Brief Communication

Remote sensing techniques for determining landcover features: applications for a species at risk

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Abstract: Remote sensing techniques are becoming more advanced and commonplace in conservation biology, and are used to study spatial patterns of various taxa. The main objective of this study was to determine whether supervised classification of landcover types within Landsat imagery could be accurately used to find or locate islands on lakes that may have been overlooked during ground transects in central Saskatchewan. Additionally, we used telemetry data from collared female caribou to determine which islands were used and in which season(s), and to determine island characteristics that make caribou more likely to select them. We were able to successfully identify all islands within bodies of water relevant to collared caribou using a supervised classification method, which suggests that our methods were adequate. We also determined that none of the island characteristics significantly influenced caribou selection according to an occupancy model, however females tended to choose islands with a higher vegetation cover (NDVI) during the summer months and a proportionally lower snow cover during the winter months, likely as forage and predator avoidance strategies respectively. Finally, we suggest directions for future studies as well as implications for both wildlife managers and land-use planners in Saskatchewan, Canada.

Key words: remote sensing; calving islands; spatial ecology; species at risk; *Rangifer tarandus caribou*.

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Introduction

Remote sensing techniques are becoming more advanced and more commonplace in conservation biology (Atzberger, 2013; Tedesco *et al.*, 2014). Using Landsat imagery to verify ground transect data can increase the accuracy of studies that use modelling techniques (Bastin *et al.,* 1993; Foody, 2002; Fisher *et al.,* 2006), which is crucial when considering wildlife movement or connectivity of habitat (Soto *et al.,* 2009). Landsat imagery can also be used to offset the cost of collecting spatial data, ground transects are often extremely time-consuming and expensive (Fisher *et al.,* 2006; Perry & Enright, 2007). The majority of current geographic information systems (GIS) support remote sensing technology for use by conservation biologists, planners, decision-makers, and other researchers.

Studying spatial patterns of wildlife is an incredibly efficient practice, especially for species that tend to be elusive. For example, boreal woodland caribou (*Rangifer tarandus cari-*

bou), listed federally as a Species at Risk, tend to reside in old-growth forest and thus cannot always be found during ground landscape transects or aerial population counts (Wittmer *et al.,* 2007; Avgar *et al.,* 2015). Additionally, despite being a mainly terrestrial animal, female woodland caribou may use islands during the calving season (Bergerud, 1985; Cumming & Beange, 1987). This is a unique phenomenon among ungulates; neither deer, moose, nor elk have been documented using islands to calve (Bolger *et al.,* 2007).

Using remote sensing techniques to measure land cover a fairly widespread practice, especially when studying more elusive species (Edenius *et al*., 2003; Theau and Duguay, 2004; Theau *et al*., 2005). For example, Edenius *et al*. (2003) used remote sensing techniques to delineate spring habitat for reindeer as it occurs in snowbeds. These classes of vegetation are typically rather difficult to examine as snowmelt occurs much more slowly than the surrounding areas. Additionally, Theau and Duguay (2004) and Theau et al. (2005) measured lichen cover to better estimate the distribution of caribou during the summer months in Canada.

Remote sensing techniques are also often used to create a baseline for comparisons relevant to the scope of the study. For example, Hansen et al. (2001) used remote sensing to measure the loss of suitable wintering habitat for caribou in Canada over the course of twenty-two years. Additionally, Falldorf et al. (2014) used remote sensing of Landsat imagery to determine areas likely to be overgrazed by deer and thus unavailable to reindeer during the winter. Finally, remote sensing techniques can be as coarse or as sensitive as is relevant to the study. Johnson and Gillingham (2008) suggested that fine-resolution data verified through on-the-ground sites would be the most effective for the estimation of species' distributions.

