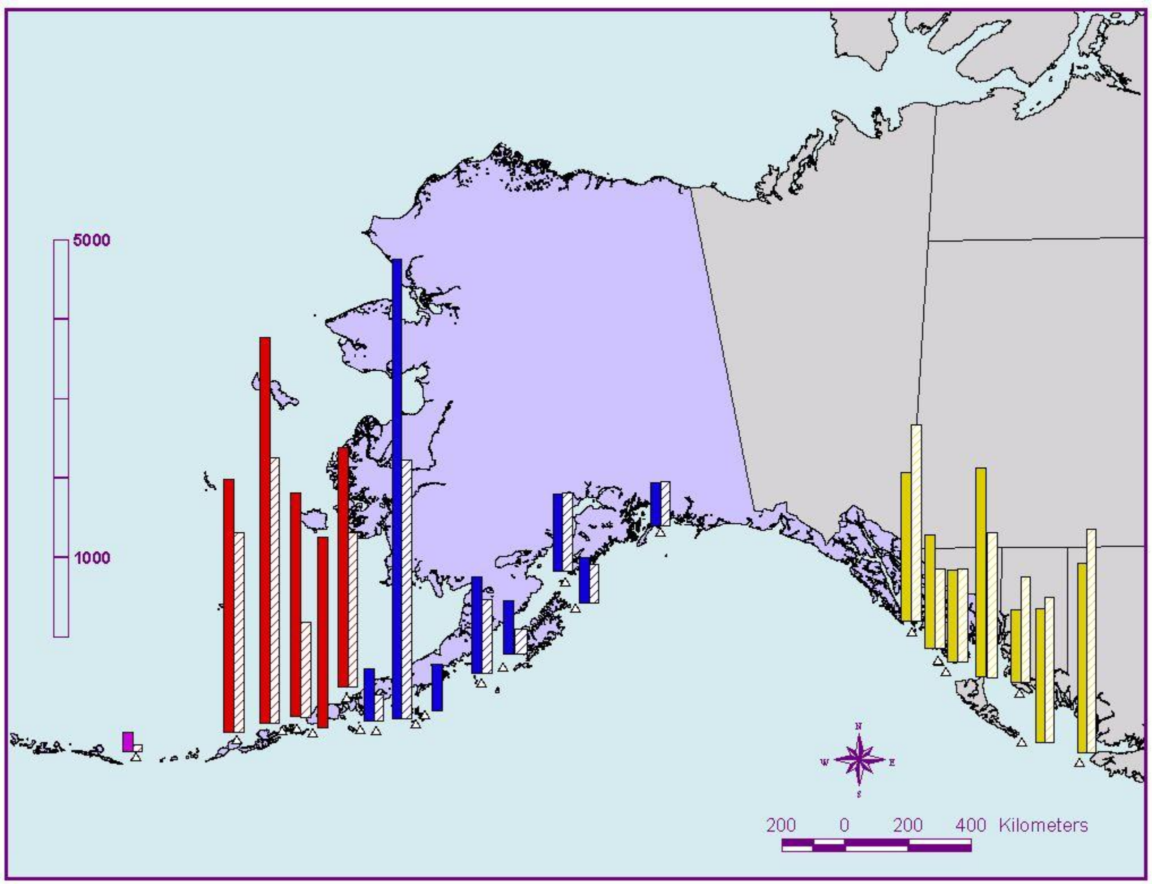
The bottom line for Hg…

- Very young (≤ 3 months) pups seem to have the highest exposure to mercury
- Pups in the more western populations appear to be exposed to higher levels of mercury through maternal diet
- Hair appears to be an efficient excretory mechanism for newborn pups.
- Protective value of selenium?.....

What's next for contaminants in WAI:

1) Analysis of THg in 2012 hair and blood
2) THg Body burden analysis (n=5)
3) Selenium content of tissues
4) Late gestation – model individual diet to assess foraging strategies (generalist/ specialist/ generalist population of specialists)
5) OC contaminants – pups: blubber, milk
Adult female(s): blubber
necropsy tissues (blubber, liver, brain)

PCB concentrations ng/g l.w. & DDT (striped bars) in SSL scats, 1998-2001



Far ranging environmental contamination in SSL that varies on a finer regional scale than just eastern and western stock

Beckmen, K., K. Pitcher, K. Burek, and G. Ylitalo In revision. Organochlorine contaminant concentrations in scats collected on Steller sea lion (*Eumetopias jubatus*) rookeries. Archives of Environmental Contamination and Toxicology.

Acknowledgments:

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Stable Isotopes to interpret contaminants:

Using chemical feeding ecology to understand variability in mercury concentrations in western Aleutian Steller sea lions.

