Resource Selection Function Analysis of Beaufort Beluga Whales to Determine Use of Ice and Shelf Habitat

[1,2]Loseto, L.L., [2]Richard, P., [2,3]Stern, G.A., [2]Orr, J., [1,2]Ferguson, S.H.

[1]Department of Zoology, University of Manitoba, Winnipeg MB, R3T 2N2, Canada [2]Freshwater Institute Fisheries and Oceans Canada, Winnipeg MB R3T 2N6, Canada, [3]Department of Geography, University of Manitoba, Winnipeg MB R3T 2N2, Canada

Abstract

Sexual dimorphism and segregation has many implications for understanding habitat selection by marine mammals, including conservation. We tested for sexual segregation in habitat use of satellite tagged beluga whales in the eastern Beaufort Sea from late summer to early fall in 1993, 1995 and 1997 by employing resource selection function models according to sea ice concentration and shelf habitats. A distance analysis was also conducted to examine gender differences in the distance to coastlines and islands in the Canadian archipelago. Habitat selection differed with age, sex, and reproductive condition of whales according to three groups: the first selected open water habitats and were largely comprised of females with calves and a few smaller males; the second selected habitat along the ice edge and were comprised of both males and females; the third selected regions of heavy ice concentration and were comprised of large males. Females relative to males were often closer to the mainland in shallow regions. Beaufort beluga whales summer in a region undergoing hydrocarbon exploration and climate warming. From a conservation perspective, protecting beluga summer habitat requires consideration of intra-population segregation of habitat use as it likely relates to different feeding and foraging ecology of reproductive and gender groups.

Introduction

- Sexual dimorphism and segregation has been documented in most mammals (Ralls 1977, Bonefant et al., 2004, Bowyer 2004); however research has generally not considered the implications of these patterns for marine mammals. Marine mammals do exhibit sexual segregation, for example in the extremely dimorphic northern elephant seals; where males range from 1.5 to 10 the size of females, requiring a different feeding strategy and differential use of habitat to maintain their size (LeBoeuf et al., 2000).
- Beluga whales (*Delphinapterus leucas*) are dimorphic, males are larger than females (Harwood and Smith 2002), but length and weight vary among populations (Doidge, 1990) making it difficult to relate sizes to age/reproductive classes. Every spring the eastern Beaufort Beluga population travel from the Bering and Chukchi Seas to the eastern Beaufort Sea in the summer. The summer harvest of beluga whales by communities from the Inuvialuit settlement region (NT Canada) represent an important component of their subsistence lifestyle.
- Although there are no indications of beluga population decline have been observed over the summer habitat in the Mackenzie Delta, evidence of significant climate warming effects have been observed (Barber et al., 2001) and dramatic increases in hydrocarbon exploration are forecasted. Both environmental changes will likely result in an increase in ship traffic in the region. Thus this presently healthy population will likely face striking dramatic changes to its summer habitat requiring management knowledge about whale-environment relationships. However, little is known about their habitat use, and how habitat use differs among gender and age classes.

Here we examined sexual segregation of summer habitat use in Beaufort Beluga whales using satellite data collected from 25 whales captured in 1993, 1995 and 1997 according to the following questions.

1) **does habitat use differ among gender according to resource selection functions (RSF; (Arthur 1996) in sea ice concentration and the presence or absence of shelf habitat ?**
2) **if there is intrapopulation sexual segregation of habitat use then how do whales group according to RSF values?;**
3) **does distance to the mainland coastline and archipelago islands differ similarly among groups as a secondary confirmation of the above patterns?**

Methods: Habitat Use & Sexual Segregation

Habitat Delineation

- Ice concentration (from the Canadian Ice service) and shelf were the two resource variables chosen to examine habitat use based on availability (Fig 1.). Four **Habitat Categories** were devised for the model defined as:

Category 1: Open water off shelf (< 10% ice &> 200m bathymetry)

Category 2: Mixed Ice (20% to 80% ice)

Category 3: Closed Ice (> 90% ice)

Category 4: Open water in shelf (< 10% ice & < 200m bathymetry)

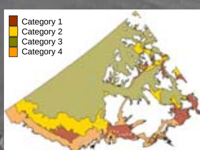

Fig. 1 Habitat category map for one week in August, 1995. Colored dots represent satellite transmissions for that week.

