Exploring alternative hypotheses for the lack of recovery of Steller sea lions in Alaska.

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Alternative hypotheses – Basic strategy

"EAST vs WEST"

- investigate age, seasonal or sex related differences in parameter within the stable eastern DPS
- compare stable and declining DPS at similar ages

Population Dynamics

Survival, Reproduction Recruitment and Distribution

- Pup branding
-Summer brand resighting throughout SEA and PWS
-Field camp at Lowrie Island and Sugarloaf Island – brand resights

Physiological Studies

Identification of Weaning & Diet

- Stable isotopes (whiskers), Fatty acids (blubber), Scats

Body Condition & Nutrition

- Morphometrics
- Deuterium, BIA
- Blood chemistry
- Muscle biochemistry
- Total body oxygen stores

Contaminants & Disease

- Serology, Parasitology, Virology, Contaminants, Hp

Foraging Ecology

Juvenile Movement & Dive Ontogeny

-Dispersal, development of diving duration and depth
-Organization of diving behavior
- ontogeny of fine scale foraging behaviour

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Dive Capture of Steller sea lions

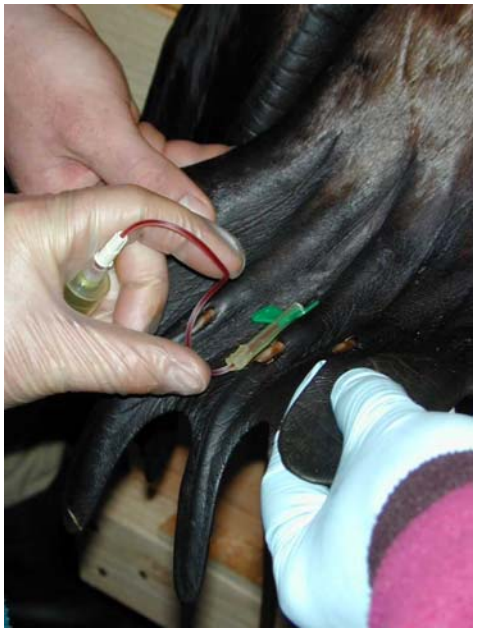
Photo: Shane Moore

Underwater capture
n = approx. 650

Ages: 2-24 months
-plus the odd animal
24-48 months of age

Vibrissae, serum, blubber and milk

In a subset of young animals captured, it is also possible to collect a sample of ingested milk. This provides the most direct evidence of diet composition and reflects the recent dietary intake of lactating adult females.



Lack of recovery of Steller sea lions in Alaska: Alternative hypotheses

- **nutritional stress** – body condition, blood chemistry (fasting or starvation), metabolic rate
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Evidence of poor nutrition in Steller sea lions during the 1980's:

- body size of sea lions (age 1-10 years) significantly lower in 1980s than in 1970s
- lower pregnancy rates in 1980s than 1970s indicating possible high rate of fetal mortality
- change in diet as seen in stomach contents
- concurrent declines in harbor seals, fur seals and some piscivorous seabirds

Steller sea lion physiology and ecology in the 1990's: in conflict with the nutritional stress hypothesis

- no evidence of high pup mortality
- no evidence of poor adult female body condition
- similar birth weights of pups in east and west
- faster growth rates of pups in declining population
- no blood chemistry or hematology evidence of poor pup health in east or west
- blood chemistry evidence of longer fasting periods in eastern pups, agrees with longer foraging trips
- longer perinatal period and time spent nursing in western stock

Conclusions from 1990's data:

1. Adult females in the west were able to secure enough food to adequately nurse their pups within the first 4 to 6 weeks of lactation
2. If food limitation is a problem (in the 1990's and today), it may affect larger, late lactation pups and newly weaned juvenile sea lions

If nutrient intake has been limiting the recovery of this species due to adult females being unable to support larger late lactation pups we would expect to see:

1) Lower body mass at a given age in western population
2) Lower percent body fat at a given age in western population

Indices of body condition:

- body mass
- standard length, girth at 6 locations
- percent total body lipids (deuterium dilution technique, bioelectrical impedance analysis -BIA)
- blubber depth (imaging ultrasound)

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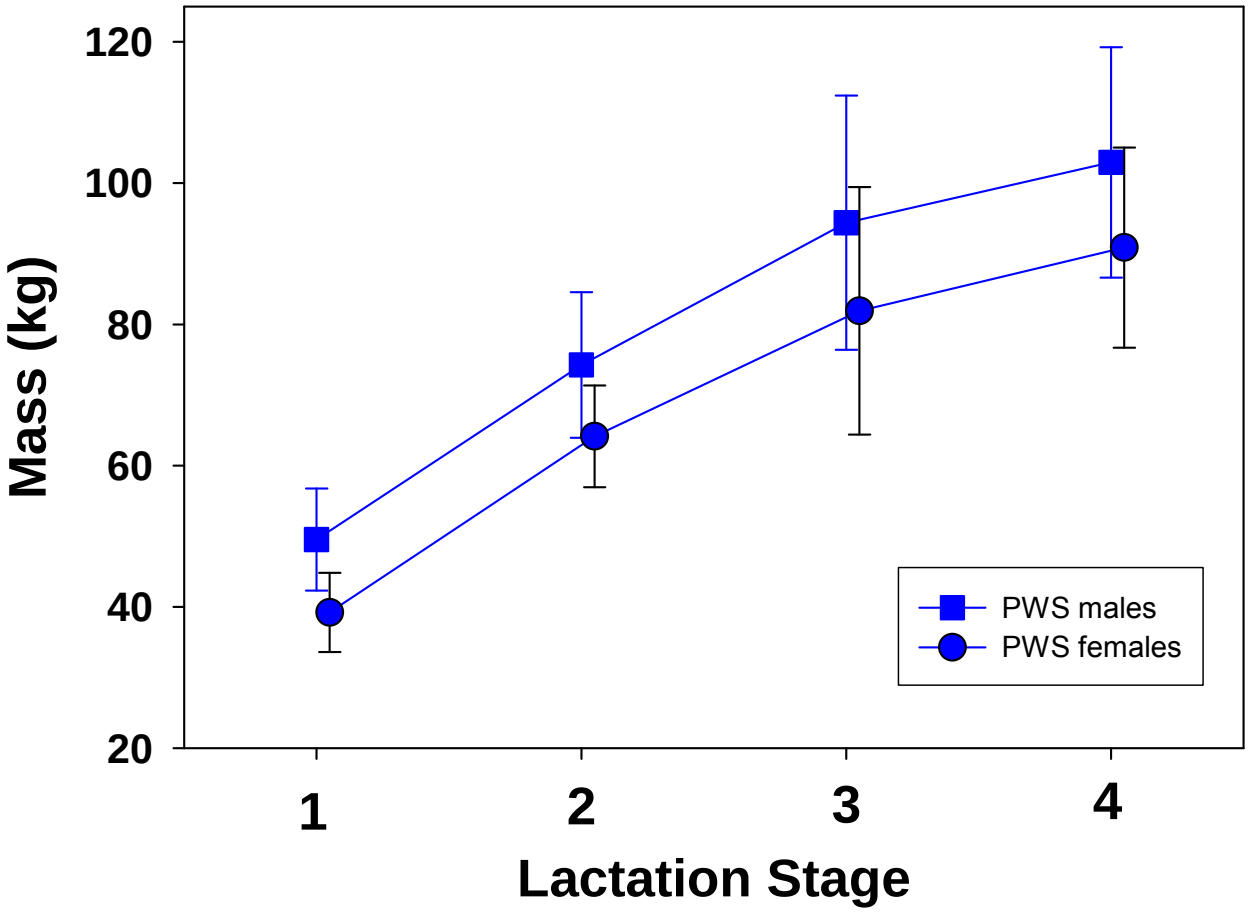
Methods

- 382 Steller sea lion pups, 2 to 11 months of age using the underwater dive capture method
- captured between 1998 and 2005 in 4 regions of Alaska
  - Southeast Alaska (SEA)
  - Prince William Sound (PWS)
  - Gulf of Alaska (GOA)
  - Aleutian Islands (AI)

Sexually Dimorphic Species:



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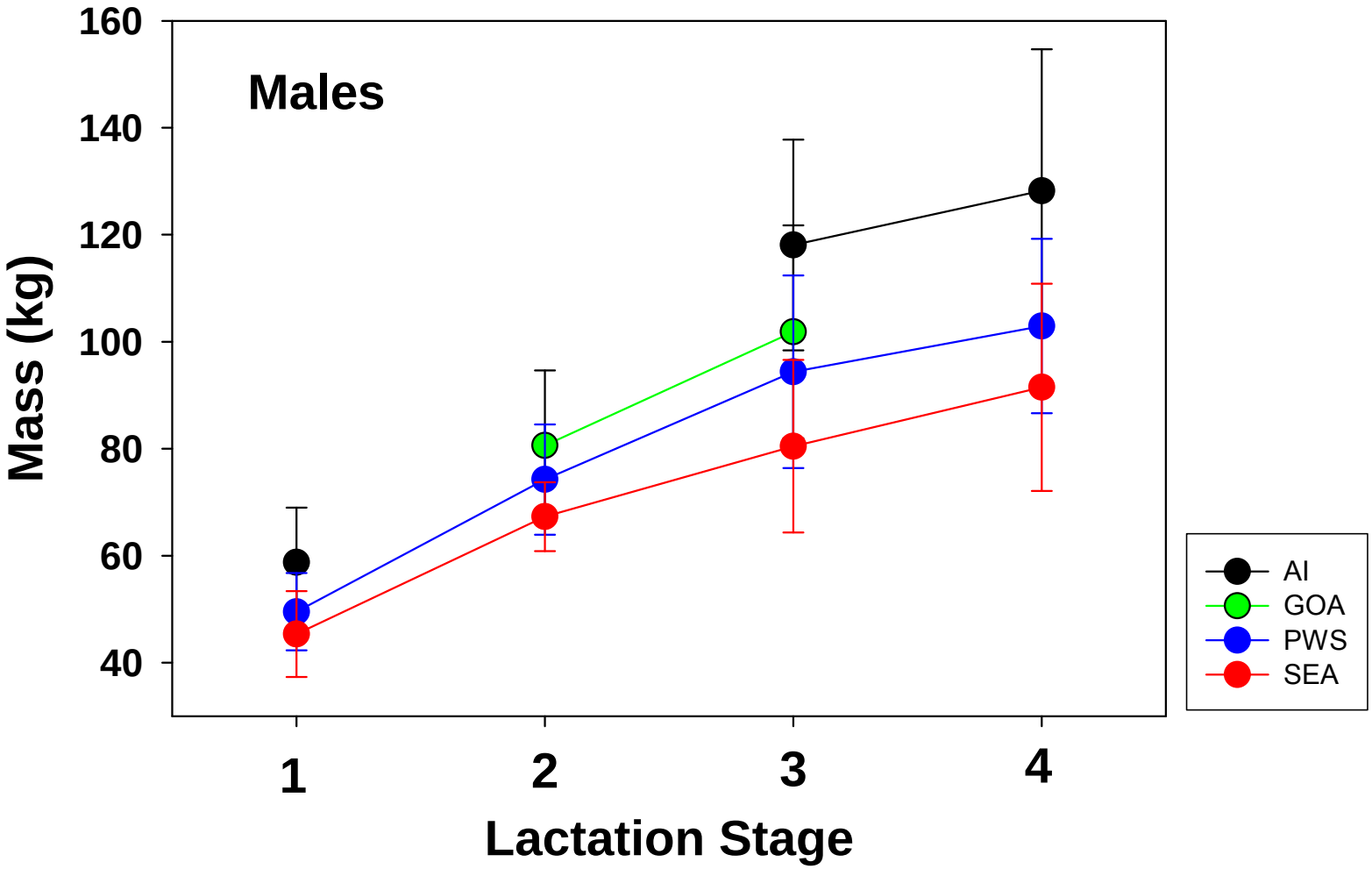
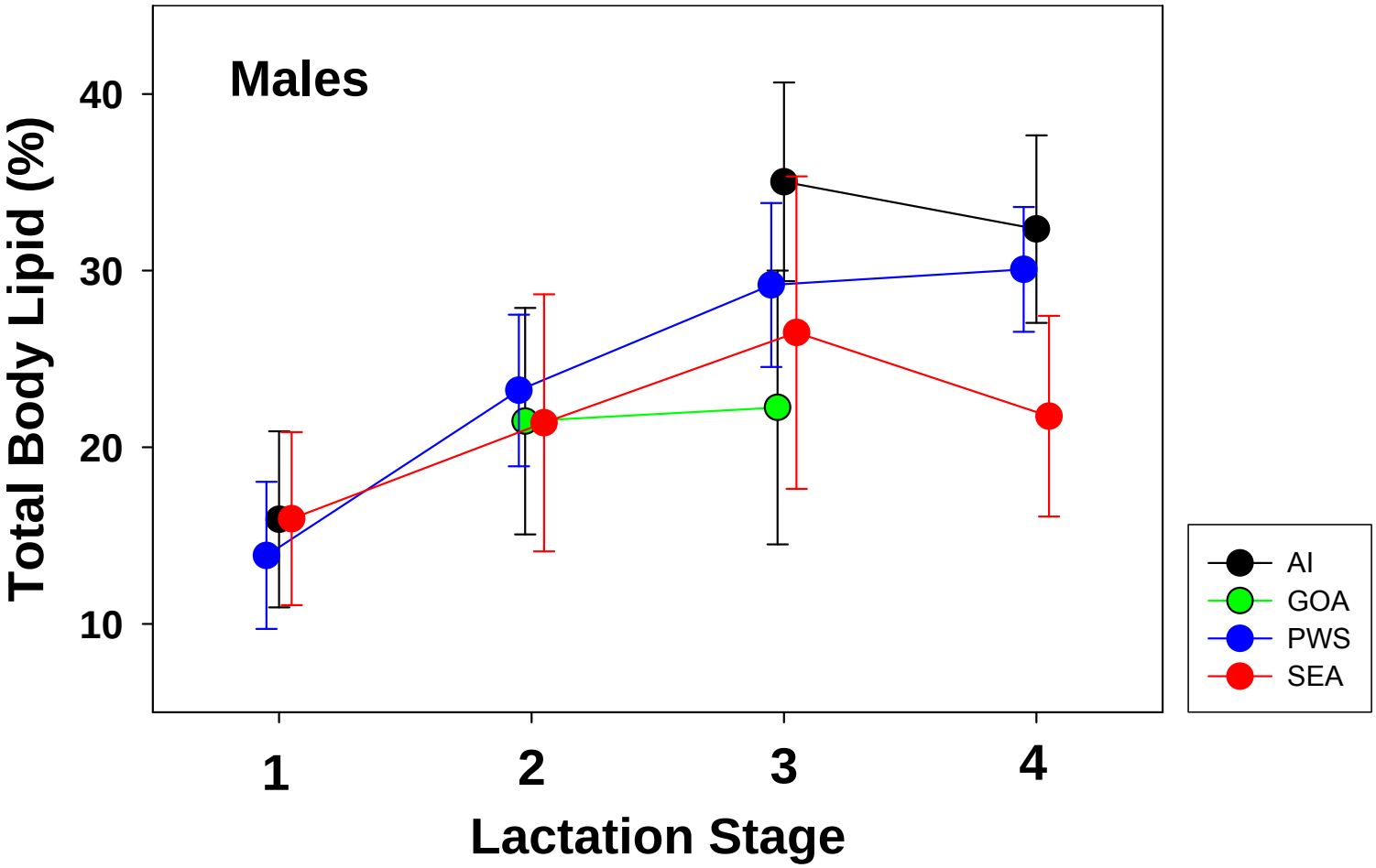
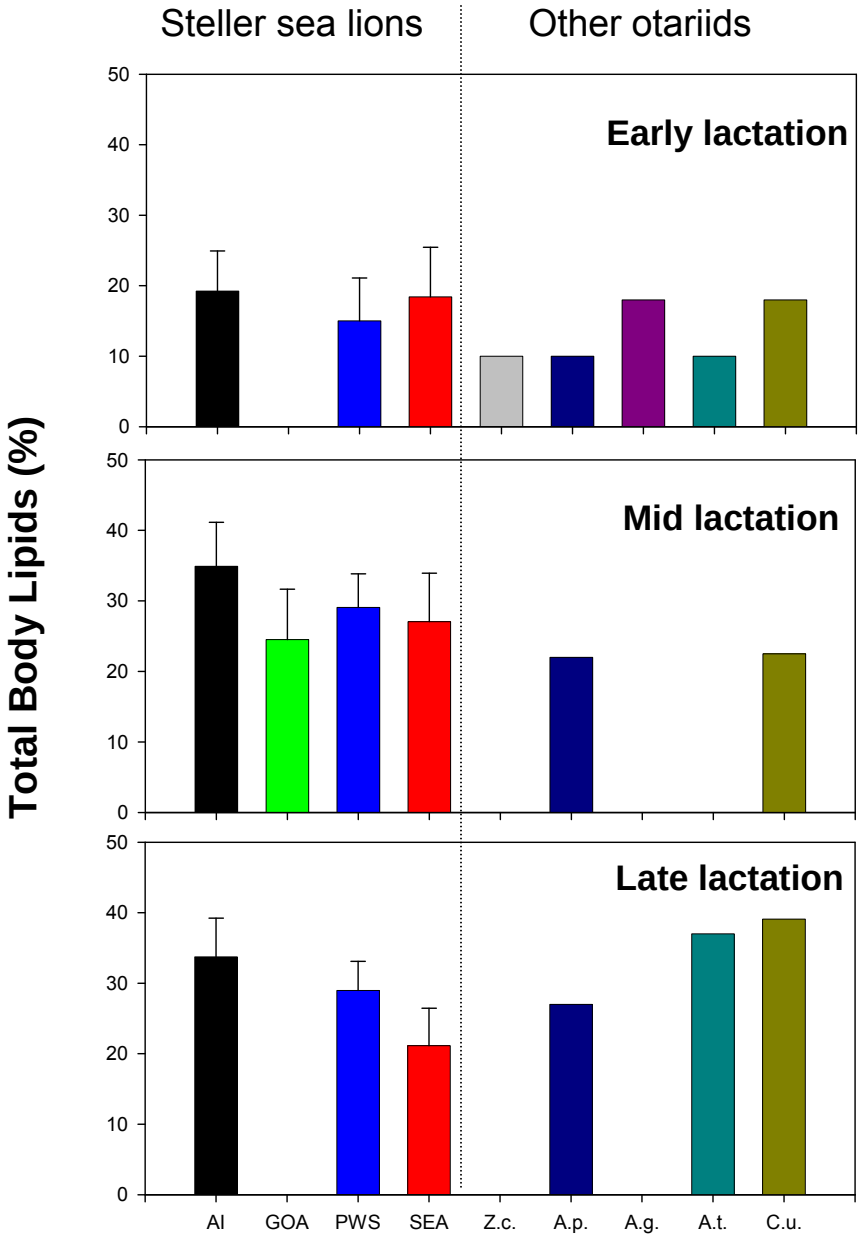




