Density Estimates for Minke Whales off Kaua'i and the Northern Marianas Islands Using Acoustic Line-transect Survey Data: Pros and Cons of Passive Acoustic Density Estimation

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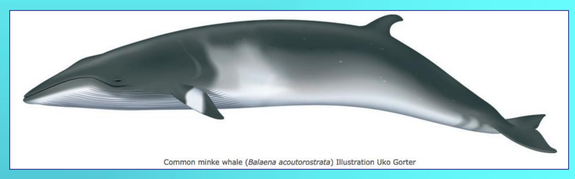


BACKGROUND

- Minke whales are rarely sighted in the subtropical North Pacific waters during winter and spring.
- Passive acoustic methods such as towed hydrophone arrays can be used to detect and localize 'boings' (see Fig 1. below) during surveys.
- These data can be analyzed using distance sampling.
- We use examples from two studies to highlight the biases and issues associated with the methods used.

WHAT IS A BOING?

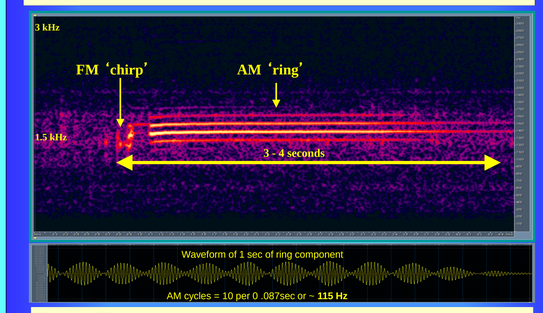


Figure 1. Boings are produced primarily during winter/spring breeding season. The boing is a complex 2-part signal consisting of a brief frequency modulated (FM) 'chirp' followed by a 3-4 sec. amplitude modulated (AM) 'ring. This sound is unique to minke whales in the North Pacific (Rankin & Barlow, 2013).

WHERE AND WHEN

Two Study Areas (see map below):

- Northern Mariana Islands: 616,000 km^2 *(the size of Portugal & Spain).*
- Kauai: 2055 km^2 *(part of a U.S. Navy underwater test facility).*

Study Period (Winter-Spring):

- 2006 - N. Mariana Islands
- 2010 - Kauai

Study Area Habitats & Features:

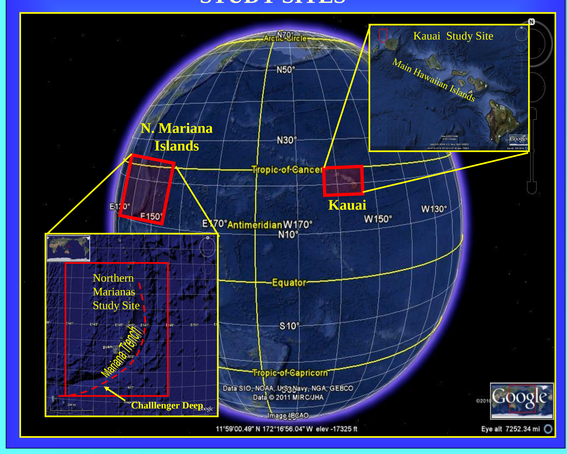
Kauai

- Extinct volcanic island with steep relief and deep waters close to shore.
- Pacific Missile Range Facility (PMRF), a seafloor hydrophone array.

Northern Mariana Islands

- Extensive island chain that includes Guam (a US Navy Base) & Saipan
- Includes the Marianas Trench (the world's deepest underwater trench)

STUDY SITES



OBJECTIVES

- To use passive acoustic methods to estimate the abundance of minke whales at two different breeding areas in the North Pacific Ocean.
- To compare the advantages and disadvantages of passive acoustic density estimation relative to 'traditional' visual methods.

WHAT DID WE DO?

Field Methods:

- Systematic line-transect surveys
- Towed hydrophone array system
- Visual observations

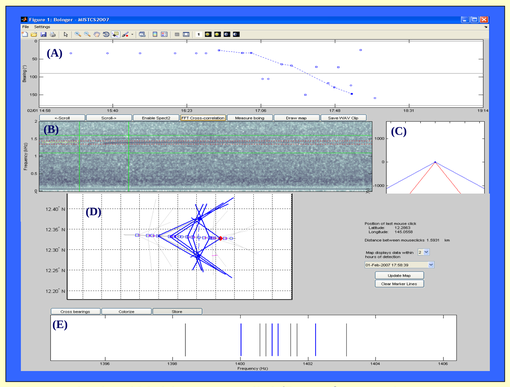
Post Processing:

- Boinger custom written Matlab software (see box below)
- Ishmael's automated boing detector (Martin et al. 2013)

Analyses:

- Distance sampling analysis using 'Distance' software (Ver. 6.2)

POST-PROCESSING



A custom developed Matlab program called 'Boinger' was used to post-process acoustic (.wav file) and GPS data by allowing semi-automated analysis of boing localizations. Panels from top to bottom: (A) time-bearing display. (B) Spectrogram measurement. (C) Cross-correlation bearing display. (D) Bearing Localization map. (E) Dominant Signal Component panel (after Martin et al. 2013)

ABUNDANCE ESTIMATION

- Boings were post-processed using program Boinger (see Figure above).
- Perpendicular distances from Boinger were exported to program Distance.
- Abundance estimated using 'Conventional Distance Sampling' in Distance.