The main objective of this study was to determine whether supervised classification of Landsat imagery could be accurately used to identify islands on lakes that may have been overlooked during ground transects in central Saskatchewan, Canada. Additionally, we used telemetry data from collared female caribou to determine which islands were used and in which season(s), and to determine island characteristics that made them more attractive to caribou. We also suggested implications that could be further studied that would likely be of interest to multiple stakeholders. Understanding caribou spatial movements is relevant to researchers using GIS technologies and remote sensing for spatial research, as well as to decision-makers and conservation managers when planning for recreational activities in areas frequented by endangered species.

Methods

Remote sensing

We used landcover classification techniques to determine the location of islands within central Saskatchewan, Canada. We downloaded image files with thirty metre resolution from the open-access Landsat 8 server for summer months (July through September) and winter months (December through February) in 2015 and 2016. These seasons do not necessarily correspond to the biological seasons of caribou, but instead were delineated based on the likelihood of snow cover. We assumed that it would be unlikely for Landsat 8 images to have snow cover from July to September, and that it would be likely for Landsat 8 images to have snow cover from December to February. We chose to download images from two different seasons to eliminate any bias caused by seasonal differences, such as leaf cover, algae content of lakes obscuring islands, or snow cover making islands indistinguishable from ice. We specifically chose images with less than 10% cloud cover and did not apply any corrections in order to maintain consistency and avoid errors associated with color corrections.

We conducted a maximum likelihood supervised classification to distinguish mainland, islands, and water in central Saskatchewan, using the Image Classifier tool in ArcGIS v.10.3.1 (ESRI, 2016). We applied a water-land mask to the Landsat images and used additional training sites to ensure overall accuracy. Because the study area was relatively small, we manually and meticulously examined the classification to find errors. We used Google images with one metre resolution to verify telemetry locations that corresponded to bodies of water to ensure we did not misclassify landcover. We designated a minimum of 500,000 pixels and 30 distinct mainland, island, and water features to ensure precision. We used telemetry data from collared female caribou (n=24) collected weekly between 2005 and 2009 in the area to determine which islands had presumably been used, and ensured that no islands were missed in our classification of Landsat 8 imagery. We also noted the season during which caribou used each island, based on the information recorded by the GPS collars.

It should be noted that telemetry data must be interpreted with caution, as GPS signals can be intercepted and misreported by tree canopy as well as other features on the landscape (Minton *et al.,* 2003; Fatemieh *et al.,* 2011). With this in mind, we designated island usage by the observed presence of caribou on or around islands, and assumed that islands without telemetry data were unused.

Quality analyses of used islands

We noted the characteristics of islands used by female caribou as well as an equal number of randomly selected unused islands based (Table 1). The details we noted for each island included the surface area of the island, the distance and orientation (north, south, east, or west) from mainland, the surface area of the body of water surrounding the island, as well as the vegetation cover (NDVI; summer season) and proportion of snow cover (winter season). We assumed that a higher NDVI would correlate with a greater presence of caribou due to the availability of resources and that a lower proportion of snow cover would correlate to a greater presence of caribou due to resource accessibility. We ran a one-way analysis of variance (ANOVA) to determine whether the characteristics of presumably used islands differed from the characteristics of presumably unused islands. We also created a density model using R v.3.2.2. (R Stats Package, R Core Team, 2016) to determine which characteristics, if any, were likely to influence island selection by female caribou. Density models estimate distribution patterns based on location data; in the case of our study, we used telemetry data to model density and distribution patterns.

Results

Remote sensing and telemetry

Using our classification method, we managed to identify all islands within central Saskatchewan that were used by female caribou. Several locations recovered from the collared female caribou corresponded to bodies of water, but the majority of these bodies of water held islands and we assumed the caribou were travelling to or from the islands. The islands within these bodies of water were all determined by landcover classification of the Landsat 8 imagery. Location points over the course of four years (n=10, 20, 15, and 1 in 2005, 2006, 2007, and 2008, respectively) suggested that female caribou travelled on or around five different bodies of water. These telemetry points spanned the entire year, though the majority (n=37) occurred when lakes would likely be frozen (between December and February). The remaining telemetry points (n=9) occurred between mid-June and September, when females would likely be calving or have a calf at heel.