Total body lipids of otariid pups:



(Rea et al. Anchorage 2009)

Preliminary unpublished data, do not cite

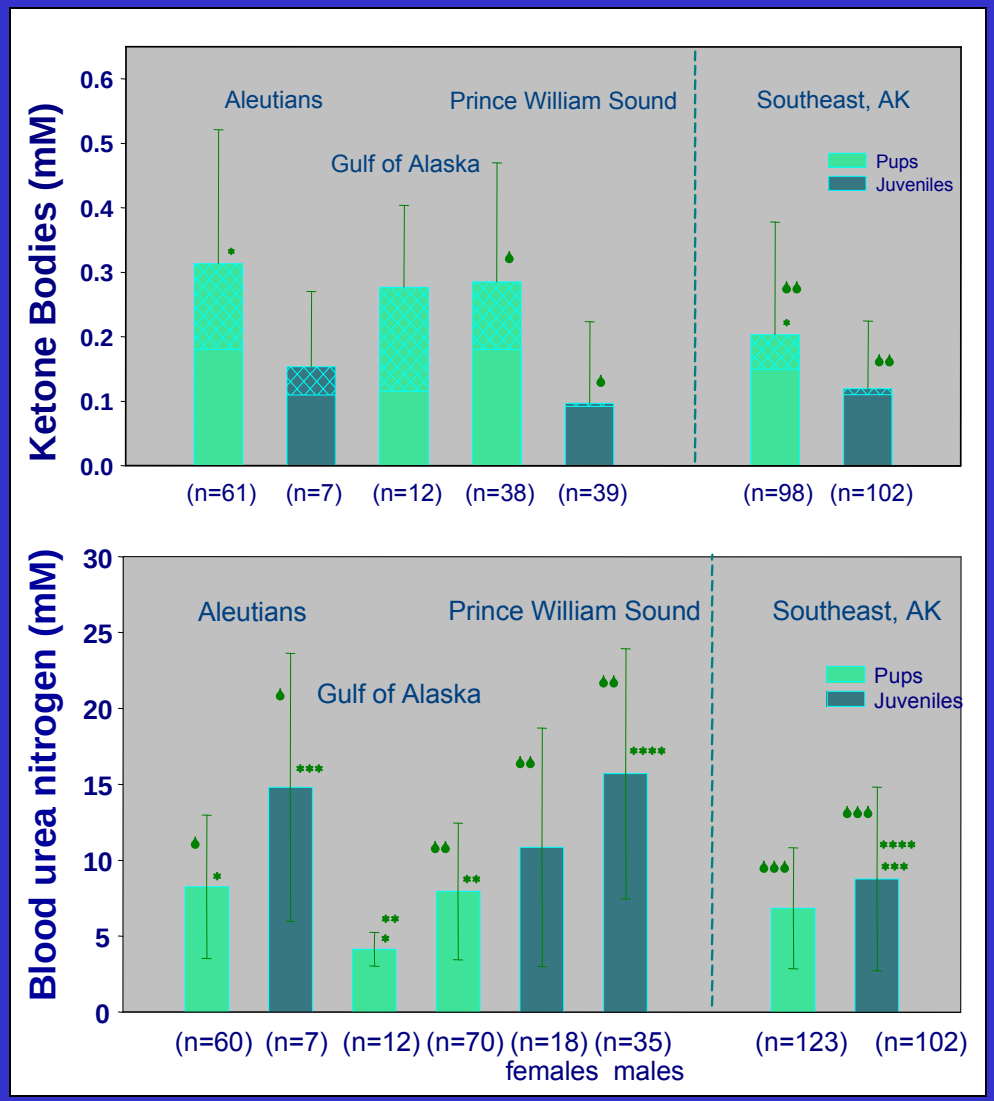
Conclusions:

1) Mean body mass of pups was higher in western stock regions than in SEA at all stages of lactation (males and females)

2) Percent total body lipid content was higher in AI pups than in SEA pups during late lactation (males and females)

3) Compared to other otariid species there was no evidence of poor body condition in Steller sea lion pups during the first year of development

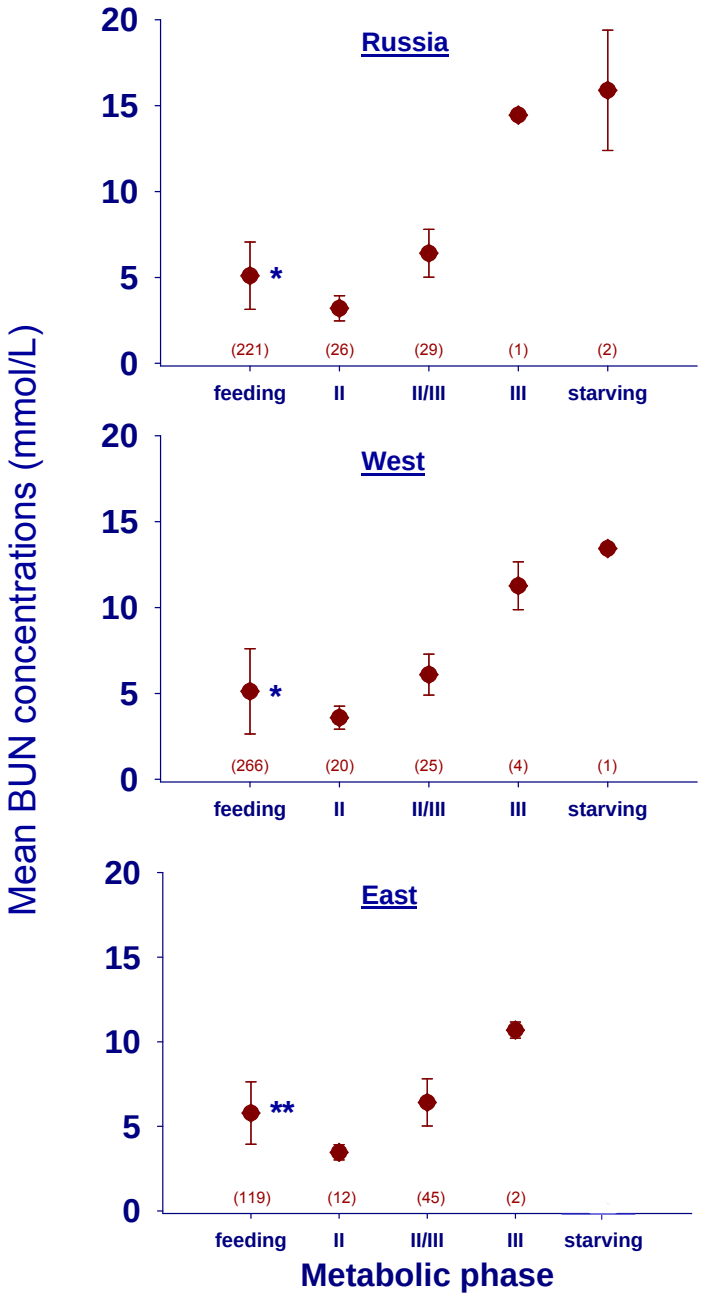
No evidence of starvation in the western stock



While ketone body (HBA) results suggest a slightly higher proportion of western stock pups were fasting, there is no evidence of elevated BUN to indicate longer than expected maternal foraging trips.

Plasma BUN concentrations in juveniles were significantly higher than pups, consistent with a diet higher in protein from fish compared with milk from suckling.

Preliminary unpublished data, do not cite

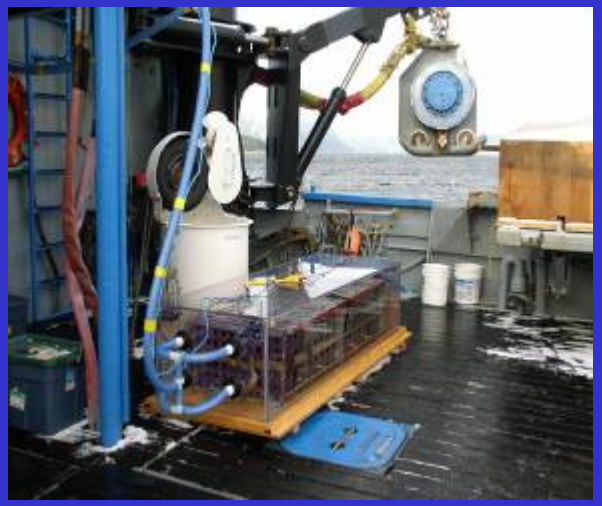


Neonates - The majority of pups in each region were feeding or recently fed; some pups were fasting more than 2.5 days, and a handful of pups were fasting longer and entered phase III fasting or starvation as shown by their metabolite profile.

Rivera et al. 2009 Anchorage poster

Preliminary unpublished data, do not cite

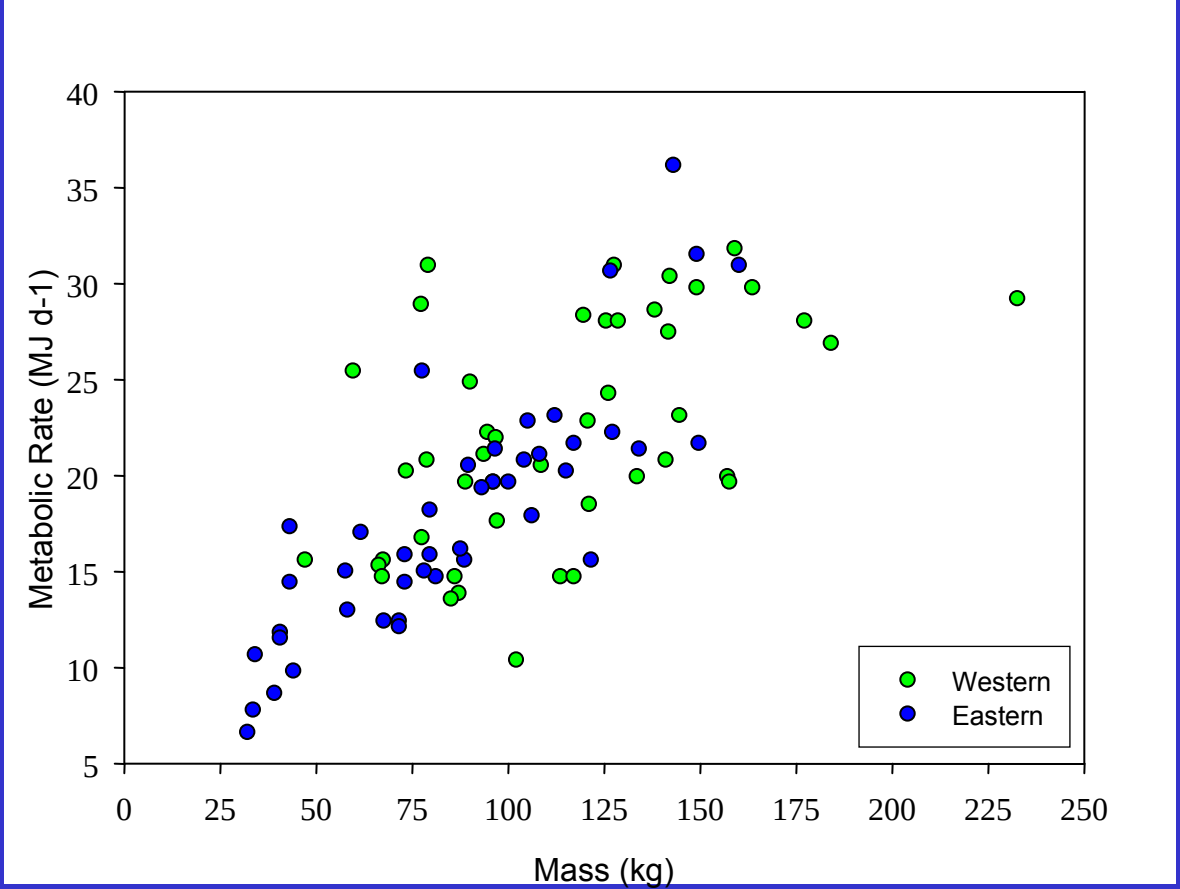
Metabolic depression



Steller sea lions decrease their metabolic rate (oxygen consumption) by 15 – 24% when fed a diet that was low in energy over a 2 week period (Rosen and Trites 2002).

