Horning M, Mellish JE. 2012. *Predation on an Upper Trophic Marine Predator, the Steller Sea Lion: Evaluating High Juvenile Mortality in a Density Dependent Conceptual Framework*. PLoS ONE 7(1):e30173.
• **Updated results through July 31st 2012** *(Nov 2011)*

• Clarify intent of PLoS ONE model

• Present one additional model output
The impact of predation on Steller sea lions in the Gulf of Alaska

**METHODS**

- **Life History Transmitters – LHX tags**
  - Life-long implants that monitor vital signs
    (with Wildlife Computers Inc. - Horning & Hill, J. Oceanic Engineering 2005)
  - *Post-mortem* satellite-linked data retrieval
  - *Known fate data* w. spatio-temporally unlimited re-sight effort
  - 2 tags per animal to increase and determine event detection probability
  - Determination of causes of mortality from temperature, light and dielectric sensors
    *Predation vs other causes*
    (Horning & Mellish, Endangered Species Research 2009)

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Timeline

• 36 (8f + 28m) weaned sea lions (age 13-25 months) released with LHX tags from 2005 through 2011
  (Mellish et al. Aquatic Mammals 2006
  Horning et al. BMC Veterinary Research 2008)

• > 34,000 exposure days monitored through July 2012
  (29,500)

• 10 carcass simulations (9)
METHODS

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CONTROLS

• LHX tags - *studies in quarantined captivity @ASLC*: low morbidity, zero mortality, **full recovery in 45 days** *(Mellish et al., JEMBE 2007; Horning et al., BMC Vet. Res. 2008; Petrauskas et al., J. Exp. Zool. 2008; Walker et al., AABS 2009)*

• Survival confirmed >45d for all released animals

• No differences in dive behavior from LHX tags or captivity *(Mellish et al., JEMBE 2007; Thomton et al., ESR 2008)*

• $P_{\text{detect}} > 0.98$ (carcass simulations & live returns) *(0.99)* → **likely no mortalities undetected in study group** *(Horning & Mellish, PLoS ONE 2012)*

• No differences detected in survival to brand re-sight controls (NMFS) - **Survival ages 1-5 years (1-3):**
  - LHX 0.413 *(0.26 – 0.64)*
  - NMFS 0.413 *(0.27 – 0.55)* *(updated from Horning & Mellish, PLoS ONE 2012)*
**RESULTS**

- **16 mortalities detected** (12) from 14 mo to 4.1 yrs age
- **All 14 events with data** (11) were due to predation (circles)
- None near rookeries, only 1 in summer
- Predation risk is highest for 12-24 months (after weaning) and declines for older animals
  - 12-23: 41.5% (17-63)
  - 24-35: 16-20% (3-35)
  - 36-47: 5.4% (0-16)
  - 48-59: 7.4% (0-22)

**What happened, and where?**

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**What predators?**

- At least 3 in 14 predation events *could* be attributed to Pacific sleeper sharks
- *Lamnid* sharks (white shark, salmon shark) are 8-16°C above ambient
- Most of the other 11 events were likely transient killer whales?

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- **Surface**
- 20 m
- 100 m
- 200 m

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The numbers

Updated contemporary *survival schedule* for region: *(survival rate for each year-class – by sex)*

• Cumulative juvenile survival rates (12-60 months) **0.413 (0.26 – 0.64)** controls = 0.413 (0.27 - 0.55) do *not* support *hypothesized* recovery and still appear *below* pre-decline rates

**BUT: age-bias and gender balance!**

• *Holmes et al. 2007 (females!):*
  Pre-decline estimate: **0.64**
  Peak decline estimate: **0.36 (0.33-0.40)**
  Modeled post-decline: **0.61 (0.59-0.66)**
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RESULTS

The numbers

Updated contemporary survival schedule for region: (survival rate for each year-class – by sex)

• 50.3% of females born are consumed before primiparity
  32.7% survive to primiparity

• Survival schedule supports natality $\geq 0.69$
  (Maniscalco et al. PLoS ONE 2010)
  for a steady or increasing population

• We find no support for the hypotheses advanced by Holmes et al. (Ecol. Appl. 2007)
  of recovered juvenile survival, and depressed natality – right now, in this region.
A density-dependent *qualitative* model using the updated survival schedule to evaluate:

- How may predation be linked to the reproductive output of population?

- How would that affect other vital rate metrics and the population trajectory?
Where did this happen?

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THE MODEL

Conceptual predation model

Modified birth-pulse Leslie Population Matrix using updated contemporary survival schedule

No fecundity schedule, not time variant!

3 key assumptions:

• Constant natality! (held at 0.69)
• Non-predation mortality held constant
• Age-structured consumption by predators varies with density!

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Assumptions:

- Age structured, density dependent consumption of sea lions! As there are fewer sea lions, predators shift to eating more younger animals!
THE INTENT OF THE MODEL

- Pup difference = *Potential trajectory*, matches decline data <70%
- J/T matches retrospective analysis (Holmes et al. 2003, 2007)

*ONLY to support age structured, density dependent predation idea!*

- Female recruitment **cut in half** *without any changes in natality*
- P/nP is lowest at fastest drop in density
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CONCLUSIONS

- Predation *could* effectively reduce the reproductive potential of the population by 50% @ const. natality
- Even theoretical natality = 1 would only shift equilibrium density from current 20% to 30%
- Predation may be biggest constraint on the recovery of the species in the region
- Escape from ‘predation-driven productivity’ pit may only be possible at reduced predation
CONCLUSIONS

• Our findings apply to the present time and the Gulf of Alaska only

• With predators focus on juveniles, population age structure has to change as sea lion density changes. *This is not accounted for in Holmes et al. model.*

• Recruitment, potential trajectory and P/nP are *all* linked to and affected by predation and how it might change with density. *This is also not accounted for in Holmes et al. model.*

• Holmes et al. 2007 model predictions are unrealistic within GOA and certainly outside

• P/nP is a poor estimator of birth rates
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- Ships: MV Norseman I & II crew
- LHX tags: Wildlife Computers Inc, Redmond, WA

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Gradual cooling:

- allows estimation of mass at time of death (Horning & Mellish, ESR 2009)
- with delayed light, air, uplinks: death by disease, starvation, entanglement, drowning...
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The LHX Project Life History Transmitters – LHX tags

METHODS

Precipitous tag cooling, **immediate** sensing of light & air, **immediate** uplinks:
dismemberment, predation

![Graph showing temperature over time with points marked for air, water, and various LHX tags: TJ33, TJ51, TJ35, TJ47. The graph shows temperature fluctuations from air and water with time markers at 0:00 and 12:00 hours.]