Alaska Fisheries Science Center

Protected Species Science Program Review

Theme 2: Otariid Pinniped Science

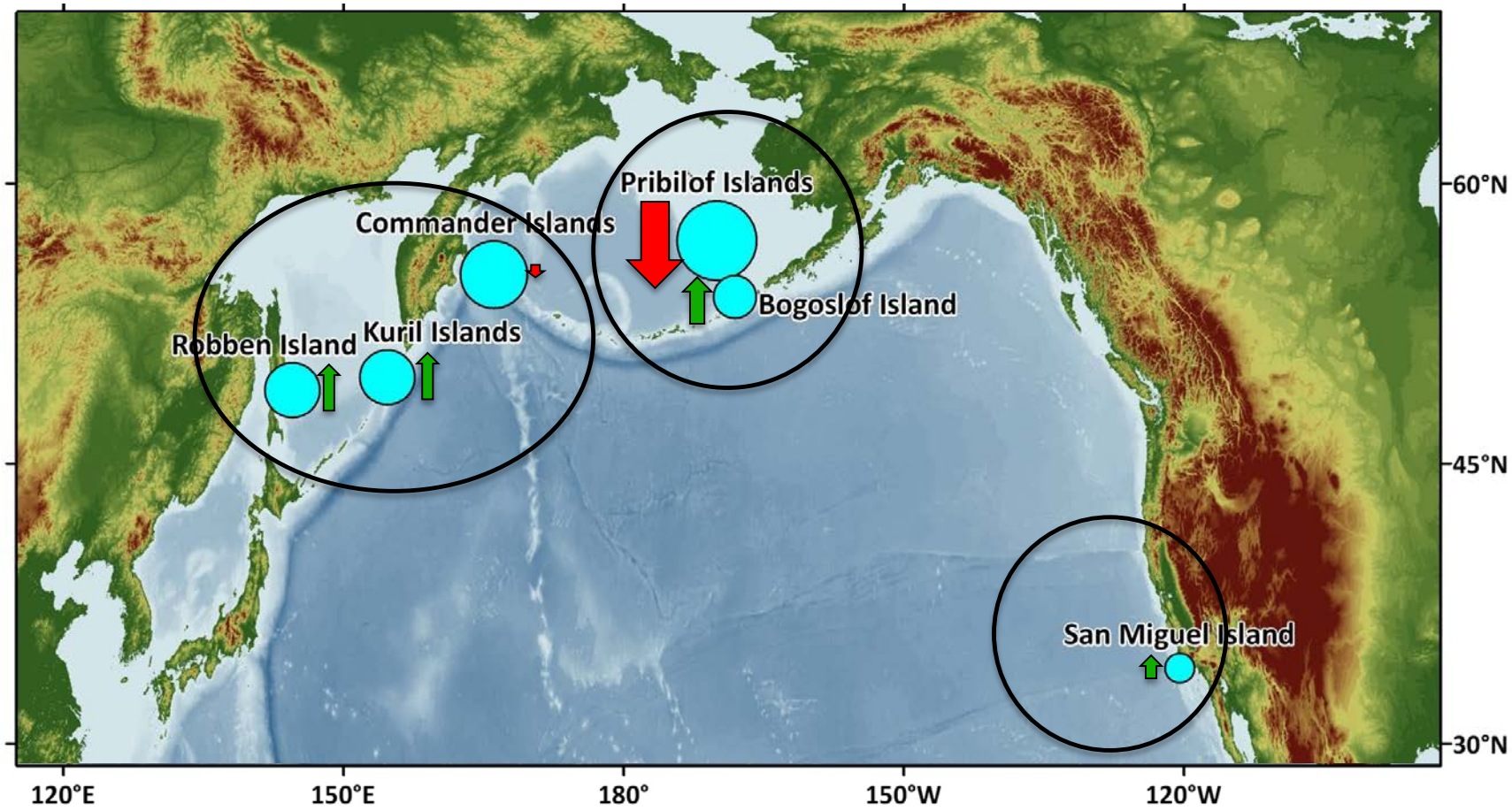
Northern fur seals

Alaska Ecosystems Program

Tom Gelatt

16-20 March 2015

Northern fur seal abundance, stock structure, trends



- ~1,200,000 northern fur seals in North Pacific
- Two stocks in US: Eastern Pacific, California; mixed during winter migration
- Eastern Pacific stock designated as “depleted” under the MMPA
- Regional variation in population trends

Mandates and guidance for research

Mandates

- Marine Mammal Protection Act (MMPA) requirements for stock assessments.

Guidance

- Conservation Plan for the Northern Fur Seal
- Recommendations from AKR and Co-management partners

Northern fur seal potential threats

Potential causes of declines on the Pribilofs

- Predation
- Disease
- Anthropogenic effects
- Contaminants
- Competition with fisheries for prey
- Environmental changes

Overview of northern fur seal research

Thematic questions to address mandates/guidance

1. What is the abundance and trend of northern fur seal populations in Alaska?
2. What are the survival and reproductive rates of northern fur seals?
3. What habitat and prey species are important to northern fur seals in the summer (Bering Sea) and winter (North Pacific)?
4. How does health and condition vary among locations and years?

