Humpback whale distribution and habitat use

State of the Gitga'at Ocean 2015

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A detailed manuscript of this study is available upon request.

HIGHLIGHTS

- Since 2005, humpback whales have been surveyed by the North Coast Cetacean Society and the Gitga'at Guardian Cetacean Monitoring Program.
- Humpbacks use all Gitga'at waters, but focus habitat use in outer channels early in the summer then gradually move into interior channels by late fall.
- "Before" (southwest of Gil Island) and "after" (northeast of Gil Island) phases of this habitat use pattern were most evident in July and October.
- Oceanographic surveys in 2015 suggest that whales are not simply following their food; foraging habits and/or social interests may be driving this curious pattern.

METHODS

Visual surveys 2005-2014

Over the course of a decade, whale surveys were conducted in the Kitimat Fjord System (KFS) an average of once per month by two collaborative research efforts: the Gitga'at Cetacean Monitoring Program and North Coast Cetacean Society (NCCS) study (Fig. 1, left panel). Gitga'at surveys began in Hartley Bay and included the circumnavigation of Gribbell and Gil Islands. The remainder of the survey route varied according to weather conditions and available daylight. Beginning in 2013 additional surveys focused on the outer channels (primarily Caamano Sound), beginning and ending at the GW camp at Rennison Island. NCCS surveys were conducted in non-winter months during good weather conditions with visibility greater than 3 nautical miles and sea state no greater than Beaufort 3 (small wavelets with a few whitecaps). All surveys began from the south end of Gil Island. On both platforms, 2-3 observers scanned

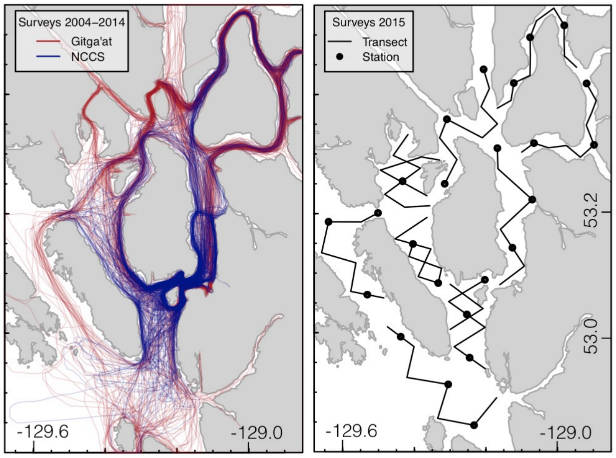

Figure 1. *Left*: Survey effort by Gitga'at (red) and NCCS (blue), 2005 - 2014. *Right*: 2015 survey plan: transects (lines) and oceanographic stations (dots) aboard *RV Bangarang*.

for cues of whale presence including blows, splashes, flukes, fins, or breaches. Groups were approached slowly in order to obtain identification photographs, estimate group size and record behavior.

2015 survey efforts

May through September 2015, simultaneous visual and oceanographic surveys were conducted aboard the *RV Bangarang*, a 12 m motorsailer, with a team of three researchers. Circuits of the study area were completed within a target duration of 20 days, during which we visited a grid 24 of stations (Fig. 2, right panel). Whale surveys were conducted using a method called line-transect sampling. Acoustic backscatter was sampled with a Syqwest Hydrobox to map the distribution of krill-like prey, which were best visualized when the transducer was set to 200 kHz and fish-like prey which were best visualized at 33 kHz. During transects, surface water temperature and salinity were sampled at 0.3m depth every two seconds with a Seabird Electronics 45 thermosalinograph (TSG). At each station, we sampled chlorophyll-a, a proxy for nutrient availability, with a WetLabs ECO-FL fluorometer mounted to a SBE25plus CTD.

