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

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Award Number: N000140910534

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Award Number: N00014-10-1-0429

LONG TERM GOALS

The overall goal of this project is to increase our understanding of the ecology and acoustic behavior of minke whales in the Hawaiian and Pacific Islands. The species is highly elusive in this area, making traditional visual methods ineffective; hence a suite of complementary passive acoustic methods have been adopted.

OBJECTIVES

Specific objectives involving the St Andrews team for this year were:

1. Obtain an estimate of minke whale density within the Pacific Missile Range Facility (PMRF) instrumented range, located off Kauai, Hawaii;
2. Obtain an estimate of the number of minke whale vocalizations per unit time and space for the same area;
3. By dividing the second quantity by the first, obtain an estimate of the vocalization rate of minke whales in this area.

Other objectives for the overall project are given in the main report by PI Norris; see also the report by Co-PI Martin of the SPAWAR Systems Center Pacific for work undertaken in pursuit of objective 2.

**APPROACH**

Our approach for meeting objective 1 was to undertake a passive acoustic line transect survey within the study area. To meet objective 2, concurrent passive acoustic monitoring was undertaken using some of the seafloor-mounted hydrophones at PMRF. Once objectives 1 and 2 are realized, calculating 3 is straightforward.

**WORK COMPLETED**

*Passive acoustic line transect survey*

The survey was designed by Norris, in consultation with the St Andrews team. The design called for four separate traverses of the study area, each traverse or “leg” involving a set of zig-zag transect lines (Figure 1), oriented to take advantage of prevailing sea conditions. The survey was undertaken by Norris and his field team between 13 March and 14 April 2010, using the quiet motor sail boat R/V Dariabar. A total of 845.2 km of transect lines were surveyed. (Note – this value for transect length is preliminary, as some discrepancies were found in the data records that need checking.) Preliminary acoustic analysis was undertaken to generate a set of distances for use in the line transect analysis.

Norris attended the advanced distance sampling workshop taught by Thomas and others in St Andrews in August 2010, during which an analysis of the preliminary data was completed.

*Fixed passive acoustic monitoring*

Concurrent with the line transect survey, Co-PI Martin made recordings from a set of seafloor-mounted hydrophones in the PMRF range (see separate report by Martin for details). Subsequent analysis, performed in collaboration with the St Andrews team, used methods based on spatially-explicit capture recapture (SECR) models to estimate vocalization density.

**RESULTS**

*Passive acoustic line transect survey*

Preliminary analysis of the line transect acoustic data yielded 46 localized animals, at distances ranging from 1 to 9.74 km (Figure 2). The software Distance (Thomas et al. 2010) was used to fit various candidate detection functions to the distance data, and a model based on the Fourier series, with one cosine term (uniform plus cosine model, in Distance parlance), was selected. The data showed fewer detections at small distances than would be expected under a monotonic decreasing detection function: for example the above model predicts around 7.5 observations between 0 and 1 km, but none were actually recorded. There are three potential explanations for this: (1) the preliminary analysis used to produce distances was flawed; (2) animals close to the transect line move away but continue vocalizing; (3) animals close to the transect line (e.g., 1 km away) stop vocalizing as the ship approaches. We are undertaking quality control assessments of all distances at present, so are addressing explanation 1. If explanation 2 is correct, no further action is required: the total number of detections is correct, and the fact that there are fewer than expected out to 1 km or so, and more than
expected at somewhat larger distances does not affect the detection function fit, which smooths through this discrepancy (Figure 2a). If explanation 3 is correct, there are too few detections at close distances but no compensating detections at slightly larger distances, so the correct solution is to truncate the data from 0-1km, so that these do not influence the detection function fit. Since at this stage it is not possible to know whether (2) or (3) is the correct approach, we present results from both.

The analysis that assumed movement (explanation (2)) yielded a density estimate of 4.45 animals per 1000 km$^2$, with corresponding coefficient of variation (CV) of 18.43%, and 95% confidence interval (CI) 3.07-6.46. Given a study area of 1900 km$^2$, this corresponds to an estimated abundance of 8 animals (95% CI 6-12). In the analysis, each of the 4 traverses (“legs”) of the study area was treated as a temporal stratum, and results by leg are given in Table 1.

The analysis that assumed reduced vocalization rate close to the line, and hence used left truncation at 1km (explanation (3)) yielded a density estimate of 5.91 animals per 1000 km$^2$, with CV 17.31% and 95% CI 4.15-8.39. The corresponding abundance is 11 animals (95% CI 8-16). Results by stratum are given in Table 1.

**Fixed passive acoustic monitoring**

Results from the analysis of these data are presented in the report by Martin. This also includes an initial estimate of the vocalization rate.

**Future work**

Line transect effort and distances to each sighting will be further validated by Norris, in collaboration with Martin and Janik. Re-analysis of the resulting data will be performed by Norris and Thomas. Ongoing analysis and validation of the SECR is planned by Martin, in collaboration with Thomas. Obtaining vocalization rates is then straightforward, and variance can also be calculated easily, since the estimates of animal and vocalization density are independent.

Janik will provide most of his allocated time in the coming six months during the analysis of vocal interactions of minke whales.

**REFERENCES**

**Table 1. Estimates of density and abundance from the towed line transect survey**

<table>
<thead>
<tr>
<th>Stratum</th>
<th>#observations</th>
<th>Density km(^{-1}) (x10(^{-2}))</th>
<th>95%CI km(^{-1}) (x10(^{-2}))</th>
<th>Abundance</th>
<th>95%CI</th>
<th>%CV</th>
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<tr>
<td>Leg 1</td>
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<td>0.341</td>
<td>0.161-0.723</td>
<td>6</td>
<td>3-14</td>
<td>33.3</td>
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<tr>
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<td>20</td>
<td>0.597</td>
<td>0.398-1.15</td>
<td>11</td>
<td>6-22</td>
<td>28.5</td>
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<tr>
<td>Leg 3</td>
<td>14</td>
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<td>0.182-0.973</td>
<td>8</td>
<td>3-18</td>
<td>31.0</td>
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<td>Leg 4</td>
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<td>0.214-0.843</td>
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<td>4-16</td>
<td>29.6</td>
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<tr>
<td>Mean</td>
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<td>0.445</td>
<td>0.307-0.646</td>
<td>8</td>
<td>6-12</td>
<td>18.5</td>
</tr>
</tbody>
</table>

Assuming evasive movement of animals close to the trackline when the survey vessel passed by (analysis with no left truncation)

Assuming a decrease in vocalization rates of animals close to the trackline when the survey vessel passed by (analysis with left truncation at 1km)
Figure 1. Ships track over 4 survey legs, locations of localized animals, and approximate study area boundary.
(a) Assuming evasive movement of animals close to the transect line (i.e., no left truncation)

(b) Assuming reduction in vocalizations close to the line (i.e., truncation at 1km)

Figure 2. Histograms of observed detection distances, and fitted detection functions.