
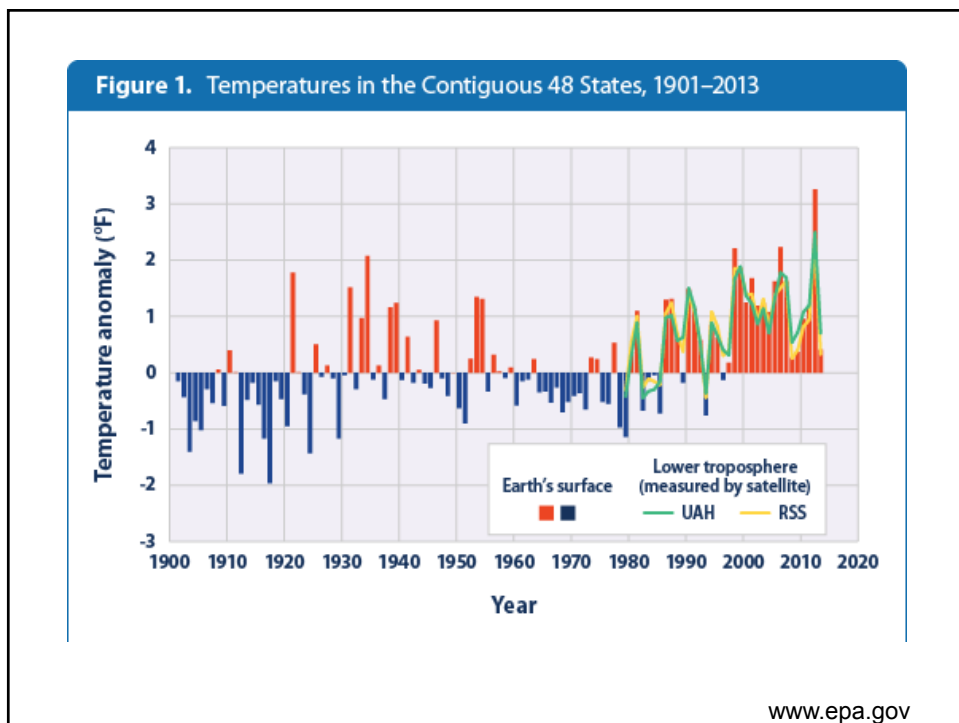


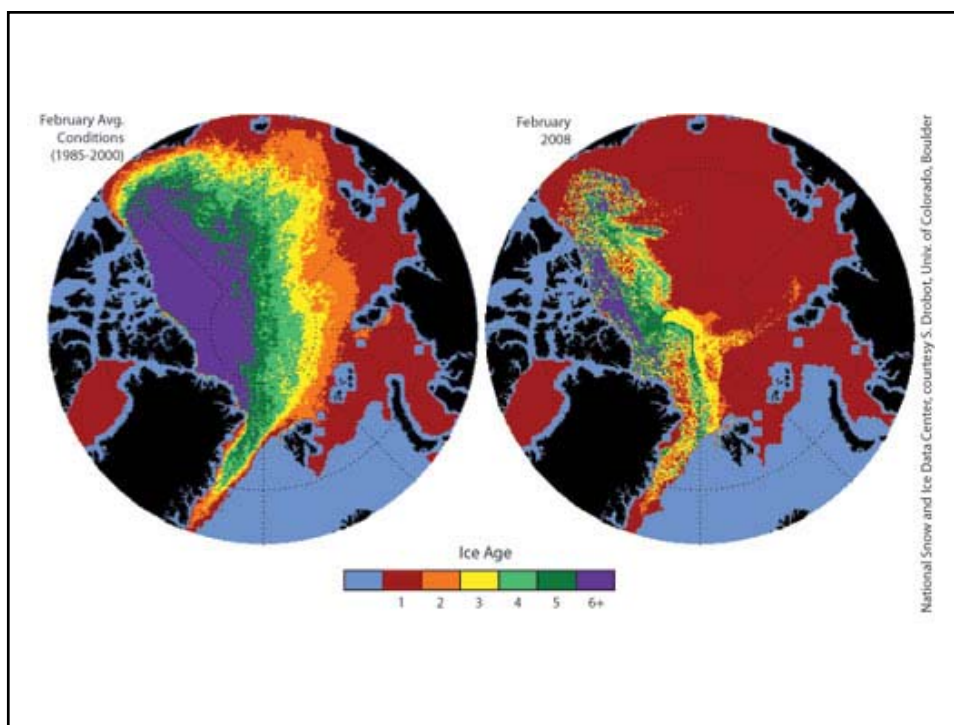
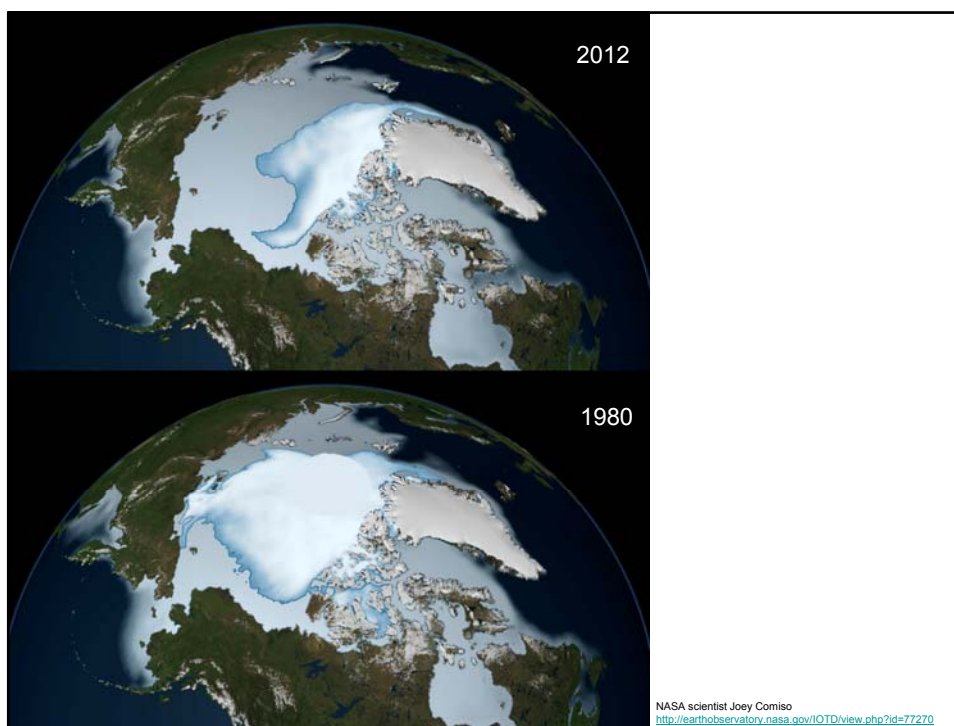
# Nature, Nutrition, and the Environment:

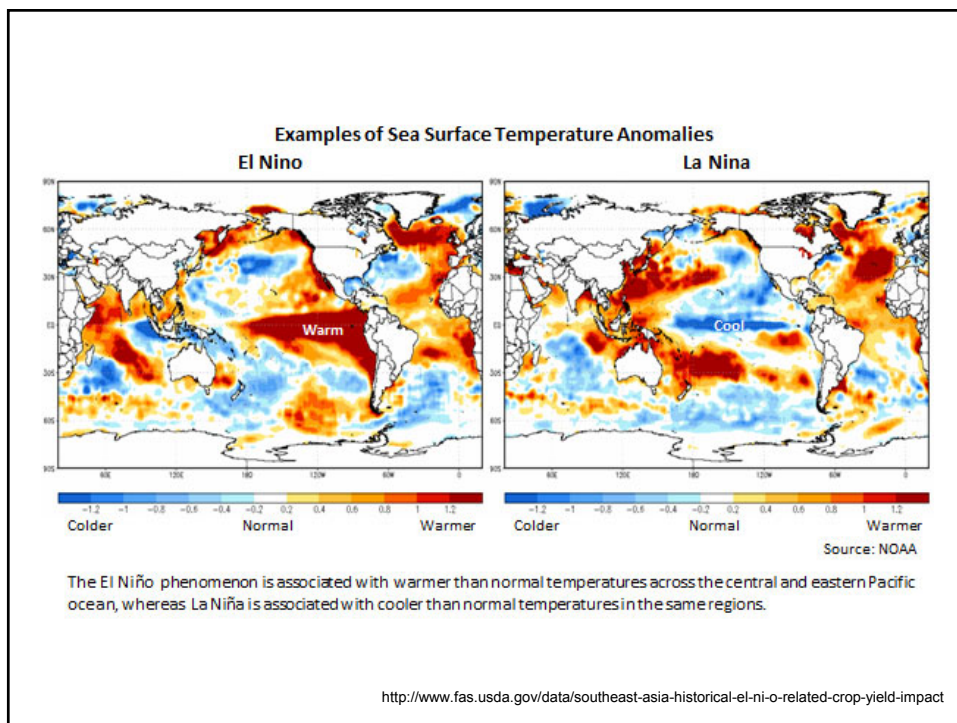
## *The ecophysiology of differential growth strategies among phocids*

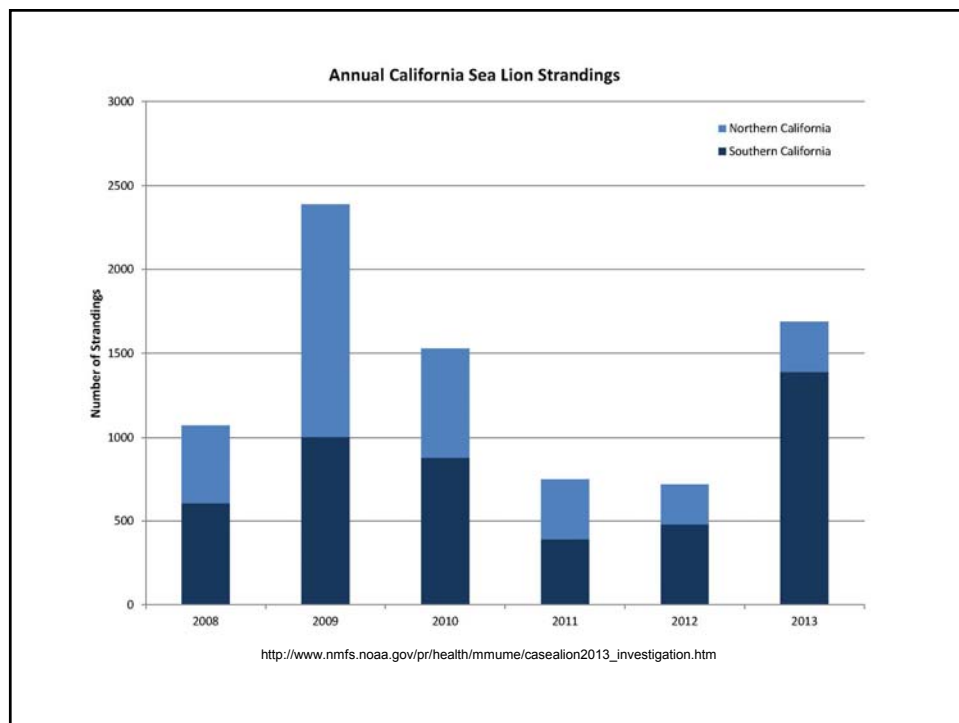
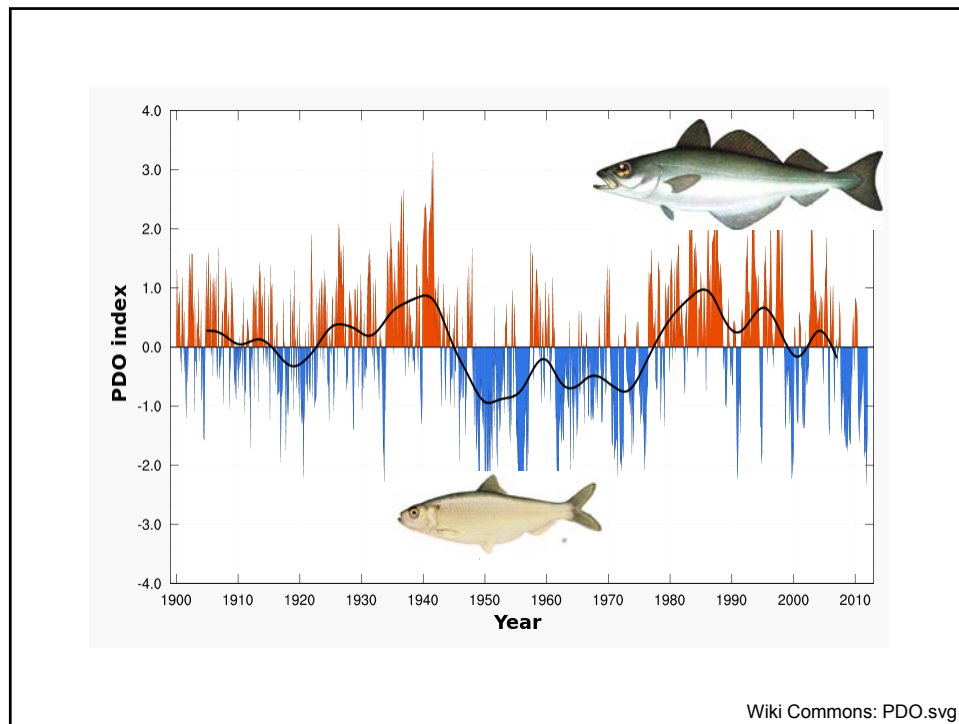
Dr. Julie Avery  
University of North Florida  
Department of Biological Science