Rea LD, Castellini JM, Correa L, Fadely BS, O'Hara TM

For IsoEcol August 2012

"Hair [THg] was highly variable among pups, ranging from 3.7 to 63.9 µg/g dwt. Pups born with the highest [THg] in their hair (above 40 µg/g) showed significantly higher $\delta^{15}N$ in vibrissa tissue grown during late gestation ($F_{2,25}$=8.61, p=0.0019) suggesting that their mothers may have incorporated higher trophic level fish into their diet. The wide distribution of both $\delta^{13}C$ and $\delta^{15}N$ seen in late gestation vibrissae segments of these pups illustrates the diverse nature of the isotopic signature of the diet of adult females, whether that be driven by trophic level of the prey species, the geographic location of foraging, or both."

Diverse diets in summer:

Table 2. Overall percentage frequency of occurrence (FO), relative occurrence (RO), relative abundance (RA), and index of importance (IIMP) of prey identified in Steller sea lion scats collected from sites in the Kodiak Archipelago (1999 to 2005). Prey highlighted in bold occurred with ≥10% FO in any single collection. Prey with values of 0.0 indicate actual value was <0.1

Prey identified	FO	RO	RA	IIMP
Poachers: family Agonidae	0.5	0.2	0.1	0.1
Sand lances: family Ammodytidae				
Pacific sand lance (*Ammodytes hexapterus*)	**41.7**	**13.2**	**38.6**	**16.1**
Sablefishes: family Anoplopomatidae				
Sablefish (*Anoplopoma fimbria*)	0.8	0.2	0.1	0.2
Tubesnouts: family Aulorhynchidae				
Tubesnout (*Aulorhynchus flavidus*)	0.7	0.2	0.1	0.1
Deep sea smelts: family Bathylagidae				
Northern smooth tongue (*Leuroglossus schmidti*)	0.0	0.0	0.0	0.0
Ronquils: family Bathymasteridae				
Searcher (*Bathymaster signatus*)	0.1	0.0	0.0	0.0
Unidentified ronquils (Bathymasteridae)	0.2	0.1	0.0	0.0
Northern ronquil (*Ronquilus jordani*)	0.1	0.0	0.0	0.0
Herring: family Clupeidae				
Pacific herring (*Clupea pallasi*)	**23.0**	**7.3**	**6.3**	**7.7**
Sculpins: family Cottidae				
Artedius spp.	0.0	0.0	0.0	0.0
Unidentified sculpins	**3.8**	**1.2**	**0.5**	**0.8**
Armorhead sculpin (*Gymnocanthus galeatus*)	0.0	0.0	0.0	0.0
Red Irish lord (*Hemilepidotus hemilepidotus*)	0.3	0.1	0.0	0.1
Yellow Irish lord (*Hemilepidotus jordani*)	0.1	0.0	0.0	0.0
Unidentified Irish lord (*Hemilepidotus* spp.)	**10.8**	**3.4**	**1.6**	**2.4**
Plain sculpin (*Myoxocephalus jaok*)	0.1	0.0	0.0	0.0
Triglops spp.	0.0	0.0	0.0	0.0
Lumpsuckers: family Cyclopteridae				
Smooth lumpsucker (*Aptocyclus ventricosus*)	**0.5**	**0.1**	**0.1**	**0.1**
Unidentified lumpsuckers	**1.3**	**0.4**	**0.2**	**0.3**
Sleeper sharks: family Dalatiidae				
Pacific sleeper shark (*Somniosus pacificus*)	0.0	0.0	0.0	0.0
Anchovy: family Engraulidae				
Anchovy (*Engraulis mordax*)	0.0	0.0	0.0	0.0
Cods: family Gadidae				
Saffron cod (*Eleginus gracilis*)	0.1	0.0	0.0	0.0
Unidentified gadids (Gadidae)	**10.3**	**3.3**	**1.8**	**3.3**
Pacific cod (*Gadus macrocephalus*)	**31.9**	**10.1**	**5.6**	**9.5**
Pacific tomcod (*Microgadus proximus*)	0.1	0.0	0.0	0.0
Walleye pollock (*Theragra chalcogramma*)	**36.8**	**11.6**	**10.9**	**15.1**
Sticklebacks: family Gasterosteidae				
Threespine stickleback (*Gasterosteus aculaeatus*)	0.4	0.1	0.1	0.1
Sailfin sculpins: family Hemitripteridae	0.0	0.0	0.0	0.0
Greenlings: family Hexagrammidae				
Unidentified greenlings	0.5	0.2	0.1	0.1
***Hexagrammos* spp.**	**2.5**	**0.8**	**0.5**	**0.5**
Kelp greenling (*Hexagrammos decagrammus*)	0.1	0.0	0.0	0.0
Rock greenling (*Hexagrammos lagocephalus*)	1.4	0.4	0.2	0.2
Atka mackeral (*Pleurogrammus monopterygius*)	0.7	0.2	0.1	0.2

