What male humpback whale song chorusing can and cannot tell us about their ecology

Strengths and limitations of passive acoustic monitoring of a vocally active baleen whale

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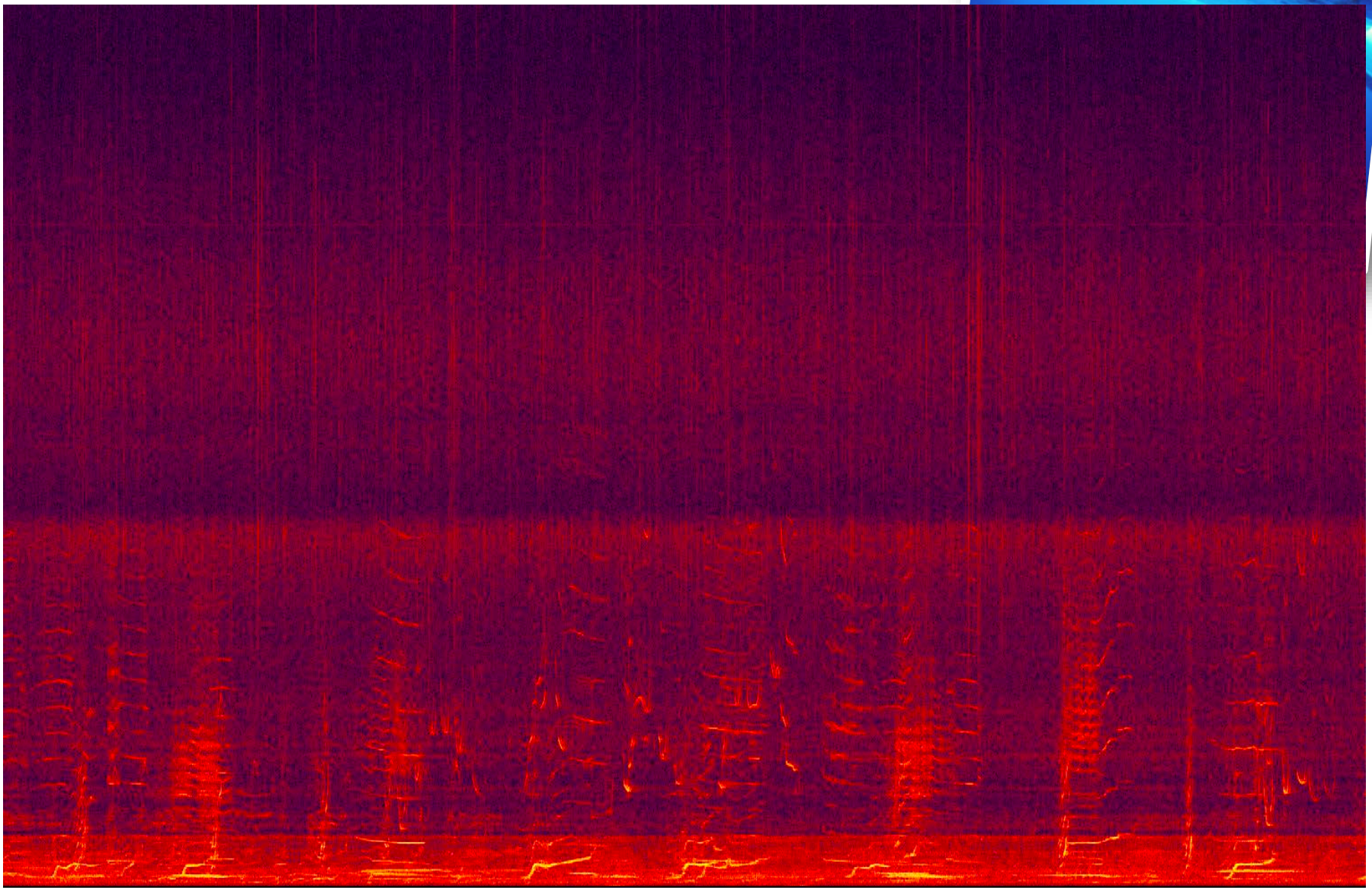
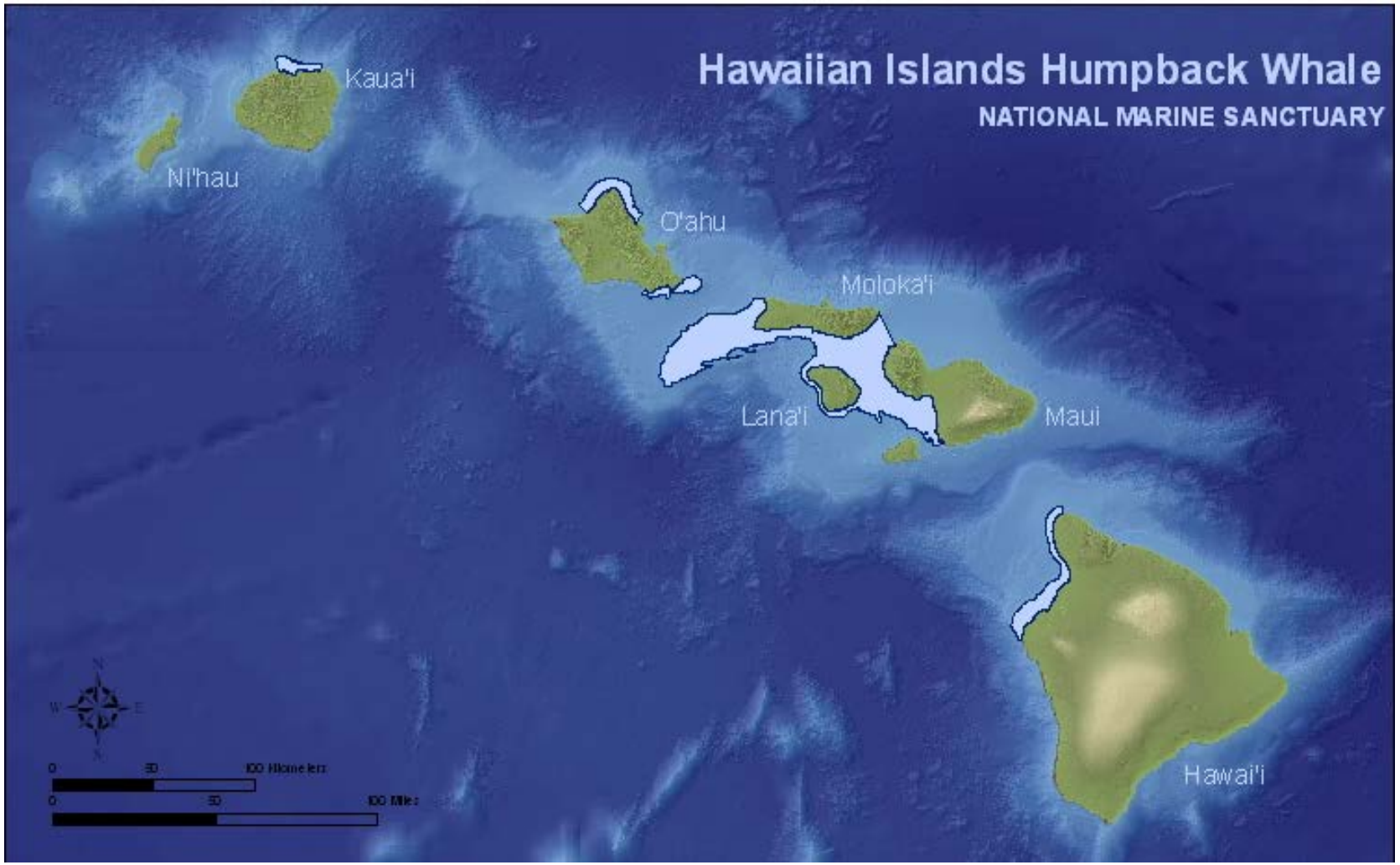
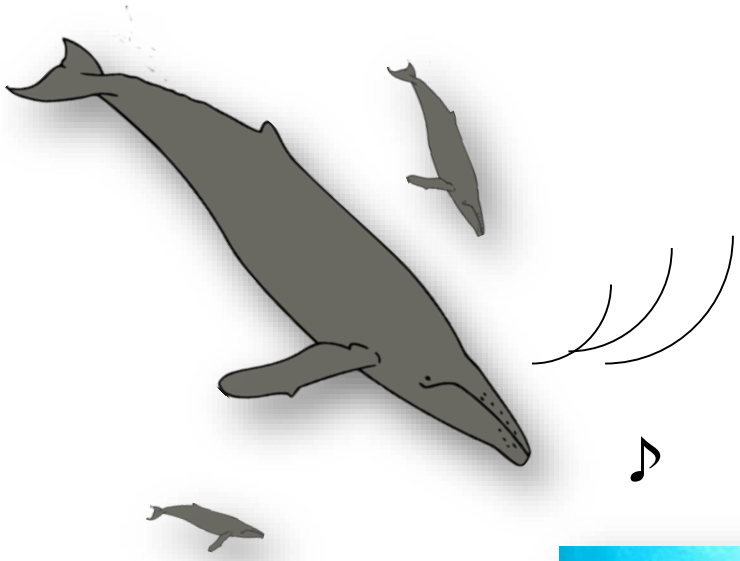