25 February 2015  
University of Florida, Aquatic Animal Health Seminar







## Importance: Big Picture

- “Nutritional Stress”

- Reduced quantity or quality of prey
- Catastrophic
- Subtle affect
  - difficult to identify

- Reduced Intake

- Reduced growth
- Increased susceptibility
  - Disease & Predation
- Reduced Survival



## *Comparative physiology of growth and development*

### Link between nutrient intake and energy allocation for growth and storage

- Inter-species comparison (between)
  - Differential growth rates
- Intra-species comparison (within)
  - Greater growth = greater survival
  - Larger pups at weaning better rates of survival

Muelbert et al., 2003; Harding et al., 2005

## Order Carnivora

Pinniped “fin-footed”

### Family

Otariidae ~Sea lion

Phocidae ~Seal

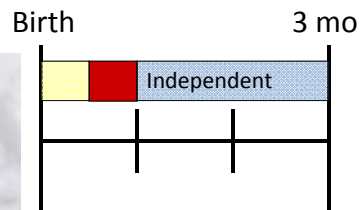
Odobenidae ~Walrus



### Diverse Taxa

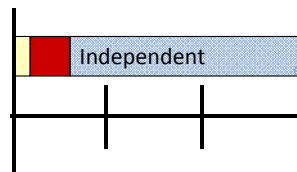
- Distinct life history strategies
- Differential growth rates

### Harp seal



- 10 kg at birth
- 12 d lactation
- 50% lipid milk
- Rapid growth 2 kg / d (20% / d)
- 2 week post wean fast

### Hooded seal




- 25 kg at birth
- 4 d lactation
- 60% lipid milk
- **Rapid** growth 7 kg / d (30% / d)
- 2 week post wean fast

Schulz and Bowen, 2004



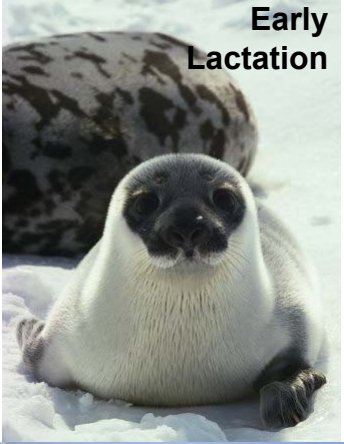
60% fat and 5% protein  
 — 60,000 kcal/day  
**109 BIG MAC/day**




- 7 kg gain / d
- 25 kg birth mass (30% gain/d)
- 50-60kg wean mass

(Lydersen et al 1997, J Comp Physiol B 167:81-88)

