Alaska Fisheries Science Center

Protected Species Science Program Review

Theme 2: Otariid Pinniped Science

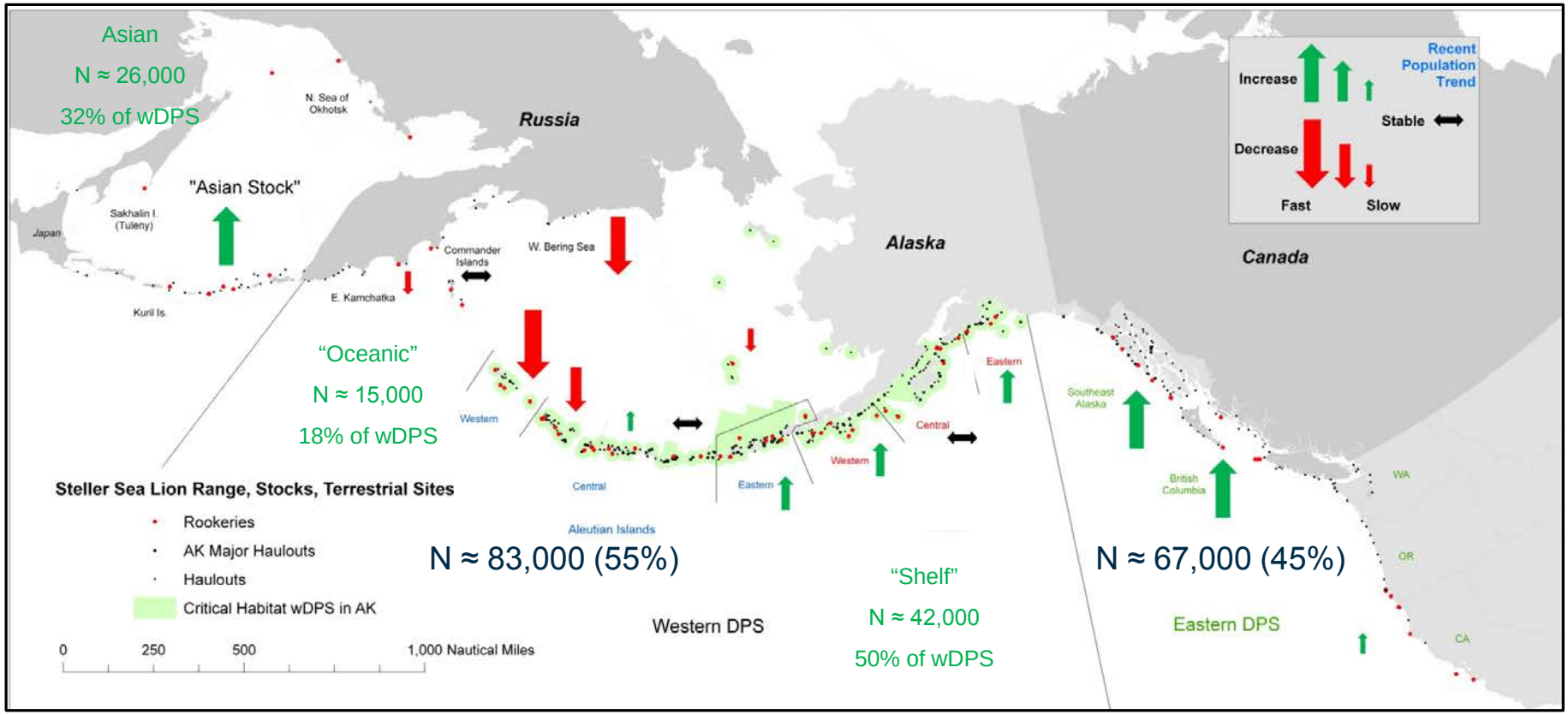
Steller sea lions

Alaska Ecosystems Program

Tom Gelatt

16-20 March 2015

Steller sea lion abundance and stock structure



- ~150,000 Steller sea lions in North Pacific
- Two Distinct Population Segments: wDPS endangered, eDPS delisted
- Sub-structure within wDPS
  - Asia, Pelagic Alaska, Shelf Alaska
- Regional variation in recent population trends

Mandates and guidance for research

Mandates

- Marine Mammal Protection Act (MMPA) requirements for stock assessments.
- Endangered Species Act (ESA)
  - Steller Sea Lion Recovery Plan – identified 78 actions
  - Post-Delisting Monitoring Plan for the eastern DPS

Other Guidance

- ESA Section 7 Biological Opinions (BiOps)
- North Pacific Fisheries Management Council (NPFMC) letters to NMFS
- Reviews of BiOps and science by State of Alaska, CIE, and NRC

Steller sea lion potential threats

Potential causes of declines/lack of recovery

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

Overview of Steller sea lion research

Thematic questions to address mandates/guidance

1. What is the abundance and trend of Steller sea lion populations in Alaska?
2. What are the survival and reproductive rates of Steller sea lions?
3. What prey areas, habitats, and species are important to support Steller sea lion recovery?
4. Are natural and human activities affecting the recovery of Steller sea lion populations?

Steller sea lion research program

- *Population abundance and trend monitoring*
- *Survival and reproductive (vital) rates estimation*
- *At-sea habitat use/foraging ecology*
- *Food habits*
- Health and condition
- Population abundance, trends, and vital rates estimation of Russian Steller sea lion populations
- Stock structure

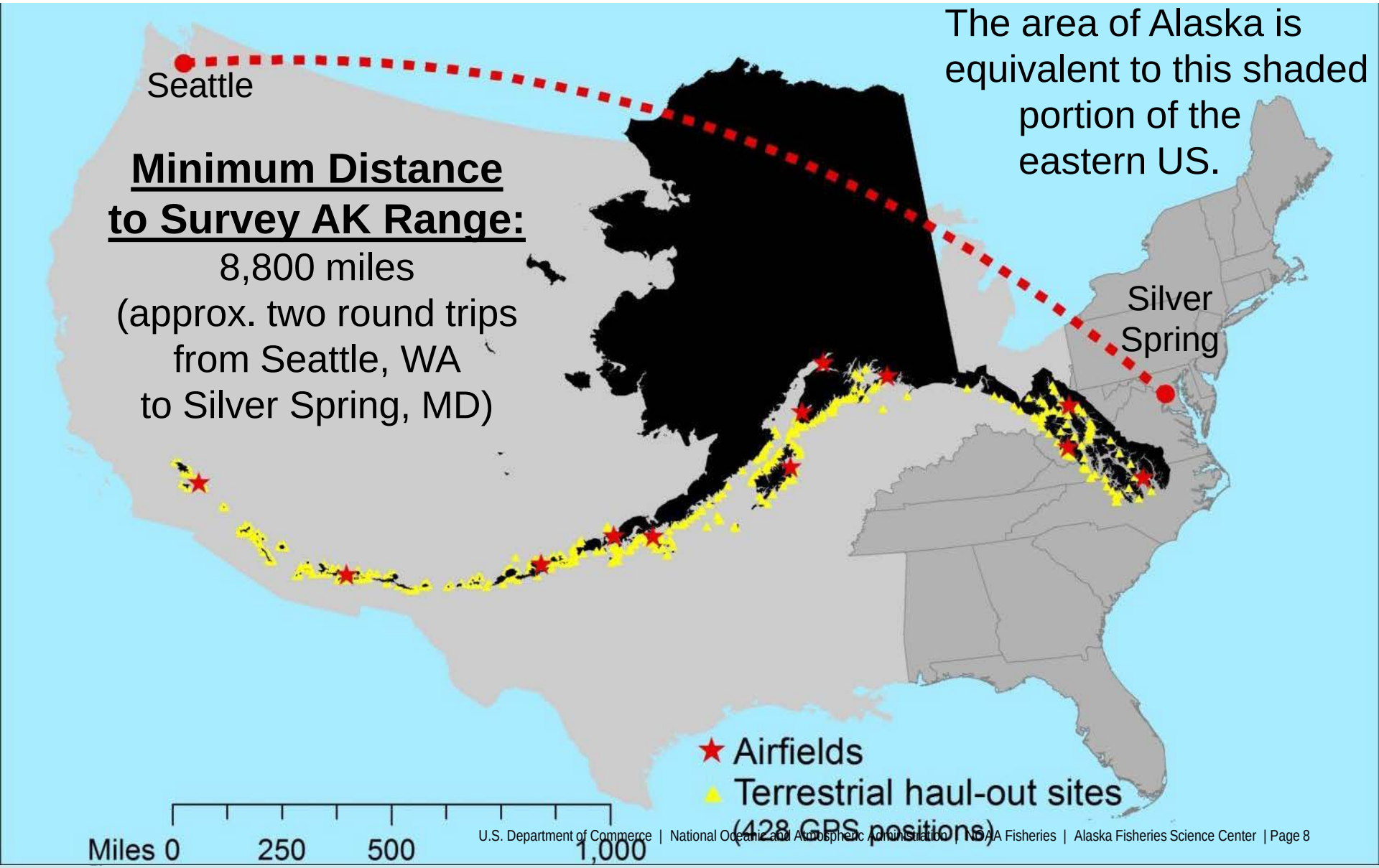
Population abundance and trends

- Are there regional differences?
- Do trends meet criteria for recovery?

