The Acoustic Ecology and Behavior of Minke Whales in the Tropical Pacific Islands

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The Acoustic Ecology and Behavior of Minke Whales in the Tropical Pacific Islands

Localization and abundance estimation
characterization of calls
population structure
and effects of boat noise
Background

Minke Whales – North Pacific Population

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~ 10 m

Jason Gedamke
Background

Minke whale biology:

- small and elusive baleen whale
- max length ~10m
- weight of 10 tons (10,000 kg)
- Behavior relatively unknown
Minke Whale Distribution

Source: www.iucnredlist.org/details/2474/0
Minke Whale Distribution
(North Atlantic & Pacific)

Source: www.projectminke.com/worldwide.htm
Minke Whale Distribution (Southern Hemisphere)

Balaenoptera acutorostrata bonaerensis

Source: www.projectminke.com/worldwide.htm
Minke Whale Distribution (dwarf form)

Source: www.projectminke.com/worldwide.htm
Minke Whales

Minke Whale Status:

• **IUCN classification:** ‘Least Concern’

• **Not listed as endangered or threatened in U.S. waters**

• **Targeted by Norwegians and Japanese whaling industry**
Minke Whales
Issues – North Pacific

Management and Conservation
• Population structure, Uncertain
• Winter distribution, abundance & behavior, Unknown
Minke Whale Sightings
(Hawaiian Islands)

Source: NOAA Stock Assessment Report 2004
What is a ‘Boing’?


What is a ‘Boing?’

Signal design feature to reduce masking??

0.1 sec

= 1/Pulse repetition Rate
Questions

1) Can boings be used as indicators of population structure?

2) Are boing rates affected by changes in (self) vessel noise?

3) Can boings be used to estimate abundance of calling minke whales?
Study Areas

- Hawaiian Islands
- Midway Island
- Marianas Islands

~4000 nm
Central Pacific Study Area
Hawaiian Islands

PMRF
Kauai

100 km
Fixed Seafloor Array

PMRF seafloor hydrophone array

50 km

Hydrophones (~100 Hz - 20 kHz)
Field Methods

*Concurrent* real-time acoustic monitoring and near real-time localization using:

- fixed sea-floor hydrophones
- towed hydrophone arrays
Field Methods

Towed Hydrophone Array and Visual Observations
Data Processing & Analysis

Call me
Ishmael
Integrated System for Holistic
Multi-channel Acoustic Exploration and Localization

PAMGUARD
XBAT
MATLAB®
OSPREY
Questions

1) Can boings be used as an indicator of population structure?

2) Are boing rates affected by vessel noise?

3) Can boings be used to estimate abundance of calling minke whale?
Boing Analysis

Semi-automated analysis
Boing Analysis

Dominant Signal Component

DSC
# Boing Comparison

## Tree Analysis
**Guam, Kauai and Midway**

<table>
<thead>
<tr>
<th>Observed</th>
<th>Predicted</th>
<th>Guam</th>
<th>Kauai</th>
<th>Midway</th>
<th>n</th>
<th>% Correct</th>
</tr>
</thead>
<tbody>
<tr>
<td>Guam</td>
<td></td>
<td>26</td>
<td>5</td>
<td>4</td>
<td>35</td>
<td>74%</td>
</tr>
<tr>
<td>Kauai</td>
<td></td>
<td>11</td>
<td>23</td>
<td>6</td>
<td>40</td>
<td>58%</td>
</tr>
<tr>
<td>Midway</td>
<td></td>
<td>11</td>
<td>7</td>
<td>22</td>
<td>40</td>
<td>55%</td>
</tr>
<tr>
<td>Overall</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>105</td>
<td>62.30%</td>
</tr>
</tbody>
</table>
### CART Classification Scores

<table>
<thead>
<tr>
<th>Observed</th>
<th>Predicted</th>
<th>Guam</th>
<th>Kauai</th>
<th>n</th>
<th>% Correct</th>
</tr>
</thead>
<tbody>
<tr>
<td>Guam</td>
<td></td>
<td>27</td>
<td>8</td>
<td>35</td>
<td>77%</td>
</tr>
<tr>
<td>Kauai</td>
<td></td>
<td>16</td>
<td>24</td>
<td>40</td>
<td>60%</td>
</tr>
<tr>
<td>Overall</td>
<td></td>
<td></td>
<td></td>
<td>75</td>
<td>68.50%</td>
</tr>
</tbody>
</table>
Boing Comparison

Tree Analysis

Guam and Kauai

Normalized Importance

Growing Method: CRT

Dependent Variable: Location
Boing Comparison (DSC)

Frequency Histogram

Dominant Signal Component (DSC)

# of observations

Hz

Interval
0-100
100-110
110-1120
1120-1130
1130-1140
1140-1150
1150-1160
1160-1170
1170-1180
1180-1190
1190-1200
1200-1210
1210-1220
1220-1230
1230-1240
1240-1250
1250-1260
1260-1270
1270-1280
1280-1290
1290-1300
1300-1310
1310-1320
1320-1330
1330-1340
1340-1350
1350-1360
1360-1370
1370-1380
1380-1390
1390-1400

Kauai
Midway
Guam
Questions

1) Can boings be used as an indicator of population structure?