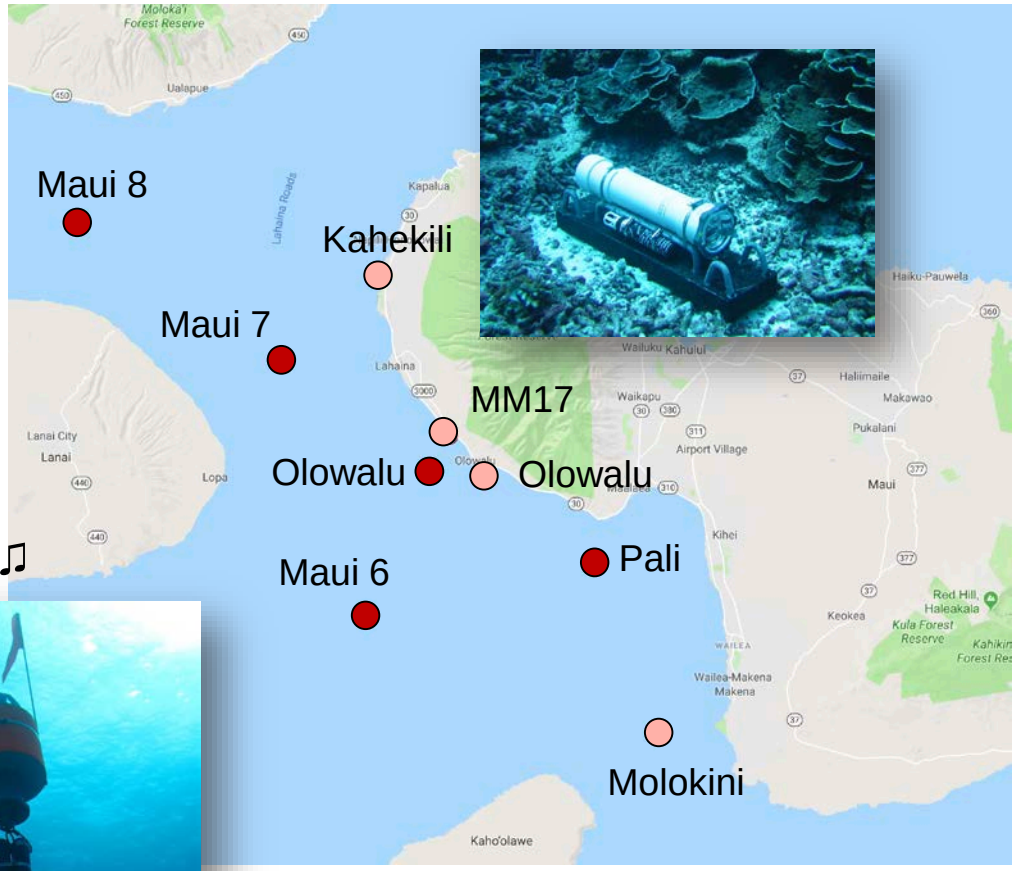
Data Collection

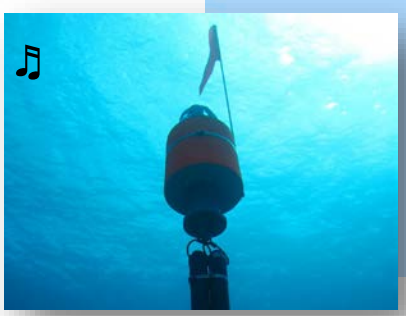


Data Collection

- Passive acoustic monitoring with **E**cological **A**coustic **R**ecorders (EARs)



