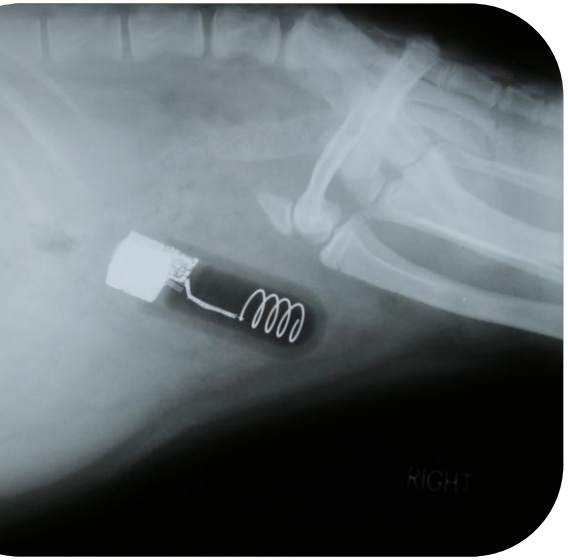
Horning M, Mellish JE. 2012. *Predation on an Upper Trophic Marine Predator, the Steller Sea Lion: Evaluating High Juvenile Mortality in a Density Dependent Conceptual Framework*. PLoS ONE 7(1):e30173.

The impact of predation on Steller sea lions in the Gulf of Alaska

- **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

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)

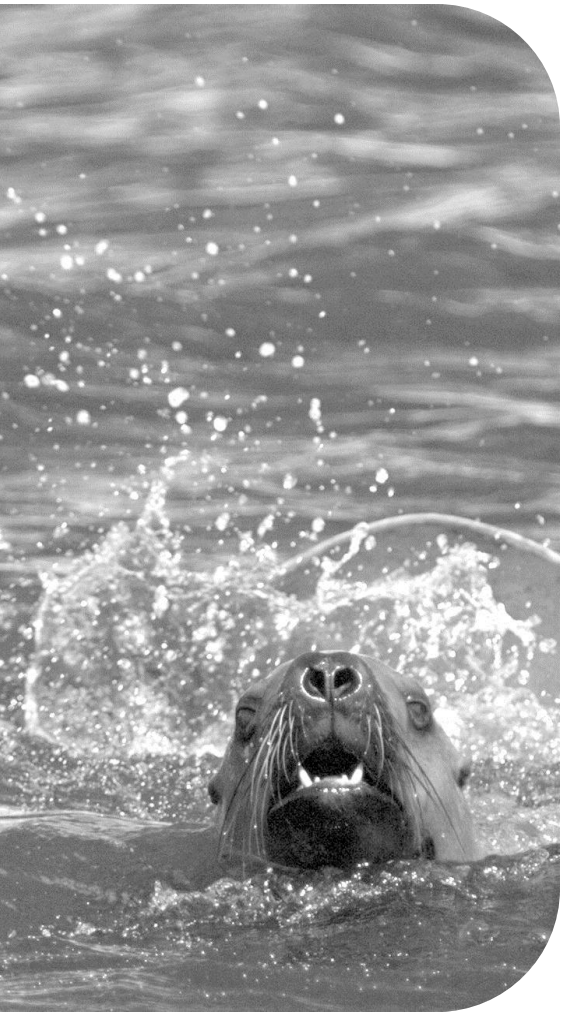
The impact of predation on Steller sea lions in the Gulf of Alaska