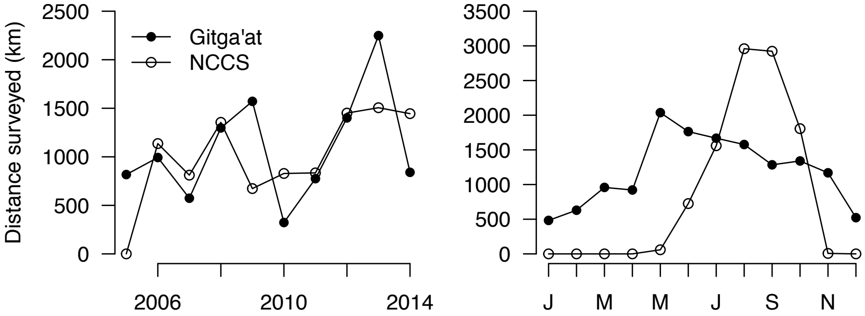

Figure 2. Survey effort (km) by Gitga'at and North Coast Cetacean Society (NCCS) platforms, 2004-2014. *Left*: Annual survey effort (June through November only). *Right*: Monthly survey effort (all months).

Analysis

To test the seasonal pattern in whale distribution, we divided the study area into 26 blocks and used a statistical procedure called Monte Carlo randomization . Acoustic backscatter down to 300m was characterized by its integrated volume, mean intensity, and dispersion through the water column. We used generalized additive models (GAMs) to test for and elucidate relationships between humpbacks, the prey field, and other environmental variables. The model's ability to predict whale distribution based on select variables (ie. prey availability, sea surface temperature and salinity, etc.) was used as our metric of the importance of each variable.

SUMMARY

Decade of surveys reveal whale "wave"

Gitga'at effort comprised 182 days spanning all 10 years of the survey period. NCCS effort comprised a total of 252 days, beginning in 2006. Effort was concentrated April to November, but occasional opportunistic trips occurred from December to March. In general, survey lengths for both platforms increased during summer months and in the latter years of the study decade (Fig. 3).

Between 2005 and 2014, NCCS and Gitga'at surveys found a total of 4,783 humpbacks. Pooled sightings from all years confirmed that, even after correcting for effort, the whale wave was strongly apparent (Fig. 4). Sightings and

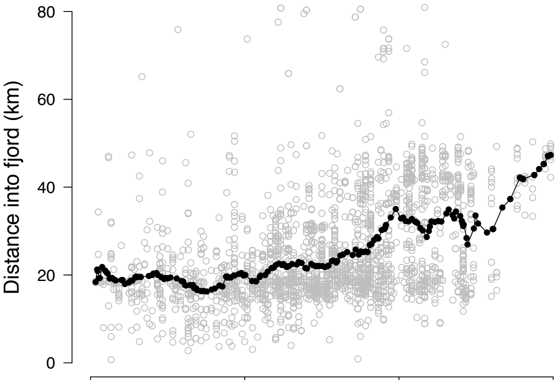

Figure 3. As summer turns to fall (x-axis), humpbacks sightings occur increasingly deeper into the Kitimat Fjord System (y-axis). Black line is running 10-day mean of raw sightings (gray dots, n=2,527) from Gitga'at and North Coast Cetacean Society surveys 2004 - 2014.

effort were also pooled into pairs of years and density across the territory was mapped, confirming that the wave occurs annually (Fig. 4).