Partners:

- NMFS Southwest Fisheries Science Center
- NOAA Aircraft Operations Center
- US Fish and Wildlife Service

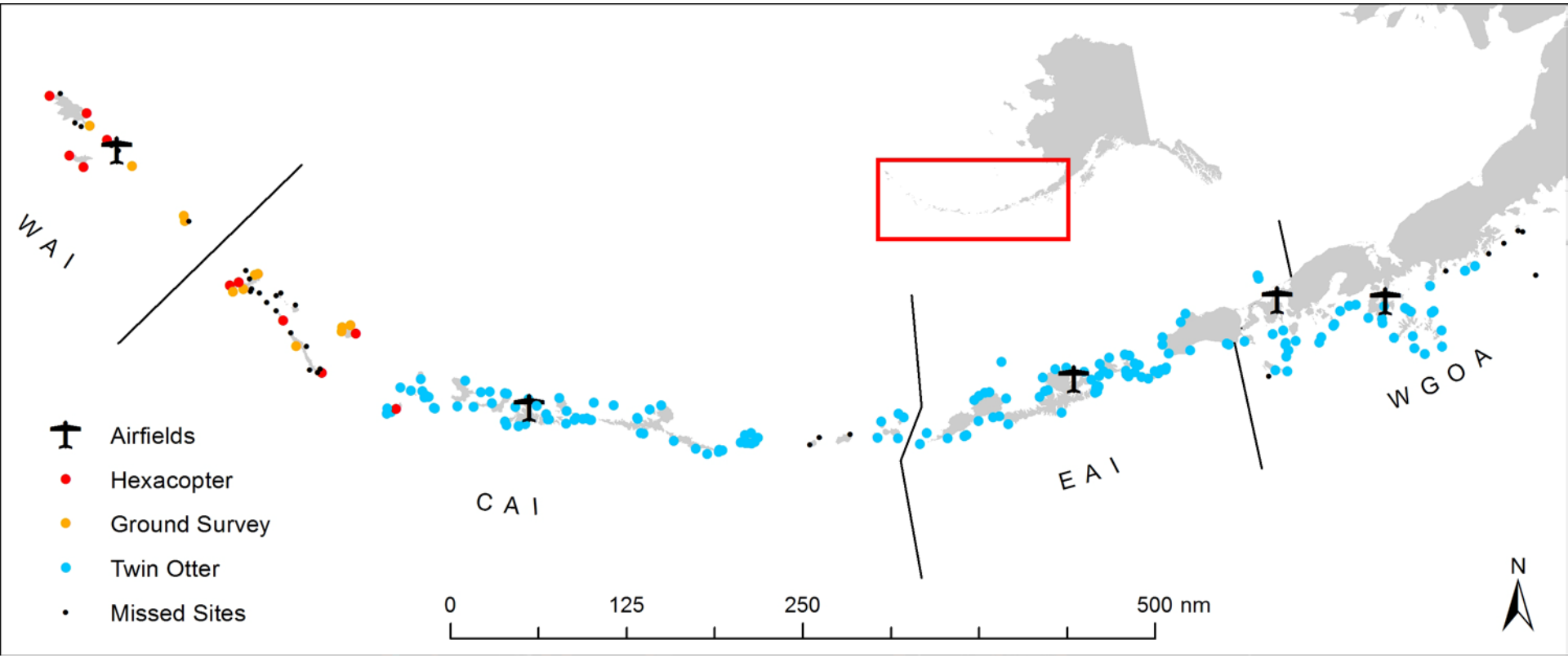
Population trend methods



The area of Alaska is equivalent to this shaded portion of the eastern US.

Minimum Distance to Survey AK Range:
8,800 miles
(approx. two round trips from Seattle, WA to Silver Spring, MD)

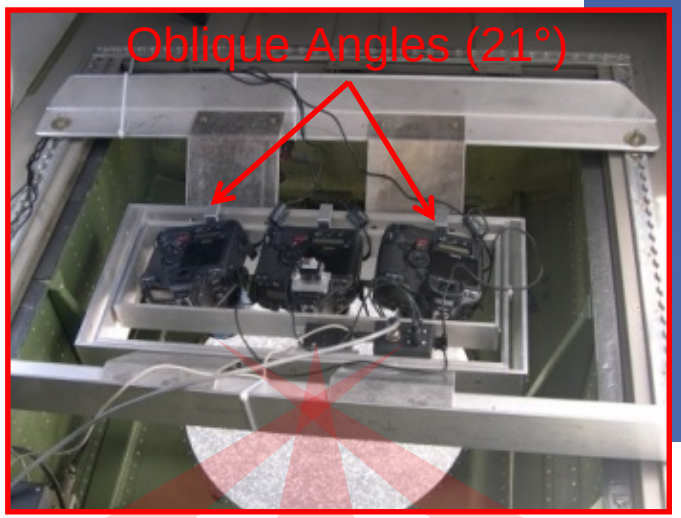
Population trend methods – 2014 Survey

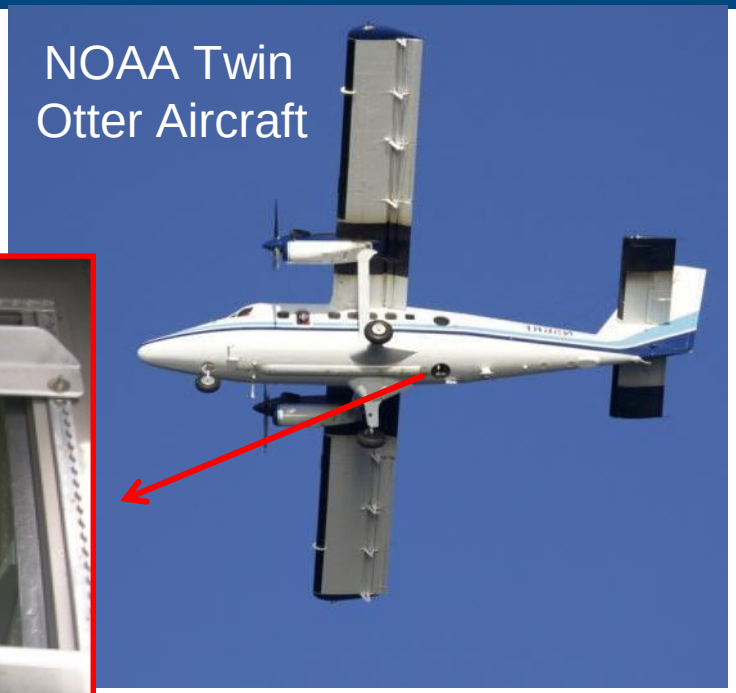


- Three methods
  - Twin Otter manned aircraft where airports were 'plentiful' ~200 sites
  - Ship-based unmanned aircraft flown from shore 11 sites
  - Ship-based visual counts (ground survey) 12 sites

Population trend methods

- 3 camera mount
- Mounted in belly port
- Forward motion compensation
  - Reduces blur
- Three 85 mm lenses
  - 10% sidelap
  - 60% top-bottom overlap
- Total footprint:
  - ~200,000 ft^2 @ 750 ft altitude





