Optimizing range-wide monitoring strategy for tufted puffins


ncascades.org

SAFS Quantitative Seminar
November 18, 2022


aquarium.org

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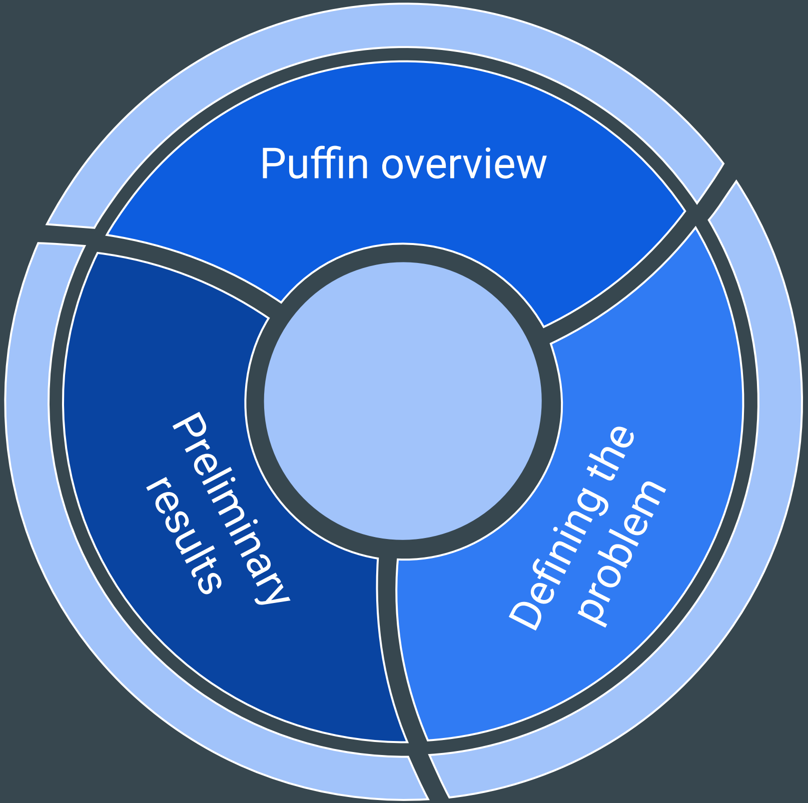
TALK OUTLINE



Scott Pearson

PUFFIN OVERVIEW

Let’s talk about Tufted Puffins

- Burrow-nesters
  - Burrows can be 5 feet deep!
- Live at sea most of the year
- Can start breeding at 3 yrs, are considered breeding adults by 5 yrs
- Feed largely on small fish, namely sand lance and capelin

Scott Pearson

Let's talk about Tufted Puffins

Scott Pearson

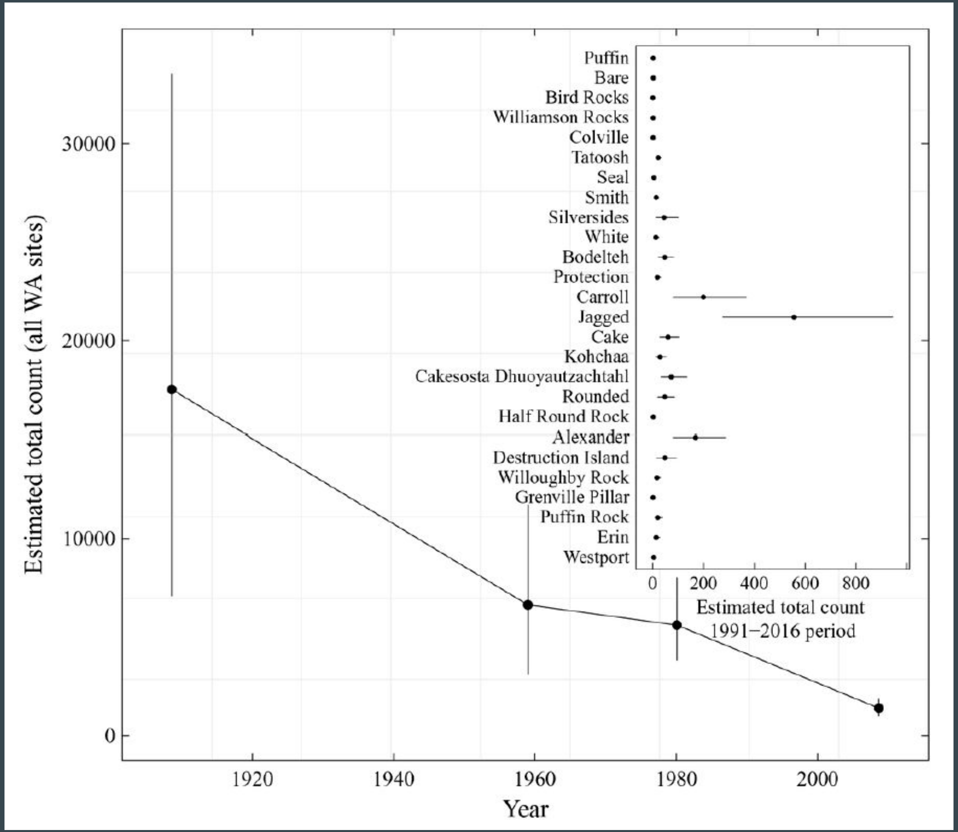
Megan Boldenow


Shawn Stephensen


All Seasons - Common
All Seasons - Uncommon
Breeding - Common
Breeding - Uncommon
Winter - Common
Winter - Uncommon
Migration - Common
Migration - Uncommon

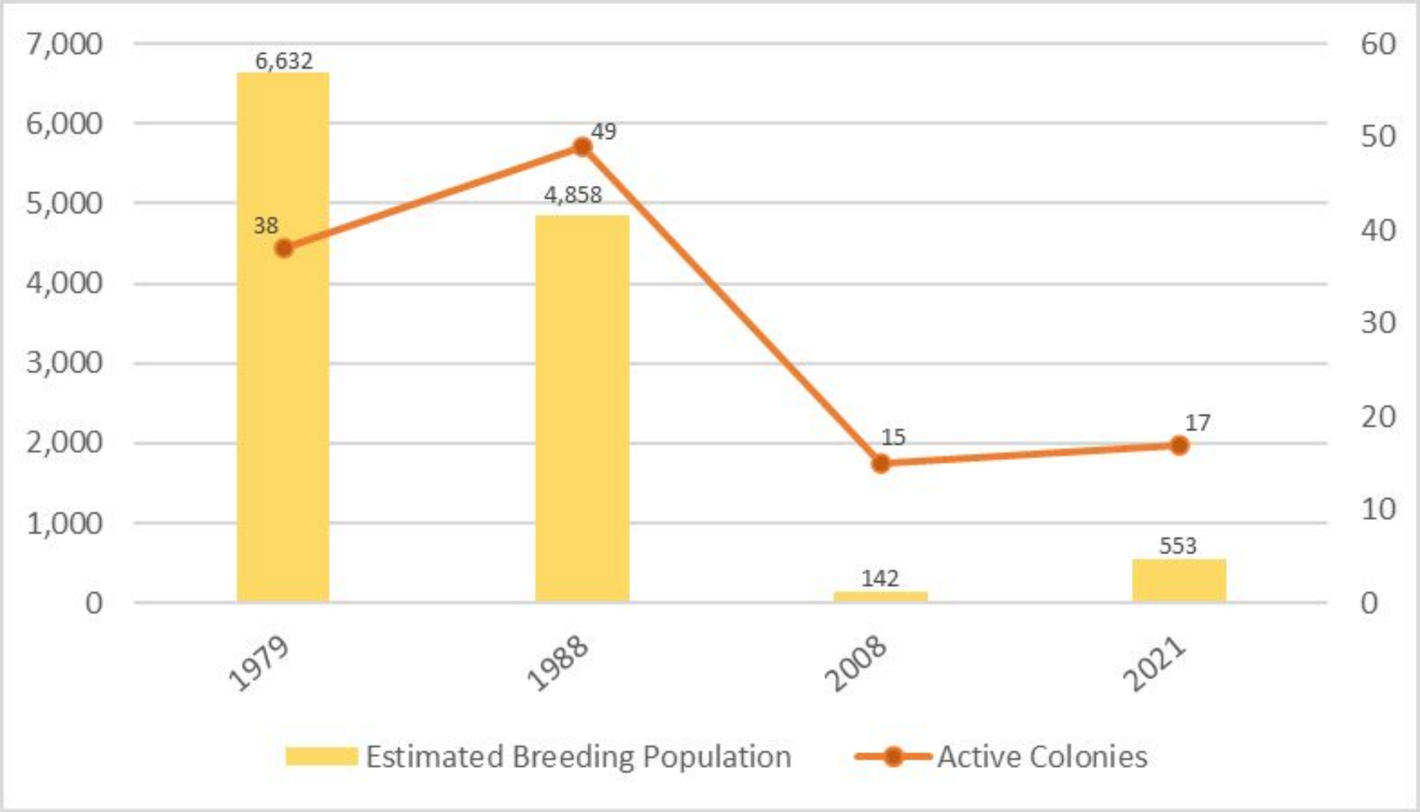
Audubon

Washington State



Pearson et al. (2022)