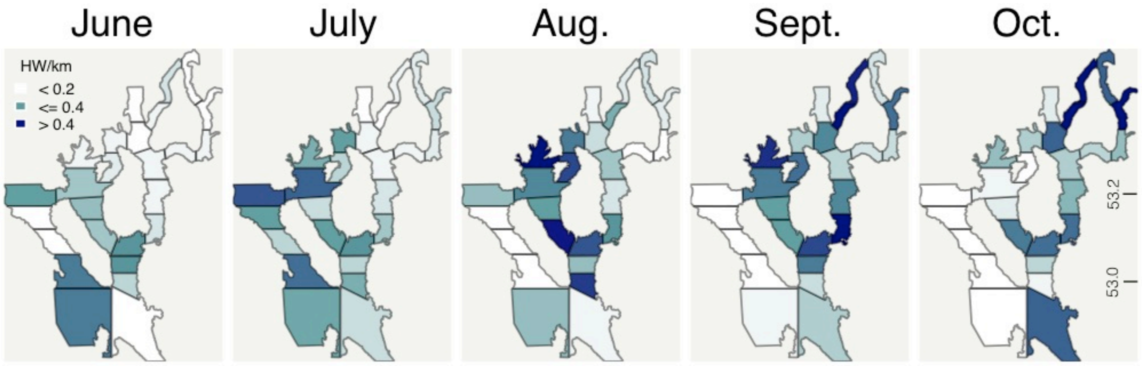

Figure 4. Areas of high humpback density (dark blue) propagate inland month to month, according to 2004 - 2014 surveys from Gitga'at and North Coast Cetacean Society (NCCS) platforms were pooled then spatially stratified (n = 26 strata).

Statistical confirmation of "wave" pattern

The Monte Carlo test found that results were nonrandom at the 5% significance level in most geographic blocks in most months. The pattern was most evident in July and October. The test suggested that the move inland actually happens fairly abruptly between August and September. In general the pattern was more significant in the interior channels to the northeast of Gil Island.

Statistical results broadly supported the existence of a wave of humpback density that propagates from outside to inside waters, but not uniformly so. Notable exceptions to the pattern include certain waters directly south of Gil Island, near Whale Point, and the entrance to Surf Inlet. The Whale Point area had unexpectedly high densities throughout summer and early fall, and Surf Inlet, in the outer channel of Caamano Sound, had high humpback densities in the early fall.

2015 survey confirmed the "wave"

In 2015, the five surveys covered a total of 1,653km of trackline 117 days. 968 humpbacks were observed, 430 of which were seen during transect effort. While humpbacks were abundant in all survey months, the highest numbers were observed in August. The monthly distribution of these sightings confirms that the "humpback wave" occurred again in 2015 (Fig. 5). As the wave propagated inland, humpback densities also became less concentrated. The most dispersed humpback distribution was observed in September.

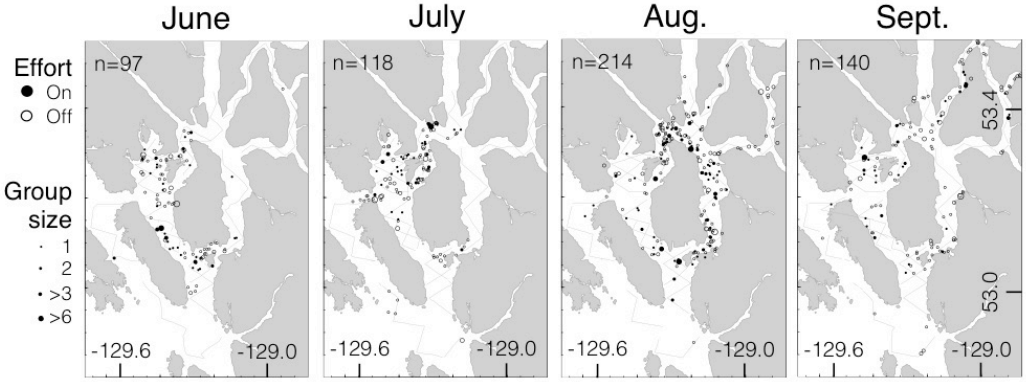

Figure 5. Humpback sightings from the 2015 surveys aboard *RV Bangarang*.

Habitat drivers of the “wave”

Acoustic backscatter, which allows for the visualization of potential prey, declined throughout the summer, beginning in outer channels only then dispersing throughout the fjord system (Fig. 6). There seemed to be no directional wave of prey into the interior waters. As a result, the habitat model based on prey metrics alone gave the poorest explanation of humpback distribution, while the most complex model, which combined prey variables with physical variables such as sea surface temperature and salinity, performed best. When examined from month to month in 2015, we found that prey distribution was a good predictor of humpback distribution in early summer (June), but performed worse and worse through to September. The best-performing habitat models suggest that krill-like backscatter (200 kHz) was the most important prey predictor of humpback distribution. Important non-prey related variables included chlorophyll-a, sea surface temperature and salinity, day of year, and geospatial coordinates.