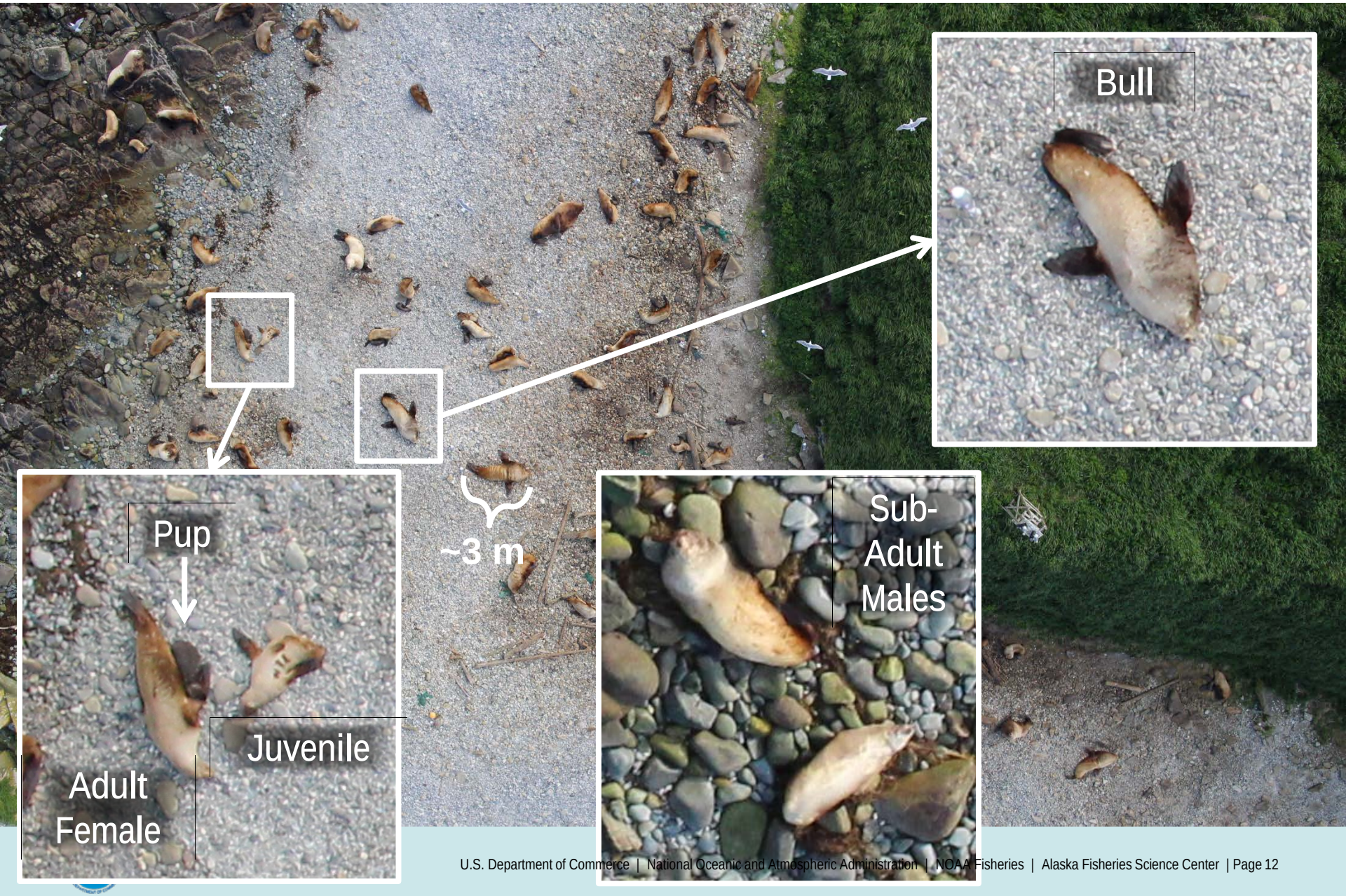
High resolution images

- 1 pixel < 1 in^2

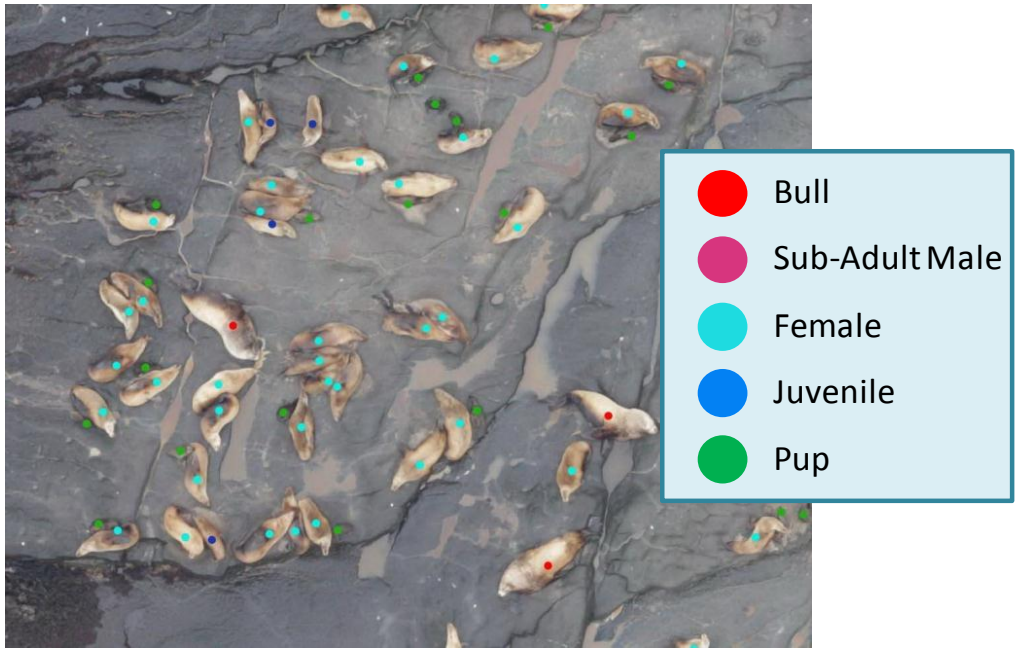
Population trend methods

- In 2014 added use of APH-22 Hexacopter carrying a vertically-mounted camera

Population trend methods



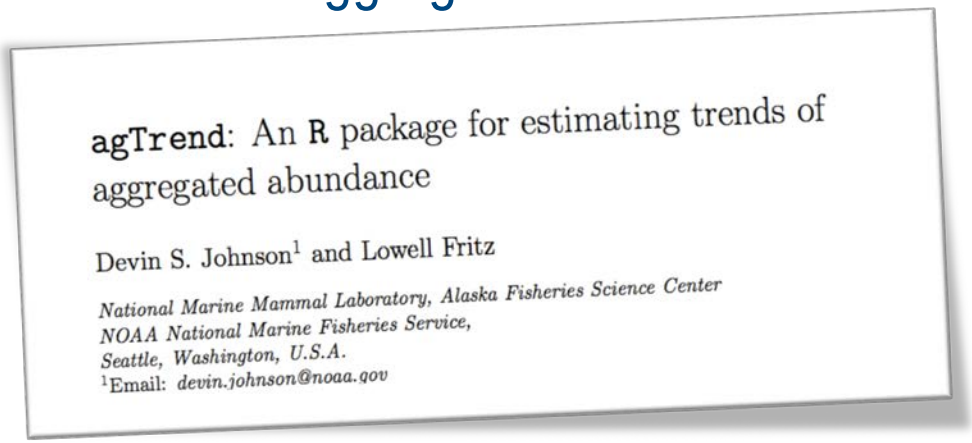
Population trend methods



- 2 independent counters using Photoshop script
- High resolution monitors
- Reconcile counts so differences < 5% and <20 nonpups, <10 pups
- Report mean count

Population trend: agTrend, an R package

- We developed an add-on package for the 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

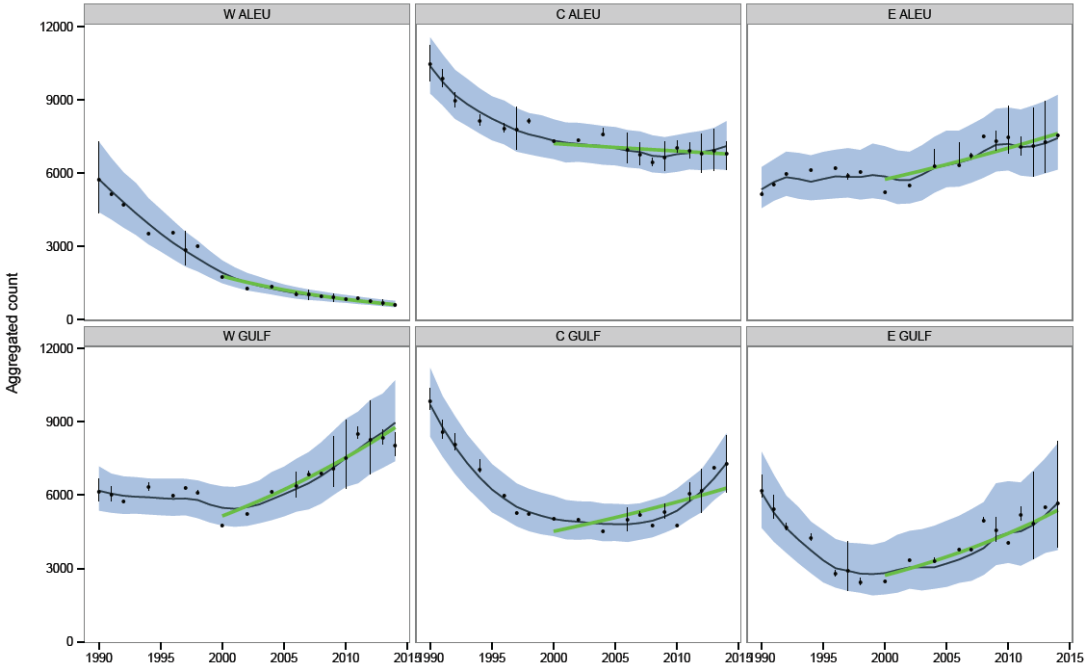
National Marine Mammal Laboratory, Alaska Fisheries Science Center
NOAA National Marine Fisheries Service,
Seattle, Washington, U.S.A.
[1]Email: *devin.johnson@noaa.gov*