Measured metabolic rate of 93 free-ranging SSL (2 to 44 months of age) in eastern and western populations to determine if there was any evidence of metabolic depression in either stock

No differences in metabolic rate were observed between sea lions sampled from eastern and western populations.



Hoopes (2008)

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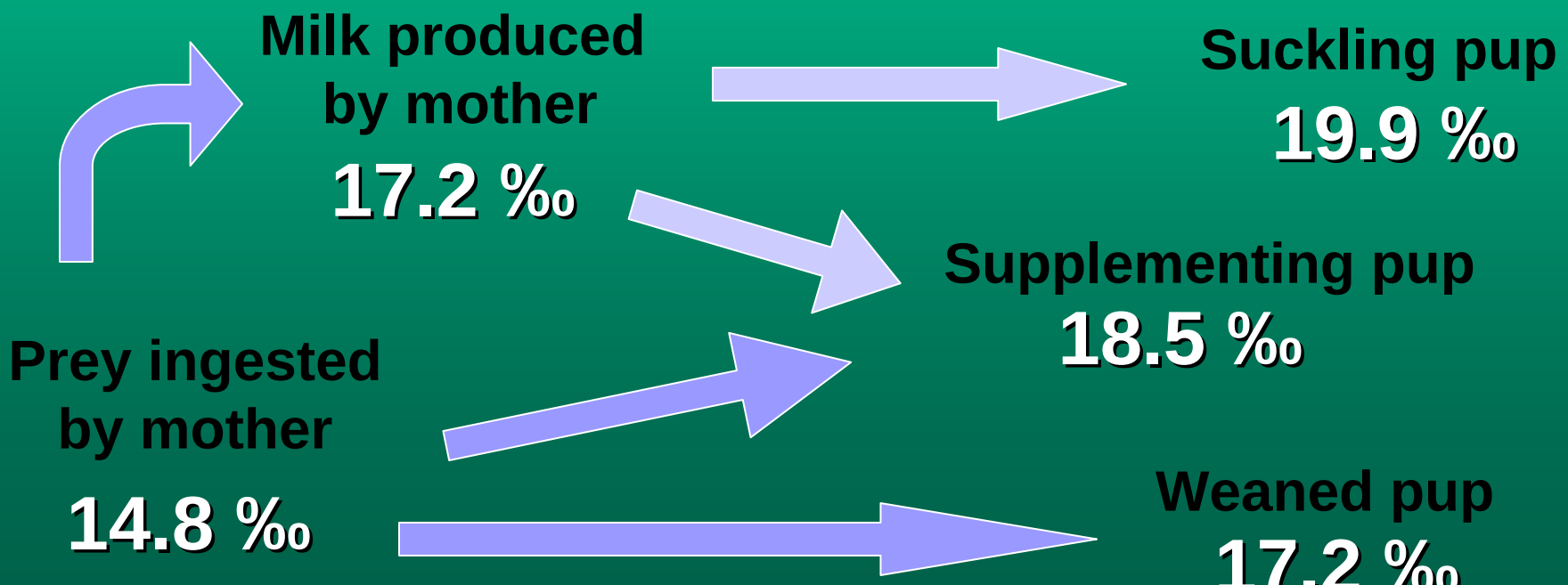
Timing of weaning and diet assessment (mothers and pups)

1. behavioral observations and modified mark-resight
2. stable isotope changes in vibrissae
3. fatty acid composition of blubber

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



Carbon Ratios:

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

Latitude

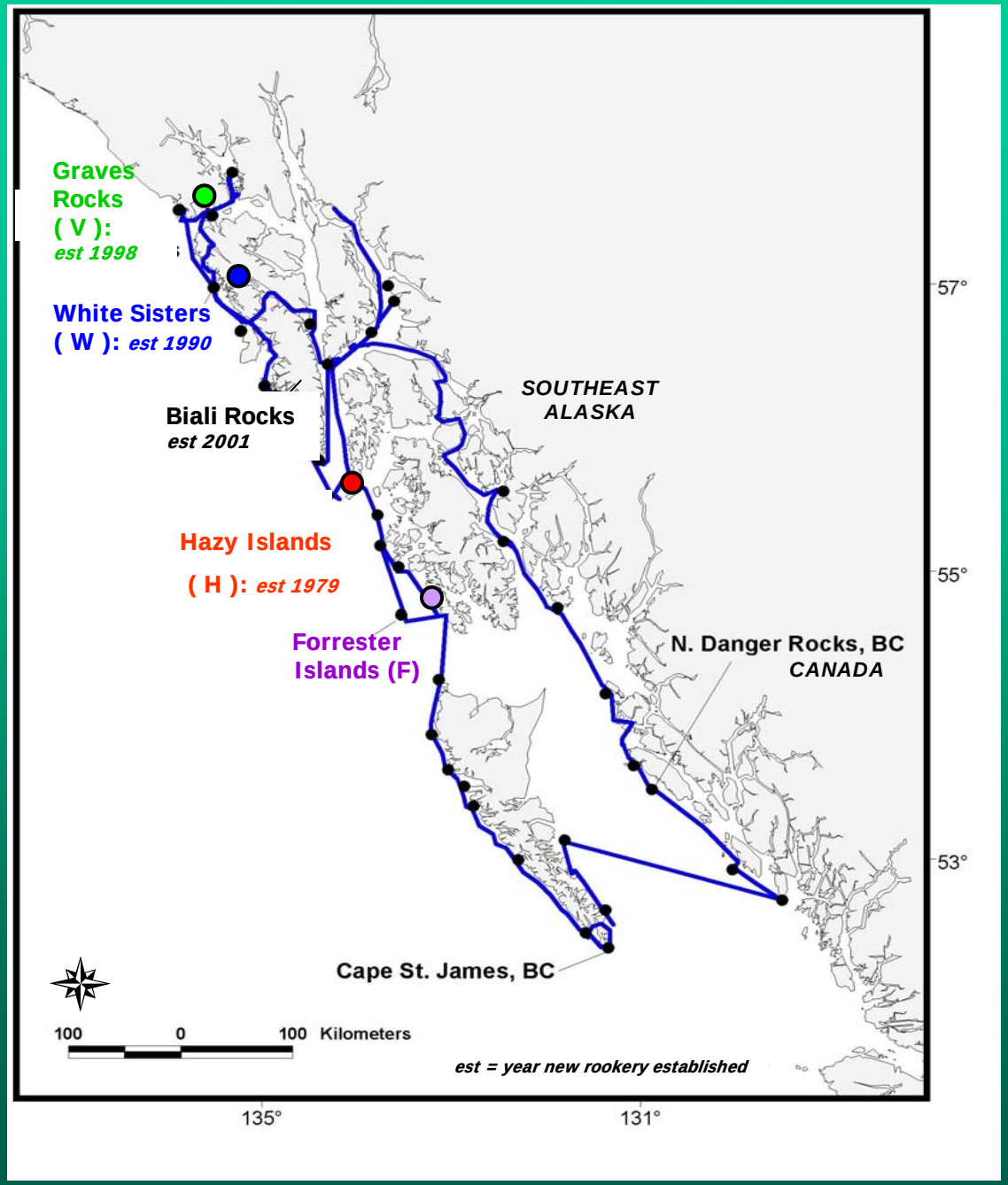
Middle = ↑ $\delta^{13}C$ **High = ↓ $\delta^{13}C$**

Marine Food Webs

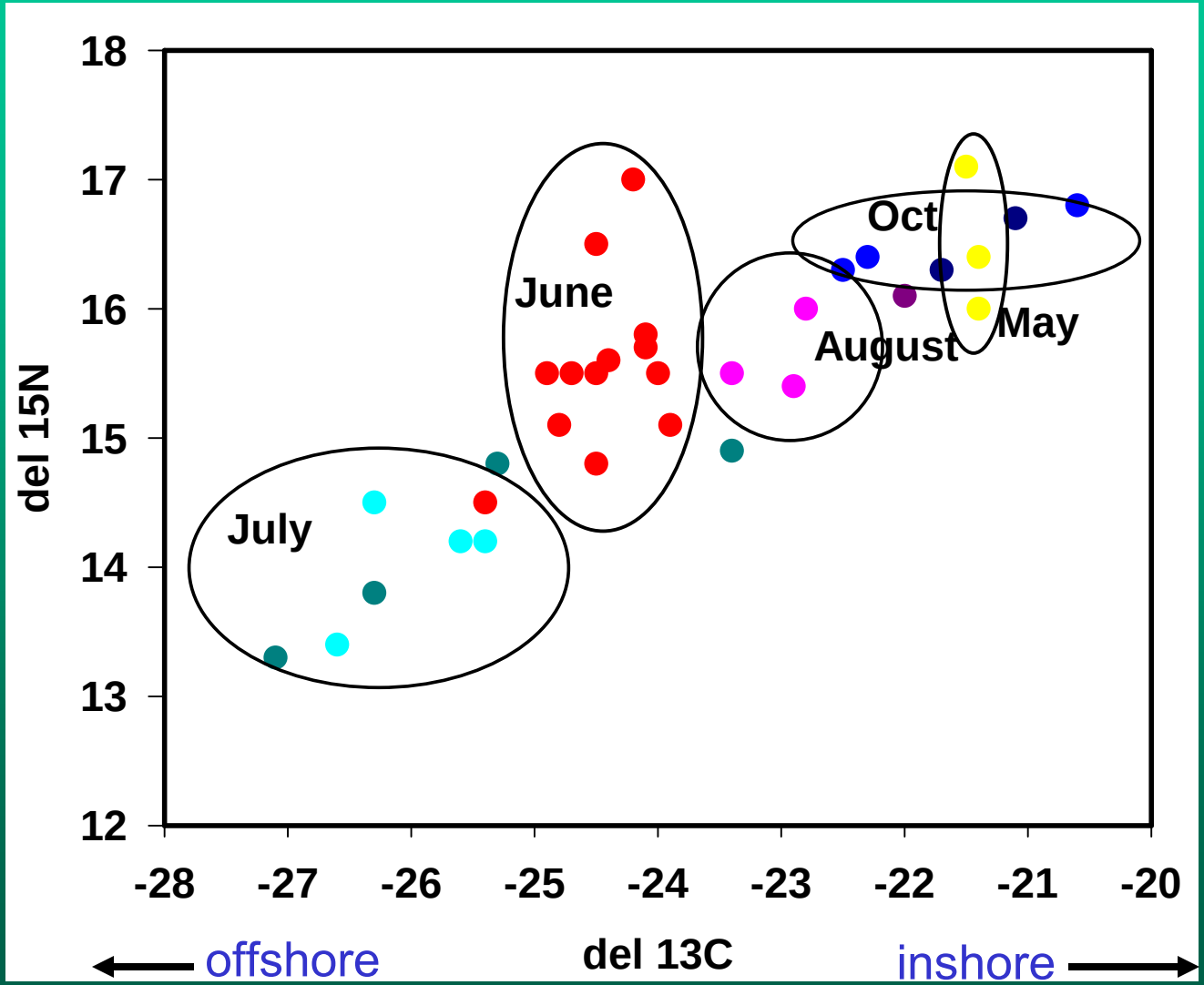
Near-shore or Benthic = ↑ $\delta^{13}C$

Off-shore = ↓ $\delta^{13}C$

Southeast Alaska Steller Sea Lion Rookeries



Ingested milk samples collected from pups in Southeast Alaska



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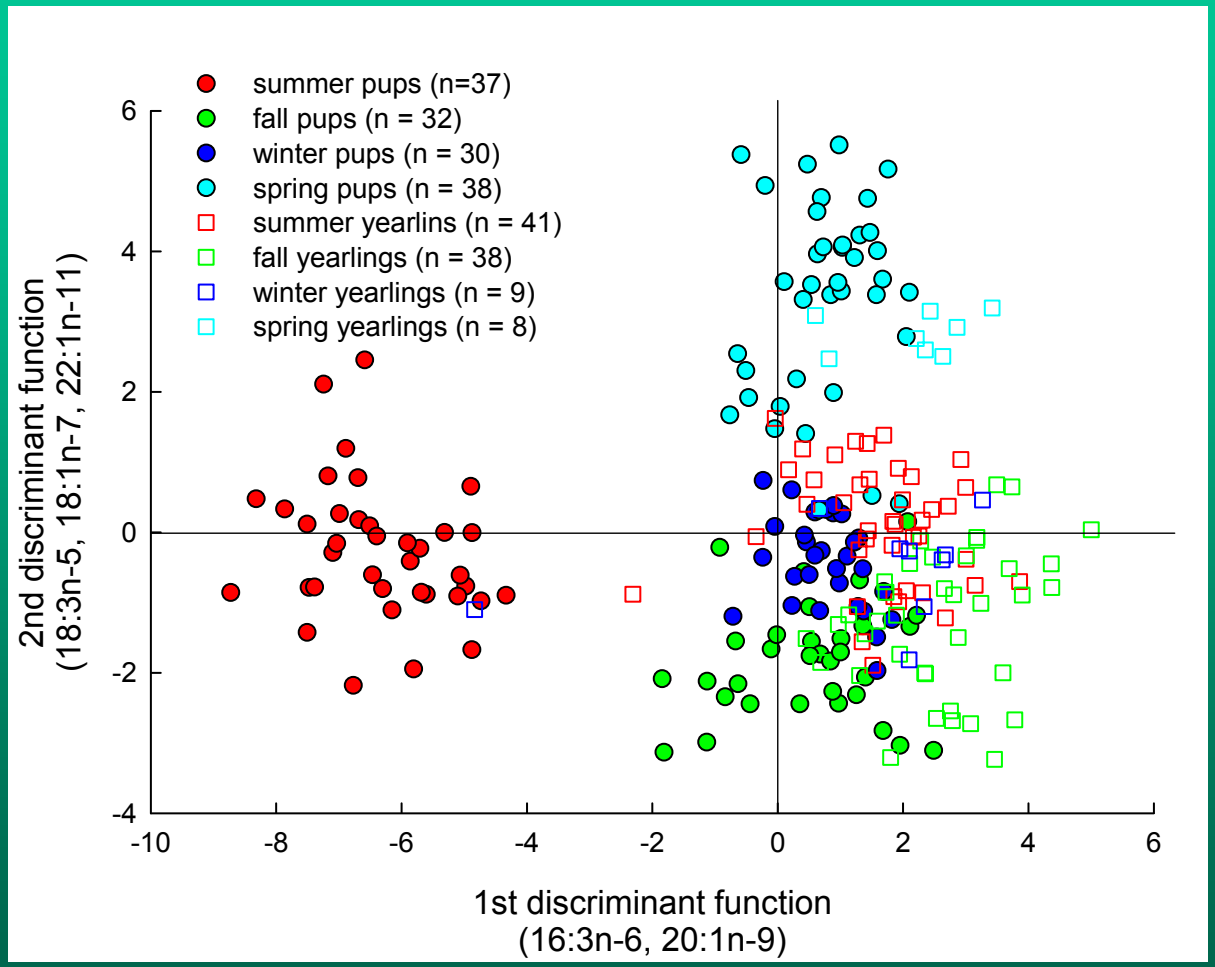
Blubber fatty acid composition in Steller sea lions captured in Southeast Alaska



Ingested milk samples collected in PWS (n=16) and SEA (n=49) also support that lactating females changed diet seasonally in both PWS and SEA. These seasonal changes in pup milk diet and transitions to independent feeding are reflected in blubber composition (Beck et al. 2007).

