A Comparison of Acoustic Based Line-Transect Density Estimates for Sperm Whales and Minke Whales in the Northern Marianas Islands

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Introduction

This is talk will cover:

- Acoustic based, line-transect survey and analytical methods for estimating densities of whales
- Explain and compare analysis methods used
- Assumptions (and violations), and known biases
- Results
- Caveats
- Recommendations

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Line-Transect Methods (a review)

- well developed for visual based surveys of mm's
- they can also be applied to passive acoustics, BUT
- requires some important assumptions to be met

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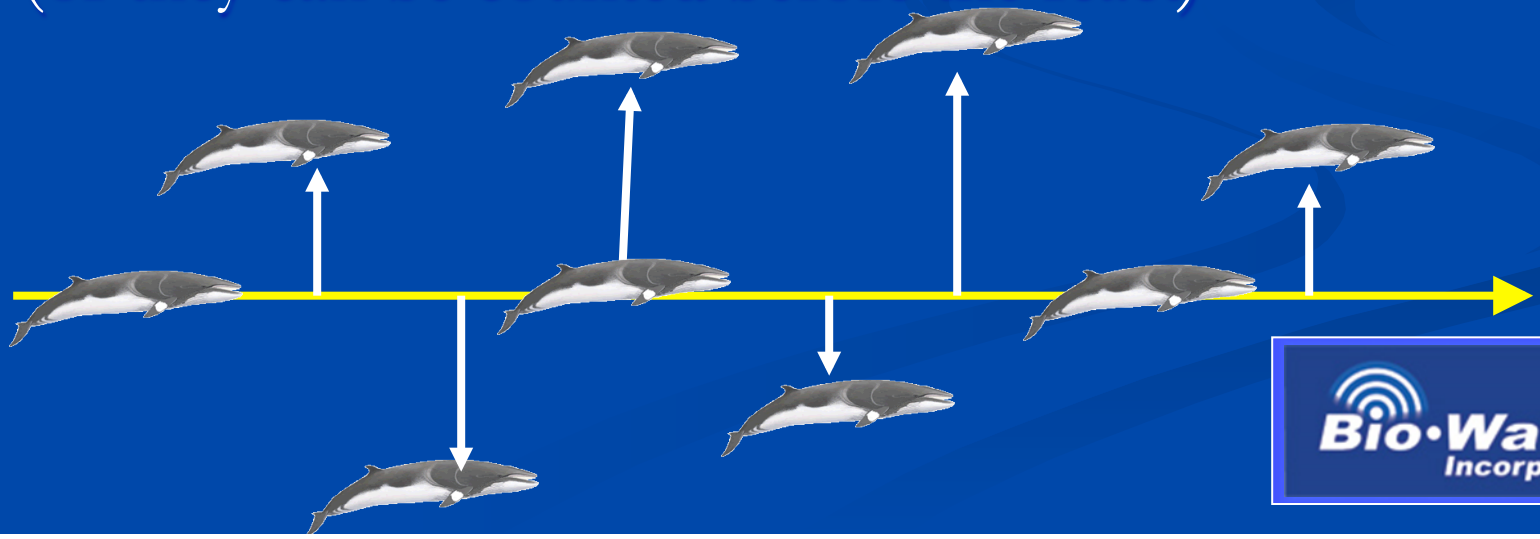
Line-Transect Methods

Assumptions:

- **all** animals on the line are counted **g(0)** = 1
- perpendicular distances can be precisely measured
- animals do not react strongly to vessel
  (or they can be counted before the react)



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Line-Transect Methods

$$\text{Density} = \frac{n}{(a)\,\hat{P}}$$

n ← # of animals (counted/localized)

Area → (a)

$\hat{P}$ ← Probability (of detecting an animal)

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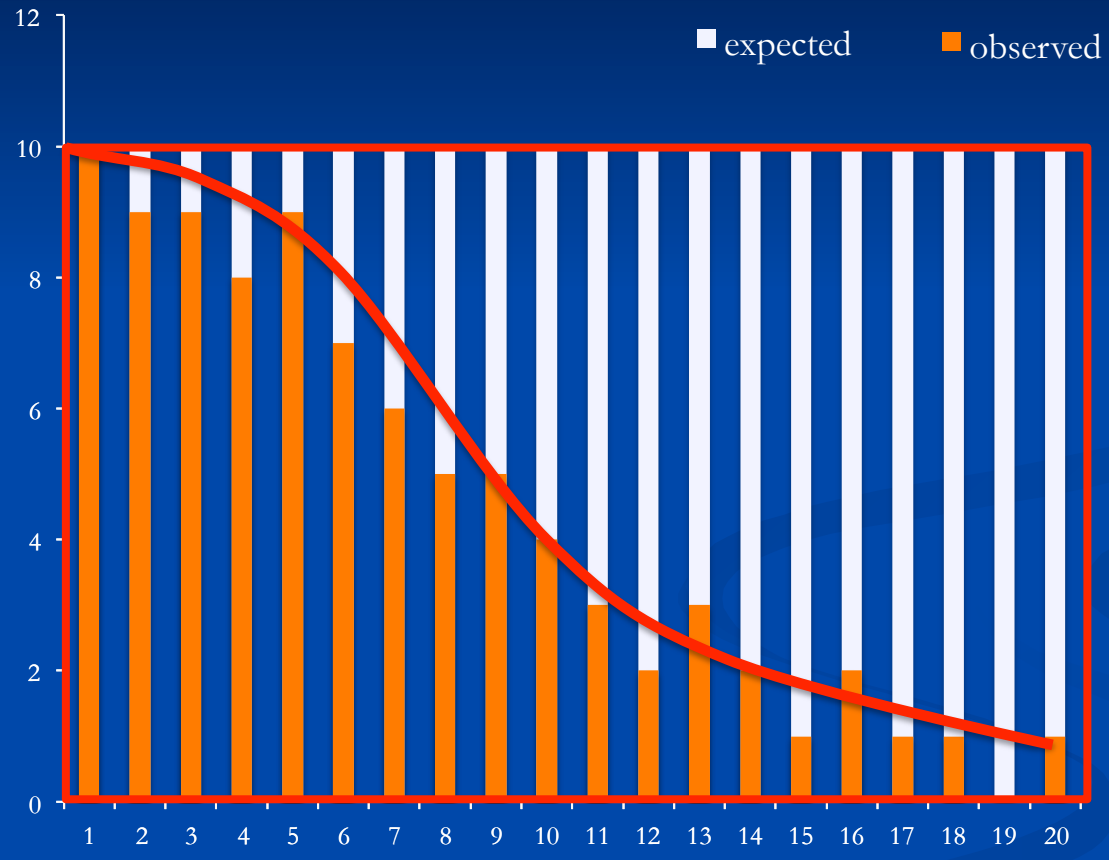
Line-Transect Methods



# of animals

distance from trackline

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METHODS

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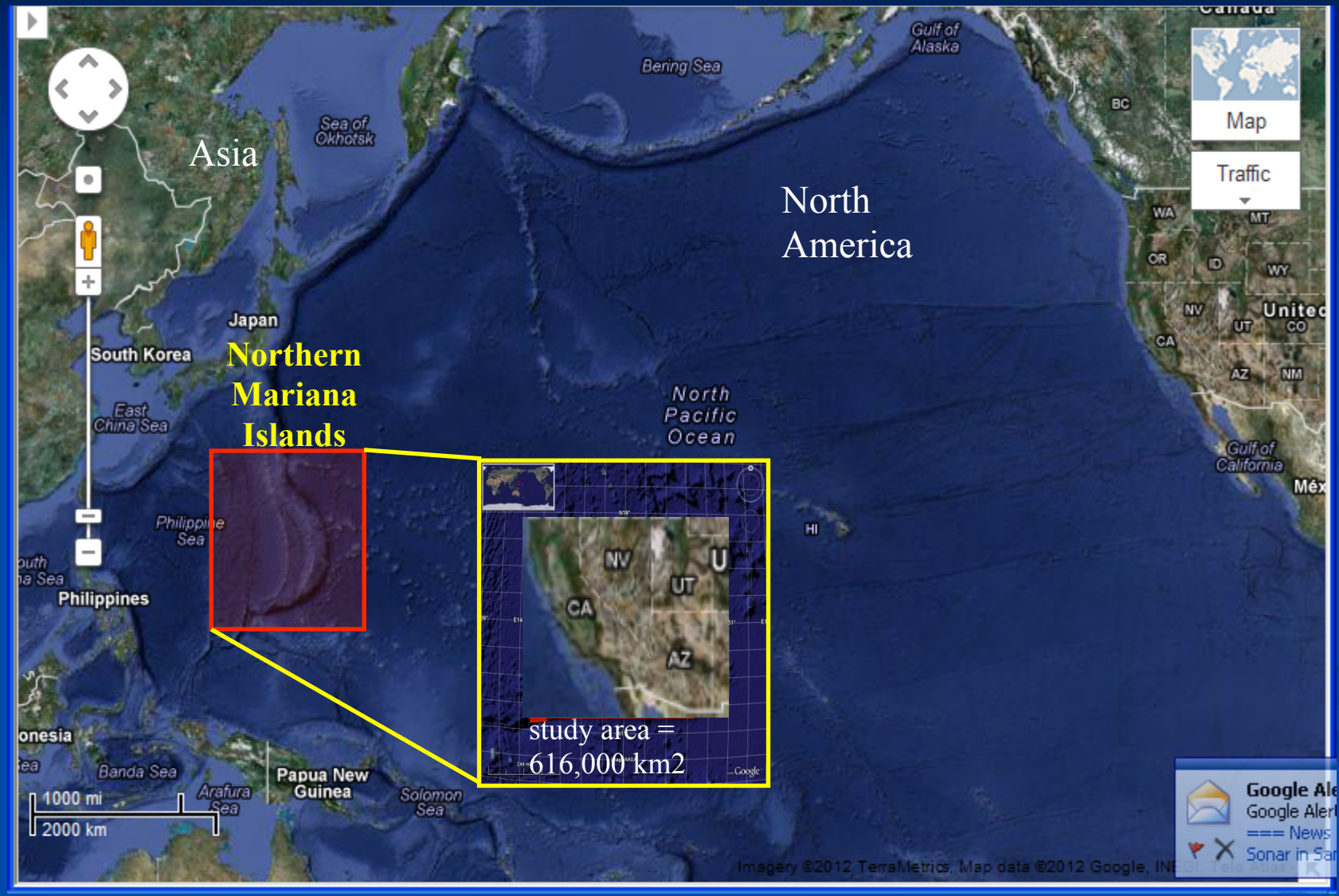
Study Area


Asia
North America
Japan
Northern Mariana Islands
South Korea
East China Sea
Philippine Sea
Philippines
Bering Sea
Sea of Okhotsk
Gulf of Alaska
North Pacific Ocean
Gulf of California
Banda Sea
Arafura Sea
Papua New Guinea
Solomon Sea
1000 mi
2000 km
study area = 616,000 km2
Map
Traffic
Imagery ©2012 TerraMetrics, Map data ©2012 Google

Methods

Line-Transect Surveys

- large (noisy) research vessel
- towed hydrophone array system
- visual observers

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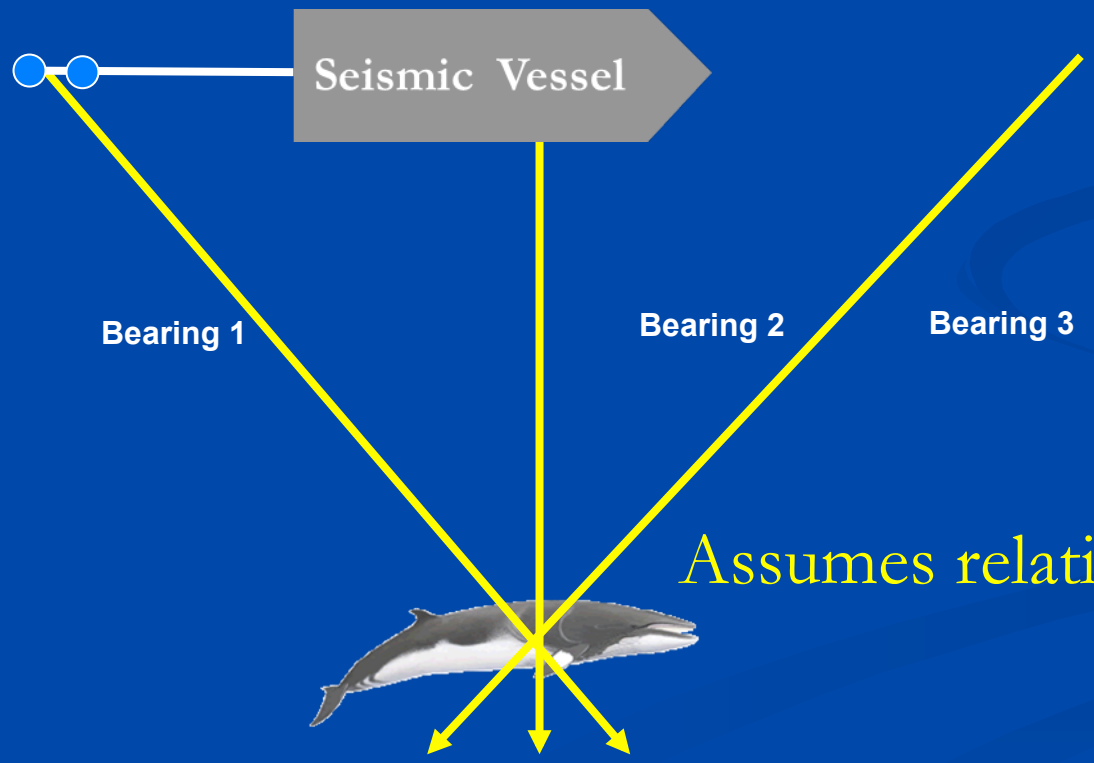
Localization Method (Target Motion Analysis)



Assumes relatively stationary animal!

