Dive Behavior of Humpback Whales off Northern California and Behavioral Response to Ships

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SAC Meeting
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Collaboration Efforts

- Moss Landing Marine Laboratories
- Subcontract with Cascadia
- ONR Funded
Animal Behavior
Humpback Whales
Eastern North Pacific Stock

Map showing the migration routes of Humpback Whales from their summer feeding grounds in Alaska to their winter breeding grounds in Mexico and California.
Humpback Whales
Eastern North Pacific Stock

Calambokidis et al. 2015
Ship Strike Risk

Keiper et al. 2011
Behavioral Response
Goals

- Examine differences between nearshore and offshore dive behavior
- Investigate the context of close encounters with ships and behavior response to encounters
Tagging
Dive Classification

Surface dive: 10-50 m

Exploratory dive: > 50 m, no foraging

Foraging dive: > 50 m, forage lunges
Dive Parameterization

![Graph showing dive parameterization with depth in meters and local time in hours and minutes. The graph includes a shaded area highlighting the descent speed (m/s).]
Dive Parameterization

Dive duration (s)

Depth (m)

Local Time

11:43:00  11:48:00  11:53:00  11:58:00
Dive Parameterization

Maximum dive depth (m)
Dive Parameterization

Lunges per dive
Dive Parameterization

Ascent speed (m/s)
Dive Parameterization

Post-dive surface duration (s)
Dive Parameterization
Tagging Efforts

203 hours dive data
- 142 hours daytime
- 61 hours nighttime

1,900 dives
- 1,278 surface dives
- 141 exploratory dives
- 481 foraging dives
Regional differences in dive behavior

• Regional dive differences
  - Nested PERMANOVA
  - SIMPER analysis
  - Variance partitioning
Regional Differences: Foraging Dives

Shorter, shallower foraging dives, fewer lunges, shorter post-dive surface durations

Longer, deeper foraging dives, more lunges, longer post-dive surface durations

PERMANOVA: p<0.004
Regional Differences: **Surface Dives**

- **Bodega Canyon**: Shorter surface dives, shorter post-dive surface durations.
- **Continental break and slope**: Shorter surface dives, shorter post-dive surface durations.
- **Coastal continental shelf**: Longer surface dives, longer post-dive surface durations.
- **Monterey Bay**: Longer surface dives, longer post-dive surface durations.

**PERMANOVA:** $p < 0.08$
Behavioral Response to Ships
GPS Interpolation
Close Encounters

9 encounters

7 ships / 6 whales

6-19 min / 26 m
Individual Whale Analyses

- Dive behavior versus ship distance
  - Principal component analysis (PCA) scores

- Randomized intervention analysis (RIA)
  - Before versus after encounter
Case Study: 20130902-2 and Hanjin Argentina

26 m encounter
13 minutes
Case Study: 20130902-2 and Hanjin Argentina

<table>
<thead>
<tr>
<th>Time (1 sec-interval)</th>
<th>Distance (km)</th>
<th>Depth (m)</th>
<th>Distance to whale</th>
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<td>Whale</td>
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<td>Whale Dive Profile</td>
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<td>-60</td>
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</tbody>
</table>

closest distance: 26 m
Case Study: 20130902-3 and SS Maui

157 m encounter
17 minutes
Case Study: 20130902-3 and SS Maui

Distance (km)

Depth (m)

closest distance: 57 m

Whale Dive Profile

Time (1 sec-interval)
Behavioral Response

After encounters:

↑ Descent speed

↓ Ascent speed

↑ Respiration

Indicative of:

- Evasive action

- Increased stress
Behavioral Response

- Context-dependent
- Response detection
- Natural variability

Behavioral response detection < 700 m
Encounters

- 6 out of 15 whales (40%)
- 9 encounters in 3.5 days
- 5 out of 9 encounters (56%)
  - One juvenile whale (n=2)
  - One injured whale (n=3)
Risk Factors

70% all dives less than 50 m

n = 1224
Diel Habitat Use

- **58%** in Daytime (n = 782)
- **92%** in Nighttime (n = 442)
Prey Distribution

- Euphausiid (*Euphausia pacifica*)
- Euphausiid (*Thysanoessa spinifera*)
- Northern Anchovy (*Engraulis mordax*)
- Pacific Herring (*Clupea pallasii*)
- Pacific Sardine (*Sardinops sagax*)
Risk Factors

Bodega Canyon

Shipping lanes

Ship encounters

Gulf of the Farallones

N

Justin Sullivan

John Calambokidis, Cascadia Research
Combined Drivers of Dive Behavior

Bodega Canyon Dive Behavior

- Proportionately more surface dives than whales in other regions
- Longest post-dive surface durations after foraging dives
Fitness Implications of Disruption

- Sub-lethal effects of chronic encounters
- Must acquire energy for entire year
- Disruption may affect fitness
- Individual to population level effects
Next Steps

• More tag deployments
• Sound playback experiments
• Fine-scale kinematic movements
• Hormone/stress levels
• Publish!
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Questions? Recommendations?