Fine scale trends in habitat preference in humpback whale (*Megaptera novaeangliae*) female-calf pairs within the Hawaiian breeding grounds.

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Abstract

The AuAu channel between the islands of Maui and Lanai, Hawaii is heavily utilized as a breeding ground by humpback whales of the Central North Pacific stock and comprises critical habitat for this resurging population. Our study explores fine scale dynamics of habitat preference within this region. Data were collected along randomly placed transect lines that provided equal coverage of inshore and offshore regions of the AuAu channel, during March 2008 and 2009. Locations of 114 groups, containing a total of 246 whales were obtained. Details of group location, composition and behavior were recorded, along with measurements of abiotic factors, namely current and turbidity.

A preliminary review of our results suggests that patterns of habitat preference in this region differ from those reported for other breeding regions. Whereas most mysticete female and calf pairs prefer shallow, inshore waters, in this region female and calf groups showed no such preference.

Less than 10% of all calf groups were found in depths of less than 30 m; mean water depth for all groups containing a calf was 44.8 (SD 12.6) m. Groups without calves were found in slightly, but significantly deeper waters (mean depth 51 (SD 12.3) m; t = -2.637, p=0.01). However, in contrast to other mysticete breeding grounds, there was no evidence of any finer scale social stratification (X^2 = 10.240, p=0.069 for all social groups and X^2 = 1.66, p= 0.435 for different social groups containing calves). Current and turbidity showed very little variation with location, however, a review of the local bathymetry within a range of mysticete breeding regions suggests that topography and depth gradients may influence habitat preference within these areas.

Introduction

For migratory mysticetes such as the humpback whale, extensive migrations from foraging regions to spatially disparate breeding regions are a seasonal event. These migrations may be an anti-predator strategy, reducing predation pressure on young, naïve calves (Forney and Wade 2006). Additionally, they may be driven by the need for energy conservation; nearly all breeding areas occur in relatively warm waters, where SST > than 21°C (Rasmussen et al. 2007).

Within breeding regions, shallow, inshore waters may be especially important to female-calf pairs. Several studies report evidence of social stratification, where females with calves preferentially use inshore waters, thereby avoiding areas where active breeding groups congregate (e.g. Smultea 1994, Ersts and Rosenbaum 2003). This avoidance may be warranted, as associations with multiple male groups lead to increased energy expenditure for female-calf pairs (Cartwright and Sullivan 2009, in press). Additionally, inshore waters may be calmer, and this may be an important consideration as many young mysticete calves are relatively poor swimmers (Cartwright and Sullivan 2009, Taber and Thomas 1984).

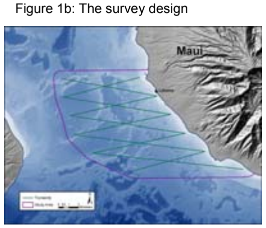
In this study we focus on the Hawaiian breeding grounds, an area that is currently used by over 50% of the Central North Pacific Stock (SPLASH 2008). Within Hawaiian waters, the AuAu channel, between Maui and Lanai is especially favored by female-calf pairs (Mobley et al 1999, Craig et al 2000). We use quantitative techniques to survey spatial variability in this area and test two alternate hypotheses: (1) Female-calf pairs prefer shallow, inshore waters and (2) there is evidence of social stratification in humpback whale groups within this region. We review spatial variability in relation to the bathymetry of the channel and examine variation in current and turbidity within the study area.

Methods

Figure 1a: The study site

Surveys were conducted in March '08 and '09, within the study area shown in Figure 1a. The survey design comprised of an equally spaced zig-zag sampler between parallel waypoints at 1' intervals across the study area (Strindberg and Buckland, 2004). Starting points were chosen randomly, and each leg of the zigzag was considered an independent sample.
Surveys were conducted in sea states of ≤ Beaufort 2 and vessels traveled at ~ 5 knots. Sightings within 90 degrees of the forward bow and 1000 meters of the survey line were recorded. Initially only those groups within 500m of the survey line were included in the sample. This buffer was later extended to 750m, to maximize the sample size for the subsequent spatial analysis.

Figure 1b: The survey design



For each sighting, latitude and longitude were recorded using handheld GPS units. Current was measured at a depth of 10m using a standard General Oceanics flow meter and turbidity was measured at 20m, using an In-Situ Troll 900 probe. Photo ID's were obtained and used to eliminate any chance of pseudo replication, either over the course of the day, or between survey vessels.

Survey Data: Surveys were collected on 29 different days, comprised 143 hours of observation and covered 451.3 km along the survey lines. Using a 500m, the initial data set included 114 groups, 246 animals and the extended data set, incorporating all animals within the 750m buffer, included 292 animals.

Results

- Groups with calves were found in slightly, but significantly shallower water than groups without calves. There was no significant difference in distance from shore.

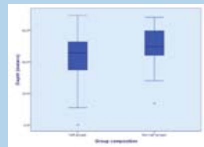


Figure 2a: Mean depths for all sightings, classified by presence or absence of calves. Mean water depth for groups with calves was 44.8 (s.d. 12.6) m; mean water depth for groups without calves was 51.1 (s.d. 12.4) m respectively. This difference was significant (t = -2.637; d.f. = 112, p = 0.010).

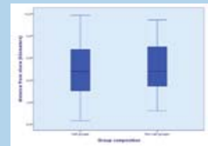


Figure 2b: Mean distance from shore for all sightings, classified by presence or absence of calves. Mean distance for groups with calves =4.83 (s.d. 2.45) km, for groups without calves 5.05 (s.d. 2.17) km. Here, the difference was not significant (t = -0.477; d.f. = 112, p = 0.634).