Population trend: agTrend, an R package

Benefits:

- Accounts for survey methodology changes
- Can aggregate sites as desired (even after the fact)
- Uses data from all sites with non-zero counts rather than pre-selected list of 'trend' sites (method used through 2013)
- Forecast into the future (PVA)
- Handles different definitions of "trend"

wDPS non-pups by Region



Fritz et al. (2015)

Population trend: data quality

- For de-listed eastern DPS: >80% chance of detecting a 3%/yr reduction in pup production
  - Through 2013, change in pup counts = +4%/yr
- For endangered western DPS: >80% chance of detecting significantly positive growth by 2014 and >90% by 2018
  - These were estimates made using data collected through 2008 when trend was not different from 0
  - Through 2014, change in non-pup counts = +2%/yr
- Counts and updated trend estimates are made available each year for NPFMC winter meeting (February)

Population monitoring: strengths

- Breeding season only (late June through early July)
  - Highest % of animals hauled out during the year
  - Most consistent time period to survey
- > 2 weeks after mean pup birth date
- Best method to detect changes in population status across a large range
- Consistent survey timing over 30+ year dataset
- Combination of manned and unmanned aerial platforms significantly improves coverage
- Aerial pup counts significantly reduces disturbance (relative to past ground counts)

Population monitoring: limitations/weaknesses

- Not a census
  - Unknown % of animals at sea during survey
  - Assume no significant temporal trend in % at-sea
- Manned aircraft survey challenges
  - Safety
  - Fog and low ceilings
  - Remote and scarce airfields
  - Local terrestrial topography (steep cliffs, downdrafts)
- Does not capture non-breeding season distribution

Vital rates estimation

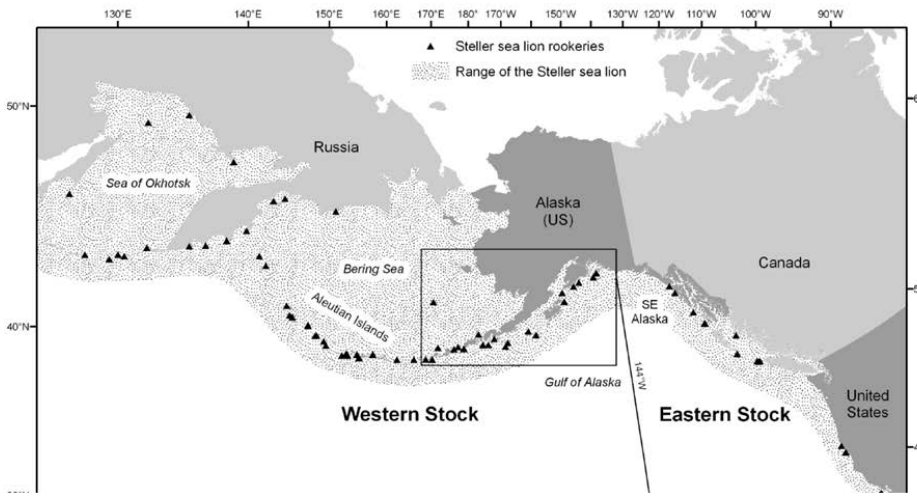
- Are reproductive and survival rates adequate to support population recovery? Are there regional differences?
- Data also used to assess movements of individuals.

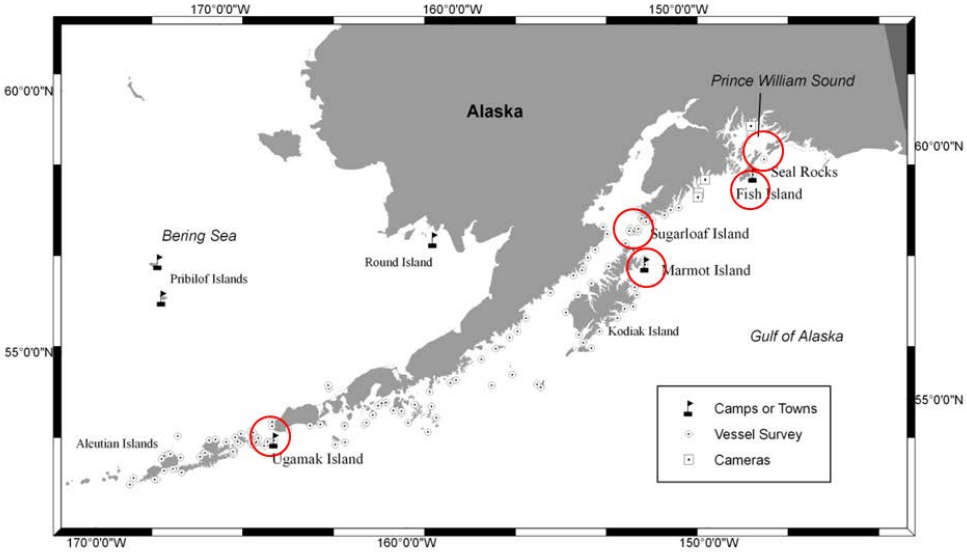
- Partners:
  - Alaska Department of Fish and Game
  - Alaska SeaLife Center
  - University of Alaska, Univ. of British Columbia, Oregon State Univ.
  - US Fish and Wildlife Service
  - North Pacific Wildlife Consulting
  - Tribal Governments of Saint Paul and Saint George Islands

Vital rates estimation methods

- Pups individually marked at <6 weeks old on rookeries.
  - Leading letter of mark corresponds to natal rookery
- Observations of marked animals during 1 May – 31 August used for analysis
- Sighting effort from: small-boat observations supported by research vessels, land-based observations, remote video and camera installations, manned and unmanned aerial survey platforms, interested members of the public

Vital rates estimation methods – western stock NMML



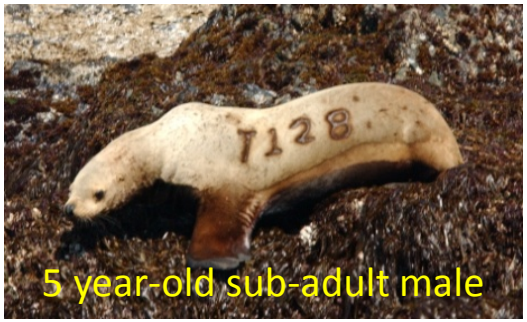


- 1987-88: 1 rookery (Marmot) in central Gulf of Alaska
- Since 2000: 5 rookeries E. Aleutians – E. Gulf of Alaska
- Since 2011: 2 rookeries in W & Central Aleutians

Vital rates: populations, areas, time periods

- Eastern DPS
  - 1994-95 SEAK N=799; sightings through 2003 ADFG (Pendleton et al. 2006)
  - 2001-05 SEAK N=1995; sightings through 2009 ADFG (Hastings et al. 2011)
  - 2001-11 OR-CA N=1309; NMML ongoing
- Western DPS in Alaska
  - 1987-88 CGOA N=751; sightings through 2003 (Pendleton et al. 2006)
  - 2000-05 EAI-EGOA N=1449; sightings through 2011 (Fritz et al. 2014)
  - 2005-10 EGOA N=199; ASLC ongoing
  - 2007-present WAI-CGOA N=796; NMML ongoing
- Western DPS in Russia
  - 1990s-present N=1000s; Burkanov (NMML & NPWC ongoing)

