Effects of Sea Lion Predation on Willamette River Salmonid Viability

Presenter: Matt Falcy

Corresponding Summary Page(s): 18-21
Effects of Sea Lion Predation on Willamette River Salmonid Viability
Population Viability of Willamette River Winter Steelhead

An assessment of the effect of sea lions at Willamette Falls

July 7, 2017

Matt Faicy, PhD
Fish Conservation Biologist
Oregon Department of Fish and Wildlife

Spring Chinook Status Assessment

McKenzie, Clackamas, and Sandy River Populations

A memorandum to
Fish Division
Oregon Department of Fish and Wildlife

Submitted
June 6, 2018
Matt Faicy, PhD
Fish Conservation Biologist
Oregon Department of Fish and Wildlife
Willamette winter Steelhead Populations

- Molalla
- North Santiam
- South Santiam
- Calapooia

Extinguished (2011)

Low

Moderate

Current Status (2011)
Goal: Quantify threat of extirpation posed by sea lions

Method: Population Viability Analysis (PVA)

Data
- Adult abundance
- Age at maturity
- Proportion hatchery
- Harvest
- Sea lion mortality

Model
- Population dynamics
- Programming

Model
- Population simulator
- CPU time

Result
- Probability of extirpation

Scenarios
- With sea lions
- Without sea lions
A stock-recruitment model reveals density-dependent population dynamics
Goal: Quantify threat of extirpation posed by sea lions

Method: Population Viability Analysis (PVA)

Data
- Adult abundance
- Age at maturity
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- Harvest
- Sea lion mortality

Model
- Population dynamics
  - with sea lions
  - without sea lions
- Programming

Model
- Population simulator
  - cpu time

Result
- Probability of extirpation
Steelhead Spawner Abundance

Base enumeration
• counted at Willamette Falls (WF)
• 62% at WF spawn in focal populations (U of I)

Apportion to populations
• amount of spawning habitat
• redd-density surveys
• multiple imputation for missing observations
Sea Lion Predation

Observe (surface) feeding events

Stratified three-stage cluster sampling design
- days of week
- site-shift (block of hours at given site)
- 30-min observation bouts (3 of 4)

Predation events assigned to species
- observed
- species composition at window (1, 7, 14 d)
- Monte Carlo
Sea Lion Predation

Expand estimated predation for steelhead run passing before predation monitoring.
Calculate Recruits associated with Spawners at time $t$, $R_s(t)$

<table>
<thead>
<tr>
<th>Year</th>
<th>Spawn</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1000</td>
</tr>
<tr>
<td>2</td>
<td>2000</td>
</tr>
<tr>
<td>3</td>
<td>1500</td>
</tr>
<tr>
<td>4</td>
<td>800</td>
</tr>
<tr>
<td>5</td>
<td>3000</td>
</tr>
<tr>
<td>6</td>
<td>2500</td>
</tr>
<tr>
<td>7</td>
<td>3000</td>
</tr>
</tbody>
</table>
Calculate Recruits associated with Spawners at time $t$, $R_s(t)$

Plus age composition

Proportion of hatchery fish on spawning grounds (hatchery fish not progeny of “spawners”)

Spawner abundance

$$R_s(t) = \sum_{a=1}^{6} A_{t+a,a} \left( \frac{S_{t+a} \times (1 - pHOS_{t+a})}{1 - HR_{t+a}} + M_{t+a} \right).$$

Age composition

Harvest rate (some fish get caught before returning).

Mortality from pinnipeds
Goal: Quantify threat of extirpation posed by sea lions

Method: Population Viability Analysis (PVA)

Data:
- Adult abundance
- Age at maturity
- Proportion hatchery
- Harvest
- Sea lion mortality

Model:
- Population dynamics
- Programming

Model:
- Population simulator
- CPU time

Result:
- Probability of extirpation

Scenarios:
- with sea lions
- without sea lions
Population Dynamics

- Density-dependence
- Sea lion predation and fishing mort are additive
- Multi-model inference

Bayesian analysis
- Yields probability-based inference for parameters.
- MCMC provides random draws of parameters that include covariance.
- WAIC has cross-validation properties: get density at each datum within the MCMC, then compute over MCMC instead of conditioning on a point estimate (AIC, DIC).