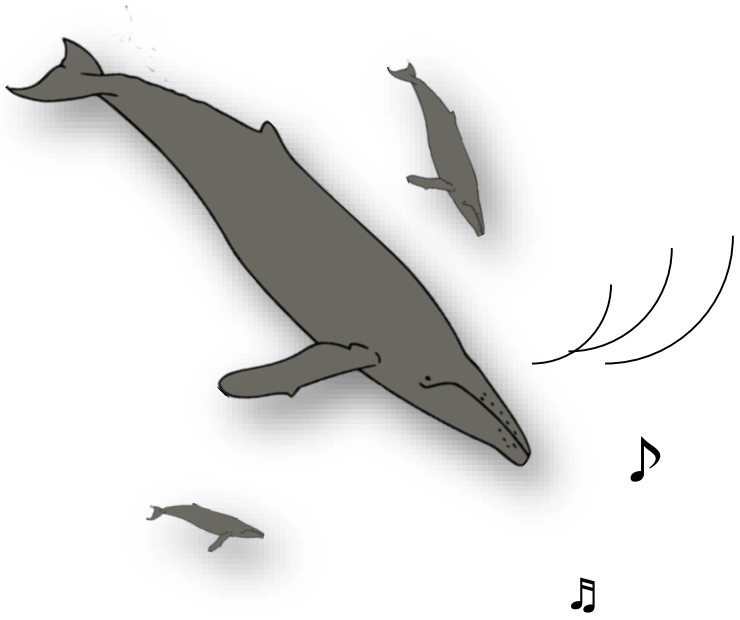


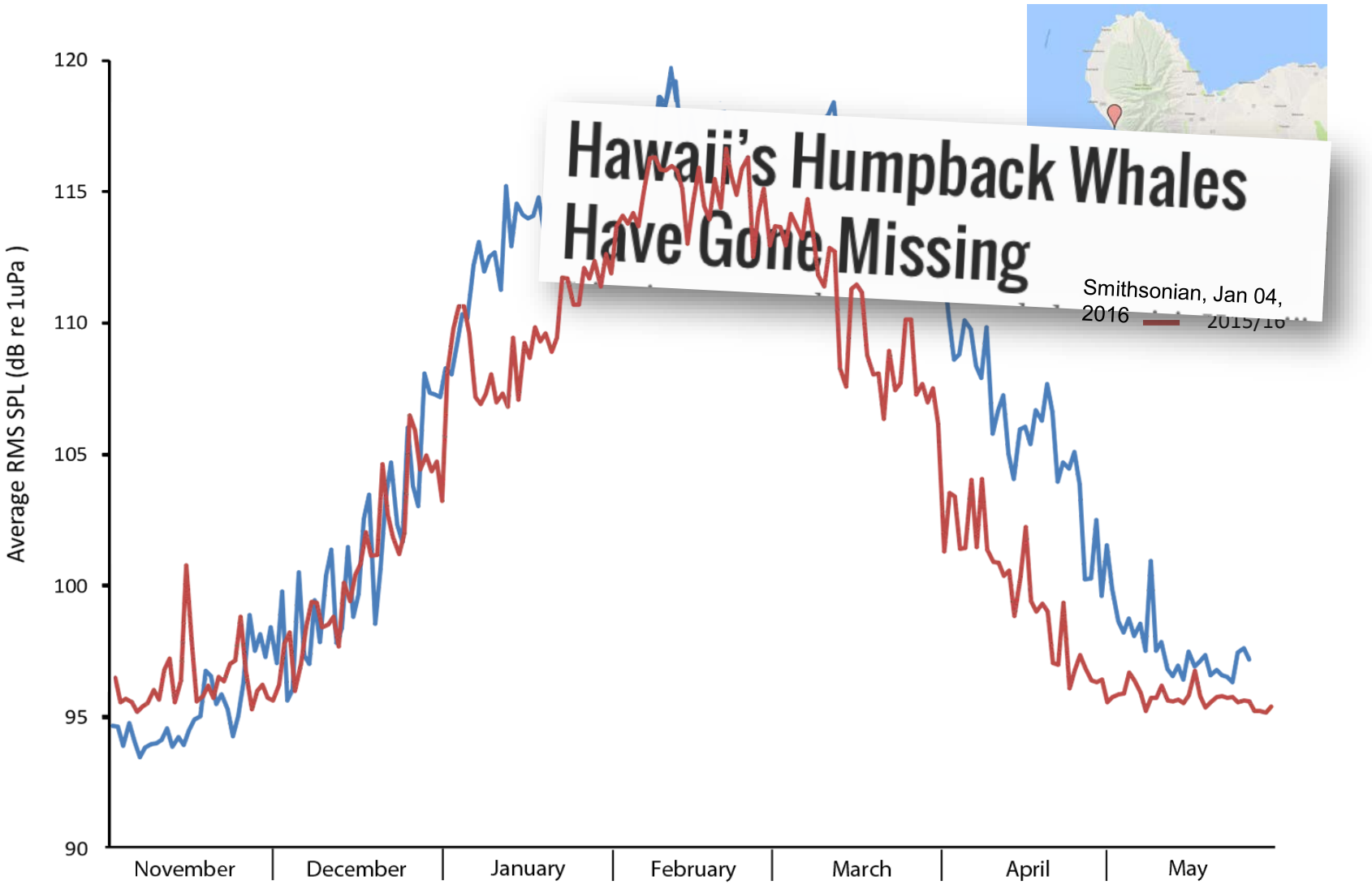


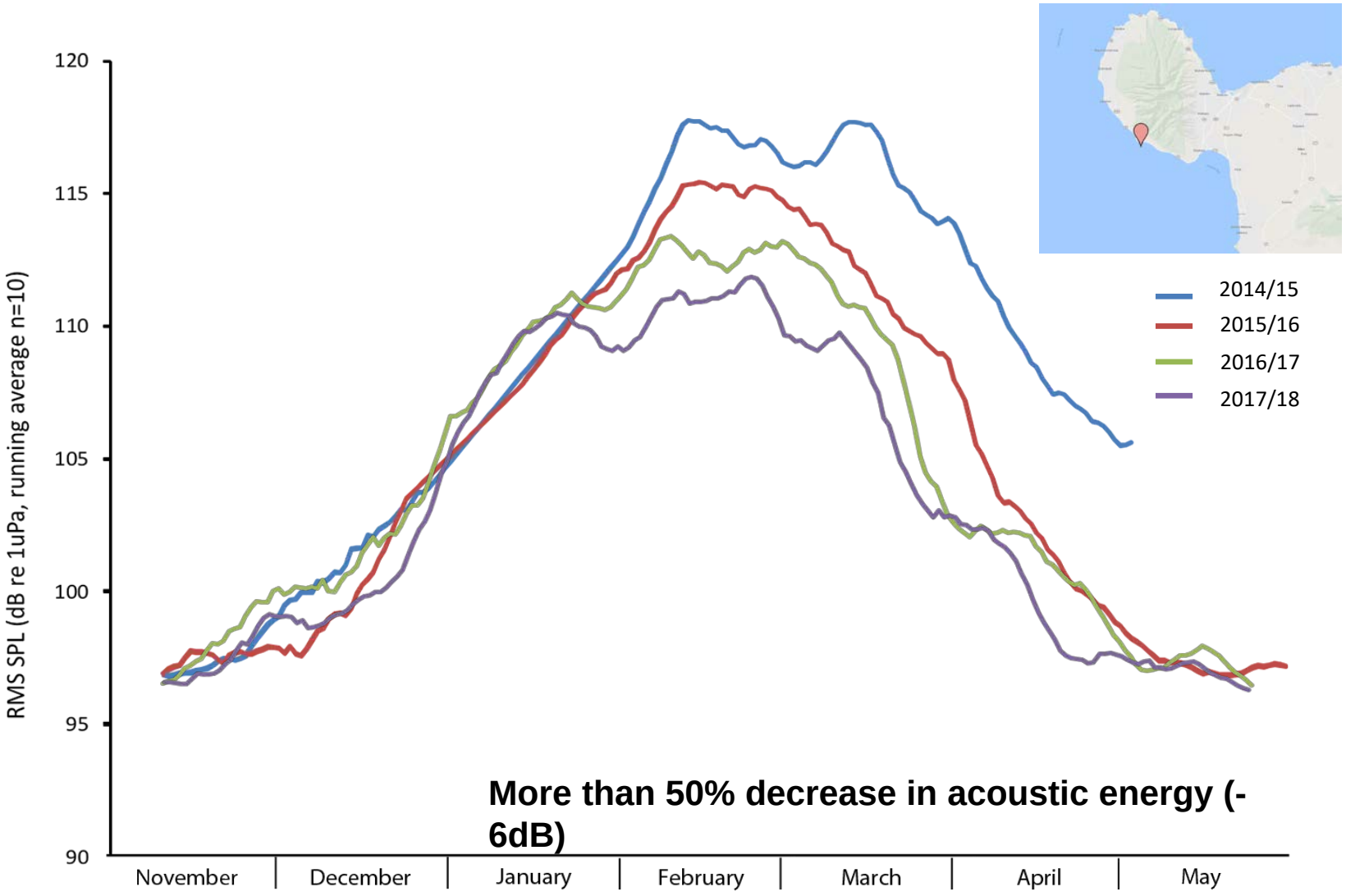
- November – May, 2014 - 2018
- 30s/5min 10% duty cycle
- Sampling rate: 25-50 kHz
- RMS SPL (Averages) (from Matlab™)
- 0-1.5 kHz frequency band

Data Collection

- Passive acoustic monitoring with **E**cological **A**coustic **R**ecorders (EARs)




Hawaii's Humpback Whales Have Gone Missing
Smithsonian, Jan 04, 2016
2015/16
Average RMS SPL (dB re 1uPa)
120
115
110
105
100
95
90
November
December
January
February
March
April
May


RMS SPL (dB re 1uPa, running average n=10)
120
115
110
105
100
95
90
November
December
January
February
March
April
May
2014/15
2015/16
2016/17
2017/18
More than 50% decrease in acoustic energy (-6dB)

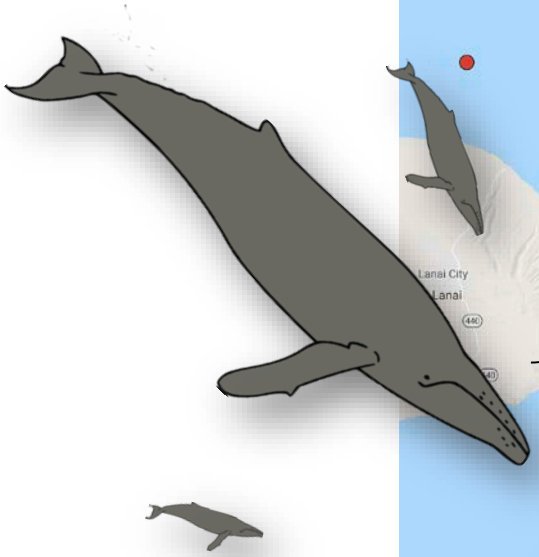
2. Micro-scale habitat use of humpback whales around Maui Nui, Hawaii

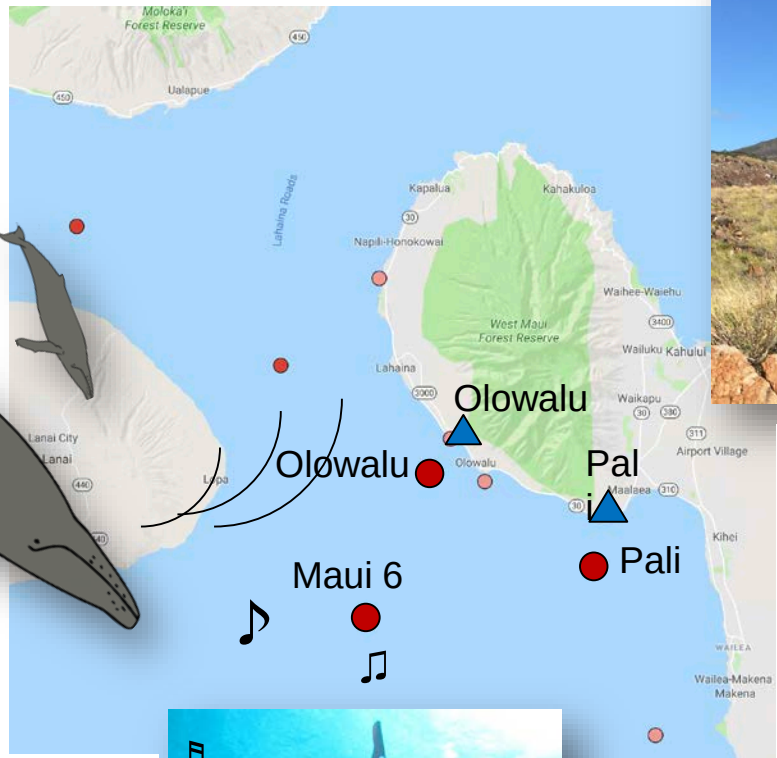
Objective

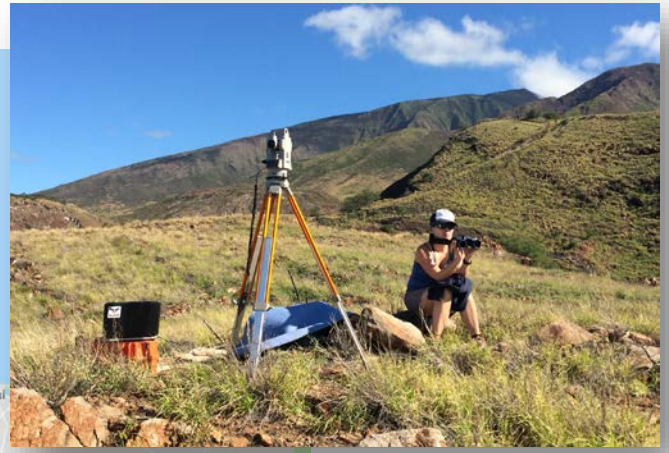
Using a multi-method approach, understand the micro-scale temporal and spatial patterns of habitat use of humpback whales in Maui Nui on two temporal scales (seaonal vs. diel)

Do whales cluster in space and/or time?

