U.S. Navy Marine Species Monitoring Program

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US Navy Marine Species Monitoring Program – Annual Technical Review Meeting
San Diego, CA *14-17 March 2016*

From Clicks to Counts

Using passive acoustic monitoring to estimate the density and abundance of Cuvier's beaked whales in the Gulf of Alaska

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Objectives

- Detect and localize beaked whales and obtain '*perpendicular*' distances to **individual** animals (e.g. acoustic localization).

- Use conventional distance sampling (cds) to estimate density and abundance of Cuvier's beaked whales in the Gulf of Alaska (GoA).

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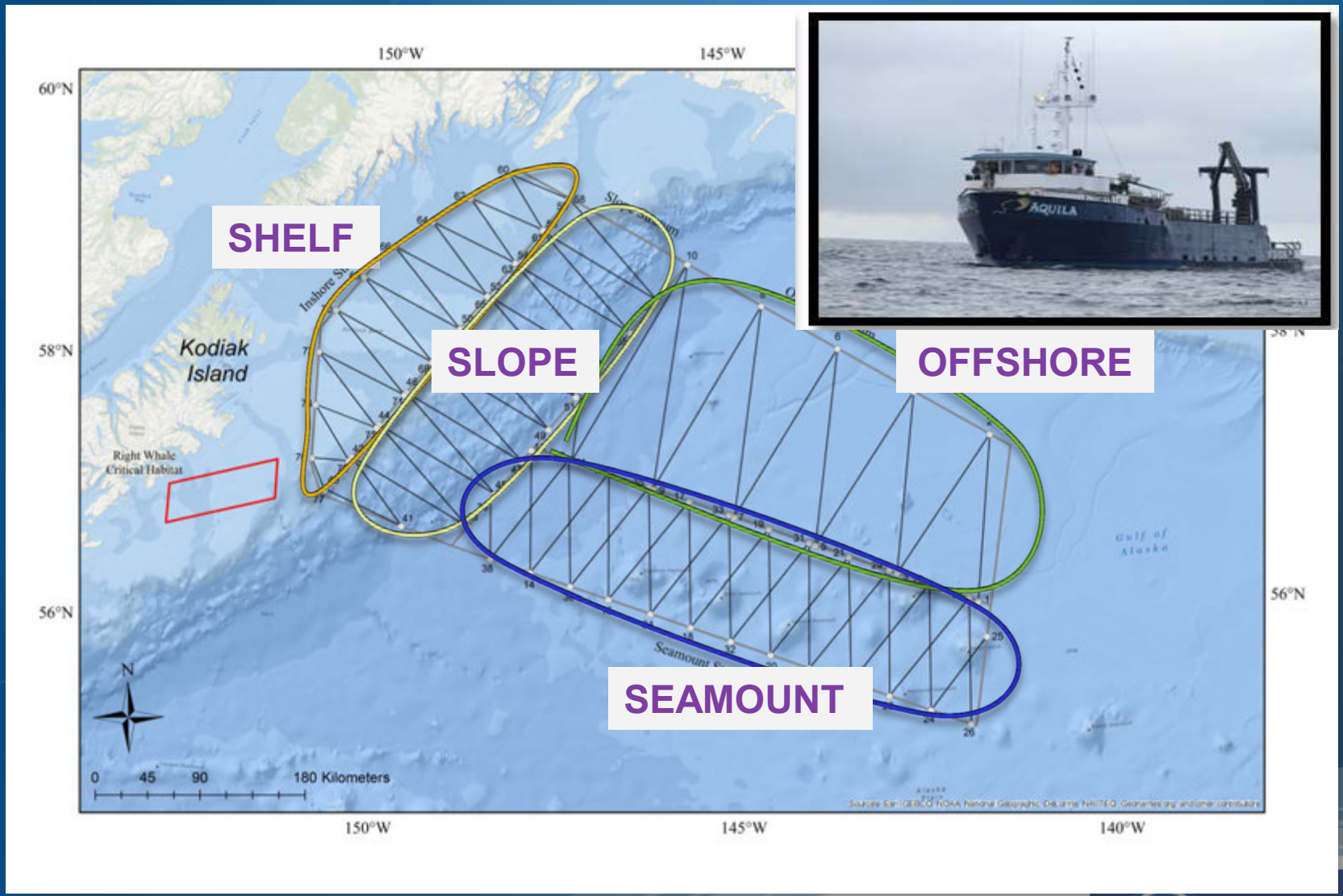
Study Area & Survey Design



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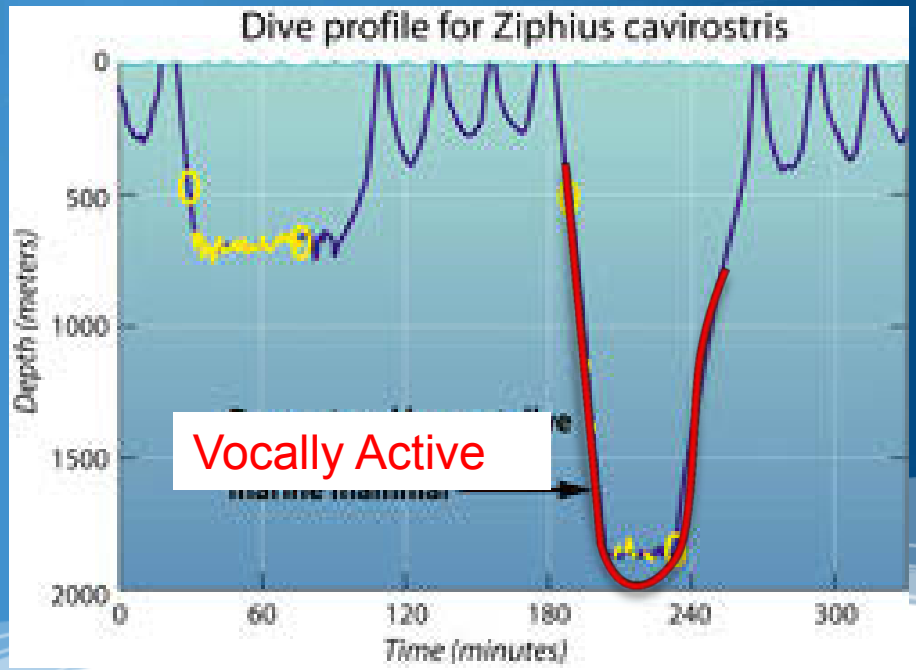
Beaked Whale Ecology