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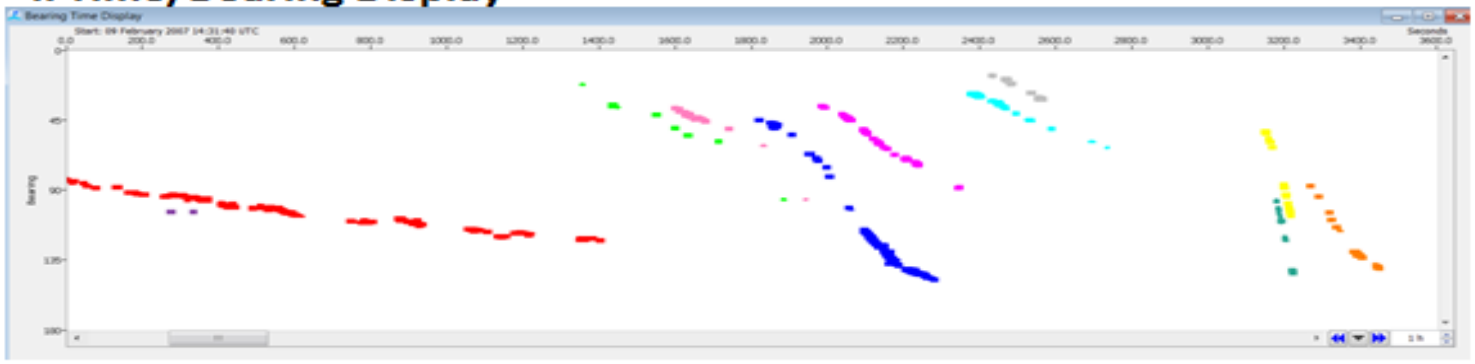
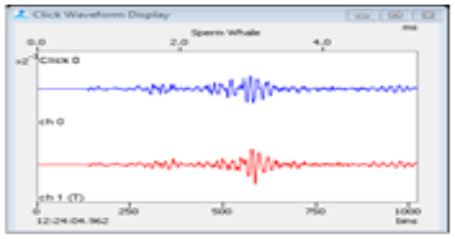
Methods
Post-Processing

- Minke Whales – Ishmael & Boinger
- Sperm Whales PAMGuard (viewer mode)

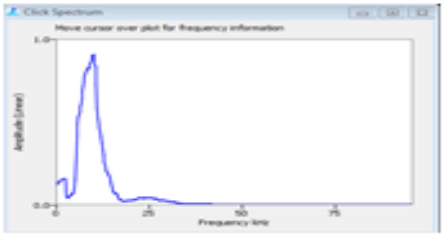
I. Time/Bearing Display



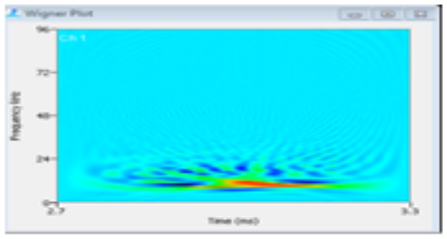
II. Waveform



III. Click



IV. Wigner Plot



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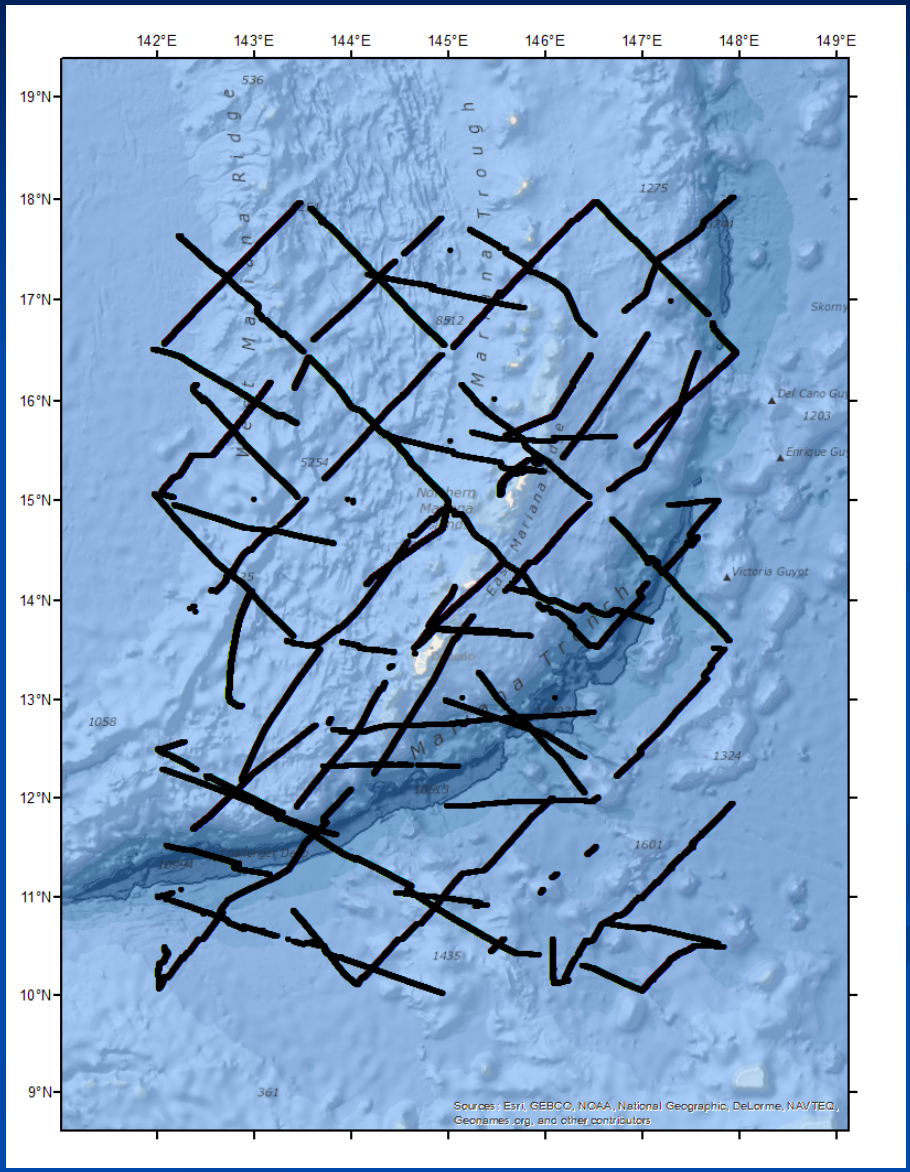
RESULTS

Survey Effort

- 616,0000 km2
- 11,854 km of trackline effort
- >50% of effort was > B4 sea state



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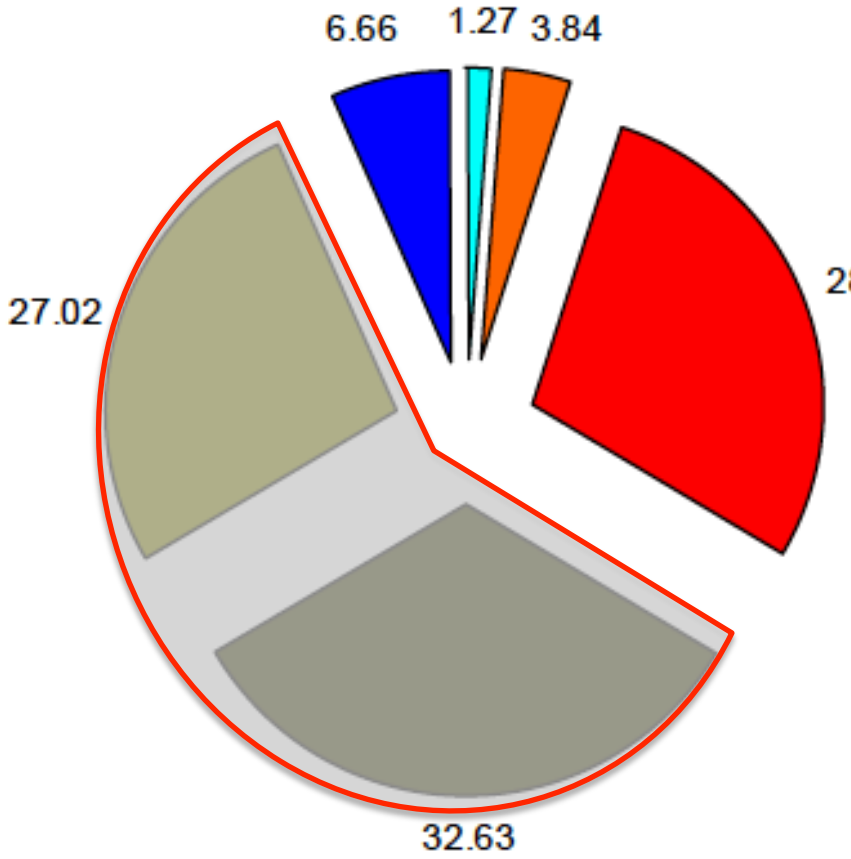
Survey Effort

% Beaufort Sea State (BSS)



