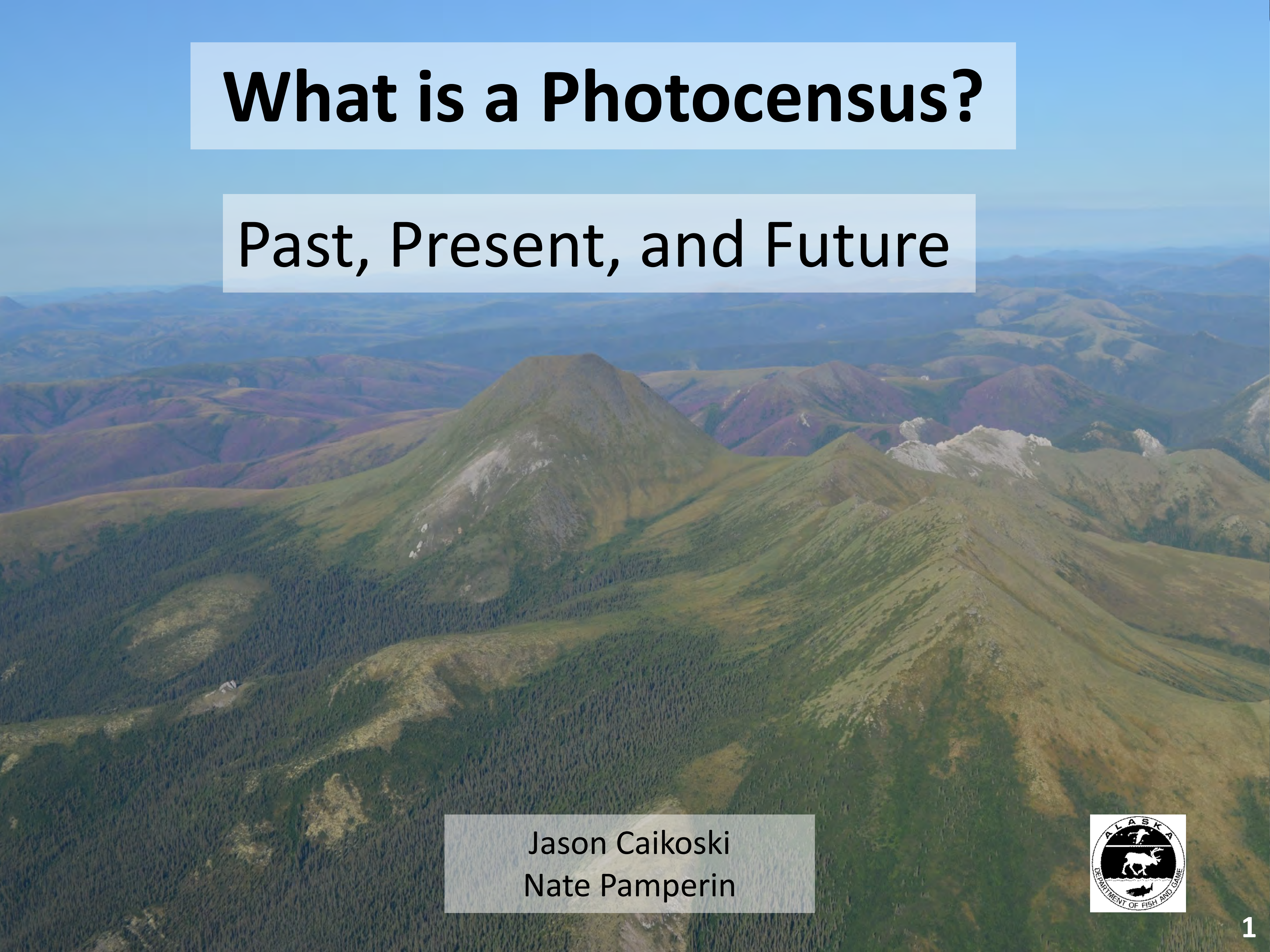


What is a Photocensus?

Past, Present, and Future

Jason Caikoski
Nate Pamperin

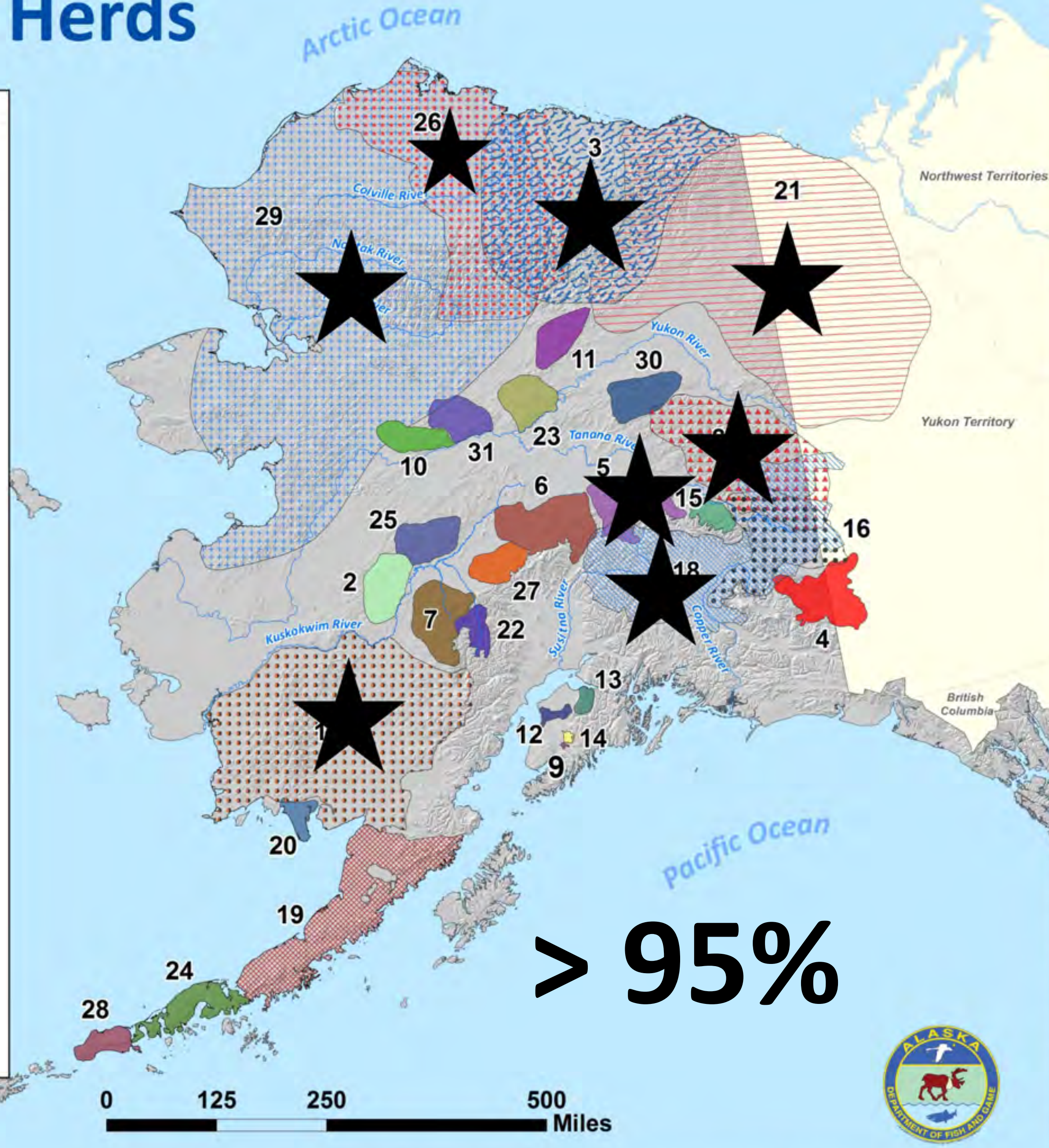
Why is it “always” about the Photocensus?