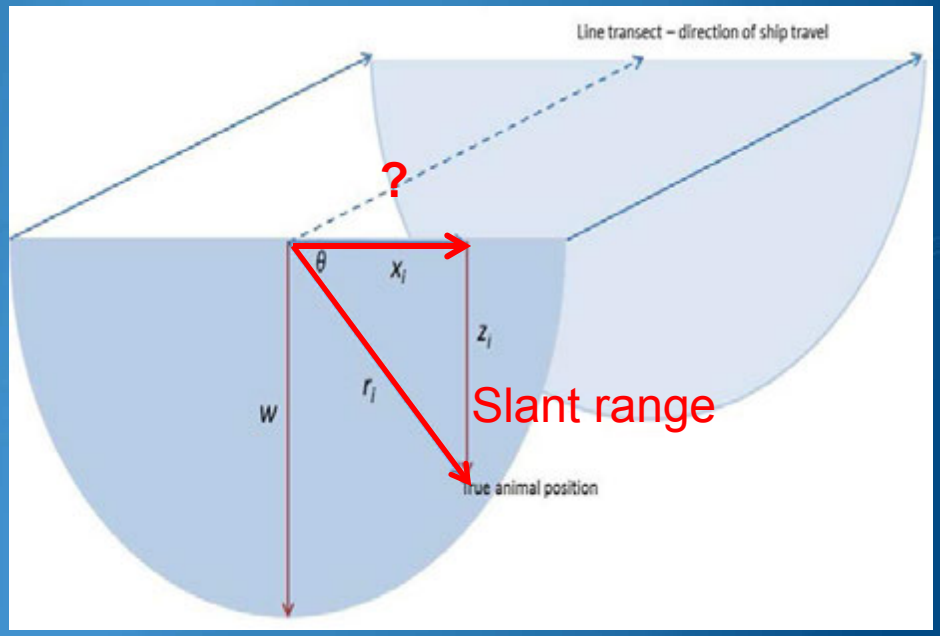
- 3 species of beaked whales occur in GoA
  - Cuvier's beaked whale (*Ziphius cavirostris*),
  - Baird's beaked whale (*Berardius bairdi*),
  - Stejneger's beaked whale (*Mesoplodon stejnegeri*).
- Feed on squid & benthic fish
- Deep-diving: Foraging dive durations > 1 hr @~2000 m
- Often occur in small groups
- Cryptic surface behavior
- Vocally active during foraging dives



Tyack et al. 2012
http://www.whoi.edu/main/newsreleases/2006?tid=3622&cid=16726

The Problem with Deep Divers

- Unknown animal depth = unknown **horizontal** distance.
- Problem for any species where **dive depths are similar to the detection range.**
- Ignoring the problem overestimates distances and **underestimates** density.



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Methods

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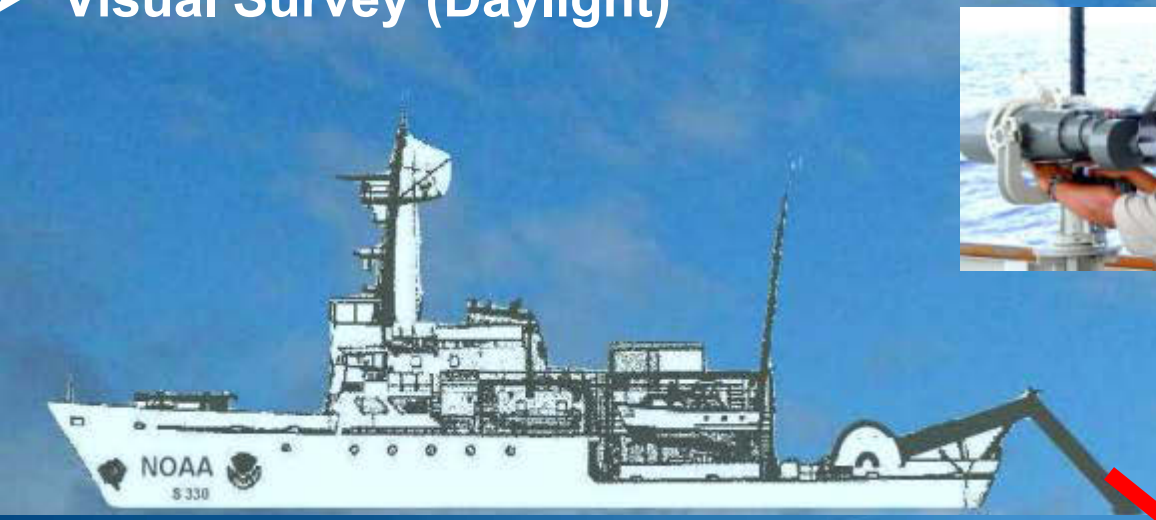
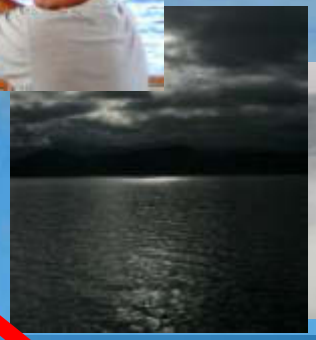
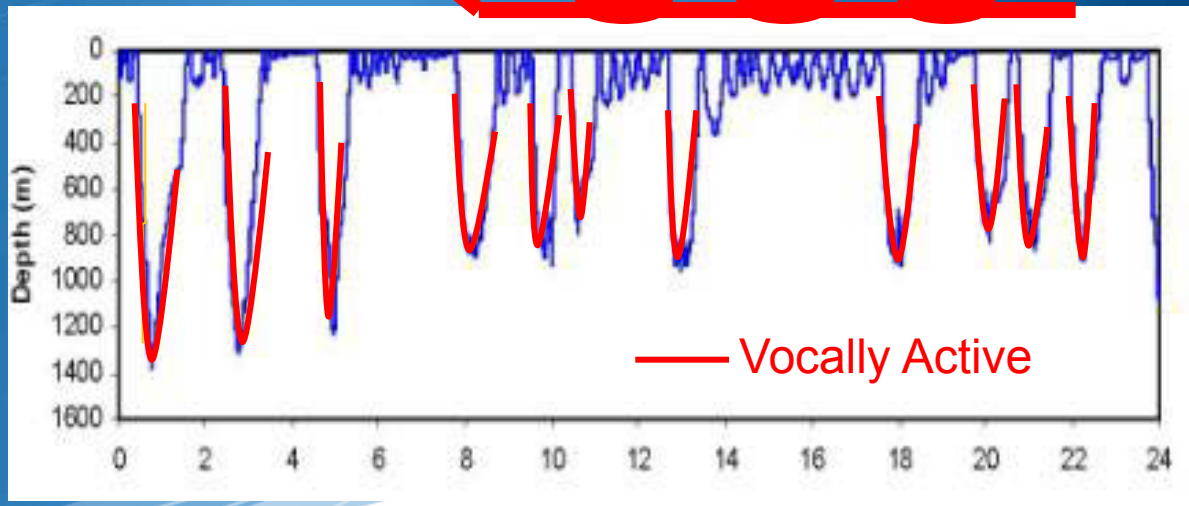
Survey Methods