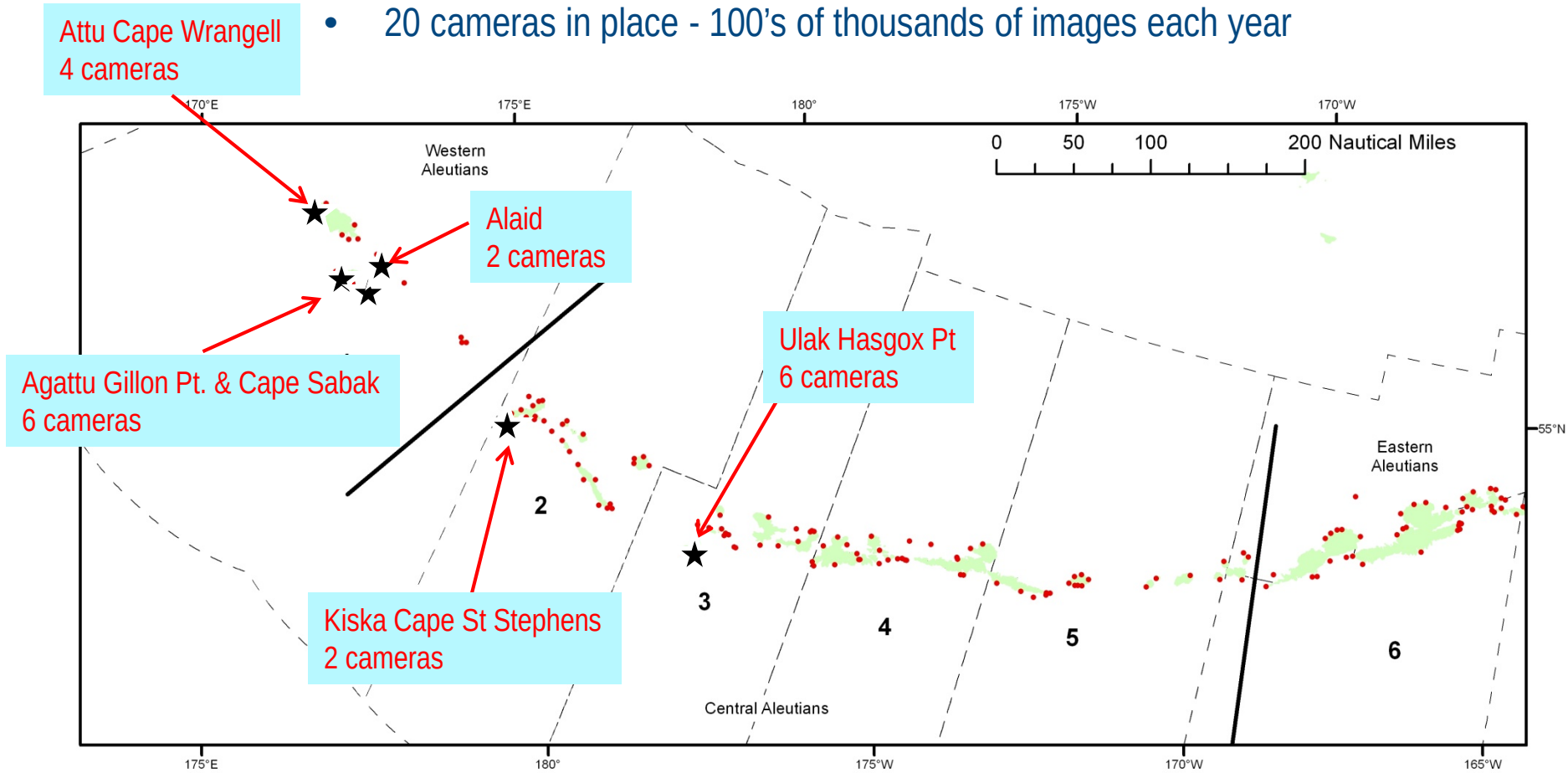
T128 branded 4 July 2002 on Marmot Island



T128 observed 20 June 2007 at Latax Rocks

Vital rates estimation methods – W&C Aleutians

- Started marking in western Aleutians in 2011 at Agattu/Gillon Point.
- Added Ulak/Hasgox Pt central Aleutians in 2013
- Began placing cameras at rookeries and haulouts in 2012
- 20 cameras in place - 100's of thousands of images each year



Vital rates estimation methods

- Field identifications of marked animals supported by high-resolution digital photographs in 99% of individual sightings.
- Cormack-Jolly-Seber open population mark-recapture models estimate sighting probability and apparent annual survival (MARK).
- Age, sex, time of year, rookery, and region used to model sighting probability and survival

Vital rates estimation: data quality

- From 2000-2005, AFSC branded 1,449 pups at 5 wDPS rookeries
- From 2001-2011, branded animals from these cohorts were observed over 18,000 times across the North Pacific Ocean
- 60% of all branded pups were observed at least once at age one or greater, a high percentage given only 61-83% of pups survive their first year
- These sightings yielded estimates of age-, sex-, and rookery-specific survival that have standard errors ranging from 0.011-0.081 for the first 11 years. SEs are expected to decrease as additional sightings of branded sea lions from the 2000-2005 cohorts occur.
- Anticipate survival estimates calculated for sea lions branded at rookeries west of Ugamak Island in the Aleutian Islands will have a precision similar to that achieved since 2001. In this area, ~ 10 years of observational effort will be required to obtain survival rates and ~15 years for reproductive rates, but movement information will be obtained sooner.

Vital rates estimation: data quality

- Precision exceeds that initially predicted because resight probabilities are > than anticipated
- If branding continues as planned, we estimate that CVs of pooled rookery age-specific survival rate estimates will be ~ 4%.

- For Pacific Northwest: 200 animals (100 each sex) necessary to detect a 30-60% decline in survival from 0-4 years with 80% power assuming a detectability of 30-50%.

Vital rates estimation: strengths

- Monitoring of vital rates reveals how population is responding and magnitude of threats
  - For wDPS SSLs, juvenile survival in 2000s much greater than during 1980s when population was declining. Direct mortality (e.g., shooting, incidental catch, predation?) lower now.
- Enables us to model population and estimate total abundance
- Initial group of rookeries represented over half the range of wDPS SSLs in Alaska
- 2-month long field camps at rookeries provide high quality information on survival and reproduction
- Sighting probabilities higher than initially projected indicating resight protocols are effective

Vital rates estimation: weaknesses

- W & Central Aleutian rookeries not included in study until 2011.
  - Decline continuing here and data/power will be limited due to relatively small sample sizes.
- Expensive to obtain sightings and service cameras across more than 2,000 miles of southern Alaska – vessel charters > $300K/yr.
- Cameras may be used in other places to augment effort, but 100's of hours necessary to analyze images.
  - Volunteer program

At-sea habitat use

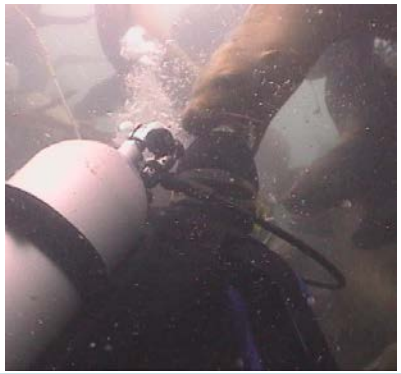
- What prey areas, habitats, and species are important to support Steller sea lion recovery?
  - Is designated critical habitat, as currently defined, adequate to protect sea lions?
  - What oceanographic features reflect important foraging habitat?

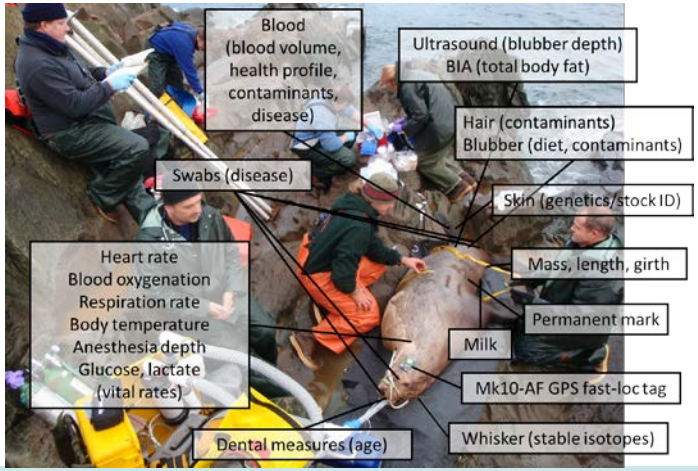
Track adult female sea lions overwinter in area of greatest decline

- Partners:
  - Alaska Department of Fish and Game
  - Vancouver Aquarium
  - University of Alaska Fairbanks

