Nature, Nutrition, and the Environment:

*The ecophysiology of differential growth strategies among phocids*

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*Department of Biological Science*

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University of Florida, Aquatic Animal Health Seminar

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**Figure 1.** Temperatures in the Contiguous 48 States, 1901–2013

www.epa.gov
NASA scientist Joey Comiso
http://earthobservatory.nasa.gov/IOTD/view.php?id=77270


February 2008

National Snow and Ice Data Center, University of Colorado, Boulder

Ice Age

1 2 3 4 5 6+
The El Niño phenomenon is associated with warmer than normal temperatures across the central and eastern Pacific ocean, whereas La Niña is associated with cooler than normal temperatures in the same regions.

Wiki Commons: PDO.svg

http://www.nmfs.noaa.gov/pr/health/mmume/casealion2013_investigation.htm

Annual California Sea Lion Strandings

http://www.nmfs.noaa.gov/pr/health/mmume/casealion2013_investigation.htm
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**
  - Birth: 10 kg
  - 12 d lactation
  - 50% lipid milk
  - Rapid growth: 2 kg / d (20% / d)
  - 2 week post wean fast

- **Hooded seal**
  - Birth: 25 kg
  - 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)

Environment

Fast Ice

Pack Ice

Harp Seal

Hooded Seal
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 Somatotropic 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 (≥ 25 d)
• Serum and Morphometrics collected at each capture
  • Mass, Standard Length, Axial Girth

Average Growth Rate 0.55 kg / d

Richmond 2008
Slow Growth Rate 0.29 kg / d

Fast Growth Rate 0.64 kg / d

Richmond 2008
**Can the response of the Somatotropic axis in early development account for species differences in growth rate?**

- Intra-species comparison (within)
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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*

**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*
Morphometrics

Nutritional Status
Low Nutrition Fed Fasting

Blubber depth (cm)
0 1 2 3 4 5
Hooded Seal
Harp Seal

a
b,x
a,y
b,y

Neonate Late Nursing Weaned

Mass (kg)
0 10 20 30 40
Hooded seal
Harp seal

a,x
a,y
b,x
b,y

Neonate Late Nursing Weaned

Standard length (cm)
0 5 10 15 20
Hooded seal
Harp seal

x
a,y
b
a,b

Neonate Late Nursing Weaned

Growth Hormone
Domestic species decline with age

GH (ng/ml)
0 5 10 15 20 25
Hooded seal
Harp seal

x
a,y
b
a,b

Neonate Late Nursing Weaned

Parker et al. 2011 Society for Marine Mammalogy
Insulin-like Growth Factor-I

Domestic species increase with age

IGF Binding Proteins

Domestic species decline with age
Domestic species increase with age
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

Parker et al. 2011 Society for Marine Mammalogy
Can the response of the Somatotropic 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

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 Somatotropic 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


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

<table>
<thead>
<tr>
<th></th>
<th>Expected</th>
<th>Harbor Seal</th>
<th>Elephant Seal</th>
</tr>
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<tbody>
<tr>
<td>GH</td>
<td>↓</td>
<td>↓</td>
<td>↓</td>
</tr>
<tr>
<td>IGF-I</td>
<td>↑</td>
<td>=</td>
<td>=</td>
</tr>
</tbody>
</table>

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

Ortiz et al. 2003, Richmond et al. 2008

Ghrelin

Dailey and Richmond, 2013, SICB

Ortiz et al. 2003
Findings

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</tr>
<tr>
<td>IGF-I</td>
<td>↑</td>
<td>=</td>
<td>=</td>
</tr>
<tr>
<td>Ghrelin</td>
<td>↓</td>
<td>↑</td>
<td>↑</td>
</tr>
</tbody>
</table>

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

Dailey and Richmond, 2013, SICB

<table>
<thead>
<tr>
<th></th>
<th>Ice Breeders</th>
<th>Land Breeders</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Hood Seal</td>
<td>Harp Seal</td>
</tr>
<tr>
<td>Growth Rate (kg/d) % birth mass</td>
<td>7 30%</td>
<td>2 20%</td>
</tr>
<tr>
<td>GH (ng/ml)</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>IGF-I (ng/ml)</td>
<td>350</td>
<td>400</td>
</tr>
<tr>
<td>Ghrelin (pg/ml)</td>
<td>450</td>
<td>250</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Nutrient Intake</th>
<th>GH</th>
<th>IGF-1</th>
<th>IGFBP-2</th>
<th>IGFBP-3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal food intake with increasing age</td>
<td>↓</td>
<td>↑</td>
<td>↓</td>
<td>↑</td>
</tr>
<tr>
<td>Restricted food intake</td>
<td>↑  / =</td>
<td>↓</td>
<td>↑  / =</td>
<td>↓  / =</td>
</tr>
<tr>
<td>Long-term nutrient deficit</td>
<td>↑↑</td>
<td>↓</td>
<td>↑</td>
<td>↓</td>
</tr>
</tbody>
</table>

Arrows indicate increasing or decreasing change

Adapted from Richmond 2008

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**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

Photo © ADFG 2005

Bearded Seal

Harp Seal

Ribbon Seal

Spotted Seal

Ringed Seal

Collaborators

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The Marine Mammal Center (TMMC)
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University of Alaska Anchorage (UAA)
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University of Connecticut (UCONN)
Steve Zinn, Genevieve Comeau, Amanda Pariello, Kat Carey
University of North Florida (UNF)
Rachael Dalley, Rachel Cimino, Savannah Parker

Permits & IACUC
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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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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.