Table 1. Details of islands within central Saskatchewan. Islands presumably used by caribou were determined based on telemetry from GPS-collared females, while an equal number of presumably unused islands were chosen via random selection.

Lake in Saskatchewan	Caribou use	Surface area of island (km^2)	Distance from mainland (m)	Orientation from mainland	Surface area of water (km^2)	NDVI	Proportion of snow cover
Clarke lake	Yes	26.1	429.2	Northeast	274.8	0.0835	0.1109
Clarke lake	Yes	32.4	463.7	Northwest	274.8	0.0852	0.1103
Dore lake	Yes	35.1	631.8	Northwest	291.0	0.0948	0.1170
Lawrence lake	Yes	58.3	389.9	Northeast	13,216.2	0.1128	0.0976
Weyakwin lake	Yes	175.5	653.4	South	75,539.4	0.1146	0.1187
Weyakwin lake	Yes	220.5	479.8	Southwest	75,539.4	0.1148	0.1147
Weyakwin lake	Yes	130.5	1,877.2	West	75,539.4	0.0985	0.0982
Weyakwin lake	Yes	1,027.8	772.5	Northwest	75,539.4	0.1102	0.1119
Mean		213.3	712.2	NA	39,526.8	0.1018	0.1099
Crean lake	No	156.6	560.6	West	125,457.7	0.0569	0.0933
Crean lake	No	293.4	844.2	Southwest	125,457.7	0.0987	0.1034
Tibiska lake	No	77.4	446.5	South	8,633.8	0.0373	0.6327
Labiuk lake	No	63.9	181.0	East	1,730.2	0.0971	0.1149
Mirasty lake	No	83.7	346.7	East	12,854.1	0.1020	0.1150
Delaronde lake	No	101.7	722.1	Southeast	130,185.9	0.0776	0.0921
Smoothstone lake	No	4,043.7	2,045.3	East	284,085.0	0.1169	0.0931
Davies lake	No	0.365	43.8	Northwest	1,622.1	0.1009	0.1107
Mean		602.6	648.8	NA	86,253.3	0.0859	0.1694

Quality analyses of used islands

The observed characteristics of islands that were used by females did not differ significantly from islands that were unused by females, however certain trends were noticed. The average NDVI of islands used by caribou tended to be higher than islands that were unused, and the average snow cover of used islands tended to be lower than unused islands (Table 2). Additionally, the average distance from mainland to used islands was larger than the average distance from mainland to islands that were unused (Table 3).

Discussion

Remote sensing and telemetry

We were able to determine all islands in central Saskatchewan where female caribou have been documented. While we expected that remote sensing techniques would properly classify the majority of the islands, we were surprised that 100% of relevant islands were correctly classified. This suggests that our method of using a minimum of 500 000 pixels and 30 distinct landcover types (30 lakes, 30 areas of mainland, 30 areas of island) for each Landsat 8 image was

Table 2. Summary statistics of prediction for each characteristic of islands used by caribou. These results were found by creating density models in R. We found no distinct predictor variables, likely due to small sample size.

Predictor of selection	P-value	AIC
Surface area (island)	1	78.36
Distance from mainland	1	78.36
Surface area (water)	1	68.36
NDVI	1	50.36
Snow cover	0.999	50.36

Table 3. Summary statistics of island characteristics. F and the P-value were determined by a one-way ANOVA.

Characteristic	Island use	Mean	F	P-value
Surface area (island; km^2)	*Used*	213.3	0.590	0.455
	Unused	602.6		
Distance from mainland (m)	*Used*	712.2	0.051	0.824
	Unused	648.8		
Surface area (water; km^2)	*Used*	144,502.5	1.176	0.296
	Unused	86,253.3		
NDVI	*Used*	0.1018	2.273	0.154
	Unused	0.0859		
Snow cover	*Used*	0.1099	0.804	0.385
	Unused	0.1694		

sufficient to accurately classify landcover using the Image Classifier tool in ArcGIS. Telemetry data documented female caribou on or around bodies of water 46 times; this was a much smaller number than we expected, though it is not surprising as caribou are largely terrestrial animals. We found that caribou presumably used 8 different islands within central Saskatchewan. Unfortunately, such a small sample size was not sufficient to determine whether females significantly selected for or avoided certain island characteristics.