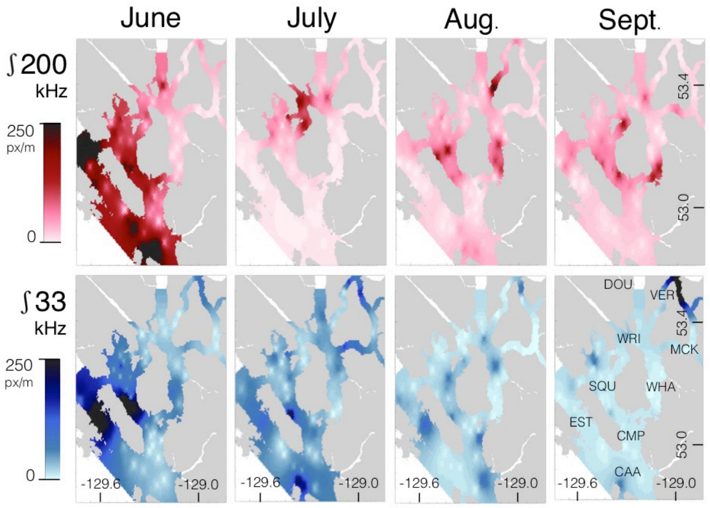

Figure 6. Integrated backscatter (px m^{-1}; total pixel values per meter of trackline) interpolated from 5km bins of trackline within each monthly survey, summer 2015. Color scales range from noise floor to the season’s maximum reading. Noise at 200kHz indicates krill-like prey, while noise at 33kHs indicates fish-like prey.

Our most curious results were a) the generally low importance of prey metrics relative to environmental variables, b) the decline in Prey model rank from first in June to among the worst in remaining months, and c) the general decline in performance of all models as the season wore on. The growing prediction error in all models throughout the summer suggests that we failed to sample some habitat component that became increasingly important into the fall.

Cautious about context

This study involved 1) long-term, four-season monitoring that identified spatial pattern and developed hypotheses, followed by 2) new fieldwork dedicated to hypothesis testing. While we recommend this research procedure in general, we acknowledge the limitations of using a single summer to explain a long-standing pattern. 2015 may have been an exceptional year in terms of ocean conditions that decoupled humpbacks from their typical associations with prey or environmental variables. Indeed, it was in the aftermath of the “warm blob” and at the onset of an El Niño (Bond et al., 2015, CPC 2016). It is particularly difficult to discount site-fidelity related behavior, which would have been acquired and refined over many years.

MANAGEMENT CONSIDERATIONS

Whale-climate coupling

If the “whale wave” is a response to changes in prey or their environmental proxies, then its ultimate mechanism is oceanographic. As in most fjord systems, the KFS experiences strong offshore-inshore gradients in ocean conditions and weather driven by seasonal signals in climate and water mixing (MacDonald et al., 1983, Fig. 10). These midsummer gradients may help whales orient themselves or cue them towards the habitat they need. Gradients are maintained by estuarine circulation, which is a seaward surface flow of relatively freshwater atop a deeper landward countercurrent (Syvitski et al., 1987). Estuarine flow is governed by snowmelt and, to a lesser degree, seasonal rains (Masson and Cummins

2000). Gradients are disrupted with the onset of fall storms, whose sea waves and strong winds overwhelm estuarine flow and collide with downwards outflows of cool air, inducing vigorous mixing (Thomson 1981, Freeland and Farmer 1980). By wintertime KFS waters are relatively homogenous (MacDonald et al., 1983). The breakdown of cue gradients could disperse prey and/or instigate prey production deeper inland. In this way, the timing of the "whale wave" may be related to the shifts between estuarine circulation and autumn mixing by storms. Both of these processes are governed by climate, including inter-annual oscillations and long-term trends. If so, whale use of fjord habitats could be particularly sensitive to global trends in climate.