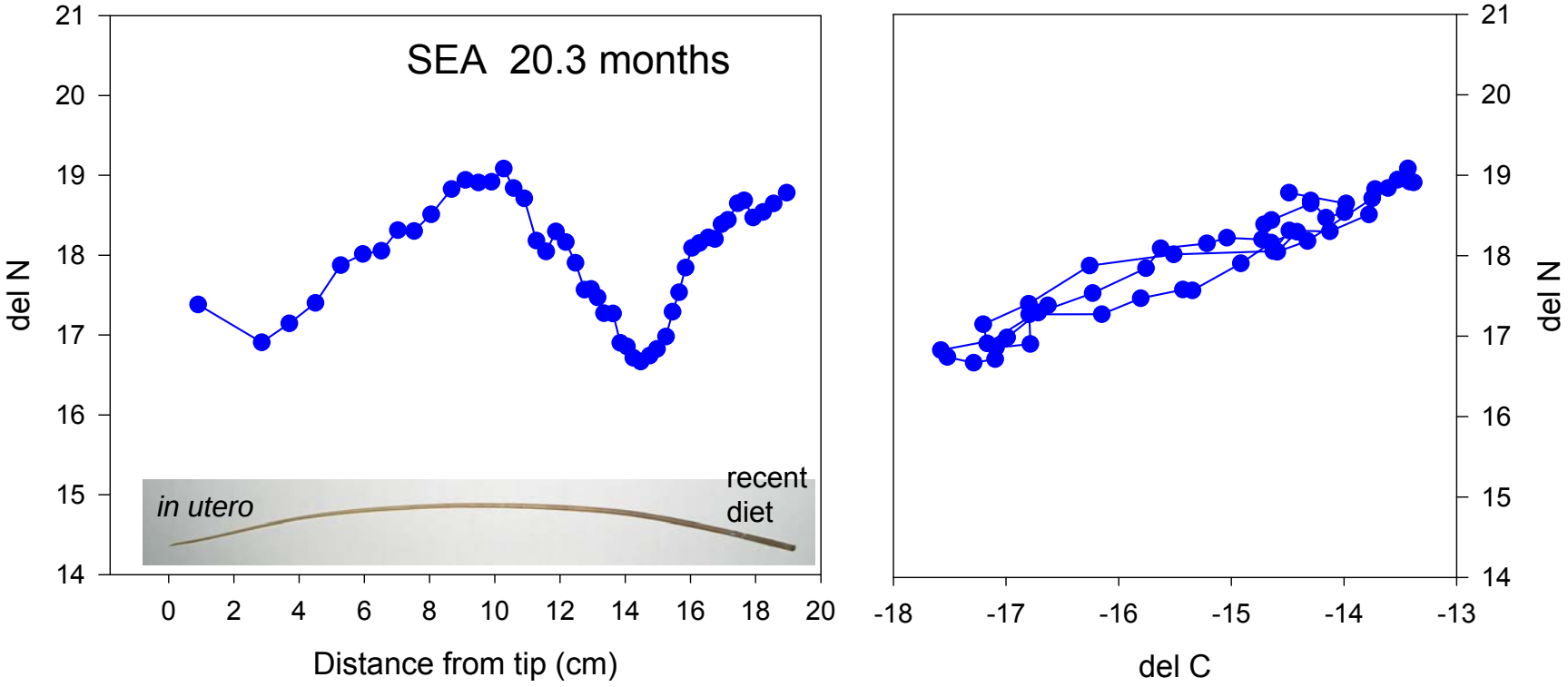
Growth of the vibrissae produces a timeline of isotopic signatures that reflect the composition of the diet at the time of deposition, with most recent diet reflected in the root.

- metabolically inert
- resistant to degradation
- isotopically representative of the body protein pool

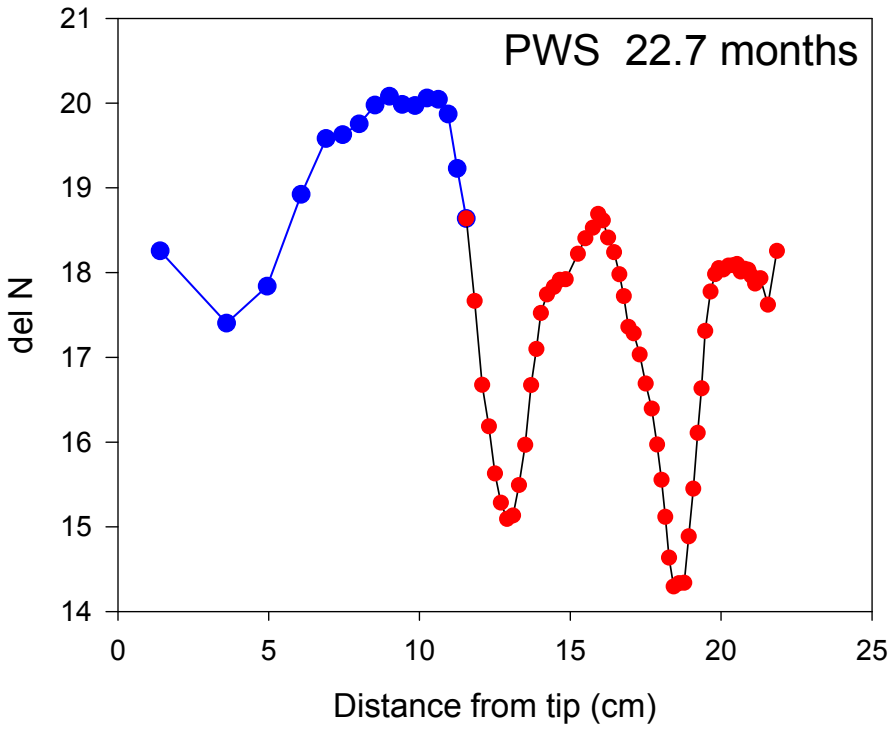
Steller sea lion pups are born with developed vibrissae, thus the tip of the vibrissae represents tissue grown in-utero, and reflects the maternal diet during this period of fetal development.

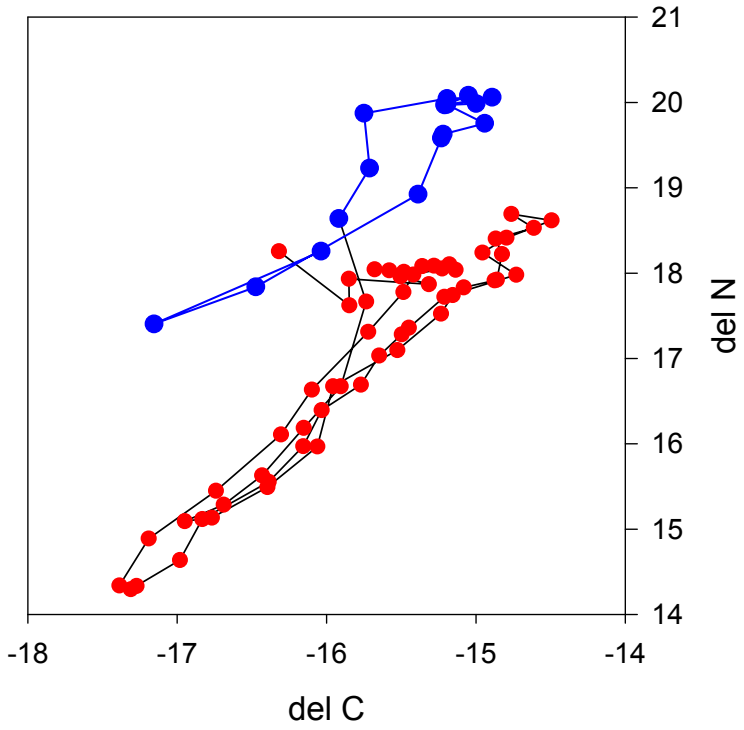
Methods:

- vibrissae sections ranging from 3.0 to 0.1 cm (2.00-2.40 mg)
- continuous flow isotope ratio mass spectrometry at the USGS Crustal Imaging Laboratory in Denver and the UAF Stable Isotope Facility.

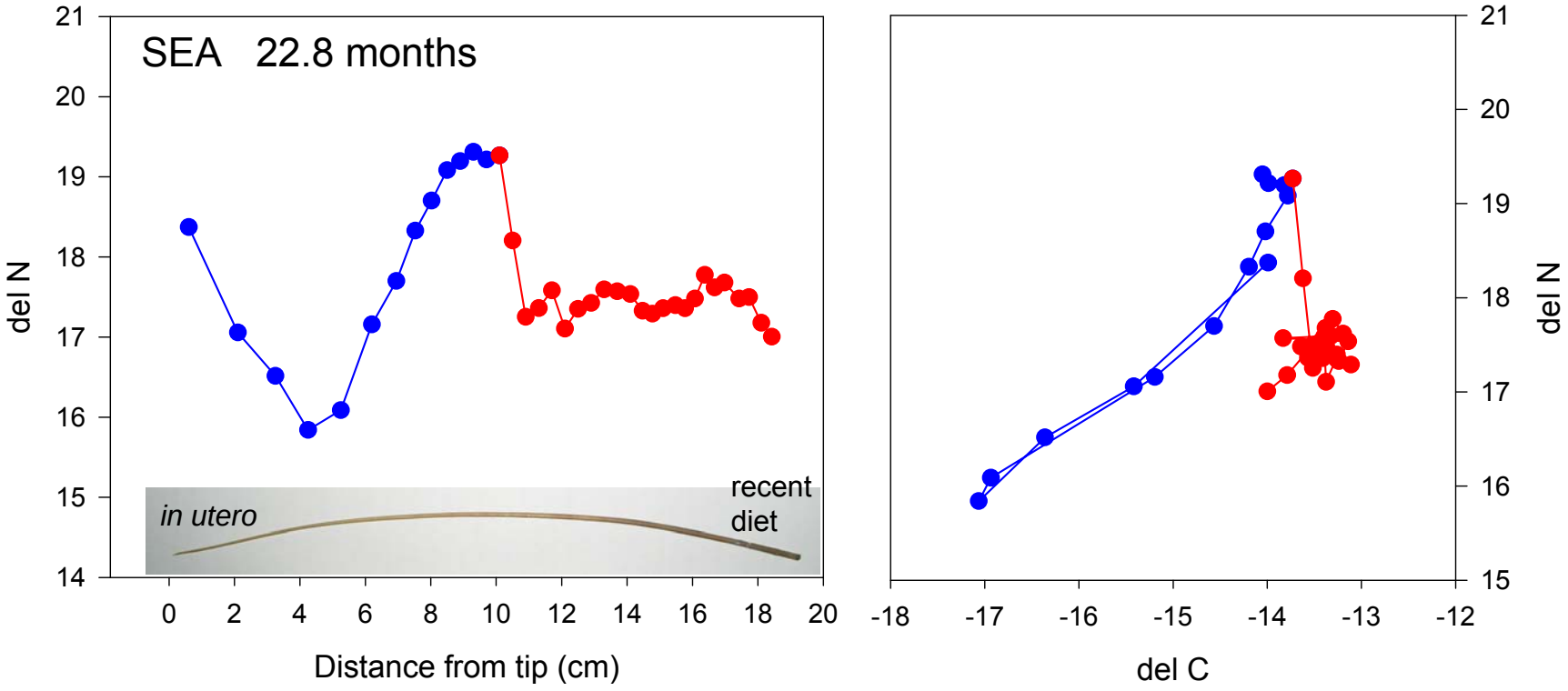


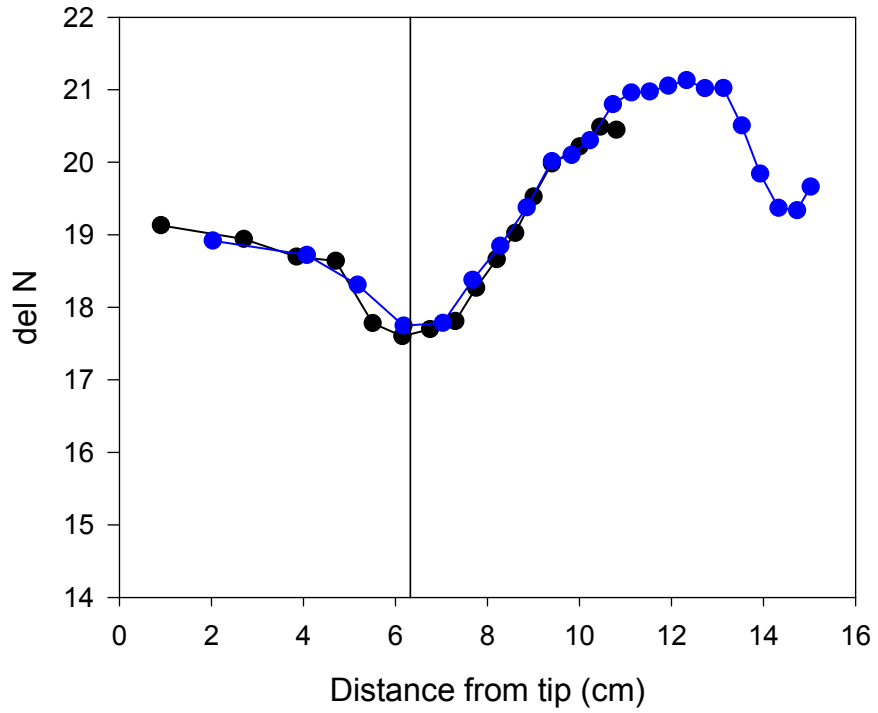
Isotopic profile for a nutritionally independent (?) free-ranging juvenile (22.7 months of age) captured in Prince William Sound, Alaska.