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)*

The impact of predation on Steller sea lions in the Gulf of Alaska

CONTROLS



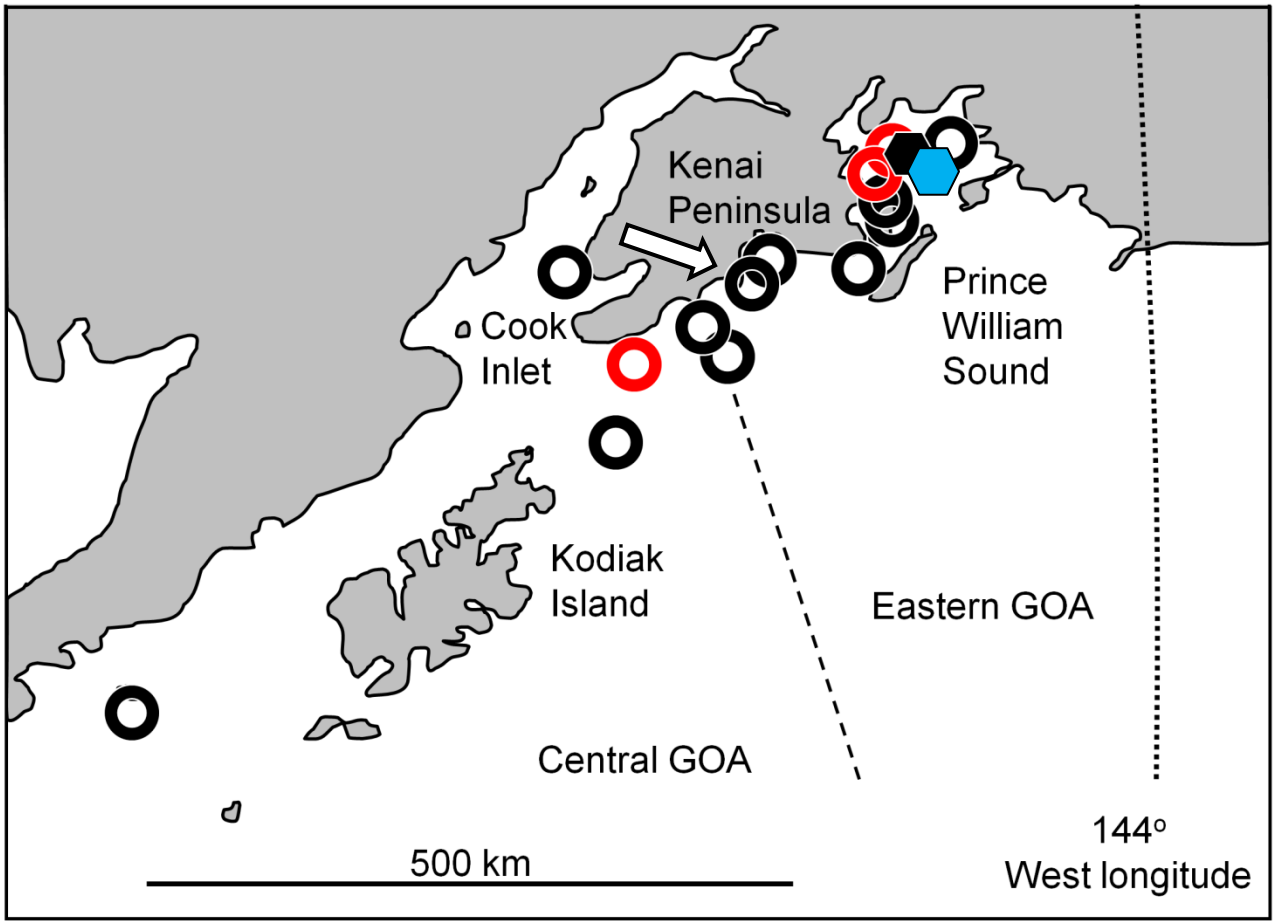
- LHX tags - *studies in quarantined captivity @ASLC:* low morbidity, zero mortality, *full recovery in 45 days*
  (Mellish et al., JEMBE 2007; Horning et al., BMC Vet. Res. 2008; Petrauskas et al., J. Exp. Zool. 2008; Walker et al., AABS 2009)
- Survival confirmed >45d for all released animals
- No differences in dive behavior from LHX tags or captivity
  (Mellish et al., JEMBE 2007; Thomton et al., ESR 2008)
- P_{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)*

The impact of predation on Steller sea lions in the Gulf of Alaska

What happened, and where?

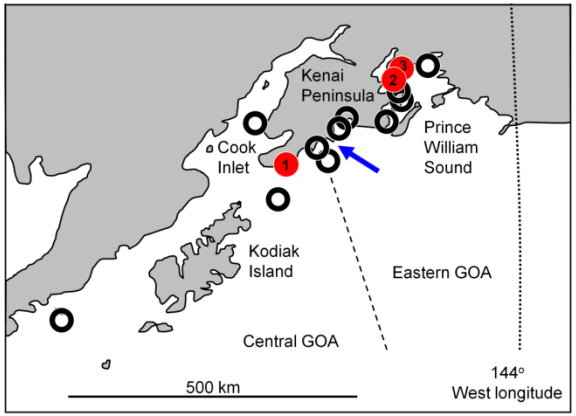
- **16 mortalities detected** *(12)* from 14 mo to 4.1 yrs age
- **All 14 events with data** *(11)* **were due to predation** (circles)
- None near rookeries, only 1 in summer
- Predation risk is highest for 12-24 months (after weaning) and declines for older animals

