Western Steller Sea Lions: Population Trends and Vital Rates

Alaska Ecosystem Program
NOAA Fisheries
National Marine Mammal Laboratory
Alaska Fisheries Science Center
Seattle, WA
Outline

Abundance and Trends
- Western Stock (DPS) in Alaska
- Eastern DPS in SE Alaska
- Russia

Survival
- Western DPS: E Aleutians – E Gulf of Alaska
- Comparisons with SE Alaska (eastern DPS)
- Changes in western DPS survival 1970s-2000s
- Possible relationships between survival, natality, population trends and differences in life history between E & W DPSs
Steller Sea Lion Stocks and Regions in AK

- Eastern and Western Distinct Population Segments (DPS)
- Eastern, Central, Western Aleutians & Gulf of Alaska; SE AK
- Rookery Cluster Areas 1-11
Western Stock
Ulak/Hasgox Point – Central Aleutians
Decreasing: 272 Pups
515 Adults and Juveniles
SSL Pup Counts 2009 & 2011

- All rookeries
- Major haulouts
- Western DPS in AK
## Change in SSL Pup Counts
2009 to 2011

- All rookeries
- Major haulouts
- Western DPS in AK

### Graph

- 2005 to 2009

<table>
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<th>WALEU</th>
<th>CALEU</th>
<th>EALEU</th>
<th>WGULF</th>
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### Notes
- The graph shows changes in SSL pup counts from 2005 to 2009 across various rookeries and haulouts in Alaska.
Change in SSL Pup Counts 2001/02 to 2009 or 2011

- All rookeries
- Major haulouts
- Eastern & Western DPS in AK

![Chart showing changes in SSL pup counts from 2001/02 to 2009 or 2011.](chart-image)
AREA 4 – ONLY PART OF CENTRAL/WESTERN ALEUTIANS THAT HAD AN INCREASING PUP TREND 1990-2011

Non-Pups

Pups

4 TANAGA - ATKA

-0%/y

2000-2011

5 AMLIA - IS OF 4 MTNS

+2.2%/y

2000-2011
Steller Sea Lion Non-Pup Population Trends in AK

- Similar increasing trends in EAI-EGOA and SE AK (~+3%/y)
- Decreasing trend in W&C Aleutians (~-3%/y)
- Increasing trend in western DPS (~2%/y)
SSL survey areas in Russian waters

Six areas are established in Russian waters for surveys.
**Western Bering Sea, 1980-2010**

- Number, ind.
  - Western Bering Sea Non-Pups
    - *98% decline since 1982*
  - Eastern Kamchatka:
    - *non-pups 81% decline since 1983*
    - *pups 50% decline since 1986*
Known Steller sea lion sites

<table>
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<tr>
<th>Major Areas</th>
<th># Sites</th>
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<td>Kuril Islands</td>
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<td>Sea of Japan &amp; Sakhalin</td>
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<td>Western Bering Sea</td>
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<td>Kamchatka</td>
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<td>Commander Islands</td>
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<td>Northern Sea of Okhotsk</td>
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<td>Total All Areas</td>
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SSL survey areas along coast of Asia

Known Steller sea lion sites

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<tr>
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<tr>
<td>Total All Areas</td>
<td>182</td>
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</table>

Number of pups and non-pups in SSL survey areas along coast of Asia:

- 1970: Asian not recovering, Western recovering
- 1980: Asian not recovering, Western recovering
- 2000: Asian not recovering, Western recovering
- 2010: Asian not recovering, Western recovering

SSL survey areas along coast of Asia

SSL survey areas along coast of Asia

SSL survey areas along coast of Asia

SSL survey areas along coast of Asia
SSL Range-wide Non-pup Trends

Steller Sea Lion Range, Stocks, Terrestrial Sites
- Rookeries
- AK Major Haulouts
- Haulouts
  - Critical Habitat w/DPS in AK

Western DPS
- Russia
- Japan
- Sakhalin I. (Tunany)
- Kuril Is.
- Commander Islands
- W. Bering Sea

Eastern DPS
- Alaska
- Canada
- WA British Columbia
- OR CA

Recent Population Trend
- Increase
- Decrease
- Stable
- Fast
- Slow

Population Trend
- Stable
- Decrease
- Fast
- Slow

SSL Range-wide Non-pup Trends
Questions on Abundance and Trend?