**Early Lactation**




**Late Lactation**




# Environment

**Fast Ice**



ARKIVE  
www.arkive.org



**Harp Seal**

© Francois Gohier / www.arkive.com

**Pack Ice**




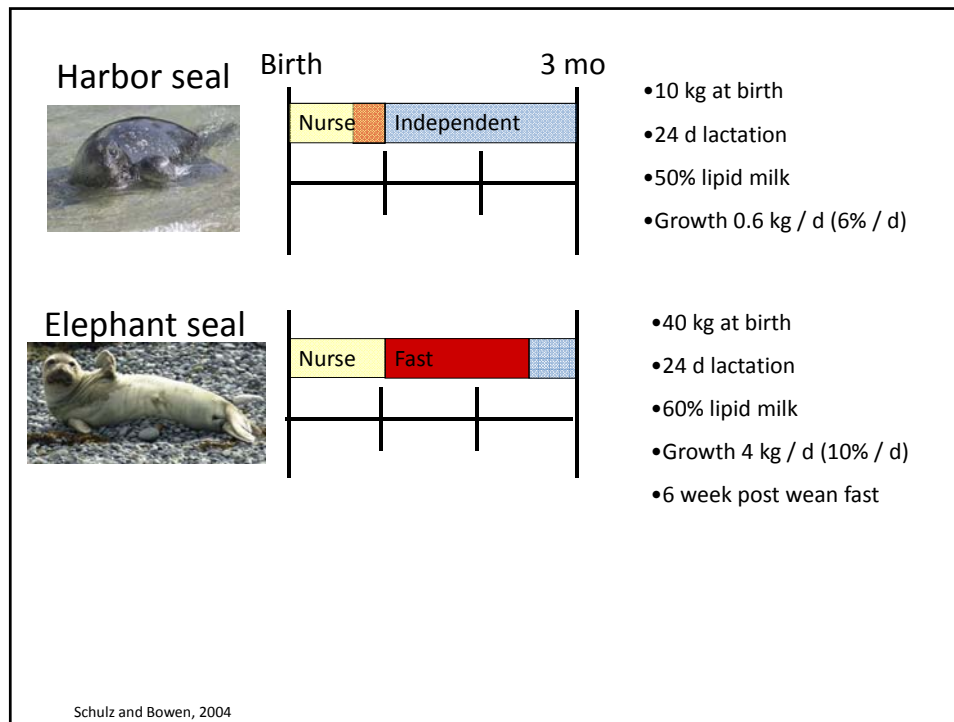



Photo: ACECRUMAS



**Hooded Seal**

gettyimages



## *Physiological Factors*

### *Nutrient Allocation and Growth Rate*



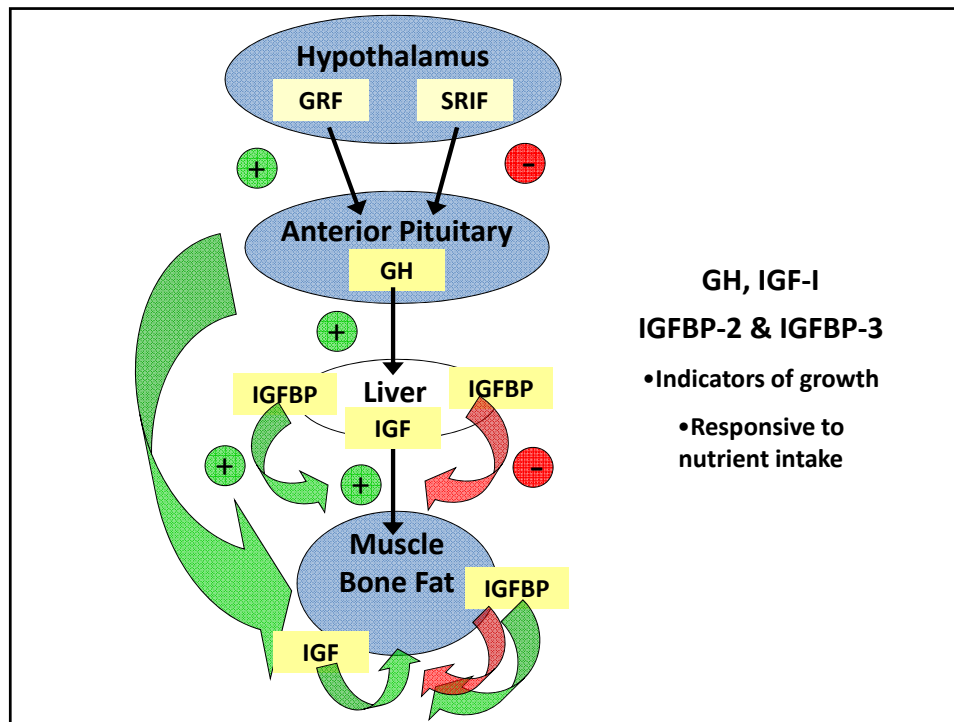
#### Somatotropic Axis

Multiple components change in predictable manner with:

Age, sex, nutrition

Rausch et al., 2002; Govoni et al., 2003; Richmond et al., 2008





*Can the response of the Somatotrophic axis in early development account for species differences in growth rate?*

- Intra-species comparison (within)
  - Greater growth = greater survival
  - Larger pups at weaning better rates of survival

*Growth rate in free-ranging harbor seal pups*

*Richmond 2008*



- Inter-species comparison (between)
  - Differential growth rates



*Precocial Hooded seal vs. Altricial Harp seal*

*Parker et al. 2011*



*Parker et al. 2011 Society for Marine Mammalogy*

# Free-Ranging Harbor seal

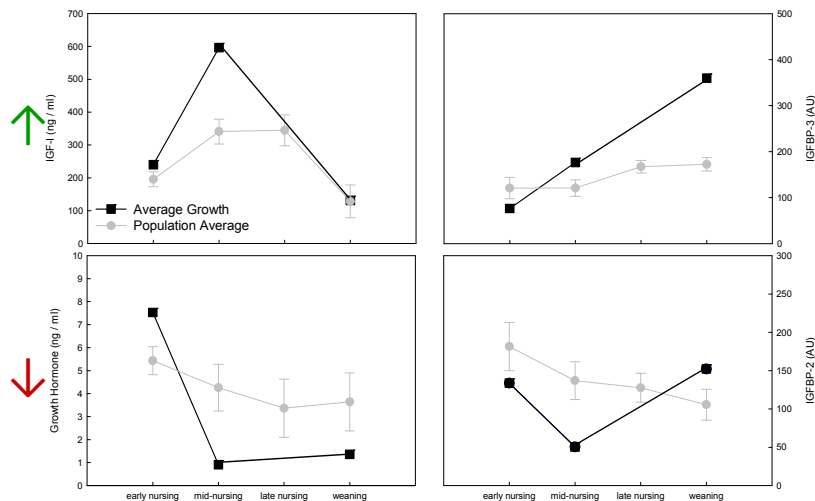
Collaboration with University of Maine, Orono ME



- Gulf of Maine
- Captured shortly after birth (n = 85)
- Age determined by
  - umbilical status (Boulva, 1975)
  - Model included sex, nursing status, mass, SL, canine length (Skinner, 2006)
- Marked for subsequent re-capture
  - Early Nursing (0 to 7 d)
  - Mid Nursing (8 to 14 d)
  - Late nursing (15 to 24 d)
  - Weaned ( $\geq 25$  d)
- Serum and Morphometrics collected at each capture
  - Mass, Standard Length, Axial Girth

