Data Supplements

Table S1. List of covariates evaluated for inclusion in the cattle habitat selection models at the Starkey Experimental Forest and Range, Oregon, USA.

Covariate	Description	Resolution (m)
Landscape		
slope	Slope in degrees	30
north aspect	Cosine of the aspect	30
east aspect	Sine of the aspect	30
solar	Solar radiation on 1 August 2008	30
water	Distance to all water (km)	30
water (late)	Distance to late season water (km)	30
Human		
fence	Distance to nearest fence (km)	30
open road	Distance to roads open to traffic (km)	30
service road (< 2011)	Distance to service roads (2005 to 2010) (km)	30
service road (≥ 2011)	Distance to service roads (2011 to 2012) (km)	30
road (< 2011)	Distance to all roads (2005 to 2010) (km)	30
road (≥ 2011)	Distance to all roads (2011 to 2012) (km)	30
Soil		
clay	Percent clay	Polygon[1]
sand	Percent sand	Polygon[1]
silt	Percent silt	Polygon[1]
organic	Percent organic matter	Polygon[1]
pH	Soil pH	Polygon[1]
awc	Soil available water capacity	Polygon[1]
soil depth	Soil depth	Polygon[1]
Vegetation		
canopy cover	Percent canopy cover	30
ch	Canopy height	30
cbd	Canopy bulk density[2]	30
edge20	Distance to edge (forest > 20% cover) (km)	30
edge30	Distance to edge (forest > 30% cover) (km)	30
edge40	Distance to edge (forest > 40% cover) (km)	30
heterogeneity	Heterogeneity in veg. cover (in a 90-m radius)	30
fir	Douglas/Grand fir	30
pine	Lodgepole/Ponderosa pine	30
pine/fir	Pine/Fir mix	30
grass	Open grassland	30
meadow	Wet meadow	30

1. Minimum mapping unit of 0.9 hectares
2. Mass of available canopy fuel per unit canopy volume

Table S2. Correlation matrixes estimated using Pearson's correlation coefficient. No correlations were identified with the categorical covariates: fir, pine, pine/fir, grass, and meadow. Bold indicates a correlation of $|r| \geq 0.60$.

Landscape covariates

	slope	north aspect	east aspect	solar	water	water (late)
slope	1.0000					
north aspect	-0.0430	1.0000				
east aspect	0.0690	-0.0028	1.0000			
solar	-0.5409	-0.5221	-0.0853	1.0000		
water	-0.3458	-0.1047	-0.1026	0.3070	1.0000	
water (late)	-0.2400	-0.0524	-0.0274	0.2099	**0.6111**	1.0000

Human covariates

	fence	open road	service road (< 2011)	service road (≥ 2011)	road (< 2011)	road (≥ 2011)
fence	1.0000					
open road	0.4762	1.0000				
service road (< 2011)	-0.1506	-0.1095	1.0000			
service road (≥ 2011)	-0.1211	-0.1090	**0.9840**	1.0000		
road (< 2011)	0.0003	0.2091	**0.7933**	**0.7853**	1.0000	
road (≥ 2011)	0.0335	0.2095	**0.7667**	**0.7942**	**0.9793**	1.0000

Soil covariates

	clay	sand	silt	organic	pH	awc	soil depth
clay	1.0000						
sand	-0.0409	1.0000					
silt	**-0.6593**	**-0.7243**	1.0000				
organic	**-0.8414**	0.0340	0.5530	1.0000			
pH	**0.6398**	-0.2444	-0.2546	**-0.7025**	1.0000		
awc	**-0.9161**	-0.2992	**0.8573**	**0.7305**	-0.5142	1.0000	
soil depth	**-0.8533**	-0.3101	**0.8208**	**0.8004**	**-0.6221**	**0.9346**	1.0000

Vegetation covariates

	cc	ch	cbd	edge20	edge30	edge40	heterogeneity
cc	1.0000						
ch	**0.6631**	1.0000					
cbd	**0.7974**	0.5160	1.0000				
edge20	-0.0480	-0.0832	-0.0924	1.0000			
edge30	-0.4492	-0.3620	-0.4066	0.5855	1.0000		
edge40	-0.4205	-0.2965	-0.3684	0.2382	0.5975	1.0000	
heterogeneity	-0.3063	-0.2721	-0.2395	-0.2680	0.0011	0.0701	1.0000

Table S3. Candidate models of habitat selection by cattle at the Starkey EFR, Oregon, USA. Model number (No), model structure (model), and the degrees of freedom (K) are presented. For all models, water was defined distance to all water sources, as it better predicted cattle use for all seasons than did late season water (water(late)).