Northern fur seal research program in Alaska

- *Population abundance and trend monitoring*
- *Vital rates (survival and reproduction) estimation*
- *At-sea foraging ecology*
- Health and condition
- Prevalence of disease

Population abundance and trends

- Estimate recent trends in abundance at rookeries and breeding islands in Alaska
- Address long-term declines in abundance at the Pribilof Islands, and the growth of a recently established colony on Bogoslof Island
- Estimate size and status of the Eastern Pacific stock of northern fur seals

Partners:

- Tribal Government of St. Paul Island
- St. George Island Traditional Council

Population trends: methods

Polovina Cliffs rookery, Saint Paul Island

- The most reliable index of population trends is pup production
  - Estimated using the Lincoln-Petersen method (mark-recapture/“shear-sample”)
  - Conducted biennially at St. Paul and St. George Islands (Pribilofs)
  - Conducted opportunistically at Bogoslof Island and at Sea Lion Rock (Pribilofs)

Population trends: methods

- Approximately 10% of the live pups are marked at each rookery (based on prior pup production estimate)
- Ratio of marked pups is observed by two independent observers during two rounds of sampling.
- Observer ratios are averaged for each round of sampling to generate two estimates of live pup abundance.
- Estimates are averaged and dead pup numbers are added to obtain the total pup production estimate.

Population trends: agTrend, an R package

- Add-on package developed for R statistical environment (Johnson and Fritz 2014)
- http://nmml.github.io/agTrend
- Model counts at *all* sites
  - Zero-inflated log-normal model to augment missing data
  - Augmented data used to aggregate into regions
  - Trends calculated from aggregated data

agTrend: An R package for estimating trends of aggregated abundance

Devin S. Johnson[1] and Lowell Fritz

National Marine Mammal Laboratory, Alaska Fisheries Science Center
NOAA National Marine Fisheries Service,
Seattle, Washington, U.S.A.
[1]Email: devin.johnson@noaa.gov

Benefits:

- Accounts for survey methodology changes
- Can aggregate sites as desired (even after the fact)
- Forecast into the future (PVA)
- Handles different definitions of “trend”

Population monitoring: data quality

- CV's have been below 0.11 since 2000, and below 0.02 since 2002.
- Assuming the estimates are representative of production, the estimates are of high precision and accurate describing trend.
- Currently, pup production estimates are available by the end of the year in which the data were collected.
- Models are being pursued to investigate the source and magnitude of the error around the pup production estimates.

Population monitoring: strengths

- Pup production is the most reliable measure to detect changes in population trends
- Pronounced, predictable pupping season provides consistency
- Long-term dataset
- Computationally efficient

Population monitoring: limitations and weaknesses

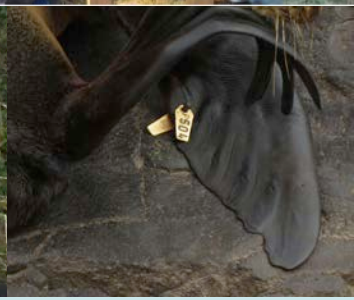
- Due to logistical difficulties, estimates of pup production at Bogoslof and Sea Lion Rock are not conducted on a regular schedule.
- Pup production is only an index for total abundance, rather than a direct measure.
- Requires experienced personnel for safety, and for sampling procedures.
- Pribilof Islands pup production estimates are labor intensive.

Vital Rates

- What elements of their life history (age-specific reproductive or survival rates) are implicated in the current population decline?
- Can we detect evidence for a change in population trajectory
- Partners:
  - Tribal Government of St. Paul Island
  - St. George Island Traditional Council

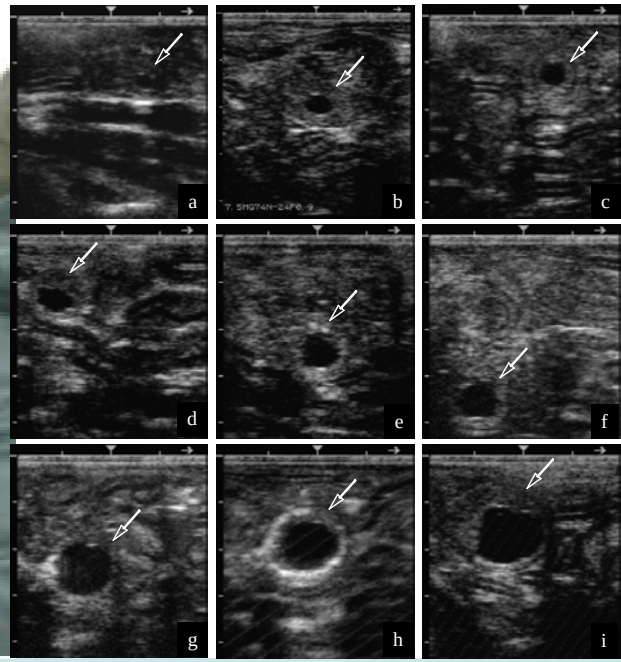
Vital rates methods overview

- Historic vital rates estimates for null model of population stability
- Adults and pups captured, tagged in both flippers ~ Oct 1st on 3 rookeries
  - St. Paul: Polovina Cliffs 2007-2014, Zapadni Reef (pups only) 2010-2014
  - St. George: South 2009-2014
- Re-sighting of marked animals July-Oct from overlooking cliffs or blinds