Next: Survival – Model and Branding Results
Estimation of changes in vital rates

Modeling - time-varying Leslie matrix (Holmes & York 2003; Holmes et al. 2007)

- Used data from Central Gulf aerial surveys – pup and non-pup counts
- Developed a recruitment index (% juvenile based on size)
- Changed survival and reproductive rates to fit observed counts and % juvenile
- Start with estimates from the mid-1970s based on lethal sample

Steller sea lion length measurements from aerial photograph taken over Kodiak’s Cape Ugat on 12 June 2008
CGOA Female Vital Rate Changes over Time

- Vital Rates of 1970s are baseline (=1)
- ‘Low’ survival in late 80s-early 90s
- ‘High’ survival in 2000s
  - Similar or greater than 1970s
- Decline in birth rate
- Pattern suggests change in magnitude of factors affecting population
  - Decline in direct mortality
  - Increase in indirect effects
Steller Sea Lion Survival: Branding and LHX Populations, Time Periods and Methods

- **Eastern DPS**

- **Western DPS**
  - Pups branded 2000-05 EAI-EGOA N=1449; sightings through 2011 (NMML)
  - Life History Transmitter (LHX) 2005-11 EGOA N=36; (Horning and Mellish 2012)
  - Pups branded 1987-88 CGOA N=751; sightings through 2003 (Pendleton et al. 2006)
NMML Steller Sea Lion Branding Western DPS

- 1,449 pups
- 5 rookeries in the E Aleu through EGOA
- 6 cohorts: 2000-2005
- Sightings thru 2011
Western DPS Survival at Age

- No regional differences
- Females > Males
- 1st year > 2nd year
- More pronounced in males
- No cohort differences
Cumulative Female Survival to Age

FEMALES

- 2000s CGOA brand
- 1998-2004 CGOA model

2000s branding and model results nearly identical
Cumulative Female Survival to Age

- Survival to ages 3-5 10-20% lower in 2000s than 1970s
- Survival to ages 7-11 similar in 2000s than 1970s
Cumulative Survival to Age

CGOA Survival in 2000s much greater than in late 80s-early 90s
**Brand & LHX**

- LHX data ages 2-5 only
- LHX 8 females, 28 males
- LHX ~ Branded males @ 2-3 y
- LHX > Brand @ 4-5 y
Cumulative Survival to Age: Brand & LHX

Brand and LHX survival nearly identical ages 1-5 in the 2000s
Cumulative Survival to Age: Brand, LHX & Model

Brand and Model FEMALE Survival to Ages 3-5 > LHX ~MALE
Are our conclusions different from Horning and Mellish’s?

• Yes and No

• H&M: “…our data demonstrate continued low juvenile survival in the Prince William Sound/Kenai Fjords region of the Gulf of Alaska…”

• Juvenile survival in 2000s 2X higher than 80s and slightly lower than in 1970s
  • 1970s > 2000s >> 1980s
  • Not continued low juvenile survival

• In 2000s, LHX results = Branding results for sample with same sex composition
  • 28 males, 8 females

• Survival of Females > Males

• H&M compared mostly male (LHX) with female (Holmes et al. 2007) survival

• Survival in 2000s is NOT lower than estimated by Holmes et al.
  • We found that LHX=Brand=Model for 2000s

• Survival in 2000s is NOT stalling recovery
  • Survival to maturity is not currently low
  • E Gulf population (Prince William Sound/Kenai Fjords) is increasing

• Killer whale predation is likely a major component of total juvenile sea lion mortality but it is not likely a threat to recovery in the EGOA-EAI region
Western DPS 2000s Survival Summary

- Females > Males
- No cohort differences 2000-2005
- No regional differences in survival EAI through EGOA
- 1st year > 2nd year
  - Consistent with older weaning age
- Brand = LHX in EGOA ages 2-5
- Population Trend:
  - EAI and EGOA are INCREASING
  - CGOA is STABLE
- Consistent with Reproductive Rate: (EAI & EGOA) > CGOA
Western DPS vs Eastern DPS

- East: 1st year < 2nd year
- West: 1st year > 2nd year
- Ages 2-8 Similar
Cumulative Female Survival to Age

CGOA (west) higher survival than SE AK (east)
Western DPS vs Eastern DPS

- Survival to adulthood: West (EGOA-EAI) > East (SE AK)
- Survival in 1st year: West > East
- Population trend: East ≈ West
- Consistent with Reproductive Rate: East > West
Western DPS vs Eastern DPS (2)