Ricker Models

<table>
<thead>
<tr>
<th>Model</th>
<th>Equation</th>
<th>WAIC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model 1: Each pop separate</td>
<td>$R_{t,p} = \alpha_p S_{t,p} e^{-\beta_p S_{t,p} + \epsilon_{t,p}}$, where $\epsilon \sim N(0, \sigma_p)$</td>
<td>225</td>
</tr>
<tr>
<td>Model 2: Shared error variance</td>
<td>$R_{t,p} = \alpha_p S_{t,p} e^{-\beta_p S_{t,p} + \epsilon_{t,p}}$, where $\epsilon \sim N(0, \sigma)$</td>
<td>249</td>
</tr>
<tr>
<td>Model 3: Shared productivity</td>
<td>$R_{t,p} = \alpha S_{t,p} e^{-\beta_p S_{t,p} + \epsilon_{t,p}}$, where $\epsilon \sim N(0, \sigma_p)$</td>
<td>218</td>
</tr>
</tbody>
</table>
Population Dynamics

- Density-dependence
- Sea lion predation and fishing mort are additive
- Multi-model inference

Bayesian analysis

- Yields probability-based inference for parameters.
- MCMC provides random draws of parameters that include covariance.
- WAIC has cross-validation properties: get density at each datum within the MCMC, then compute over MCMC instead of conditioning on a point estimate (AIC, DIC).
Goal: Quantify threat of extirpation posed by sea lions

Method: Population Viability Analysis (PVA)

Data
- Adult abundance
- Age at maturity
- Proportion hatchery
- Harvest
- Sea lion mortality

Model
- Population dynamics
- Programming

Model
- Population simulator
- CPU time

Result
- Probability of extirpation

Scenarios
- with sea lions
- without sea lions
for i=1:length(X)
    y(i,:) = normrnd(X(i,1),X(i,2),[1,50]);
end

\[
\sum_{i=1}^{n} (y_i - \bar{y})^2
\]
Population Simulator

**Replication**

1000 random draws of parameters per population.

- For each draw, magnitude of error (variance of residuals) and autocorrelation are recomputed.
- Each draw used to simulate 100 years.

+ 100 replications of the process described above.

= 100,000 simulations of 100 years per population

**Allee effects** (negative density dependence)

- If \( N_t < 100 \), then no reproduction
- If \( N_{t:t+3} < 100 \) (4 consecutive years), then functionally extirpated

\[
\text{Pr[extirpation]} = \frac{\#\text{extirpations}}{100,000}
\]
Example output

- **N. Santiam**
  - Simulated vs Empirical Spawner Abundance over years

- **S. Santiam**
  - Simulated vs Empirical Spawner Abundance over years

- **Calapooia**
  - Simulated vs Empirical Spawner Abundance over years

- **Molalla**
  - Simulated vs Empirical Spawner Abundance over years
**Goal:** Quantify threat of extirpation posed by sea lions

**Method:** Population Viability Analysis (PVA)

- **Data**
  - Adult abundance
  - Age at maturity
  - Proportion hatchery
  - Harvest
  - Sea lion mortality

- **Model**
  - Population dynamics
  - Programming

- **Model**
  - Population simulator
  - CPU time

- **Result**
  - Probability of extirpation

**Scenarios**
- with sea lions
- without sea lions
## Probability of Extirpation

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Population</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>North Santiam</td>
</tr>
<tr>
<td>Without Sea Lions:</td>
<td>2%</td>
</tr>
<tr>
<td>With Sea Lions:</td>
<td>lowest observed predation (2015)</td>
</tr>
<tr>
<td>average predation (2016)</td>
<td>27%</td>
</tr>
<tr>
<td>highest observed predation (2017)</td>
<td>64%</td>
</tr>
</tbody>
</table>
Population Viability of Willamette River Winter Steelhead

An assessment of the effect of sea lions at Willamette Falls

July 7, 2017

Matt Facer, Ph.D.
Fish Conservation Biologist
Oregon Department of Fish and Wildlife

Spring Chinook Status Assessment

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Spring Chinook Assessment

• Uses same PVA method as steelhead.

• However, abundance time series begins in 2002 because the proportion of hatchery-origin spawners in the McKenzie is unknown prior to 2002.

• Short time series complicates assessment.

• Comparison among three populations of spring Chinook:
  - McKenzie (exposed to pinnipeds at Willamette Falls)
  - Clackamas (not exposed to pinnipeds at Willamette Falls)
  - Sandy (not exposed to pinnipeds at Willamette Falls)
Trends in abundance

Natural Origin Spawners

McKenzie ChS

Sandy ChS

Clackamas

Geometric Mean Rate of Interannual Change, %
Recruits per Spawner

### Population

<table>
<thead>
<tr>
<th>Median</th>
<th>McKenzie</th>
<th>Clackamas</th>
<th>Sandy</th>
</tr>
</thead>
<tbody>
<tr>
<td>RRS=1</td>
<td>RRS=0.5</td>
<td>RRS=0</td>
<td>RRS=1</td>
</tr>
<tr>
<td>0.51</td>
<td>0.65</td>
<td>0.89</td>
<td>0.94</td>
</tr>
<tr>
<td>0.25</td>
<td>0.29</td>
<td>0.35</td>
<td>0.55</td>
</tr>
<tr>
<td>SD</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**RRS**: Relative Reproductive Success of hatchery-origin fish. If low, then recruits are progeny of natural-origin fish.
## Probability of Extirpation

**RRS:** Relative Reproductive Success of hatchery-origin fish. If low, then recruits are progeny of natural-origin fish.