Vital rates methods: reproduction

- Ultrasonographic examination for pregnancy during captures in 2007, 2008 for direct comparison of pregnancy in early gestation with historic collection data
- Re-sighting in July-early August gives direct estimation of proportion pupping with minimal bias when re-sighting rates are high, and can be corrected for bias with state-based capture-mark-resighting models



Vital rates methods: survival

- Adult females returning in July-Aug provide basis for estimating their annual survival
- Juveniles tagged as pups returning in Aug-Oct provide the same beginning at age 2
- Capture-Mark-Resighting statistical models are used for estimation of survival rates

Vital Rates Data Quality - Mark-Resight Model

- A simple age specific model was used for simulation and estimation
- Model parameters were estimated from early results (2010-2013) on South rookery then used for power simulations
- Model:
  - p: ~ageClass {2, 3, and [4,Inf)}
  - S: ~ageClass {(0,2], (2,3], (3, 4], and (4, Inf)}

Mark-Resight Model

- Empirical Age specific survival estimates
  - 0-2yr = 0.25
  - 2-3yr = 0.64
  - 3-4yr = 0.74
  - 4+ yr = 0.77 (adult survival)

- Age specific detection estimates
  - 1 yr = 0.0 (fixed)
  - 2yr = 0.2
  - 3yr = 0.67
  - 4+ yr = 0.92

Simulated MR Data

- Sample sizes (female only) from 2010-2013 used for first 4 years of model simulation
  - South
    - Pups: 917, 890, 471, and 563
    - Females: 171, 199, 0, and 4
  - Polovina Cliffs
    - Pups: 138, 57, 38, and 162
    - Females: 31, 94, 44, and 40

Simulated MR Data

- Additional deployments were simulated for 4 years into the future
  - South
    - Pups: 250–1000/yr
    - Females: 10–200/yr
  - Polovina Cliffs
    - Pups: 25–300/yr
    - Females: 10–200/yr
- Following data simulation, age-specific model was fitted and parameters recorded

Results- Coefficients of Variation

- South
  - age 0: 0.175 – 0.155 (CV at smallest sample to largest)
  - age 2: 0.25 – 0.22
  - age 3: 0.096 – 0.094
  - age 4+: 0.18 – 0.16
- Polovina Cliffs
  - age 0: 0.30 – 0.22
  - age 2: 0.425 – 0.325
  - age 3: 0.111 – 0.110
  - age 4+: 0.30 – 0.23
- All sample sizes produced reasonable variation in estimates (i.e, CVs substantially less than 1)

Results- Root Mean Squared Error

- South
  - age 0: 0.02 – 0.01 (RMSE smallest sample to largest)
  - age 2: 0.06 – 0.02
  - age 3: 0.04 – 0.04
  - age 4+: 0.06 – 0.03
- Polovina Cliffs
  - age 0: 0.06 – 0.02
  - age 2: 0.13 – 0.05
  - age 3: 0.05 – 0.03
  - age 4+: 0.11 – 0.04

Vital Rates: strengths

- Resighting effort has resulted in very high annual re-sighting rates, and the potential for high precision in both survival and reproductive estimates
- Longitudinal sighting histories are a rich dataset for correlating vital rates with potential causal factors (e.g., disease, condition, foraging behavior, previous reproductive effort)

Vital Rates: weaknesses/limitations

- Tag loss can bias survival estimates downward if not estimated accurately
  - Double-tagging allows some for adjustments in survival estimates
  - Variety of tags now tested, with newest tags showing very low loss rates
- Permanent emigration also a source of negative bias in survival estimates if not estimated
  - Some corrections for nearby emigration (adjacent sections of Polovina Cliffs) appear possible from limited surveys
  - Extent of non-local emigration is not resolved

At-sea foraging ecology

- Address variation in habitat use, foraging behavior and diet among:
  - Age/sex classes
  - Breeding sites (islands and rookeries)
- Evaluate relationships between habitat use and diet
- Assess habitat use by northern fur seals during summer (Bering Sea) and winter (North Pacific)
- Examine how oceanographic and biophysical features influence habitat use and foraging behavior
- Describe changes in foraging ecology related to increasing abundance at Bogoslof