12-23:	41.5%	(17-63)
24-35:	16-20%	(3-35)
36-47:	5.4%	(0-16)
48-59:	7.4%	(0-22)

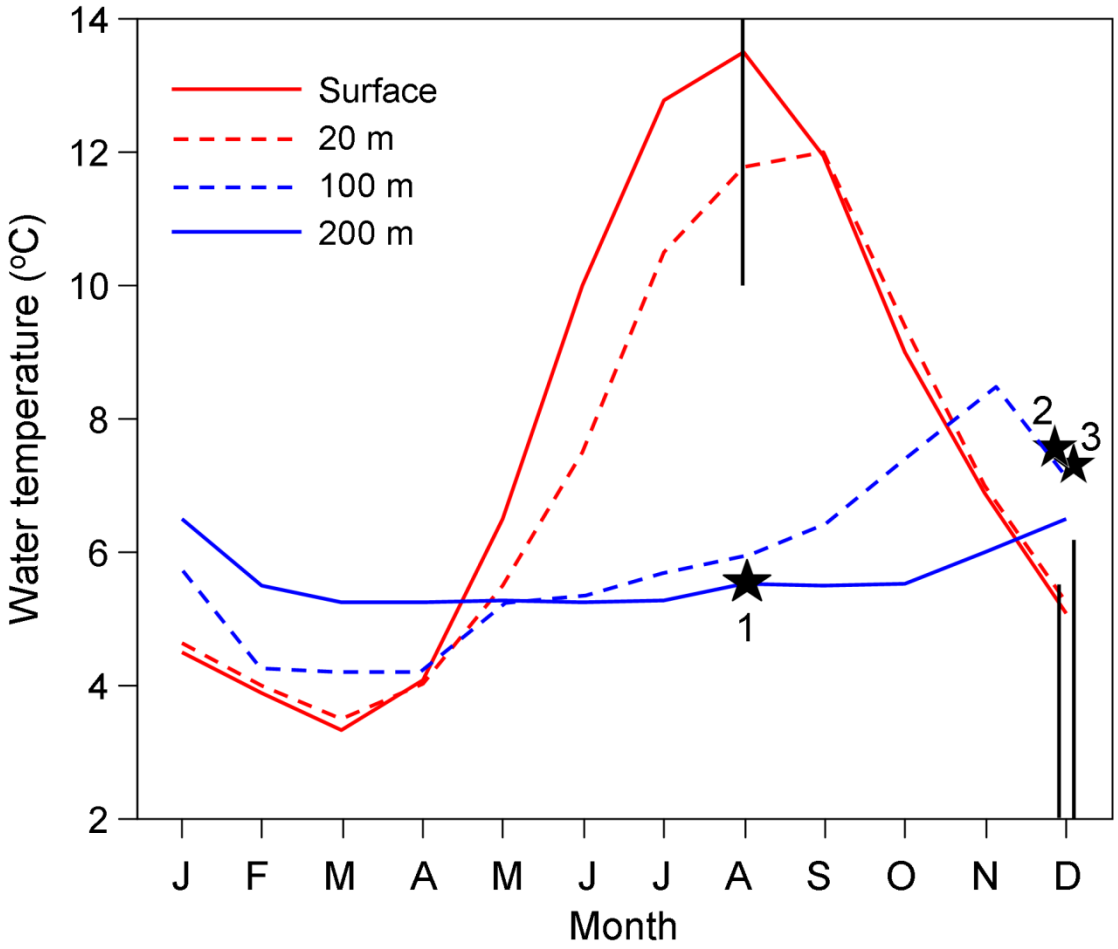


The impact of predation on Steller sea lions in the Gulf of Alaska

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?



The impact of predation on Steller sea lions in the Gulf of Alaska

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)*

The impact of predation on Steller sea lions in the Gulf of Alaska

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* >= 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*.

Conceptual predation model

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?

Conceptual predation model

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

No fecundity schedule, not time variant!