- Abundance!
- Trend
- Most relied on by: advisory, management, and regulatory boards, management agencies, public
- Difficult to obtain:
  - Expensive, difficult logistics
  - Weather, caribou behavior

Alaska Caribou Herds

Herd Name	Herd Size (2016*)
1. Adak	2,700
2. Beaver Mountains	560
3. Central Arctic	22,000
4. Chisana	700
5. Delta	2,985
6. Denali	2,330
7. Farewell-Big River	625
8. Fortymile	52,000
9. Fox River	80
10. Galena Mountain	100
11. Hodzana Hills	780
12. Kenai Lowlands	120
13. Kenai Mountains	130
14. Killey River	375
15. Macomb	1,500
16. Mentasta	335
17. Mulchatna	30,000
18. Nelchina	49,000
19. Northern Peninsula	2,700
20. Nushagak Peninsula	1,000
21. Porcupine	197,000
22. Rainy Pass	625
23. Ray Mountains	1,200
24. Southern Peninsula	1,700
25. Sunshine Mountains	560
26. Teshekpuk	40,000
27. Tonzona	625
28. Unimak	190
29. Western Arctic	202,000
30. White Mountains	650
31. Wolf Mountain	450

* Update completed in 2016, year of herd size and estimate type vary



> 95%

Outline

1. **Mechanics of a photocensus: AKA minimum count caribou photocensus, modified APDCE, "traditional method"**
   (Davis et al., 1979; Valkenburg et al., 1985)

2. **Application of a statistical method for estimating abundance from minimum count photocensus data**

3. **Digital upgrade**

Basic Premise

1. Post-calving aggregations (grouping) occur due to severe insect harassment

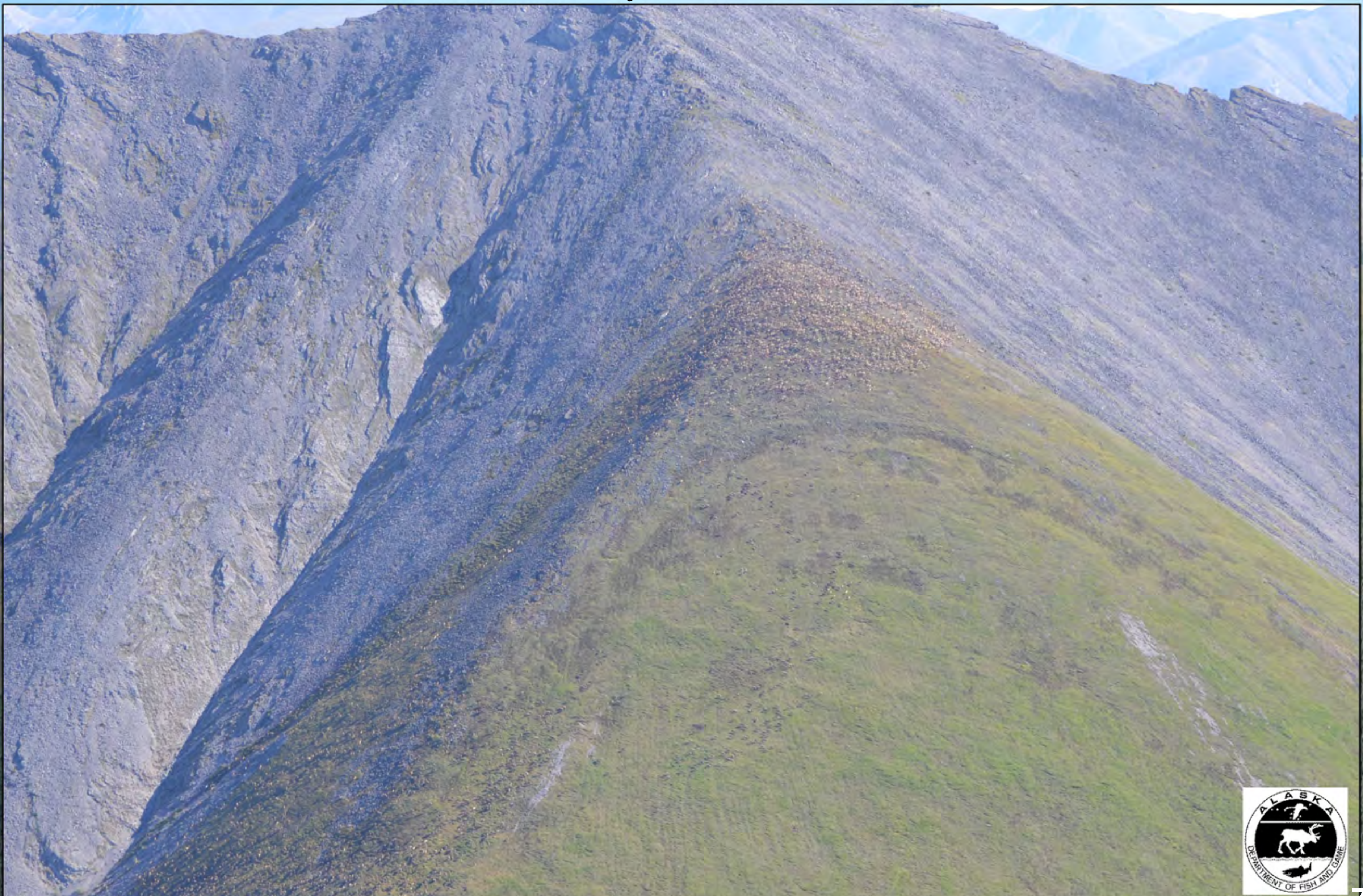
2. Groups are located using radiocollars