<table>
<thead>
<tr>
<th>Population</th>
<th>McKenzie</th>
<th>Clackamas</th>
<th>Sandy</th>
</tr>
</thead>
<tbody>
<tr>
<td>RRS=1</td>
<td>Max CSL</td>
<td>No CSL</td>
<td>RRS=1</td>
</tr>
<tr>
<td>Model 1</td>
<td>0.35</td>
<td>0.23</td>
<td>0.007</td>
</tr>
<tr>
<td>Model 2</td>
<td>0.45</td>
<td>0.30</td>
<td>0.33</td>
</tr>
</tbody>
</table>
Caveat: no sign of density-dependence

- A density-independent model would have produced more pessimistic results.
- Regardless of PVA mechanics, the McKenzie is clearly performing worse.
Effects of Sea Lion Predation on Willamette River Salmonid Viability

Matt Falcy
California sea lion and Steller sea lion population status, life history & ecology, behavior, distribution, etc.

Presenter: Bob DeLong

Corresponding Summary Page(s): 21-22
California sea lion Population Growth and Status*

Achieving the goals of the Marine Mammal Protection Act

Journal of Wildlife Management
DOI:10.1002/jwmg.21405
A novel method to assess population growth and status

- Conceptually simple but requires extensive population data
- Time series of **39 years of pup counts** for all rookeries (6) in California waters 1975 – 2014 (Lowry et al 2017)
- **Sex and age- Specific Survival Rates** (28 years) 1975 to 2013 (DeLong et al 2017. MM Sci.)
- Use annual pup counts and survival estimates to **reconstruct abundance of all age and sex components of population** for each year
- Fit generalized logistic growth curve to time series of population size at each year to estimate MNPL, K and population status
<table>
<thead>
<tr>
<th>Year</th>
<th>Pup count</th>
<th>F</th>
<th>M</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1975</td>
<td>12,499</td>
<td>49,136</td>
<td>39,788</td>
<td>88,924</td>
</tr>
<tr>
<td>1976</td>
<td>14,749</td>
<td>51,944</td>
<td>42,226</td>
<td>94,170</td>
</tr>
<tr>
<td>1977</td>
<td>11,712</td>
<td>50,784</td>
<td>40,415</td>
<td>91,199</td>
</tr>
<tr>
<td>1978</td>
<td>13,449</td>
<td>50,942</td>
<td>39,971</td>
<td>90,913</td>
</tr>
<tr>
<td>1979</td>
<td>14,145</td>
<td>52,151</td>
<td>40,661</td>
<td>92,812</td>
</tr>
<tr>
<td>1980</td>
<td>14,878</td>
<td>53,180</td>
<td>41,153</td>
<td>94,333</td>
</tr>
<tr>
<td>1981</td>
<td>16,701</td>
<td>54,748</td>
<td>42,249</td>
<td>96,997</td>
</tr>
<tr>
<td>1982</td>
<td>20,540</td>
<td>58,881</td>
<td>45,899</td>
<td>104,780</td>
</tr>
<tr>
<td>1983</td>
<td>11,595</td>
<td>55,342</td>
<td>41,465</td>
<td>96,807</td>
</tr>
<tr>
<td>1984</td>
<td>13,550</td>
<td>53,657</td>
<td>39,354</td>
<td>92,911</td>
</tr>
<tr>
<td>1985</td>
<td>15,224</td>
<td>53,753</td>
<td>39,259</td>
<td>93,012</td>
</tr>
<tr>
<td>2004</td>
<td>43,490</td>
<td>114,985</td>
<td>85,342</td>
<td>200,327</td>
</tr>
<tr>
<td>2005</td>
<td>48,331</td>
<td>122,423</td>
<td>92,825</td>
<td>215,248</td>
</tr>
<tr>
<td>2006</td>
<td>56,144</td>
<td>135,829</td>
<td>106,364</td>
<td>242,193</td>
</tr>
<tr>
<td>2007</td>
<td>54,088</td>
<td>144,443</td>
<td>114,561</td>
<td>259,004</td>
</tr>
<tr>
<td>2008</td>
<td>59,774</td>
<td>156,091</td>
<td>125,359</td>
<td>281,450</td>
</tr>
<tr>
<td>2009</td>
<td>35,914</td>
<td>154,229</td>
<td>121,926</td>
<td>276,155</td>
</tr>
<tr>
<td>2010</td>
<td>33,873</td>
<td>139,983</td>
<td>106,348</td>
<td>246,331</td>
</tr>
<tr>
<td>2011</td>
<td>62,109</td>
<td>155,174</td>
<td>120,315</td>
<td>275,689</td>
</tr>
<tr>
<td>2012</td>
<td>67,396</td>
<td>171,149</td>
<td>135,071</td>
<td>306,220</td>
</tr>
<tr>
<td>2013</td>
<td>42,913</td>
<td>146,010</td>
<td>107,652</td>
<td>253,662</td>
</tr>
<tr>
<td>2014</td>
<td>47,691</td>
<td>148,499</td>
<td>109,107</td>
<td>257,606</td>
</tr>
</tbody>
</table>
Result