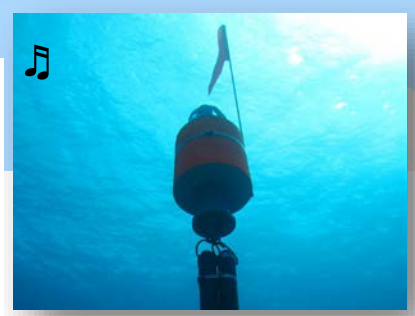
Data Collection





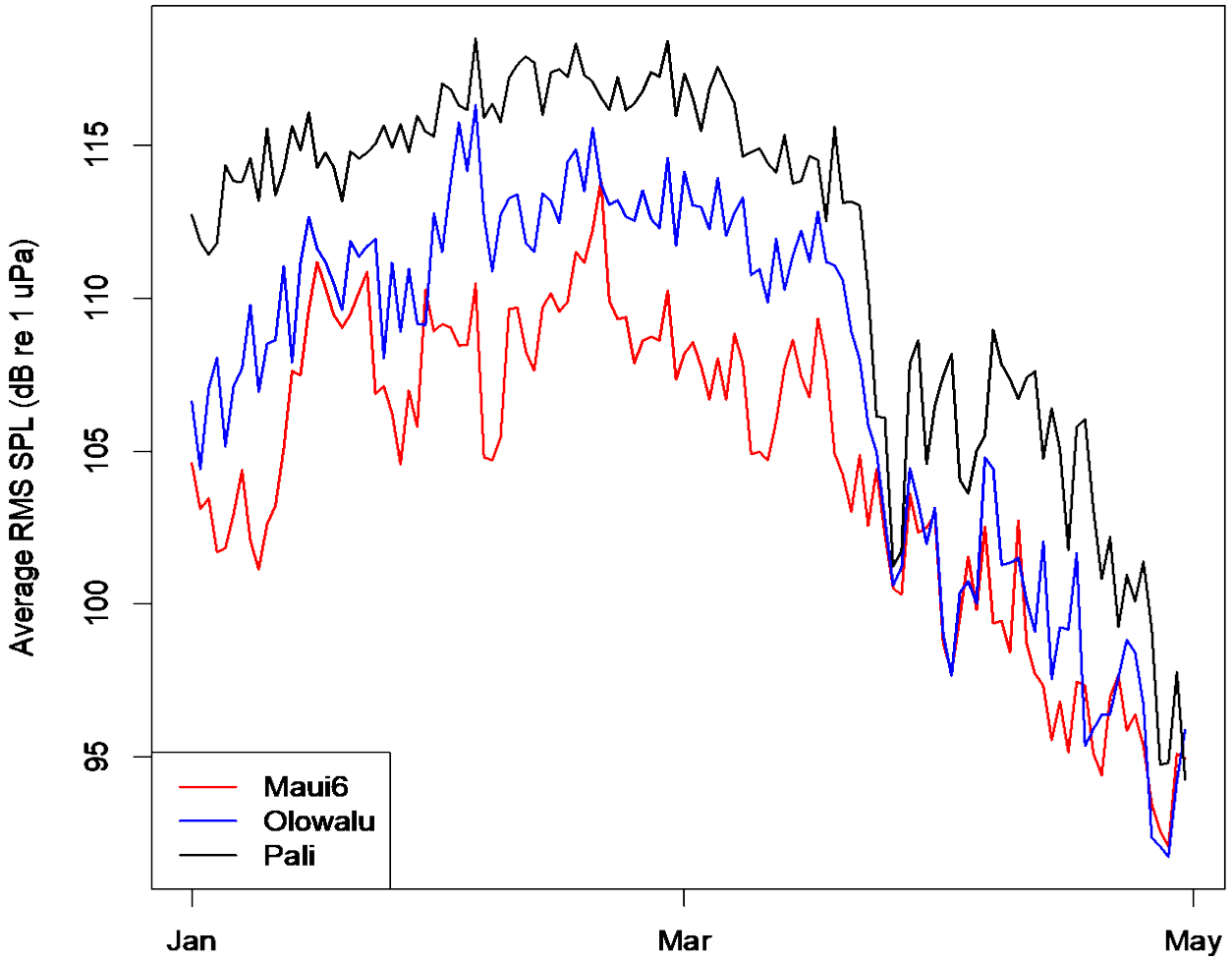


- mid-Jan 2017 – mid-Apr 2017
- Up to six 30-minute scans from 8:00/8:30 – 13:30/14:00
- Whale positions in lat/long
- Whale composition and behavior
- Environmental data
- Derived habitat factors for each whale (depth, distances, …)