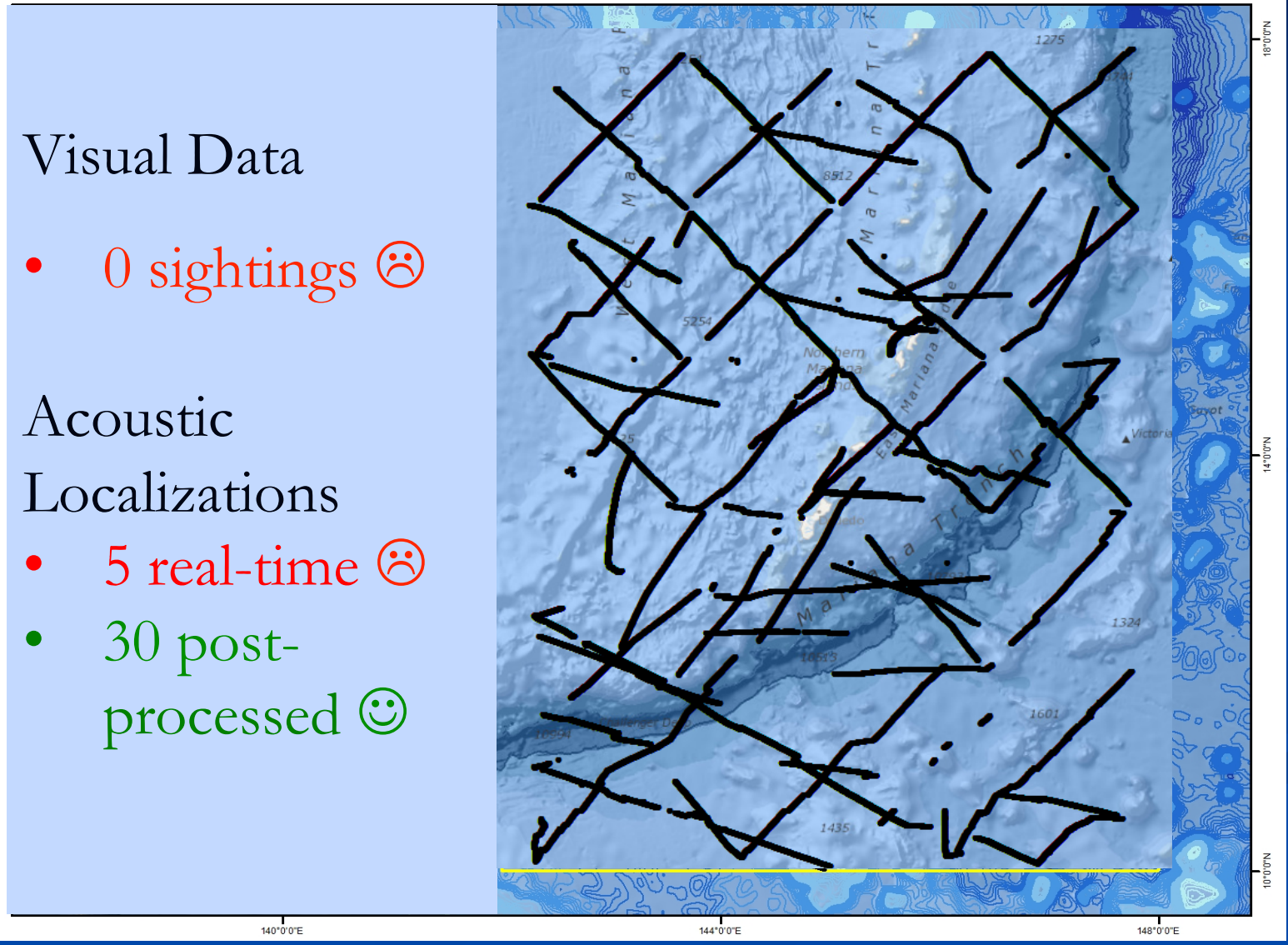
Minke Whale Localizations

Visual Data

- 0 sightings ☹

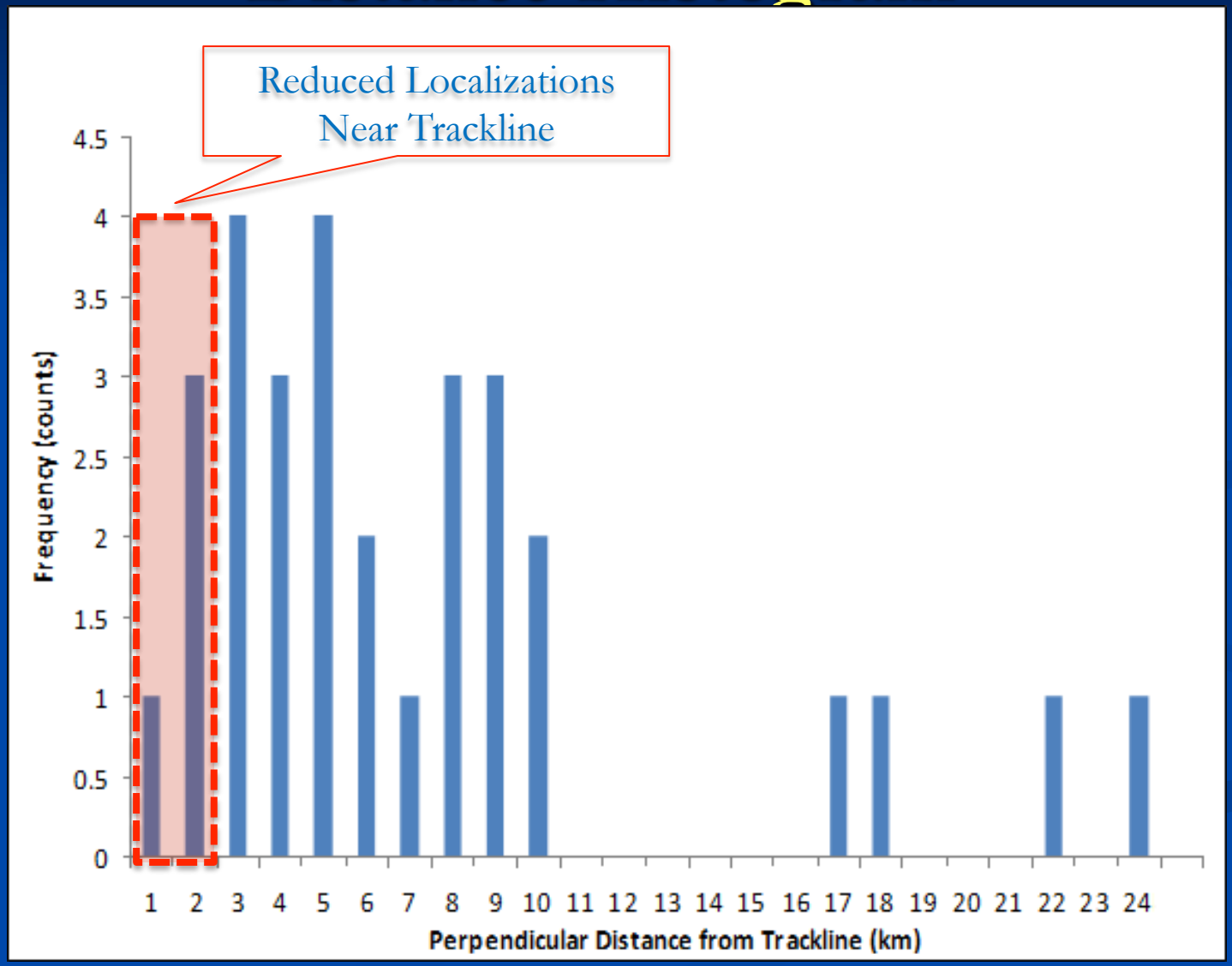
Acoustic Localizations

- 5 real-time ☹
- 30 post-processed ☺

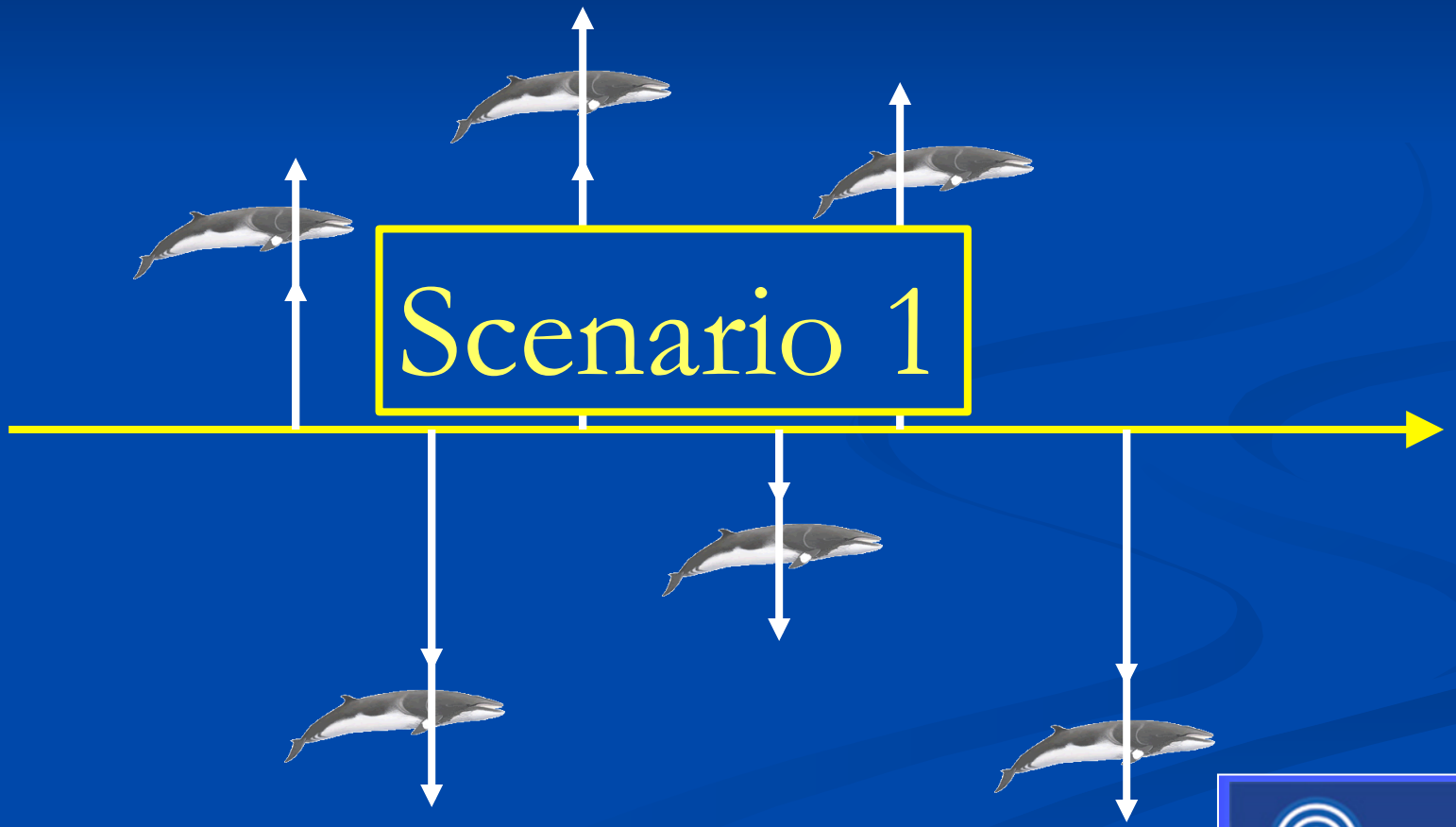


Minke Whales

Distance Histogram



Animal Responses
Avoidance



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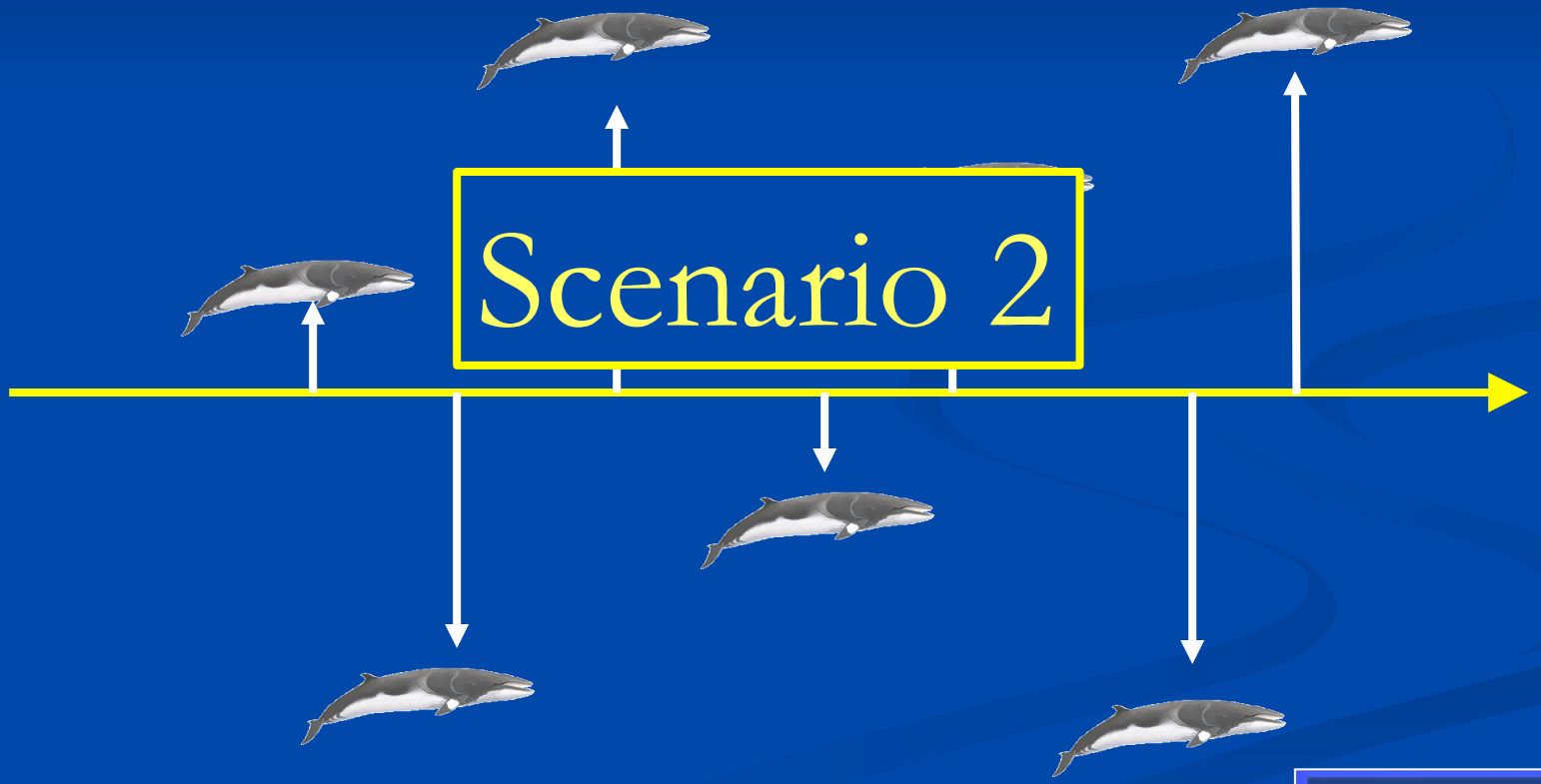
Animal Responses (Reduced Calling)



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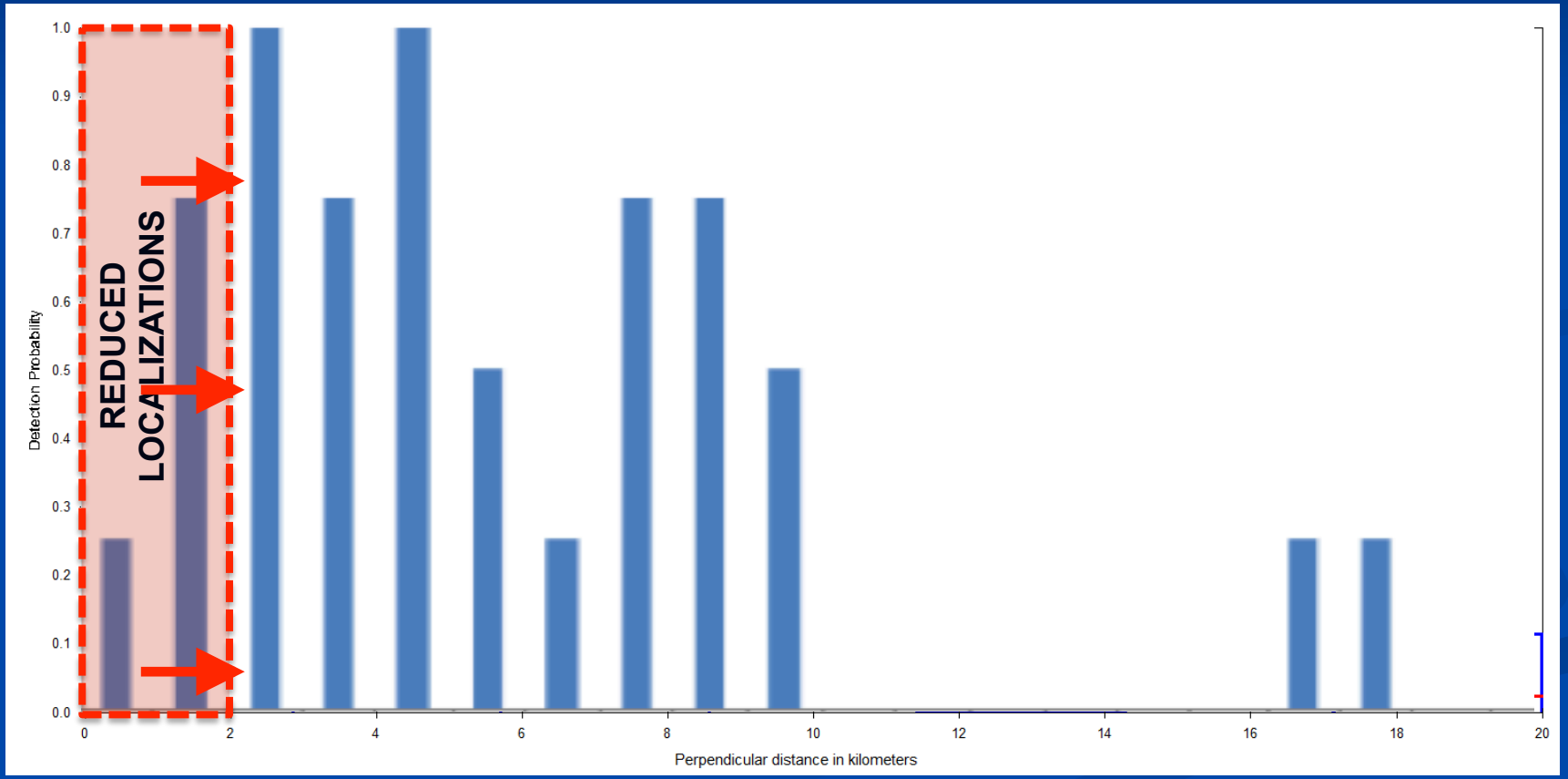
Detection Function