- Consistent with West more ‘K’ and East more ‘r’ selected

- ‘K’ selection - West
  - Higher survival rate (shown here)
  - Longer maternal care (1\textsuperscript{st} yr higher survival?)
  - Lower reproductive rate (hypothesized)
  - Larger body size

- ‘r’ selection - East
  - Lower survival rate (shown here)
  - Shorter maternal care (1\textsuperscript{st} yr lower survival?)
  - Higher reproductive rate (hypothesized)
  - Smaller body size

- If true, West would take longer to recover than East once direct mortality threats removed since it has lower reproductive rate
Future Research

• Publish wDPS survival paper (brand) in 2012
• Initiate natality estimation (brand)
• Continue development of size distribution methods
  o Juvenile recruitment in areas with no marked animals
• Development of age-structured model
  o All areas using counts, survival, size, natality
• Field Work 2012-13
  o Aerial surveys to count pups and non-pups
    o SE AK  EAI: manned; part of post de listing monitoring for eDPS
    o CAI  WAI: possible use of unmanned aircraft (UAS)
  o Brand sighting camps and cruises
Questions on Survival and Vital Rates?

Next: Composition – Age, Sex, Length
Sighting Probability

Eastern Gulf of Alaska
- Seal Rocks & Fish Island

Central Gulf of Alaska
- Sugarloaf & Marmot

Eastern Aleutian Islands
- Ugamak
Composition and Length

- Aerial survey data
- Across all of Alaska, not just where we branded
- Pup-Female Ratios
  - Relative ‘natality’
- Length distribution and Modeling
  - Regional Variation in Adult Female length
    - Identified with Pups or Juveniles
    - Eastern vs. Western DPS
    - Within Western DPS
  - Finite Mixture Distribution Modeling
    - Juvenile proportion within Western DPS
    - Compare Increasing vs. Decreasing Areas
    - EGOA-EAI (brand data) vs. CAI-WAI (no brand data yet)
Western Stock
Ulak/Hasgox Point – Central Aleutians
Decreasing: 272 Pups
515 Adults and Juveniles
Pup:Adult Female Ratios (2008-11)

- eDPS > wDPS
- WAI < rest of wDPS
- Consistent with:
  - Natality higher in eDPS than wDPS
  - Natality low in WAI
Length Data and Population Demographics

- Photogrammetric methods and marine mammals
  - Steller Sea Lions (Holmes & York 2003; Holmes et al. 2007)
  - Cetaceans (SWFSC 1998, 2008)

- Fisheries: Length frequency data and **Finite Mixture Distribution Model**
  - Size composition for age-sex classes (Everitt & Hand 1981; Wolfe 1970)
  - Identify individual fish stocks in mixed-stock distribution of length data (Millar 1987; Wood et al. 1987)

- Steller sea lion length data & Finite Mixture Distribution Model
  - Estimate mean length and population proportion of three age-sex classes: Juvenile, adult female, and adult male (Bull and sub-adult male)
  - Use photogrammetry to measure lengths from 2008 aerial survey images (Alaskan range-wide survey)
    - “observed known adult female”
Measurement Collection (SC 3)

Sites Measured

- Rookery
- Haul Out
- Altimeter Calibration
- Stock Division (144°W)

Region | Sites | # Lengths | # Female
---|---|---|---
SE AK (eDPS) | 8 | 1284 | 241
wDPS | 60 | 4737 | 1001
EGOA | 7 | 865 | 66
CGOA | 15 | 783 | 221
WGOA | 11 | 1365 | 258
EAI | 7 | 725 | 193
CAI | 15 | 861 | 225
WAI | 5 | 138 | 38
Total | 68 | 6021 | 2243

Sites with:
- Highest relative abundance
- At least one rook/HO site selected from each RCA
- Associated altitude data
Broad Regional Comparisons
FMD Modeling Results

- Mean length and range of Juveniles and Adults (F & M)
- Proportion of measured sample (area under curve) composed of Juveniles and Adults (F & M)

![Graph showing probability density for Juvenile (1), Female (2), and Male (3) combined sites.](image)
**FMD Modeling Results**

- **Eastern DPS** females are significantly smaller than the Western DPS.
- **No difference** between Model and Observed female length.

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**Graph:**

**Adult Female**

- **eDPS (SE AK)**
- **wDPS**
- **EGOA to EAI**
- **CAI & WAI**

- *significantly smaller*
FMD Modeling Results: Age-sex Class Proportions

- Proportion juvenile: EGOA-EAI > CAI-WAI
- Population trend: EGOA-EAI > CAI-WAI
- Juvenile survival and/or natality low?
Questions on Composition – Age, Sex, Length?