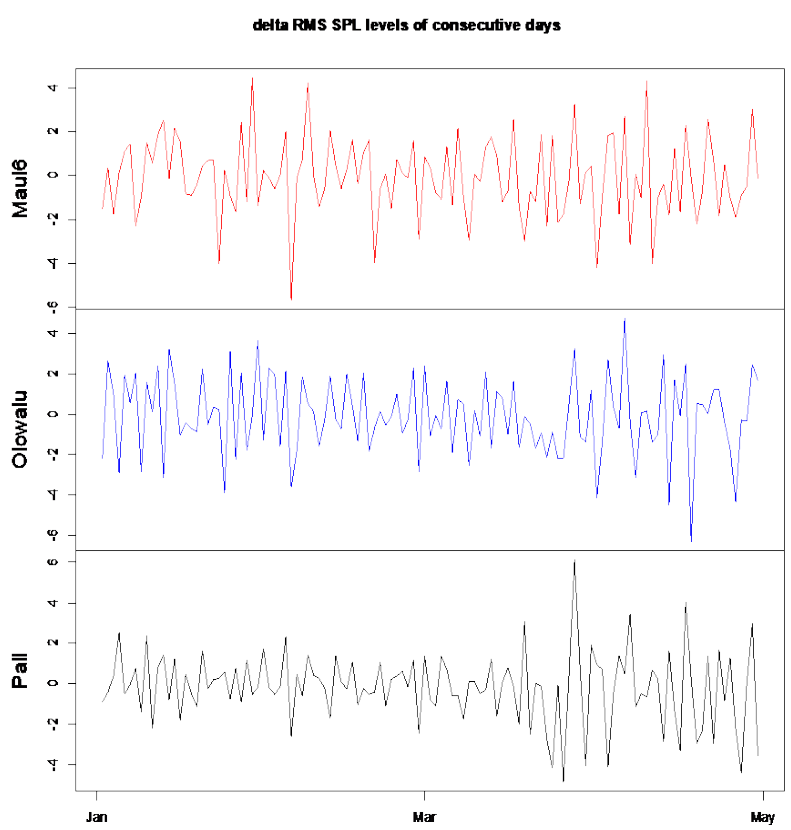


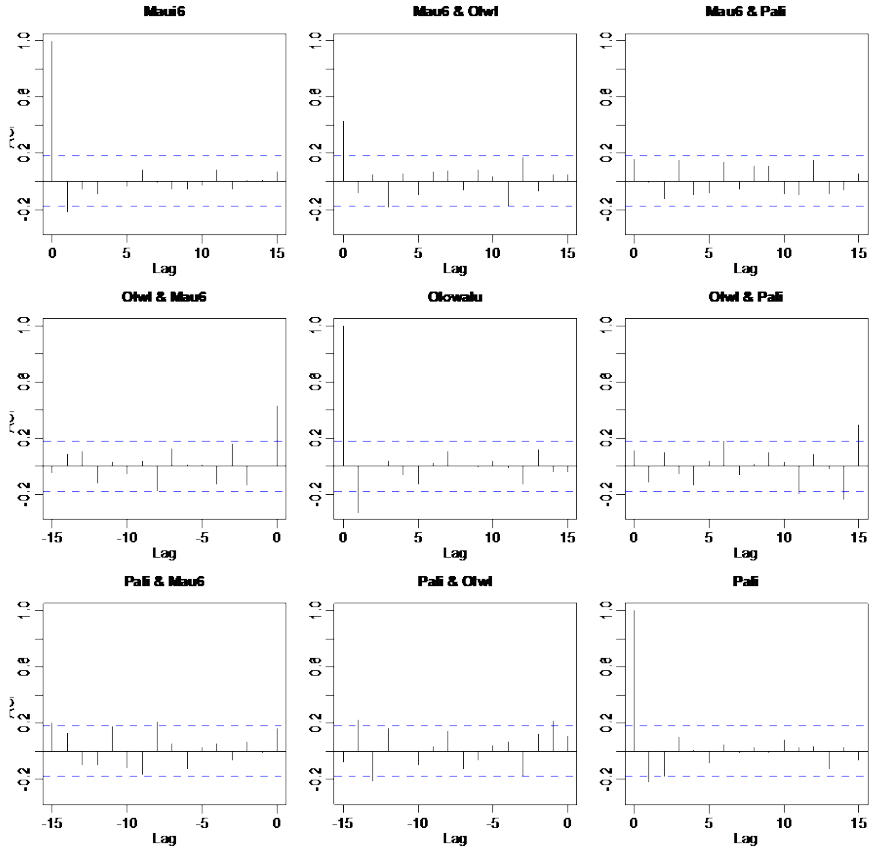
- Jan 2017 – May 2017
- 30s/5min 10% duty cycle
- Sampling rate: 25-50 kHz
- RMS SPL (Averages) (from Matlab™)
- 0-1.5 kHz frequency band
- delta_dB, normalized