Minke Whales

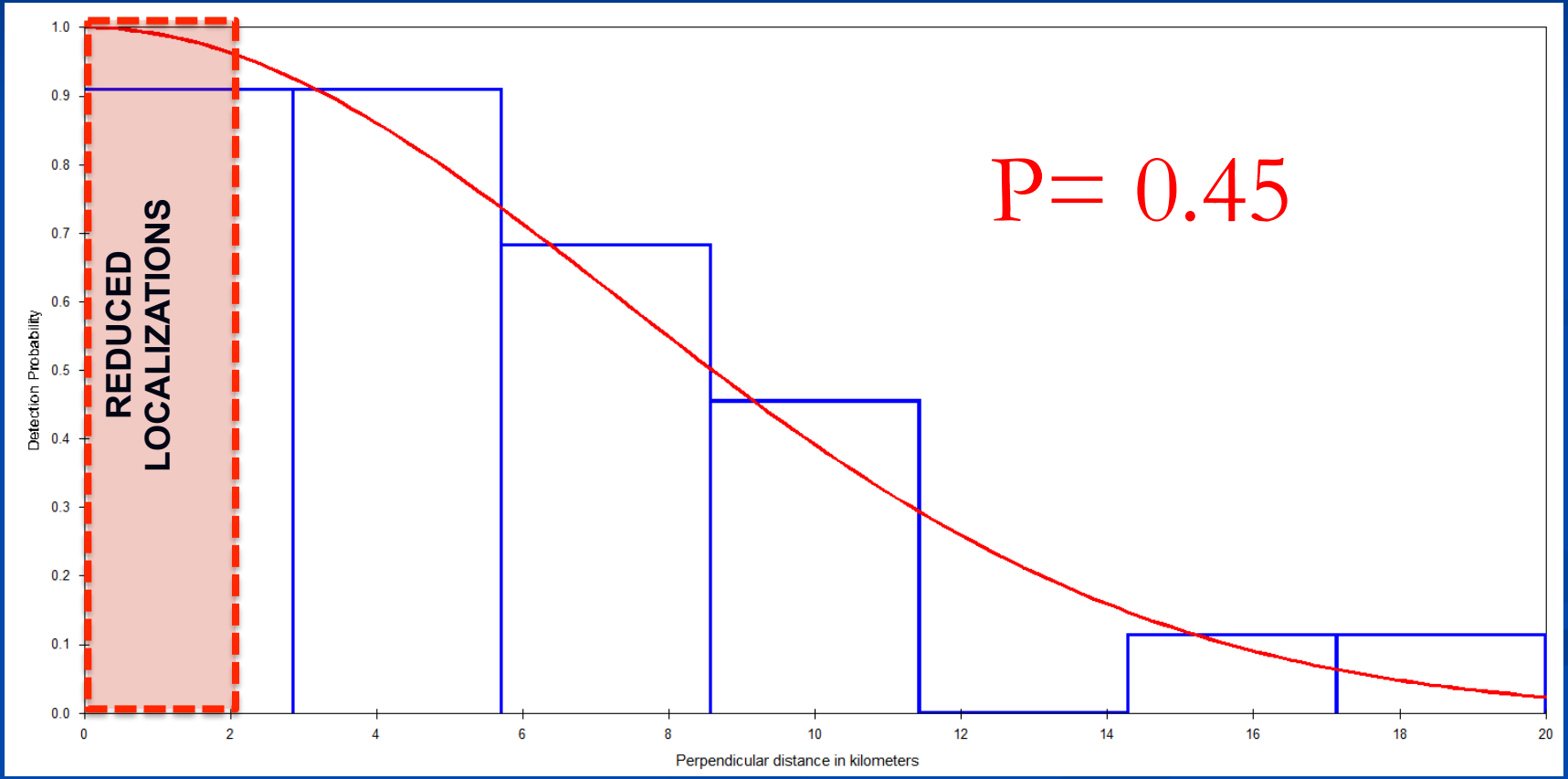
Scenario 1 - Avoidance



Detection Function

Minke Whales

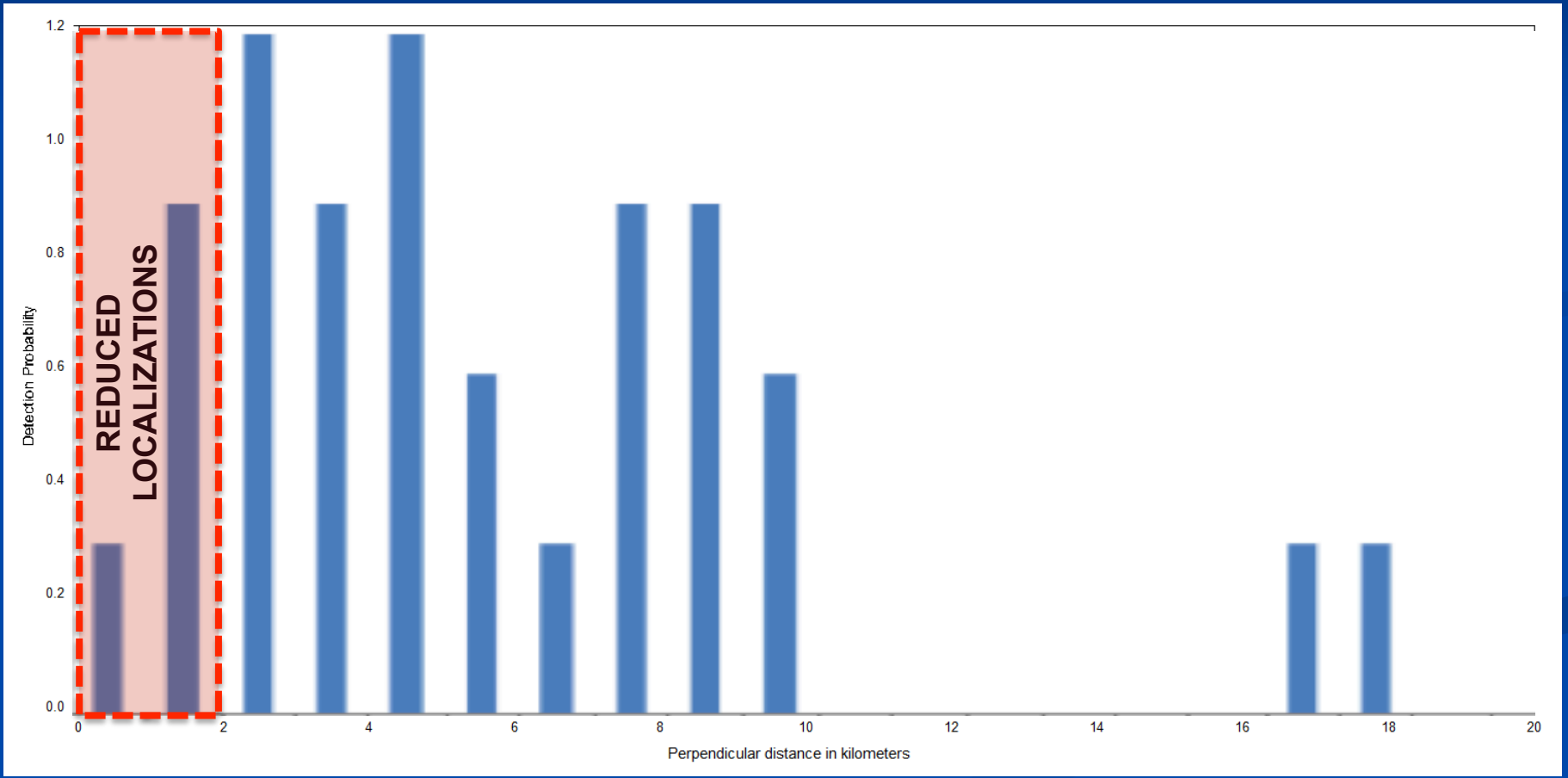
Scenario 1 - Avoidance



Detection Function

Minke Whales

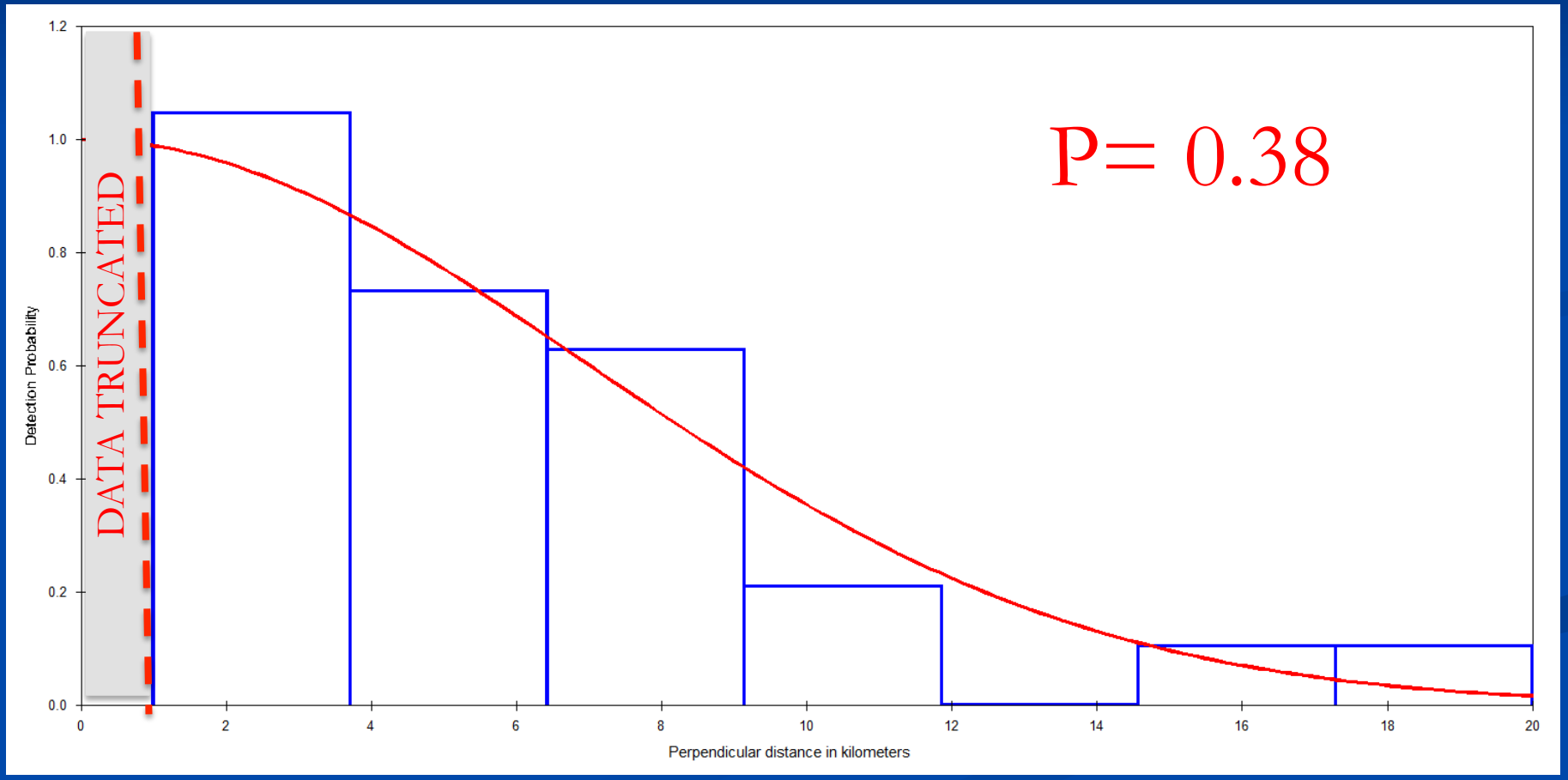
Scenario 2 – reduced calling



Detection Function

Minke Whales

Scenario 2 – reduced calling



Results

Scenario	N	95 % CI	Density (#/1000 km2)	CV (%)
#1 (avoidance)	80	41-155	0.13	34
#2 (call reduction)	91	48 - 176	0.15	34

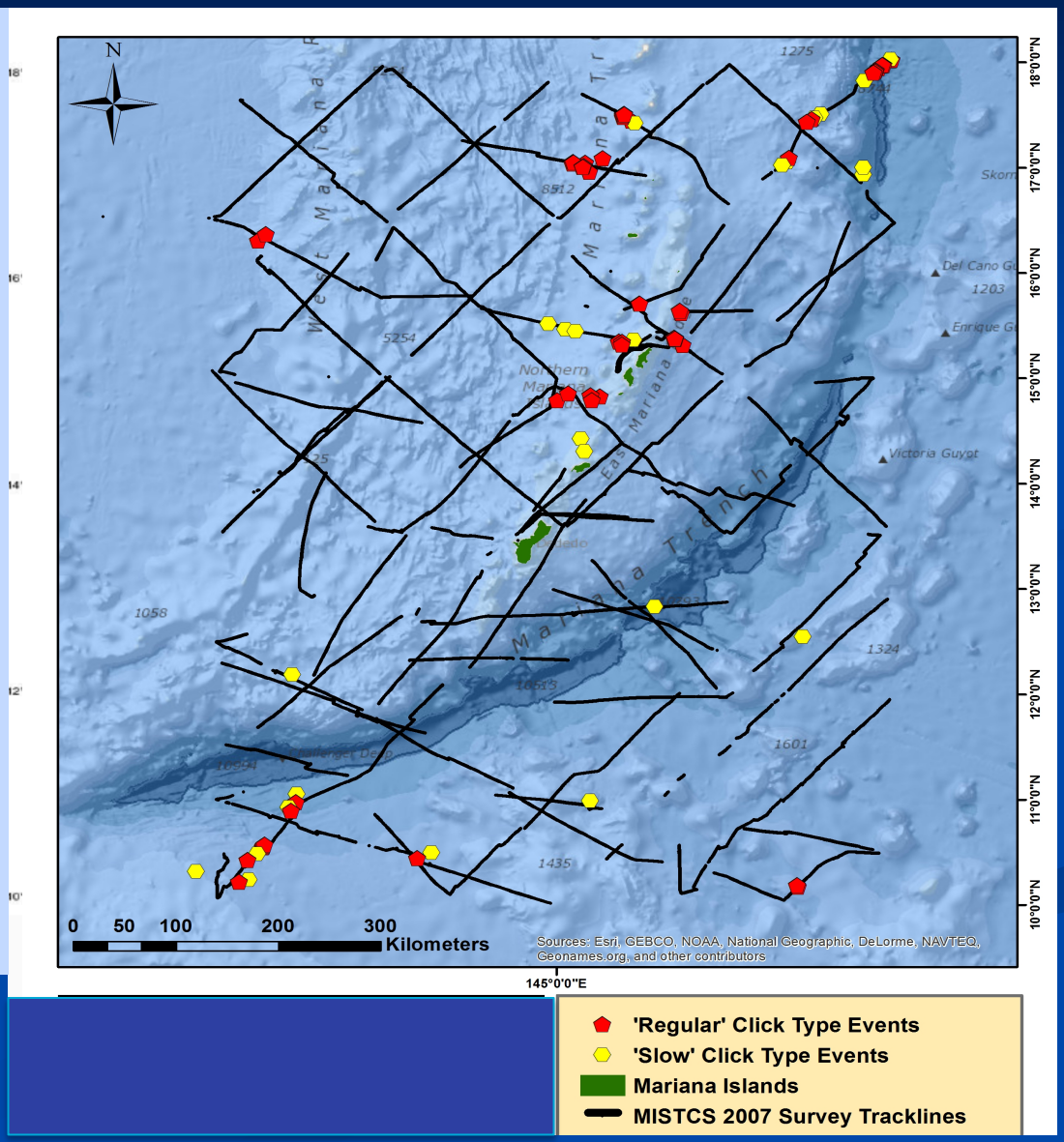
Sperm Whales Localizations

Visual Data*

- 19 sightings ☹
- Abundance = 705
- CV = 60.4% ☹ ☹

Acoustic Localizations

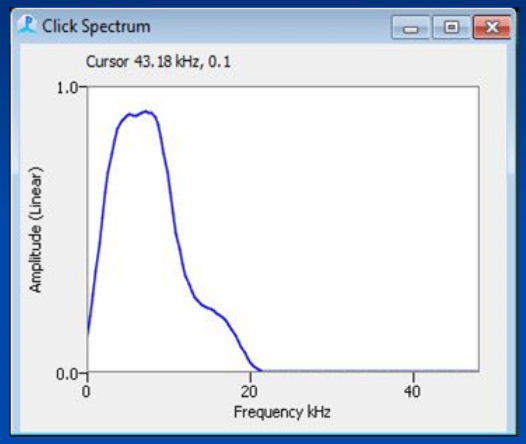
- ~30 real-time 😐
- 88 post-processed ☺

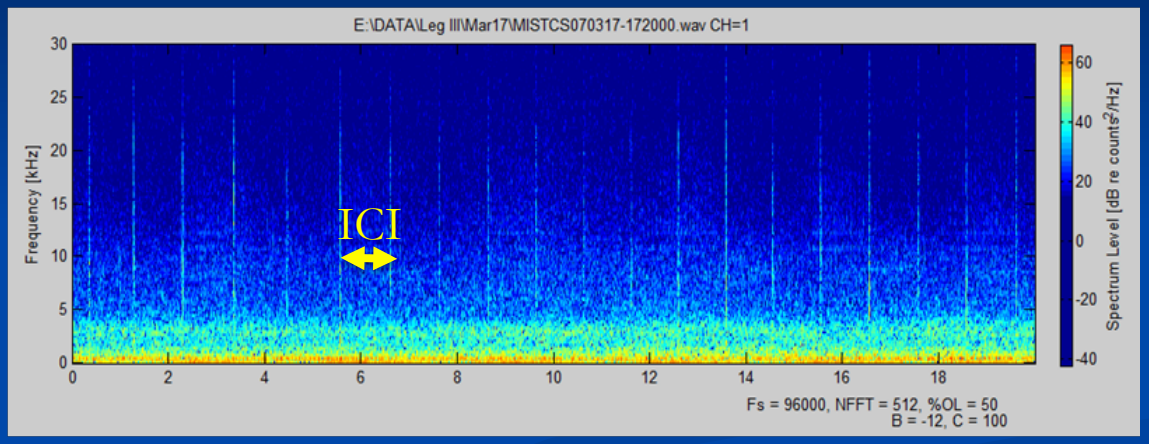


* Visual abundance estimates from Fulling et al . 2010 (Pac. Sci)