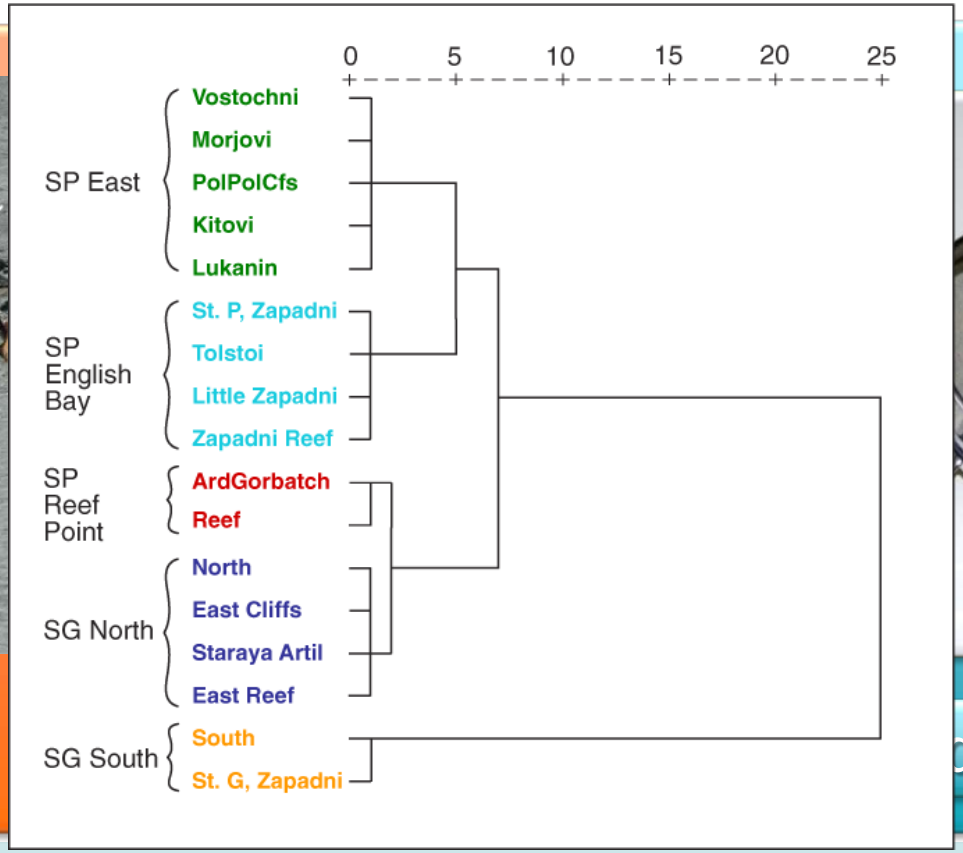
- Partners:
  - University of Washington
  - University of California San Diego
  - Dalhousie University

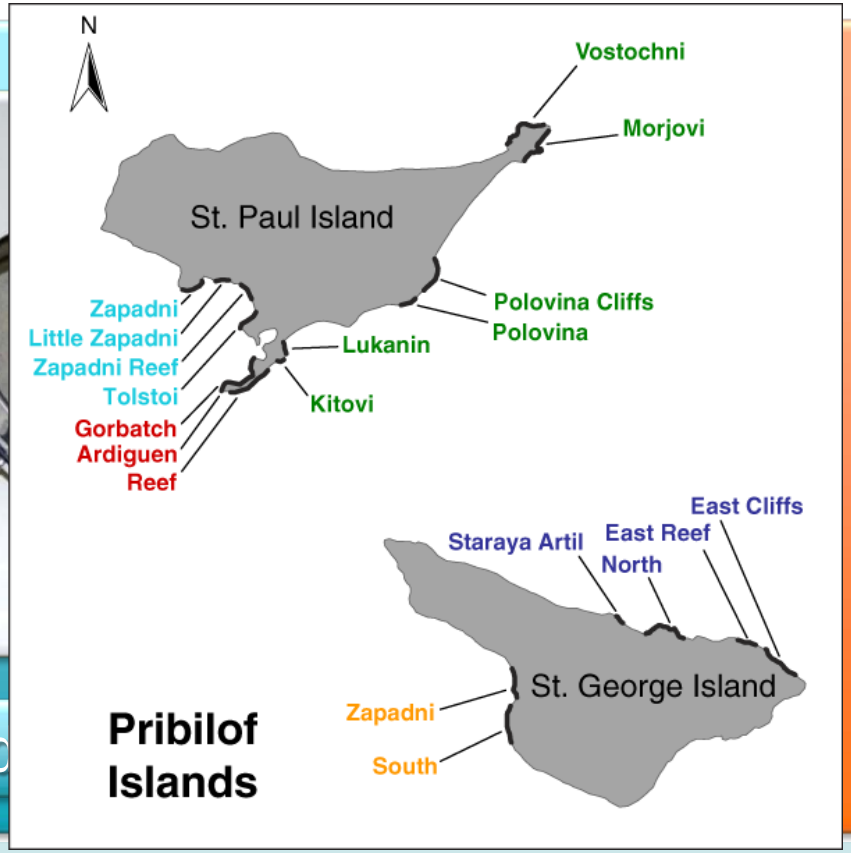
At-sea foraging ecology: methods overview

- Animal captures timed for season of interest (summer vs winter); animals captured for summer studies are typically recaptured in the fall.
- Attach archival and/or satellite-linked tags, collect samples for health, condition and diet.
- Tag data (behavior, locations) downloaded from recovered archival tags and/or via satellite/Argos, processed, and used for maps and models.
- Analyze samples to determine habitat use and diet (stable isotopes, fatty acids, and identification of prey hard parts from scats).