The results of our land cover classification suggest that supervised classification is a useful method for remote sensing of islands in central Saskatchewan, as our methods provide accurate identification of islands within bodies of water that may have been overlooked during ground landscape transects. Our results suggest that confirming the results of ground transects using remotely-sensed data could potentially increase the precision and accuracy of land cover classifications, specifically in regions with features difficult to manually examine, such as extremely large lakes. Our results also provide an overview of the attractive characteristics of islands used by female caribou during various seasons, and could be applied to other species of interest that may regularly use islands, such as sea turtles or marine mammals (Bickham *et al.*, 1996; Breed *et al.*, 2006; Lohmann *et al.*, 2008). Additionally, the land cover classification we created to distinguish bodies of water from land could be used in future studies examining land change over time.

Qualities analyses of used islands

The mean surface area of presumably used islands tended to be smaller than presumably unused islands, which could be due to the tendency of female caribou to disperse during calving and post-calving seasons and thus require a comparatively small quantity of resources (Bergerud & Page, 1987). However, we found that females used islands primarily during the winter months, which could be due to the scarcity of forage (Fancy *et al.,* 1989) and dispersal reducing intraspecific competition (Fancy *et al.,* 1989; Joly *et al.,* 2009; van Oort *et al.,* 2010). Islands with larger surface areas could likely be accommodating other caribou, resulting in intraspecific competition or predation by populations of carnivores (Geffen *et al.,* 2004).

Vegetation cover tended to be higher on presumably used islands, which could be a resource acquisition or predator avoidance strategy; increased vegetation cover could indicate increased forage as well as decreased likelihood of predator detection (Ferguson *et al.,* 2001; Ripple & Beschta, 2004). Snow cover tended to be lower on presumably used islands than presumably unused islands; this is likely related to forage (Schwab & Pitt, 1991; Walsh *et al.*, 1997; Ferguson *et al.,* 2001), as less snow would lead to more accessible lichen.

Implications for movement across the landscape

The average distance from mainland and the size of the body of water surrounding used islands tended to be larger than for unused islands. Both of these tendencies could be predator avoidance strategies as increasing the distance between islands and mainland and increasing the surface area of the body of water surrounding the island would reduce the accessibility of islands to other species (Ferguson *et al.,* 2001).

Including these islands in landscape connectivity studies is important, especially when results could lead to the implementation of policies or regulations across the landscape. Overlooking these islands in such studies could cause vast oversimplifications or underestimations of range as caribou are generally terrestrial animals. Parts of their range which may be separated by bodies of water could be marked as “unimportant”, when these areas are in fact accessible through the use of islands (Figure 1).