2) Are boing rates affected by vessel noise?

3) Can boings be used to estimate abundance of calling minke whale?
Effects of Boat Noise
(Study Design)

Condition #1

Hi Noise

Low Noise

Condition #2

Low Noise

Hi Noise

← 10 min → ← 10 min →

# of Boings / Period

(Low Noise – Hi Noise)
Effects of Vessel Noise
Long Term Spectrogram

1300 RPM
600 RPM

1 hr

Fs = 12000, Tave = 5s, NFFT = 120
B = 148, C = 165
Effects of Vessel Noise

noise decreases
Effects of Vessel Noise

# boings (low – hi noise periods)

n = 10

significant (0.05)
Questions

1) Can boings be used as an indicator of population structure?

2) Are boing rates affected by vessel noise?

3) Can boings be used to estimate abundance of calling minke whale?
Distance/Spatial Sampling
(assumptions & requirements)

- **Sample independence**
  - need to identify, track or separate individuals

- **Measurement errors** (of perp. distances)
  - Assess localization accuracy

- **Vocalization rates** (for cue counting)
  - acoustic tracking
  - focal animal follows
Abundance Estimation
(line-transect sampling)

- Line-transect sampling methods
  - need distance of animals from transect line
  - requires localization of animals (using acoustics)
Line-Transect Survey 2010

1500 km effort

1600 boings!

50 localizations
Conclusions

1) Can boings be used as indicators of population structure in minke whales?
   Yes! (but needs larger sample size)

2) What are the effects of boat noise?
   Boings rates increase when noise decreases (preliminary)
   Possible avoidance or cessation of calling when close?

3) Can boings be used to estimate abundance of calling minke whale?
   In progress – Stay Tuned!!
Ongoing Work

- **Automation** of acoustic processing methods
  - boing detections & measurements
    - more areas (station Aloha, Big Island and Palmyra)
    - temporal and seasonal comparisons
- **Localization**
  - Towed array
  - Seafloor array
Automated Processing
Towed Array Bearings
Preliminary Automated Localization Results (PMRF Seafloor Array)
Future Plans

- Examine behaviors and ecology in more detail (using a *fast motor-sailing vessel*)
  - more validations work
  - focal animal follows
  - photo-identifications
  - biopsy and
  - electronic tagging?
Acknowledgements

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R/V Dariabar: Ethan Sylva, Craig Hawkinson, Charlie & Bonnie Patten

Logistics / Field Support: Ann Zoidis, Natalie Spear
“What is a scientist after all? It is a curious man looking through a keyhole... ...trying to know what's going on”  
Jacques Yves Cousteau
THANK YOU

“What is a scientist after all?
It is a curious man looking through a keyhole, the keyhole of nature, trying to know what's going on”

Jacques Yves Cousteau
BONUS (extra) SLIDES

These were not used in the latest presentation, but might be of interest to viewers. E-mail us with any questions or comments.

info@bio-waves.net
Abundance Estimation
(why use acoustics?)

Minke whales rarely sighted in the subtropical North Pacific

Visual methods not effective
(4 sightings of minke whales in >10 years)
- high seas/swell
- animal avoidance of noisy vessels?
Abundance Estimation
Assumptions & Issues

- Sample Independence (for distance sampling)
  - Are boings from different animals?
    (requires localization)
  - Measurement of distances to animals
    (localization accuracy is an issue)
- Calling rates (for cue counting methods)
Acoustic System
(hydrophone array System)
Abundance Estimation
(point sampling)

- Point-transect sampling methods
  - requires measuring radial distance from points
  - may or may not require localization
Acoustic System

Target motion analysis

Direction of ship’s travel

Must Turn Ship to resolve side

left/right ambiguous estimates of location
Acoustic System
towed hydrophone array
(birds-eye view)

300-400 m

φ₁

φ₂

‘crossed-pair’ triangulation
Minke Whale Localizations

- Towed array localization
- Seafloor localization
- Visual sighting
- Ship track
- Towed array bearing

1 km

Ship track
Sighting!
Automated Analysis

pulse-repetition rate analysis

burst

buzz

3 sec.

4 kHz

= 10 per 0.087 sec or ~ 115 Hz
Case Study 04/27/09
Localization Effort
2009
Minke Whale Localization

*(fixed seafloor array)*

1 km

Ship track

seafloor localization

visual sighting

ship track
Results

ANIMATED GRAPHICS
Questions

1) Can boings be used as an indicator of population structure?

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3) Can boings be used to estimate abundance of calling minke whale?
Boing Comparison
Dominant Signal Component

OLD DATA!
(do not use)
Boing Comparison

Histogram of Boing Pulse Repetition Rate

Mean (92) - Eastern
Mean (116) - Central
Mean (120) - Western

Frequency of Occurrence

Pulse Repetition Rate

Old Data! (do not use)

Comparison of Seafloor Localization Methods (standard vs model-based)
Comparison of Localization Methods
Ongoing Work

- Improvement to towed hydrophone system
  - heading and depth and tilt sensor development
  - improvements towed array location algorithms
DECAF
Kauai

Len Thomas & Tiago Marques
(St. Andrews University)

Steve Martin
(SPAWAR)

See website for more details on methods
http://www.creem.st-and.ac.uk/decaf/