- MNPL (183,481), K (275,631) and population status $N_{2014}/MNPL$

- Annual Growth rate = 0.07, $N_{2014}/MNPL = 1.2$, $N_{2014}/K = 0.94$

- Increase of 1° C SST results in 7% decline in annual growth rate, bringing it to zero; 2° C SST > 14% decline in growth rate and a population decline of 7%
Model Estimates:
Males 4-7 yr ~ 29,000
Males ≥ 8 yr ~ 38,500
Potential Migrant Males in 2014 was ~67,500 animals; its fewer today.
Potential Biological Removals (PBR)

MMPA definition “the maximum number of animals, not including natural mortality, that may be removed from a marine mammal stock while allowing that stock to reach or maintain its optimum sustainable population.”

PBR is product of 3 elements: the minimum population estimate (Nmin); half the maximum net productivity rate (0.5 Rmax); a recovery factor (Fr)

Current PBR: (Nmin) 153,337 X 0.06 (1/2 Rmax) X 1.0 Fr = 9,200

Pacific Scientific Review Group (SRG) Recommended PBR (Draft): 7,823

Task Force should consider male only PBR for Section 120 removals in Columbia River as all removals are from male component of the population

PBR calculated for males > 4 years is Nmin (52,311) X ½ of Rmax of 0.12 and recovery factor of 1.0: 52,311 X 0.06 X 1 = 3,139.

PBR for males 8 years and older: Nmin is (27,451) X ½ of Rmax (0.12) and recovery factor of 1.0: 27,451 X 0.06 X 1.0 = 1,647
Steller Sea Lions in Oregon and Washington

- Population of ~8,000 breed on 1 Washington and 2 Oregon locations
- Adult and Subadult males occur in the Columbia River and have become major salmon predators at Bonneville Dam
MMPA §120(d) Considerations and Benefits Analysis

Presenter: Bryan Wright

Corresponding Summary Page(s): 22-23
Day 2
III. APPLICATION CONSIDERATIONS—SECTION 120(d) .................................................. 3

A. Sec. 120(d)(1)—population trends, feeding habits, the location of the pinniped interaction, how and when the interaction occurs, and how many individual pinnipeds are involved; .................................................. 3

1. Population status of California sea lions in the U.S. .................................................. 3
2. Population trends of California sea lions at Willamette Falls .................................. 3
3. Feeding habits of California sea lions ........................................................................... 5
4. Location of the pinniped-fish interaction ................................................................... 7
5. Timing of the pinniped-fish interaction ..................................................................... 8
6. Number of individual pinnipeds involved .................................................................. 9

B. Sec. 120(d)(2)—past efforts to nonlethally deter such pinnipeds, and whether the applicant has demonstrated that no feasible and prudent alternatives exist and that the applicant has taken all reasonable nonlethal steps without success; .................................................. 12

1. Nonlethal deterrent methods ..................................................................................... 12
2. Nonlethal deterrent efforts at Willamette Falls ......................................................... 13
3. Efficacy of nonlethal deterrents ................................................................................. 13

C. Sec. 120(d)(3)—the extent to which such pinnipeds are causing undue injury or impact to, or imbalance with, other species in the ecosystem, including fish populations; .................................................. 14

1. Status of the affected fish populations ...................................................................... 14
2. Predation rates .......................................................................................................... 17
3. Impact to UWR steelhead ......................................................................................... 18
4. Addressing predation as part of a comprehensive fish recovery strategy .............. 18

D. Sec. 120(d)(4)—the extent to which such pinnipeds are exhibiting behavior that presents an ongoing threat to public safety. .................................................. 22
Figure 1. Maximum single-day CSL count at Willamette Falls by year. Monitoring from 1995-2003 and 2014-2017 was conducted by ODFW; monitoring from 2009-2012 was conducted by PSU.
Table 1. Observed predation by California sea lions at Willamette Falls, 2014-2017.