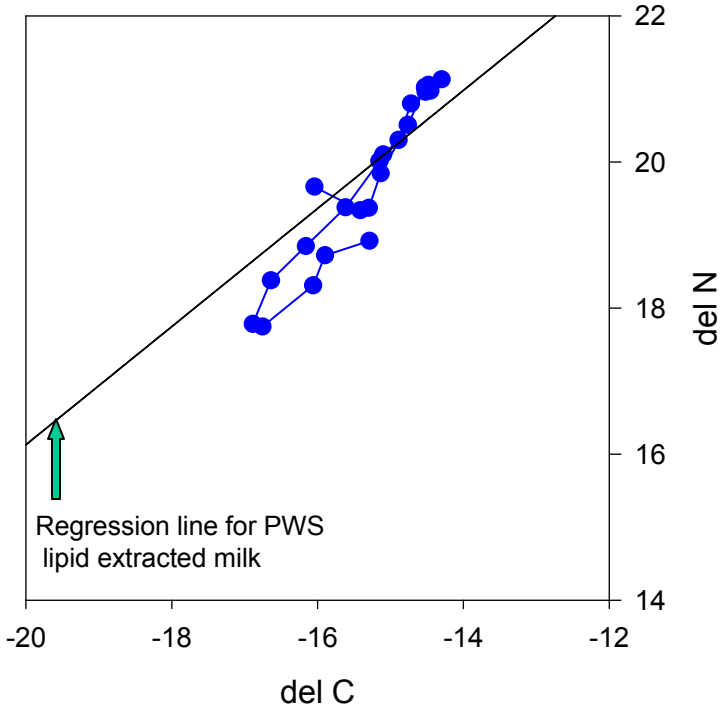




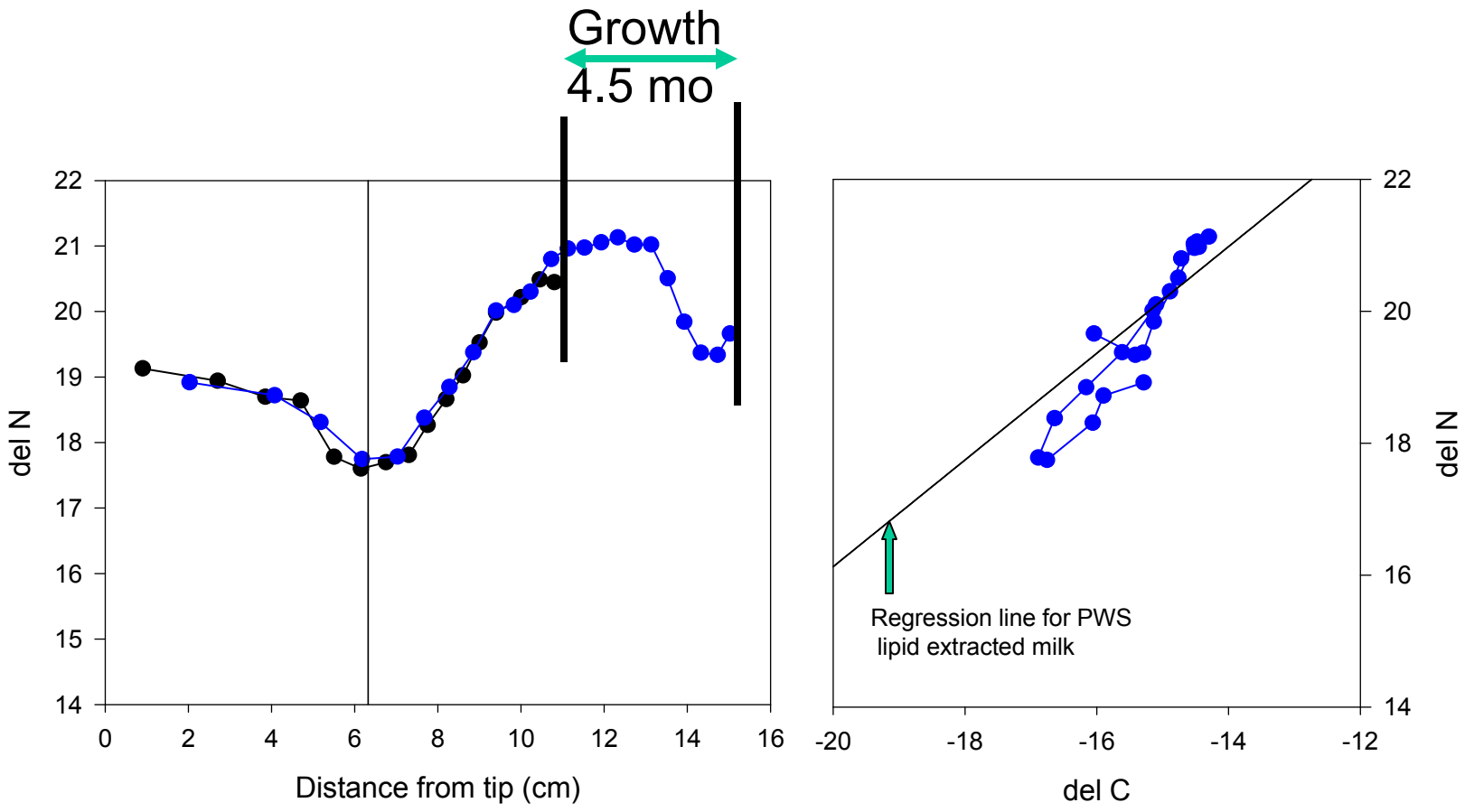
Once the weaning event has been identified, the vibrissae section that was deposited *in utero* and during nursing can provide a timeline of changes in the composition of the milk diet of the maternally dependent young, and by association a timeline of changes in the diet of the adult female producing that milk.







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



Black symbols SSL619PWS captured at 5 mo
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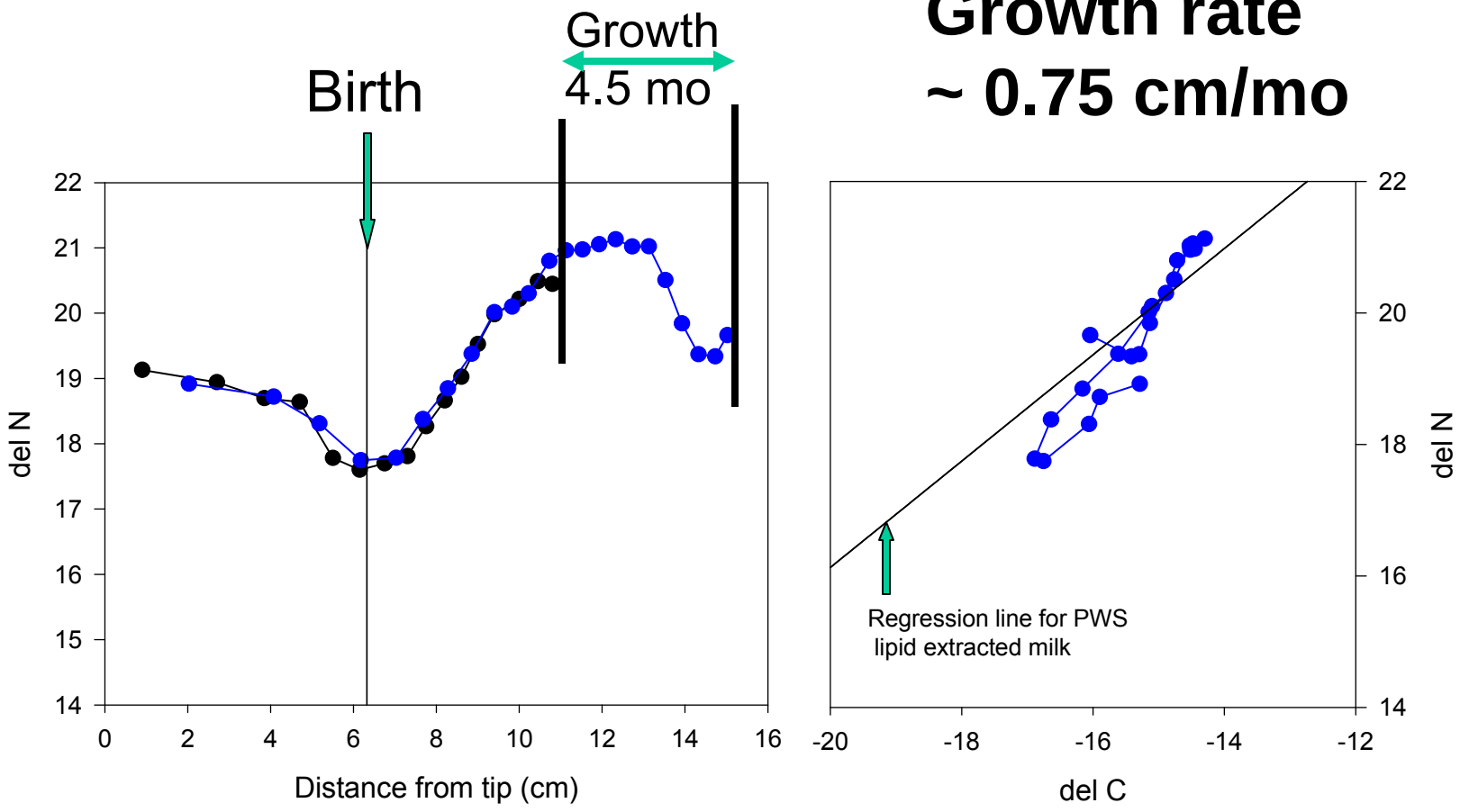
Growth rate
~ 0.75 cm/mo



Black symbols SSL619PWS captured at 5 mo
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1. Assess weaning in over 300 young of the year and juvenile Steller sea lions to determine the proportion of animals weaned at age and average weaning age by region.

2. Next - Develop statistical techniques for calculation of diet composition from stable isotopes and fatty acid signature analysis (QFASA)

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Haptoglobin (Hp):

- sensitive, but non-specific acute phase protein
- produced in the liver in response to inflammation, trauma and infection
- Hp binds free hemoglobin (Hb), to create haptoglobin-hemoglobin complex (HpHb)
- HpHb complex is removed from circulation by spleen avoiding loss of iron through kidneys
- reduced in cases of hemolytic anemia, hepatitis, liver diseases

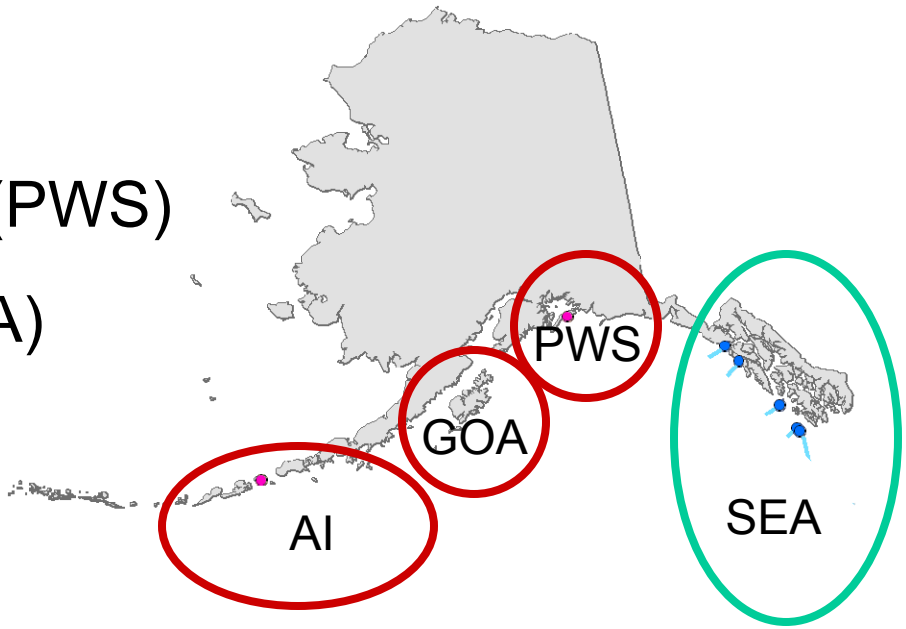
In Steller sea lions captured between 1992-1994 (n=124) :

1) Hp concentrations generally increased with age in Southeast Alaska, with exception of newborns with high Hp
2) Significantly higher Hp concentration in Aleutian Islands and Gulf of Alaska (declining populations) than Southeast Alaska (stable population)

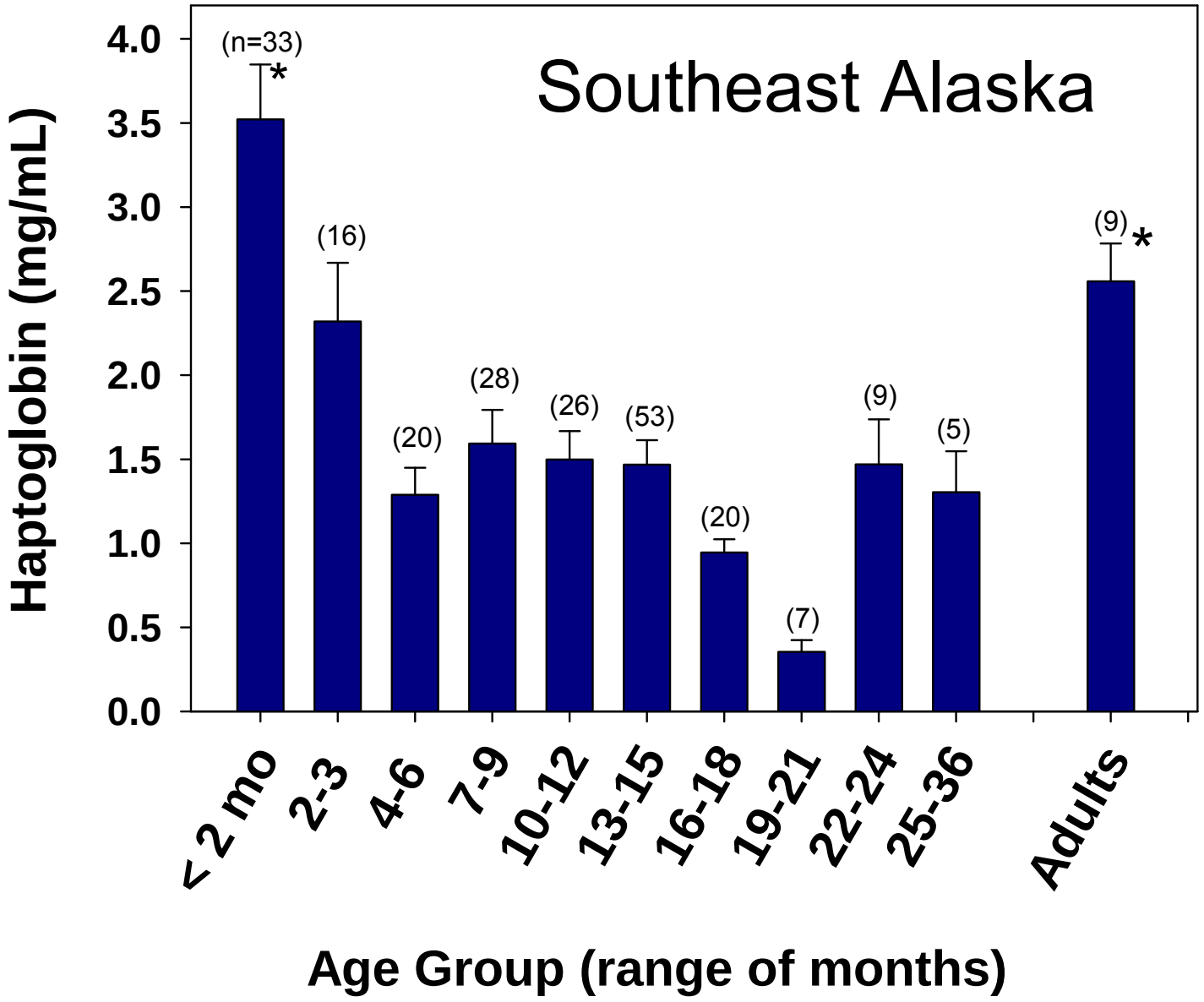
(**Zenteno-Savin et al. 1997)**

Methods: Sample sizes

- 522 Steller sea lions captured between 1992 and 2008 in 4 regions of Alaska
  - Aleutian Islands (AI)
  - Gulf of Alaska (GOA)
  - Prince William Sound (PWS)
  - Southeast Alaska (SEA)



Significantly higher haptoglobin concentrations in neonates and adults, as seen in other mammals.