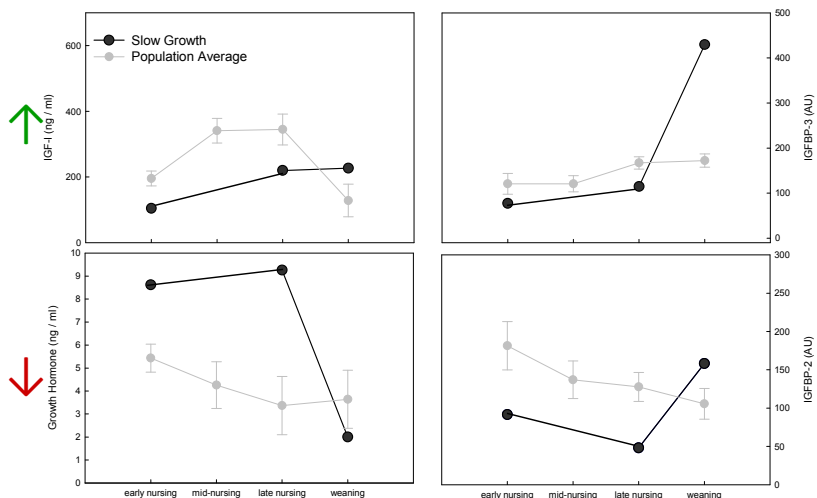
Richmond 2008

## Average Growth Rate 0.55 kg / d



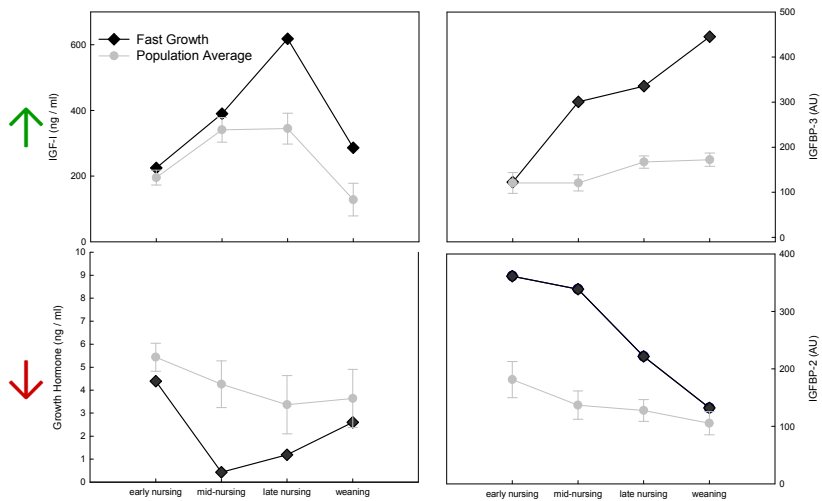
Richmond 2008

## Slow Growth Rate 0.29 kg / d



Richmond 2008

## Fast Growth Rate 0.64 kg / d



Richmond 2008

## *Can the response of the Somatotrophic axis in early development account for species differences in growth rate?*

- Intra-species comparison (within)
  - Greater growth = greater survival
  - Larger pups at weaning better rates of survival

*Growth rate in free-ranging harbor seal pups*  
Richmond 2008



Yes, predictable pattern associated with growth rate.

- Inter-species comparison (between)
  - Differential growth rates



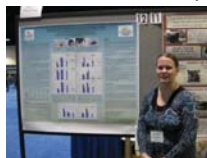
*Precocial Hooded seal vs. Altricial Harp seal*  
Parker et al. 2011



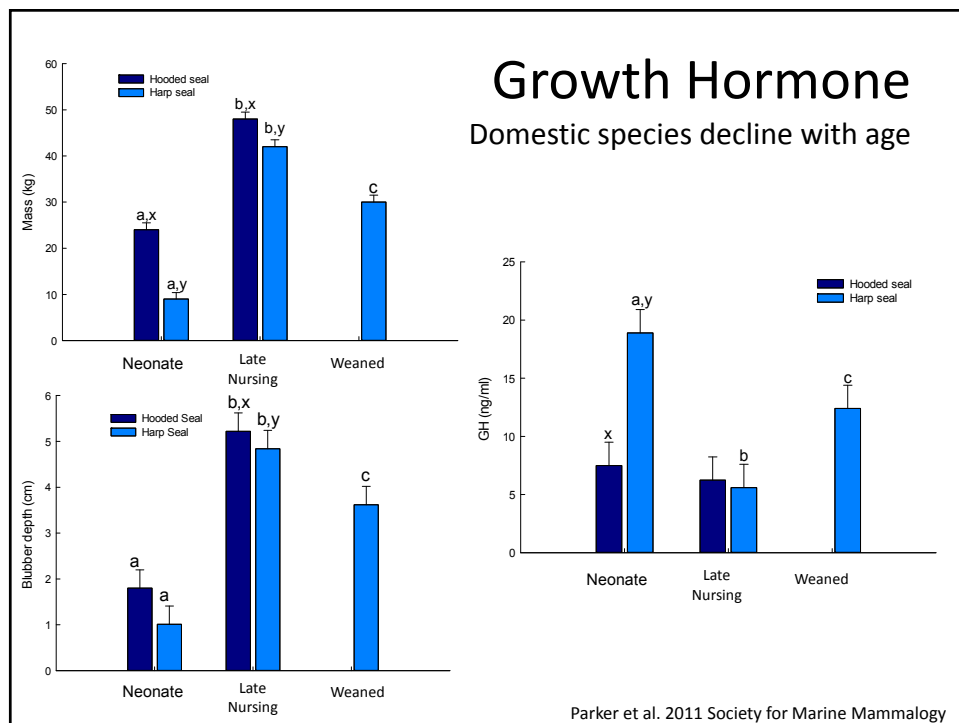
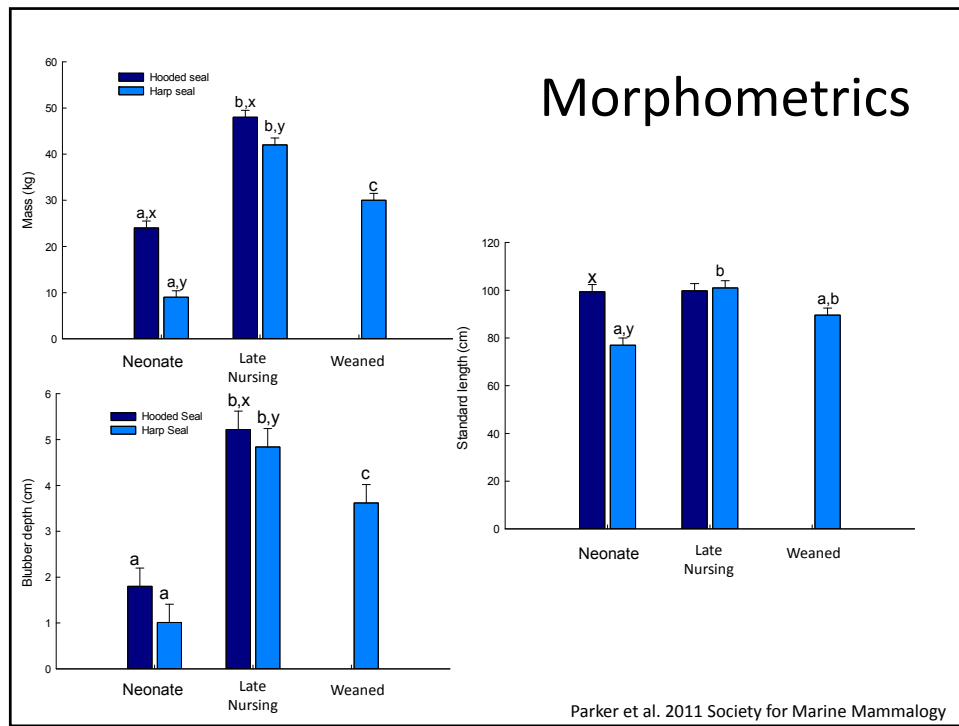
Richmond 2008