<table>
<thead>
<tr>
<th></th>
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<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Salmonids</td>
<td>959</td>
<td>1139</td>
<td>1001</td>
<td>753</td>
<td>3852</td>
<td>86.7%</td>
<td>85.2%</td>
<td>83.8%</td>
<td>82.7%</td>
<td>84.7%</td>
</tr>
<tr>
<td>Lamprey</td>
<td>126</td>
<td>175</td>
<td>182</td>
<td>145</td>
<td>628</td>
<td>11.4%</td>
<td>13.1%</td>
<td>15.2%</td>
<td>15.9%</td>
<td>13.8%</td>
</tr>
<tr>
<td>Other/unk.</td>
<td>18</td>
<td>21</td>
<td>11</td>
<td>12</td>
<td>62</td>
<td>1.6%</td>
<td>1.6%</td>
<td>0.9%</td>
<td>1.3%</td>
<td>1.4%</td>
</tr>
<tr>
<td>Sturgeon</td>
<td>3</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>5</td>
<td>0.3%</td>
<td>0.1%</td>
<td>0.0%</td>
<td>0.0%</td>
<td>0.1%</td>
</tr>
<tr>
<td>Total</td>
<td>1106</td>
<td>1337</td>
<td>1194</td>
<td>910</td>
<td>4547</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
</tr>
</tbody>
</table>
Figure 1. Illustration of the spatial component of the sampling frame for 2017. Sites 1-6 ("Falls" stratum) were each approximately 0.9-ha in area.
Figure 4. Estimated daily California sea lion abundance at Willamette Falls in 2016 based on loess model fit to weekly maximum count data (Wright et al. 2016).
Figure 6. Weekly residency of branded California sea lions (n = 48 total) at Willamette Falls sorted by year and week of first detection (darker hue = more days detected). Capture location at branding denoted by 'A' (Astoria) or 'B' (Bonneville Dam); X denotes animal was removed under MMPA Section 120; * indicates animal documented at Bonneville Dam; ** indicates animal on MMPA Section 120 list for removal. Brands recorded less than three days per year were considered unconfirmed and are not included unless photographed. [Note that this graphic will be updated once image processing from automated cameras is competed.]
## Hazing / non-lethal deterrents

<table>
<thead>
<tr>
<th>Year</th>
<th>Start</th>
<th>End</th>
<th>Days</th>
<th>Shell Crackers</th>
<th>Rubber projectiles</th>
<th>Seal bombs</th>
<th>CSLs</th>
<th>SSLs</th>
</tr>
</thead>
<tbody>
<tr>
<td>2010</td>
<td>3/26</td>
<td>4/30</td>
<td>8</td>
<td>~800</td>
<td>~30</td>
<td>~400</td>
<td>NA</td>
<td>0</td>
</tr>
<tr>
<td>2011</td>
<td>2/7</td>
<td>4/26</td>
<td>49</td>
<td>6,863</td>
<td>135</td>
<td>2,771</td>
<td>860</td>
<td>0</td>
</tr>
<tr>
<td>2013</td>
<td>2/4</td>
<td>4/29</td>
<td>81</td>
<td>10,976</td>
<td>601</td>
<td>8,042</td>
<td>1,871</td>
<td>45</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Run*</th>
<th>Estimated predation</th>
<th>% of potential escapement</th>
</tr>
</thead>
<tbody>
<tr>
<td>wSTH</td>
<td>780</td>
<td>557</td>
</tr>
<tr>
<td>nmCH</td>
<td>496</td>
<td>899</td>
</tr>
<tr>
<td>sSTH</td>
<td>712</td>
<td>172</td>
</tr>
<tr>
<td>mCH</td>
<td>1,703</td>
<td>4,149</td>
</tr>
</tbody>
</table>

* wSTH = winter steelhead; nmCH = spring Chinook salmon (not marked); sSTH = summer steelhead; mCH = spring Chinook salmon (marked)
** As of 8/15/2017
Expected benefits
# Expected benefits