3. Probability of a group containing a collared caribou is proportional to the number of caribou in the group

4. Groups are missed because they do not contain radio collar(s)

2013 PCH photocensus
No collars: 160 caribou

2013 PCH photocensus
3 collars: 5,200 caribou

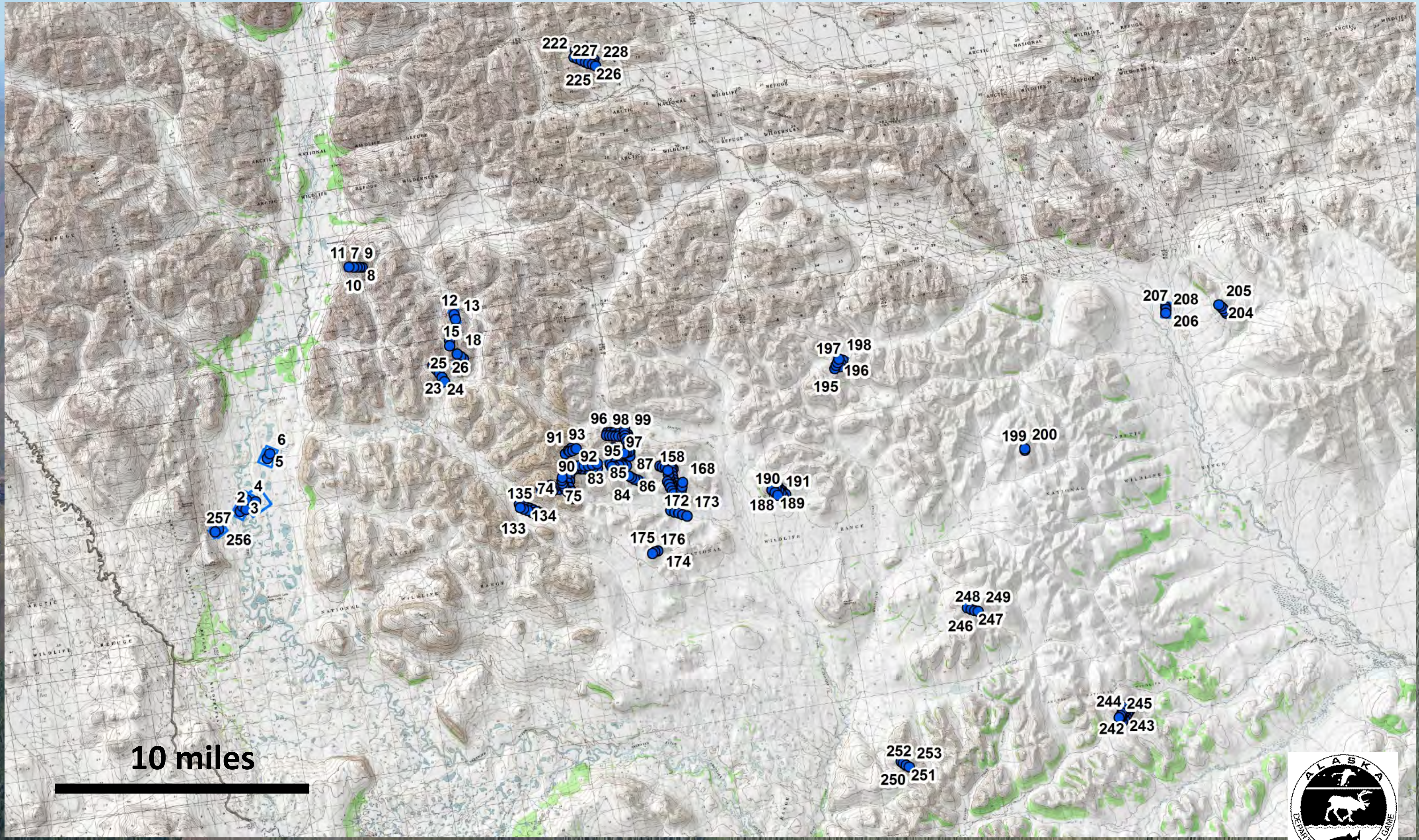


2013 PCH photocensus
7 collars: 21,300

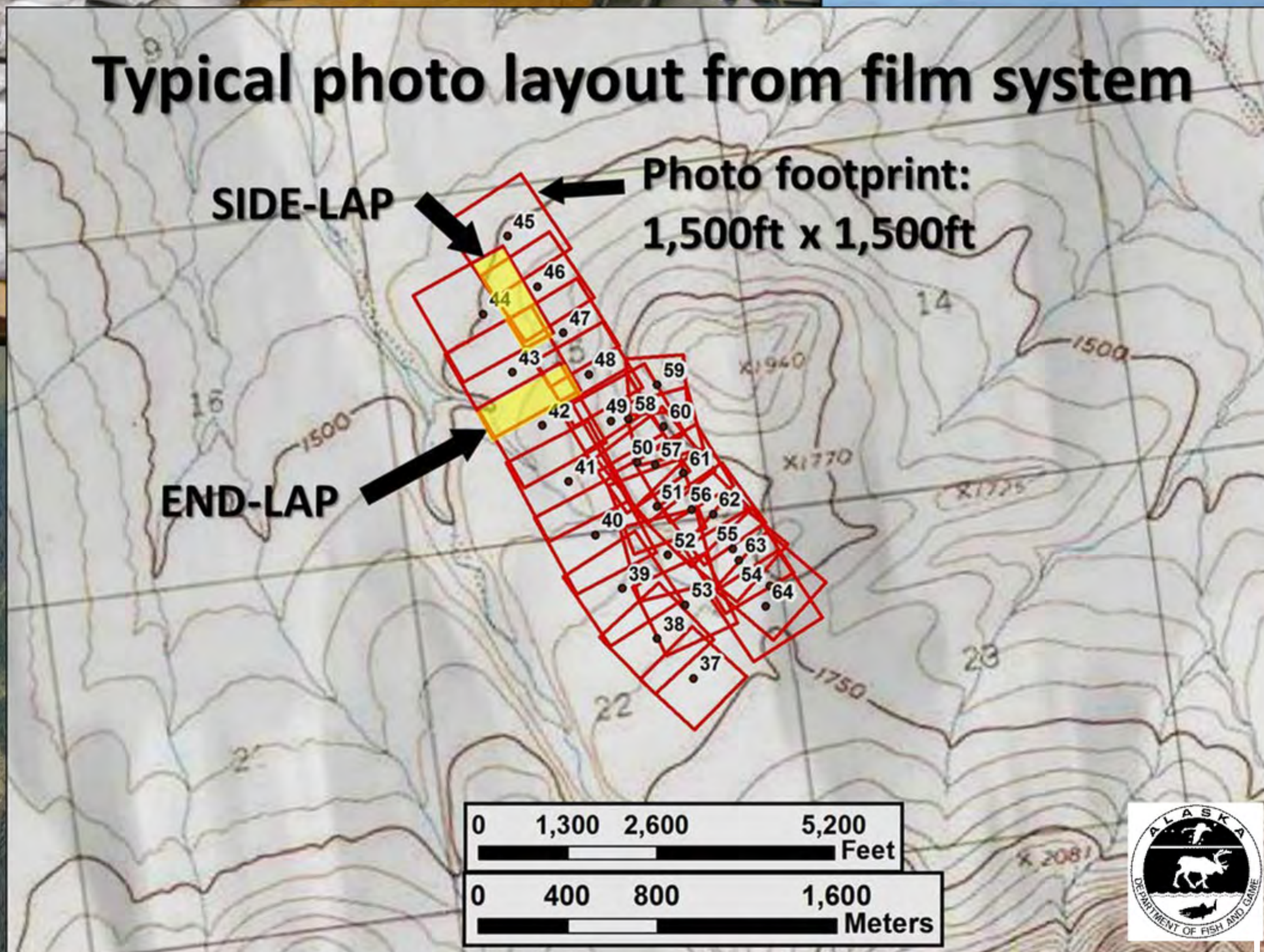
Western Arctic Herd, 2013
31 collars: 91,200 caribou