Oregon State

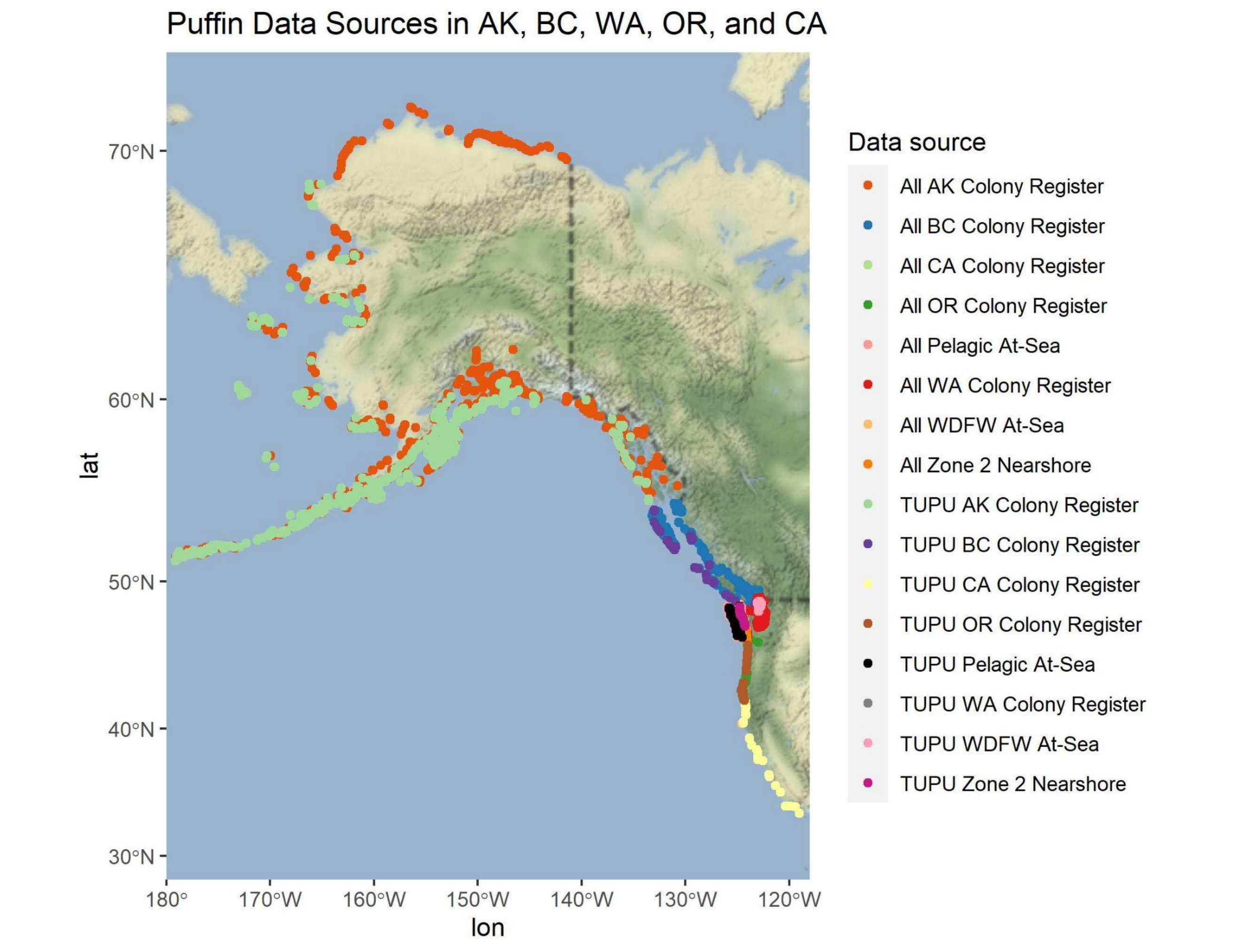


Stephensen et al. (2022)

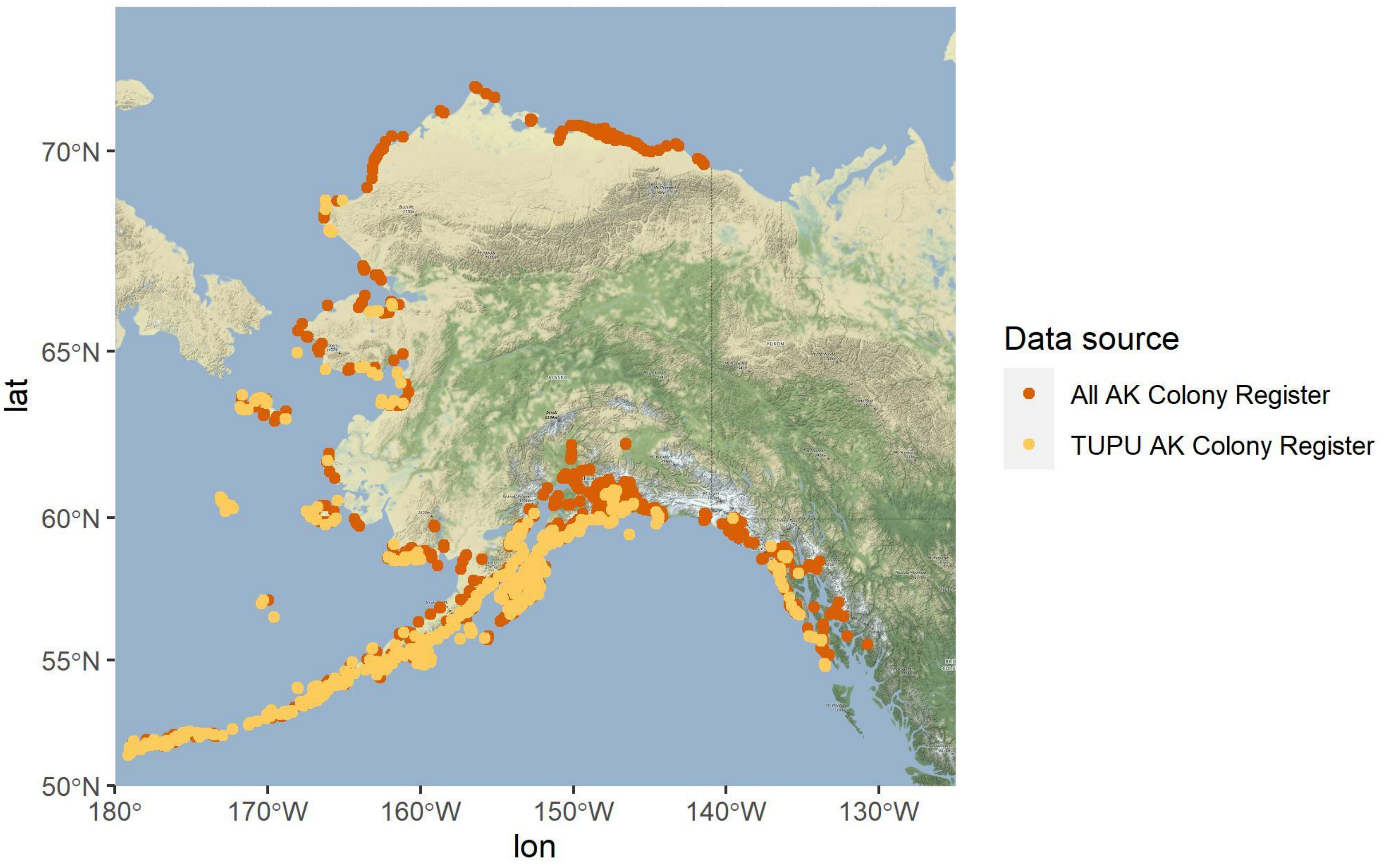
Why is this work important?

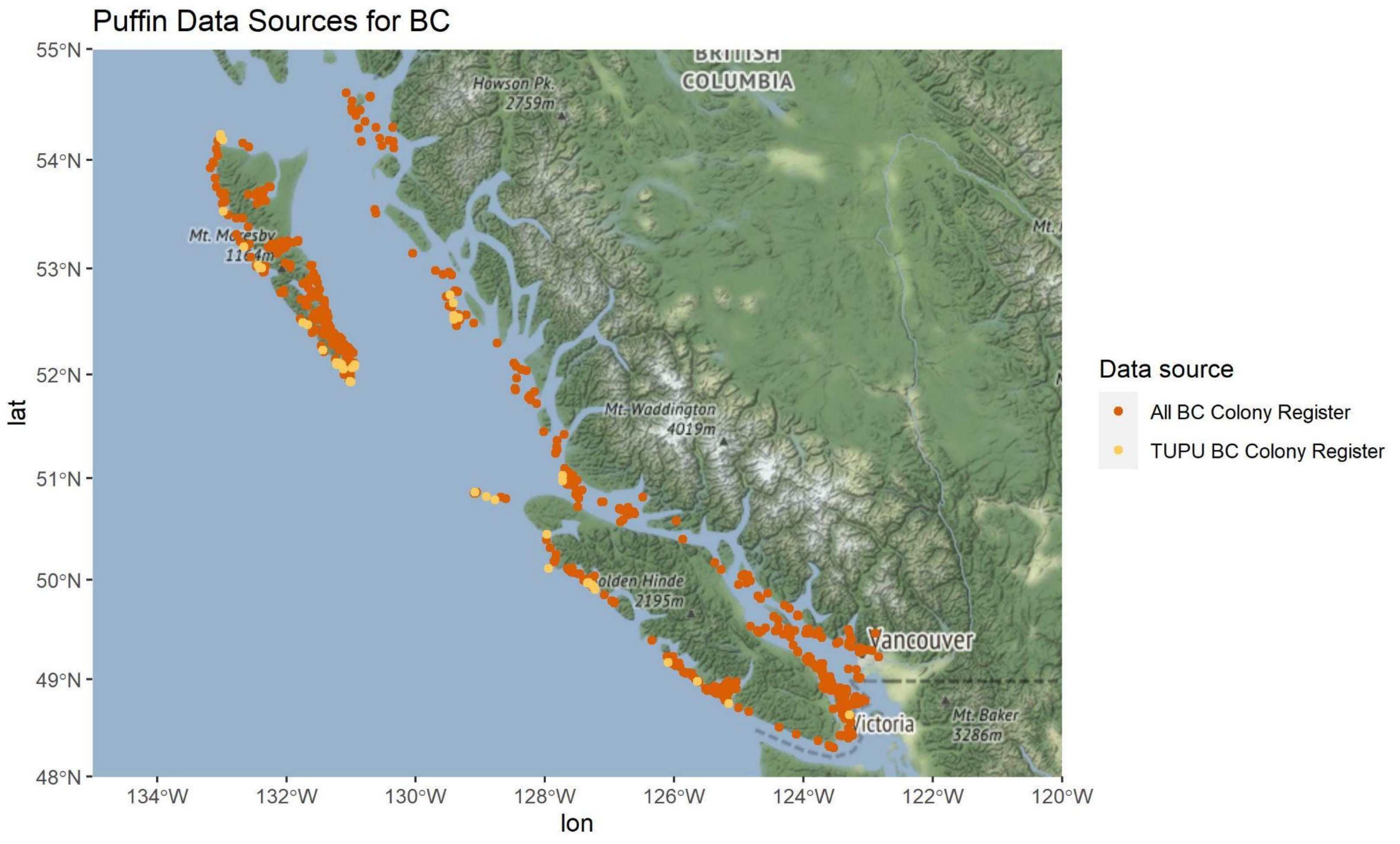
- Burrow-nesting seabirds are notoriously difficult to monitor
- Puffin monitoring efforts are largely localized, making it hard to infer long-term, large-scale population trends
- This species is data-limited
- There is great interest from federal and state agencies