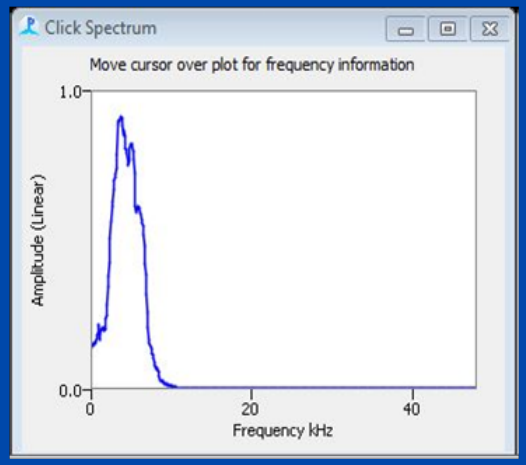
Click Types

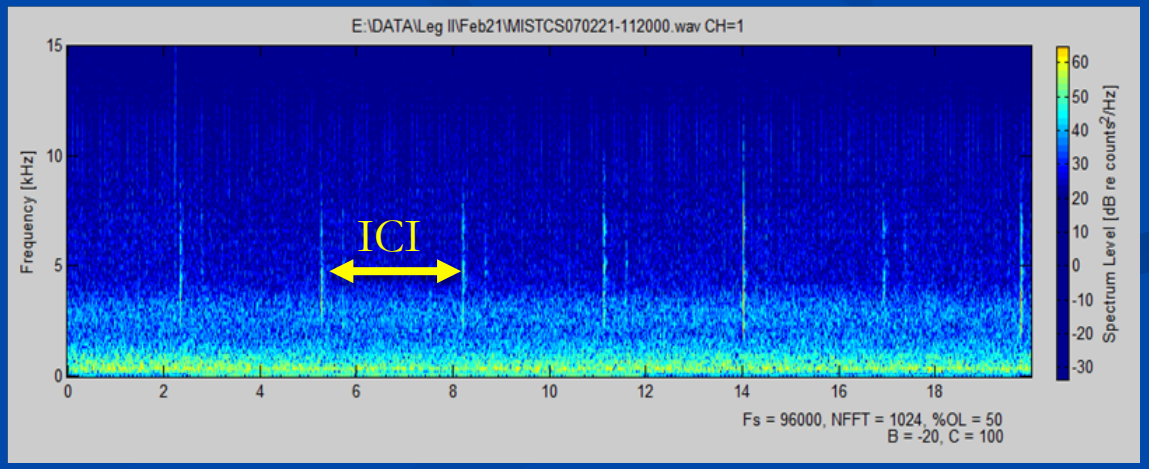
Regular (usual) Females & Juveniles



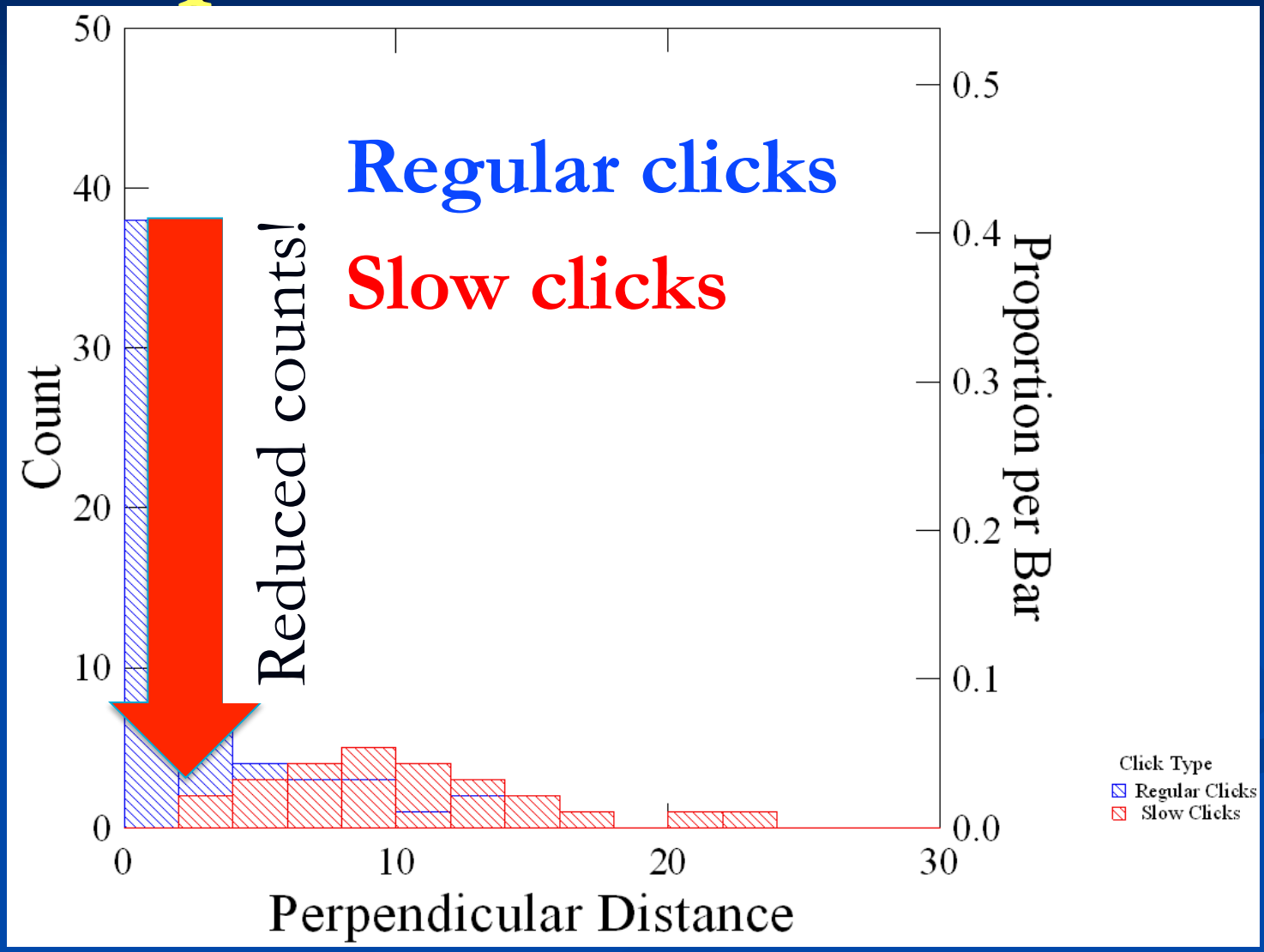


Slow Mature Males





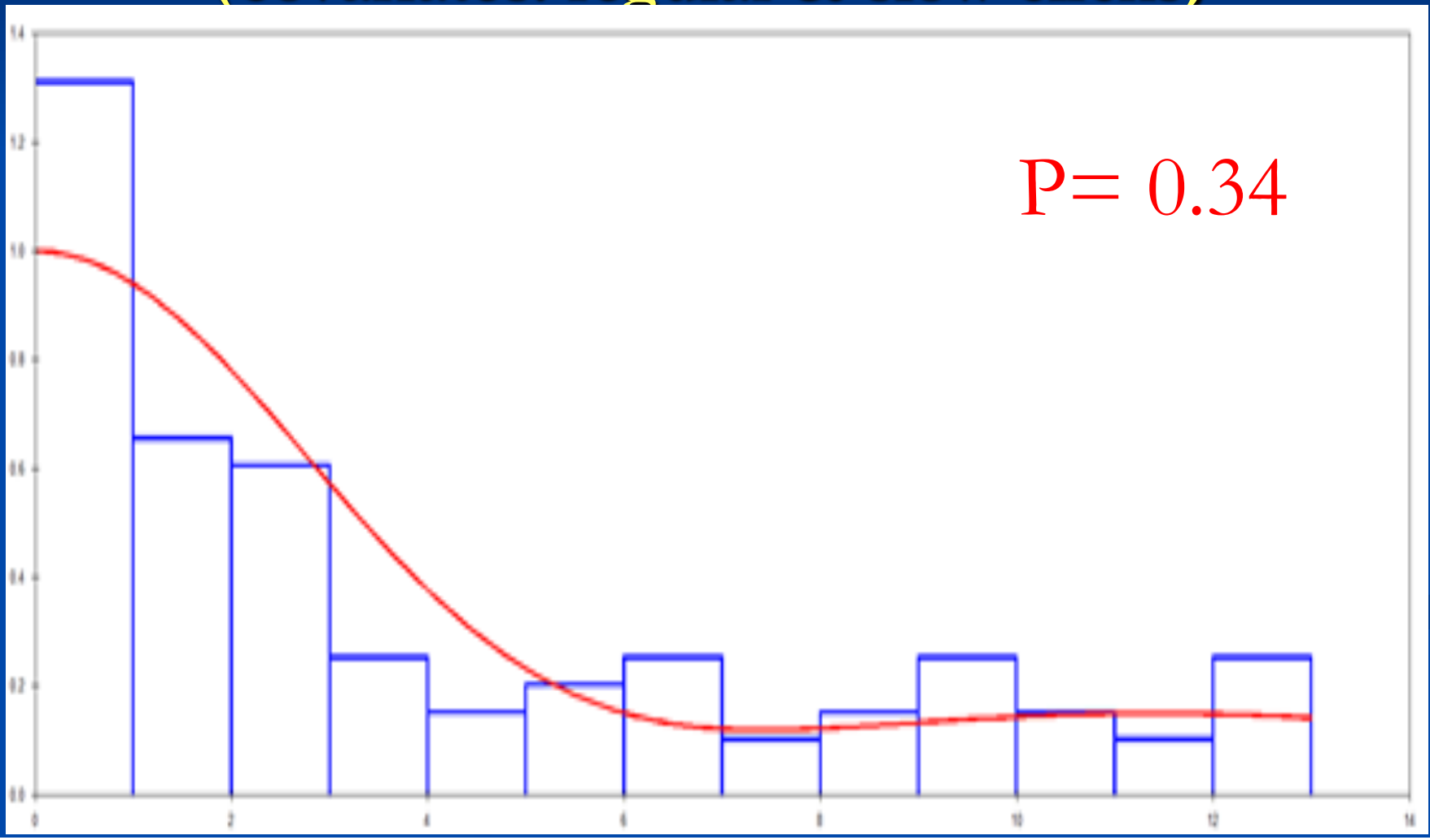
Histograms
All Sperm Whale clicks



Sperm whales

MCDS global detection function

(covariates: regular & slow clicks)



Results
Sperm Whales

ABUNDANCE/DENSITY ESTIMATES				
	N	**Density***	**CV**	**95% C.I**
Visual Estimates*	705	1.23	**60%**	228-2,181

Density* is per 1000 km2

***Visual abundance estimates from Fulling et al . 2010 (Pac. Sci) and used a slightly different area**

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Results

Sperm Whales

POST STRATIFIED RESULTS (Slow and Regular clickers)			
Strata Type	**N**	**Density***	**CV**
Regular clickers (fem + juv)	450	0.73	39%
Slow clickers (males)	65	0.11	39%

Density* is per 1000 km2

Results

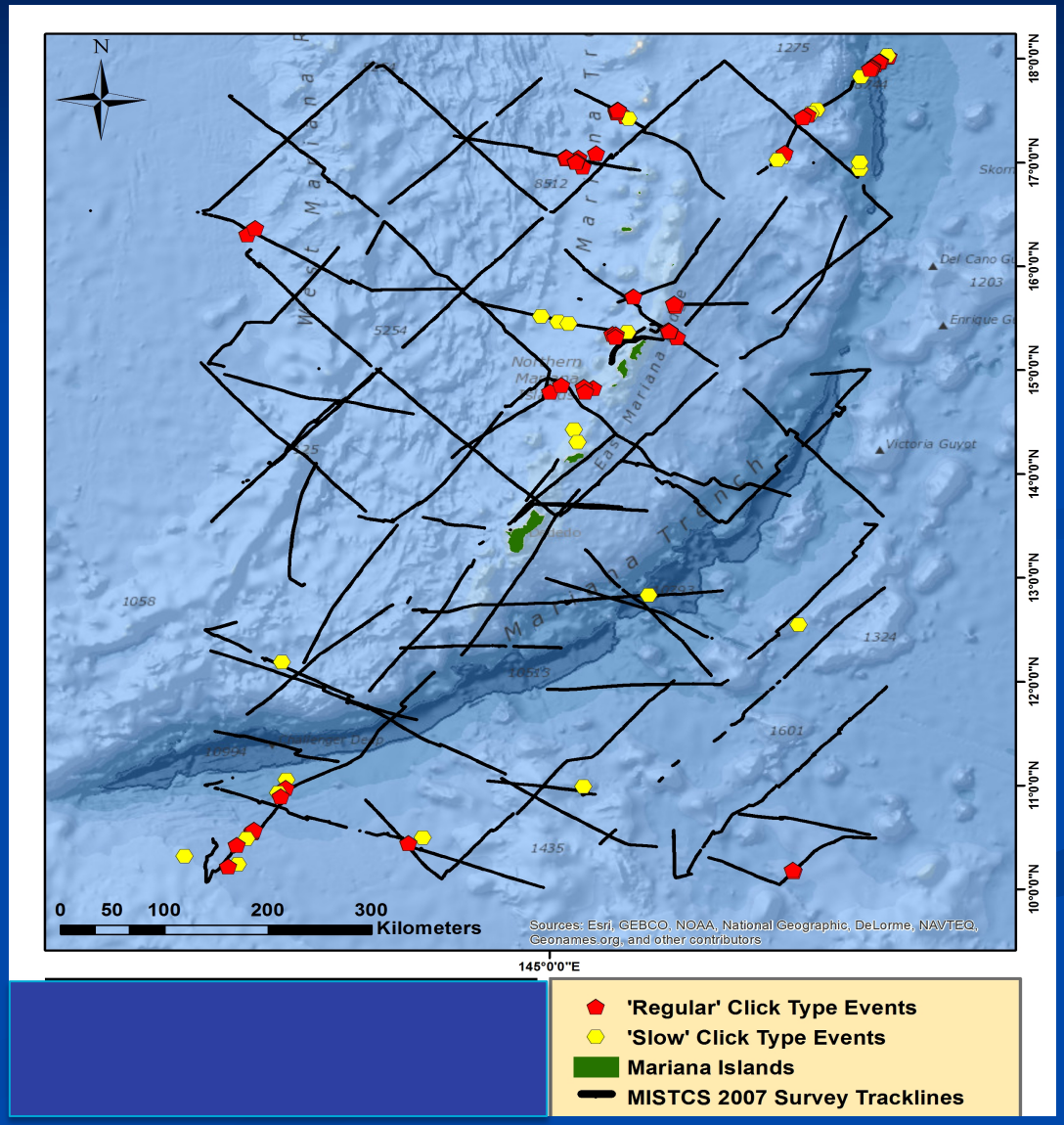
Sperm Whales

- 19 sightings ☹
- Abundance = 705
- CV = 60.4% ☹ ☹

- 88 acoustic localizations ☺
- Abundance = 516
- CV = 39 % ☺☺

- Bonus! Estimates for Males (65) and females/juv's (450)

☺☺☺



DISCUSSION

- (Violations of) Assumptions
- Biases and Error
- Caveats
- Recommendations

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(Violation of) Assumptions

$G(0) < 1$

(not all animals on trackline detected)

Results in an underestimation of abundance

- amount of bias depends how severe this effect is

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(Violation of) Assumptions

Animals must not respond to Vessel

Avoidance ?

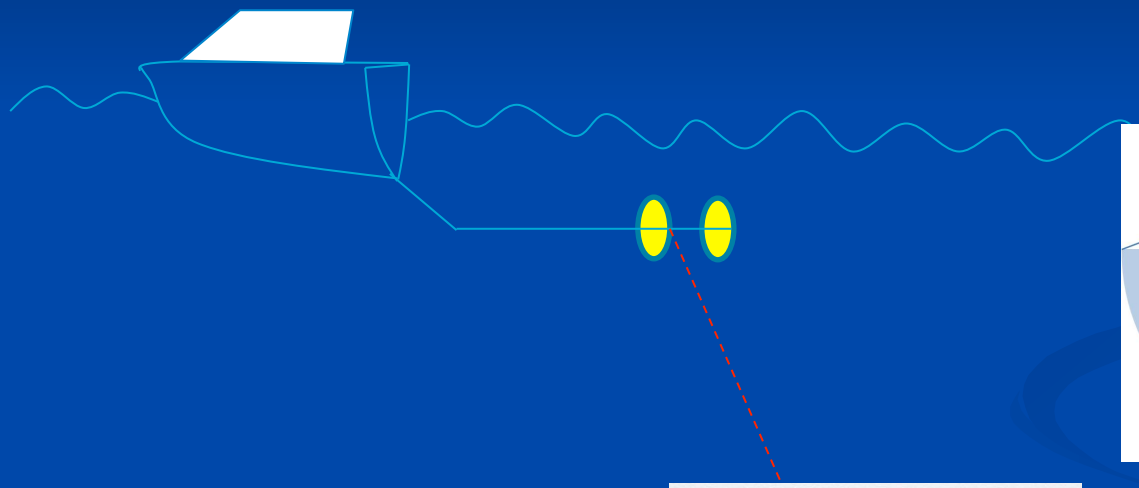
or

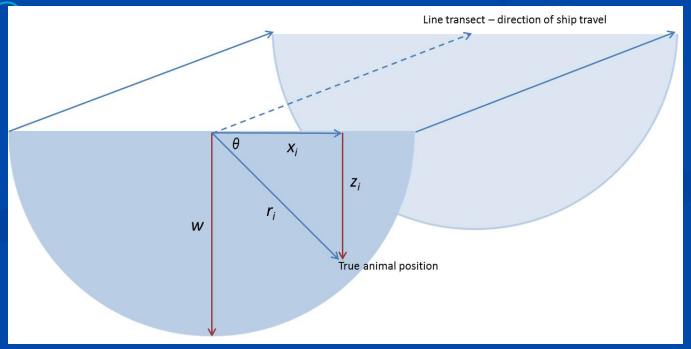
Reduced vocalizations near trackline ?

Difficult to Access which it is!

Measurement Errors

See Tina Yack's Talk Tomorrow!





Ignoring this problem overestimates distances and **underestimates** density.

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University of St Andrews

Caveats

- We are only estimating abundance of calling animals
  - Not a problem for sperm whales
  - Not sure about minke whales but possibly < 50%

  (under- estimation)
- Missed or undetected (or un-localizable) animals

  (under- estimation)

  There are measurement errors that likely affect P

  (under- estimation)

Recommendations

- Distance methods are versatile, try various approaches to handle issues with acoustic data
- If possible, address violations of assumptions.
- We need a better understanding of responsive movement and vocal behaviors relative to vessels.
  - vocalization rates
  - responsive animal movements
- Conduct simultaneous tracking and/or tagging

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Summary

- Post processing of data using new methods resulted in major increases in localizations over real-time processing methods.
- Advanced distance sampling methods were used to estimate density and abundance of two very different species.
- Acoustic based estimates have lower CV's than visual estimates but might have other biases.
- Acoustic estimates are probably biased low.

Questions?