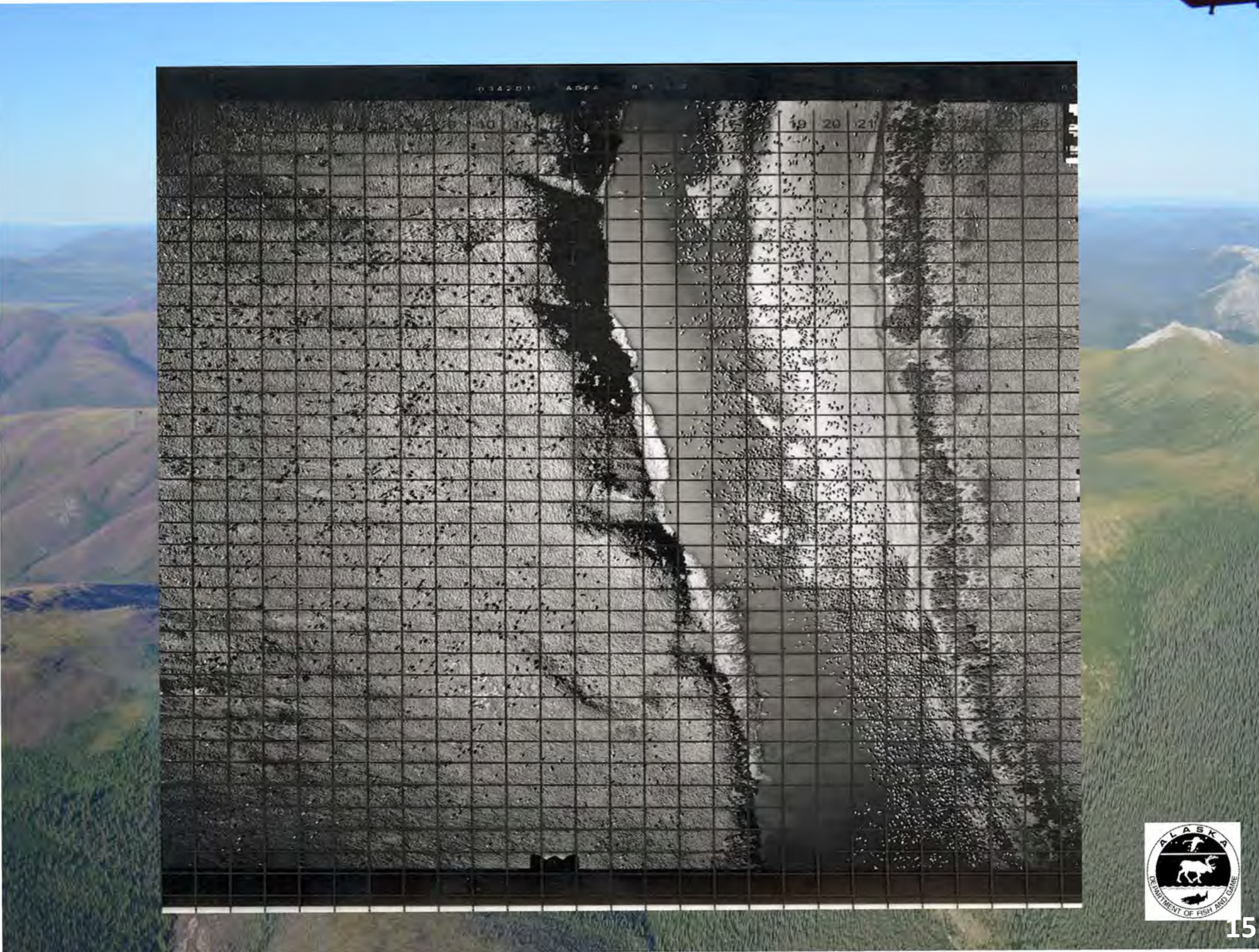
- Two aircraft outfitted with photo equipment
- Use declassified military cameras from WWII
- Software program automates photography, linked with GPS and radar altimeter and displayed in real time on screen

2013 PCH Photocensus Group Distribution



Example of Photo Footprints From One Group


Typical photo layout from film system
SIDE-LAP
Photo footprint:
1,500ft x 1,500ft
END-LAP
45
46
44
47
43
48
59
49
58
60
42
50
57
61
41
51
56
62
40
55
52
63
39
54
64
53
38
37
14
15
22
23
1500
1750
X1940
X1770
X1725
X 2081
0 1,300 2,600 5,200
Feet
0 400 800 1,600
Meters
ALASKA
DEPARTMENT OF FISH AND GAME



Minimum Count = summation of all caribou enumerated from photographs (includes groups with and without collars)

Minimum Count = summation of all caribou counted on photographs (includes groups with and without collars)

1. What about missing collars?
2. Uncollared groups located?
3. How do we address mixing of herds?
4. Groups not photographed?
5. No measures of uncertainty !!!

Application of a statistical method for estimating abundance from minimum count photocensus data

Rivest et al 1998

Model Assumptions

1. **Radiocollars are randomly distributed (can be tested)**
2. **Caribou are accurately counted on photos (none missed, no double counting)**
3. **A "group" is definable (clean definable perimeter, function of aggregation)**

and $\mathrm{var}(\hat{T})$ is approximately equal to $\mathrm{var}[g(T)]/\mathrm{E}[g'(T)]^2$. The evaluation of $\mathrm{var}[g(T)]$ is technical since it involves two phases of sampling; it is presented in the Appendix. The expectation of $g'(T)$ is given by

$$\mathrm{E}[g'(T)] \approx \frac{n}{T^2}\sum_{i=1}^{M}\frac{N_i^2\mathrm{E}(\epsilon_i\delta_i)(1-N_i/T)^{n-1}}{p_i\pi_i^2} - 1 = \frac{n}{T^2}\sum_{i=1}^{M}\frac{N_i^2(1-N_i/T)^{n-1}}{\pi_i} - 1$$

since $\mathrm{E}(\epsilon_i\delta_i) = P(\epsilon_i = 1)P(\delta_i = 1 \mid \epsilon_i = 1) = p_i\pi_i$. Combining this with the findings of the Appendix yields

$$\mathrm{var}(\hat{T}) = \left(1 - \frac{n}{T^2}\sum_{i=1}^{M}\frac{N_i^2(1-N_i/T)^{n-1}}{\pi_i}\right)^{-2} \times \left(\sum_{i=1}^{M}\frac{N_i^2(1-\pi_i)}{\pi_i} + \sum_{i\neq j}^{M}\frac{N_iN_j\gamma_{ij}}{\pi_i\pi_j} + \mathrm{E}_1\left\{\sum_{i=1}^{m}\frac{(1-p_i)}{p_i}\left\{\frac{N_i}{\pi_i} - X_i\frac{\sum^m N_ip_i'/p_i}{\sum^m X_i\pi_ip_i'/p_i}\right\}^2\right\}\right), \qquad (5)$$

where E_1 is the expectation with respect to the first-ph

A variance estimator $v(\hat{T})$ is constructed using the me

in the sums are multiplied by indicator functions, taken

to this term are sampled, and divided by the estimated

equal to 1. For instance, $N_iN_j\gamma_{ij}/\pi_i\pi_j$ is multiplied by

$$v(\hat{T}) = \left(1 - \frac{n}{\hat{T}^2}\sum_{i=1}^{m'}\frac{N_i^2(1-N_i/\hat{T})^{\prime}}{\hat{p}_i\hat{\pi}_i^2}\right. \times \left(\sum_{i=1}^{m'}\frac{N_i^2(1-\hat{\pi}_i)}{\hat{p}_i\hat{\pi}_i^2} + \sum_{i\neq j}^{m'}\frac{\cdots}{\hat{p}_i} + \sum_{i=1}^{m'}\frac{1-\hat{p}_i}{\hat{p}_i^2}\left(\frac{N_i}{\hat{\pi}_i} - X_i\cdots\right.\right.$$

5. The Distribution of the Collared Animals in the Groups

A key assumption underlying the statistical procedures proposed in this paper is the random distribution of the radio-collared animals across the groups. Statistical methods for testing this assumption are presented in this section. Likelihood-based methods for selecting the model for the phase 2 detection probabilities are also suggested.