Resource Selection Function

- Satellite tracking of Beaufort Beluga whales was provided by Richard et al. (2001) for 1993, 1995, and 1997 (Table 1).
- Daily location data was averaged to one location per day, daily distance travelled was calculated with the distance formula, and the 95% average movement of all whale individuals was 137.2 km. Daily distance was used for the radius of buffer zone for available habitat for each beluga location
- RSF's were employed to assess habitat use patterns. Resource selection indices are calculated as (use)/(%availability) for each habitat type (Manly, 1993; Arthur et al., 1996).
- The set of ratios for all habitat categories was used as the resource selection function (Manly, 1993). Selection indices (b_i) were calculated for each animal and habitat category.

Cluster & Distance Analysis

- Cluster analysis was used to objectively to group individual whales based on similarity of bi values of habitat (K-means on Systat 11, using average method, distance metric was Euclidian distance; or cluster in SAS.
- Distance to the mainland coastline and island coastlines was assessed to provide a test of the resource selection analysis and cluster results.
- Random points were generated to confirm whether observed whale distances were significantly different than random. All location points for all whales for all three years were combined to estimate home range (Kernal 95%, ref. from animal movements package).
- Within the home range random points equivalent to actual locations were generated using animal movement software package.
- Shortest distance to one of the following islands; Banks, Melville, Victoria, Prince Patrick, Eglington and Byam martin Island was determined and used for a distance for each point in addition to distance to the mainland coastline.

Results

Habitat Use Summary

- Habitat use was not random (bi = 0.25).
- According to the MANOVA whales did not select habitat differently among years or gender (years P=0.18; gender, P=0.19), and no interaction was present (P = 0.06).
- However, three groups were identified with the cluster analysis (Figure 2).

Table 1. Beluga whale year, tag ID, sex, lenght, number of days used for RSF analysis, bi values for each habitat category, and designated cluster group

						Habitat Category bi values				
Year	Tag ID	Sex	Length (cm)	Calf length (cm)	N Days	Open Water	Mixed Ice	Closed Ice	Open Water on Shelf	Cluster Groups
1993	17002	M	457		11	0.12	0.32	0.53	0.037	3
	17005	M	442		61	0	0.71	0.29	0	3
	17009	F	302		14	0.66	0	0	0.34	1
1995	17001	M	427		27	0.52	0.17	0.31	0	2
	17002	M	404		28	0.72	0	0	0.28	1
	17003	M	432		17	0.02	0.2	0.75	0.04	3
	17004	M	373		24	0.5	0.04	0.14	0.31	1
	17005	M	353		23	0.42	0.2	0.16	0.23	1
	17007	F	373		26	0.38	0.34	0	0.27	1
	17008	Fc	361	182*	9	0.64	0	N/A	0.36	1
	8754	Fc	363	217	23	0.35	0	N/A	0.65	1
	17010	M	399		26	0.35	0.39	0.21	0.04	2
	17011	M	402		25	0.22	0.25	0.46	0.07	3
	17012	M	404		30	0.15	0.32	0.31	0.22	2
	17013	M	402		30	0.13	0.31	0.52	0.03	3
	17014	Fc	340	223	30	0.18	0.36	0.23	0.23	2
1997	2118	Fc	374	?	27	0.34	0.14	0.51	0	2
	10692	Fc	338	243	33	0.55	0.19	0	0.25	1
	10693	M	395		48	0.41	0.11	0.34	0.14	2
	8754	M	405		50	0.3	0.26	0.33	0.11	2
	8755	M	400		58	0.64	0.08	0	0.28	1
	25846	M	374		46	0.56	0.16	0.19	0.08	1
	8757	M	379		37	0.35	0.14	0.39	0.11	2
	8758	M	421		46	0.3	0.08	0.54	0.09	2

* new born

Groupings According to Gender & Size

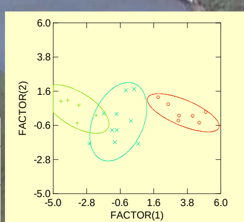

Figure 2. Canonical Scores Plot of individual beluga bi values, displaying the three groups derived by the cluster analysis. Red circles represents group one, open water, blue diamonds represents group two, ice edge, and green triangles represent group three, closed ice.

Open water:
(5 females, 3 w *calves*, 4 small males),
Open water & Heavy ice/ice edge:
(10 males; 2 females)
Heavy ice concentration:
(5 males; included 3 *largest*)

- Group 1 displayed strong use of the open water habitat categories off and on the shelf (x bi values =0.55; 0.28 respectively). This group was comprised of nine individuals, five were females of which three had calves, and the males ranged from 353 to 404 cm.
- Group 2 selected the open water off shelf habitat category (x bi value = 0.35) as well as the heavy ice concentration habitat. This group was comprised of two females with calves and ten males.
- Group 3 selected the heavy ice habitat category followed by the mixed ice habitat (mean bi value =0.53;0.34 respectively). This group was comprised of five males, three of which were the largest in of all the tagged whales.