Acknowledgements:

St. Andrews/CREEM: L. Thomas & D. Harris

Sponsors: NAVFAC Pacific & HDR

Correspondence:

thomas.f.norris@bio-waves.net

END OF TALK

Main Talking Points

- Main points –
- Covariates reduced CVs?
- Post stratification allowed density for Adult Males and slow clickers and regular clickers
- Did not left truncate for reduced loclalizations near trackline because it did not matter???
- Biases associated with acoustic probably had limited effects on the abundance estimate (repeat)

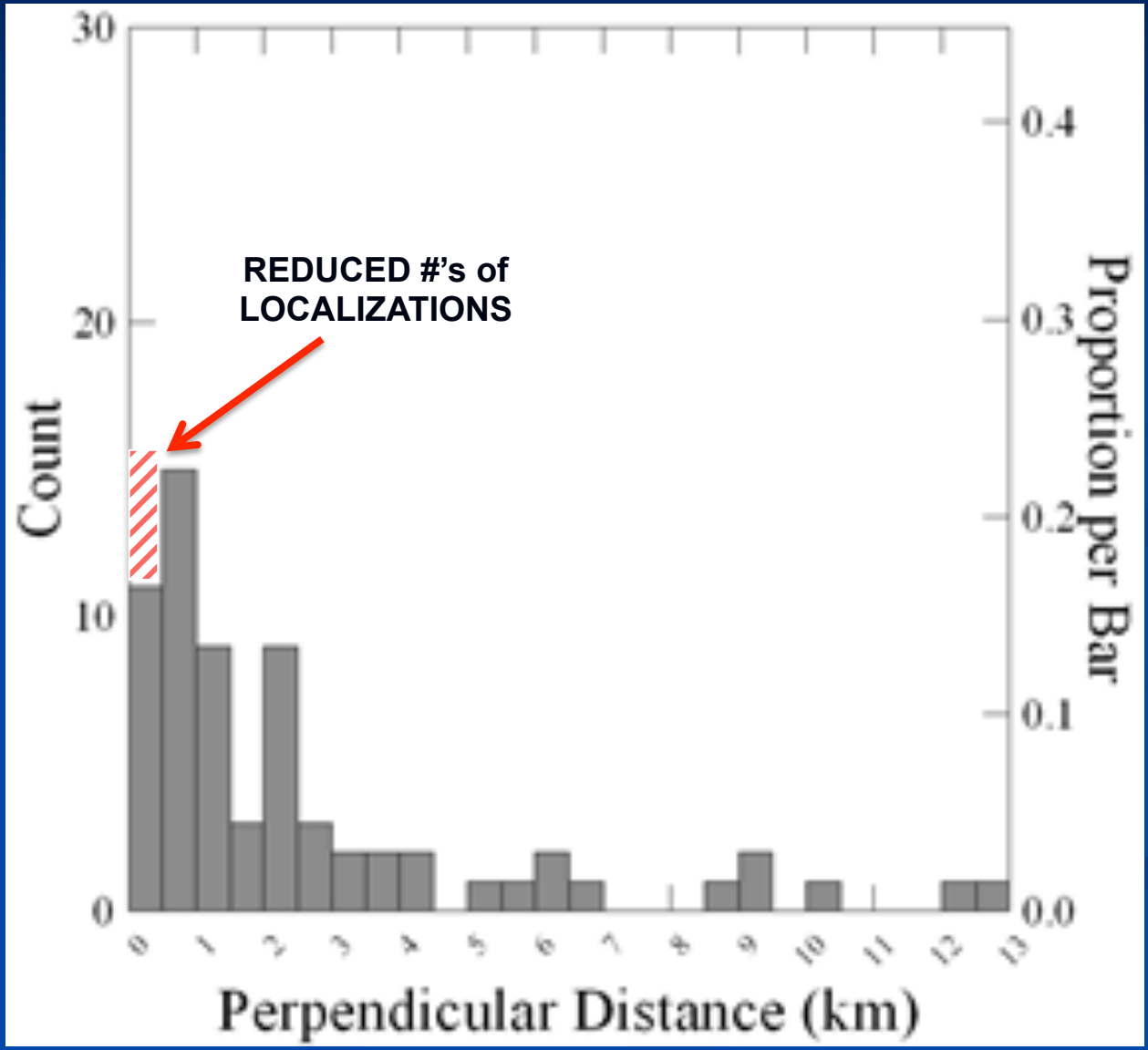
Main Talking Points

- Main points –
- Large area surveyed for 2 very different species that are difficult to detect visually in this remote and windy area
- Explain slow and regular (usual) click types
- Acoustic PM CVs were much lower than visuals
- Minke's were low densities but high enough acoustic encounter rates to estimate density
- Biases associated with acoustic probably had limited effects on the abundance estimate

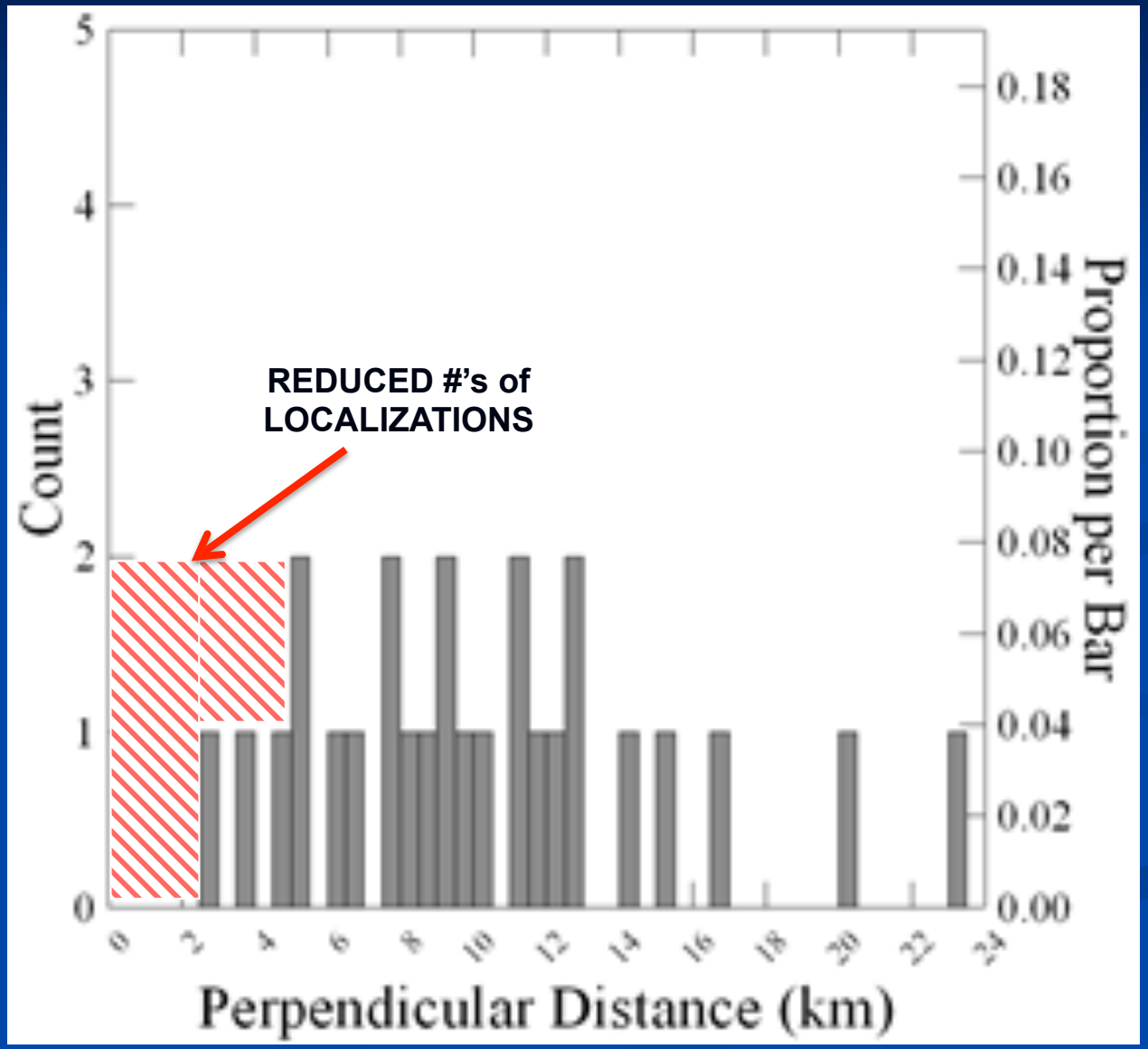
From page 35 in Advanced Distance Sampling Book

…covariates are incorporated into the estimation of the detection probabilities via the scale parameter of equation 3.10
In this formation, the covaritates are assumed to affect the *rate* (my emphasis) at which detectability decreases as a function of distance. Depending on the choose of standardization of distance in the adjustment terms, covariates need not influence the shape of the detection function.

Regular clicks

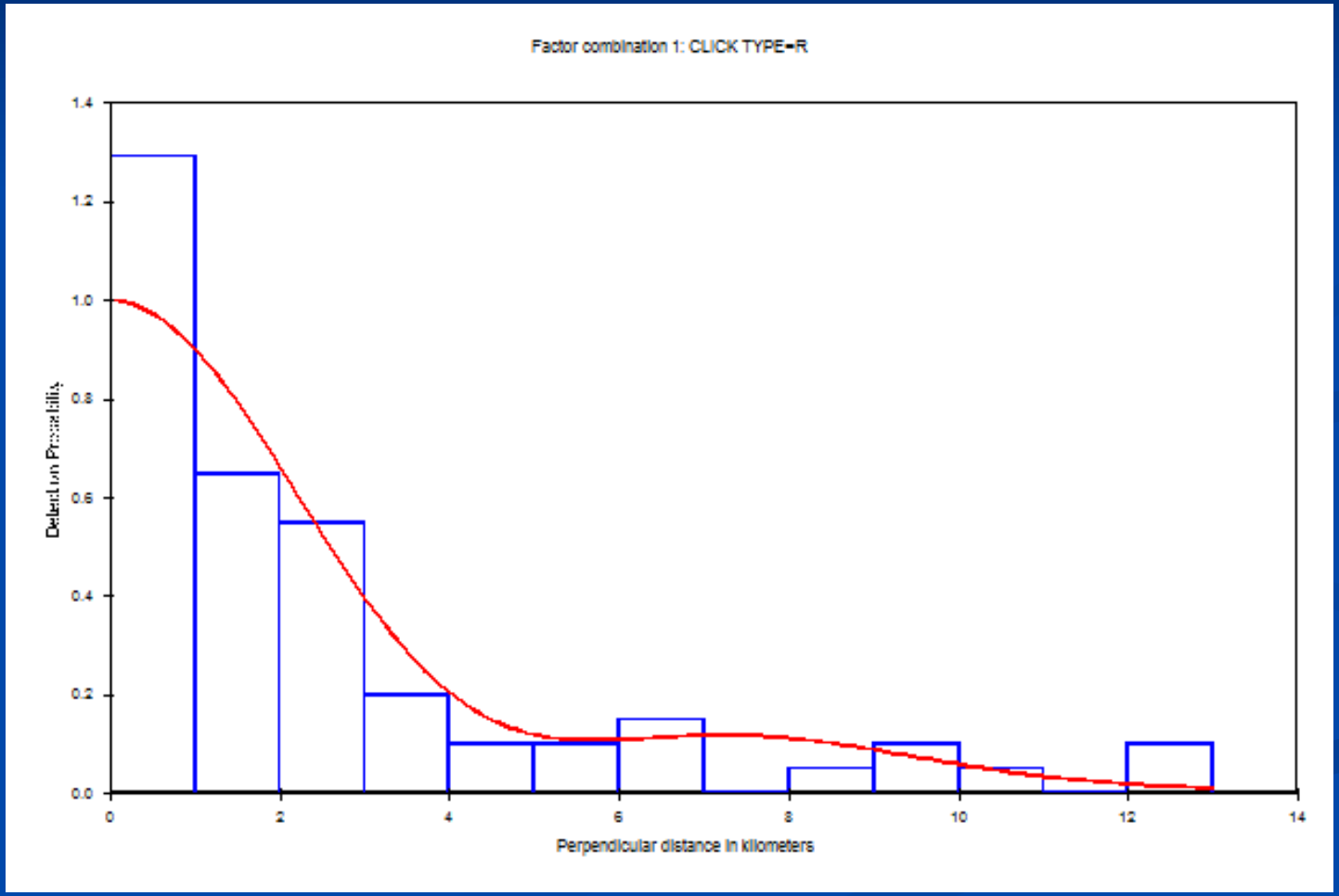


Slow Clicks

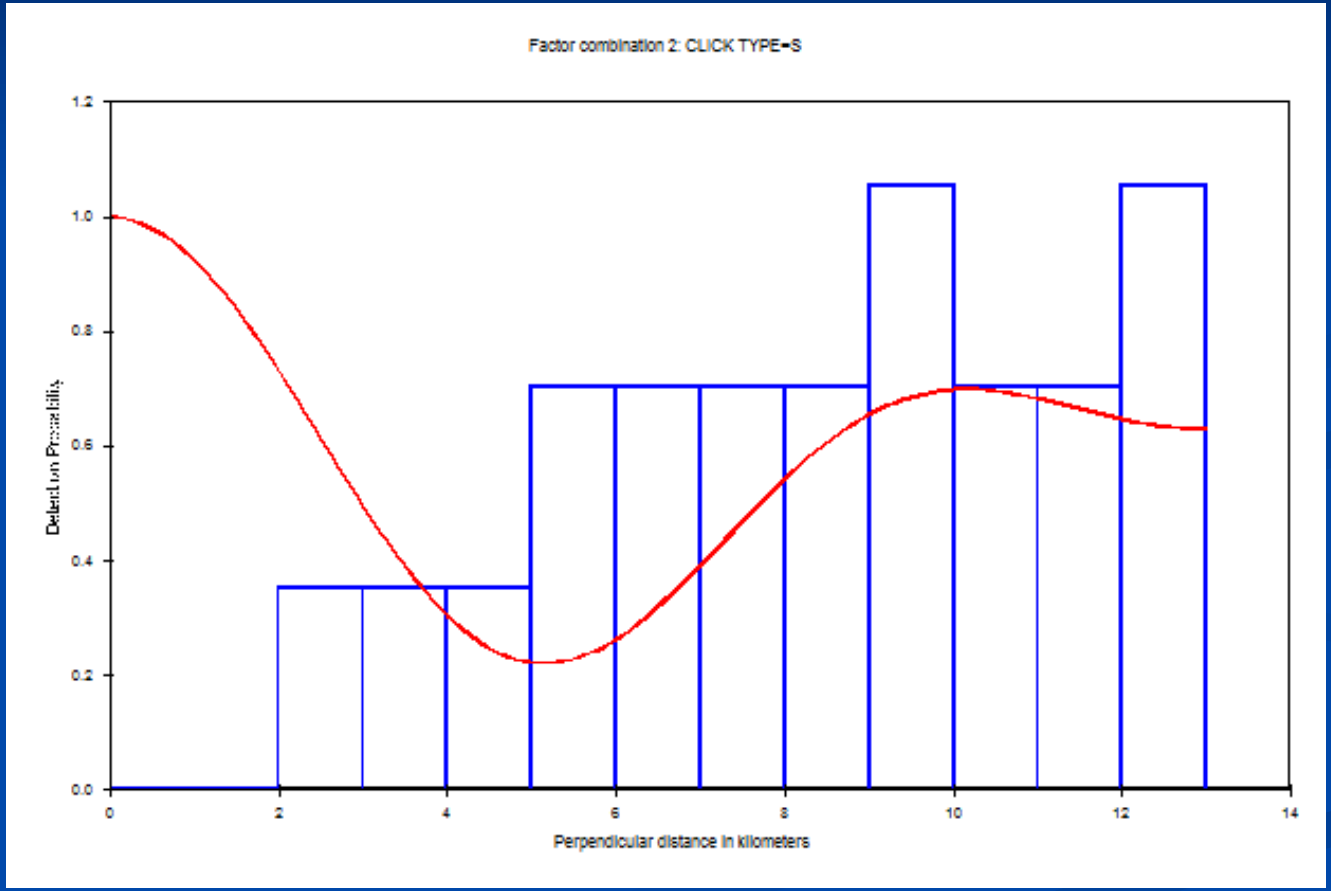

REDUCED #'s of
LOCALIZATIONS
Count
Proportion per Bar
Perpendicular Distance (km)
0
1
2
3
4
5
0.00
0.02
0.04
0.06
0.08
0.10
0.12
0.14
0.16
0.18
0
2
4
6
8
10
12
14
16
18
20
22
24