If the radio-collared animals are randomly distributed, then the probability function of the number of collared animals in group i is easily derived. It is, for $k = 0, 1, \ldots$, given by

$$f(k) = \frac{\binom{N_i}{k}\binom{T-N_i}{n-k}}{\binom{T}{n}} \approx \binom{n}{k}\left(\frac{N_i}{T}\right)^k\left(1-\frac{N_i}{T}\right)^{n-k} \approx \frac{[(nN_i)/T]^k}{k!}\exp[-(nN_i)/T],$$

where the last approximation is valid as long as n is large and N_i/T is small. The distributions of the variables X_i that are observed are not Poisson, however. Their distributions depend on the phase 2 detection probabilities. They are given by

$$P(X_i = k) = \frac{1}{-}p_k\frac{[(nN_i)/T]^k}{k!}\exp[-(nN_i)/T] = f\left(k, \frac{nN_i}{T}\right),$$

robability for a group containing k collared animals and

ch a way that the probabilities sum to 1.

$k = 0$ and $p_k = r$ when k is positive; thus, the X_i's are

$'(X_i = k) = f_H(k, (nN_i)/T)$, where f_H is the truncated

$$\frac{\lambda^k}{[\exp(\lambda) - 1]}, \qquad k = 1, 2, \ldots.$$

ability function of X_i is $f_I(k, (nN_i)/T)$, where f_I is giv-

$$\frac{\lambda^k(1-r^k)}{\mathrm{)}(\lambda) - \exp(\lambda r)]}, \qquad k = 1, 2, \ldots.$$

0.

le values: 0 at $k = 0$, r for $1 < k < B$, and 1 for $k \geq B$. In

is $f_B(k, (nN_i)/T)$ and f_B is given by

$$\frac{(1-r)p_k^{B'}]\lambda^k}{1 - (1-r)\sum_{j=1}^{B-1}\lambda^j/j!]}, \qquad k = 1, 2, \ldots,$$

for detecting overdispersion. Because of the phase 2 sampling, the probability function for X_i is $f(k, nN_i/T)$. When r, the parameter for the phase 2 detection, is known, f is a natural exponential family. A score test for overdispersion in f is proposed to test the randomness assumption.

Dean's (1992) method is used to construct the test. Let $\theta = -\log T$ and $d_i = \log(n) + \log(N_i)$ be a natural parametrization for the exponential family. In this notation, $f(k, nN_i/T) = \exp[k(\theta + d_i) - g(\theta + d_i) + c(k)]$, where g and c are functions depending on the phase 2 detection probabilities. The maximum likelihood estimate $\hat{\theta}$ of θ is the solution of

$$\sum X_i = \sum g'(\theta + d_i),$$

where g' is the derivative of g. The expectation and the variance of X_i are easily calculated as $\mathrm{E}(X_i) = g'(\theta + d_i)$ and $\mathrm{var}(X_i) = g''(\theta + d_i)$. The test for overdispersion is given by formula (1.10) of Dean (1992) as

$$z_{\mathrm{obs}} = \sum\left\{[X_i - g'(\hat{\theta} + d_i)]^2 - g''(\hat{\theta} + d_i)\right\}/\hat{V},$$

where

$$\hat{V}^2 = \sum_{i=1}^{m'}\left\{g''''(\hat{\theta} + d_i) + 2[g''(\hat{\theta} + d_i)]^2\right\} - \frac{\left[\sum g'''(\hat{\theta} + d_i)\right]^2}{\sum g''(\hat{\theta} + d_i)}$$

and g'', g''', g'''' represent the second, third, and fourth derivatives of g, respectively. For an alternative hypothesis of overdispersion, this test is unilateral. The hypothesis of randomness is rejected at the 5% level if z_{obs} is larger than 1.645.

For the independence model, one has $g(\theta) = re^\theta + \log\{\exp[(1-r)e^\theta] - 1\}$ and

$$g'(\theta) = re^\theta + \frac{(1-r)e^\theta\exp[(1-r)e^\theta]}{\exp[(1-r)e^\theta] - 1} = e^\theta + \frac{(1-r)e^\theta}{\exp[(1-r)e^\theta] - 1}.$$

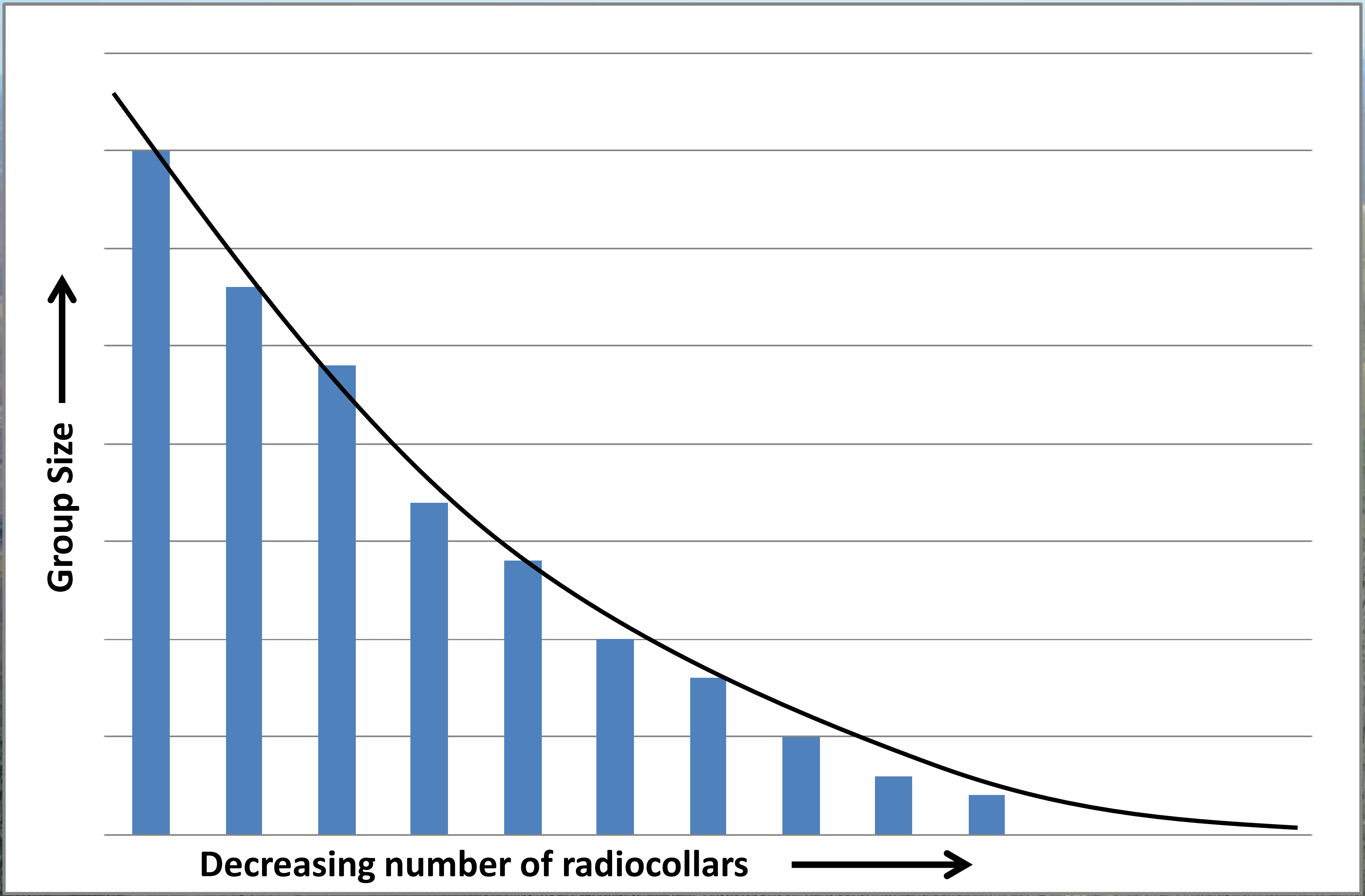
Let $z = (1-r)e^\theta$ and $h = z/(e^z - 1)$. Since,