## Probabilities of extirpation (100 year PVA)

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Winter steelhead population</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N. Santiam</td>
</tr>
<tr>
<td>Sea lion predation</td>
<td></td>
</tr>
<tr>
<td>None</td>
<td>2%</td>
</tr>
<tr>
<td>Low (2015)</td>
<td>8%</td>
</tr>
<tr>
<td>Average (2016)</td>
<td>27%</td>
</tr>
<tr>
<td>High (2017)</td>
<td>64%</td>
</tr>
</tbody>
</table>

* Excluding Calapooia and assuming independence

Reproducible results (data and code): [www.falcy.weebly.com/pva](http://www.falcy.weebly.com/pva)
Expected benefits

<table>
<thead>
<tr>
<th>CSLs removed</th>
<th>Winter steelhead</th>
<th>Summer steelhead</th>
<th>Spring Chinook-unmarked</th>
<th>Spring Chinook-marked</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>46</td>
<td>431-913</td>
<td>496-1052</td>
<td>495-1049</td>
<td>2204-4672</td>
<td>3626-7686</td>
</tr>
<tr>
<td>92</td>
<td>1000-1665</td>
<td>1152-1918</td>
<td>1148-1913</td>
<td>5114-8518</td>
<td>8414-14014</td>
</tr>
</tbody>
</table>

Monte Carlo simulation assumptions

- Predation rate: 2 salmonids/d (conservative)
- CSL Residency: 1-21 weeks
- Salmonid run proportions: 60.8% hatchery Chinook, 13.6% wild Chinook, 13.7% summer steelhead, 11.9% winter steelhead
Table 5. Summary of California sea lion predation on salmonids extrapolated to river strata in 2017 based on relative amounts of predation observed between the two strata in 2014-2015. Note, however, that the 2014-2015 estimates themselves represent less temporal coverage than 2016-2017 (see Figures 1-3 and Appendix A).

<table>
<thead>
<tr>
<th>Year</th>
<th>Stratum</th>
<th>Estimated California sea lion salmonid take</th>
<th>% California sea lion salmonid take</th>
<th>Site-adjusted % California sea lion salmonid take</th>
</tr>
</thead>
<tbody>
<tr>
<td>2014</td>
<td>Falls</td>
<td>1,842</td>
<td>50%</td>
<td>60%</td>
</tr>
<tr>
<td></td>
<td>River</td>
<td>1,848</td>
<td>50%</td>
<td>40%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3,690</td>
<td>100%</td>
<td>100%</td>
</tr>
<tr>
<td>2015</td>
<td>Falls</td>
<td>3,620</td>
<td>63%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>River</td>
<td>2,156</td>
<td>37%</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>5,775</td>
<td>100%</td>
<td></td>
</tr>
<tr>
<td>2016</td>
<td>Falls</td>
<td>4,585</td>
<td>63%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>River</td>
<td>2,870*</td>
<td>37%</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>7,455*</td>
<td>100%</td>
<td></td>
</tr>
<tr>
<td>2017</td>
<td>Falls</td>
<td>2,673</td>
<td>100%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>River</td>
<td>1,615*</td>
<td>100%</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>4,288*</td>
<td>100%</td>
<td></td>
</tr>
</tbody>
</table>

*Extrapolations based on 2014 and 2015 estimates.
Compensatory Pinniped Immigration

Presenter: Bryan Wright

Corresponding Summary Page(s): 23-25
Replacement critique

Compensatory immigration?

“Attempts to control predator numbers through spatially restricted culling typically faces a compensation process via immigration from surrounding source populations.”
Compensatory Immigration Challenges
Predator Control: An Experimental Evidence-Based Approach Improves Management

NICOLAS LIEURY, Institut Mammalogique d'Alsace, Aix-Marseille Université, Technopôle de Nozay, 38320 Saint-Priest-en-Jarez, France
SANDRINE RUELLE, Office National d'Etudes et de Recherches Aerospatiales, Toulouse, France
SEBASTIEN DEVILLARD, Laboratoire Statistique et Modélisation des Écosystèmes, UMR5558, Villeurbanne F-69622, France
MICHEL ALBARET, Office National d'Etudes et de Recherches Aerospatiales, Toulouse, France
FRANCK DROUER, Fédération de Secours pour la Nature de l'Île de France, 10440, France
ALEXANDRE MILLON, Institut Mammalogique d'Alsace, Aix-Marseille Université, Technopôle de Nozay, 38320 Saint-Priest-en-Jarez, France

ABSTRACT Attempts to mitigate the impact of invasive species on native ecosystems increasing large land masses where control, rather than regulation, is the management objective. Depression of indigenous species to a level where they are bridge species for other invasive species is an opportunity. The compensatory potential of increased immigration following intensive American mink population control is diluted by male-biased dispersal.