At-sea foraging ecology : methods

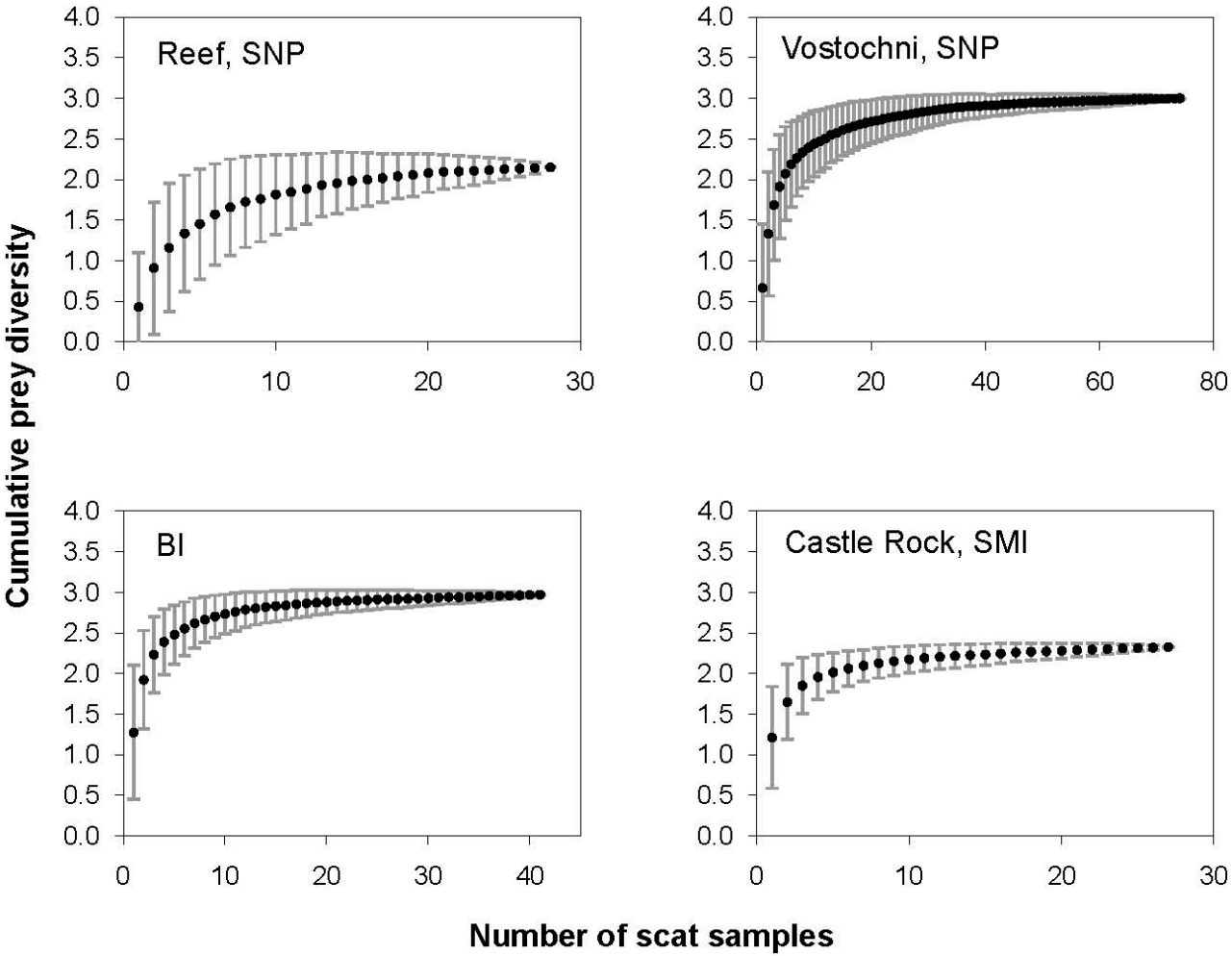
- Scats collected from rookeries, processed, and hard parts analyzed to identify prey and determine FO, MNI, and size.
- Hierarchical cluster analysis was used to examine regional trends in prey occurrence and generalized linear models were used to examine temporal trends.