Preliminary unpublished data, do not cite

Hp Methods:

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  - Prince William Sound (PWS)
  - Southeast Alaska (SEA)

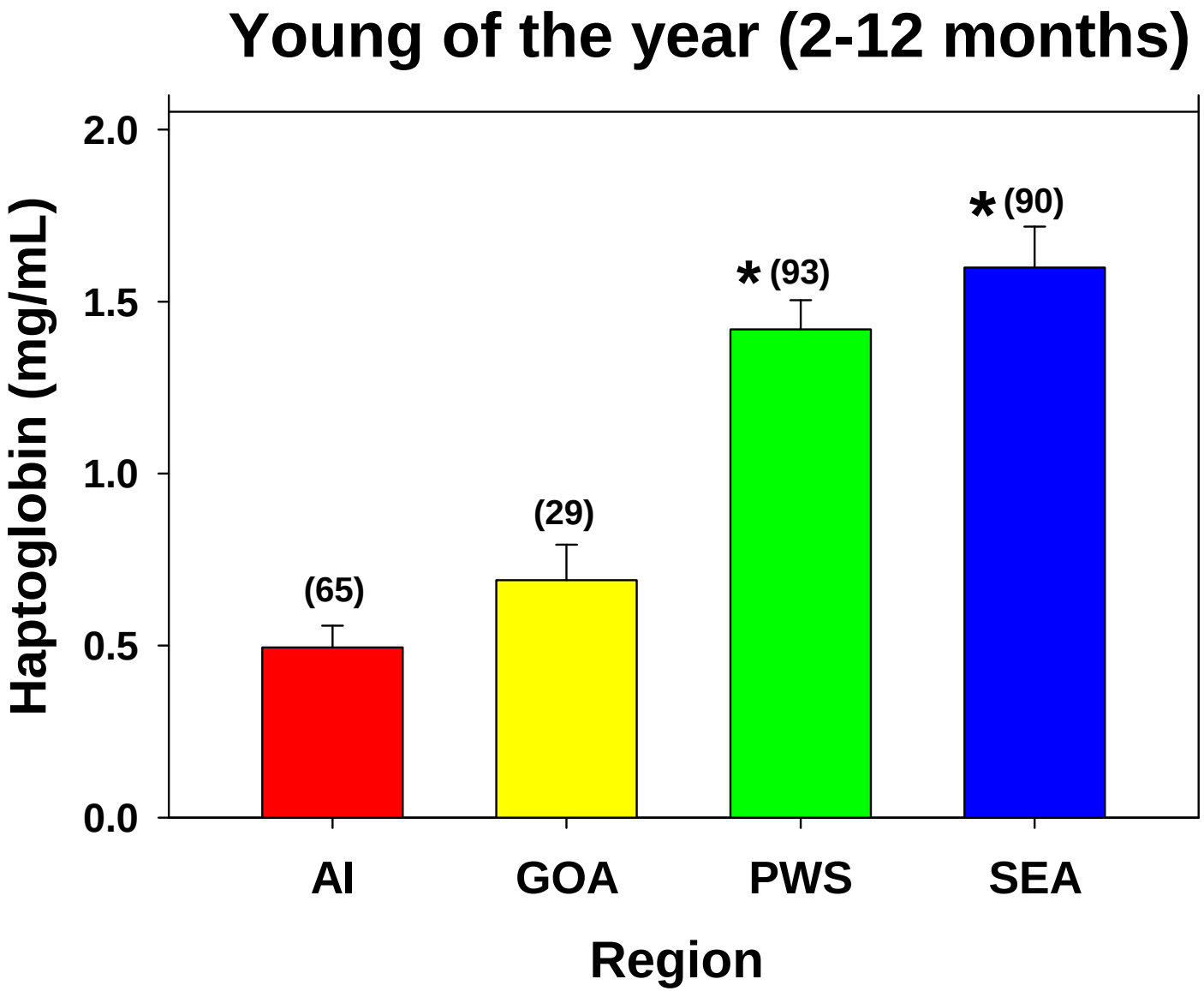
wDPS

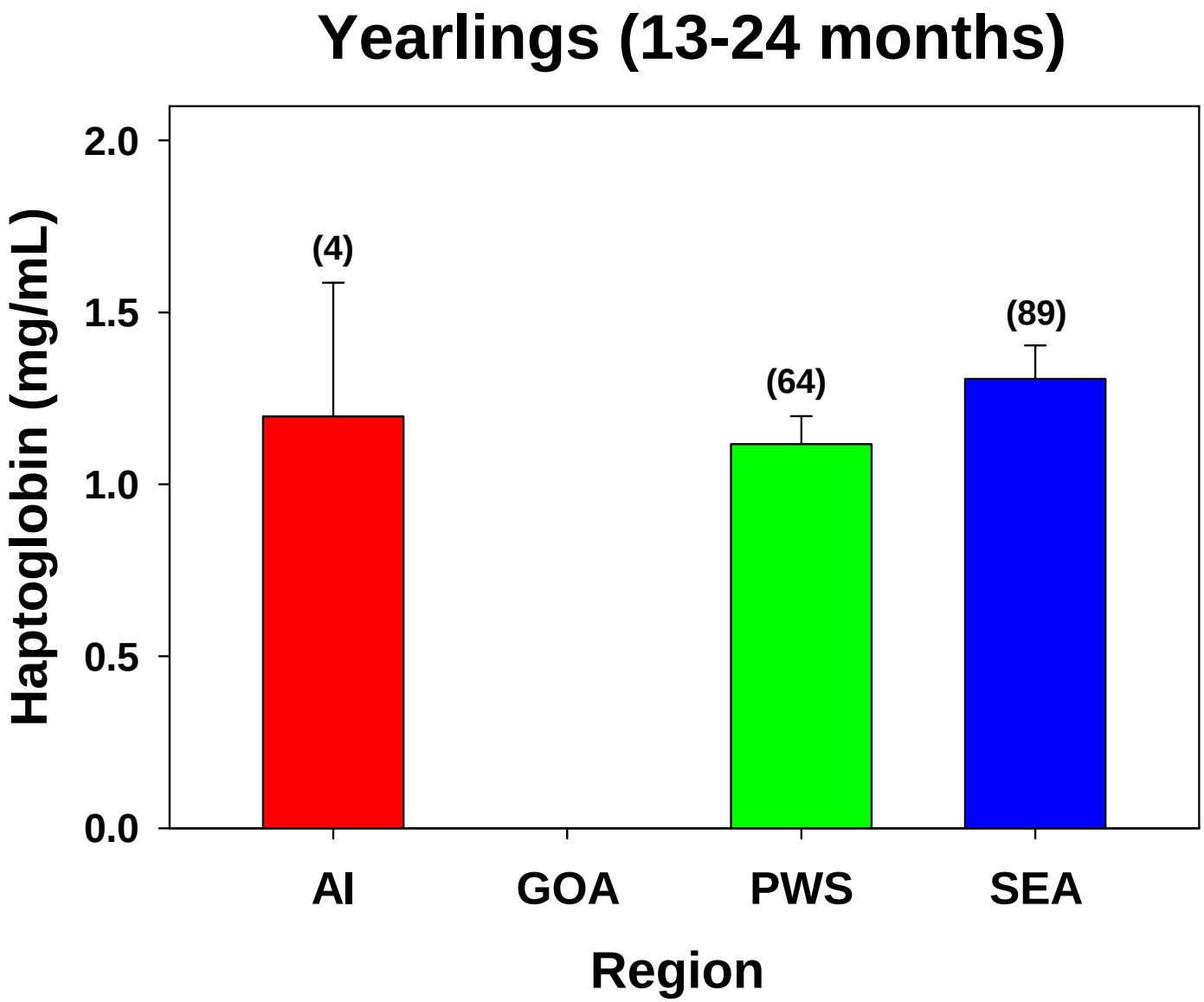
eDPS

- Phase Haptoglobin colorimetric assay

Sample sizes by area

Age Class	Age (months)	Region in Alaska			
		AI	GOA	PWS	SEA
Pup	< 2	5	10	--	33
YoY	2 - 12	65	29	93	90
Yearling	13 - 24	4	--	64	89
Juvenile	25 - 48	1	--	9	15
Adult	> 48	--	6	--	9
Total		75	45	166	236





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Conclusions:

Contrary to trends in the early 1990's, concentrations of Hp in the Aleutian Islands and Gulf of Alaska are not elevated as compared to Southeast Alaska (where the population has been steadily increasing) **at least for young of the year between 2-12 months of age.**

High rookery densities may result in higher parasite or disease transmission for young animals in Southeast Alaska (i.e. in pups up to 2 months old hookworm prevalence is highest in SEA 42.6%, 8.0% in PWS and in lowest in AI 16.1%, then 0% in animals older than 5 months; Beckmen et al. poster at Alaska Marine Science Symposium, Anchorage, Jan 2010)

Hookworm - Results

- Prevalence of patent infections in 2-4 wk old pups varied by rookery sampled 2003-2005
- Prevalence significantly lower at western stock (12.5%) vs. eastern stock (42.6%) consistent with declining density
- Prevalence at 2-3 mos. of age in SE was highest at 69%
- Prevalence was 0% in pups >5 months old

(Beckmen et al. 2010 poster)

Preliminary unpublished data, do not cite

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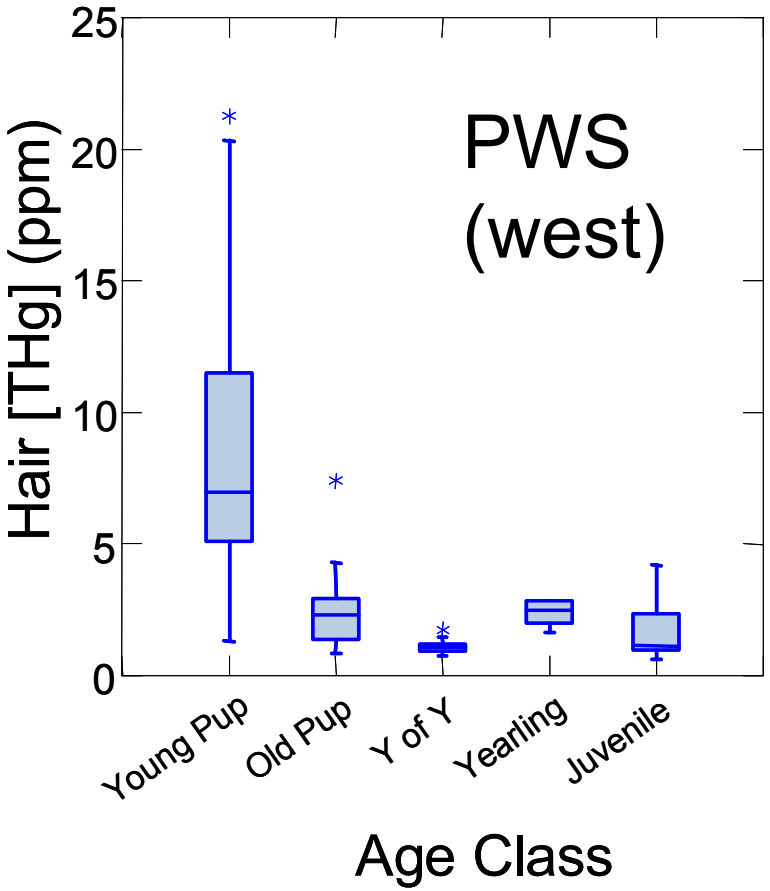
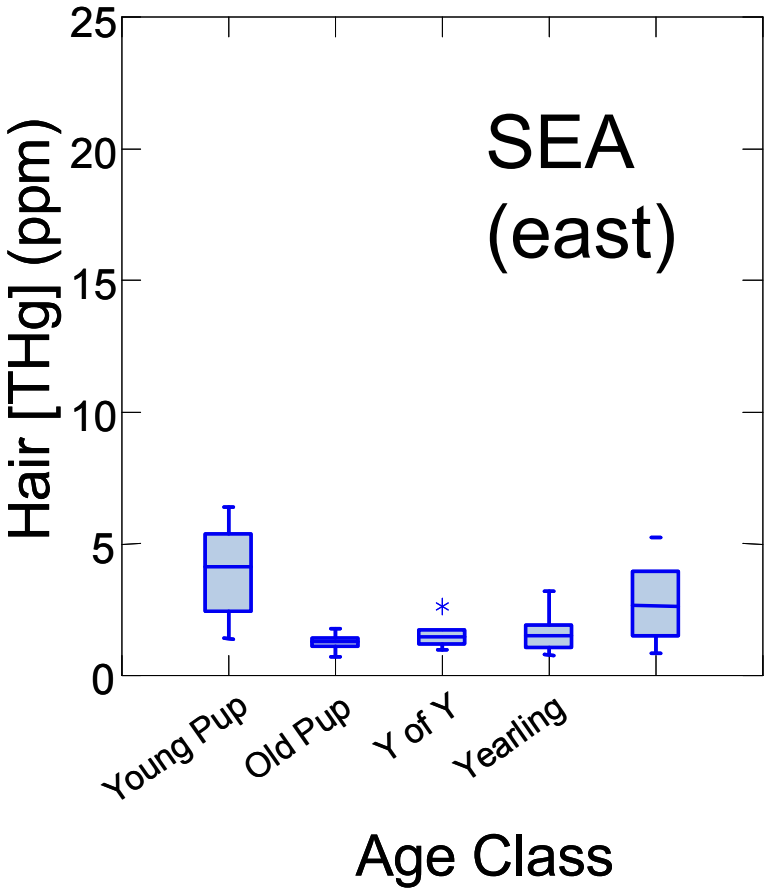
Mercury (Hg) effects:

- Impaired neurological development
- Neurological effects
- Immune system
- Kidney damage
- Gastrointestinal
- Lungs
- Fetal exposure

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





Castellini, Beckmen, Rea and O'Hara (Quebec 2009)

Preliminary unpublished data, do not cite

Mercury and Selenium in Liver - Steller Sea Lion Pups (2- 4 weeks old)

	THg (ppb)	MeHg (ppb)	%MeHg	Se (ppb)
SEA	637 ± 377 (n=9)	326 ± 172 (n=9)	52 ± 7 (n=9)	660 ± 245 (n=8)
PWS	941 ± 305 (n=4)	379 ± 60 (n=4)	44 ± 15 (n=4)	587 ± 124 (n=4)