- **Visual Survey (Daylight)**



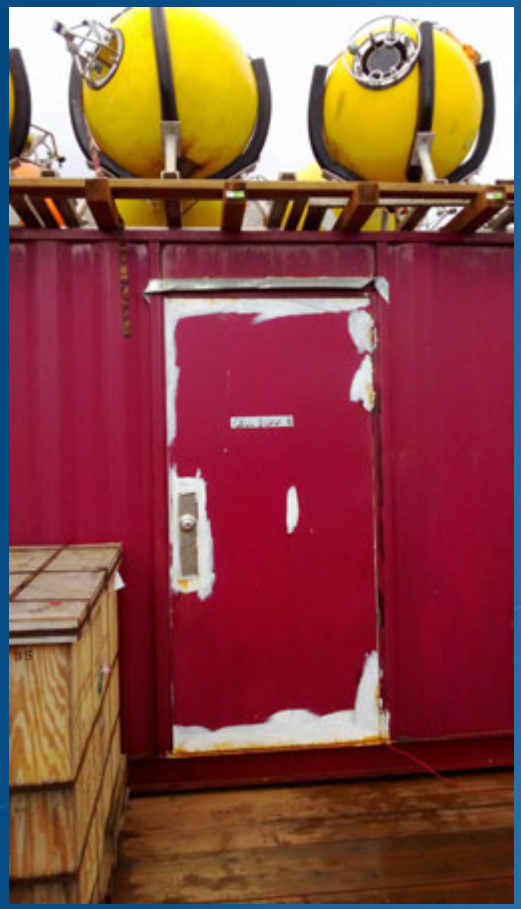


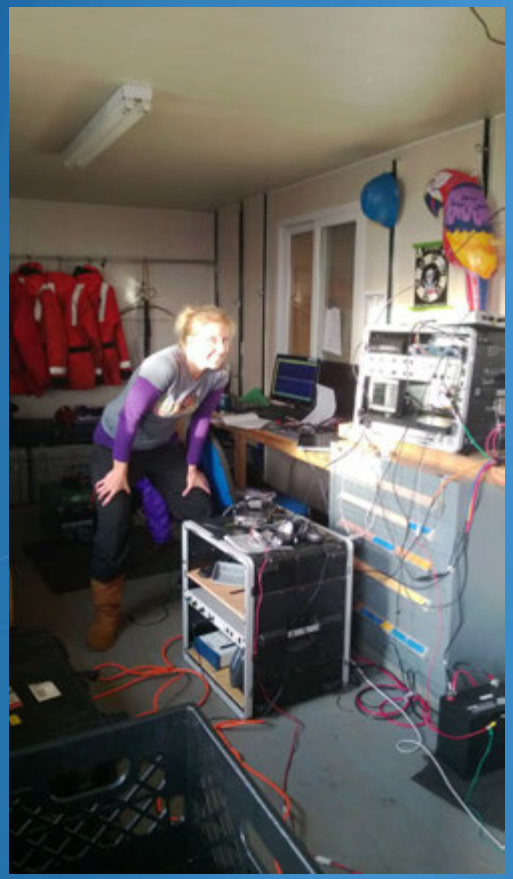
- Acoustic Survey: (24 hrs)



Baird, et al. 2005.