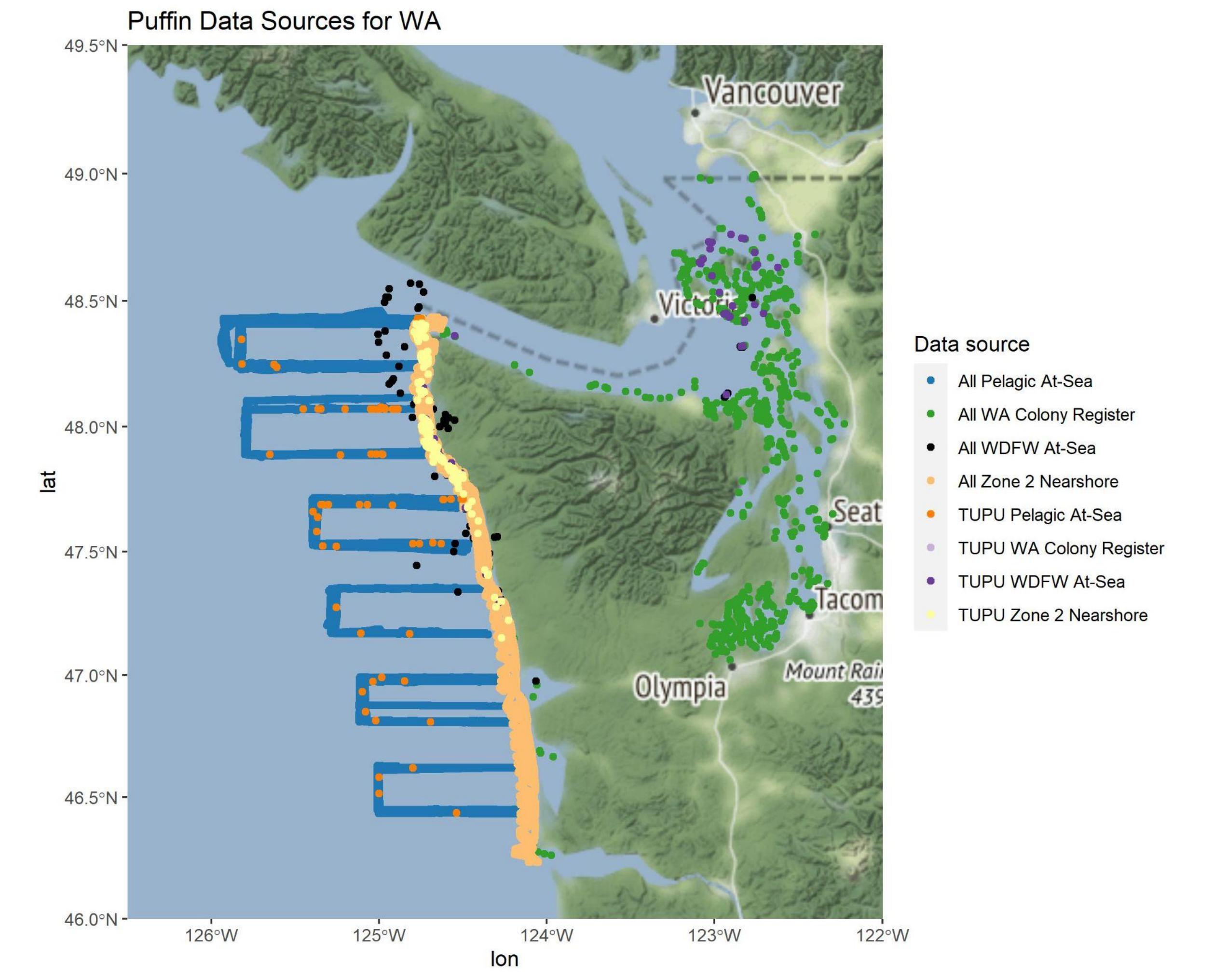
Megan Boldenow


Puffin Data Sources in AK, BC, WA, OR, and CA
Data source
All AK Colony Register
All BC Colony Register
All CA Colony Register
All OR Colony Register
All Pelagic At-Sea
All WA Colony Register
All WDFW At-Sea
All Zone 2 Nearshore
TUPU AK Colony Register
TUPU BC Colony Register
TUPU CA Colony Register
TUPU OR Colony Register
TUPU Pelagic At-Sea
TUPU WA Colony Register
TUPU WDFW At-Sea
TUPU Zone 2 Nearshore
lat
70°N
60°N
50°N
40°N
30°N
lon
180°
170°W
160°W
150°W
140°W
130°W
120°W

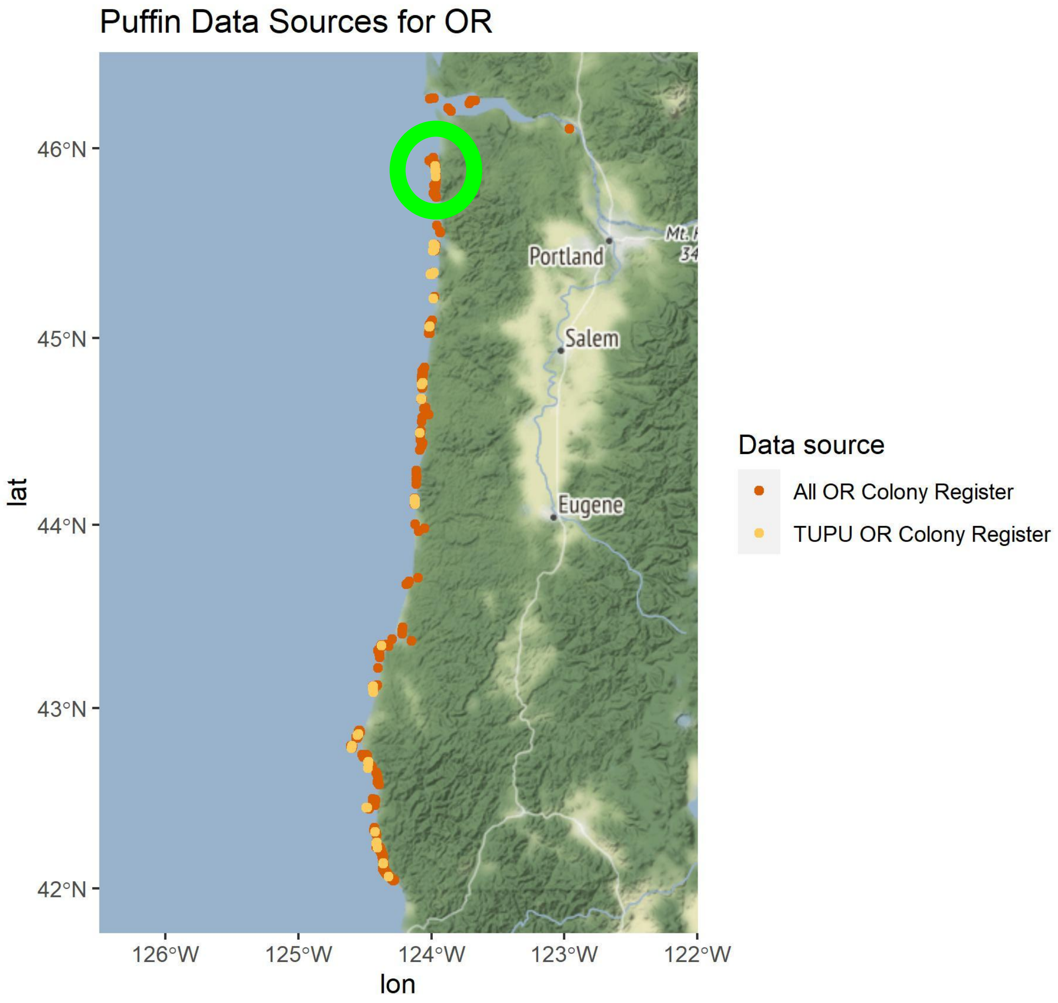
Puffin Data Sources for AK



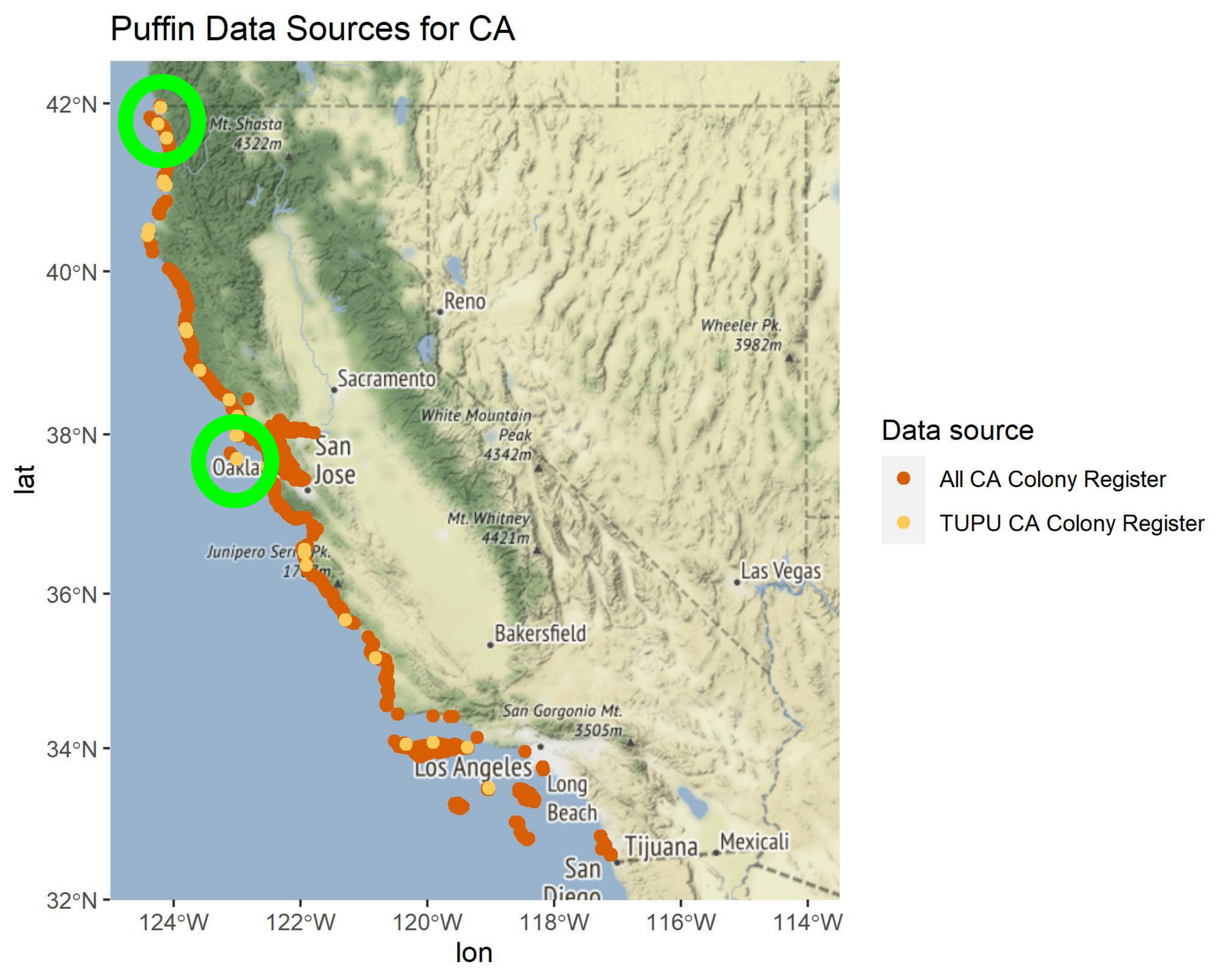

Puffin Data Sources for BC
55°N
54°N
53°N
52°N
51°N
50°N
49°N
48°N
lat
134°W
132°W
130°W
128°W
126°W
124°W
122°W
120°W
lon
BRITISH
COLUMBIA
Howson Pk.
2759m
Mt. Waddington
4019m
Vancouver
Victoria
Mt. Baker
3286m
Data source
All BC Colony Register
TUPU BC Colony Register