No	Model	K
1	slope + water + water^2 + road + canopy cover + canopy cover^2 + pine + pine/fir + grass + meadow	11
2	slope + north aspect +water + water^2 + road + soil depth + canopy cover + canopy cover^2 + pine + pine/fir + grass + meadow	12
3	slope + water + water^2 + open road + sand + soil depth + canopy cover + canopy cover^2 + edge20 + pine + pine/fir + grass + meadow	14
4	slope + north aspect + east aspect + water + water^2 + open road + service road + sand + soil depth+ canopy cover + canopy cover^2 + edge20 + heterogeneity	14
5	slope + north aspect + water + water^2 + open road + service road + canopy cover + canopy cover^2 + edge20 + heterogeneity + pine + pine/fir + grass + meadow	15
6	slope + north aspect + east aspect + water + water^2 + open road + service road + canopy cover + canopy cover^2 + edge20 + heterogeneity + pine + pine/fir + grass + meadow	16
7	slope + north aspect + water + water^2 + open road + service road + sand + soil depth + canopy cover + canopy cover^2 + edge20 + heterogeneity + pine + pine/fir + grass + meadow	17
8	slope + north aspect + east aspect + water + water^2 + open road + service road + sand + soil depth + canopy cover + canopy cover^2 + edge20 + pine + pine/fir + grass + meadow	17
9	slope + north aspect + east aspect + water + water^2 + open road + service road + sand + soil depth + canopy cover + canopy cover^2 + edge20 + heterogeneity + pine + pine/fir + grass + meadow	18

Table S4. Top models from the Bayesian information criterion (BIC) model selection for two behaviors of cattle and two seasons (see Table S2 for model covariates corresponding to model numbers for top model). Fit for all models using k-fold cross validation and the Spearman rank correlation coefficient was significant ($p < 0.001$). Model weight (w) and model fit using the k-fold cross validation and the Spearman's rank correlation coefficient (r_s).

Year	Behavior	Season	Top Model	w	r_s
2005	Mobile	Early	6	0.99	1.00
2005	Mobile	Late	8	0.99	1.00
2005	Stationary	Early	9	1.00	1.00
2005	Stationary	Late	7	0.92	0.99
2006	Mobile	Early	7	0.90	1.00
2006	Mobile	Late	9	1.00	1.00
2006	Stationary	Early	8	0.98	1.00
2006	Stationary	Late	9	1.00	1.00
2007	Mobile	Early	7	0.99	1.00
2007	Mobile	Late	7	0.99	1.00
2007	Stationary	Early	9	1.00	1.00
2007	Stationary	Late	8	0.78	1.00
2008	Mobile	Early	8	1.00	1.00
2008	Mobile	Late	1	1.00	1.00
2008	Stationary	Early	5	0.97	1.00
2008	Stationary	Late	9	0.99	0.99
2009	Mobile	Early	9	1.00	1.00
2009	Mobile	Late	9	1.00	1.00
2009	Stationary	Early	9	1.00	1.00
2009	Stationary	Late	7	0.98	1.00
2010	Mobile	Early	5	0.98	0.99
2010	Mobile	Late	6	1.00	1.00
2010	Stationary	Early	5	1.00	1.00
2010	Stationary	Late	9	1.00	1.00

Table S4. (continued)

Year	Behavior	Season	Top Model	w	r_s
2011	Mobile	Early	8	1.00	1.00
2011	Mobile	Late	9	0.99	1.00
2011	Stationary	Early	6	0.97	1.00
2011	Stationary	Late	9	1.00	0.99
2012	Mobile	Early	8	1.00	1.00
2012	Mobile	Late	9	1.00	0.99
2012	Stationary	Early	3	1.00	0.99
2012	Stationary	Late	8	1.00	1.00

Table S5. Out-of-sample model fit for habitat selection models of mobile cattle using Spearman's rank correlation coefficient. Models were compared against the data used to build the model (i.e., mobile early model compared to mobile early locations), the location data not used in that model for the same year, and all data combined for that year. Significance of $p \leq 0.05$ is denoted with an asterisk.