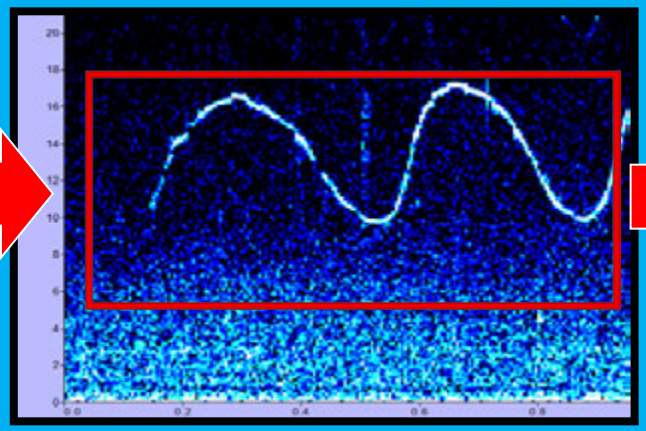
Our Home In the Acoustics Lab



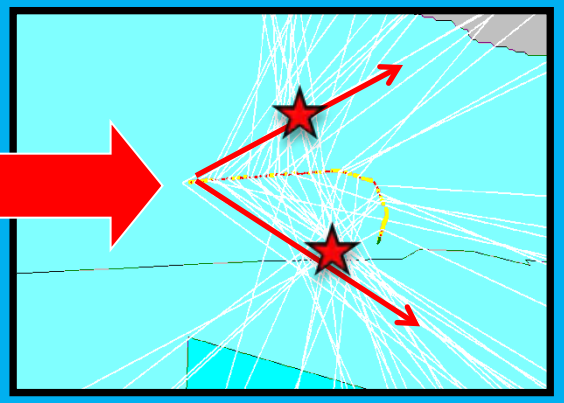


Manual Detection/Tracking

Ishmael

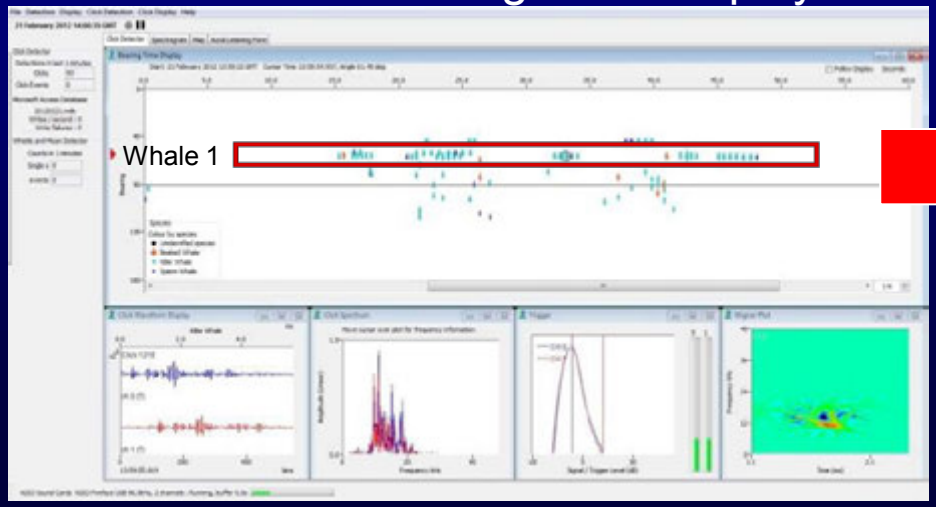


WhalTrak II

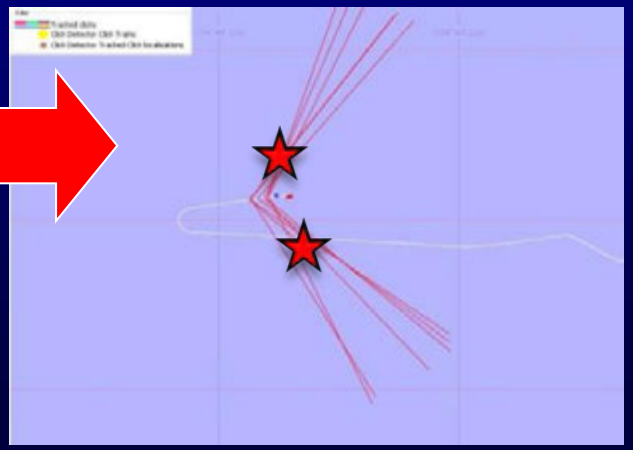


Semi-Automated Detection/Tracking

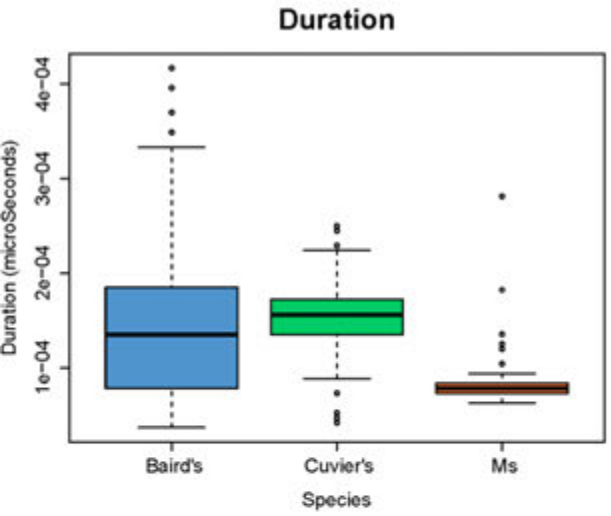
PAMGuard Bearing Time Display

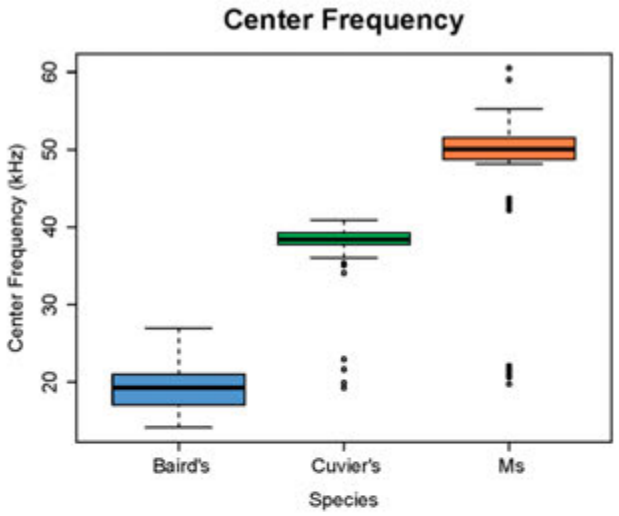


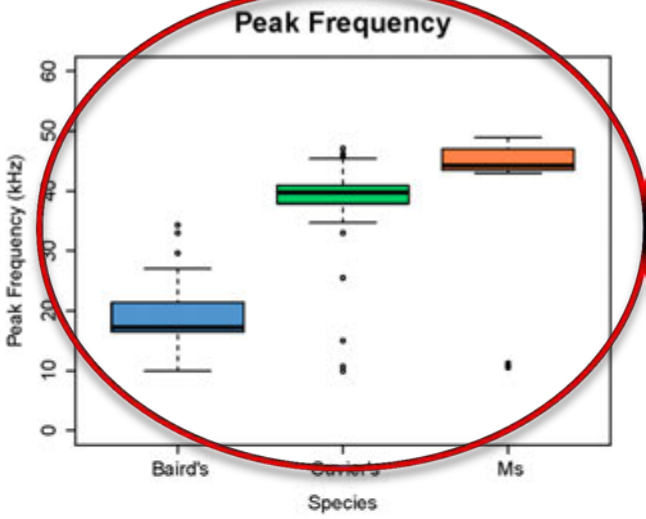
PAMGuard Map Display

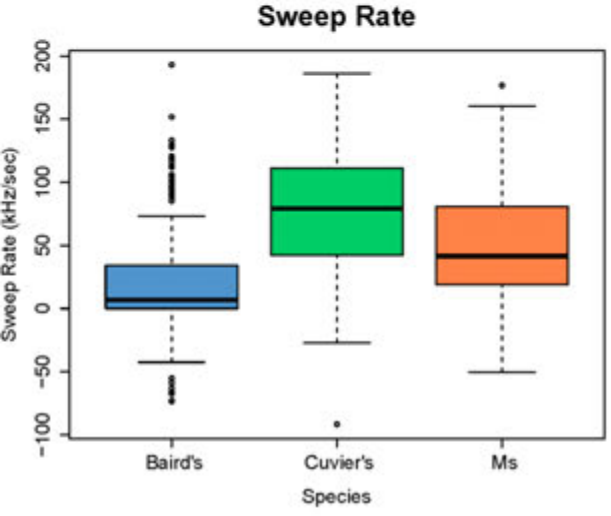


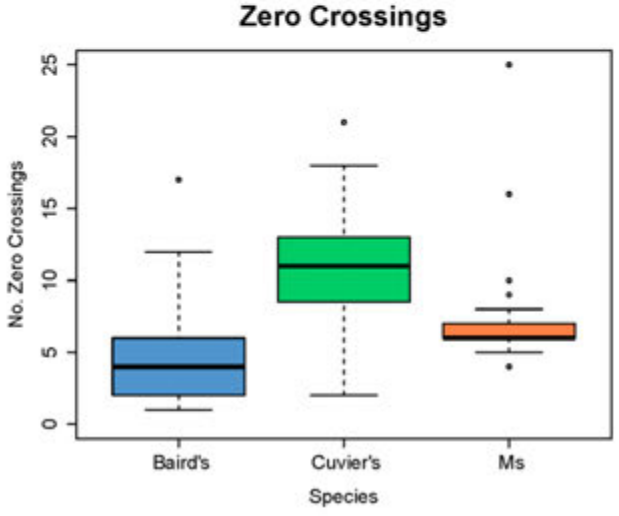