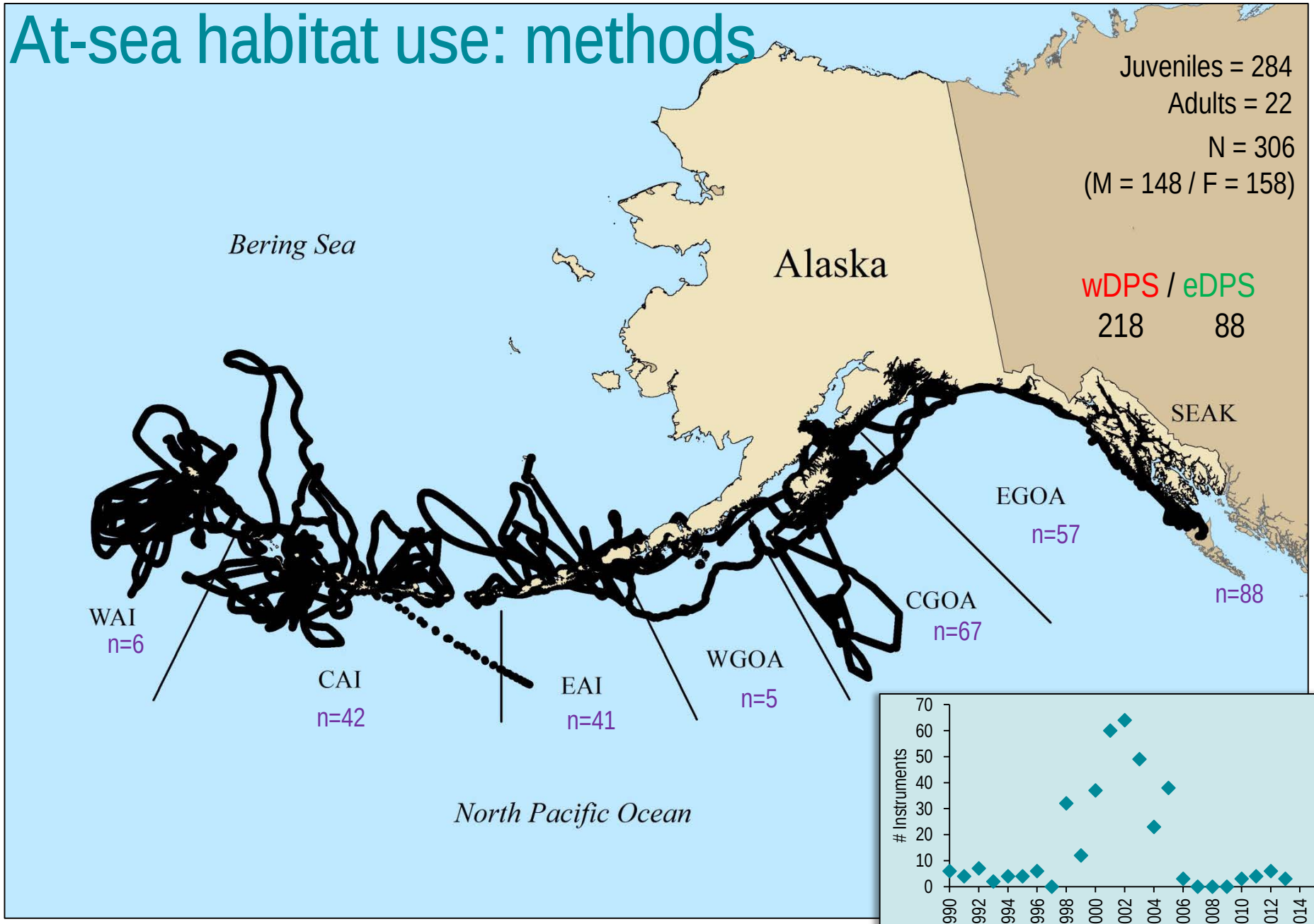
At-sea habitat use: methods overview

- Capture trips timed for animal age, season of interest and to avoid molt period (e.g. adult females captured in September-November to track over winter).
- Captures in water (juveniles, 2000-2005) and land (juveniles and adults) using research vessel support.
- Satellite-linked tags attached, multitude of measurements and samples collected.
- Tag data (binned dive behavior, locations) downloaded via satellite/Argos and processed.
- Processed data used for maps and models.



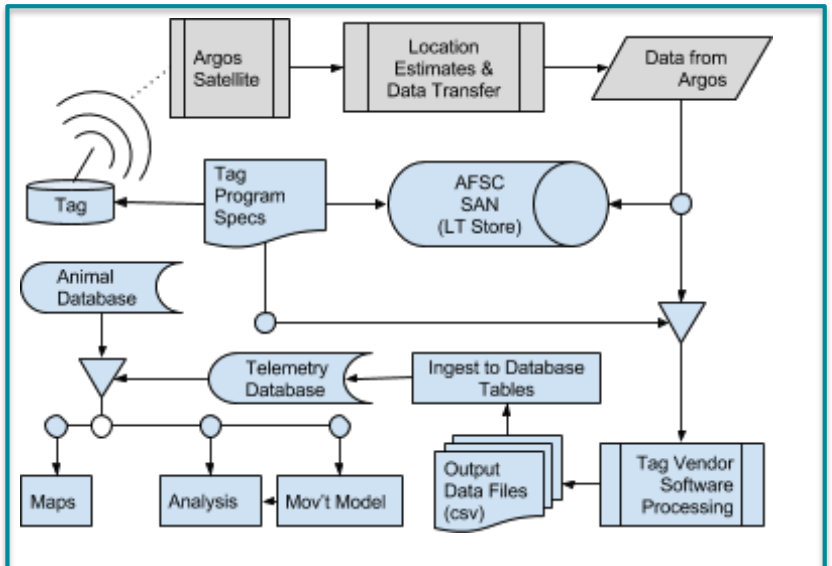


At-sea habitat use: methods

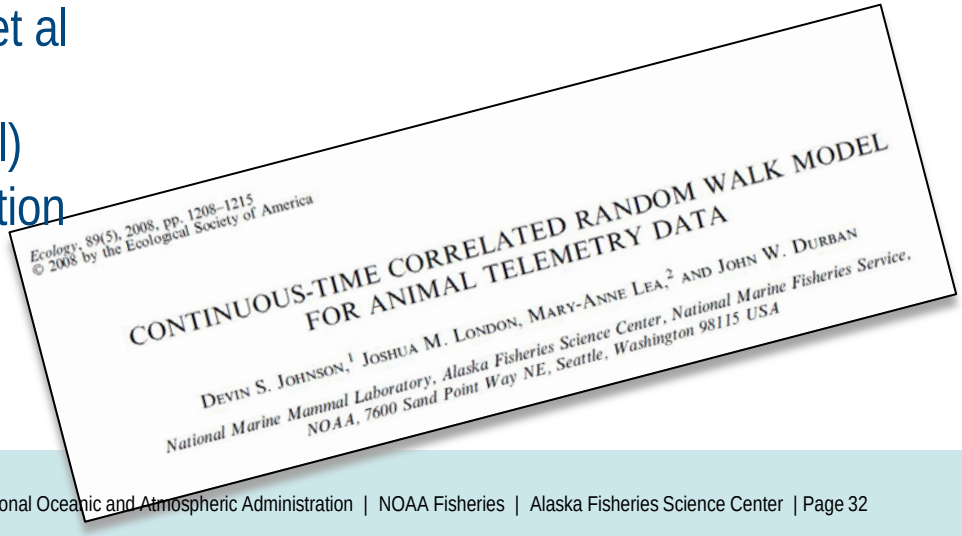


At-sea habitat use: data quality

- Recent implementation of fast-loc GPS technology
- Tag data received via Argos, pre-processing controlled by Argos & tag manufacturer
- Telemetry location data speed filtered at 2 m/s (McConnell et al. 1992)
- Location data (Argos and GPS) merged with wet/dry data via time stamp (if available)
- Animals assumed to be wet (at-sea) for days missing wet/dry data
- 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
© 2008 by the Ecological Society of America