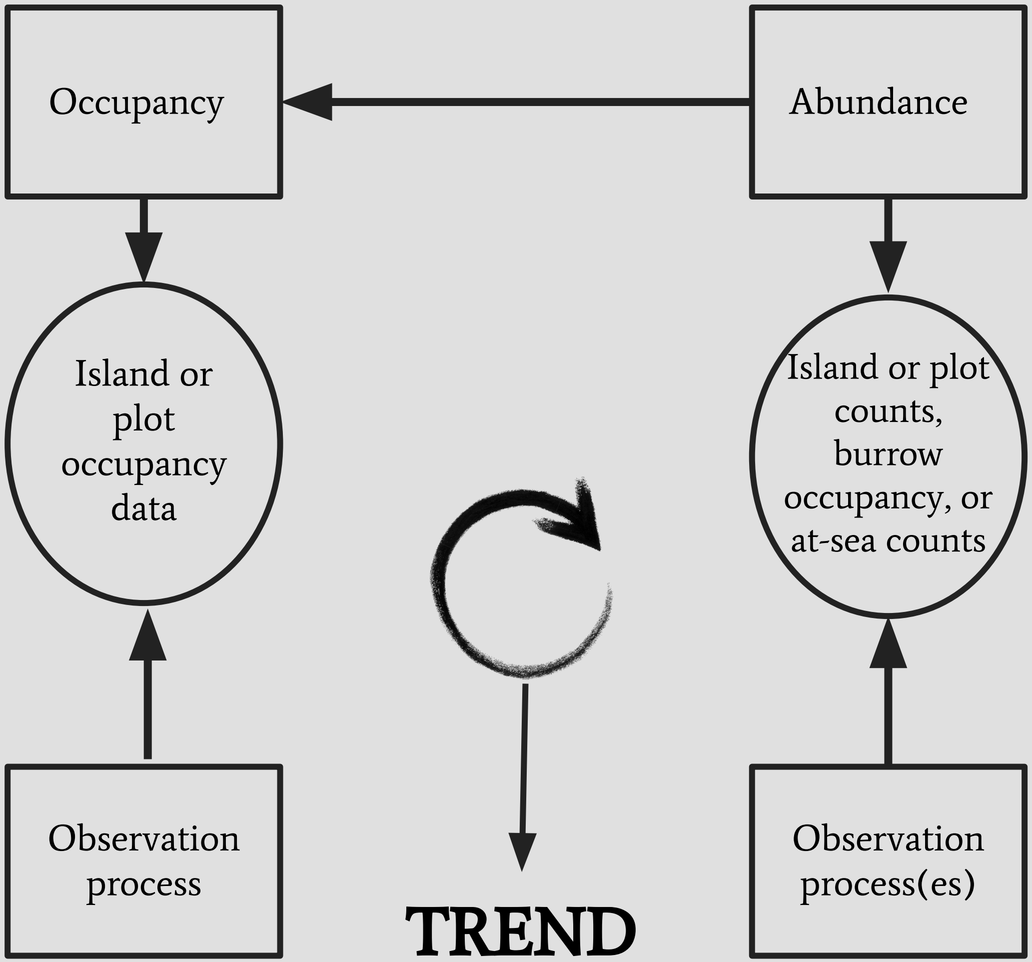
Puffin Data Sources for WA
49.5°N
49.0°N
48.5°N
48.0°N
47.5°N
47.0°N
46.5°N
46.0°N
lat
126°W
125°W
124°W
123°W
122°W
lon
Vancouver
Victoria
Seat
Tacom
Olympia
Mount Rai
439
Data source
All Pelagic At-Sea
All WA Colony Register
All WDFW At-Sea
All Zone 2 Nearshore
TUPU Pelagic At-Sea
TUPU WA Colony Register
TUPU WDFW At-Sea
TUPU Zone 2 Nearshore



Puffin Data Sources for OR
46°N
45°N
44°N
43°N
42°N
lat
126°W
125°W
124°W
123°W
122°W
lon
Portland
Salem
Eugene
Data source
All OR Colony Register
TUPU OR Colony Register


Puffin Data Sources for CA
lat
lon
42°N
40°N
38°N
36°N
34°N
32°N
124°W
122°W
120°W
118°W
116°W
114°W
Mt. Shasta 4322m
Reno
Wheeler Pk. 3982m
Sacramento
White Mountain Peak 4342m
San Jose
Mt. Whitney 4421m
Las Vegas
Bakersfield
San Gorgonio Mt. 3505m
Los Angeles
Long Beach
Tijuana
Mexicali
San Diego
Data source
All CA Colony Register
TUPU CA Colony Register

DEFINING THE PROBLEM


Occupancy
Abundance
Island or plot occupancy data
Island or plot counts, burrow occupancy, or at-sea counts
Observation process
TREND
Observation process(es)

Thinking about the population model...

$$N_{juv,site,t} = N_{ad,site,t} * f_{site,t}$$

$$N_{imm,site,t} = N_{imm,site,t-1} * \psi_{i,i} * S + N_{juv,site,t-1} * S$$

$$N_{ad,site,t} = N_{imm,site,t-1} * (1 - \psi_{i,i}) * S + N_{ad,site,t-1} * S$$

Thinking about the population model...

$$N_{juv,site,t} = N_{ad,site,t} * f_{site,t}$$

$$N_{imm,site,t} = N_{imm,site,t-1} * \psi_{i,i} * S + N_{juv,site,t-1} * S$$

$$N_{ad,site,t} = N_{imm,site,t-1} * (1 - \psi_{i,i}) * S + N_{ad,site,t-1} * S$$

$$\Downarrow$$

$$N_{site,t} = N_{site,t-1} * \lambda_{site,t}$$

Apparent survival

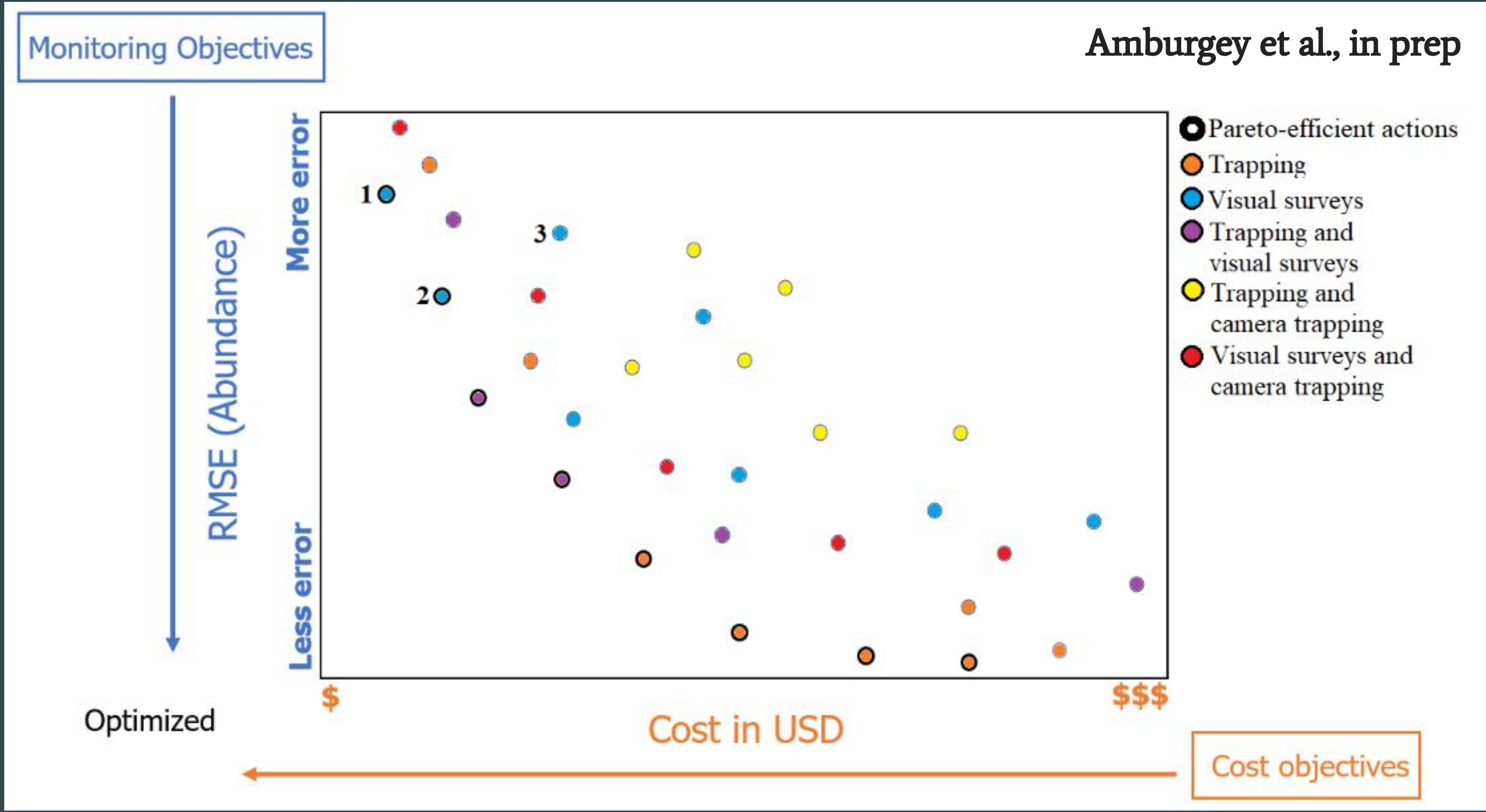
- Morrison et al. (2011)
  - Triangle Island, BC
  - 96 banded TUPU, mostly 5-yo+ breeding adults; annual survival of females 0.96 +/- 0.05; males 0.91 +/- 0.06
- Morrison et al. (2009)
  - Triangle Island, BC
  - 133 banded TUPU fledglings; proportion resighted over a 6-yr period
- Vodolazova et al. (2021)
  - Russia
  - 44 marked TUPU, return rates

What is current project goal?

- Identify and evaluate possible range-wide monitoring strategies based on performance and cost

audubon.org

Optimality & making complex decisions



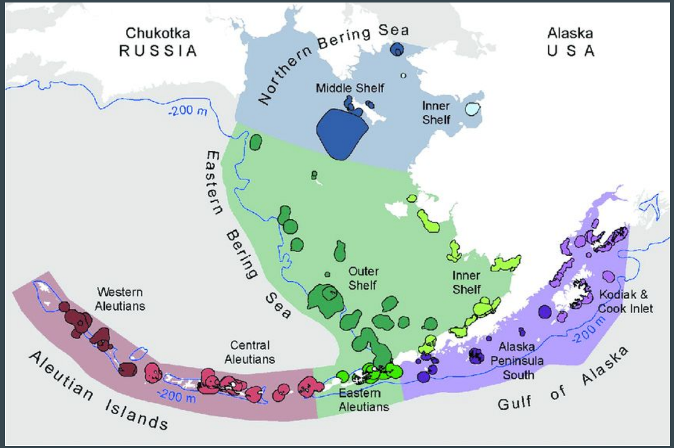
What are work plan steps?

- Define state space and temporal space
- Define monitoring objectives
- Identify monitoring alternatives
- Simulate data from monitoring alternatives and evaluate statistical performance
- Develop cost model and estimate cost of alternatives
- Present tradeoffs for discussion given performance and cost

Seattle Aquarium

Define state space and temporal space

- Allowing inference across five LMEs:
  - California Current
  - Gulf of Alaska
  - Bering Sea – Aleutian Islands
  - East Bering Sea
  - North Bering - Chukchi Seas
- Annual plan for foreseeable future?