3 key assumptions:

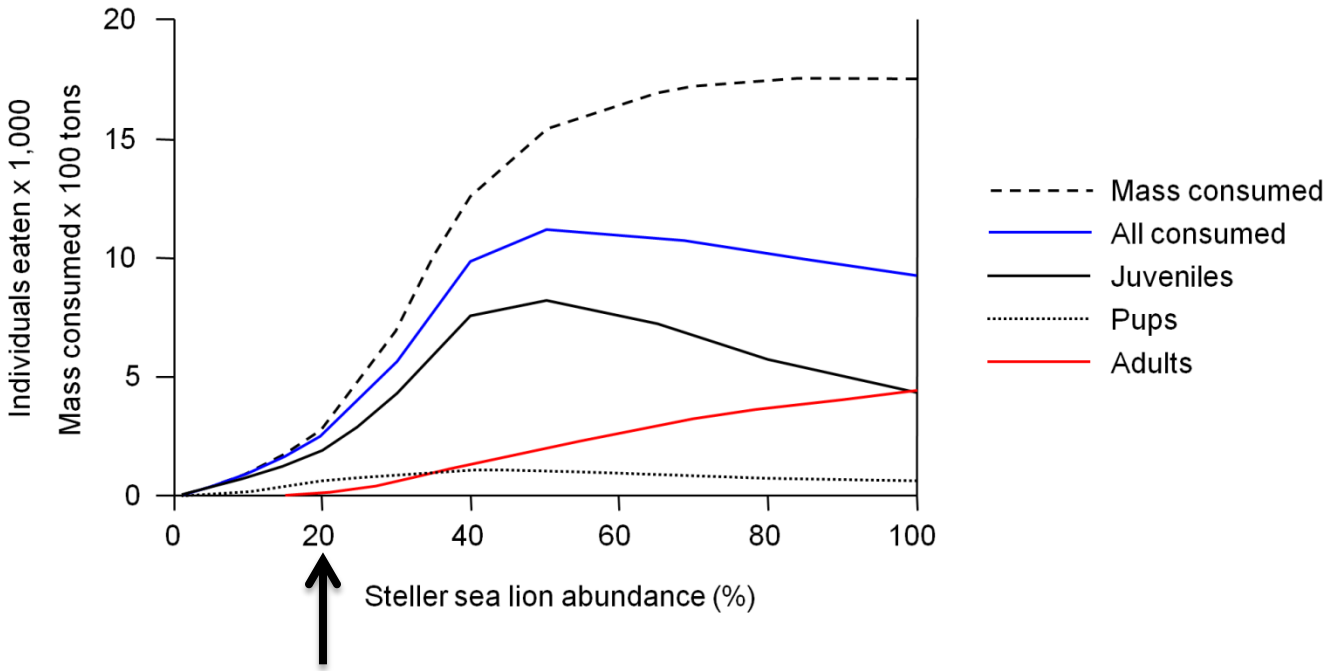
- Constant natality! *(held at 0.69)*
- Non-predation mortality held constant
- *Age-structured* consumption by predators *varies with density*!

The impact of predation on Steller sea lions in the Gulf of Alaska

Conceptual predation model

Assumptions:

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

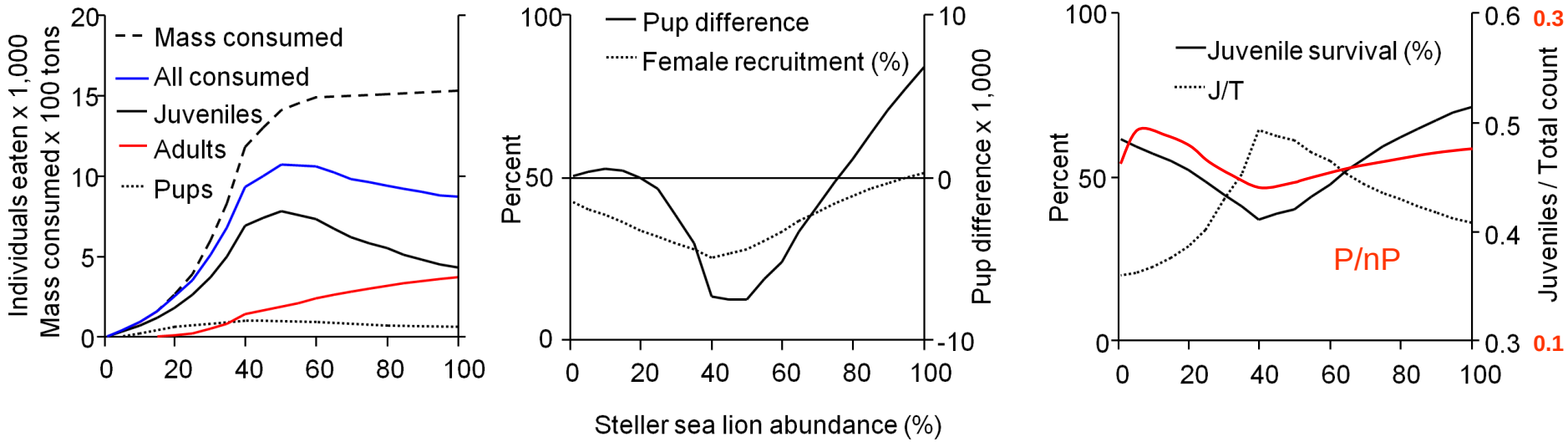


The impact of predation on Steller sea lions in the Gulf of Alaska

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 <u>cut in</u> half *without any changes in natality***
- **P/nP is lowest at fastest drop in density**

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**

Acknowledgements

Thank you to:

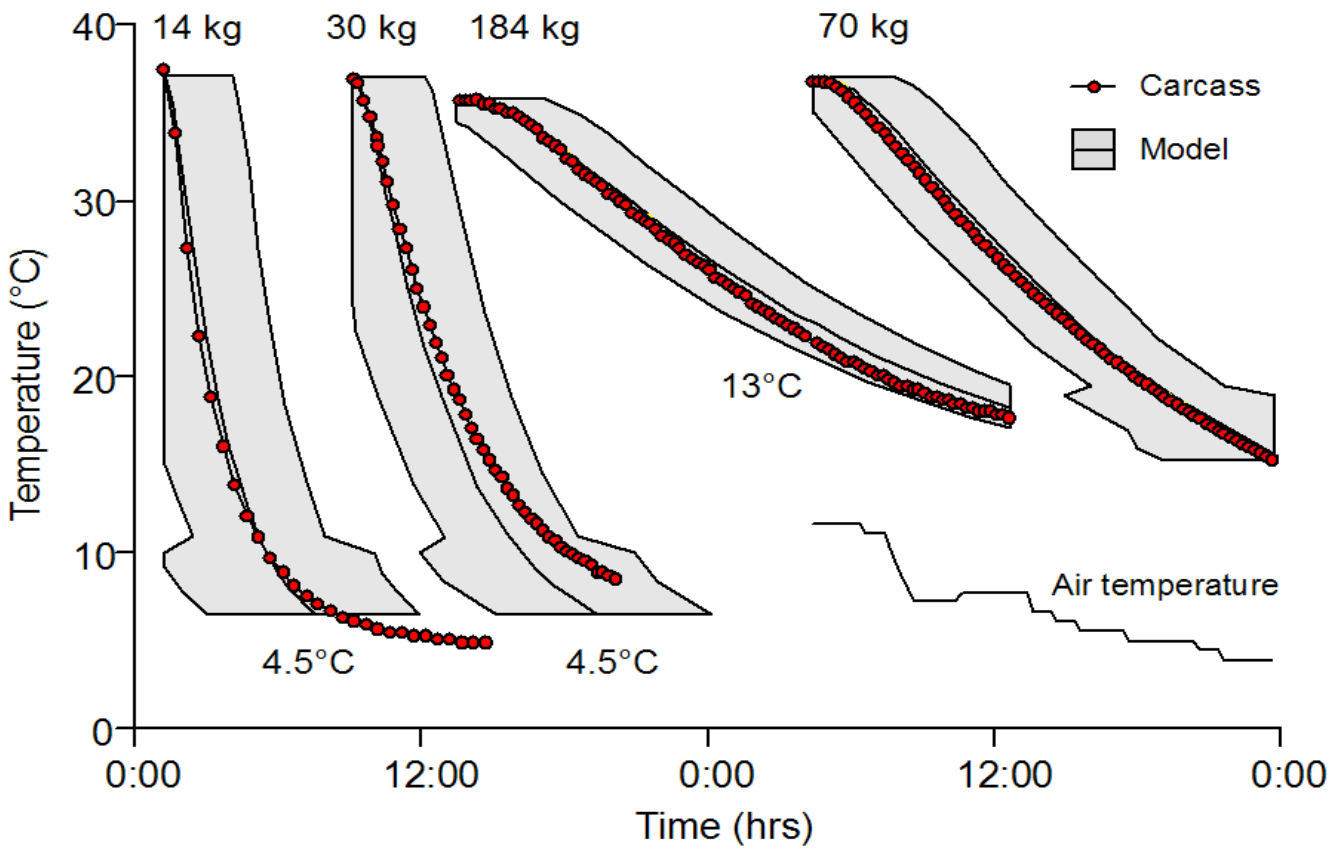
- Vets: Marty Haulena, Pam Tuomi, Carrie Goertz
- Support: ASLC capture and husbandry teams
- OSU students: Norma Vazquez, Stephen Meck
- Ships: MV Norseman I & II crew
- LHX tags: Wildlife Computers Inc, Redmond, WA