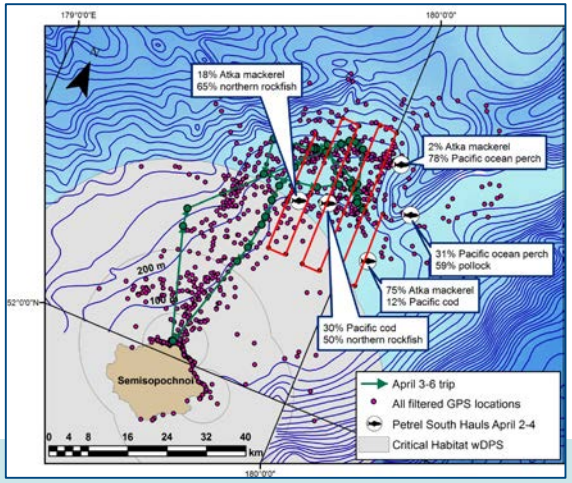
CONTINUOUS-TIME CORRELATED RANDOM WALK MODEL FOR ANIMAL TELEMETRY DATA

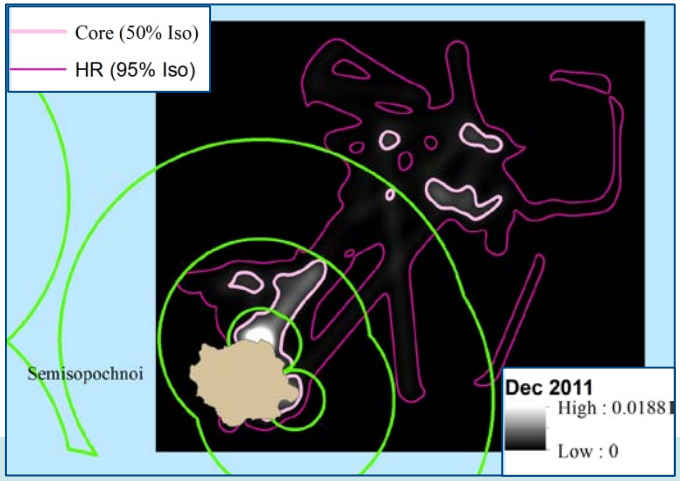
DEVIN S. JOHNSON,[1] JOSHUA M. LONDON, MARY-ANNE LEA,[2] AND JOHN W. DURBAN

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

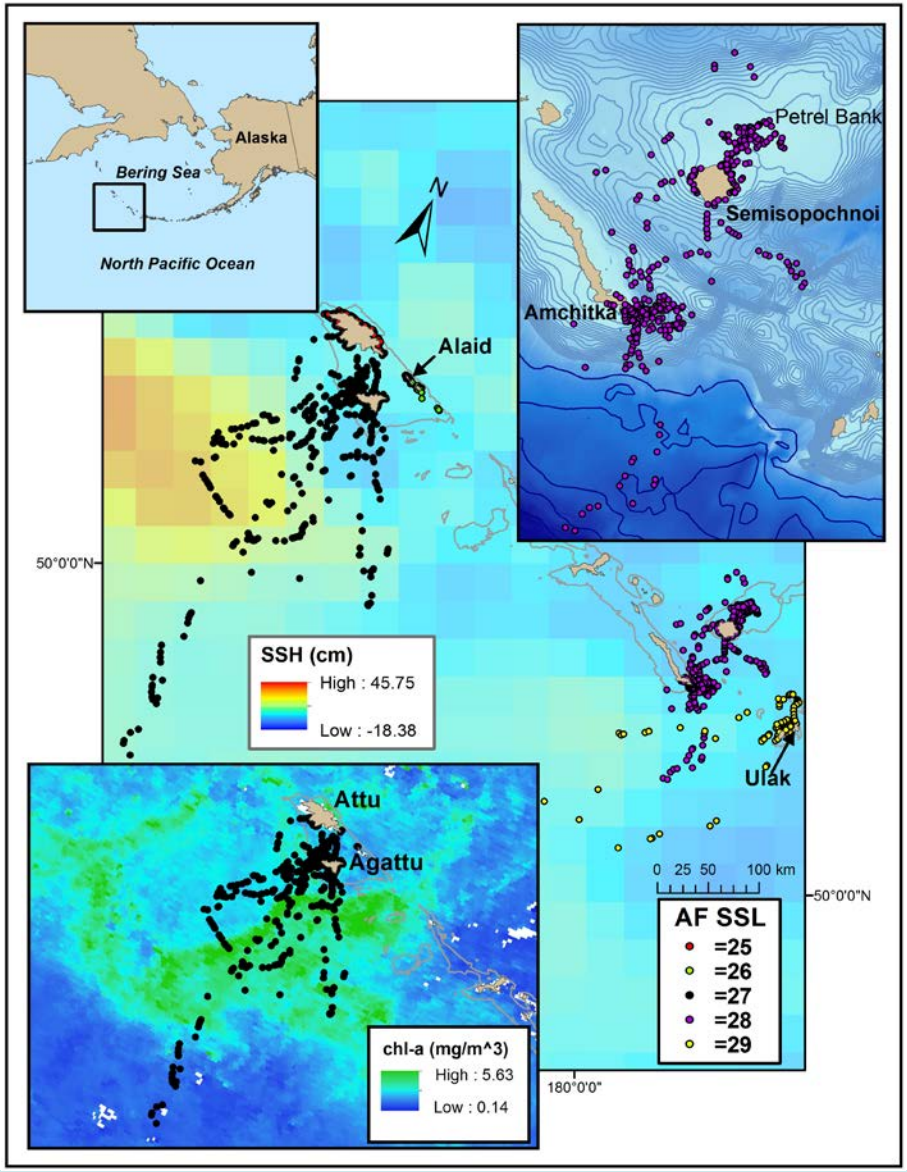
- Modeling habitat use:
  - Spatially link dive behavior variables with predicted locations.
  - Combine with categorical and continuous predictor variables in linear mixed-effects models (examples):
    - individual, month, year, season, region, % daylight, %lunar illumination
    - static environmental: bathymetry, slope, distance to nearest site, distance from shore
    - dynamic environmental: SST, chlorophyll-*a* (Aqua MODIS), sea surface height (AVISO)
  - Monthly Kernel Density Estimates (KDE; 0.5 km resolution) for each individual.
    - Binomial GAMs used to determine probability of being in home range/core areas given associated predictor variables.
    - GAMs used to examine KDE within home ranges as a function of associated predictor variables.





At-sea habitat use: strengths

- Have proven that endangered large adult female Steller sea lions can be safely captured and handled.
- First winter movements and habitat use recorded for adult female sea lions in the central-western Aleutian Islands using telemetry.
- New modeling efforts integrate habitat use of previously collected juvenile and newly acquired adult female telemetry data with dynamic environmental features obtained from remote-sensing orbital satellites (and *preliminary* bioprobes incorporated into satellite tags).



At-sea habitat use: weaknesses/limitations

- Limited sample sizes due to logistics (costs, animal accessibility, weather, etc.).
- Limited tag longevity (battery power, tag loss, etc.).
- Opportunistic deployments; thus, deployment frequency requires combining datasets over time and limits ability to explore spatial-temporal variability.
- Large complex data sets (requires database expertise and support, computing power, server storage, etc.).

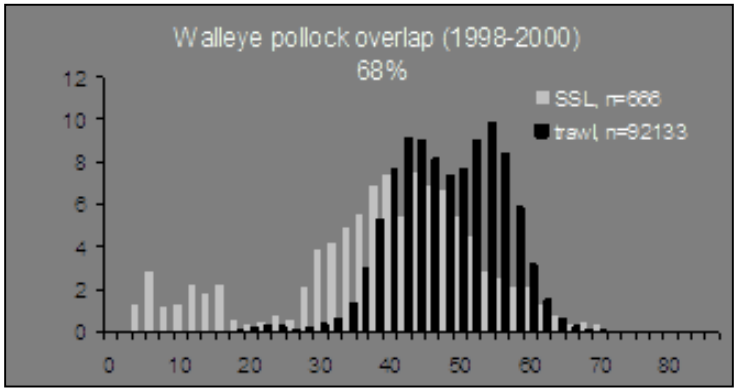
Food habits

- How does sea lion diet vary seasonally, geographically, and inter-annually?
- What prey species are important to support recovery?

- Partners:
  - Alaska Department of Fish and Game
  - Sea Mammal Research Unit, British Columbia
  - Fisheries and Oceans Canada (Nanaimo)

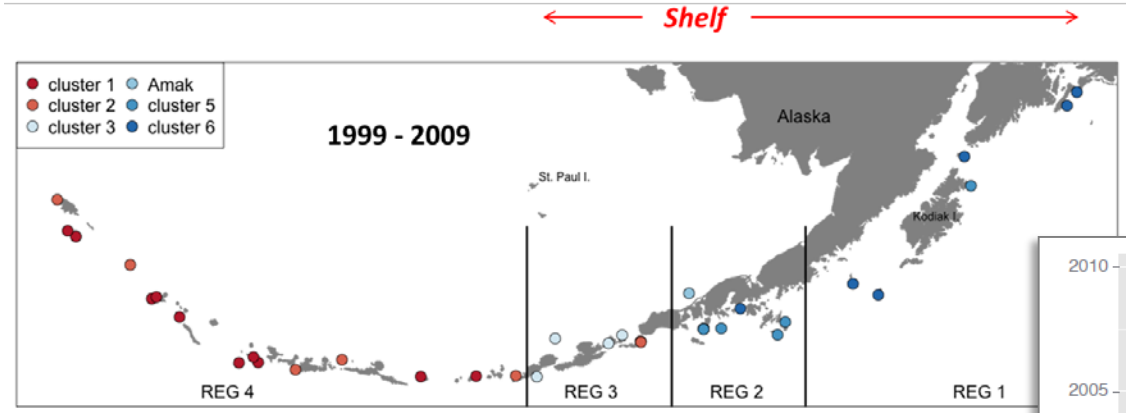
Food habits: methods

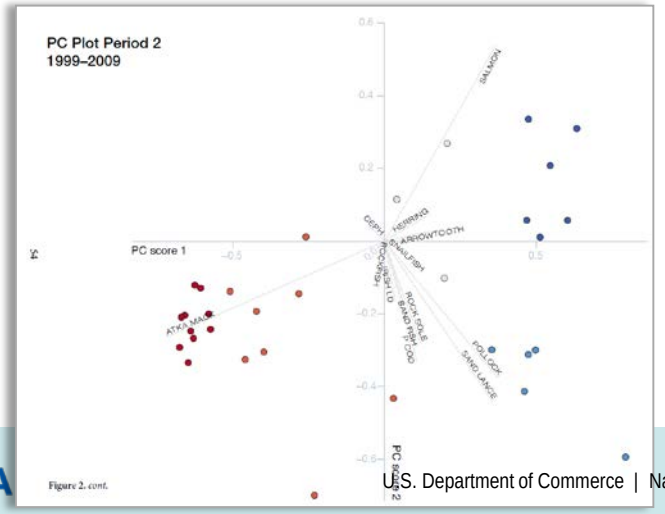
- Scats collected from summer rookeries and winter haulouts throughout Aleutian Islands and Gulf of Alaska
  - Scats processed and percent frequency of occurrence of prey species to lowest taxon possible calculated.
  - Original prey size can be estimated from fish bone and otolith regressions.

