Acoustic Characterization of Pingers on Shark Control Nets

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Overview

• Introduction: acoustic alarms
• In situ recordings of pingers
• Source characterization
• Contribution of pingers to noise budgets
• Modelling pinger detectability
Map of shark nets deployed along the Gold Coast, Queensland, Australia
Map of shark nets deployed along the Gold Coast, Queensland, Australia
Gold Coast, Queensland, Australia
Acoustic Alarms on Shark Nets

- Are installed to reduce entanglement
- Are intended to highlight the net
- Through associative learning, marine mammals associate the acoustic alarms with the obstruction (the net)
- The intention is not to scare animals away
- In fact, some marine mammals approach pingers to investigate
Examples of Acoustic Alarms

- Fumunda 3 kHz
- Lien & McPherson 2.9 kHz
- Airmar 10 kHz
Fumunda F3 pinger + humpback whales at the Gold Coast
Pinger Interior

- Electrode
- Battery location
- Estimated piezo ceramic location
- 'Mid point'
- 'Electrode end'
- 'Battery end'
Pinger Recording Apparatus

Side view, pinger in vertical position

Top view, with apparatus reference rotation angles
Fumunda F3 pinger spectrum

Harmonic is stronger than the fundamental. $f = 2.6 \text{ – } 2.8 \text{ kHz, not } 3 \text{ kHz}$
Directivity patterns inconsistent due to variable piezo placement inside pingers.

Theoretical three-dimensional directivity pattern for a circular plate.
Nominal 135 dB SPL was only reached for some pingers at some angles.
Substantial Variability in Output Level

- 3 dB ping to ping
- 5 dB broadband, pinger to pinger
- Larger variability of tone levels, pinger to pinger

<table>
<thead>
<tr>
<th></th>
<th>Minimum (dB re 1 μPa²/Hz)</th>
<th>Mean (dB re 1 μPa²/Hz)</th>
<th>Standard Deviation of Mean (dB re 1 μPa²/Hz)</th>
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<tbody>
<tr>
<td><strong>Fundamental</strong></td>
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</tr>
<tr>
<td>F3-1</td>
<td>87.24</td>
<td>97.58</td>
<td>7.11</td>
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<tr>
<td>F3-2</td>
<td>99.43</td>
<td>109.28</td>
<td>5.67</td>
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<td>F3-3</td>
<td>113.93</td>
<td>118.02</td>
<td>3.48</td>
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<tr>
<td><strong>Harmonic 1</strong></td>
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<td></td>
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<tr>
<td>F3-1</td>
<td>112.85</td>
<td>118.14</td>
<td>3.59</td>
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<tr>
<td>F3-2</td>
<td>106.85</td>
<td>118.18</td>
<td>6.62</td>
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<tr>
<td>F3-3</td>
<td>102.48</td>
<td>121.31</td>
<td>6.50</td>
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<tr>
<td><strong>Harmonic 2</strong></td>
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<tr>
<td>F3-1</td>
<td>86.63</td>
<td>98.43</td>
<td>4.51</td>
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<tr>
<td>F3-2</td>
<td>83.24</td>
<td>93.43</td>
<td>6.33</td>
</tr>
<tr>
<td>F3-3</td>
<td>100.27</td>
<td>106.39</td>
<td>3.09</td>
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<td><strong>SPLrms (&gt;2kHz)</strong></td>
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<tr>
<td>F3-1</td>
<td>119.84</td>
<td>123.81</td>
<td>2.70</td>
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<td>F3-2</td>
<td>117.51</td>
<td>124.76</td>
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<tr>
<td>F3-3</td>
<td>122.60</td>
<td>128.14</td>
<td>2.66</td>
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</tbody>
</table>
Ambient Noise @ Gold Coast

Sept. 2010, 1.5 km range

Jan. 2011, 0.5 km range

JASCO AMAR
May 2011, 0.5 km range

Spectrum Level (dB re 1 \mu Pa^2/Hz)

Frequency (Hz)

- 5th %ile
- 25th %ile
- 50th %ile
- 75th %ile
- 95th %ile

- F10 pingers
- F3 harmonic
- F3 fundamental

- Very shallow water wind, wave & flow noise
- Boats, fish & sandpump
- Snapping shrimp
Pie charts of sound ‘budgets’ measured over a 24h period at one location.

Energy [dB]
- Snapping shrimp: 17%
- F10 pinger: 14%
- F3 pinger: 14%
- Boats: 19%
- Humpbacks: 17%
- Sandpump: 4%

Energy [linear J]
- Boats: 35%
- Snapping shrimp: 59%
- Humpbacks: 2%
- F3 pinger: 0%
- F10 pinger: 0%
- Sandpump: 0%

Power [linear W]
- F10 pinger: 0%
- F3 pinger: 0%
- Snapping shrimp: 21%
- Humpbacks: 1%
- Boats: 73%
- Sandpump: 5%

SPLrms [1/3 oct @ 6 kHz]
- F10 pinger: 0%
- F3 pinger: 29%
- Humpbacks: 0%
- Snapping shrimp: 35%
- Boats: 36%
- Sandpump: 0%
Spectrogram of Pings in Ambient Noise from 4 pingers on a net

6 kHz

5.5 kHz

5 kHz
Pinger Detectability

1. Measure pinger source levels in the field
2. Model sound propagation
3. Measure ambient noise in the field
4. Estimate audiograms (ambient noise limited due to high levels of snapping shrimp noise)
5. Estimate critical ratios (20-25 dB)
- Detection ranges 50 – 200 m
- Would be much longer (> 1 km) for nominal SL (135 dB SPL)

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<td>90</td>
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<td>5.4</td>
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<td>83</td>
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<td>210</td>
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<td>31</td>
<td>110</td>
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<tr>
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<td>83</td>
<td>16</td>
<td>10</td>
<td>88</td>
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<td>10.0</td>
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<td>82</td>
<td>32</td>
<td>130</td>
<td>87</td>
<td>27</td>
<td>40</td>
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Optimal Pinger Spacing

The minimum pinger spacing $d$ can be computed via:

$$d = 2\sqrt{r^2 - v^2 T^2}$$

where
- $d =$ minimum pinger spacing [m]
- $r =$ detection radius [m] = Range column
- $v =$ swim speed [m/s]
- $T =$ quiet time in between two pings [s]

- Dugong: 250 – 400 m
- Dolphins: 50 – 100 m
- Humpbacks: 200 – 400 m
Conclusion

• We measured Fumunda F3 and F10 pingers
• Variability in f (10%), SL (<15 dB), directivity
• Ping-to-ping and pinger-to-pinger variability
• No need for sophistication...
• SL < specified by manufacturer
• Expect SL decrease as battery power decreases
• Behavioural studies should include recording of pingers rather than assuming a nominated SL.
• There are currently 3-4 pingers per net of 200m. All pingers were modelled audible to marine mammals anywhere along the net.
• Taking swim speed into consideration, for an animal swimming straight at a net, the current spacing gives enough warning, except for high burst speeds of dolphins.
• Caveat: audiogram & critical ratio data missing from resident populations
Thank you!