Seasonal Scale



Seasonal Scale

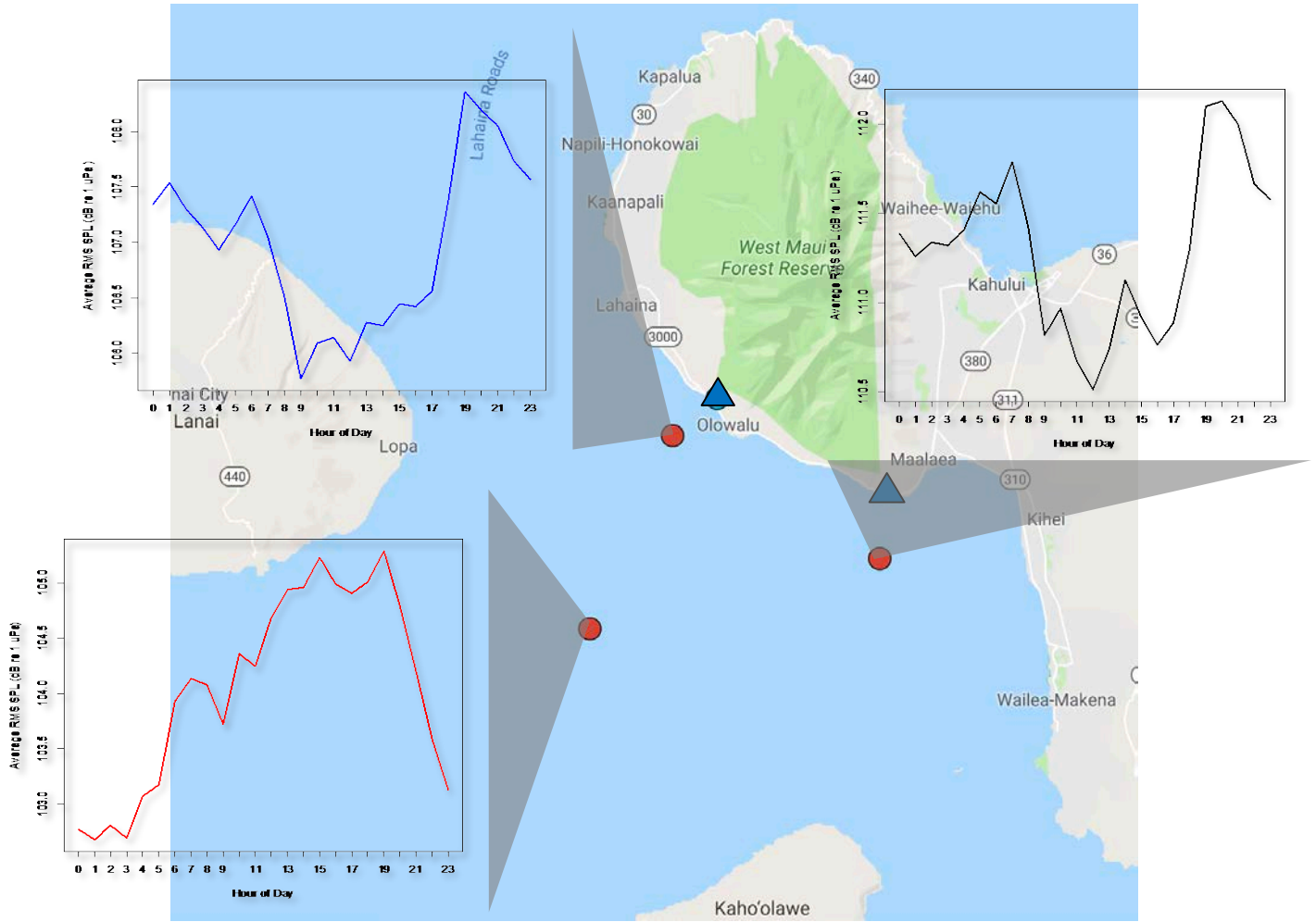




Seasonal Scale

- No clusters
- Fluid multi-site system

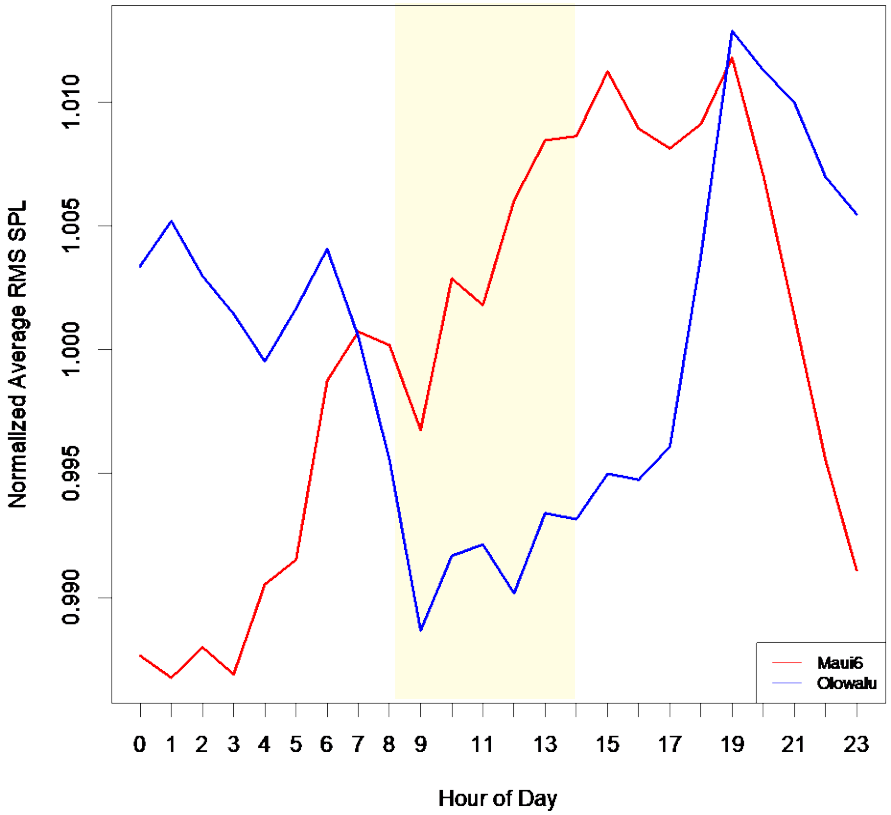
Diel Scale

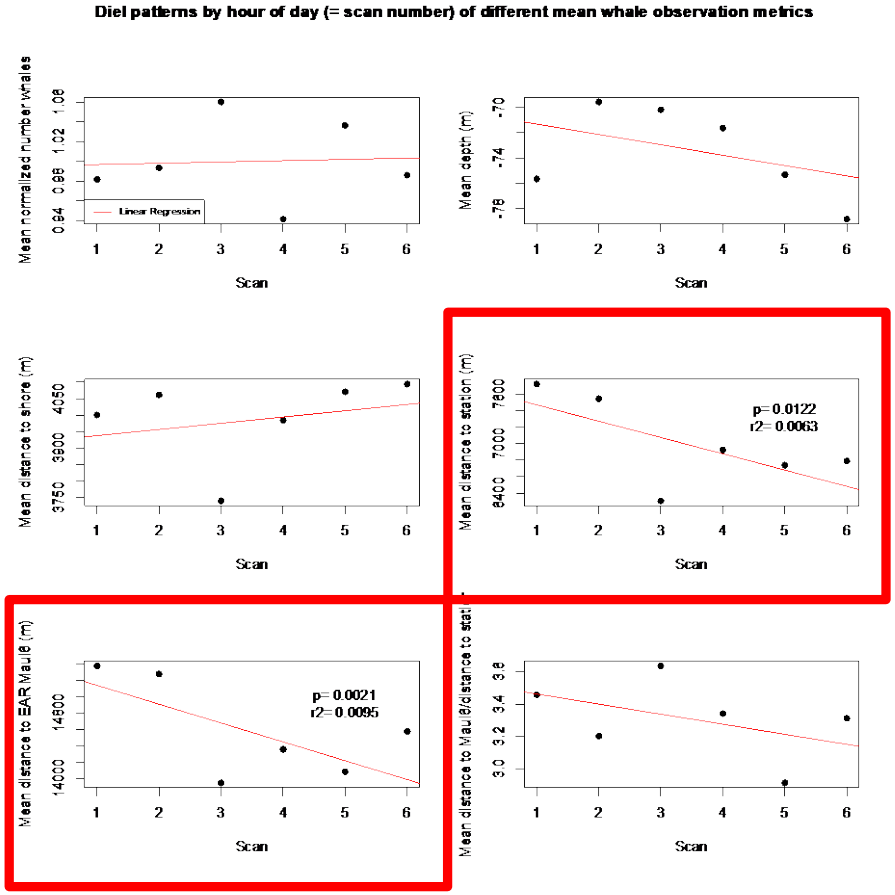

Kapalua
Napili-Honokowai
Kaanapali
West Maui Forest Reserve
Lahaina
Olowalu
Maalaea
Kihei
Waihee-Waiehu
Kahului
Wailea-Makena
Kaho'olawe
Lanai
Lopa
Lahaina Roads
Hour of Day

Diel Scale

- Whales move off-shore during the day
- Whales in different areas sing at different times of the day

Diel Scale


Normalized Average RMS SPL
0.990
0.995
1.000
1.005
1.010
0 1 2 3 4 5 6 7 8 9 11 13 15 17 19 21 23
Hour of Day
Maui6
Olowalu


Diel patterns by hour of day (= scan number) of different mean whale observation metrics
Mean normalized number whales
Linear Regression
Mean depth (m)
Mean distance to shore (m)
Mean distance to station (m)
p= 0.0122
r2= 0.0063
Mean distance to EAR Maui8 (m)
p= 0.0021
r2= 0.0095
Mean distance to Maui8/distance to stat
Scan

Diel Scale

Lahaina Roads
Kapalua
340
30
Napili-Honokowai
Kaanapali
Waihee-Waiehu
West Maui
Forest Reserve
36
Kahului
Lahaina
3000
380
311
Olowalu
Lanai
Lopa
Maalaea
440
310
Kihei
Maui 6
Wailea-Makena
Kaho'olawe

Summary

- Male song chorusing mirrors the migratory pattern of humpback whales in Hawai‘i
- *Assumption*: proportion of singing whales population size- independent

  → Song chorus can be used as a proxy for relative whale abundance

- Handle large, longitudinal data-sets
- Easy , non-invasive and affordable tool to monitor population trends (for example vs. mark/recapture) and habitat use
- Different projects/questions with one survey effort

1. **Population trend**
   - Decreasing whale song and potentially numbers since 2015/16 breeding season
   - In line with citizen-science counts, reports from other breeding and feeding grounds

Summary

2. Habitat use patterns

- Seasonal pair-wise correlation among EAR sites unclear, but preliminary analysis (fluid multi-site system?)
- Strong diel acoustic patterns, would not be observed with only one recorder
- BUT: ambiguity
  - Non-vocal whales (females, calves)
  - Physical movement vs. behavior differences
- Significant decrease of distance to station and increase of distance to Maui 6 with time of day until 2pm (but GLM probably better fit than LM)

⇨ **Synthesis of two methods reduced ambiguity and provides more wholesome picture**

What‘s next

- Influence of M/c groups on observed visual correlations
- Correct data with a detection function
- Model: influence of other factors (group comp, environment…)
- **Relationship between acoustic energy (RMS SPL) and number of whales**

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OSI
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Lisa Munger
Megan McElligott
Merra Howe
Sandy Yarbrough

Woods Hole Oceanogaphic Institution
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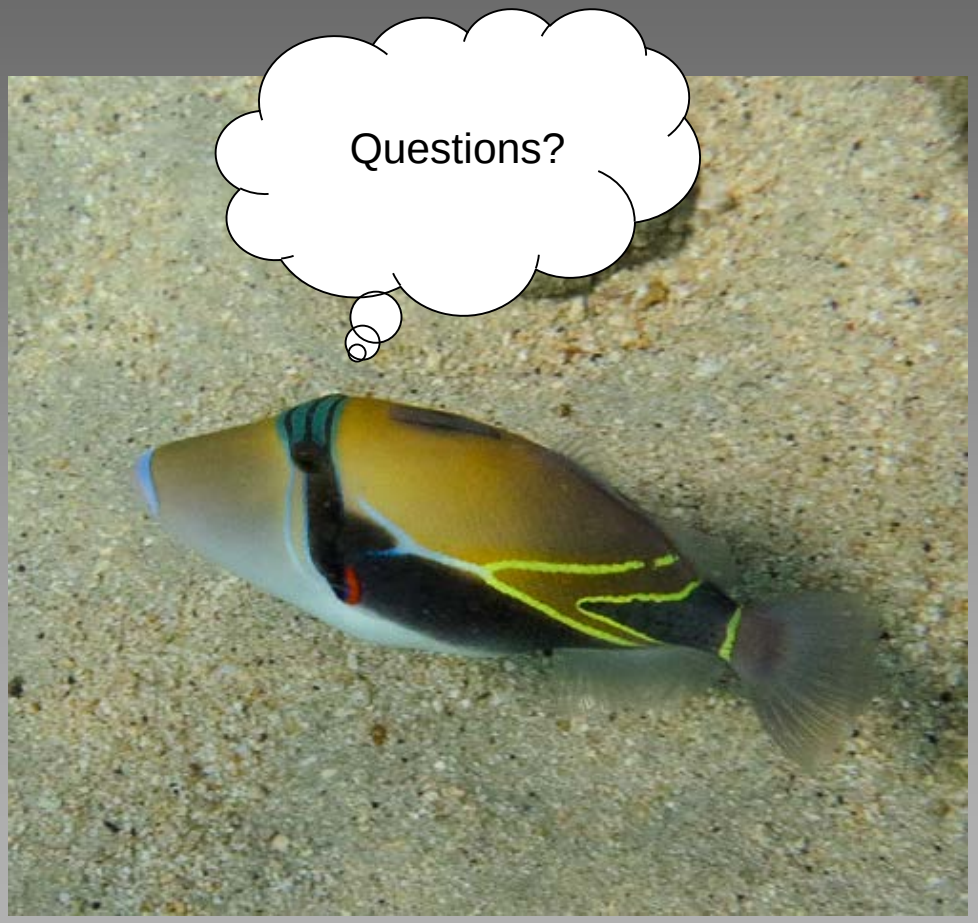
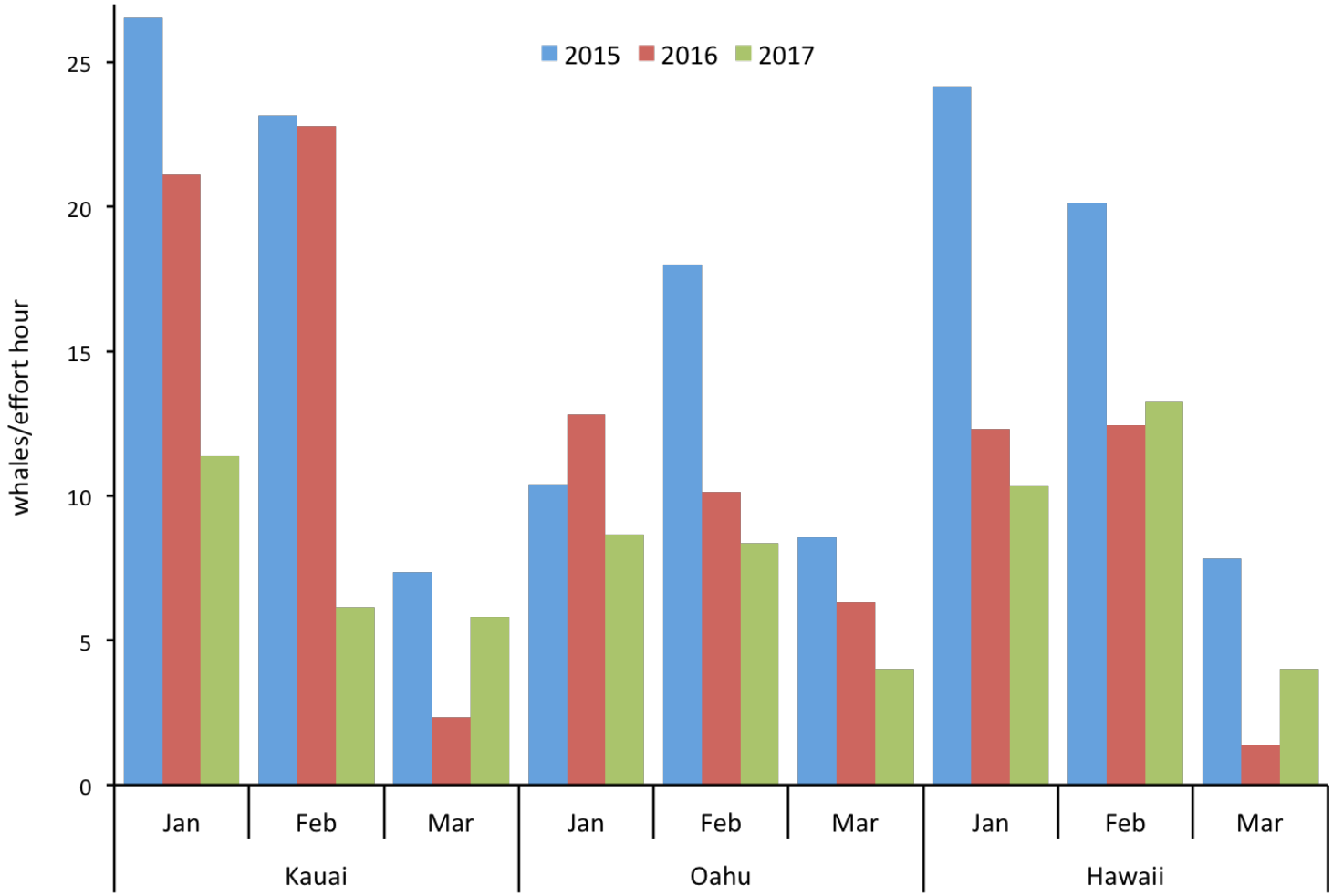
Mahalo nui loa!