Smith et al. (2019)

Transboundary Water Assessment Programme

Define monitoring objectives

American Bird Conservancy

- Maximize the probability of correctly identifying trend in abundance
- Minimize cost
- Minimize disturbance of monitoring activities

Identify Monitoring Alternatives (e.g., by LME)

What metric of abundance?	Site Selection (choose one)	Sampling Method (choose 1 or more)	Sampling Intensity (choose 1 or more)	Data analysis (choose 1 or more)

Identify Monitoring Alternatives (e.g., by LME)

What metric of abundance?	Site Selection (choose one)	Sampling Method (choose 1 or more)	Sampling Intensity (choose 1 or more)	Data analysis (choose 1 or more)
# burrows? # occupied burrows? # indiv at colony?				

Identify Monitoring Alternatives (e.g., by LME)

What metric of abundance?	Site Selection (choose one)	Sampling Method (choose 1 or more)	Sampling Intensity (choose 1 or more)	Data analysis (choose 1 or more)
	Random sample Stratified sample Adaptive sampling Maintain existing sites			

Identify Monitoring Alternatives (e.g., by LME)

What metric of abundance?	**Site Selection (choose one)**	**Sampling Method (choose 1 or more)**	**Sampling Intensity (choose 1 or more)**	**Data analysis (choose 1 or more)**
		Presence / absence Repeat boat-based Circular plots Permanent plots Line transect surveys At-sea surveys Time-lapse photos		

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			Number of sites Number of surveys Length of surveys Number of observers	

Identify Monitoring Alternatives (e.g., by LME)

What metric of abundance?	Site Selection (choose one)	Sampling Method (choose 1 or more)	Sampling Intensity (choose 1 or more)	Data analysis (choose 1 or more)
				GLM Integrated occupancy/ abundance Occupancy Abundance Reproductive success

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# burrows? # occupied burrows? # indiv at colony?	**Random sample** Stratified sample Adaptive sampling Maintain existing sites	Presence / absence Repeat boat-based **Circular plots** Permanent plots Line transect surveys At-sea surveys Time-lapse photos	**Number of sites** Number of surveys Length of surveys Number of observers	**GLM** Integrated occupancy/ abundance Occupancy Abundance Reproductive success

Develop cost model and estimate cost of alternatives

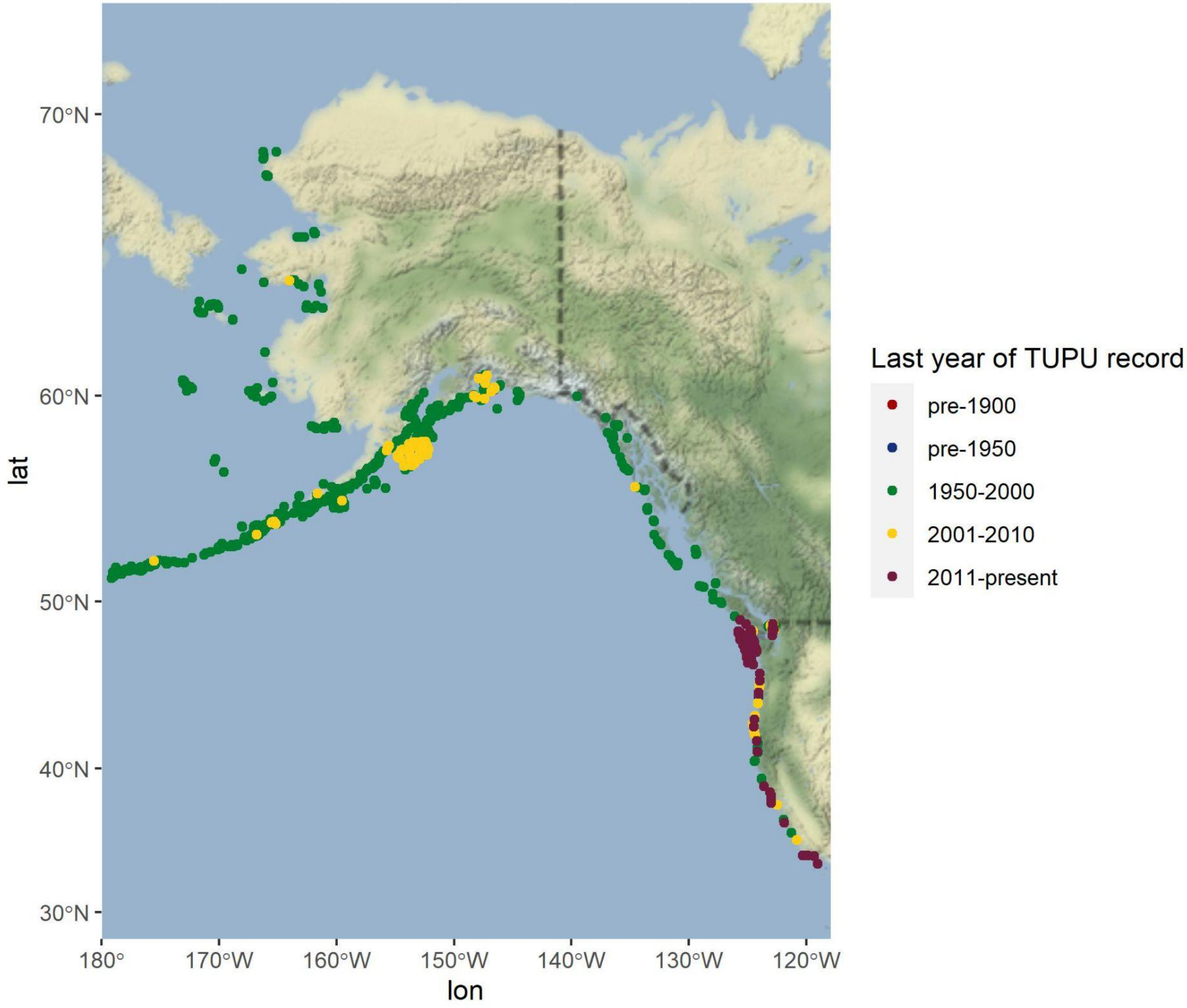
The Atlantic

- More intensive monitoring comes at a cost
    - Will need to collect cost data for various strategies

Identify Monitoring Alternatives (e.g., by LME)

What metric of abundance?	Site Selection (choose one)	Sampling Method (choose 1 or more)	Sampling Intensity (choose 1 or more)	Data analysis (choose 1 or more)
# burrows? # occupied burrows? # indiv at colony?	Random sample Stratified sample Adaptive sampling Maintain existing sites	**Presence / absence** **Repeat boat-based** **Circular plots** **Permanent plots** **Line transect surveys** **At-sea surveys** **Time-lapse photos**	Number of sites Number of surveys Length of surveys Number of observers	GLM Integrated occupancy/abundance Occupancy Abundance Reproductive success

We were also interested in how TUPU data varied across time


70°N
60°N
50°N
40°N
30°N
lat
180°
170°W
160°W
150°W
140°W
130°W
120°W
lon
Last year of TUPU record
pre-1900
pre-1950
1950-2000
2001-2010
2011-present

Presence/absence surveys

Shawn Stephensen

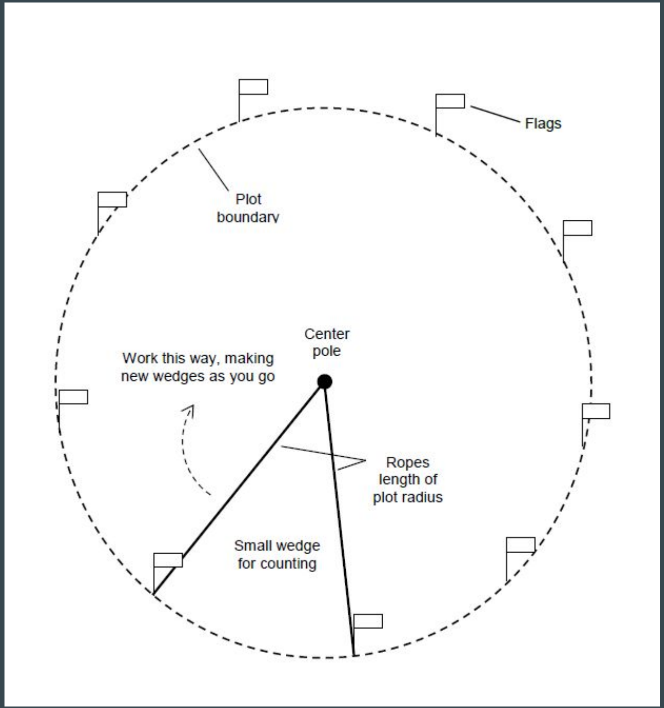
- Boat-based

Repeat boat-based counts

- Repeat visits by boat spaced one week or so apart
- Birds counted on land, water, and in air

Scott Pearson

Random circular plots



AMNWR Protocol 13, V 1.5

- 2.5-m radius circular plots placed randomly and (ideally) stratified by habitat quality