Assumptions:

- all animals on trackline detected [g(0) = 1]
- vessel moving faster than animals are moving
- no movement away from (or towards) vessel
- vocalization rates are not affected by survey vessel
- the last 2 assumptions might not be met (see 2 scenarios below)

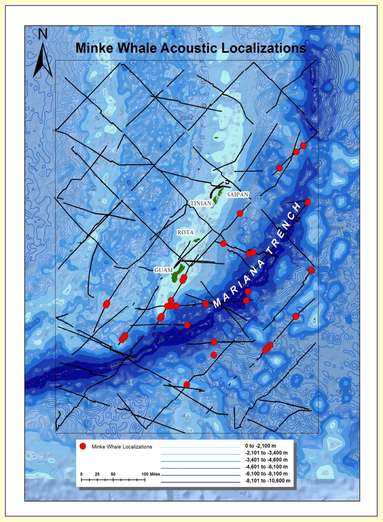
Abundance estimates calculated for 2 scenarios :

(1) Assuming animal movement away from track-line
(2) Assuming a reduction in vocalizations for animals near the track-line

Detection Functions

- Modeled for both scenarios
- For scenario (1) right truncation only (standard approach used to fit models)
- For scenario (2) right and left truncation @ 1km (to account for missed animals)

SURVEY RESULTS
Northern Mariana Islands



Northern Marianas study area with survey tracklines in black and minke whale localizations (red circles) used in the analysis.

Approximately 11,500 km of trackline was surveyed resulting in 30 acoustic localizations of minke whales used in the analysis.

ABUNDANCE RESULTS
Northern Mariana Islands

Scenario:

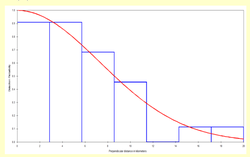
(1) assumes animal movement away from trackline
- no left truncation
- estimate = 80 animals (95% CI 41-155)
- density = 0.13 animals per 1,000 km^2 (CV = 34%)

(2) assumes a reduction in vocalizations for animals near the trackline
- left truncation at 1 km from trackline
- estimate = 91 animals (95% CI 48 - 176)
- density = 0.13 animals per 1,000 km2 (CV = 34%)

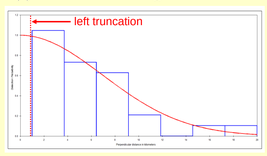
Detection Functions

- Best models for both scenarios – Half-Normal with Key Function

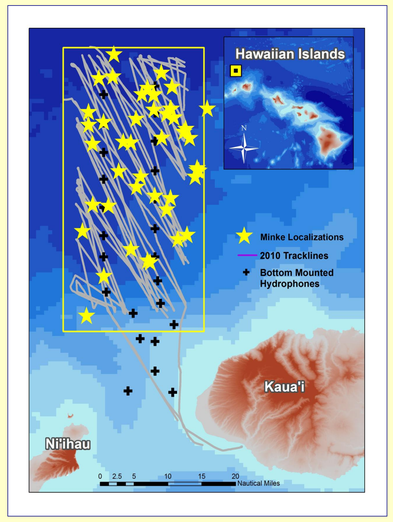
(1) No left truncation



(2) with left truncation @ 1km



SURVEY RESULTS
Kauai-PMRF



Kauai-PMRF study area with tracklines in gray and minke whale localizations (yellow stars) used in the analysis.

Approximately 900 km of trackline surveyed resulting in 50 localizations of individuals (~ 40 of which were used in the analysis).

ABUNDANCE RESULTS
Kauai-PMRF

Scenario:

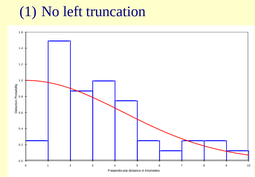
1) assumes animal movement away from trackline
- no left truncation
- estimate = 6 animals (95% CI 4-8)
- density = 3 animals per 1,000 km^2 (CV = 27%)

2) assumes a reduction in vocalizations for animals near the trackline
- left truncation at 1 km from trackline.
- estimate = 8 animals CV = 0.25 (95% CI 4-14)
- density = 4 animals per 1,000 km^2 (CV = 25%)

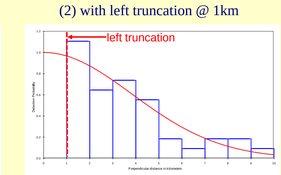
Detection Functions

- Best models for both scenarios – Half-Normal with Key Function

(1) No left truncation



(2) with left truncation @ 1km



SUMMARY / CONCLUSIONS

Abundances of calling minke whales were estimated for two areas where there were few or no sightings, in spite of significant visual effort.

PROS

- Passive acoustics are the only viable method for some species/areas.
- Passive acoustic methods are not affected by weather or sea conditions.
- Distance sampling methods can be used (with minor modifications).
- Uncertainty (e.g. CV's) of estimates are reasonable in both studies.
- Can detect and localize boings easily out to 10 km or more.
- Acoustic methods can be semi-automated

CONS

- Acoustic behaviors are variable and call rates are poorly understood.
- Must account for possible animal movements and changes in vocal behaviors.
- Left truncation may be necessary in some cases but requires additional information.
- Can only detect and localize calling animals, and thus, estimates are a minimum.
- Localization errors can be significant under some circumstances.
- In our experience acoustic estimates are usually biased low.

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