M. K. Oliver · S. B. Pietney · A. Zalewski · Y. Melero · X. Lambin

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Abstract Attempts to mitigate the impact of invasive species on native ecosystems increasing large land masses where control, rather than regulation, is the management objective. Depression of indigenous species to a level where they are bridge species for other invasive species is an opportunity. The compensatory potential of increased immigration following intensive American mink population control is diluted by male-biased dispersal.

Compensatory immigration counteracts contrasting conservation strategies of wolverines (Gulo gulo) within Scandinavia

Vincenzo Gervasi 1, 2, Henrik Brøseth 3, Erlend B. Nilsen 3, Hans Ellegren 3, Øystein Flagstad 4, John D.C. Linnell 5

1 Norwegian Institute for Nature Research, PO Box 5685 Stokken, NO-7485 Trondheim, Norway
2 Dept. of Evolutionary Biology, EIB, Uppsala University, Norbyvägen 18D, 752 36 Uppsala, Sweden

Abstract In wide-ranging species, portions of the same population often fall within different administrative jurisdictions, where different regulations apply. The same species can be fully protected or heavily harvested on different sides of a border. This can generate a source–sink dynamic from the areas with lower to those with higher mortality, a process known as compensatory immigration. We tested this hypothesis on the wolverine (Gulo gulo) population of southern Scandinavia, which is shared between two countries: Sweden and Norway. Wolverines are fully protected in Sweden, but subject to intensive population regulation in Norway. Using non-invasive genetic sampling and capture-recapture modeling, we analyzed the dynamics of wolverine survival and emigration patterns between 2002 and 2013. Wolverines in Norway experienced a lower survival rate than in Sweden. Migration across the national borders was directed towards movements from Sweden to Norway. These results functional relationships between harvest rates in Norway and emigration rates across the national border; both at the individual and population level, thus confirming the compensatory immigration hypothesis. Contrasting management regimes within the same population can generate undesired demographic and spatial dynamics, jeopardize conservation efforts and the sustainability of a border, and reduce the efficacy of conservation efforts. This calls for the adoption of
California sea lions ≠ terrestrial carnivore (e.g., fox, coyote, wolf)

• Seasonal, migratory males—not breeding pairs such as wolf pack
• Not territorially (outside rookeries)
• Little or no evidence carrying capacity reached at WF or BD (sea lions not queued up waiting to get in)
• Nearest “source” population over 100 miles away
• Ecologically valid concept does not apply in this situation
Socially transmitted wildlife behaviours that create human–wildlife conflict are an emerging problem for conservation efforts, but also provide a unique opportunity to apply principles of infectious disease control to wildlife management. As an example, California sea lions (*Zalophus californianus*) have learned to exploit concentrations of migratory adult salmonids below the fish ladders at Bonneville Dam, impeding endangered salmonid recovery. Proliferation of this foraging behaviour in the sea lion population has resulted in a controversial culling programme of individual sea lions at the dam, but the impact of such culling remains unclear. To evaluate the effectiveness of current and alternative culling strategies, we used network-based diffusion analysis on a long-term dataset to demonstrate that social transmission is implicated in the increase in dam-foraging behaviour and then studied different culling strategies within an epidemiological model of the behavioural transmission data. We show that current levels of lethal control have substantially reduced the rate of social transmission, but failed to effectively reduce overall sea lion recruitment. Earlier implementation of culling could have substantially reduced the extent of behavioural transmission and, ultimately, resulted in fewer animals being culled. Epidemiological analyses offer a promising tool to understand and control socially transmissible behaviours.
Probability of new recruitment

- High Social component
- Asocial base rate

# of existing recruits
(i.e., habituated sea lions)
P(travel from EMB to Bonneville and/or WF) = ~0.07

Recruitment = function of social and/or asocial process (i.e., follow others, follow fish, explore)

P(stay upon first arrival) = f(# sea lions, # fish, age, haul-out space?, hazing/disturbance?, ...)

P(return next year) = f(previous experience, age,...)