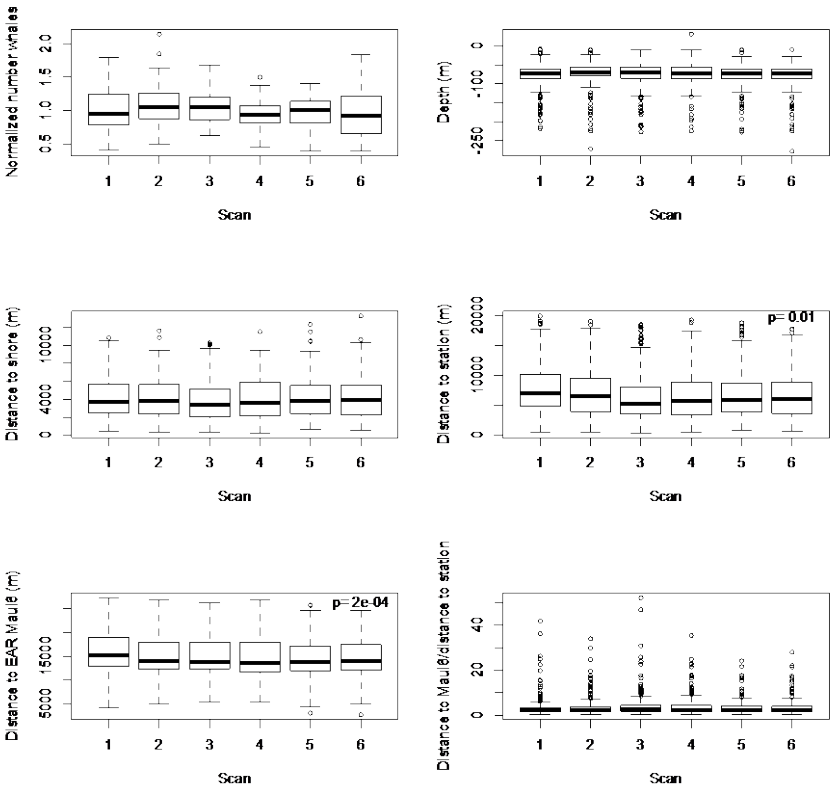


Sanctuary Ocean Count Project

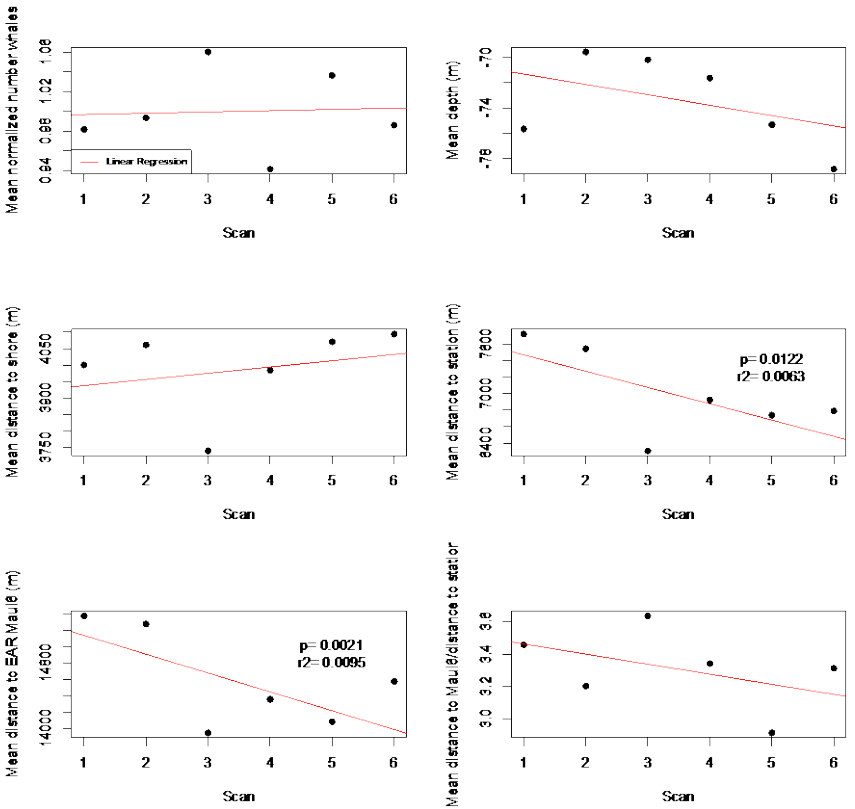


Diel Scale

Diel patterns by hour of day (= scan number) of different metrics from humpback whale observations