Distance Analysis

- A significant difference in the distance to the mainland and island coastline was observed in the comparison of randomly generated points of all whale locations (P<0.01), showing selection. - - Distance to the mainland and islands significantly differed between gender, year and there was an interaction (P<0.01). Groups devised by the cluster analysis also differed from one another (F=5.4, df=4, 2180, P<0.01).

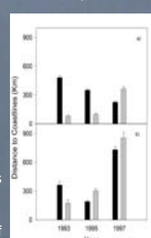

Figure 3. Average distances (+/- SE) of male and female from a) the mainland coast and b) the island coastline.

-Males were farther from the mainland coastline in ‘93 & ‘95, and closer than females in ‘97 (Fig 3).
- Males were closer to the islands in 1995 and 1997.
- Males and females were farther from the islands in 1997 when tags were placed on whales later in the season and many had already begun their westward migration.

Discussion & Conclusions

Open water

- This group supports predation risk hypothesis of sexual segregation. Since females invest in offspring it would be a beneficial strategy to select habitats that would be less vulnerable to predation such as open water regions.
- Smaller sized males in this group may be in part explained by forage selection hypothesis. Smaller sized males are young, and not sexually mature, and thus may continue to learn to forage while staying with their matriline and avoid large males that may be aggressive. Also because of their small size they may be avoiding the risk of ice entrapment.

Heavy ice

- Large sexually-dominant males may exploit enhanced feeding areas at the expense of possible predation risk to invest in the greatest mass gain which would extend size dimorphism, supporting both the predation and forage selection hypothesis.
-Risk of death by ice entrapment or predation is likely a significant risk factor for large males, thus the energy benefits of provided by feeding in these habitats must outweigh the mortality risks.
- Abundant, high-quality food provided by selecting high-risk areas may require large body size thereby supporting the forage selection hypothesis.

Ice edge

-Ice edges provide productive regions, attracting fish, birds and marine mammals. Therefore selecting ice-edge habitat supports both the foraging hypothesis as the larger males are able to attain more or a different food source at the ice edge as well as the predation hypothesis as males with the most to gain from increased foraging efficiency (i.e., enhancing sexual dimorphism) while trading off increased risk of predation and ice entrapment.
- Selection by females with calves appears risky relative to the habitat selected by other females. However, the calves are not newborn, which likely reduces susceptibility to predation, and are less constrained by small-body size physiology.

Conclusions

- Results revealed intrapopulation sexual segregation of habitat use according to three groups of whales. Results could not adequately differentiate between, both the foraging and predation avoidance hypotheses for sexual segregation.
- From a management perspective protecting beluga habitat requires meeting the needs provided by the different habitats selected by the different size and gender groups.
- Understanding the habitat requirements and ecology of the Beaufort beluga whales is particularly opportune as hydrocarbon exploration and climate warming are increasingly affecting the region.

References

Arthur, S. M., Manly, B.F.J., McDonald, L.L., Garner, G.W. (1996). "Assessing habitat selection when availability changes." Ecology 77(1): 215-227.
Barber, D. G., Hanesiak J. (2004). "Meterological forcing on sea ice concentrations in the southern Beaufort Sea over the period 1978 to 2001." J. Geophys. Res **109**.
Bonenfant, C., Loe, L.E., Mysterud, A., Langvatn, R., Stenseth, N.C., Gaillard, J., Klein, F. (2004). "Multiple causes of sexual segregation in European red deer: enlightenments from varying breeding phenology at high and low latitude." Proc. R. Soc. Lond. B **271**: 883-892.
Bowyer, T. R. (2004). "Sexual segregation in ruminants: definition, hypotheses, and implications for conservation and management." Journal of Mammalogy **85**(6): 1039-1052.
Le Boeuf, B. J., Crocker, D.E., Costa, D.P., Blackwell, S.B., Webb, P.M., Houser, D.S. (2000). "Foraging Ecology of Northern Elephant Seals." Ecological Monographs **70**(3): 353-382.
Harwood, L. A., Smith, T.G. (2002). "Whales of the Inuvialuit Settlement Region in Canada's Western Arctic: An Overview and Outlook." Arctic **55 (sup 1)**: 77-93.
Manly, B. F. J., McDonald, L.L., Thomas, D.L. (1993). Resource selection by animals: statistical design and analysis for field studies. London, England, Chapman & Hall.