Lisanne Petracca

At-sea surveys

- Birds systematically counted away from colony

usgs.gov

1-m^2 quadrats along linear transects

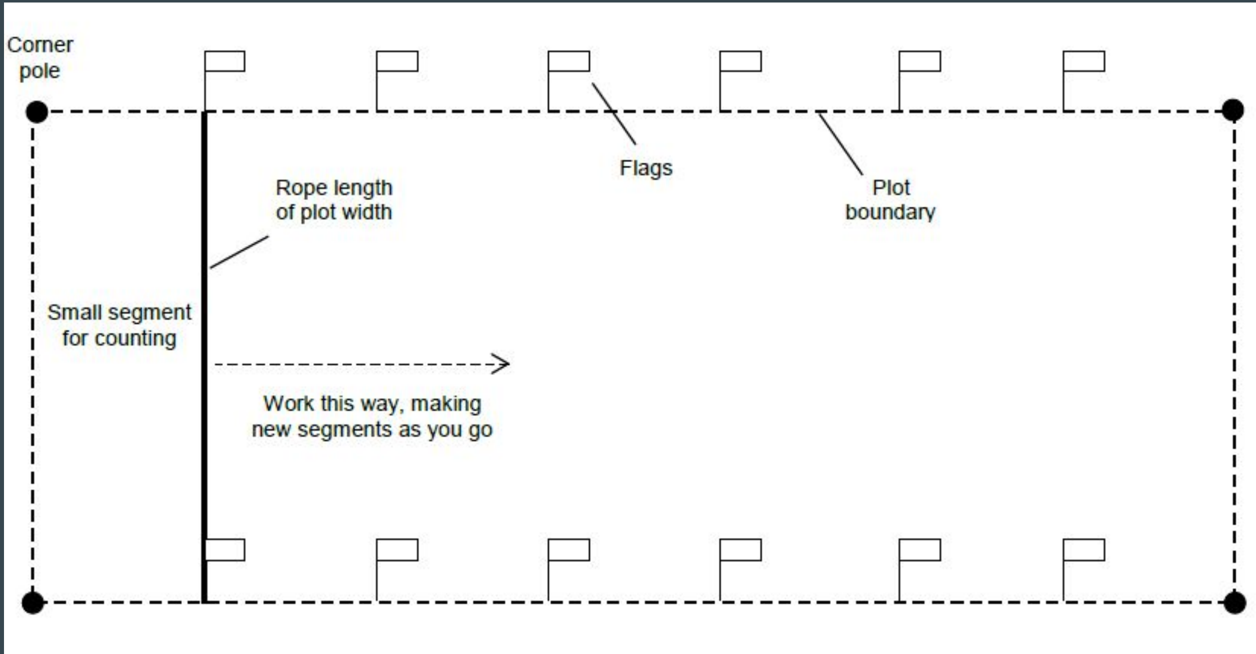
Lisanne Petracca

- 100-m transect in which 1-m^2 quadrats are assessed every 5 m


Josh Adams

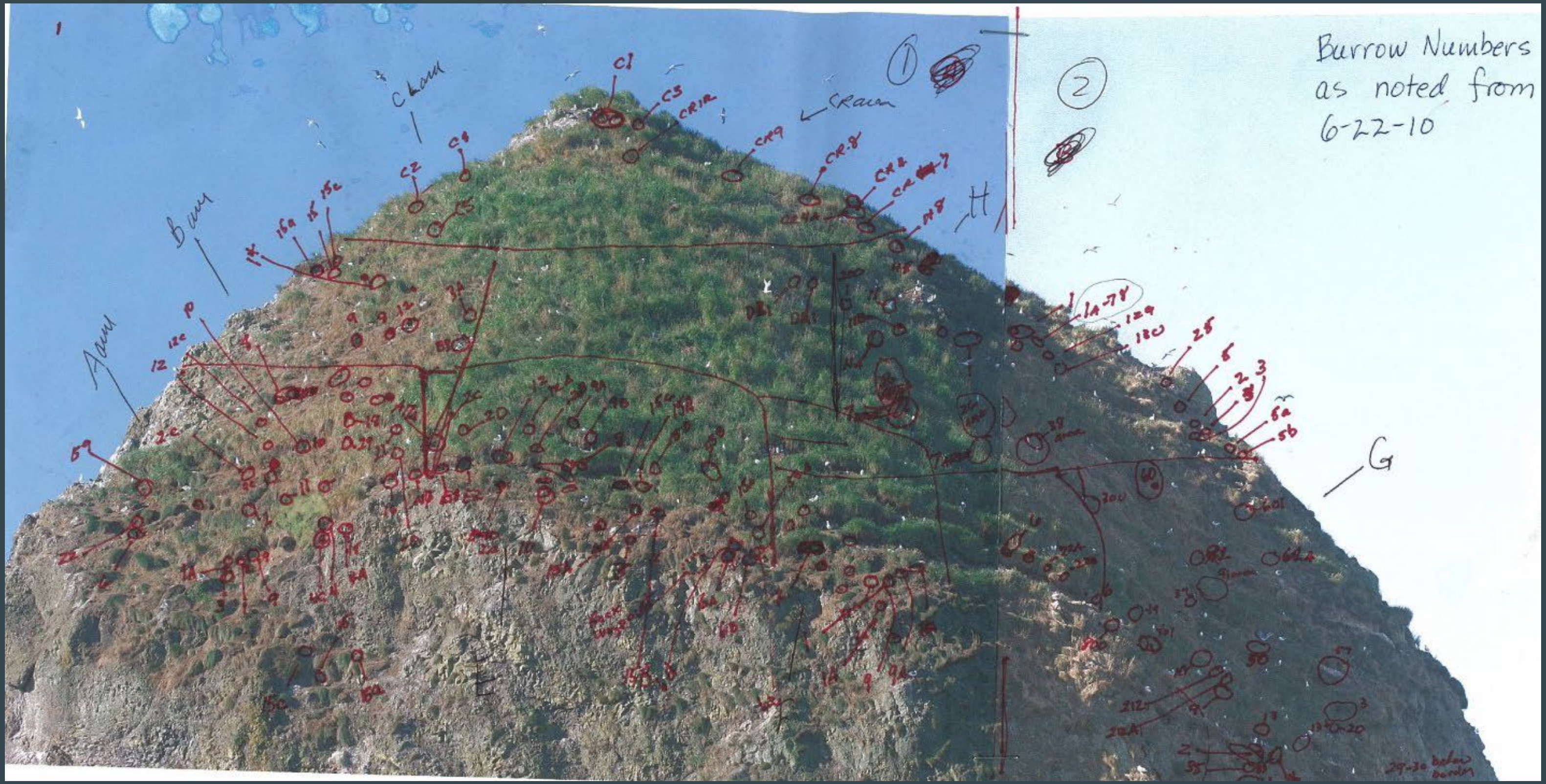
Permanent plots

- These plots are circular or rectangular
- Are of various sizes (100 - 300+ m^2)



AMNWR Protocol 13, V 1.5

Time-lapse-photography counts of birds attending the colony



Shawn Stephensen

Can be a “mix and match” strategy

What metric of abundance?	Site Selection (choose one)	Sampling Method (choose 1 or more)	Sampling Intensity (choose 1 or more)	Data analysis (choose 1 or more)
# burrows? # occupied burrows? # indiv at colony?	Random sample Stratified sample Adaptive sampling Maintain existing sites	**Presence / absence** **Repeat boat-based** **Circular plots** **Permanent plots** **Line transect surveys** **At-sea surveys** **Time-lapse photos**	Number of sites Number of surveys Length of surveys Number of observers	GLM Integrated occupancy/abundance Occupancy Abundance Reproductive success

Work plan steps

Scott Pearson

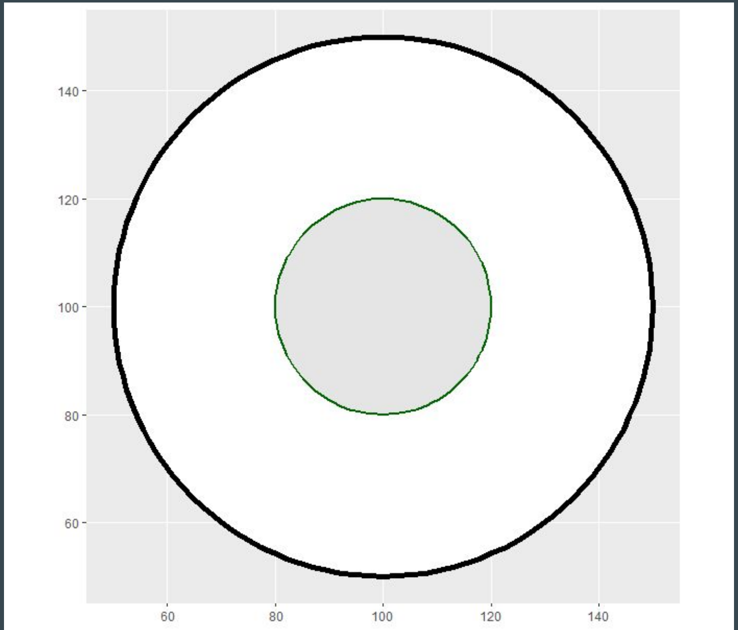
- Simulate
  - P/A surveys
  - repeat boat-based surveys
  - 2.5-m radius circle plots
  - permanent plots
  - 1-m^2 quadrats
  - time-lapse photos
- To what extent do different strategies correctly identify trends in abundance?
- Collect information for cost model
  - Maximize power to detect trend with minimized cost

PRELIMINARY RESULTS

Identify Monitoring Alternatives (e.g., by LME)

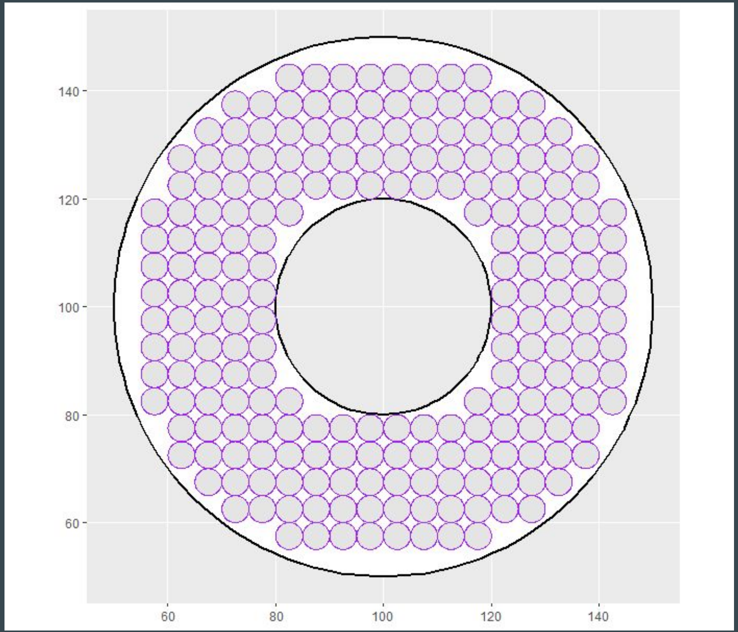
What metric of abundance?	Site Selection (choose one)	Sampling Method (choose 1 or more)	Sampling Intensity (choose 1 or more)	Data analysis (choose 1 or more)
# burrows? # occupied burrows? # indiv at colony?	**Random sample** Stratified sample Adaptive sampling Maintain existing sites	Presence / absence Repeat boat-based **Circular plots** Permanent plots Line transect surveys At-sea surveys Time-lapse photos	**Number of sites** Number of surveys Length of surveys Number of observers	**GLM** Integrated occupancy/abundance Occupancy Abundance Reproductive success

Simulating 2.5-m circular plots



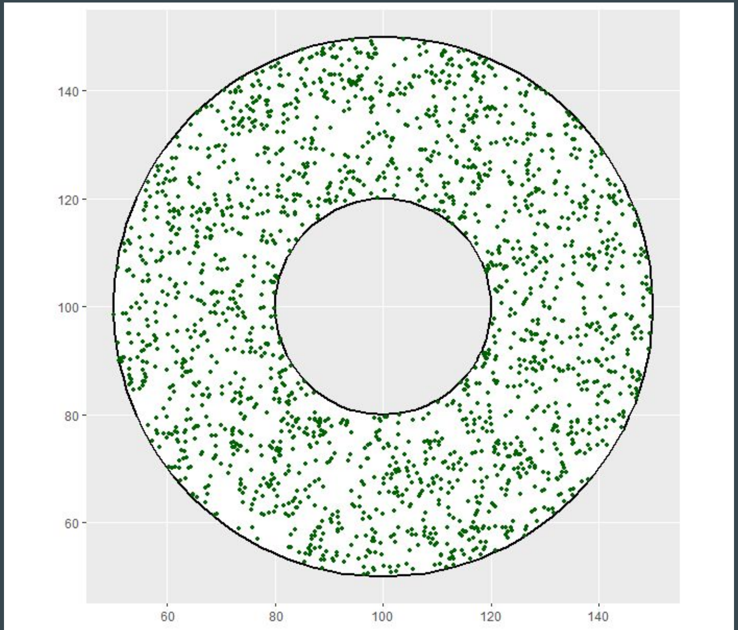
- Here we have a single hypothetical colony
  - Real size approximates Aiktak Island, an island of ~1.5 km^2 with >100K puffins
- Assigned outer 30 m “suitable” habitat