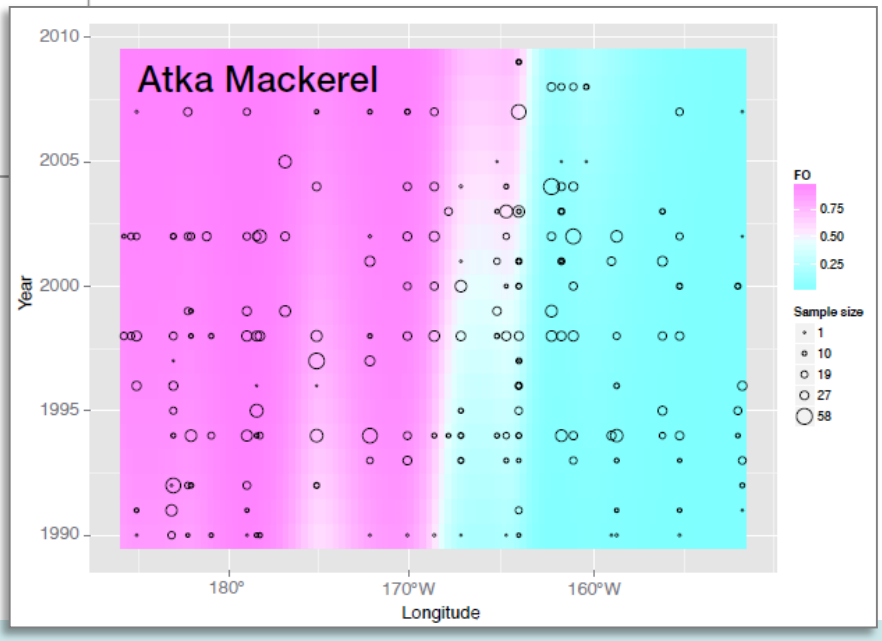


Food habits: methods

- Principal component analysis, hierarchical cluster analysis, generalized linear mixed models, and generalized additive mixed models used to reduce dimension of FO data and to examine regional and temporal trends (Sinclair et al. 2013).

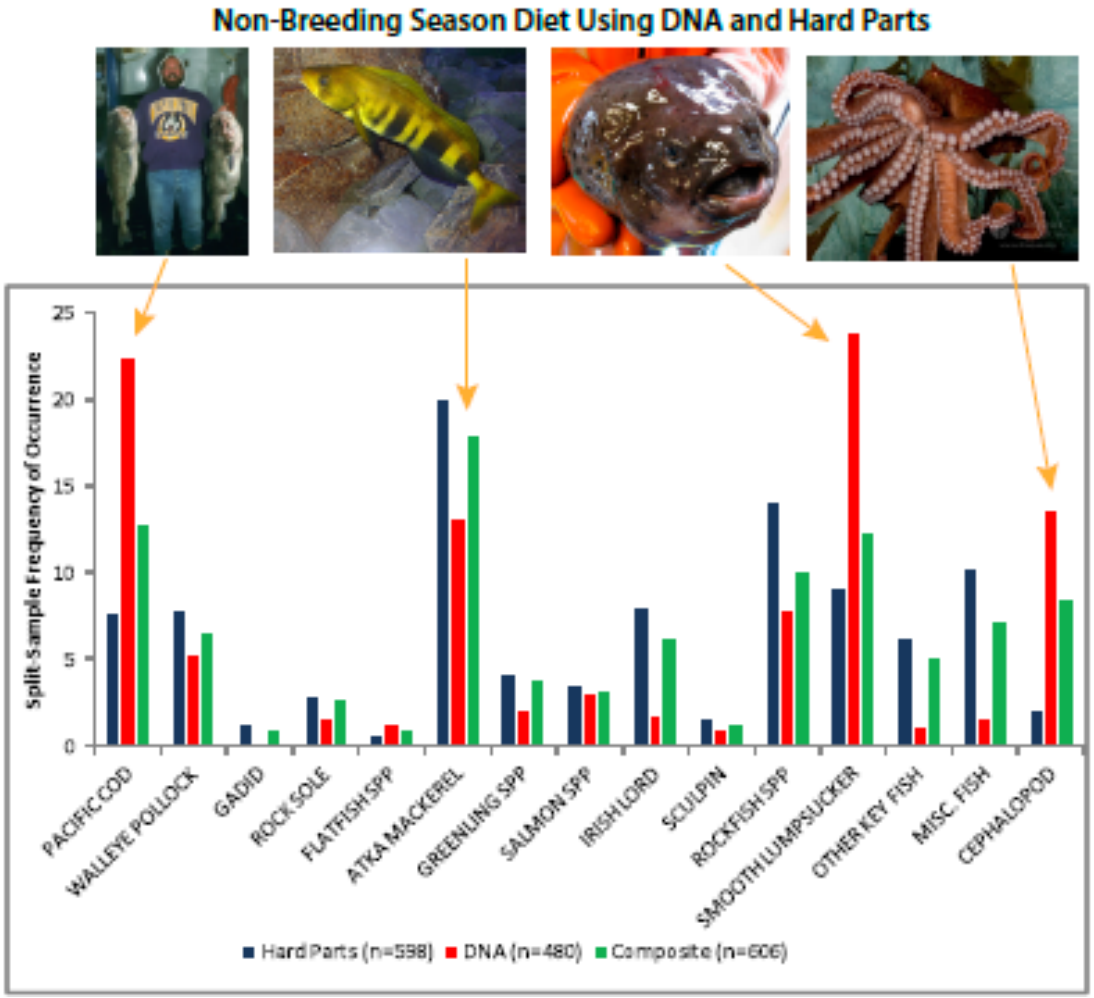






Food habits: methods

- To compare estimates of diet composition derived from scat hard parts and DNA identification, and to study the relationship between diet diversity and population trend, scats were collected from 41 sites in the Aleutian Islands.
  - Prey hard parts identified to lowest taxon level
  - DNA sequenced from scat sub-samples



Food habits: strengths

- Long-term and broad geographic collections allow comparison of diet composition over regional and decadal scales.
- Scat analysis provides information on specific prey species and sizes of prey consumed.
- DNA methods improves detection of large prey (not entirely ingested), small prey (with fragile bones), and invertebrates (with few chitinous remains).

Food habits: weakness/limitations

- Scat collections require disturbance so are generally conducted opportunistically in association with other studies.
- Scats represent relatively recent foraging and do not provide integrated long-term foraging information.
- Scats do not provide information about individual animals.
- DNA analysis of scats is expensive, consequently analysis of large sample sizes is cost prohibitive.

Steller sea lion research: communication

- Publications in peer reviewed journals
- AFSC Technical Reports
- Products for NMFS:
  - F/AKR
    - Reports or input for NEPA EA/EIS; ESA Biological Opinions and Critical Habitat analysis
  - AFSC:
    - SAFE reports
    - MMPA Stock Assessment Reports
    - AFSC Quarterly Reports
- Workshops/symposia/conferences
- Other media:
  - Tracking updates via email lists
  - NOAA video production
  - AFSC website

Steller sea lion research: data access

- AFSC website:
  - Steller sea lion pup and non-pup count databases, and list of sea lions marked since 2000.
- Data repositories:
  - GitHub
  - NOAA Oceanographic Data Center (NODC)
- PARR requirements

Steller sea lion research: recommendations

1. Continue annual population abundance surveys
   - Combined manned and unmanned systems, increase UAS capability
2. Continue observational monitoring of marked sea lions for survival/reproductive rate studies
3. Expand electronic tag deployments into under-sampled areas, and/or continue deployments in areas of concern with modified fishing management actions.
4. Continue monitoring diet, and expand use of emerging technologies for prey identification.

Steller sea lion research: questions?