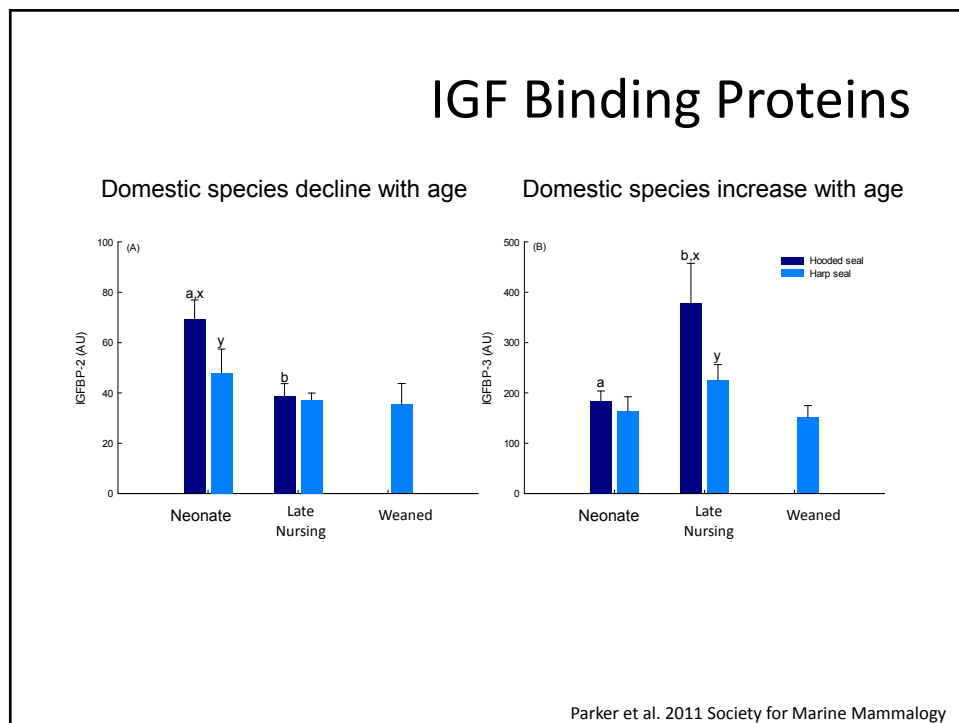
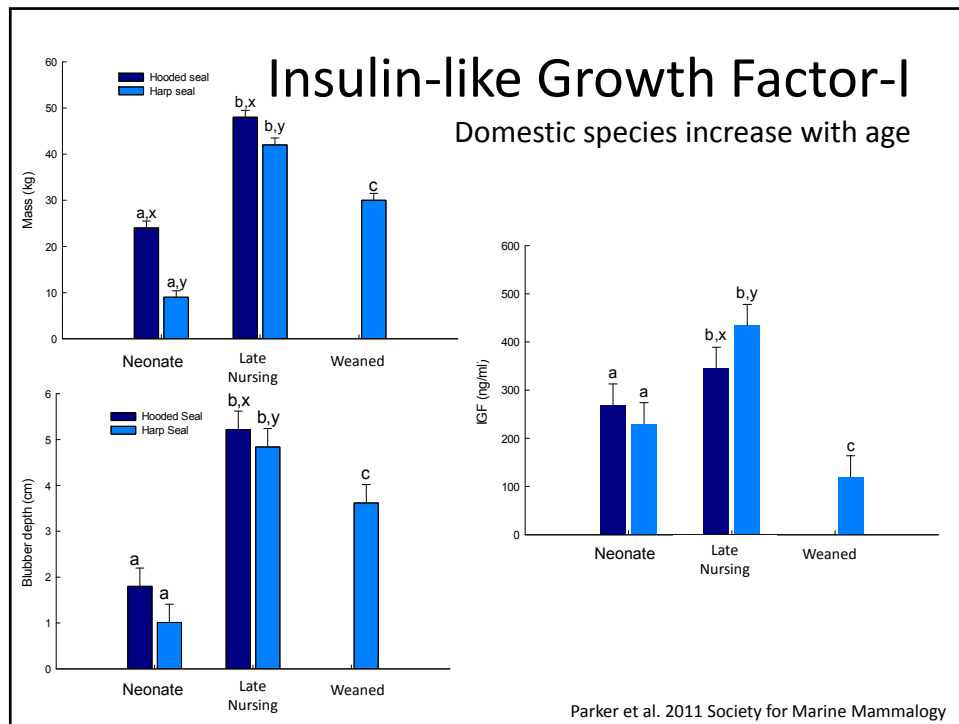
## Methods

- Free ranging seals
- Age according to pelage (coat);
  - **Neonates**
    - (n = 6 harps, 5 hoods)
  - **Nursing/weaned**
    - (n = 5 harps, 5 hoods)
  - **Late weaned**
    - (n = 5 harps)
- Morphometrics,
  - mass, blubber depth, and standard length
- Hormone analysis
  - GH & IGF-I heterologous RIA
  - Validated harp and hooded seals (Richmond & Zinn, 2009)
  - IGFBP: ligand blot following (Richmond et al., 2010)
- Statistics: ANOVA (SAS, 9.2, Raleigh, NC)