Ecological impacts of "wave"

As the whales propagate inland, so too does their ecological footprint. Although humpbacks are abundant within the Gitga'at waters, their ecological impact at any one time is highly localized. Beyond predation and competition, this impact includes the facilitation of other predators and nutrient redistribution (Roman et al., 2014). Other species may come to coordinate their use of this fjord system accordingly. Habitat use patterns like the whale wave may be a significant medium of "ecosystem engineering" among large marine predators.

Importance of long-term research

Others have studied humpbacks in this area without detecting the whale wave (Williams and Thomas 2007, Wheeler et al., 2010, Gribba and Bailey 2015), and their findings have become the basis for the impact assessment of proposed industrial activities in this fjord system (Williams and O'Hara 2010, Enbridge 2010). Long-lived, mobile predators must be observed across seasons and for many years before strategies and motivations of habitat use can be understood. Where available, research is greatly enhanced by the involvement of local residents who have the familiarity with their home system to interpret observations with unique insight. Our study highlights the value of long-term, local monitoring by indigenous communities and their partnership with non-profit and academic research organizations.

Consequences of displacement

The annual persistence and statistical strength of the whale wave demonstrate that humpback habitat use can be structured and strategic. It may facilitate the most thorough possible use of a fjord system's resources, provide similar access to other complex systems of BC's fjordland, and accommodate higher densities of humpbacks in the dwindling number of relatively undisturbed foraging grounds of the northeast Pacific coast than would otherwise be possible. It is likely coordinated with the specific oceanography of the study system, suggesting that local displacement by human impacts may have more consequences than previously supposed. Industrial projects that disrupt habitat continuity, such as shipping lanes, may be particularly detrimental to the integrity of this and other critical habitats. Until sufficiently thorough habitat use studies have been carried out, irrevocable management decisions should be treated with extreme caution.

The importance of small habitat protection

Protecting entire species ranges is typically impossible, particularly in the case of mobile oceanic predators such as whales, so we must ask which portions are most important. It is here that the common depiction of mobile predators as masters of foraging improvisation and environmental forensics can be counterproductive for conservation. Though accurate, this picture can be misconstrued as an argument against the protection of specific sites, given that an entire ocean remains available. This outlook ignores the fact, demonstrated by our findings, that mobile marine predators use sophisticated strategies not only to navigate vast swaths of marine habitat but also to tune into the specific features and attributes of certain areas and develop spatial strategies that enable its most thorough and efficient use.

ACKNOWLEDGMENTS

NCCS and *Bangarang* fieldwork was conducted under federal permit (DFO XR 83 2014) and formal research agreement with the Gitga'at First Nation. NCCS fieldwork was funded in part by the Save Ours Seas Foundation. 2015 *Bangarang* fieldwork was funded by the Gitga'at First Nation Guardian Watchmen, Canadian Department of Fisheries and Oceans, NSF Graduate Research Fellowship program (DGE-114086), and private donations from the Watson, Ayres, Cunningham, Barlow and Keen families. The authors thank World Wildlife Fund for providing GIS coordinates for NCCS 2008-2012 survey tracks, B.L. Padgett for providing inlet footage, Megan Ferguson for analytical guidance, and Katelyn Qualls for euphausiid data. EMK thanks his coauthors for introducing him to the study area and for inviting him to lead this paper, as well as the 2015 *Bangarang* crew: Mike Keen, Will Bostwick, Jay Barlow, Barb Taylor, Kim-Ly Thompson, Anne Simonis, Sam Watson, Emily Ezell, Matt Irwin, Nelle Pierson, Sara Keen, Nicholas Bruns and Jeff Garretson.

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