At-sea foraging ecology : data quality

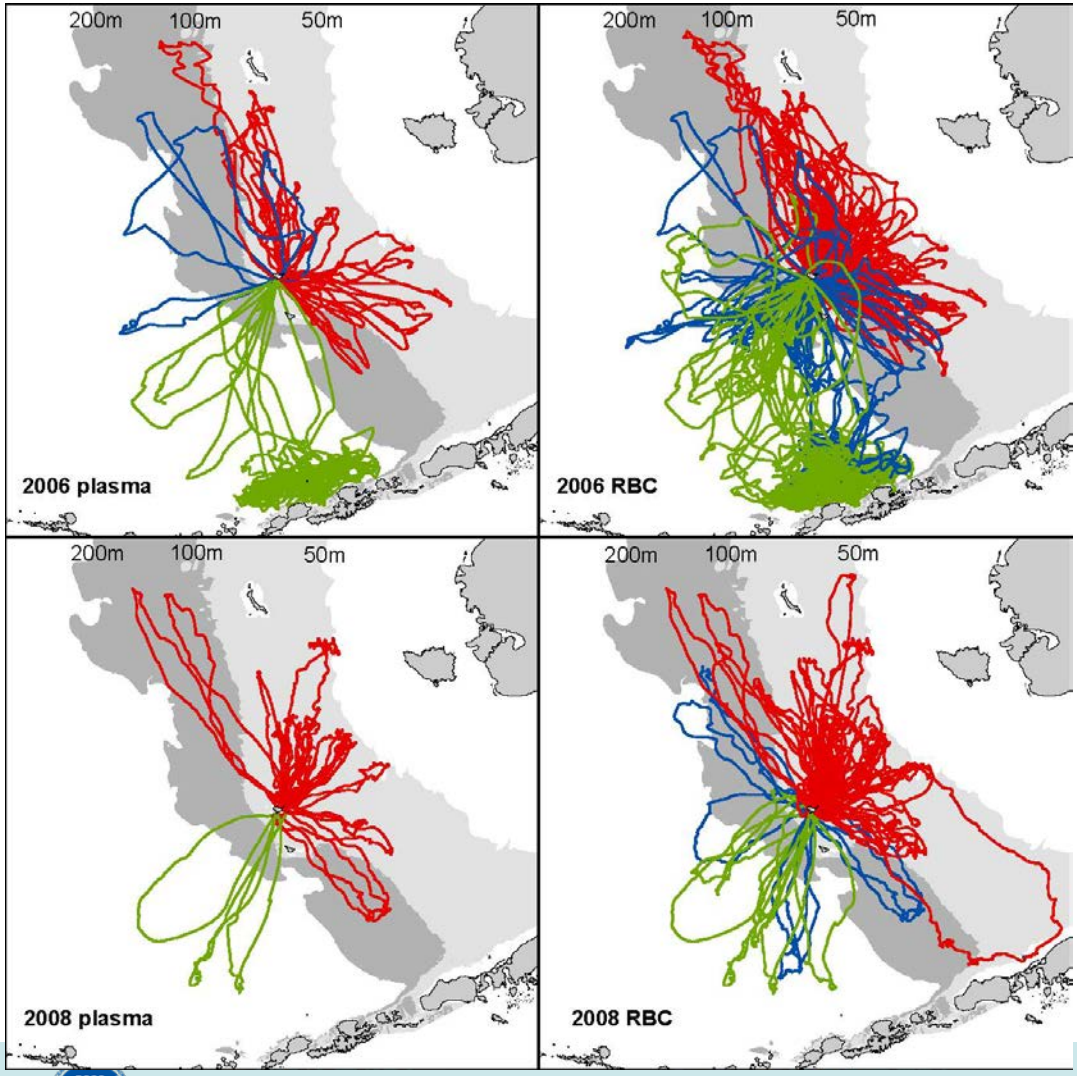
Adequacy of scat collection sample size to describe diet:

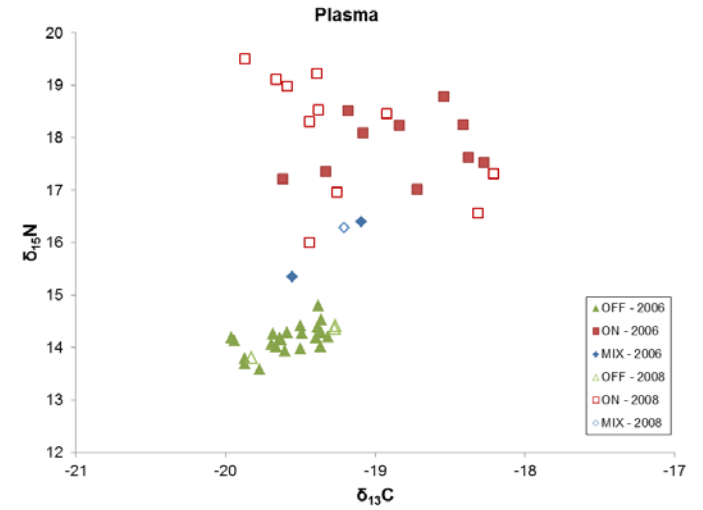


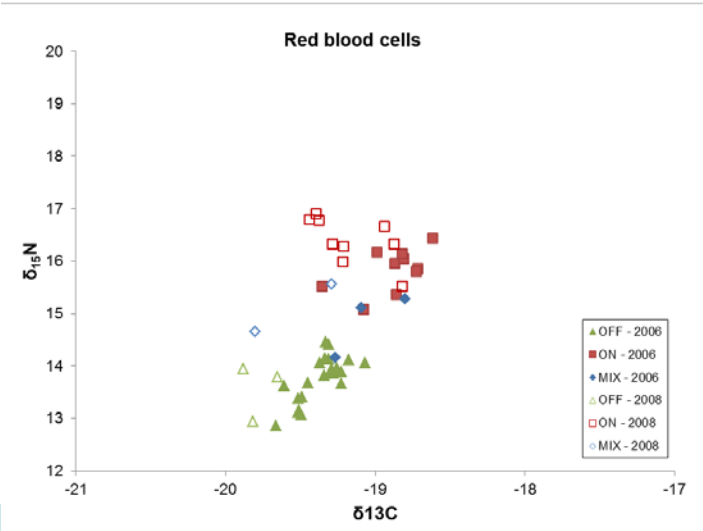
- Mean cumulative prey diversity curves based on Shannon-Wiener (H') index.