Parker et al. 2011 Society for Marine Mammalogy



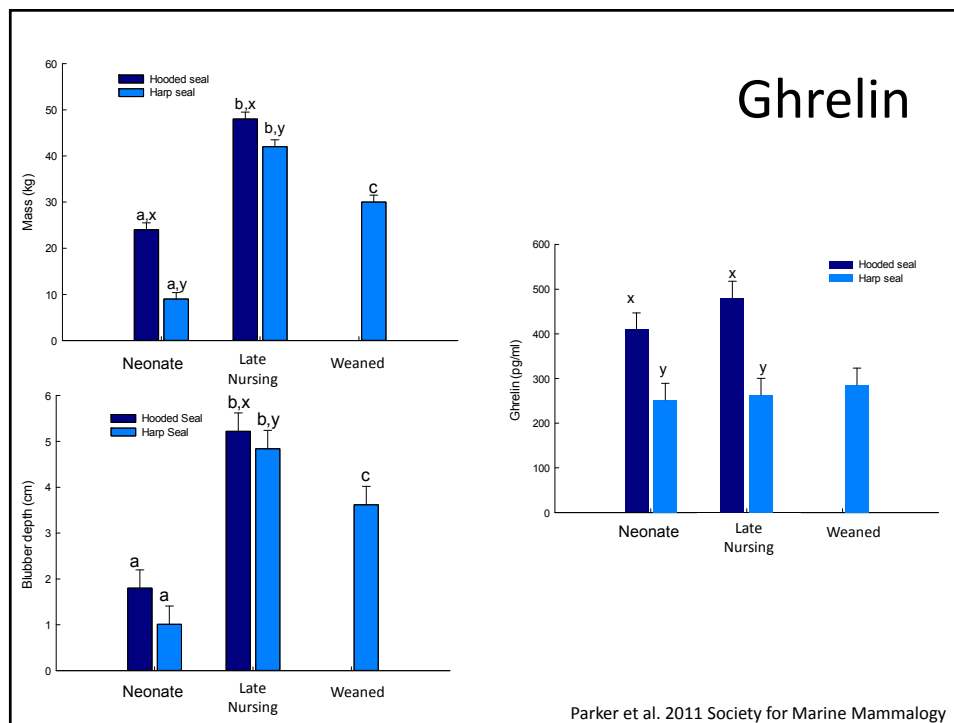




## Ghrelin

- Regulation of food intake and energy balance
- **↑** during fasting (gastric emptying)
  - Promotes feeding
- **↓** with feeding (suppressed)
  - Promotes lipid synthesis and deposition

Nakazato *et al.* 2001; Cummings *et al.* 2002; Sangiao-Alvarellos *et al.* 2011; Tschop *et al.* 2000; Takaya *et al.* 2000



*Can the response of the Somatotrophic axis in early development account for species differences in growth rate?*

- Intra-species comparison (within)
  - Greater growth = greater survival
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*Growth rate in free-ranging harbor seal pups*

Richmond 2008



*Yes. Predictable pattern associated with growth rate.*

- Inter-species comparison (between)
  - Differential growth rates

*Precocial Hooded seal vs. Altricial Harp seal*

Parker et al. 2011



*Yes. Developmental pattern similar,  
but magnitude and timing of response  
= differential growth rates*



Lower GH and BP2 with greater IGF and BP3 associated with increased growth rate in Hooded seals  
Increased ghrelin in hoods may allow increased intake and rapid deposition of adipose

Parker et al. 2011; Richmond 2008

## Response to Nutrient Intake

Does the Pinniped Somatotrophic Axis  
respond to changes in nutritional status  
in a similar manner compared with terrestrial?

## Rehabilitated harbor seal pups



**Fasting: GH & IGFBP2 ↑, IGF-I & IGFBP3 ↓**

*Associated with reduced body condition*

**Re-feeding: GH & IGFBP2 ↓, IGF-I & IGFBP3 ↑**

*Positively associated with growth rate*

**↑ intake rate = ↑ growth rate**

Level of feed intake resulted in differential growth rate reflected in hormone profile

Richmond et al. 2008. J. Zoo Wildl. Med. 39(3):342-348; Richmond, et al. 2010. Gen. Comp. Endo. 165: 286-292

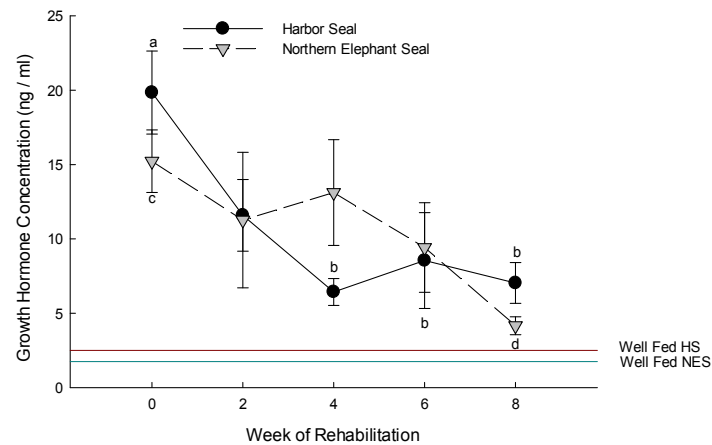
## Methods

- Harbor Seals (n=10)
- Northern Elephant Seals (n=9)
- Less than 10 days old
- Nutritional nadir
- Refeeding over 8 weeks
  - 2 week intervals
- Caloric Intake
  - Formula
  - Herring
- Body Mass
- Body Condition Index
  - Mass/Length
- GH, IGF-I, and Ghrelin
  - Heterologous Radioimmunoassay
  - Validated for HS and NES
- ANOVA with repeat measures
  - Week, species, week\*species
  - SAS (Cary, NC)