Funding: NPMRP, PCCRC, NOAA SSLRI, ASLC, NPRB

Permits: NMFS # 1034-1685; 881-1668; 881-1890, 14335, 14336

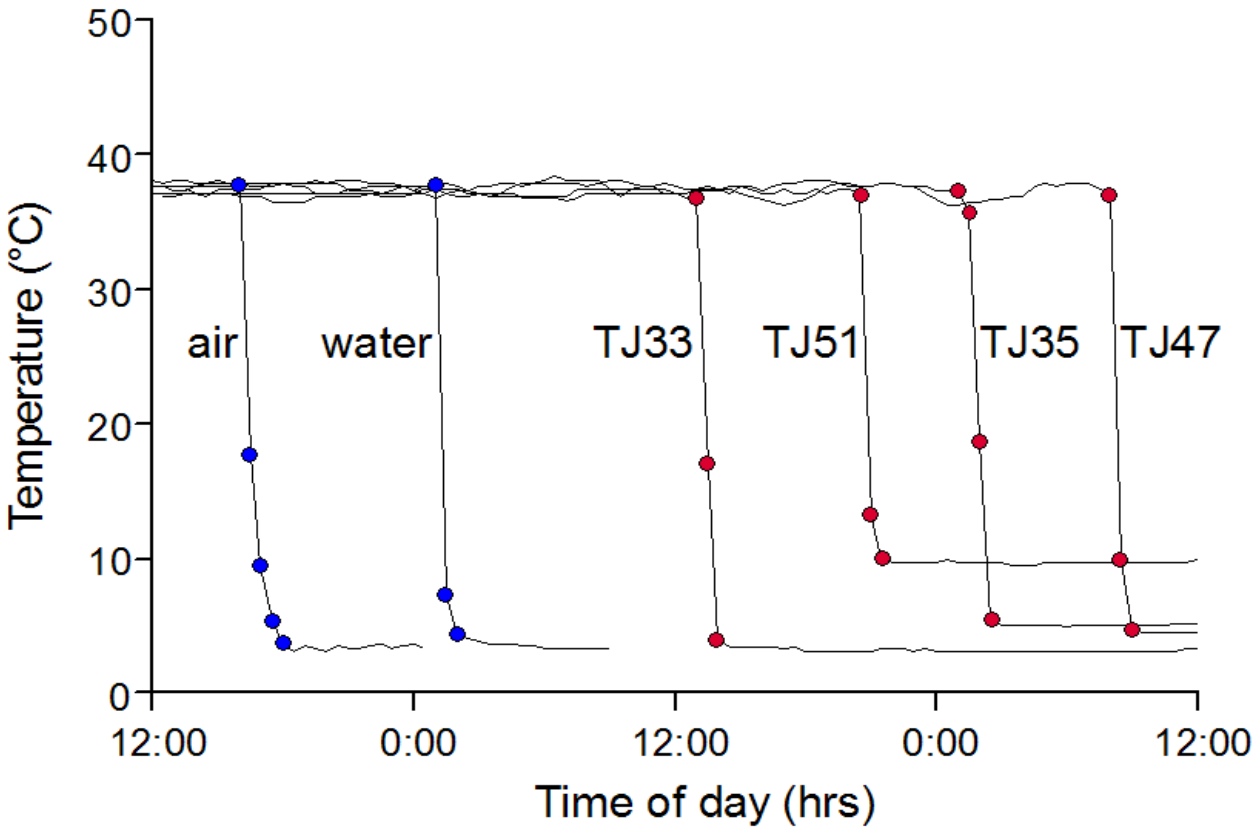
Gradual cooling:

- allows estimation of mass at time of death *(Horning & Mellish, ESR 2009)*
- *with **delayed** light, air, uplinks:* death by disease, starvation, entanglement, drowning…



The LHX Project

Life History Transmitters – LHX tags

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

dismemberment, predation