Next: Movement to and from Aleutian Islands and Russia
Movement of Branded Sea Lions to and from Aleutian Islands and Russia

- **Russian brands in US**
- **US brands**
  - **Eastern DPS**
    - SE AK, OR & CA
  - **Western DPS**
    - E Gulf, C Gulf & E Aleutians
    - W Aleutians – Agattu
      - ~ brands
      - 2011, N=54

~5: 5-month old pup branded
On Agattu 6/24/2011
Observed 11/13/2011 on Bering I,
Commander Islands, Russia

M539: Sub-adult male branded as pup on Medny I.
Observed 7/16/2011 on Attu
NMML Branding and Camera Installations in Western Aleutians 2011-12

- **Attu Cape Wrangell**
  - 2012: 4 cameras

- **Agattu Gillon Point**
  - 2011: 54 pups branded
  - 2012: 2 cameras
Movement of E Aleu – E Gulf (w DPS) brands

- **Few West of Samalga Pass 170W**
  - 9 in summer
  - 13 in winter

- **Summer (breeding)**
  - 3 in Russia - all juveniles
  - 1 adult female in Aleu
  - 2 adult males in Aleu

- **Winter (non-breeding)**
  - 5 in Russia – all juveniles
  - 3 adult females in Aleu

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<th>Winter</th>
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<td>Sugarloaf</td>
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<td>Ugamak</td>
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<td><strong>Total Individuals</strong></td>
<td><strong>8</strong></td>
<td><strong>11</strong></td>
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Note: branded individuals seen multiple times at new locations
Movement of Eastern DPS and Agattu ~ brands

- Few eDPS West of Samalga Pass 170W
  - 3 males in summer
  - 2 males in winter
- W Aleutian ~ brands move to Russia
  - Commander Islands
  - 2 ~ yearlings in summer
  - 2 ~ pups in winter

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<td>St. George Reef (CA)</td>
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<td><strong>Total Individuals</strong></td>
<td><strong>5</strong></td>
<td><strong>4</strong></td>
</tr>
</tbody>
</table>

Note: branded individuals seen multiple times at new locations
Movement of Russian brands

- **Summer (breeding)**
  - 2 adult females on Attu
  - 7 adult/sub-adult males as far as CGOA
  - 17 individuals

- **Winter (non-breeding)**
  - 2 individuals (juveniles)

<table>
<thead>
<tr>
<th>Rookery</th>
<th>Summer</th>
<th>Winter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Srednega</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Kozlova Cape</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Antsiferov</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Medny</td>
<td>11</td>
<td>2</td>
</tr>
<tr>
<td><strong>Total Individuals</strong></td>
<td><strong>17</strong></td>
<td><strong>2</strong></td>
</tr>
</tbody>
</table>

Note: M642 observed in summer & winter season
Russian Data through 2009
Western Bering Sea Non-Pups

98% decline since 1982

Eastern Kamchatka Non-Pups

-81% decline since 1983
Commander Island SSLs
- Increase 1930-1950s
- Decline through 1980s
- Rookery re-established: late 1970s
- Pups increase through 1990s
- 2000-2008: stable at low level
  - 700-800 non-pups, 220-250 pups

Medny I. rookery 2009

<table>
<thead>
<tr>
<th>Category</th>
<th>Change from 2008</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pups born</td>
<td>175 -21%</td>
</tr>
<tr>
<td>Non pup (max)</td>
<td>391 -27%</td>
</tr>
<tr>
<td>Females (max)</td>
<td>244 -17%</td>
</tr>
<tr>
<td>Bulls (total, max)</td>
<td>80 -10%</td>
</tr>
<tr>
<td>Bulls (terr, Max)</td>
<td>44 -20%</td>
</tr>
</tbody>
</table>

No decline in number “M” branded animals resighted in 2009
- Preliminary estimates (analysis in progress):
  - Negative trend in female birth rates
  - No significant changes in survival rates
Kuril Island Pups:

2000 – 2007 increase 6% / year

2009 – No significant change
(analysis in progress)
Sakhalin Island SSLs

- VERY low number till early 80s.
- One rookery established in early 80s on Tuleny (Robben) I.
- Pups number is growing rapidly through 1990s and 2000s
  - Mean trend in pup production 1983-2009 is 21%
- High pup trend due to immigration SSL from Iony I. in northern Sea of Okhotsk (brand resight data)
- Tuleny I Rookery in 2009:
  - ~ 1200 non-pups
  - ~ 500-700 pups

2009 survey results:

- three more SUMMER SSL haulout sites re-established in southern Sakhalin (they were only winter sites in the past)
- 2,000 non-pups and 11 pups were counted on the three haulout sites
- branded SSL were from northern Sea of Okhotsk and Kuril Islands
Extra Slides
Steller Sea Lion Growth

- Asymptotic length:
  - 90% final adult length reached around sexual maturity for males and females (Winship et al. 2001).
Straightness Classification: Assigned to Length Measurements

Due to small sample size of SC 1 and 2 and significant curvature of SC 4...