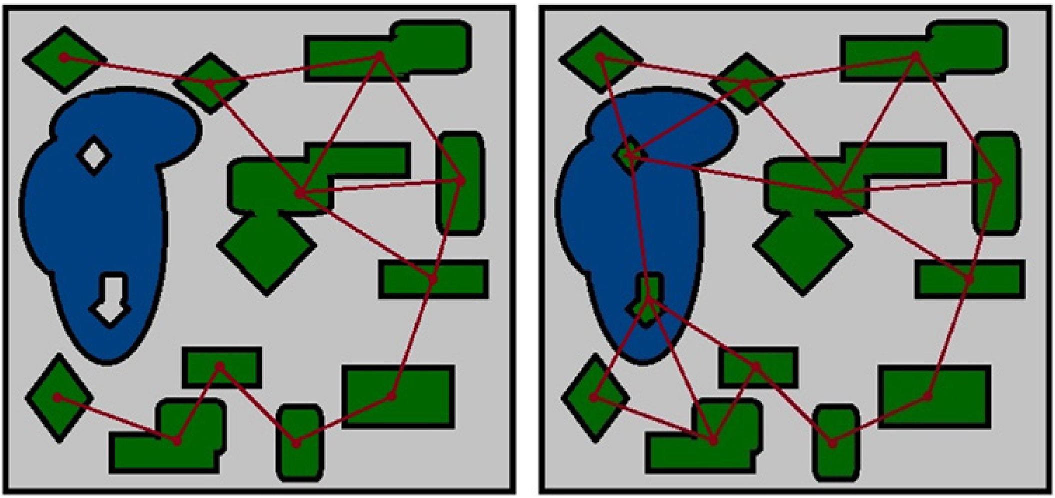

Figure 1. Connectivity of the landscape when (A) overlooking islands and (B) considering islands as suitable habitat. Areas in blue indicate water, areas in green indicate suitable habitat, and red lines indicate movement possibilities.

Future study directions

Future work should focus on the improvement of landcover classification techniques. The methods we used can be applied in a variety of environments to determine whether landcover types could be properly classified. Additionally, our landcover classification methods could be applied to determine an assortment of landscape features in the environment, including but not limited to wildfire, prescribed burns and early successional growth as a result of clear-cut forestry. These results would be beneficial to support conservation studies or anthropogenic development decisions.

Identifying regions of critical habitat – as islands are to female caribou during calving season – is an important application for remote sensing techniques in wildlife management. For example, providing a baseline for the quantity of available island habitat using Landsat imagery could be beneficial for monitoring the rising water levels and therefore estimating the effects of critical habitat loss triggered by climate change in central Saskatchewan. As binary (i.e. water versus non-water; lichen versus non-lichen) classification methods are generally accurate, estimating the relative increase of water over time would benefit decision-makers in the area.

Additionally, remote sensing techniques have been used to increase collaboration between parties with varied interests. For example, Sandstrom et al. (2003) used the knowledge of reindeer herders to ensure the accuracy of Landsat and remotely-sensed data for use in other planning and land-use scenarios. In central Saskatchewan, many recreationalists and land users frequent regions inhabited by woodland caribou. Incorporating their knowledge to increase the accuracy of remotely-sensed data could be beneficial, especially in planning for land-use scenarios which require intensive analyses of their potential effects on species at risk.

Other species in the region are also of interest to wildlife managers. For example, moose (*Alces alces*) and deer both use habitat abutting that of caribou. Using Falldorf et al. (2014)'s techniques to estimate the ranges of these other ungulates could be useful in managing the declining moose populations as well as in updating hunting regulations in central Saskatchewan. Understanding the seasonal movement patterns of female caribou is valuable for managers in order to provide safe areas for caribou crossings and to ensure islands remain accessible. We found that female caribou tended to use islands more frequently during the winter months. Managers and recreation planners could disallow use of certain areas for winter recreation, as cross-country skiing, snowshoeing, and snowmobiling can interrupt caribou crossings and create linear features on which predators can move efficiently (Paquet *et al.*, 2010). Knowledge of these seasonal patterns is also valuable to conservation biologists, as popular crossing locations can be monitored to provide an estimate of population size. Furthermore, monitoring predator populations in areas where caribou cross bodies of water could be especially valuable during seasons in which females have a calf at heel for estimating calf predation. Further research must take place before reaching any conclusive results, but our conclusions provide a valuable baseline for future studies.

Conclusion

Remote sensing techniques are a valuable tool to verify landcover data collected by ground transects. This study demonstrated that islands could be accurately classified from Landsat 8 imagery to supplement or replace landcover data collected through the use of ground transects. Telemetry data can be used in combination with remote sensing to determine areas of critical use for species at risk that should be protected from loss of habitat or connectivity. Although additional telemetry data are needed to confirm whether the female caribou in our study preferred certain island characteristics, trends can be elucidated even with limited data. Future studies incorporating the knowledge of land-users or other stakeholders could increase the accuracy of land cover classifications as they currently exist. The results from this study provide a valuable baseline for future comparison studies, as well as relevant information for wildlife conservation managers and land-use planners.

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