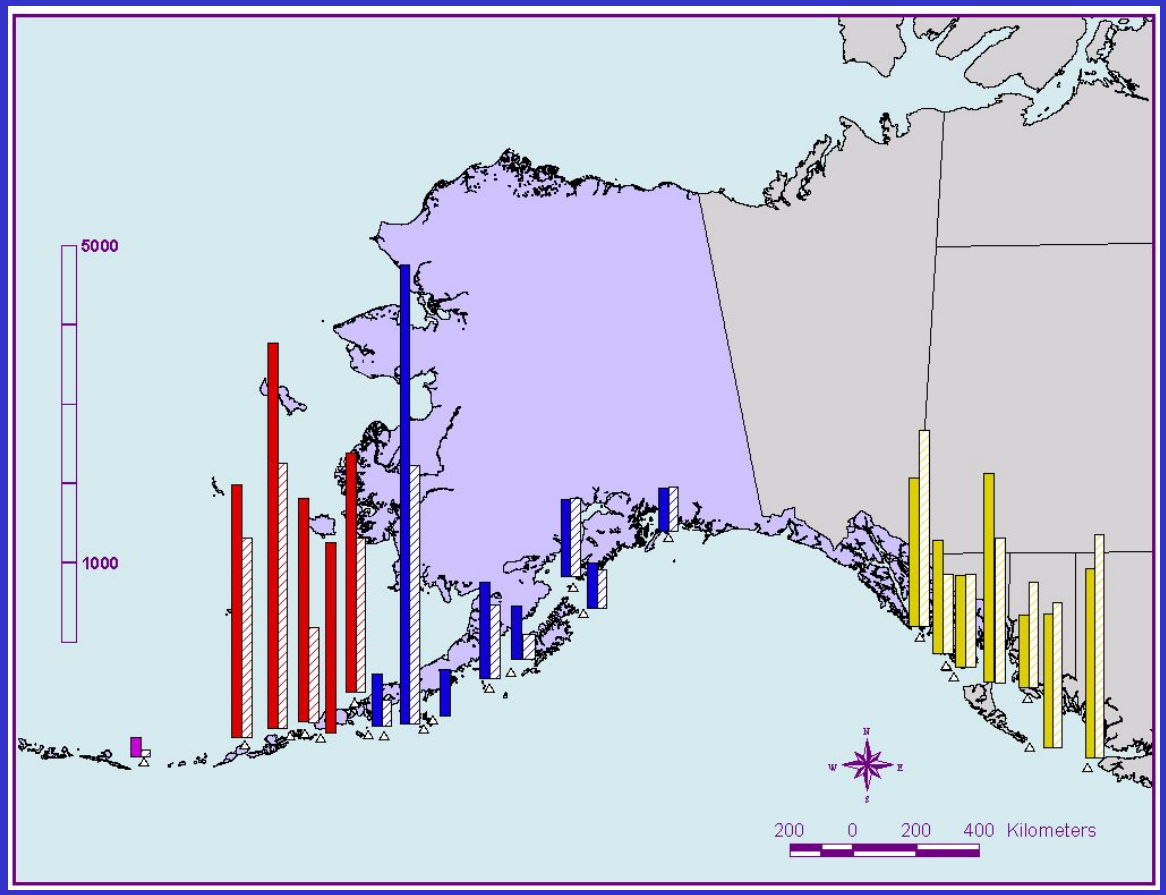
Castellini, Beckmen, Rea and O'Hara (Quebec 2009)

Preliminary unpublished data, do not cite

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
- Hair appears to be an efficient post-parturient excretory mechanism for newborn pups.

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

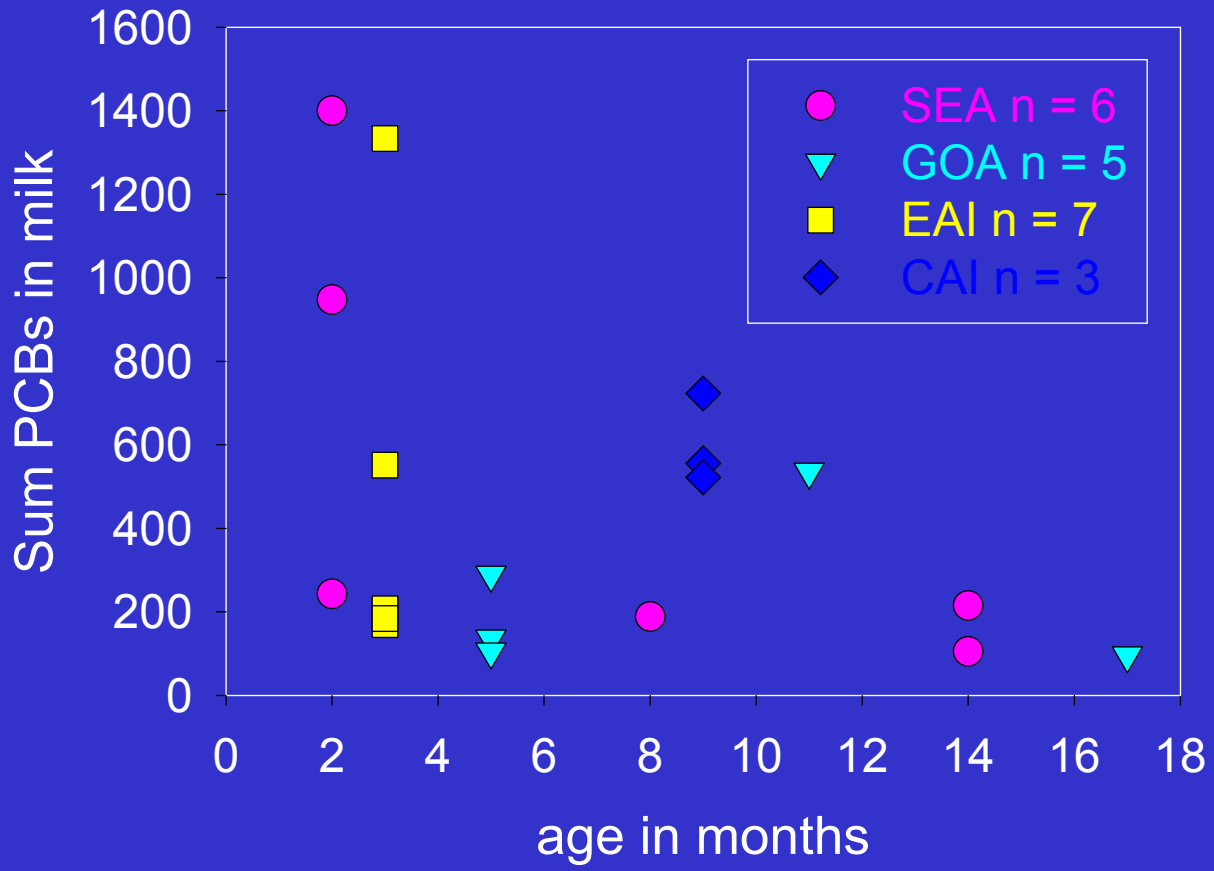
Beckmen, K., K. Pitcher, K. Burek, and G. Ylitalo In revision. Organochlorine contaminant concentrations in scats collected on Steller sea lion (*Eumetopias jubatus*) rookeries. Archives of Environmental Contamination and Toxicology.

Preliminary unpublished data, do not cite

OC contaminant exposure in free-ranging juvenile Steller sea lions

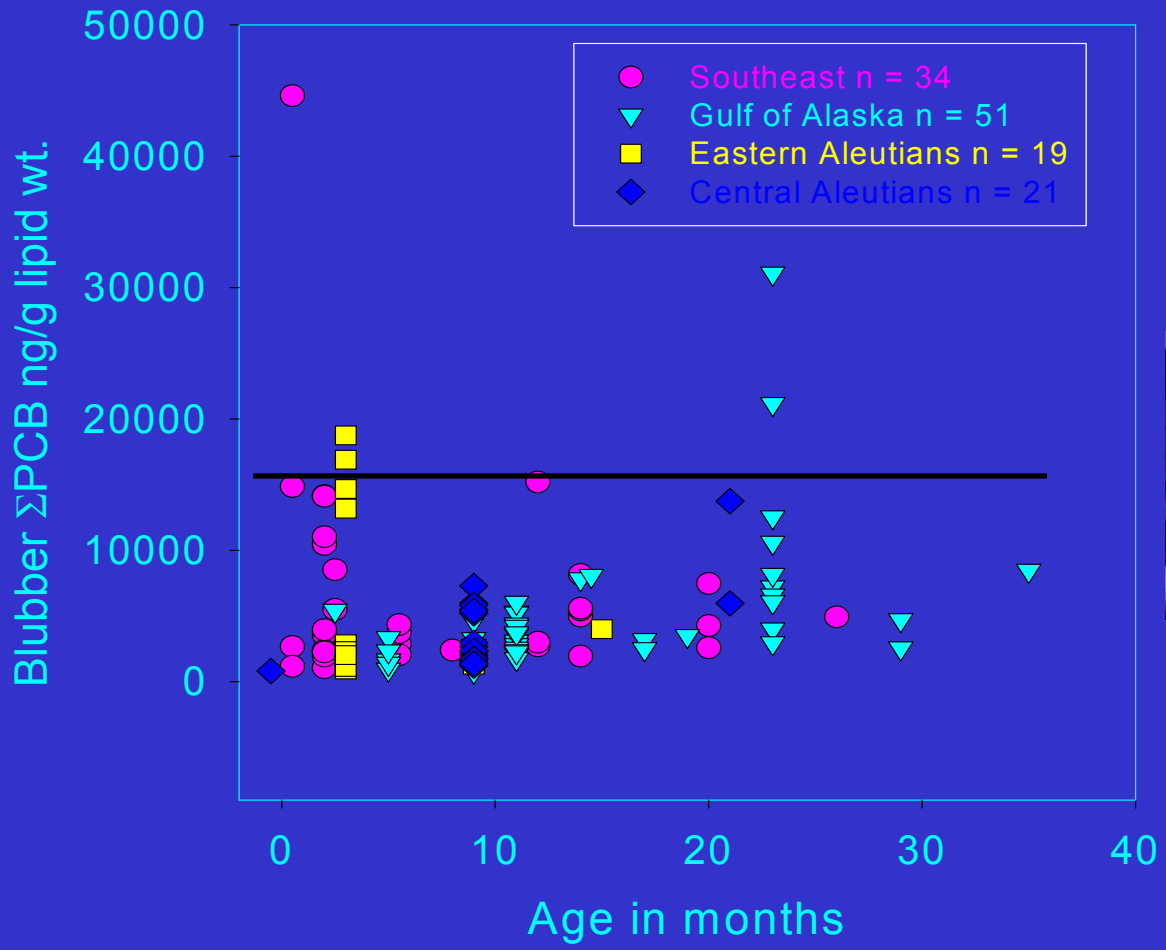
- Pup to juvenile Steller sea lions from SEA, GOA, EAI, CAI rookeries/haulouts
- 130 animals ranging from 0.5 months to 2+ yrs.
- Blubber (n=125), milk (n=21), blood (n=13), and feces (n=34)
- In conjunction with larger foraging/nutritional studies
- Extensive health/disease surveillance
- Congener-specific OC screening by HPLC

PCBs ng/g l.w. in milk obtained by orogastric gavage



PCBs are off-loaded from the adult female during lactation, the concentration in milk decreases later in lactation (Beckmen et al. unpublished data

Blubber PCBs



PCB concentrations are age and regionally dependent, typically decreasing with age (exception are 21 mo. juveniles in GOA). Black line is concentration at which immunosuppression evident in harbor seals (Beckmen et al. unpublished data)

Preliminary unpublished data, do not cite

Additional analyses

- Detailed analyses (GC/MS) on 26 blubber for pesticides (additional PCB congeners and compounds such as HCH, mirex, chlordanes, etc.) completed
- Polybrominated diethyl ethers (PBDEs) also by GC/MS on 20 of the above blubber. Levels of PBDFs very low or below detection.

A Health Assessment Approach to Steller Sea Lion Research in Alaska – Epidemiology project

Modeling of disease occurrence patterns from an epidemiology perspective :

- **Body condition**
- **Clinical chemistry**
- **Metabolite levels**
- **Hematology**
- **Contaminants**
- **Immunology**
- **Bacteriology**
- **Virology**
- **Serology**
- **Parasitology**

Kathy Burek (AK Vet. Path. Services), Kimberlee Beckmen, Camilla Lieske, Lorrie Rea (ADF&G) and Tom Gelatt (NMML)

Population Dynamics

Survival, Reproduction Recruitment and Distribution

- Pup branding
-Summer brand resighting throughout SE AK and PWS
-Field camp at Lowrie Island and Sugarloaf Island – brand resights

Physiological Studies

Identification of Weaning & Diet

- Stable isotopes (whiskers), Fatty acids (blubber), Scats

Body Condition & Nutrition

- Morphometrics
- Deuterium, BIA
- Blood chemistry
- Muscle biochemistry
- Total body oxygen stores

Contaminants & Disease

- Serology, Parasitology, Virology, Contaminants, Hp

Foraging Ecology

Juvenile Movement & Dive Ontogeny

-Dispersal, development of diving duration and depth
-Organization of diving behavior
- ontogeny of fine scale foraging behavior