GOA Beaked Whale Species

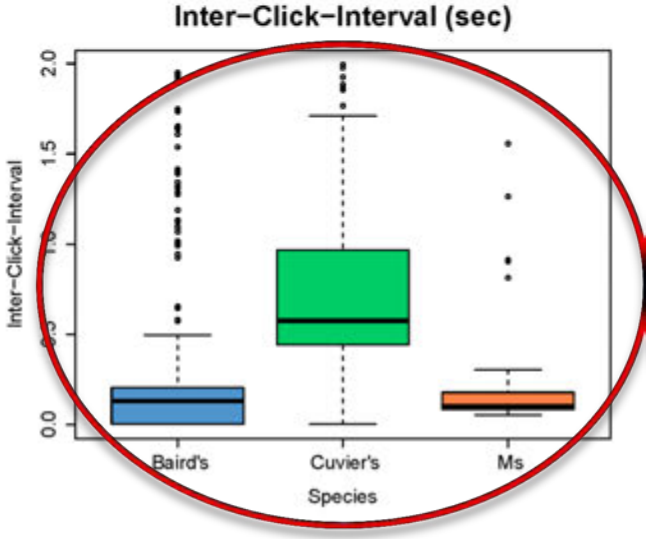






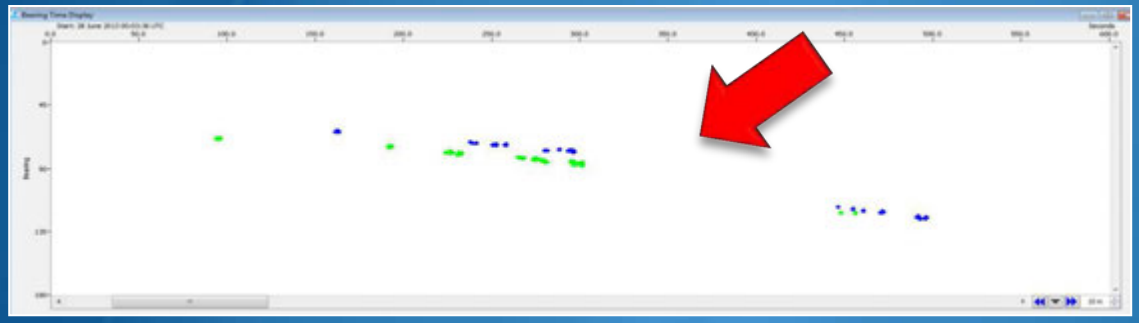




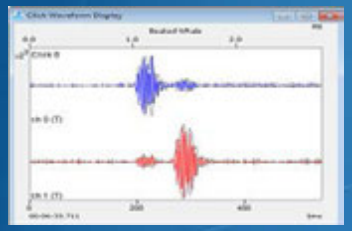


PAMGuard's 'ViewerMode'

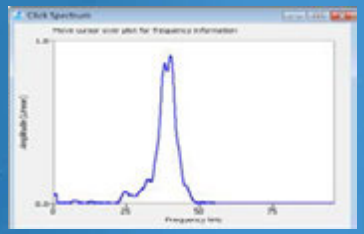
I. Time/Bearing Display



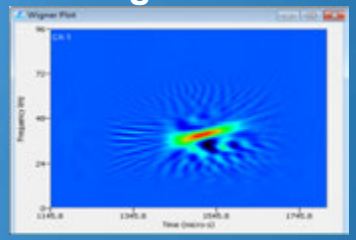
II. Waveform



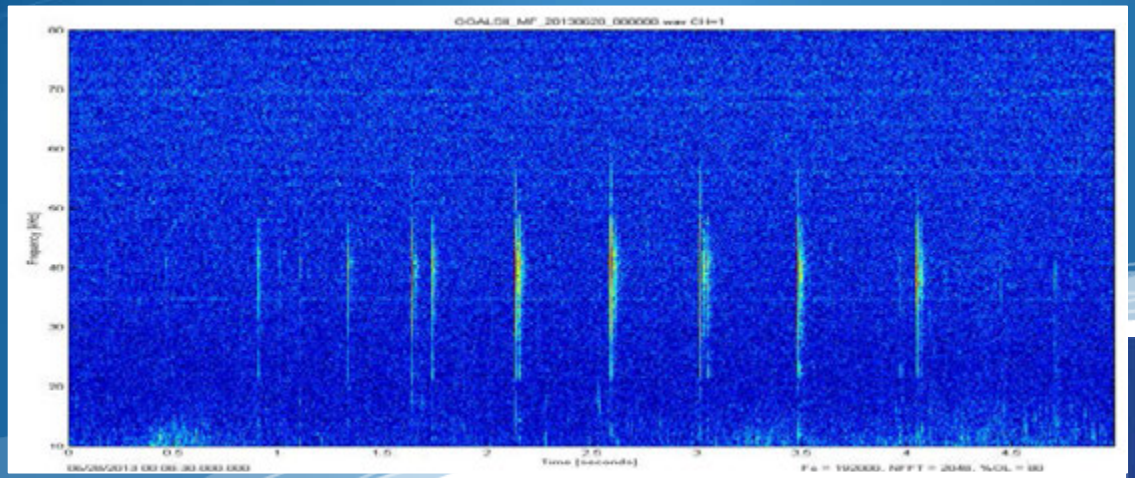
III. Click Spectrum



IV. Wigner Plot



V. Spectrogram



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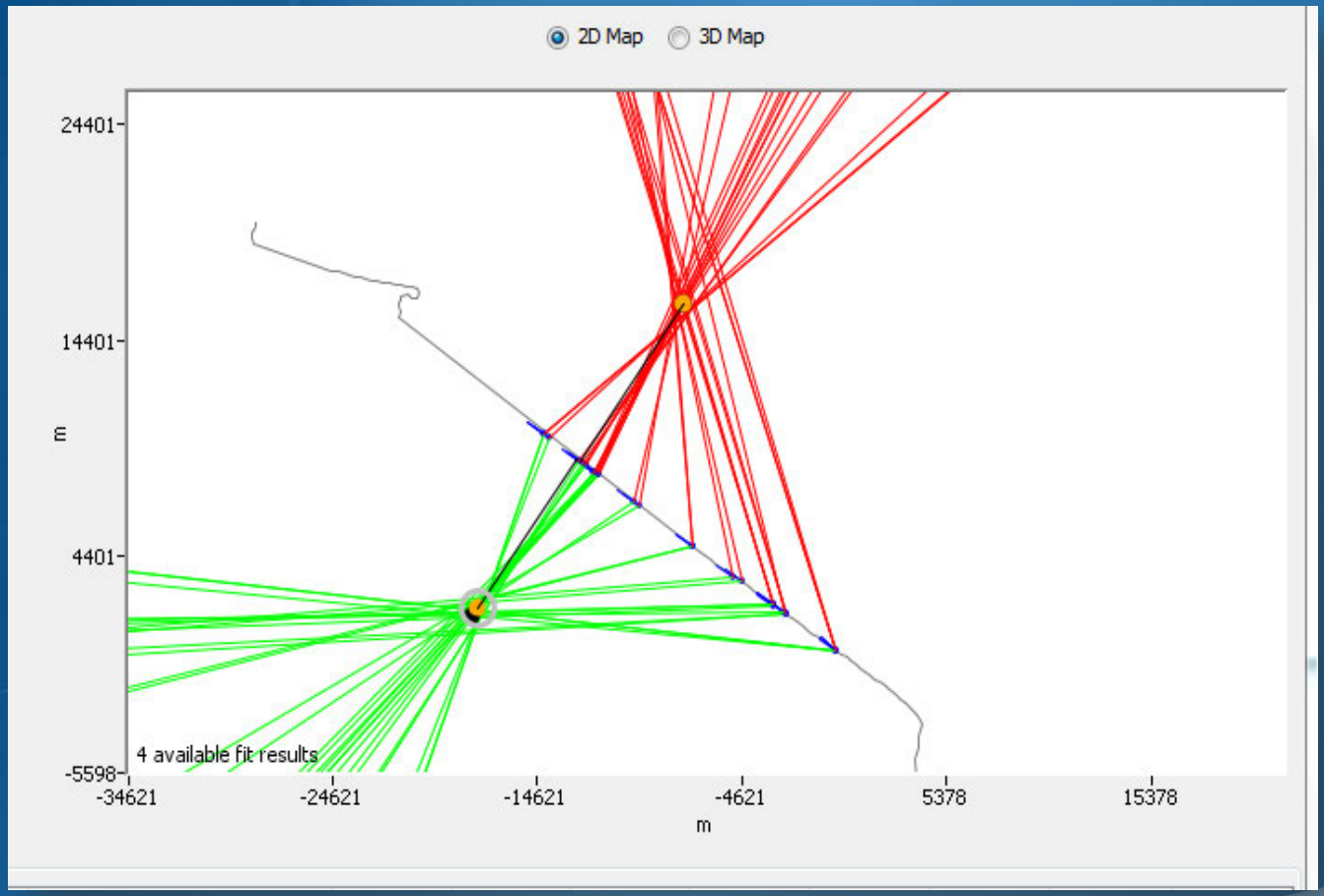
Target Motion Analysis in 'ViewerMode'