At-sea foraging ecology : methods

- Blood collected from animals with satellite tags at recapture.
- Validation of models predicting habitat use from stable isotopes.

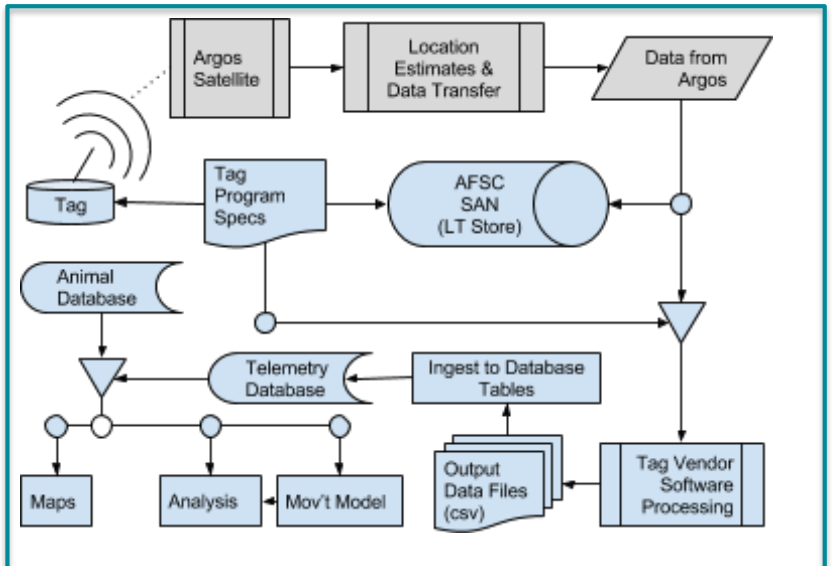




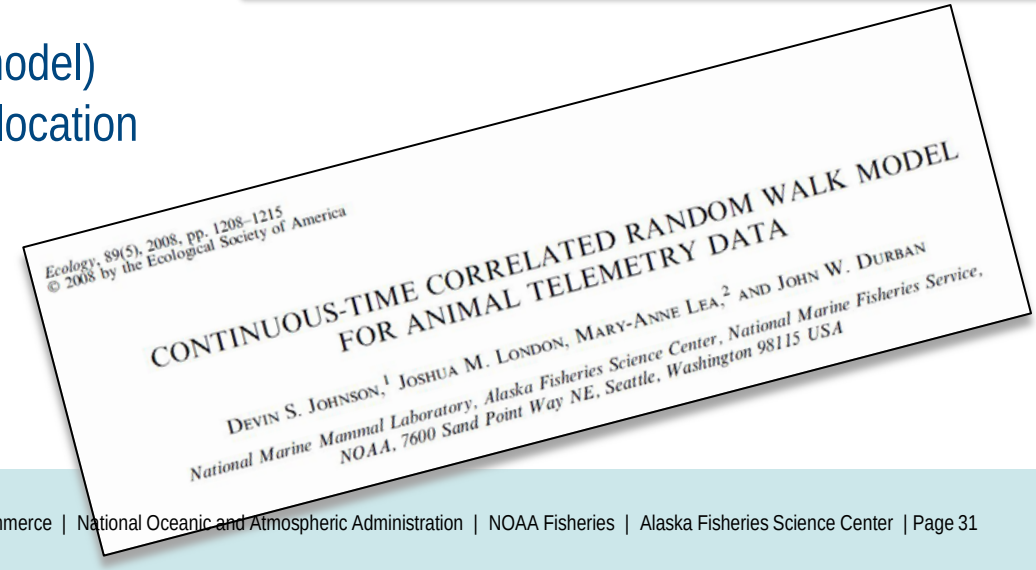


At-sea habitat use: data quality

- Recent implementation of fast-loc GPS technology improves location precision (< 100m error)
- Transmitted tag data received via Argos, pre-processing controlled by Argos & tag manufacturer
- Telemetry location data speed filtered at 3 m/s (McConnell et al. 1992)
- Location data (Argos and GPS) merged with wet/dry data (if available)
- CRAWL model of movement (Johnson et al 2008):
  - Generalized for wet/dry (stop model)
  - Allows for inclusion of error for location data (Argos data)
  - Predicts locations every 20 min