$$\frac{d}{d\theta}z = z \quad\text{and}\quad \frac{d}{d\theta}h = -(z-1)h - h^2,$$

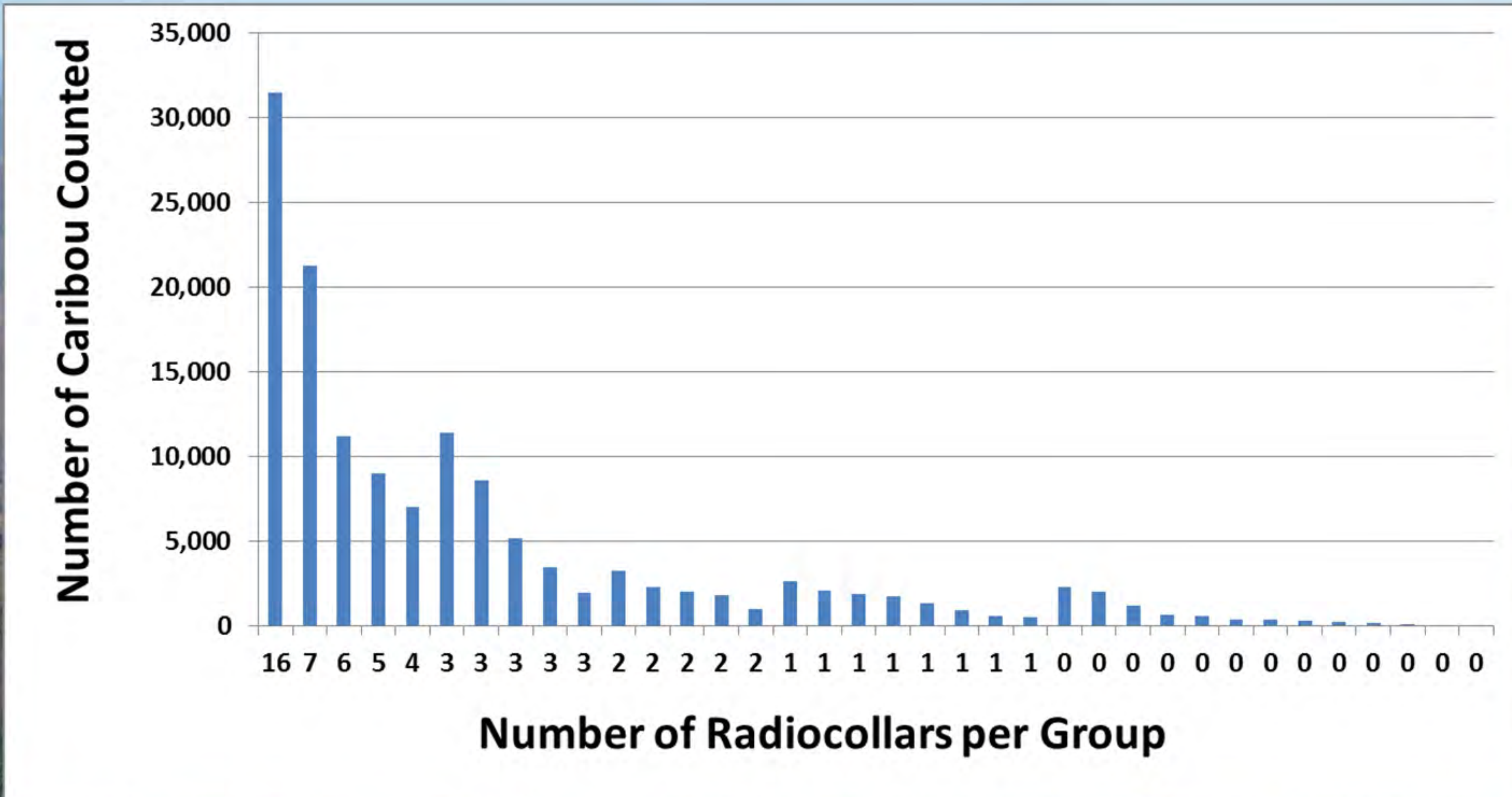
the successive derivatives of g are easily evaluated as

$$g''(\theta) = e^\theta - (z-1)h - h^2,$$
$$g'''(\theta) = e^\theta + (z^2 - 3z + 1)h + 3(z-1)h^2 + 2h^3,$$
$$g''''(\theta) = e^\theta - (z^3 - 6z^2 + 7z - 1)h - (7z^2 - 18z + 7)h^2 - 12(z-1)h^3 - 6h^4.$$