			Mobile locations				Stationary locations				All locations	
		Top	early		late		early		late			
Year	Season	Model	r_s		r_s		r_s		r_s		r_s	
2005	early	6	0.95	*	1.00	*	0.93	*	1.00	*	0.99	*
2006	early	7	0.98	*	1.00	*	0.98	*	0.99	*	1.00	*
2007	early	7	0.82	*	1.00	*	0.95	*	0.99	*	1.00	*
2008	early	8	1.00	*	0.96	*	0.96	*	0.98	*	1.00	*
2009	early	9	0.87	*	0.99	*	0.99	*	1.00	*	0.99	*
2010	early	5	0.99	*	0.98	*	1.00	*	0.96	*	1.00	*
2011	early	8	1.00	*	0.10		1.00	*	0.60		0.98	*
2012	early	8	1.00	*	0.83	*	0.99	*	0.91	*	1.00	*
2005	late	8	0.52		1.00	*	0.62		1.00	*	0.99	*
2006	late	9	0.99	*	0.96	*	0.99	*	0.88	*	0.99	*
2007	late	7	0.38		1.00	*	0.90	*	1.00	*	0.99	*
2008	late	1	1.00	*	0.99	*	0.99	*	0.89	*	1.00	*
2009	late	9	-0.14		0.99	*	0.44		1.00	*	0.94	*
2010	late	6	1.00	*	0.98	*	1.00	*	0.98	*	1.00	*
2011	late	9	0.54		0.95	*	0.65	*	0.94	*	0.96	*
2012	late	9	0.59		0.96	*	0.55		0.95	*	0.81	*

Table S6. Covariate coefficients for the top-ranked habitat selection models by pasture, season, and year for stationary cattle location data from the Starkey Experimental Forest and Range, Oregon, USA. Forest edge was estimated using the definition of forest as greater than 20% cover.

Season	Year	slope	N aspect	E aspect	water	water^2	open roads	service roads	sand*	soil depth*	canopy cover*	canopy cover^2*	forest edge	heterogeneity	pine	pine/ fir mix	grass	meadow
Bear Pasture																		
early	2006	-0.15	-0.08	-0.03	-2.64	2.03	0.45	0.98	0.65	0.24	2.97	-0.02	-10.08		0.59	0.23	-0.15	0.67
early	2008	-0.15	-0.01		-2.09	1.75	0.43	0.54			1.88	0.00	-5.03	-0.01	0.75	0.13	-0.12	0.63
early	2010	-0.16	-0.07		-2.84	2.52	0.31	0.93			2.54	-0.02	-9.45	-0.04	0.68	0.30	-0.04	0.67
early	2011	-0.19	-0.12	-0.11	2.06	-1.80	0.45	-1.73			3.04	-0.01	-12.12	-0.06	0.64	-0.06	-0.01	0.90
early	2012	-0.15			0.40	-0.82	0.50		0.18	-0.49	4.35	-0.06	-9.29		0.51	-0.05	-0.43	0.47
late	2005	-0.14	-0.12		-3.67	2.86	0.53	0.40	-1.79	0.35	1.69	-0.03	-5.68	0.02	0.54	0.42	-0.13	0.68
late	2007	-0.13	-0.06	0.05	-2.43	1.84	0.49	0.55	2.08	-0.57	3.17	-0.04	-9.54		0.61	0.13	0.18	0.69
late	2009	-0.13	0.01		-1.23	0.86	0.38	0.92	-1.36	-0.18	2.19	-0.03	-5.42	0.06	0.61	0.29	-0.12	0.60
Smith-bally Pasture																		
early	2005	-0.11	-0.10	0.17	-2.82	2.43	0.09	-0.68	0.55	-1.40	-1.07	0.08	-13.46	0.35	0.50	-0.56	-0.28	0.56
early	2007	-0.10	0.05	0.14	-2.59	1.65	0.16	-1.11	1.52	-0.12	-1.80	0.04	-10.81	0.19	0.62	-0.32	-0.25	0.87
early	2009	-0.10	0.02	0.18	-3.17	2.46	0.33	-0.03	0.76	-1.27	-1.45	0.07	-6.90	0.26	0.36	-0.01	-0.63	0.59
late	2006	-0.07	0.09	-0.22	-0.64	-0.02	-0.01	0.29	3.42	0.39	0.76	-0.04	-13.87	0.17	0.42	0.07	0.00	0.45
late	2008	-0.11	-0.13	-0.19	-2.16	1.53	0.15	-0.33	4.55	0.04	2.23	-0.06	-13.74	0.18	0.16	0.21	0.21	0.37
late	2010	-0.13	0.10	-0.21	-1.25	-0.08	0.25	-0.45	2.00	-0.23	1.28	-0.04	-6.57	0.30	0.50	-0.29	0.27	0.55
late	2011	-0.10	0.09	-0.11	-1.66	0.66	-0.06	-0.60	5.70	1.03	1.79	-0.05	-10.08	0.28	0.32	0.29	-0.26	0.50
late	2012	-0.09	0.06	-0.26	-2.45	2.28	-0.12	-0.01	4.33	-0.01	-0.36	-0.01	-12.30		0.39	0.54	-0.52	0.73