Only SC 3 lengths used in analysis
# Observed Known Adult Females

Females in close proximity to a pup/juvenile on a rookery

<table>
<thead>
<tr>
<th>Region</th>
<th>Number Females</th>
<th>Mean Length (m)</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Eastern DPS SE AK</strong></td>
<td>241</td>
<td>1.941</td>
<td>0.167</td>
</tr>
<tr>
<td><strong>Western DPS All Range</strong></td>
<td>1001</td>
<td>2.116</td>
<td>0.221</td>
</tr>
<tr>
<td>EGOA</td>
<td>66</td>
<td>2.052</td>
<td>0.280</td>
</tr>
<tr>
<td>CGOA</td>
<td>221</td>
<td>2.137</td>
<td>0.221</td>
</tr>
<tr>
<td>WGOA</td>
<td>258</td>
<td>2.119</td>
<td>0.216</td>
</tr>
<tr>
<td>EAI</td>
<td>193</td>
<td>2.137</td>
<td>0.192</td>
</tr>
<tr>
<td>CAI</td>
<td>225</td>
<td>2.102</td>
<td>0.224</td>
</tr>
<tr>
<td>WAI</td>
<td>38</td>
<td>2.054</td>
<td>0.223</td>
</tr>
<tr>
<td>RCA 1-3</td>
<td>146</td>
<td>2.056</td>
<td>0.208</td>
</tr>
</tbody>
</table>
Finite Mixture Distribution (FMD) Modeling

- Developed for fisheries science (Bhattacharya 1967; Prager & Shertzer 2005)
- Broad application (DeVries 2002)
- Three age-sex classes:
  - Juvenile (male and female), adult female, and adult male

\[ f(L_t|\pi, \mu, \sigma) = \sum_{i=1}^{I} \pi_i g_i(\pi|\mu_i, \sigma_i) \]

Distribution of sea lion lengths = Sum of 3 age-sex classes weighted by proportion
Calibration Equations

- Photographed runway number—known ground measurement (Sitka, AK)
  - Scale Factor (Wolf 1987)
  - Correct for altimeter bias (Gilpatrick 1998)
  - Pixel/cm ratio calibration
  - Linear regressions

**Altimeter Correction**

A.

\[ H_c = 0.966 H_m + 20.669 \]

\[ r^2 = 0.998 \]

\[ n = 140 \]

**Pixel Conversion**

B.

\[ L_t = 3.872E^{-3} H_m \]

\[ r^2 = 0.997 \]

\[ n = 140 \]
Final Conversion Equation

\[ L_p = 3.742E^{-3}L_t H_m + 8.003E^{-3}L_t \]

\( L_t \) = Measured length (pixels)
\( H_m \) = Measured altitude (altimeter; ft)
\( L_p \) = Measured length (meters)
**FMD Modeling Results**

<table>
<thead>
<tr>
<th>Age-Sex Class</th>
<th>Juvenile</th>
<th>Female</th>
<th>Male</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>1.524</td>
<td>1.914 (1.941)</td>
<td>2.187</td>
</tr>
<tr>
<td>SD</td>
<td>0.249</td>
<td>0.111 (0.167)</td>
<td>0.320</td>
</tr>
</tbody>
</table>

### Eastern DPS

- Mean: 1.524
- SD: 0.249

### Western DPS

- Mean: 1.580
- SD: 0.236

### EGOA through EAI

- Mean: 1.653
- SD: 0.260

### CAI & WAI

- Mean: 1.600
- SD: 0.236

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*units in meters*

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Eastern DPS adults are significantly smaller than the western DPS.
Non-pup Trends

• Eastern DPS
  – SE Alaska increasing at 3% per year since mid-1970s

• Western DPS
  – EGOA increasing at 6% per year 2000-2011
  – CGOA stable 2000-2011
  – EAI increasing at 3% per year 2000-2011