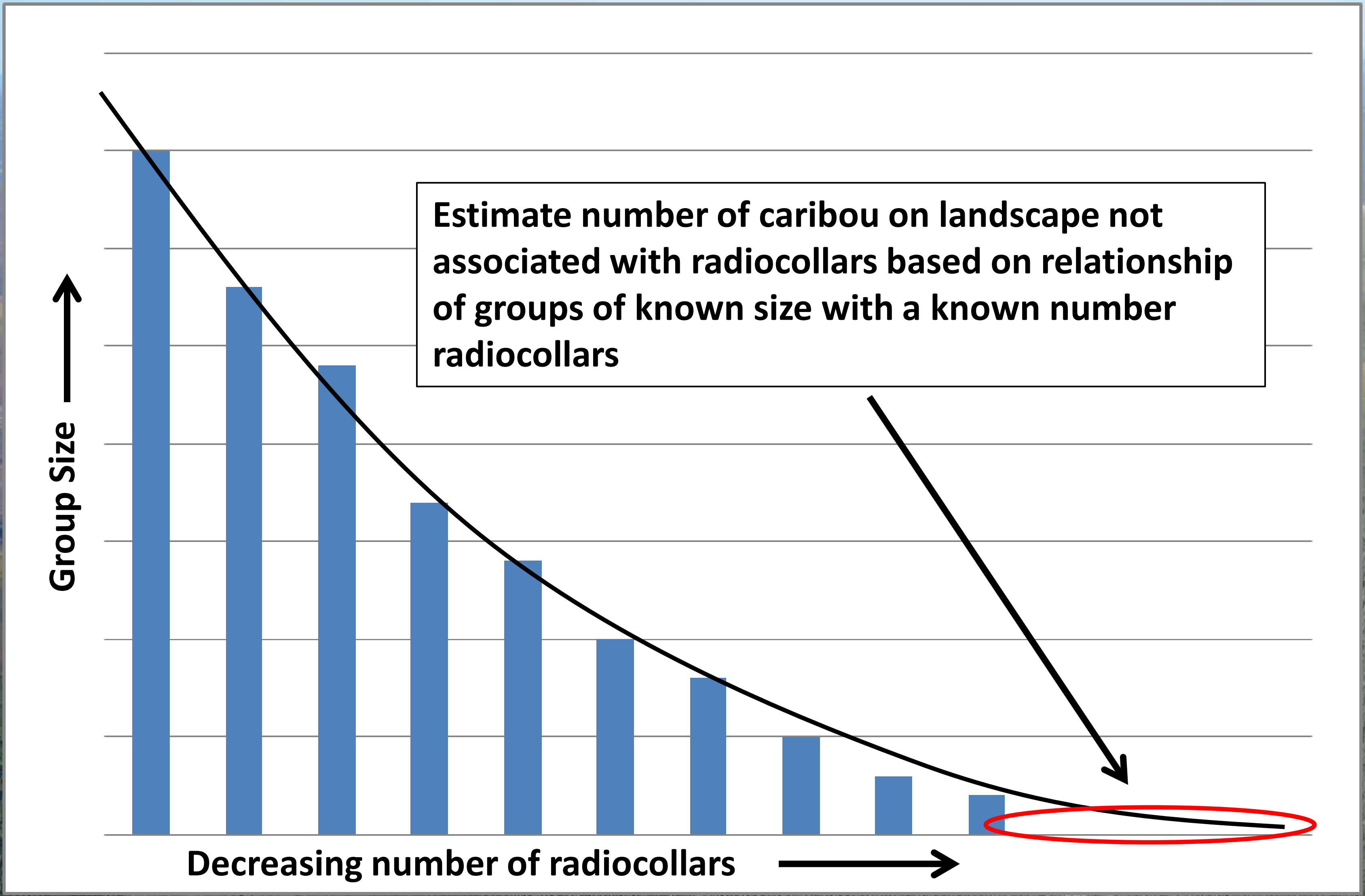
Conceptual Group Size and Collar Relationship



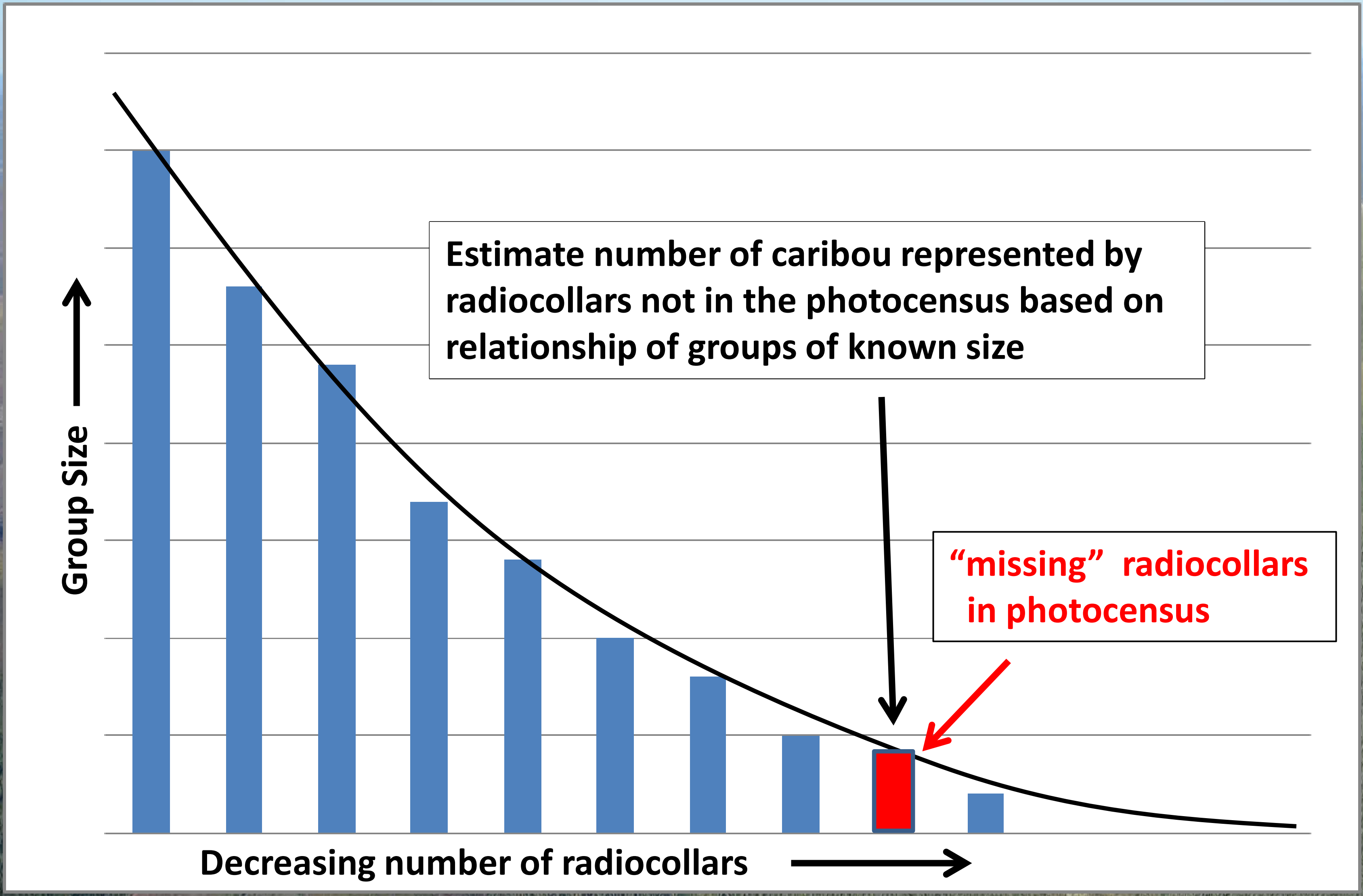
2013 PCH Group Size and Collar Relationship