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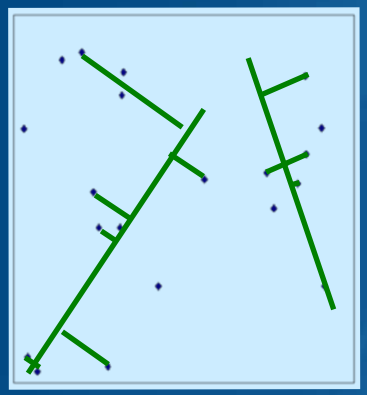
Distance Sampling

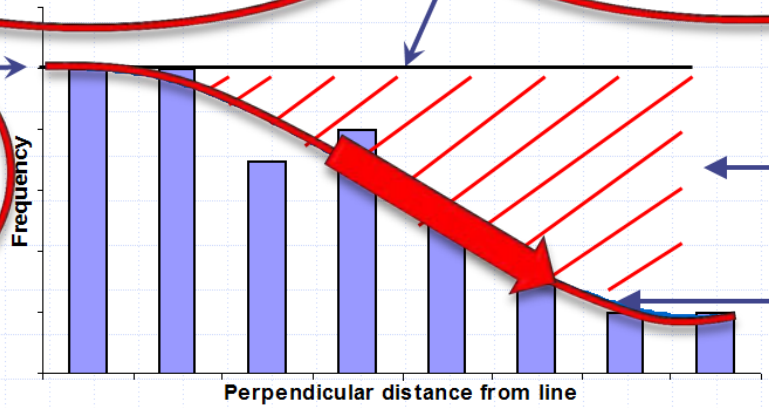


$$P_a = \frac{\text{area under curve}}{\text{area of rectangle}}$$

if you saw everything at all distances, on average the histogram bars should be here

assume you see everything at zero distance

g(0) = 1

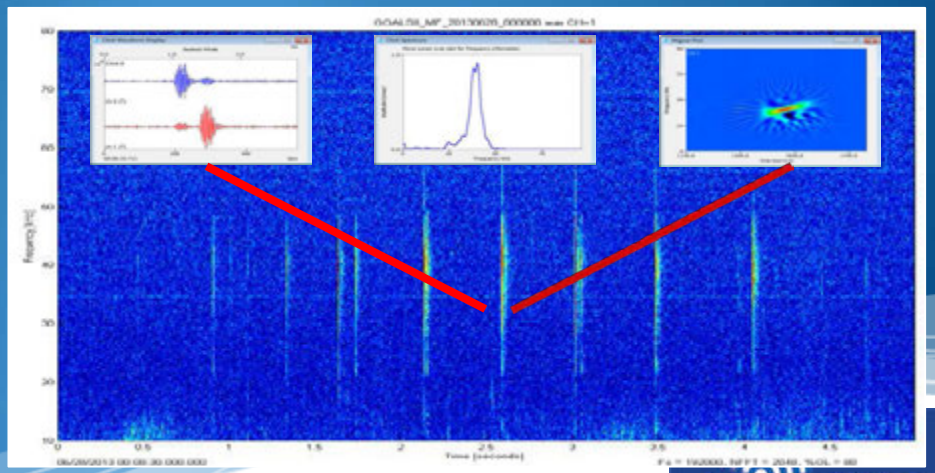


$$\hat{D} = \frac{n}{a\hat{P}_a}$$

Slide images courtesy of: http://warnercnr.colostate.edu/~gwhite/fw663/DistanceSampling.ppt

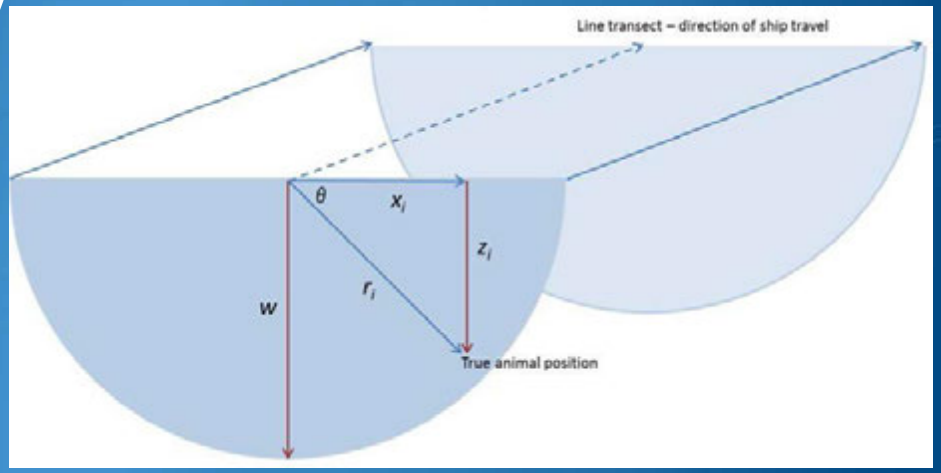
Models

- Stratified analysis
- Global detection function estimated
- 5 km right truncation
- Binned Data and used AIC to select best model



The Solution

- Use Depth Distribution Model (DSDDM)
  - Issue can be addressed by incorporating a **depth distribution** into the algorithm to estimate probability of detection.
  - Algorithm then works w/ **slant ranges** to animals
  - Still expect **horizontal distribution** of animals from transect line is **uniform**.