Simulating 2.5-m circular plots



- Created 2.5-m circular plots in suitable habitat

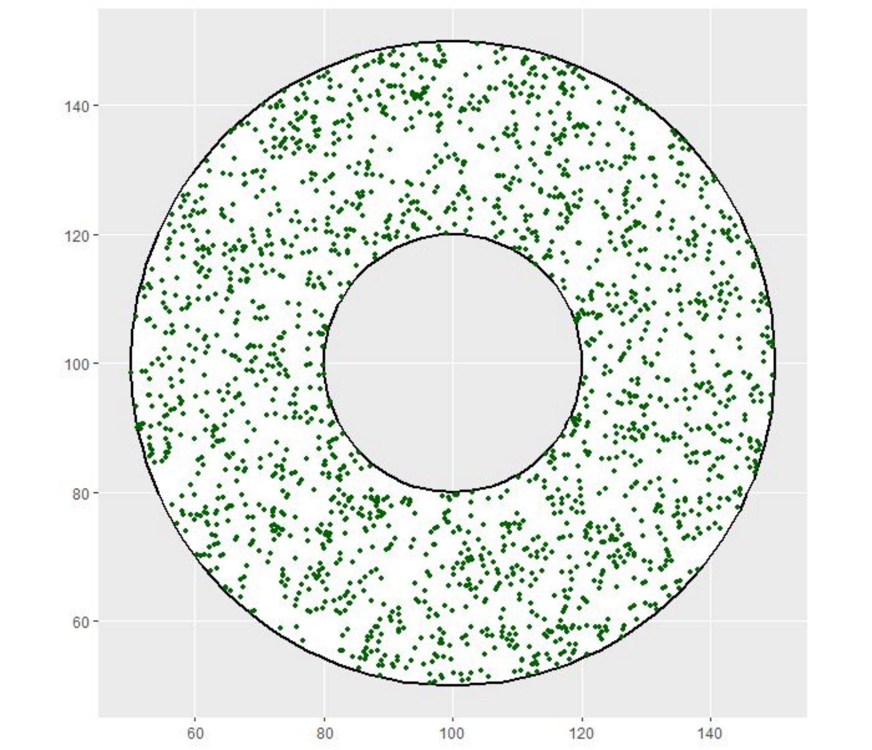
Simulating 2.5-m circular plots



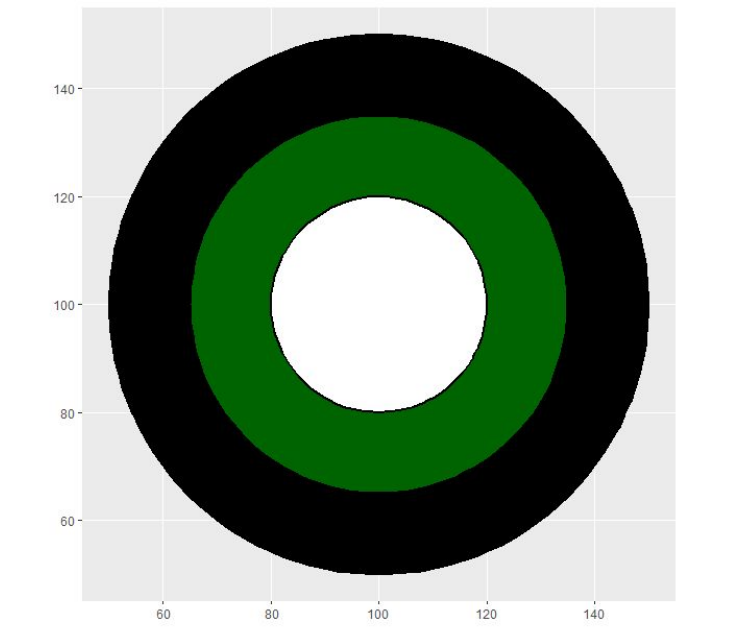
- Created clustered point processes of burrows that matched mean and max # burrows per plot

What on earth is a clustered point process?

- A Poisson point process is a collection of mathematical points randomly located in mathematical space
- In a *cluster* point process, randomly located points tend to form random clusters
- To simulate one, you provide values for
  - Intensity of the Poisson process for cluster centers
  - Mean number of points per cluster
  - Standard deviation of random displacement of a point from its cluster center



Simulating 2.5-m circular plots

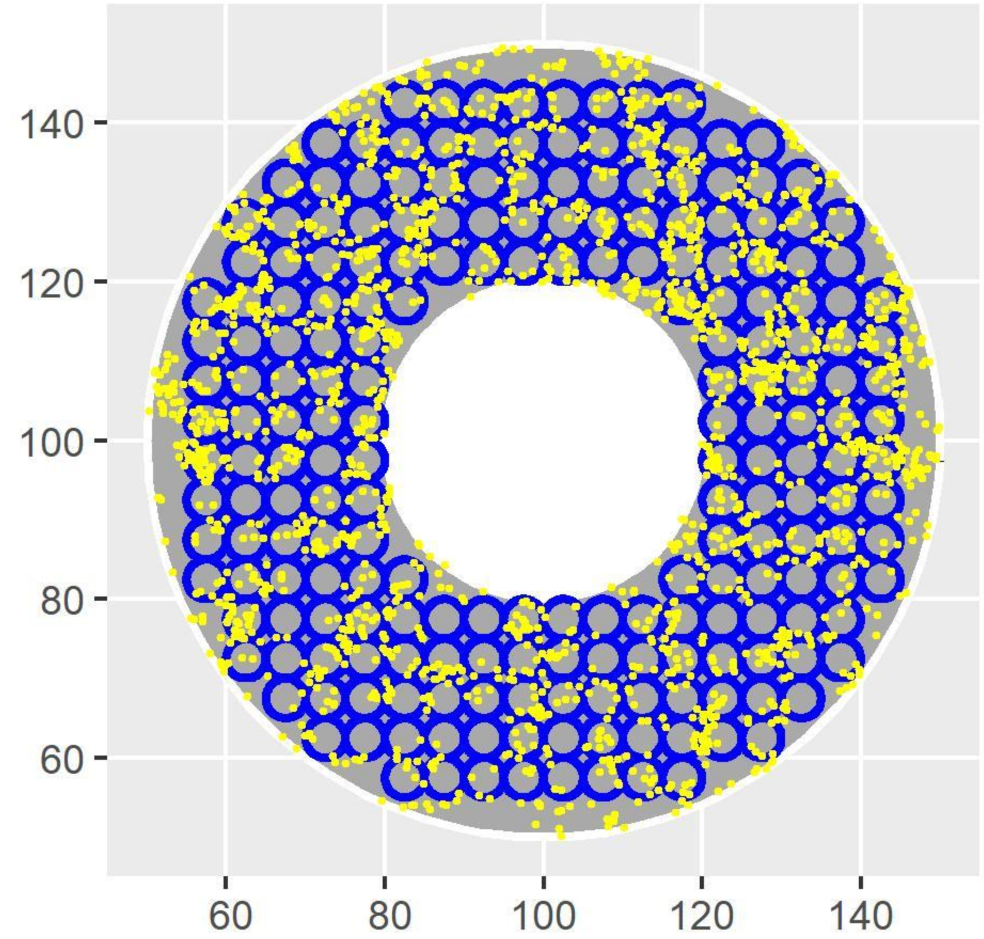


- Assigned outer 15-m buffer as habitat that is not able to be surveyed bc on cliff face

Simulation steps: single point in time

- Created 100 point processes that best represented observations
- Then ran 100 simulations on each point process that varied
    - Number of plots visited (50, 100, 250, 500, 1000)
- Assessed how well different number of plots visited captured true burrow density

Lisanne Petracca


140
120
100
80
60
60
80
100
120
140

Estimation of burrow abundance

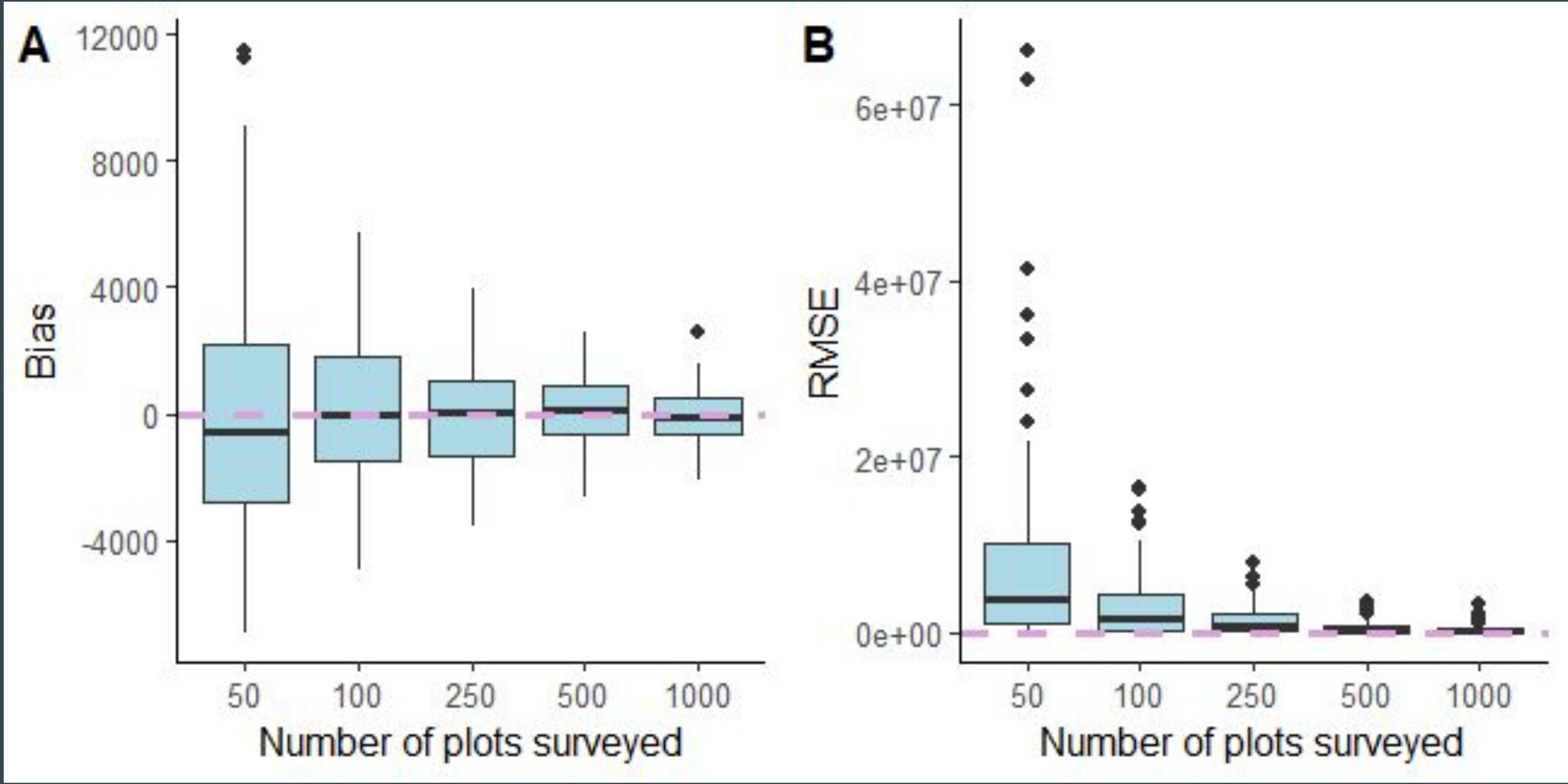
$$N_{burrows\ per\ plot} \sim negbin(\mu, \theta)$$

$$M = \frac{area_{total}}{area_{plot}}$$

$$\widehat{N} = M\bar{\mu}$$

$$s^2 = \bar{\mu} + \frac{\bar{\mu}^2}{\bar{\theta}}$$

$$\widehat{var}\,\widehat{N} = M^2 \frac{s^2}{m}\left(1 - \frac{m}{M}\right)$$



A
12000
8000
4000
0
-4000
Bias
50
100
250
500
1000
Number of plots surveyed
B
6e+07
4e+07
2e+07
0e+00
RMSE
50
100
250
500
1000
Number of plots surveyed