- When groups were classified by precise social composition, there was no evidence of fine scale stratification, either by depth or by distance from shore.

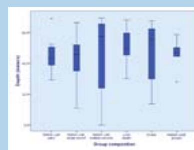


Figure 2c: Mean depths for all sightings, classified by precise social composition. Differences were not significant (Using Kruskal Wallis tests: all social groups;X^2 = 10.240, p=0.069; within groups containing calves ; X^2 = 1.245, p=0.537).

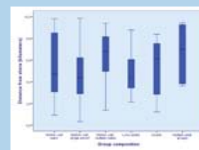


Figure 2d: Mean distances from shore for all sightings, classified by precise social composition. Differences were not significant (Using ANOVA: F = 0.321, d.f. = 2, 65, p= 0.727).

Spatial analysis

- Regions within 2 km of the shoreline were under- utilized by all social groups.

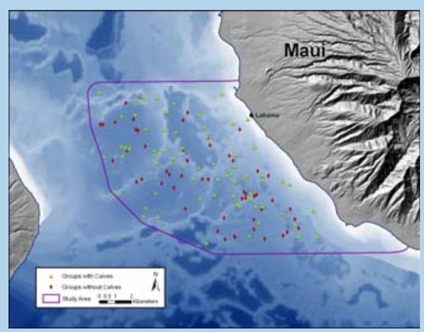


Figure 3: Distribution of all groups within 750 m buffers (n=121). Neu's index of habitat utilization reveals that areas within 2km of the shoreline are significantly under-utilized. (Using log likelihood chi-squared test on standardized selection indices: For all groups; X^2 = 29.04, p<0.005; for groups with calves; X^2 = 9.234, p<0.010). A post hoc review of the 95% confidence limits of the observed selection indices indicates that, in both analyses, it is the inshore area (<2km) that is not utilized in proportion to it's availability.

Table 1: Neu's index of habitat utilization, in vs. offshore habitats for all sightings, groups with calves in parentheses

Habitat: Distance from shore	Area (km^{-1})	Proportion of total study area	Counts (n of groups)		Neu's Standardized selection index	95% C. Intervals for proportion of actual sightings	Inference
			Obs	Exp			
<2 km	35.7	0.248	8 (7)	30 (17.1)	0.137 (0.139)	0.114 – 0.018 (0.178 – 0.02)	Under-utilized
2-4 km	29.7	0.202	39 (20)	24.4 (13.9)	0.297 (0.488)	0.412 – 0.232 (0.405 – 0.173)	Neutral
> 4km	80.2	0.558	74 (42)	67.5 (38.5)	0.563 (0.373)	0.705 – 0.517 (0.733 – 0.483)	Neutral
Totals	143.6	~1.000	121(69)	121 (69)	~1.000		

Abiotic factors

- Current and turbidity varied minimally between inshore and offshore areas.

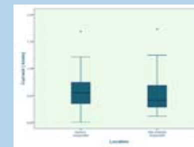


Figure 4a: Differences in mean current at inshore and offshore locations. Mean current at inshore waypoints (n=29) was 0.58 (s.d. 0.35) knots; mean current at offshore waypoints (n=31) was 0.55 (s.d. 0.36). The difference was not significant (Mann Whitney U = 407.00, p=0.530)

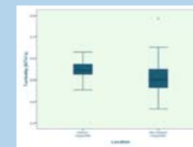


Figure 4b: Differences in mean turbidity at inshore and offshore locations. Mean turbidity at inshore waypoints (n=29) was 0.54 (s.d. 0.04) knots; mean turbidity at offshore waypoints (n=31) was 0.50 (s.d. 0.08). This small difference was significant (Mann Whitney U = 97.00, p=0.022), but is probably not biologically relevant.

Habitat preference in other breeding regions

- Female-calf pairs use inshore waters in many other breeding regions, however habitat choice may be influenced by local bathymetry.

Table 2: A selection of studies describing habitat choice seen in female-calf pairs in alternate breeding regions.

Location, local bathymetry	Mean depth / distance from shore (FC = female-calf groups)	Inferences: evidence of social stratification or habitat preference
Big Island, Hawaii. Narrow, coastal shelf adjacent to deeper waters	FC groups: Am hours 63 m, pm hours 56 m. Adults: Am hours 72 m, pm hours 66-71m	Social stratification by depth during afternoons. Ref: Smultea (1994)
Central coast, Ecuador. Coastal shelf extends 40 km off the coastline, depth on the shelf ranges from 30-50m	FC groups: 22.7m, adults: 28.4 - 35.9m. Distances from shore : FC groups – 4.8 km; Adults - 7.1km	Clear evidence of social stratification. Distances from shore reflect trends in depth choices. Ref: Felix and Haase (2005)
Antogil Bay, Madagascar. Protected bay, mean depth 41.5m; 44% of bay <40m deep.	FC groups: 60% in depths < 20m; Distance from shore for FC groups: 95% within 7km of shoreline and 20% within 1km of shoreline.	Clear evidence of social stratification. Ref: Ersts and Rosenbaum (2003)

Conclusions

- Our preliminary results suggest only minimal social stratification in the waters of the AuAu Channel.
- The inshore waters that border the west coastline of Maui are currently under- utilized by humpback whales in this region.
- Bathymetry and slope may be important factors that influence habitat choice in breeding regions.
- As our work continues, we plan to investigate spatial variation on the opposite side of this channel, along the shoreline of Lanai. This region presents a stark comparison to the highly trafficked areas along the Maui shoreline.

Key References

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