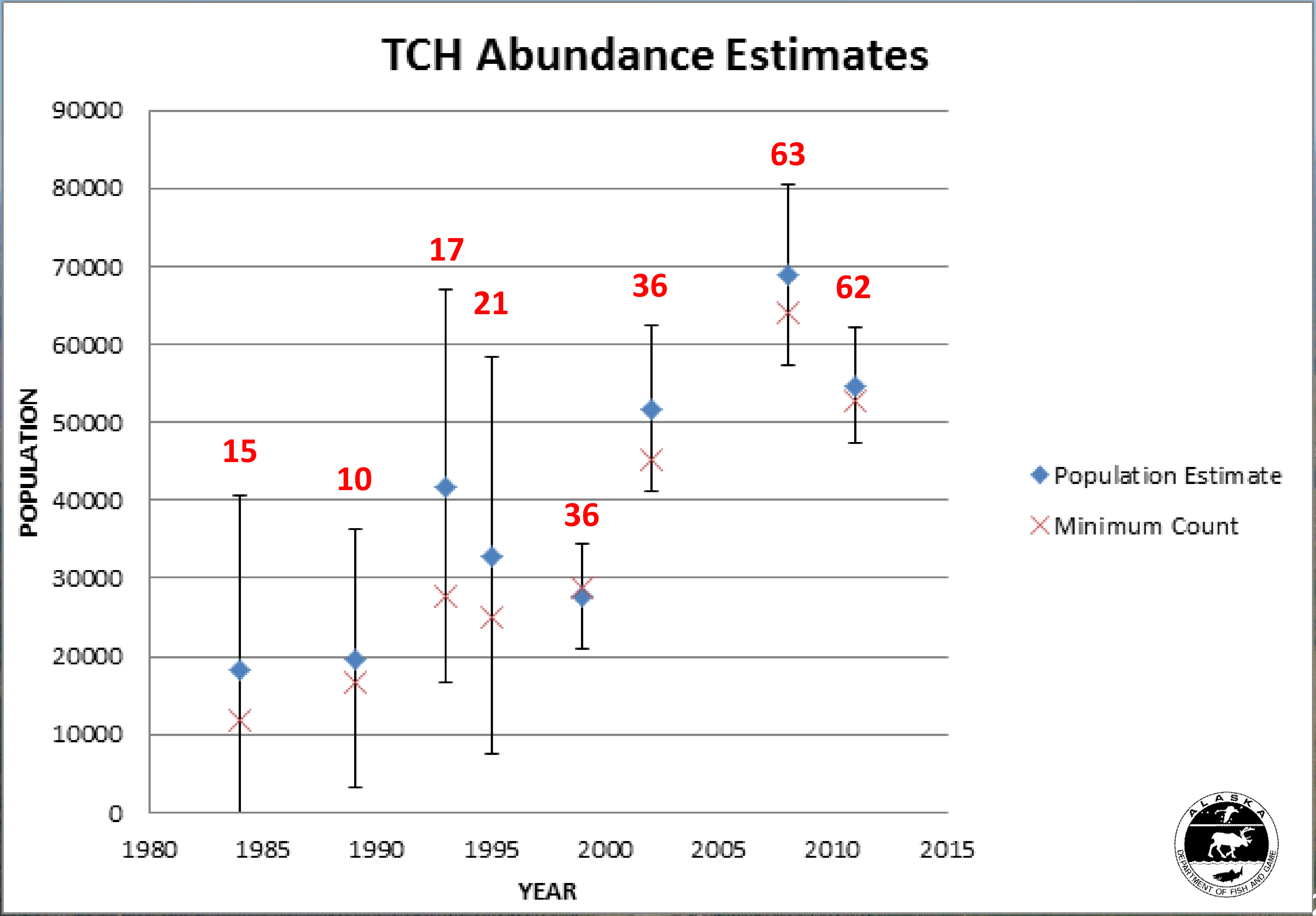
Conceptual Group Size and Collar Relationship



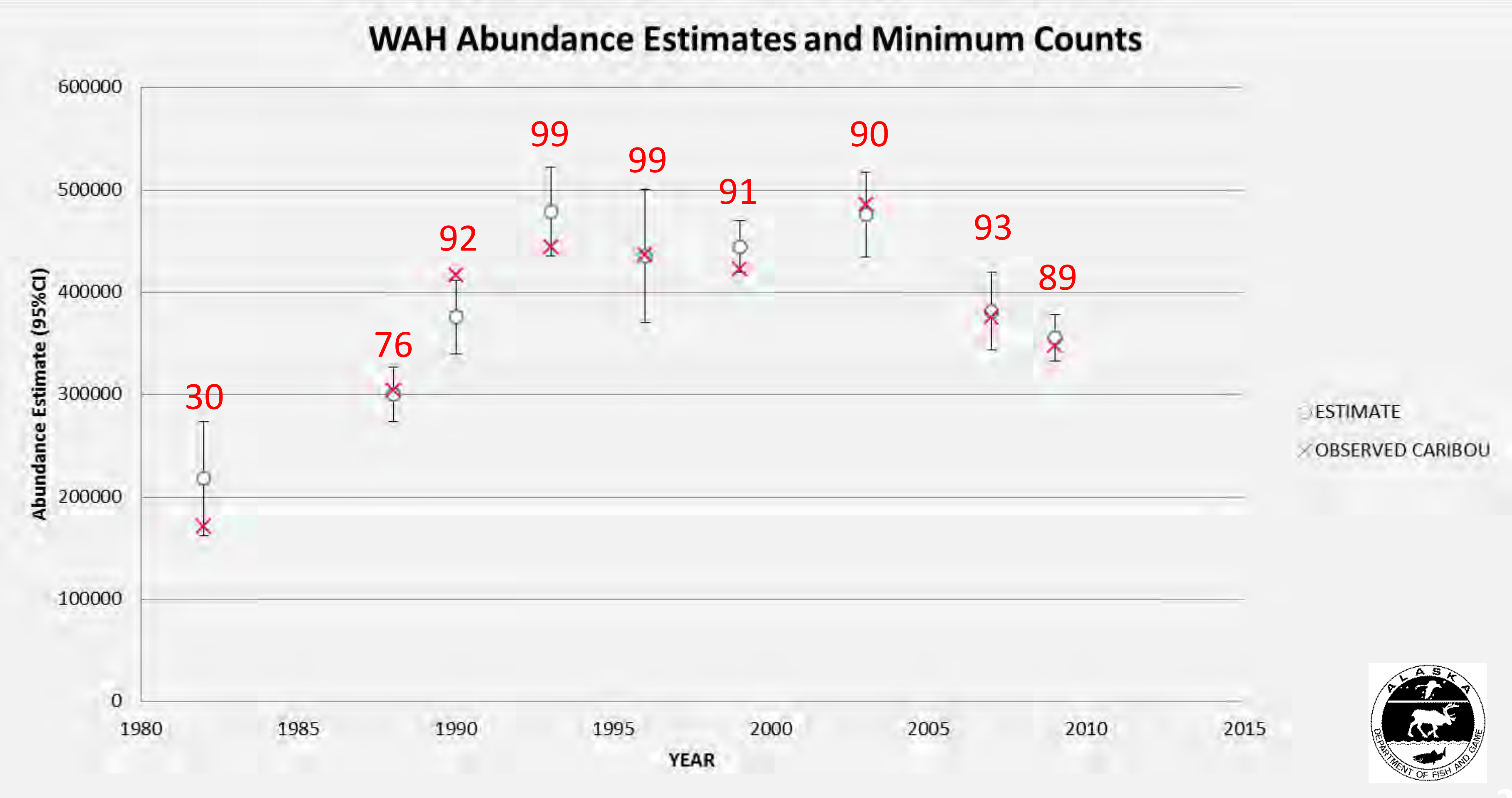
Conceptual Group Size and Collar Relationship



Case Study Results: TCH



Case Study Results: WAH




N7023
ALASKA
DEPARTMENT OF FISH AND GAME