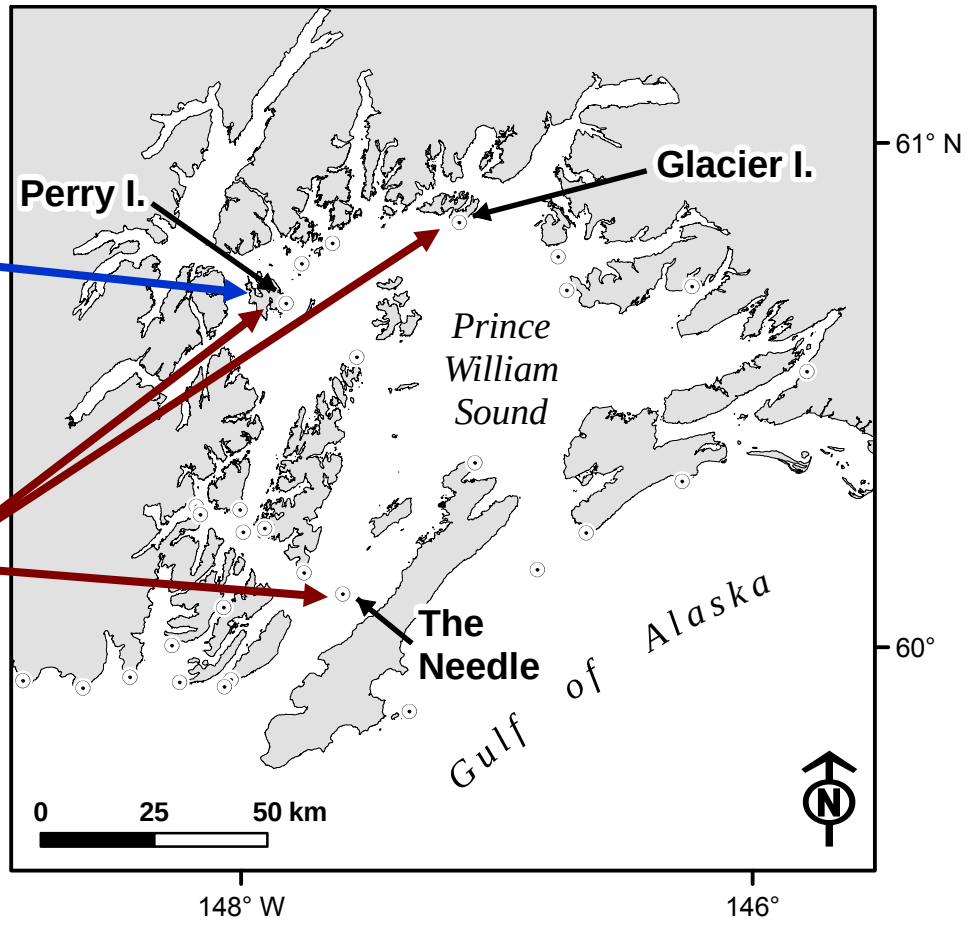
Young-of-Year Recapture Project

Initial Captures
November 2005, 2007
5 months old

n = 71 sea lions

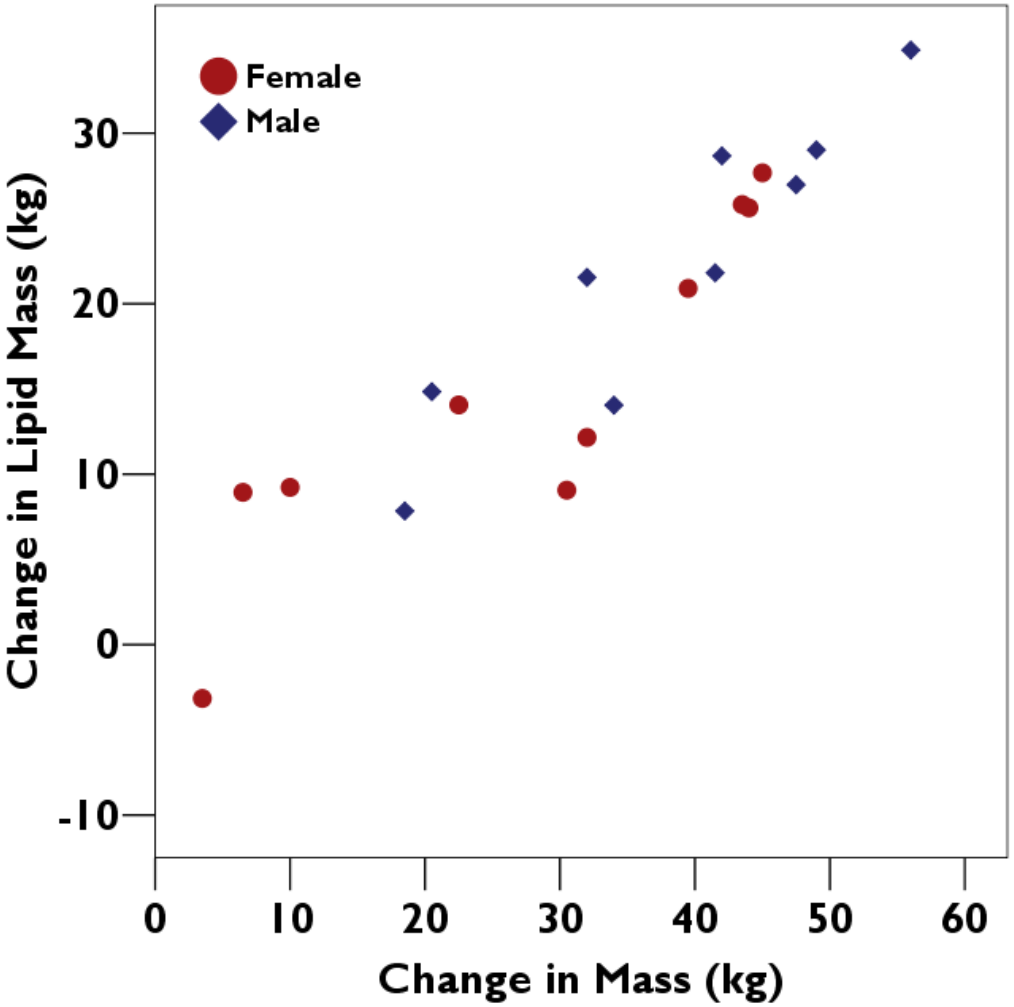
Recaptures
April 2006, 2008
9/10 months old

n = 30 sea lions



Young-of-Year Recapture Project

Range of change in mass and body fat mass

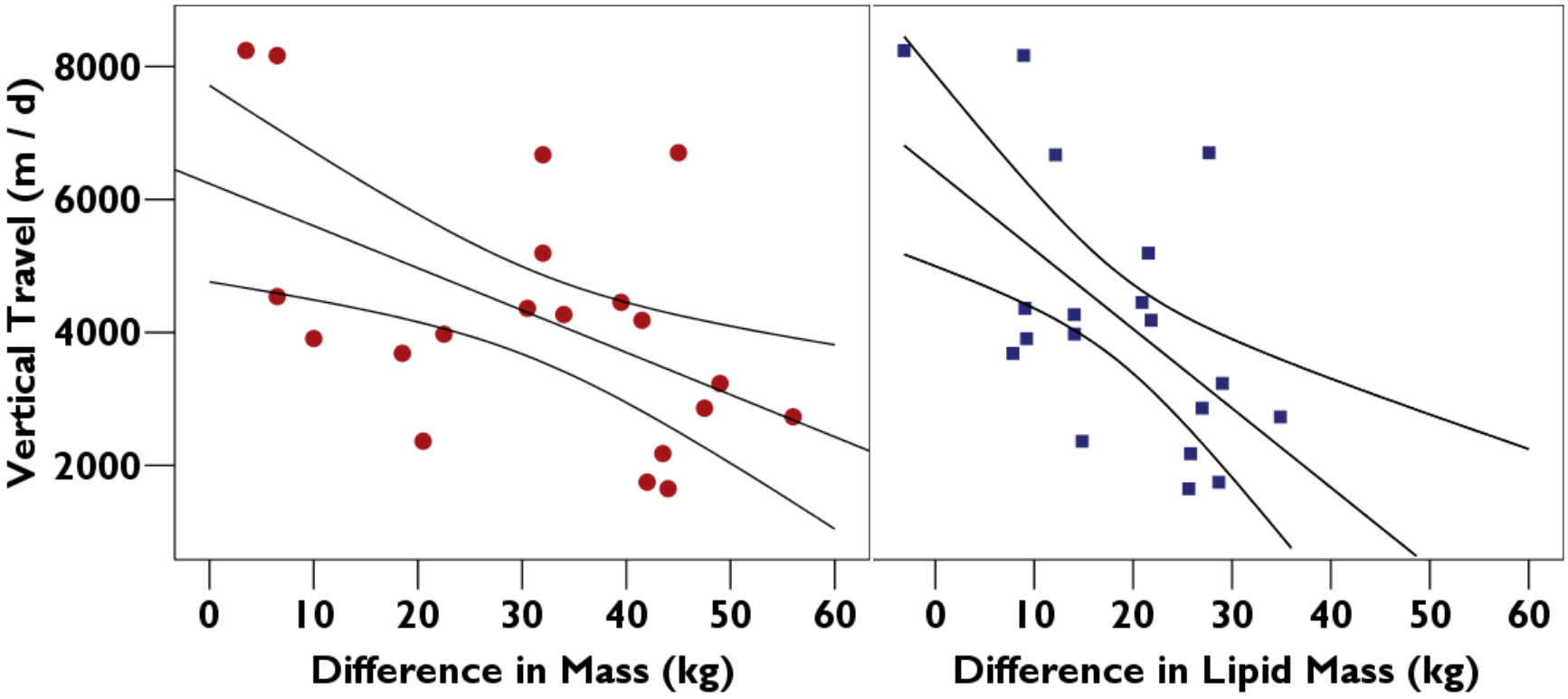


(Rehberg and Rea, poster 2010)

Preliminary unpublished data, do not cite

Young-of-Year Recapture Project

Mass and lipid increase weakly correlated with behavior

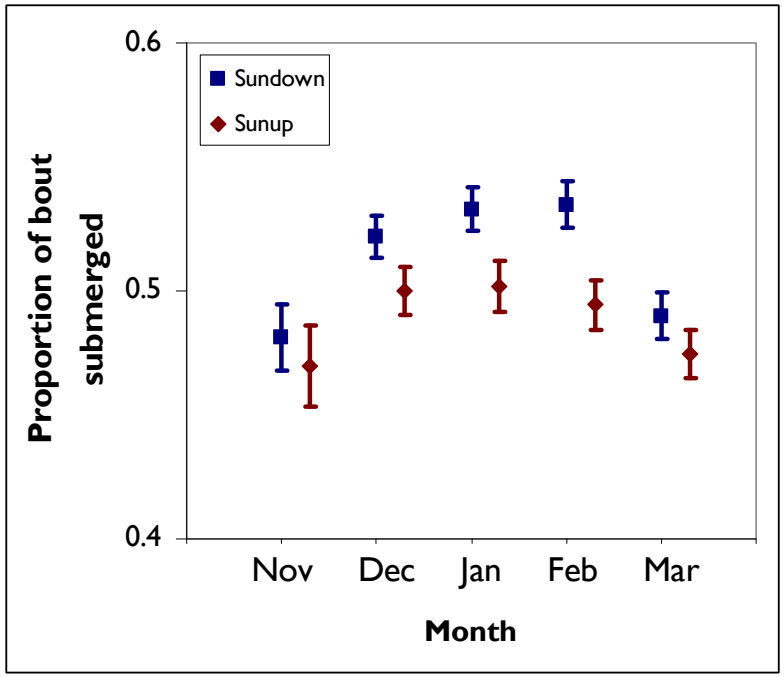


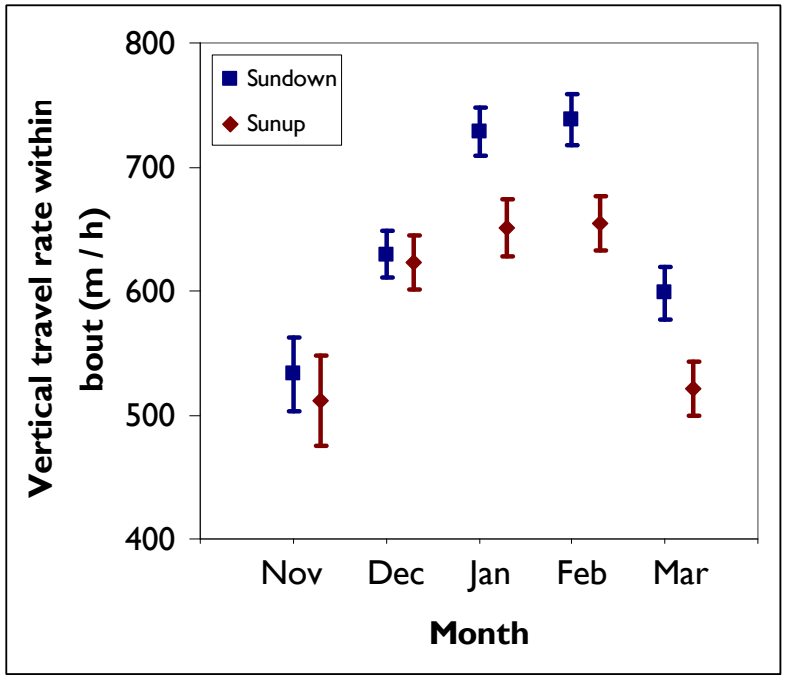
(Rehberg and Rea, poster 2010)

Preliminary unpublished data, do not cite

Young-of-Year Recapture Project

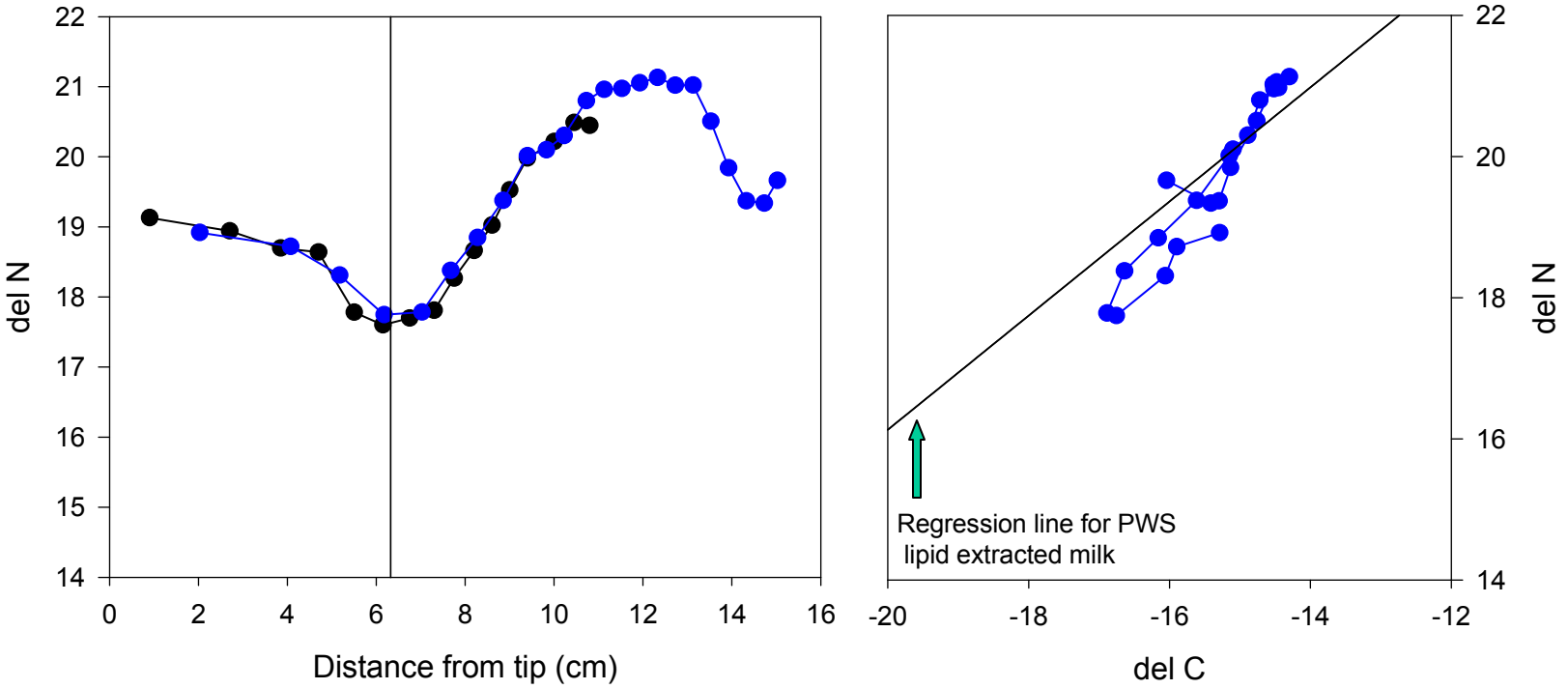
Mid-winter peak and nocturnal preference in many behavioral measures





(Rehberg and Rea, poster 2010)

Preliminary unpublished data, do not cite



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

(Rehberg and Rea, poster 2010)

Preliminary unpublished data, do not cite

Acknowledgments:

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