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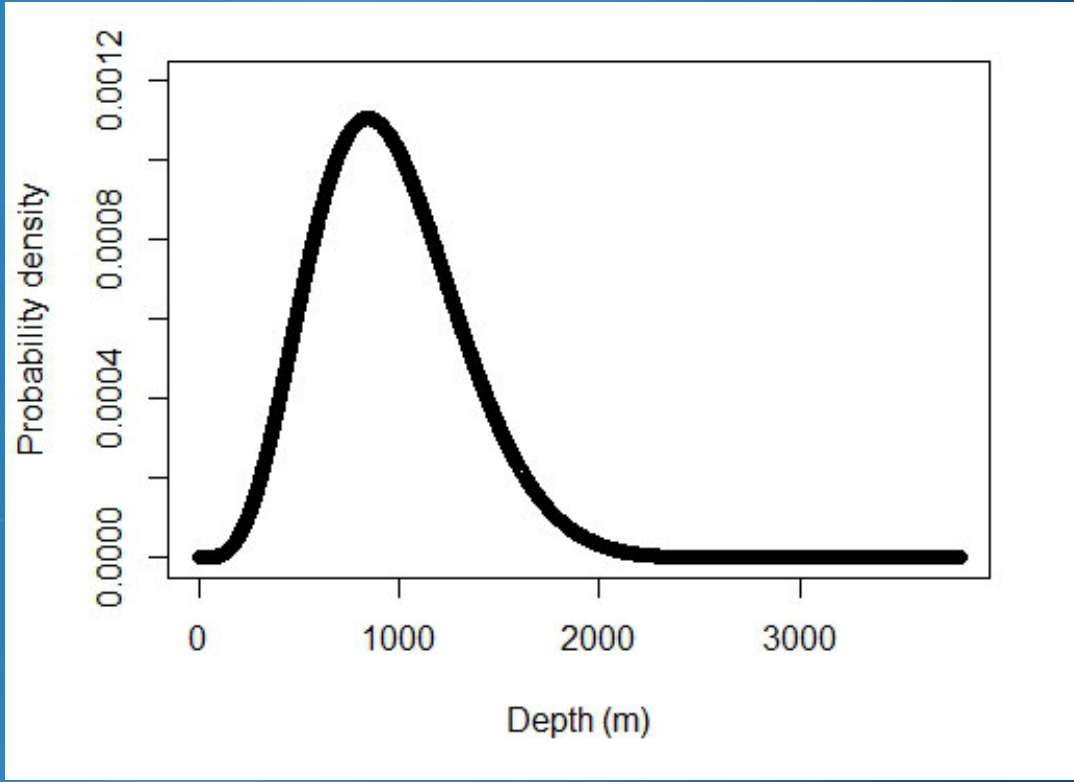
Methods

- DSDDM Methods
  - A scaled beta distribution used to describe depth distribution of **vocalizing animals**
  - Based on data from Tyack *et al*. (2006)
  - **Half normal** detection function fitted.



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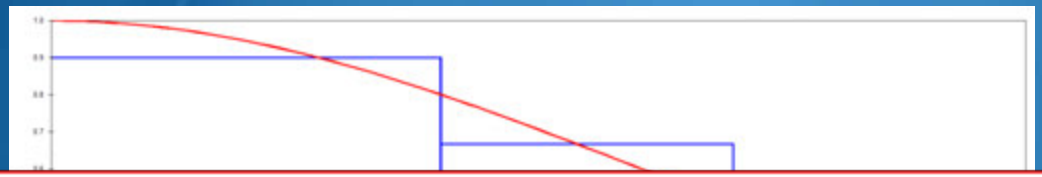
Can we account for slant range by binning data??



Binning Data can be used address slant range issue until more comprehensive and flexible DSDDM methods are readily available: Resulted in ~4% 'underestimation' vs. 20% when data were not binned

95% CI			
CVb	30%	32%	32%

** No slope stratum in estimates

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Calculating g(0)

g(0) was calculated using equation 1 from Barlow et al. 2013:

$$g(0) = (E(a) + w) / (E(a) + E(u)) = 0.51$$

where:

E(a) = the time spent actively foraging (0.582)

E(u) = the total time spent between foraging dives + the time spent in foraging dives but not clicking (1.51)

w = 2* k/v where k = the effective strip width (3.56 km) and v = the average survey speed (14.8 km).

Barlow, J., P. L Tyack, M. P Johnson, R. W. Baird, G. S Schorr, R. D Andrews, and N. Aguilar. de Soto. 2013. Trackline and point detection probabilities for acoustic surveys of Cuvier's and Blainville's beaked whales. *Journal of the Acoustical Society of America* 134(3): 2486-2496.

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Results

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Survey Results

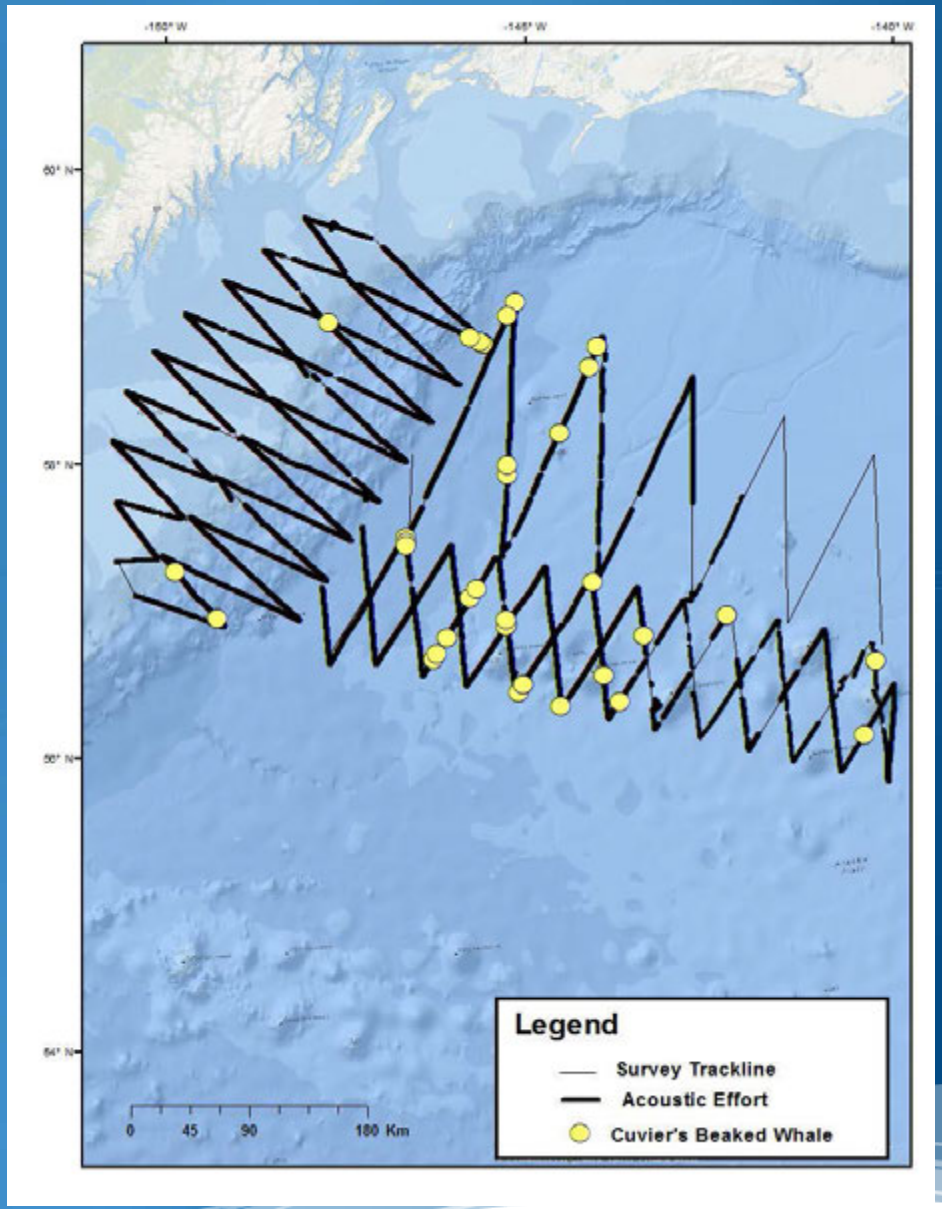
- Survey Effort included:
  - Acoustic Effort: 6,304 km, 426 hours
  - Visual Effort: 4,155 km
- Cuvier's beaked whale encounters included:
  - Acoustic Encounters: 47 (40 localized individuals)
  - Visual Encounters: 1 (1 individual)