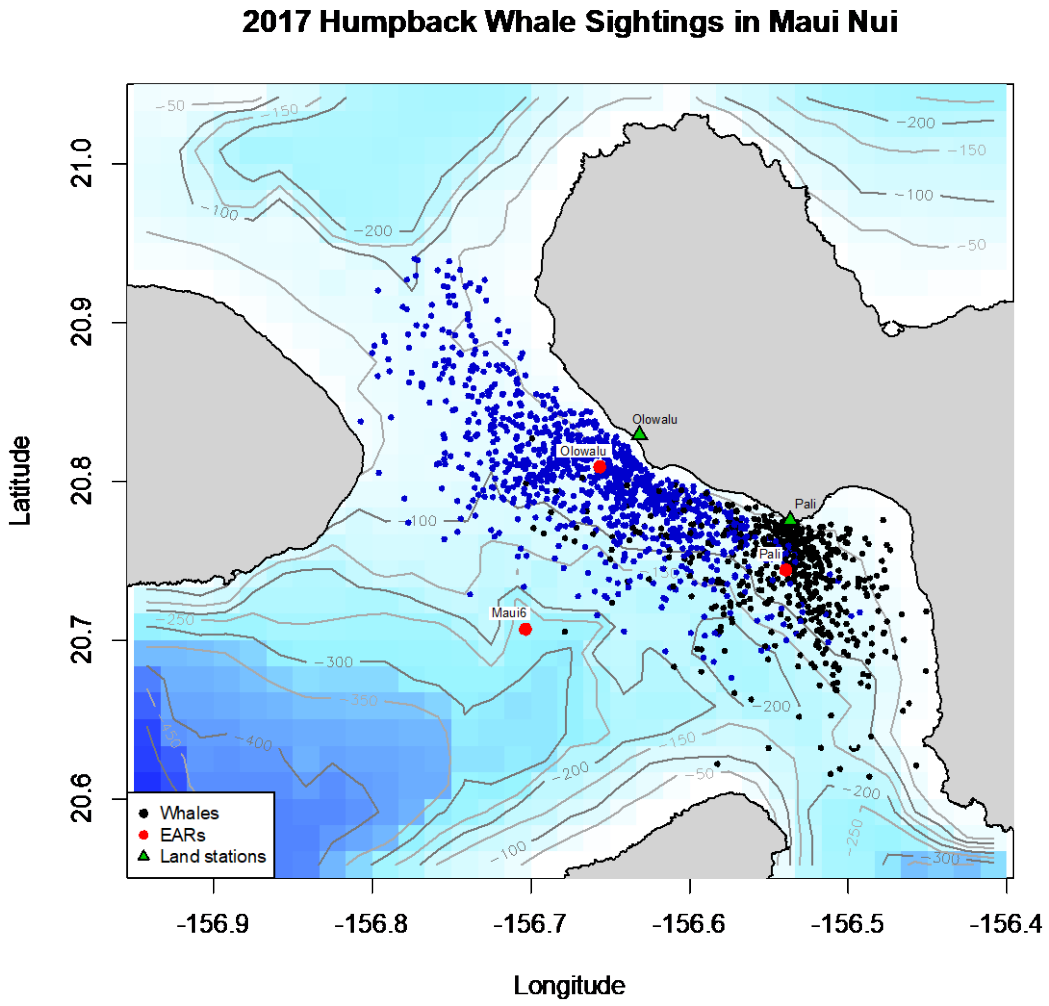


Diel patterns by hour of day (= scan number) of different mean whale observation metrics

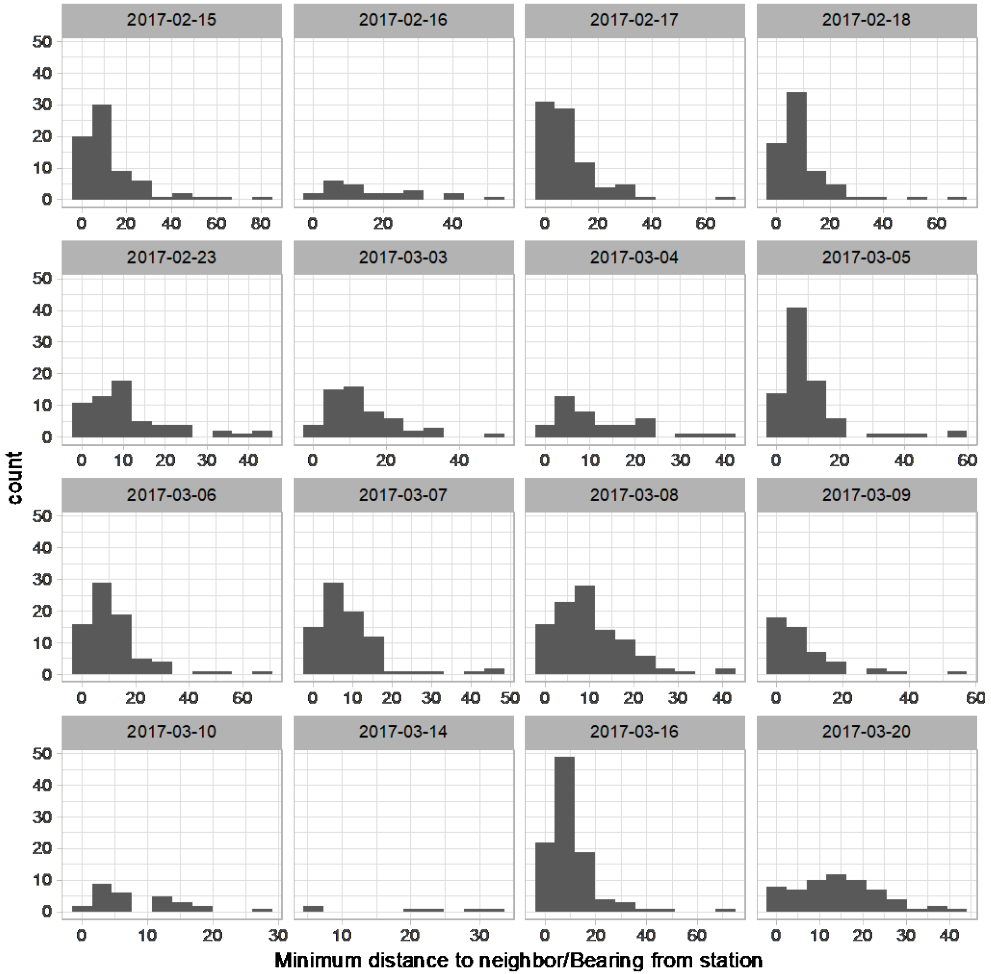


**Test for normality with QQ-plots (not shown)*

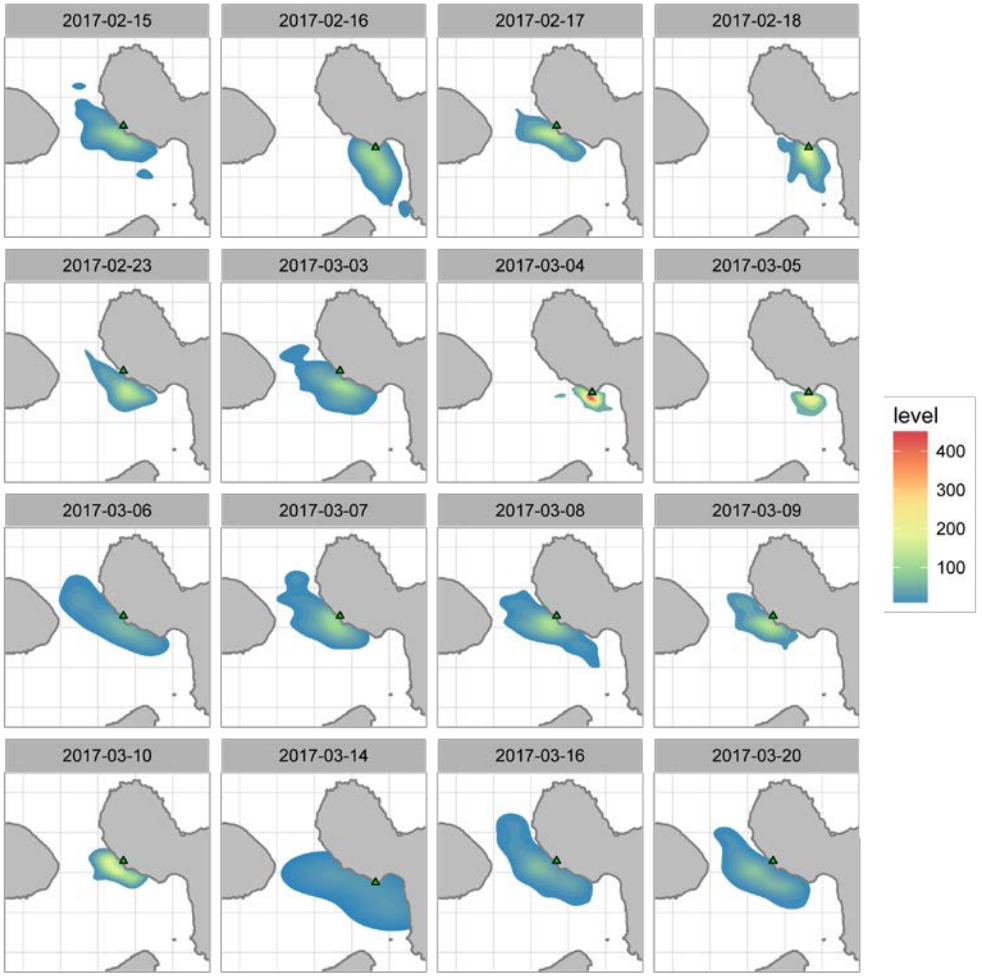
Land observations



Whale clusters



Whale clusters



Analysis

Acoustics:

***Approach*:** chorusing level is representative of relative whale abundance and reflects seasonality and diel patterns. If whales cluster and clusters move through the area, level should increase at one site while decreasing at other site with time.

- **Average RMS SPL** values per day and per hour pooled for the entire season
- Calculate **delta_dB** levels between consecutive days for each EAR site to correct for seasonality
- Pair-wise autocorrelation of delta_dB levels between sites
- Normalize **hourly averages** by mean per site and analyze pair-wise autocorrelation

Analysis

Land-data:

Approach: analyze number of sightings throughout the season and link with acoustic data for seasonal patterns. For each observation, get habitat factors and correlate with time of day (= number of scan) to investigate diel patterns.

- Normalize **daily observations** by number of scans
- Get **depths** (**package: marmap**), **distance to shore** (**package: marmap**), **distance to** respective **station** (**package: maptools/geosphere**), **distance to EAR** recorders
- ANOVA/Kruskal-Wallis for metrics ~ Scan+Date (Post-hoc Tukey HSD)