AFSC/NMML Animal Telemetry Data Management Plan


Ecology, 89(5), 2008, pp. 1208–1215
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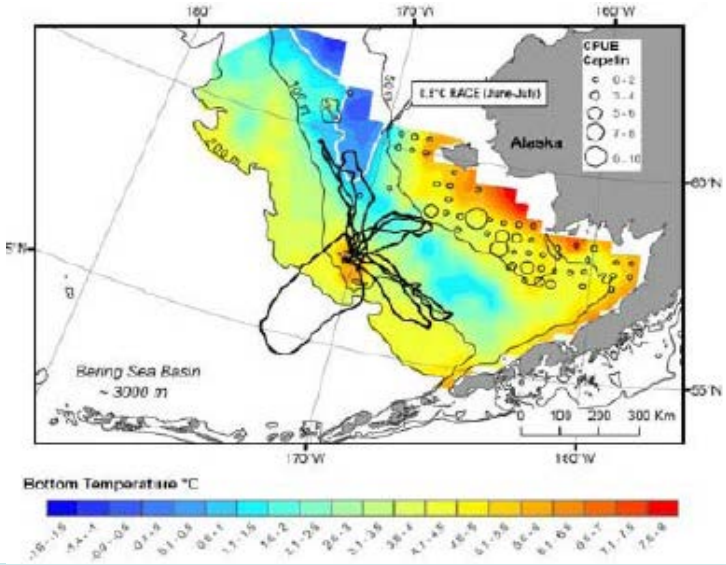
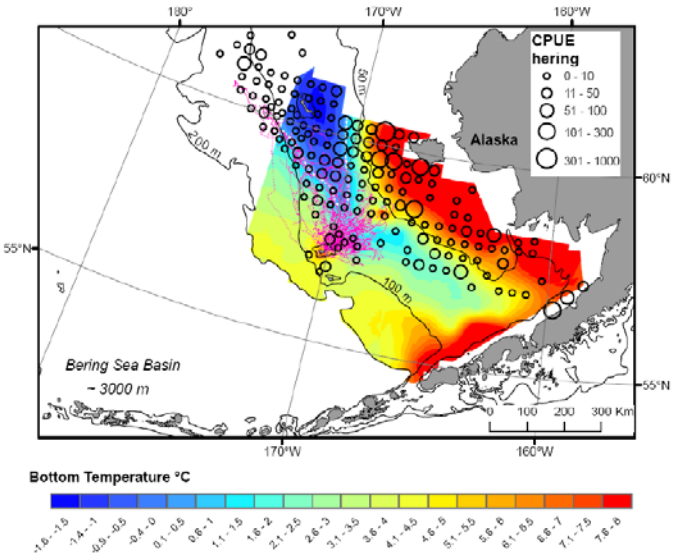
CONTINUOUS-TIME CORRELATED RANDOM WALK MODEL FOR ANIMAL TELEMETRY DATA

DEVIN S. JOHNSON,[1] JOSHUA M. LONDON, MARY-ANNE LEA,[2] AND JOHN W. DURBAN
National Marine Mammal Laboratory, Alaska Fisheries Science Center, National Marine Fisheries Service, NOAA, 7600 Sand Point Way NE, Seattle, Washington 98115 USA

At-sea habitat use: data quality

- Modeling habitat use:
  - Spatially link dive behavior variables with predicted locations.
  - Combine with categorical and continuous predictor variables in linear mixed-effects models (examples):
    - individual, month, year, season, region, % daylight, %lunar illumination
    - static environmental: bathymetry, slope, distance to nearest site, distance from shore
    - dynamic environmental: SST, wind speed, bottom temperature, chlorophyll-*a* (Aqua MODIS), sea surface height (AVISO)





At-sea foraging ecology : strengths

- All sex/age classes can be reliably captured and handled; sampling is relatively easy and is conducted at all breeding islands.
- Recaptures at the end of summer provide detailed assessment of individuals whose habitat use and foraging behavior are known.
- Habitat use can be integrated with dynamic environmental features obtained through remote-sensing orbital satellites, onboard oceanographic sensors, and subsurface profilers such as Seagliders.
- Long-term diet dataset from scats allow for trend analyses of specific species and sizes of prey.

At-sea foraging ecology : weaknesses/limitations

- Instrument related costs limit deployments.
- Sampling during ~8 month winter migration limited to instrument deployments in the fall.
- Molt influences tag retention
- Quantity of data collected from instruments is large and computationally intensive.
- No clear best approach to archive data and provide a platform for interactive public viewing.
- Scats do not provide information about individual animals, only represent recent foraging, and are limited to summer (Bering Sea); diet information representative of larger temporal/spatial scales requires further integration and validation of other methods (e.g., stable isotopes, fatty acids).

Northern fur seal research: communication

- Publications in peer reviewed journals
- AFSC Technical Reports
- Products for NMFS:
  - F/AKR
    - Reports or input for NEPA EA/EIS
  - AFSC:
    - SAFE reports
    - MMPA Stock Assessment Reports
    - AFSC Quarterly Reports
- Workshops/symposia/conferences
- Other media:
  - NOAA video production
  - AFSC website
  - Seattle Aquarium Outreach Partnership

Northern fur seal research: data access

- AFSC website:
  - Northern fur seal pup production estimates, and counts of adult males.
- Data repositories:
  - GitHub
  - NOAA Oceanographic Data Center (NODC)
- PARR requirements

Northern fur seal research: recommendations

1. Continue regular abundance surveys at the Pribilof Islands and increase survey frequency at Bogoslof Island and Sea Lion Rock.
2. Continue tagging and resight studies for survival/reproductive rates.
3. Expand electronic tag deployments into under-sampled age/sex categories, target deployments that overlap with high resolution prey surveys, and continue validation of predictive models of habitat use using stable isotopes.
4. Continue monitoring diet, and expand use of emerging technologies for prey identification (e.g., isotopic mixing model).