*Coefficient was multiplied by 100.

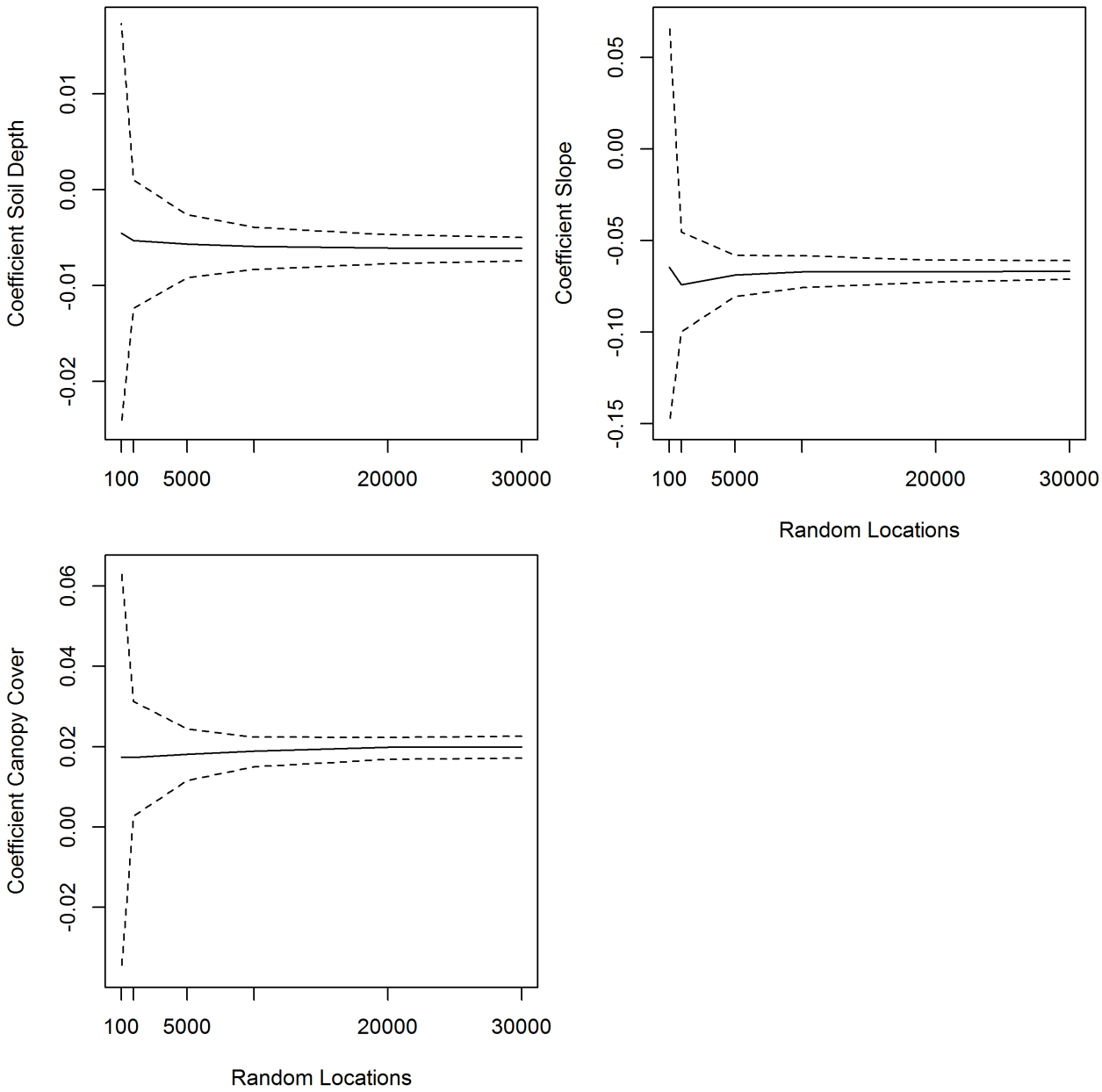

Figure S1. Example (cow 99209) of logistic regression models fit 1,000 times using incrementally increasing samples of random locations (100, 1000, 5000, 10,000, 20,000, and 30,000; Northup et al. 2013) plotted against beta coefficients for three variables (canopy cover, slope, and soil depth). At low samples of random locations, beta coefficient estimates were highly variable, but as densities reached 5,000, the estimates began to stabilize.