Species Encountered	No. Encounters	No. Localized Encounters	No. Encounters On Effort Available for Distance Sampling
Stejneger's beaked whale	14	10	10
Baird's beaked whale	32	29	18
Cuvier's beaked whale	47	43	40*

*3 encounters omitted due to poor quality of localization

Results

- Encounter rates varied by strata
  - Seamount strata contained majority of encounters
- Samples by strata
  - Offshore = 8
  - Seamount = 26
  - Slope = 6



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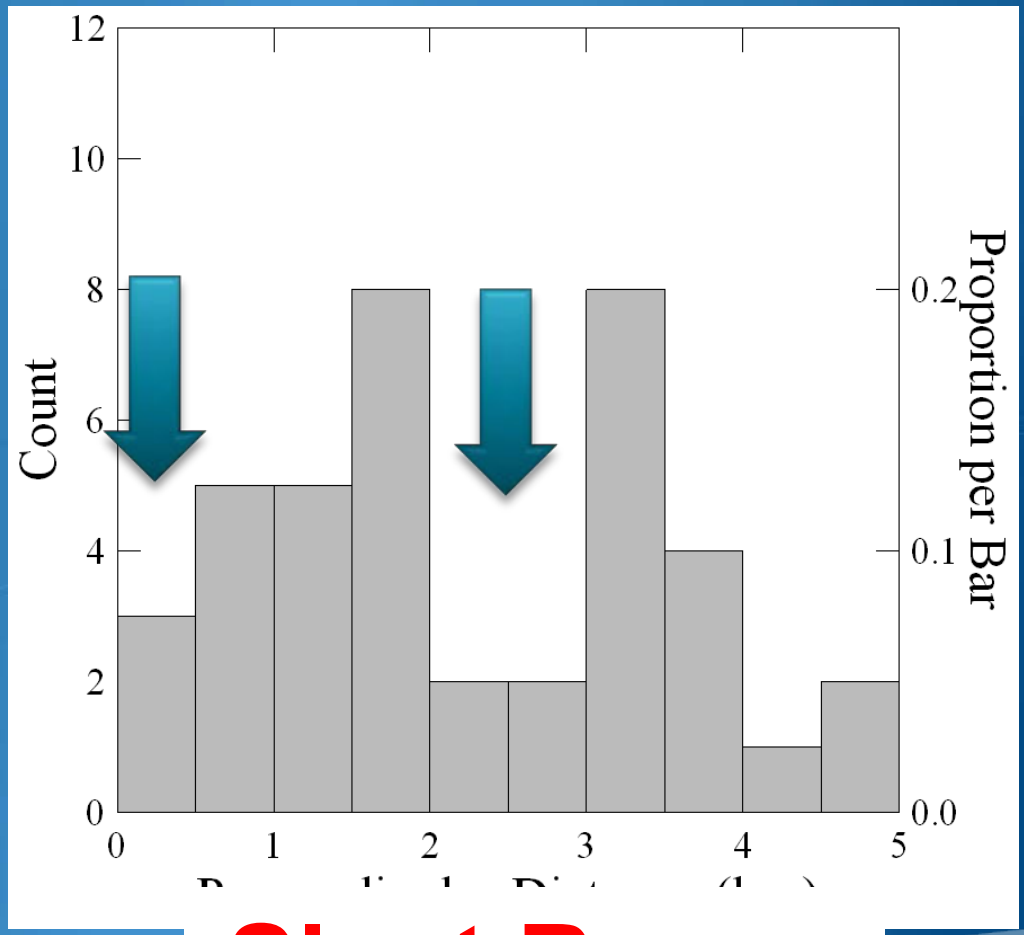
Results

- Localizations = 40 total used in analysis



Slant Range

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Final Estimates

	Offshore	Seamount	Slope	Pooled
Encounters used in analysis	8	26	6	**40**
Encounter rate	0.007	0.01	0.003	-
Encounter rate CV_b	46%	26%	69%	-
Density (#/1,000 km²)	0.20	0.30	0.08	**0.21**
Density 95% CI_b	(0.07–0. 57)	(0. 17–0. 56)	(0. 02–0. 36)	**(0. 12–0. 36)**
Abundance	222	251	57	**291**
Abundance 95% CI_b	(41–344)	(77–253)	(8–131)	(165–516)
CV_b	48%	30%	74%	**28%**

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Conclusion/Discussion

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Conclusions

- Acoustic monitoring methods are effective for estimating abundance of deep-diving, continuously clicking species.
- These are the first line-transect acoustic density estimates for Cuvier's and the first estimates in the GoA.
- Collaboration with Danielle Harris using DSDDM enabled us to characterize 'underestimation bias'.
- These methods are applicable to other species
  - Baird's acoustic encounters on effort: 18
  - Stejneger's acoustic encounters on effort: 10

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Future Work

- Acoustic Tagging of beaked whales in the GoA to provide ground truth of DSDDM depth distribution and proportion of time spent clicking (g(0)).
- Use surface reflections to estimate depth of beaked whales and obtain true perpendicular distances.
- Next survey with 3-D volumetric array
- Habitat modeling

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Thank you!

Sponsors: We would like to acknowledge **NAVFAC-Atlantic** for funding the survey and analysis effort, and **HDR, Inc**. for coordinating project logistics.

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A special thank you to the tireless and dedicated efforts of the acousticians; Jessica Crance, and Dawn Grebner. A special thank you to John Calambokidis and Cascadia Research Collective for survey planning, coordination, and support. We would also like to thank all of the participants of the survey; Jeff Foster, Annie Douglas, Michael Richlen, Jennifer Gatzke, Ernesto Vazquez and Bridget Watts, as well as the Captains and crew of the R/V Aquila.

NAVFAC Naval Facilities Engineering Command

HDR

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