……

McKenzie and Wynne 2008

Table 2 (continued)

Prey identified	FO	RO	RA	IIMP
Snailfishes: family Liparidae	**6.2**	**2.0**	**1.1**	**1.8**
Lanternfishes: family Myctophidae				
Northern lampfish (*Stenobrachius leucopsarus*)	0.0	0.0	0.0	0.0
Smelts: family Osmeridae				
Surf smelt (*Hypomesus pretiosus*)	0.1	0.0	0.0	0.0
Capelin (*Mallotus villosus*)	**8.6**	**2.7**	**7.9**	**3.9**
Unidentified smelt	**8.9**	**2.8**	**1.3**	**2.1**
Eulachon (*Thaleichthys pacificus*)	**1.1**	**0.3**	**0.2**	**0.2**
Gunnels: family Pholidae				
Penpoint gunnel (*Apodichthys flavidus*)	0.0	0.0	0.0	0.0
Unidentified gunnel	**1.9**	**0.6**	**0.3**	**0.3**
Crescent gunnel (*Pholis laeta*)	0.4	0.1	0.1	0.1
Flatfish: order Pleuronectiformes				
Arrowtooth flounder (*Atheresthes stomias*)	**34.7**	**11.0**	**5.6**	**12.5**
Rex sole (*Glyptocephalus zachirus*)	0.1	0.0	0.0	0.0
Flathead sole (*Hippoglossoides elassodon*)	0.1	0.0	0.0	0.0
Pacific halibut (*Hippoglossus stenolepis*)	**2.9**	**0.9**	**0.4**	**0.9**
Rock sole (*Lepidopsetta* spp.)	**6.7**	**2.1**	**1.0**	**1.5**
Yellowfin sole (*Limanda aspera*)	0.0	0.0	0.0	0.0
Sand sole (*Lyopsetta exilis*)	0.0	0.0	0.0	0.0
Dover sole (*Microstomus pacificus*)	0.2	0.1	0.0	0.0
Starry flounder (*Platichthys stellatus*)	0.9	0.3	0.1	0.1
Alaska plaice (*Pleuronectes quadrituberculatus*)	0.0	0.0	0.0	0.0
Unidentified flatfish	**8.7**	**2.8**	**1.2**	**2.2**
Sand sole (*Psettichthys melanostictus*)	0.2	0.1	0.0	0.0
Skates: family Rajidae	**4.6**	**1.5**	**0.6**	**1.0**
Salmonids: family Salmonidae				
Pacific salmon (*Oncorhynchus* spp.)	**26.3**	**8.3**	**4.3**	**8.4**
Dolly varden (*Salvelinus malma*)	0.1	0.0	0.0	0.0
Rockfishes: family Scorpaenidae				
Unidentified rockfish (Scorpaenidae)	0.7	0.2	0.1	0.2
Rockfish (*Sebastes* spp.)	**3.6**	**1.1**	**0.5**	**0.7**
Thornyheads (*Sebastolobus* spp.)	0.0	0.0	0.0	0.0
Dogfish sharks: family Squalidae				
Spiny dogfish (*Squalus acanthias*)	0.9	0.3	0.1	0.2
Pricklebacks: family Stichaeidae				
High cockscomb (*Anoplarchus purpurescens*)	0.5	0.1	0.1	0.1
Snake prickelback (*Lumpenus sagitta*)	0.0	0.0	0.0	0.0
Unidentified pricklebacks (Stichaeidae)	1.3	0.4	0.2	0.2
Arctic shanny (*Stichaeus punctatus*)	0.0	0.0	0.0	0.0
Black prickleback (*Xiphister atropurpures*)	0.0	0.0	0.0	0.0
Rock prickelback (*Xiphister mucosus*)	0.0	0.0	0.0	0.0
Prickelback (*Xiphister* spp.)	0.1	0.0	0.0	0.0
Sandfishes: family Trichodontidae				
Pacific sandfish (*Trichodon trichodon*)	**10.5**	**3.3**	**2.8**	**2.5**
Eelpouts: family Zoarchidae				
Shortfin eelpout (*Lycodes brevipes*)	0.0	0.0	0.0	0.0
Wattled eelpout (*Lycodes palearis*)	0.0	0.0	0.0	0.0
Unidentified fish spp.	3.1	1.0	0.4	1.0
Squids and octopus: Order Cephalopoda				
Unidentified cephalopods	2.1	0.7	0.3	0.4
Octopus spp.	2.8	0.9	0.4	0.6
Squid spp.	0.6	0.2	0.1	0.1
Marine worm: class **Polychaete**	**8.0**	**2.5**	**3.7**	**2.0**
Total		100	100	100
Samples (total)				
Scats containing identifiable prey (2760)				
Scats containing only unidentifiable prey (192)				
Empty scats (80)				
Total collected (3032)				

McKenzie and Wynne 2008