Dailey and Richmond, 2013, SICB

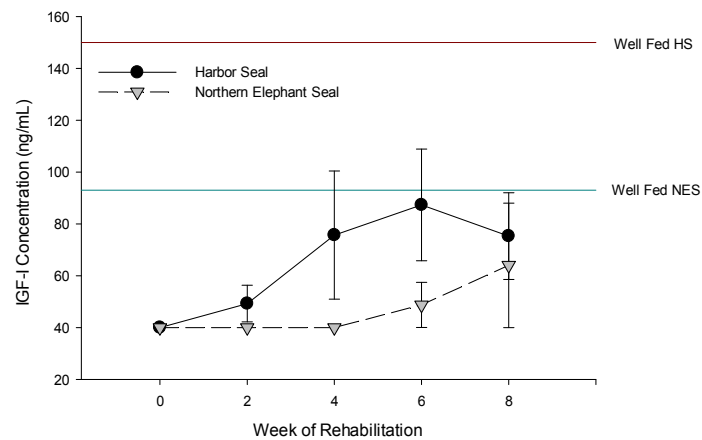
## Growth Hormone



Dailey and Richmond, 2013, SICB

Ortiz et al 2003, Richmond et al 2008

## Insulin-like Growth Factor I



Dailey and Richmond, 2013, SICB

Ortiz et al 2003, Richmond et al 2008

## Findings

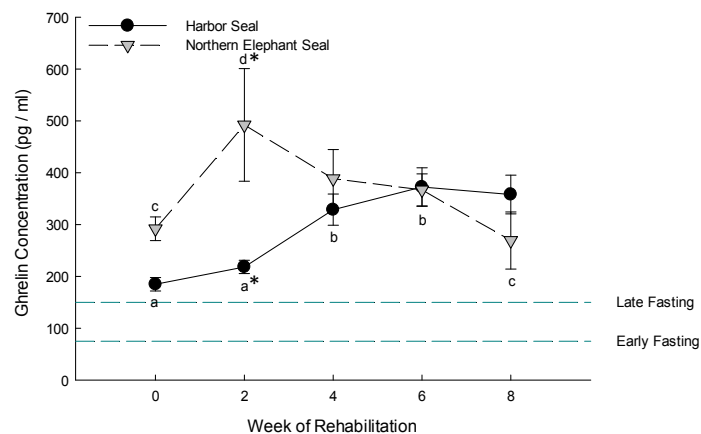
	Expected	Harbor Seal	Elephant Seal
GH	↓	↓	↓
IGF-I	↑	=	=

- High GH, Low IGF compared to free-range animals
  - Suggests low nutritional status
  - Animals likely not in positive energy balance

Dailey and Richmond, 2013, SICB

Ortiz et al 2003, Richmond et al 2008

## Ghrelin



Dailey and Richmond, 2013, SICB

Ortiz et al 2003

## Findings

	Expected	Harbor Seal	Elephant Seal
GH	↓	↓	↓
IGF-I	↑	=	=
Ghrelin	↓	↑	↑

- Hyperstimulation of Ghrelin
  - Similar to Arctic Fox response
  - Role of ghrelin as adipose promoter rather than fasting adaptation

Dailey and Richmond, 2013, SICB

	<u>Ice Breeders</u>		<u>Land Breeders</u>	
	Hood Seal	Harp Seal	Harbor Seal	Elephant Seal
Growth Rate (kg/d)	7	2	0.6	4
% birth mass	30%	20%	6%	10%
GH (ng/ml)	5	5	2.5	1.5
IGF-I (ng/ml)	350	400	150	75
Ghrelin (pg/ml)	450	250	200*	50-150

Dailey and Richmond, 2013; Parker et al. 2011

Ortiz et al 2003



# Somatotropic Axis & Population Health

Emphasizes importance of measuring  
multiple components of the somatotropic axis

Components of the somatotropic axis and their change with age and  
nutritional status

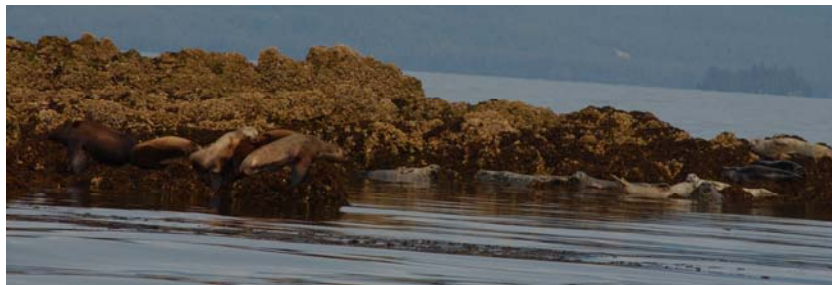
Nutrient Intake	GH	IGF-I	IGFBP-2	IGFBP-3
Normal food intake with increasing age	↓	↑	↓	↑
Restricted food intake	↑ / =	↓	↑ / =	↓ / =
Long-term nutrient deficit	↑↑	↓	↑	↓

Arrows indicate increasing or decreasing change

Adapted from Richmond 2008

## •Considerations for Predictive Index

- ✓ Predictive of Growth Rate
- ✓ Sensitive to energy intake
- ✓ Insensitive to type of fish fed
- ✓ Strong seasonal response



## Importance: Big Picture

### •“Nutritional Stress”

- Reduced quantity or quality of prey
- Catastrophic
- Subtle affect
  - Reduced growth
  - Increased susceptibility Disease & Predation
- Reduced Survival



Hooded Seal



Harp Seal



Bearded Seal



Ribbon Seal



Spotted Seal



Ringed Seal

### Collaborators

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**University of Alaska Anchorage (UAA)**  
 Jennifer Burns

**University of Connecticut (UConn)**  
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**University of North Florida (UNF)**  
 Rachael Dailey, Rachel Cimino, Savannah Parker,

### Permits & IACUC

All research authorized under the MMPA  
 Permit no. 358-1564 (ADF&G), 800-1664 (ASLC), 42-1642 (MA), 932-1489 (TMMC), and 482-1653-04 (UM)

Animal handling protocols approved by  
 UBC (A04-0169)  
 UCONN (E05-115)  
 UM (2004-01-02)  
 UNF (12-002W, 003W, 006W, 007W, 008W, 12-009)

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 UNF Coastal Biology  
 University of British Columbia  
 Quebec Labrador Foundation



Harp seal (*Phoca groenlandica*) identified by their “ragged jacket” pelage (3 wk old; Fed).



“Beater” Harp seal (*Phoca groenlandica*), ~2 wk post-weaning (4 wk old; Fast) identified by the black-spotted juvenile pelage.



“Blue-back” Hooded seal (*Cystophora cristata*), ~1 wk old (Fed). Hooded seals retain the blue-back coat for 14 months.



Harbor seal (*Phoca vitulina*), ~6 mo old).