Count
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5

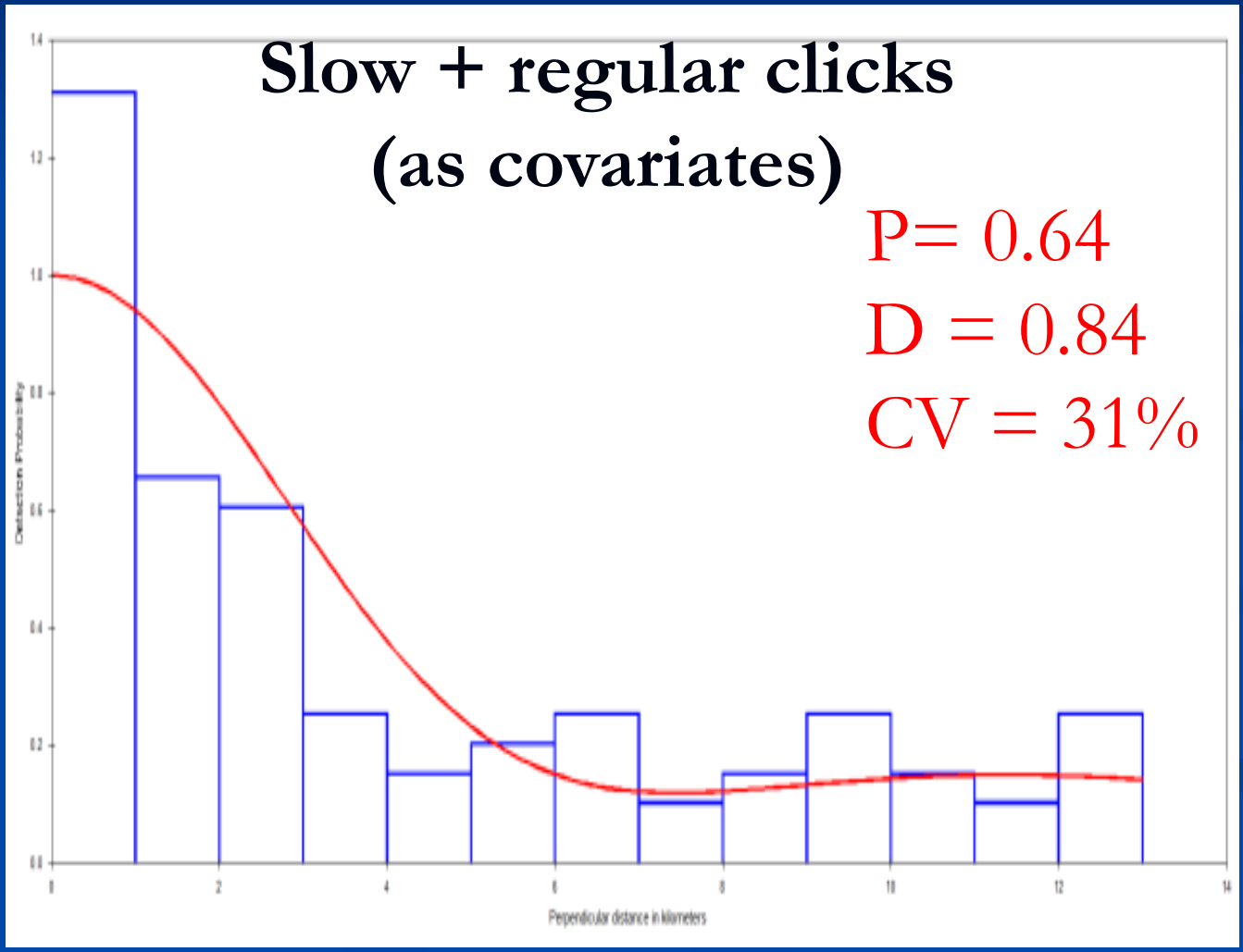
Sperm whales
detection function (regular clicks)

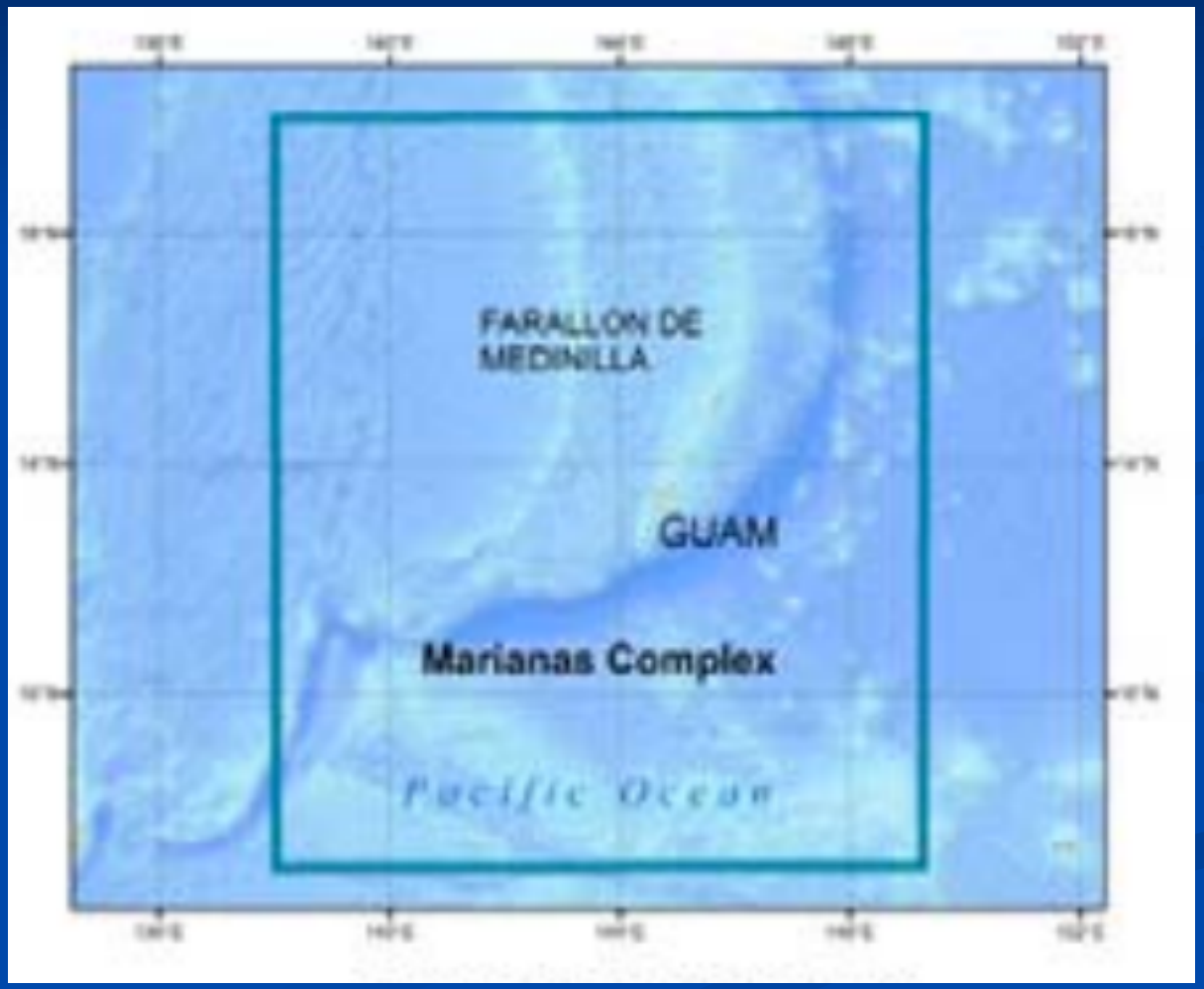


Sperm whales
detection function (slow clicks)



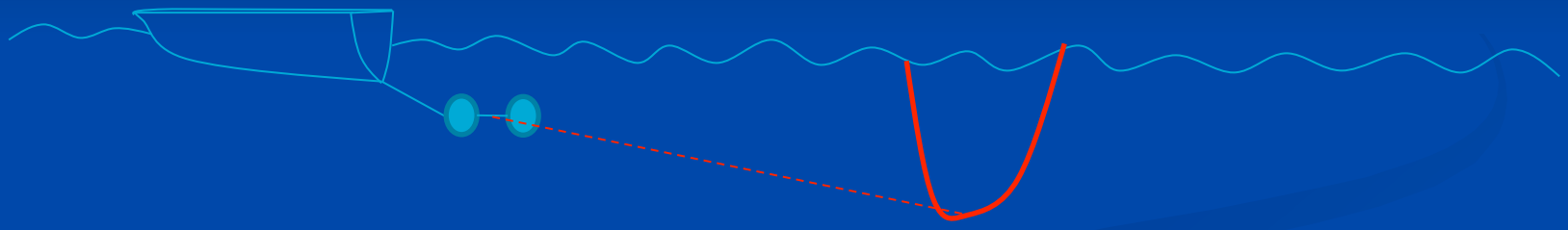
Sperm whales – Marianas
detection function (MCDS)




FARALLON DE
MEDINILLA
GUAM
Marianas Complex
Pacific Ocean

Depth Ambiguity

- Standard methods use horizontal perpendicular distance
- But perpendicular distance depends on depth of animal relative to hydrophone
- Standard methods assume these depths are the same
- If not correct, you overestimate perpendicular distances so underestimate density

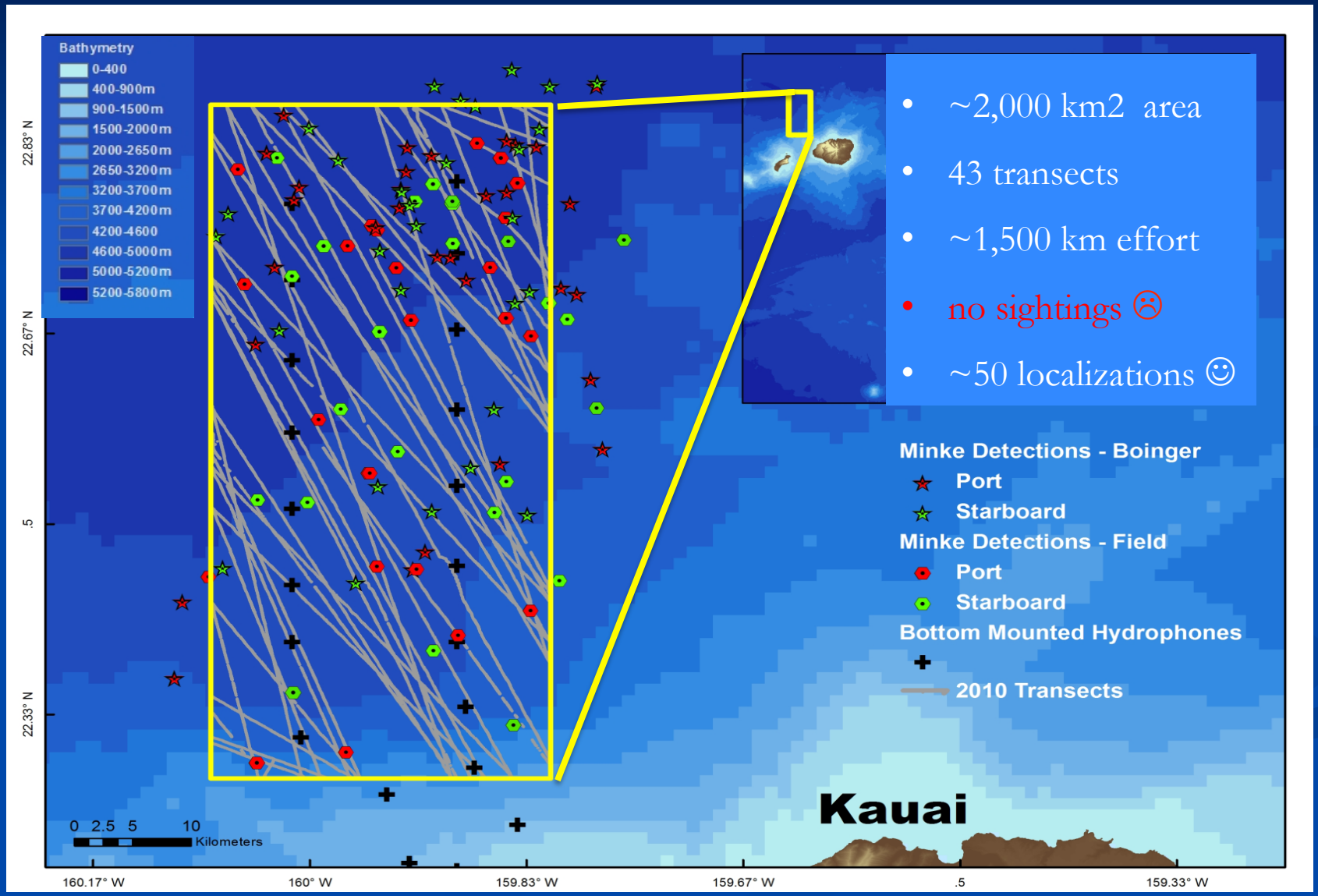


Shallow diver / large perp detection range – **no problem**

Deep diver / small perp detection range – **problem!**

- If you have a depth distribution (e.g., from tag data), analytic solution is possible (Thomas, in prep)

Minke Whale Survey - Kauai



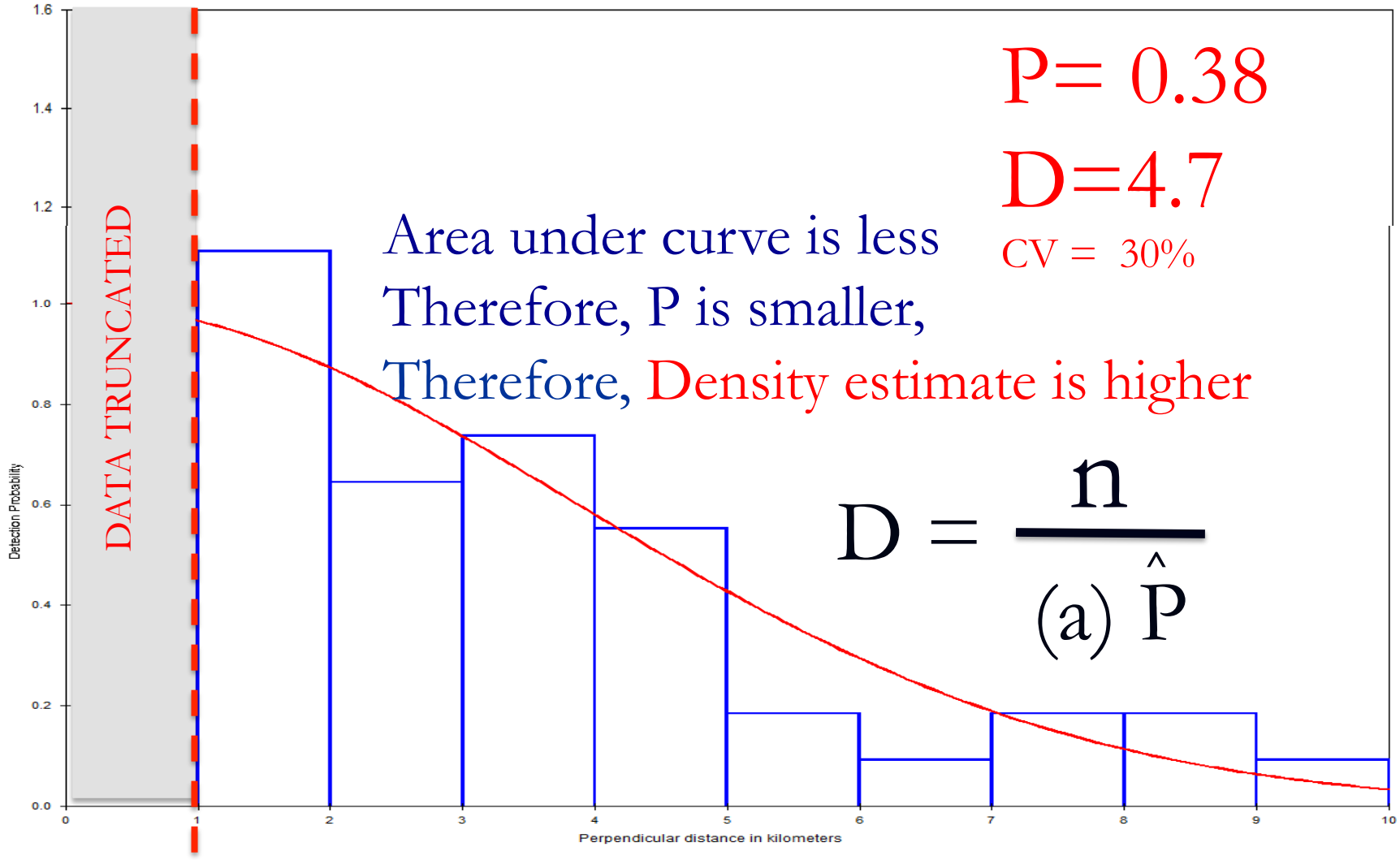
Minke Whale Summary Table (with assumptions)