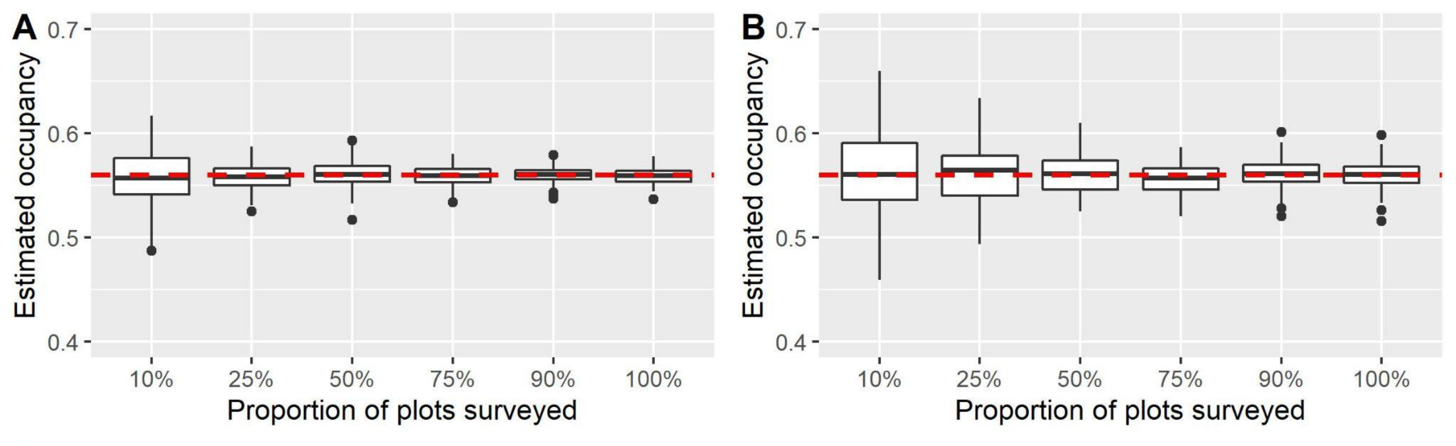
Estimation model for occupancy

$$\psi_{\text{burrow}} \sim \text{bern}(0.56)$$

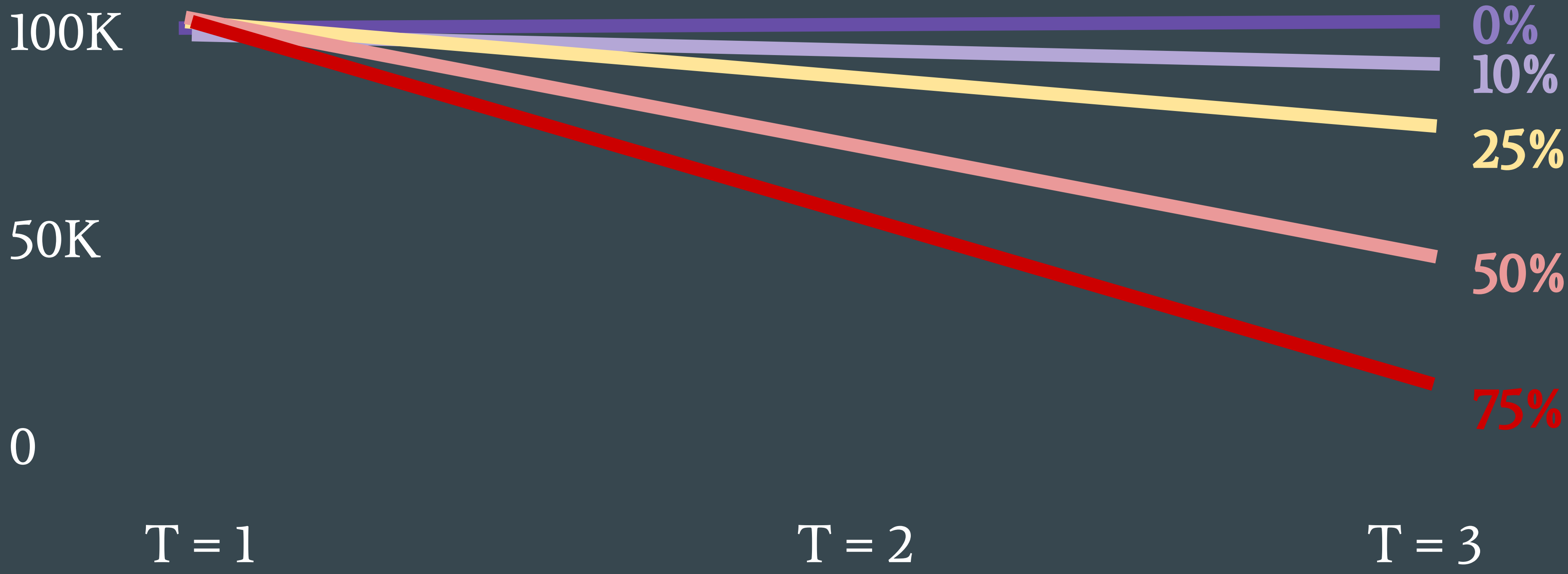
All of colony surveyable

Not all of colony surveyable

One burrow visited



Simulation steps: trend detection

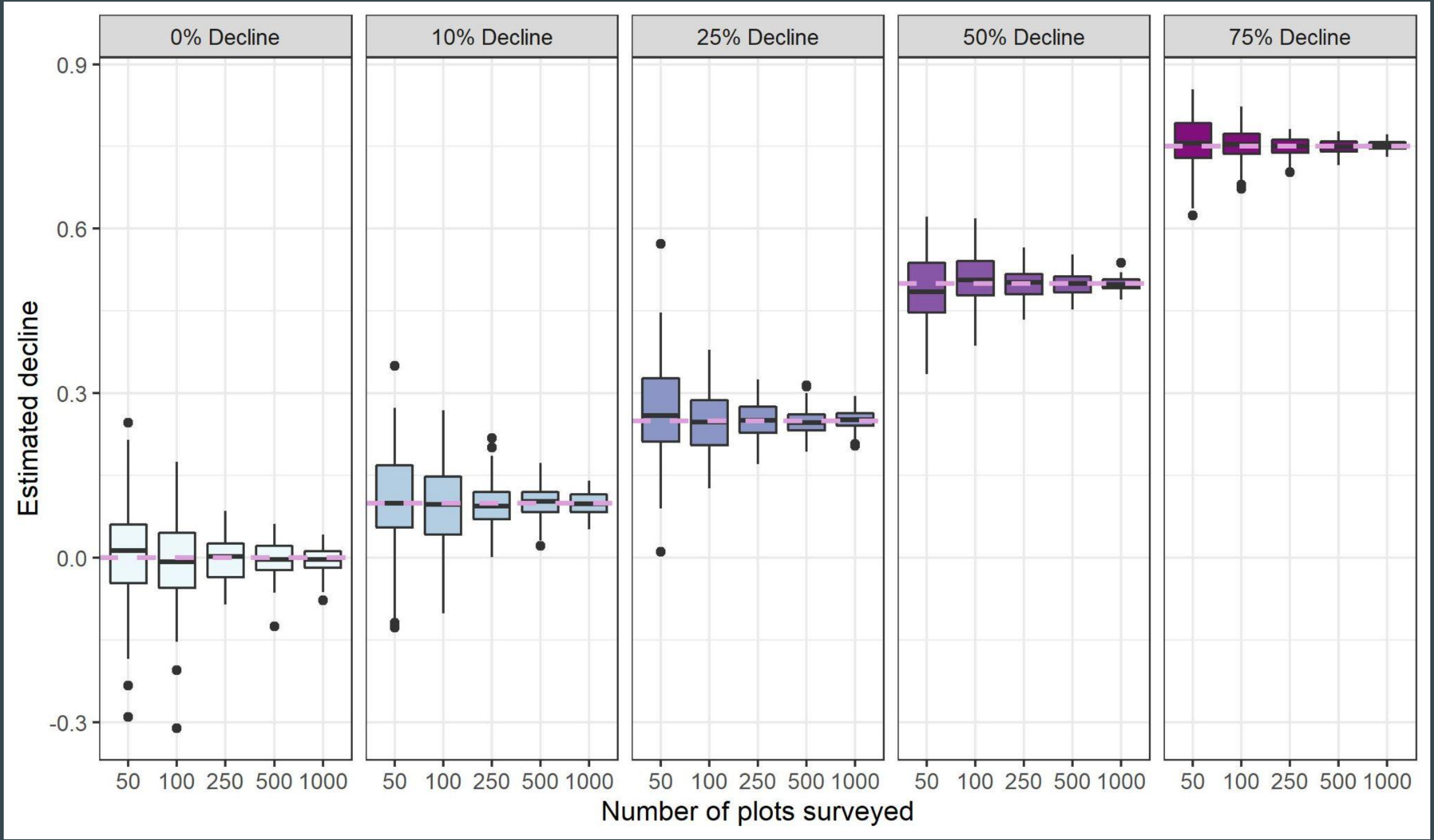


Simulation steps: trend detection

- Created 100 point processes that best represented observations
- Thinned the point processes over two time periods such that by time period 3 there was
  - No change
  - Decreases of 10%, 25%, 50%, 75%
- Then ran 100 simulations on each point process that varied
  - Trend scenario
  - Number of plots visited (50, 100, 250, 500, 1000)
- Assessed how well “true” population trend was identified at period 3

Estimation model for trend detection

$$\lambda = \frac{N_{t1} - N_{t3}}{N_{t1}}$$



0% Decline
10% Decline
25% Decline
50% Decline
75% Decline
Estimated decline
0.9
0.6
0.3
0.0
-0.3
50 100 250 500 1000
Number of plots surveyed

(Very) preliminary conclusions/thoughts

- More intensive surveying → less estimation error
- This is a simulation on one island and with a clear trend
  - Increased complexity will muddy the waters
- Will likely build in autocorrelation component

Megan Boldenow

Outstanding thoughts

- What is the role of at-sea monitoring in TUPU strategy?
- Need to incorporate detection probability
- Assessing habitat a priori
  - Drones?
  - Remote sensing?
  - Circumnavigation surveys? Or on foot in spring?
  - 3D rendering of surface from photographs?
- Do we allow new colonies to form?

Dave Kutilek

Thank you.

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@LisannePetracca