Within-year new recruitment likely independent of removals (i.e., no compensatory immigration)

Next-year recruitment likely reduced due to reduced opportunity for social transmission
U253

- Branded in Astoria 8/21/2012
- First seen at Willamette Falls 2013 and seen every year since
- Relocated to coast March 13, 2018—returned 5 days later
- Returned last week—earliest return on record
- 2019 will be 7th year (C742 headed into 11th year)
- Behavior has been growing over time
- Removing U253 next week would not result in a “replacement” the following week and probably not for several years, if ever
# Expected benefits

## Probabilities of extirpation (100 year PVA)

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Winter steelhead population</th>
<th>At least one extirpated*</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N. Santiam</td>
<td>S. Santiam</td>
</tr>
<tr>
<td>Sea lion predation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>None</td>
<td>2%</td>
<td>5%</td>
</tr>
<tr>
<td>Low (2015)</td>
<td>8%</td>
<td>16%</td>
</tr>
<tr>
<td>Average (2016)</td>
<td>27%</td>
<td>34%</td>
</tr>
<tr>
<td>High (2017)</td>
<td>64%</td>
<td>60%</td>
</tr>
</tbody>
</table>

* Excluding Calapooia and assuming independence

Reproducible results (data and code): [www.falcy.weebly.com/pva](http://www.falcy.weebly.com/pva)
Figure 6. Weekly residency of branded California sea lions (n = 48 total) at Willamette Falls sorted by year and week of first detection (darker hue = more days detected). Capture location at branding denoted by 'A' (Astoria) or 'B' (Bonneville Dam); X denotes animal was removed under MMPA Section 120; * indicates animal documented at Bonneville Dam; ** indicates animal on MMPA Section 120 list for removal. Brands recorded less than three days per year were considered unconfirmed and are not included unless photographed. [Note that this graphic will be updated once image processing from automated cameras is competed.]
Columbia River estuary
Are California Sea Lions Causing Undue Injury to Salmonids or Humans?

Presenter: Shaun Clements

Corresponding Summary Page(s): 25-27
Are CSL causing undue injury to UWR steelhead and Chinook?
WILLAMETTE WINTER STEELHEAD

Willamette Falls Count

<table>
<thead>
<tr>
<th>Year</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1974</td>
<td>0</td>
</tr>
<tr>
<td>1977</td>
<td>0</td>
</tr>
<tr>
<td>1980</td>
<td>0</td>
</tr>
<tr>
<td>1983</td>
<td>0</td>
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</tr>
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<td>2007</td>
<td>0</td>
</tr>
<tr>
<td>2010</td>
<td>0</td>
</tr>
<tr>
<td>2013</td>
<td>0</td>
</tr>
<tr>
<td>2016</td>
<td>0</td>
</tr>
</tbody>
</table>
## WILLAMETTE WINTER STEELHEAD | EXTINCTION RISK

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Single Population</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>North Santiam</td>
</tr>
<tr>
<td>Without Sea Lions</td>
<td>2%</td>
</tr>
<tr>
<td>With Sea lions</td>
<td>lowest observed predation (2015)</td>
</tr>
<tr>
<td></td>
<td>average predation (2016)</td>
</tr>
<tr>
<td></td>
<td>highest observed predation (2017)</td>
</tr>
<tr>
<td>Scenario</td>
<td>Single Population</td>
</tr>
<tr>
<td>-------------------</td>
<td>-------------------</td>
</tr>
<tr>
<td>McKenzie</td>
<td>McKenzie</td>
</tr>
<tr>
<td><strong>Without Sea Lions</strong></td>
<td>20-30%</td>
</tr>
<tr>
<td><strong>With Sea lions</strong></td>
<td></td>
</tr>
<tr>
<td>highest observed predation (2015/16)</td>
<td>33-45%</td>
</tr>
</tbody>
</table>
Do CSL pose a risk to human safety?
Sea lions 250-300,000 Population abundance

Sea lions 40+ At Willamette Falls

Months Present 3 Per Year

Months Present 10 Per Year

Salmonid ~85% Of diet
**SUMMARY IMPACT TO FISH**

### Winter Steelhead

- **4H’s**
  - Probability of Extinction: 0-5%

- **Predation**
  - Rate: 11-25%

- Increase in Probability of Extinction: 0-62%

### Spring Chinook

- **4H’s**
  - Probability of Extinction: 20-30%

- **Predation**
  - Rate: 7-9%

- Increase in Probability of Extinction: 13-15%*
SUMMARY | HOW TO MANAGE THREAT

Non lethal?
Lethal?
• Replacement?
  • Are we at carrying capacity?
    • Early arriving animals (Aug-Mar)
    • Peak period (Apr-May)
      o 7% of animals exhibit behavior
      o Animal behavior/transmission
• What we don’t know?
  o Replacement rate at low occupancy

Non lethal as part of mgmt. portfolio?
• Naïve animals?
  • Evidence
  • Practicability
SUMMARY | HOW TO EVALUATE EFFECTIVENESS?

Nov-Mar

1) Have we reduced predator presence prior to April (metric: number of sea lions present or predator days)

Apr-May

1) Have we reduced the single day maximum count (metric: single day maximum)
2) Have we reduced predation rate @ falls (stratified sampling)

PVA-reduce extinction risk