Study Location	Assumptions	Abundance	Density*	CV(%)
Northern Marianas Islands	Avoidance	158	0.26	34%
	reduced calling	181	0.30	35?%

~13% diff. in Density

Density* is per 1000 km2

If Reduced Calling
(Left Truncation)



P= 0.38

D=4.7

CV = 30%

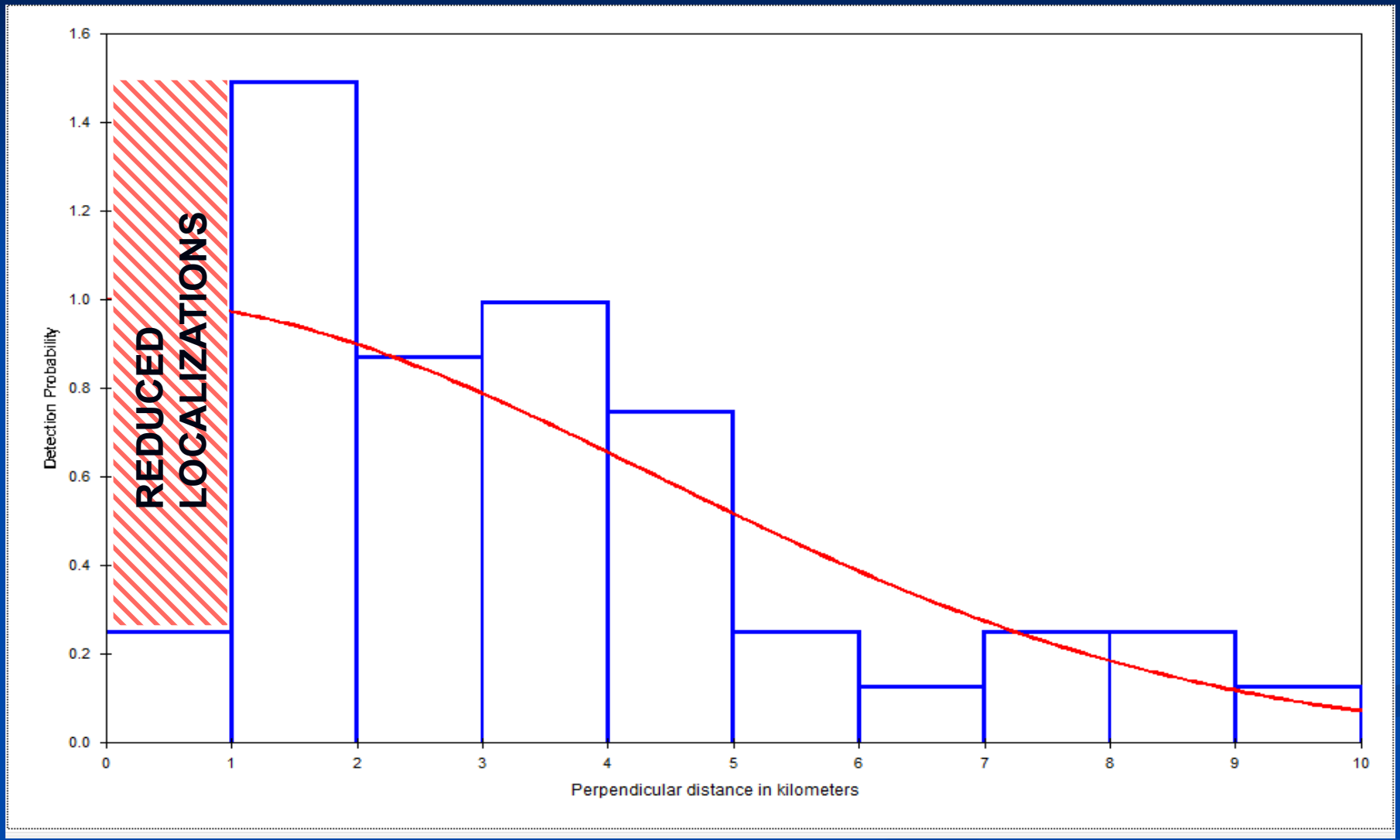
Area under curve is less

Therefore, P is smaller,

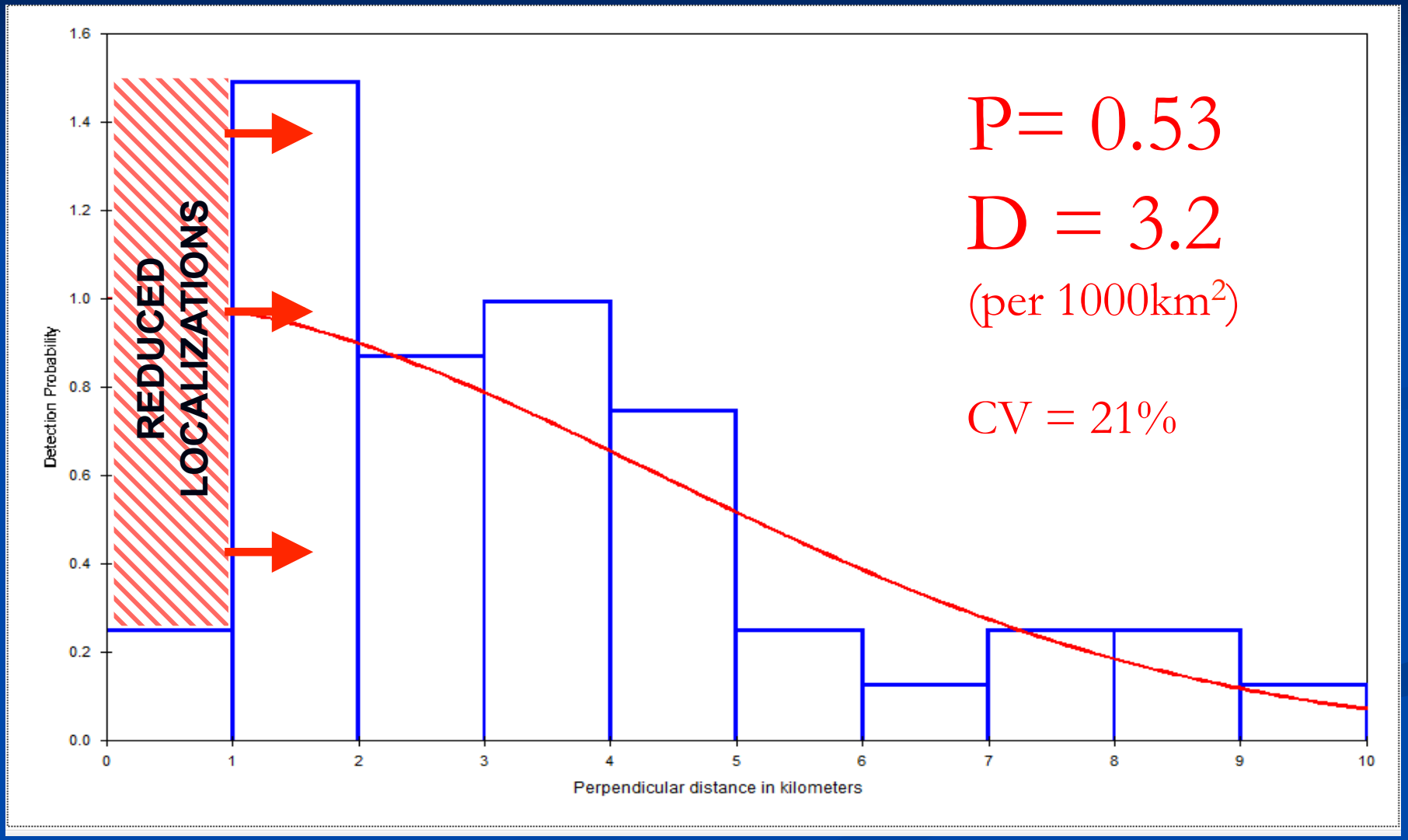
Therefore, Density estimate is higher

$$D = \frac{n}{(a)\,\hat{P}}$$

Minke Whales - Kauai



If animal movement

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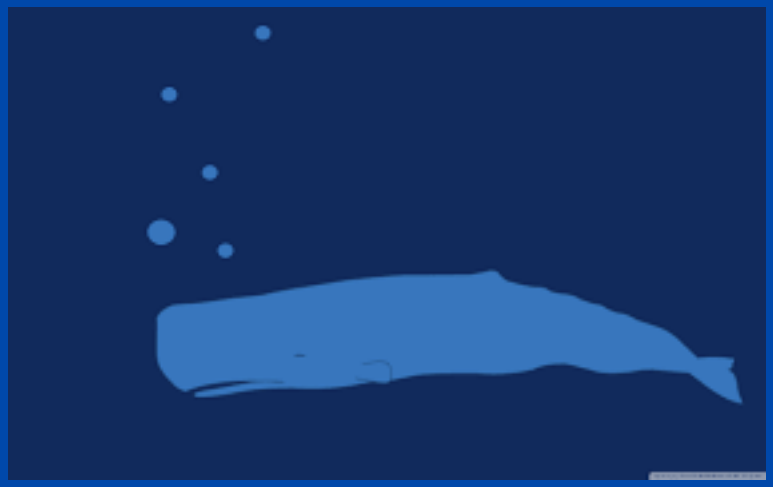
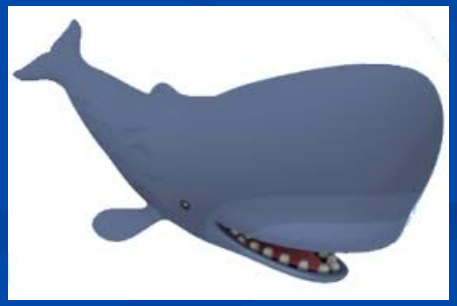




(Violation of) Assumptions

Sequential bearings are to same individual

- Localization of groups can result in large errors

Animals are vocalizing at similar depth as array

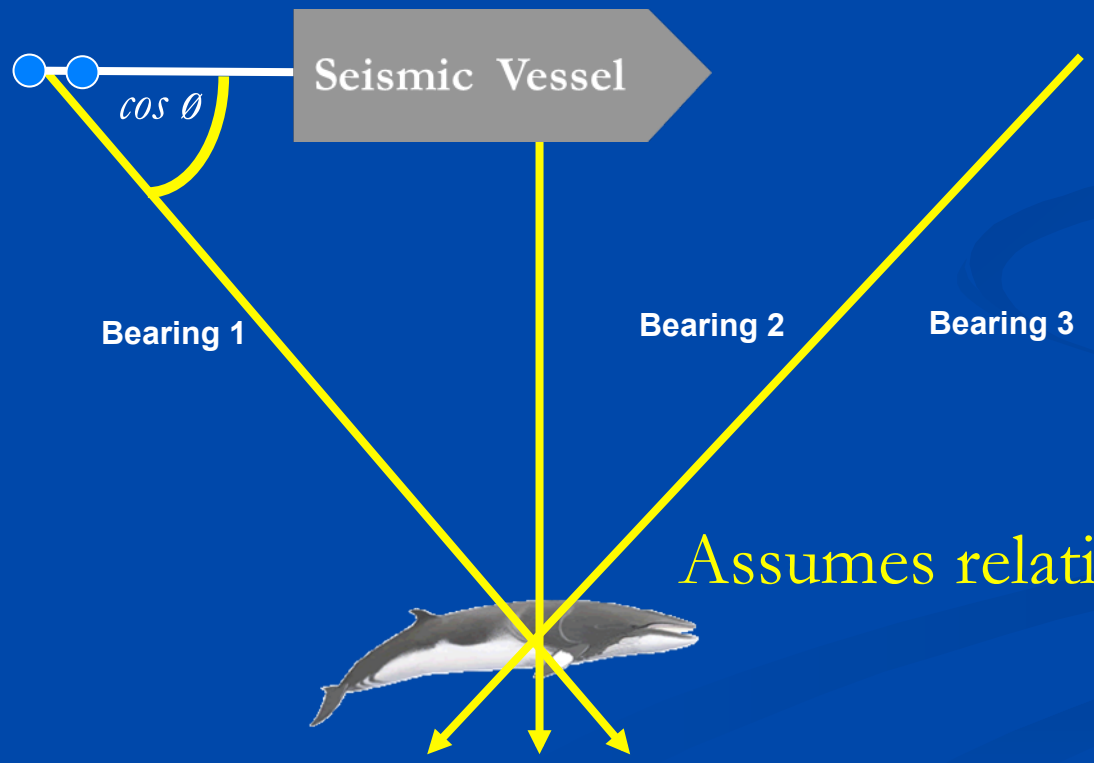
- Slant ranges may result large errors (especially for deep-divers)

Localization Method (Target Motion Analysis)

D = distance between hydrophones 1 & 2

Top View c = speed of sound in water

δt = time of arrival difference for h1 & h2



$$\cos\theta = \frac{\delta t(c)}{D}$$

Assumes relatively stationary animal!

Bio·Waves Incorporated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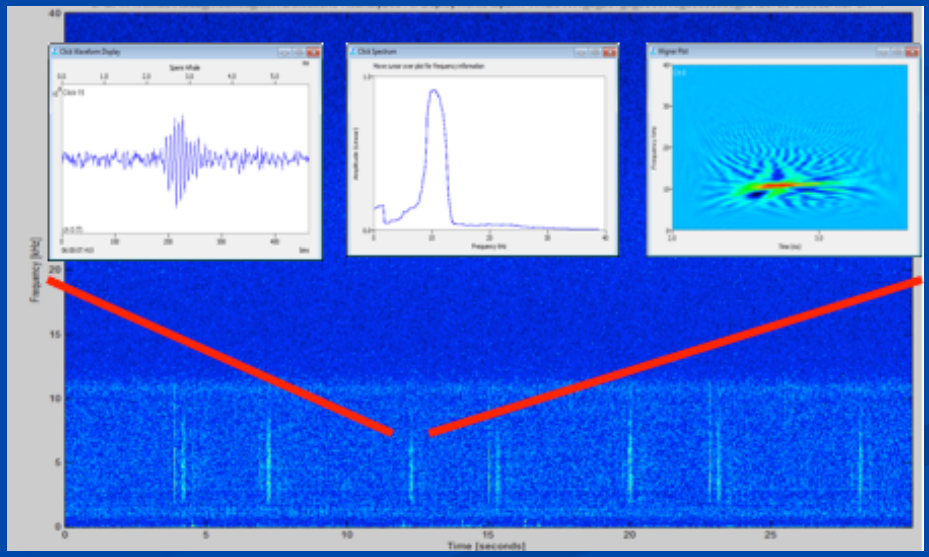
Frequency [kHz]
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