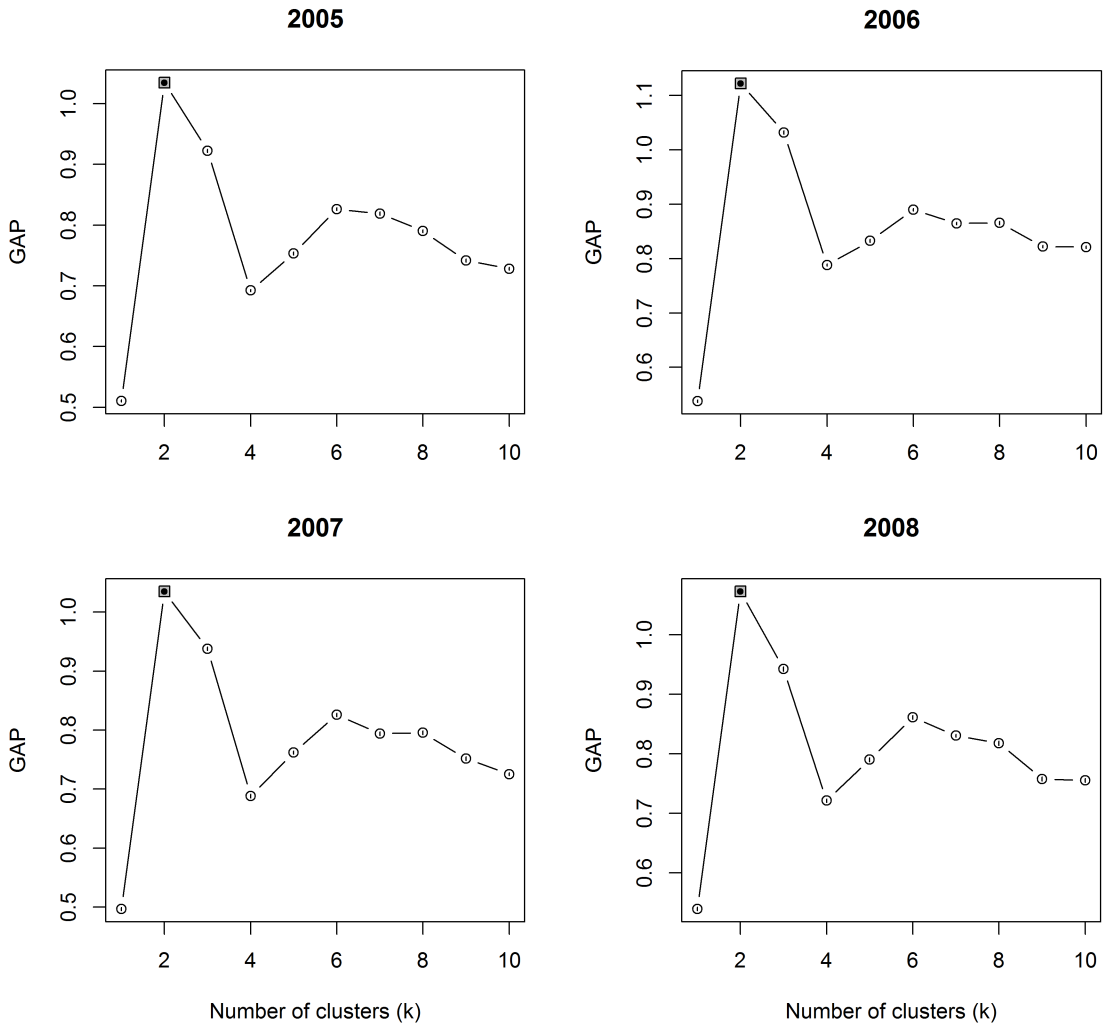

Figure S2. Gap statistic results testing the likelihood that the yearly telemetry data contained between 1 and 10 clusters. The selected numbers of clusters are denoted with a square (tolerance = 1) and black dot (tolerance = 2). Years 2005 to 2008 are presented.

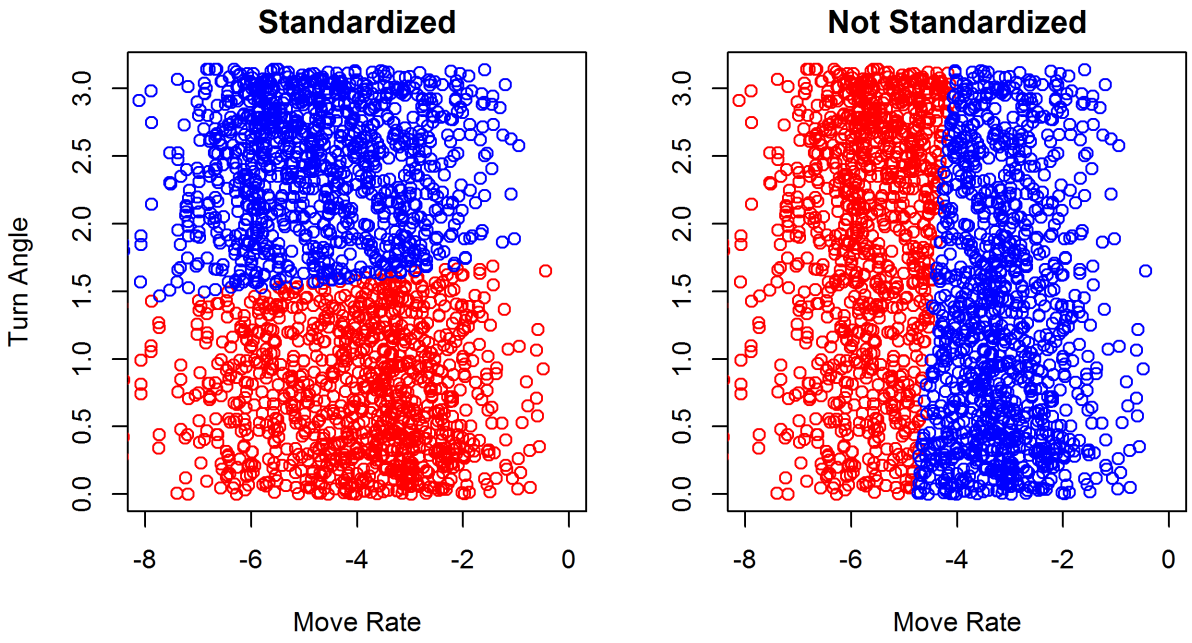

Figure S3. An example of how the distribution of the turn angle and movement rate influenced the k-mean clustering for one animal (96177). When turn angle and movement rate values were standardized, the main division between clusters was based on turn angle. However, this proved to be biologically unrealistic, as step length is the main difference between mobile and stationary behavior. Therefore, unstandardized values were retained.