Addendum to Ontario's Landscape Tool 2021 Manual (September 2021)

Overview

The two models previously used in Ontario's Landscape Tool, the Bioclimatic Moose Model and the OWHAM models, are no longer available in OLT and have been replaced by the Landscape Capability for Moose Model (LCMM). The LCMM is based on newer science and represents our current understanding of moose.

The techniques outlined in the model to import and assess moose emphasis areas remains the same.

Landscape Capability for Moose Model

Summary

The Landscape Capability for Moose Model (LCMM) is a data based, multivariate model that estimates relative carrying capacity of the landscape to support moose populations. The model was developed as a collaborative project with Rob Rempel, Art Rodgers, and Brian Naylor. The model relates moose aerial inventory (MAI) count data from across the Province to FRI-based forest composition. Output is used to predict how existing or changing forest conditions, including forest composition, structure, and pattern, will affect capability of the landscape to support sustainable moose populations. These landscape capability estimates also represent relative moose carrying capacity and is therefore suitable for evaluating habitat potential for proposed moose emphasis areas (MEAs). As model development was based on winter MAI data, the spatial resolution is at the moose home range/landscape scale (about 36 km^2), which is large enough to include early and late winter, summer feeding, thermal escape, and aquatic feeding habitat components. This landscape model best predicts capability at the scale of this overall habitat complex, although output of the model can be spatially averaged and then mapped at a finer (stand-specific) spatial scale. Although it is known that broad climatic patterns affect moose habitat capability at the Provincial scale, the purpose of this model was to focus on FRI attributes used in forest management planning.

Model Background

Habitat management for moose assumes that, in the absence of limiting factors such as predation, parasites, and hunting mortality, early successional habitats created by disturbance may contain an optimal mix of food and cover that allows moose populations to reach a maximum density (Aldous and Krefting 1946, Van Ballenberghe and Ballard 1998, Courtois et al. 2002). Optimal moose habitat contains a dynamic blend of deciduous or mixed regenerating stands interspersed with mature coniferous stands (McNicol 1990, Courtois et al. 2002). A dense shrub layer in regenerating deciduous or mixed stands, typically 11-30 years old, provides food throughout the year and mature coniferous trees provide thermal cover and concealment from predators (Schwartz and Franzmann 1989). Although they do not provide cover, open forage-producing areas, such as regenerating cutovers, and wetlands are also important components of moose habitat (Allen et al. 1988, Leptich and Gilbert 1989).

Model Development

The model uses predicted moose density as an indicator of habitat capability. Moose density was estimated using Moose Aerial Inventory (MAI) counts conducted from 2000 – 2006. Forest condition was based on summaries of Forest Resource Inventories (FRI). The spatial modeling program LSL was used to generate hexagon-based summaries of forest condition and associated moose density. The MAI plot moose counts were then linked to the forest attributes. The proportion of relevant habitat variables (Table 1) for each hexagon was calculated using total land (the sum of all non-open water types), including forested lands and wetlands, as the denominator. Calculations were made at approximately the 2500 ha scale, and these results were spatially averaged by shifting each hexagon 50% in different directions. This results in spatial averaging over approximately 10,000 ha. We modeled the relationship of moose MAI counts with landcover (after arcsine transformation) using Poisson linear regression and then used a hierarchical (sequential) model selection procedure based on changes to AIC to accept or reject 4 hypotheses related to the importance of habitat factors (Appendix Tables A1 and A2). Separate model building and selection was conducted for the Boreal and Great Lakes-St Lawrence regions. The results of the model selection, along with model coefficients are given in Appendix

Tables A3 and A4, and Table A5 lists the names and descriptions of all variables used in the OLT/LSL script.

To describe the forest conditions associated with high capability we selected polygons (hexagons) representing the top 25% of predicted moose density, and then produced a description of forest condition (inter-quartile range) for these areas (Table 2). Model results reveal that in the Boreal region a broad range of forest types were used by moose as productive-food habitat, whereas in the GLSL productive-food habitat was more restricted to hardwood forest types. As anticipated, broad expanses of younger forest associated with productive-food habitat (e.g., clear-cuts and burns) were more prevalent in the Boreal than in the GLSL. Food and cover habitat in both regions was defined by a broad range of hardwood types and mixedwoods, but with percentages almost double in the Boreal region. Conifer upland protective cover habitat was used in both regions, with relatively equal amounts. There were also similar patterns of habitat use in both regions for lowland thermal cover, thermal regulation and aquatic food habitat.

To illustrate spatially the relationship between landcover variables and predicted moose density, FRI plots for the top 25% of predicted moose density were assigned to the category high density moose (HDMoose) for a portion of landscape guide region 3W (Fig. 1A). Plots were created to describe how the conditional distribution of the high-density category changes with a selected landcover variable (Fig. 1D). The area shaded in black is associated with the category for high moose habitat capability (~ high predicted moose density). For landscape guide region 3W, high moose capability is predicted for the west side of Lake Nipigon and to the south (Fig. 1A). These areas are associated with low to moderate percentages of mixedwood, ranging from about 20% to 40% (Fig. 1C). The conditional density (CD) plots explore this relationship with more precision and reveal that the highest probabilities of a stand providing high moose capability is associated with mixedwood occurring at a rate of < 30%. CD plots for other variables are shown in Appendix Fig. A1, and for example reveal that high moose capability increases to about 5% alder and brush, after which point additional levels do not favour higher moose capability (Fig. A2).

Although helpful by visualizing relationships to individual variables, predicting high moose capability is more complex than these single variable figures imply because of the need to balance contribution of different cover types. This is also true with the summaries of average forest conditions associated with high compatibility moose habitat, as reported in Table 2. A more precise evaluation of the combined forest condition on moose habitat quality, resulting from application of the multivariate model, is found in either the mapped capability (e.g., Figure 1A), or the summary reports on percent composition for selected portions of the FMU (e.g., moose emphasis polygons or other assessment polygons). These reports can be particularly useful in planning to create or maintain the optimal mix of landcover components to promote high moose capability.

A. Moose Habitat Capability (moose per km^2)

B. Predicted Moose Density (per km^2)

C. Food and Cover: Mixed Hardwood and Softwood

D. Food and Cover: Mixed Hardwood and Softwood

Figure 1: Predicted moose capability in a portion of landscape guide region 3W (Guideline Effectiveness Monitory Study Area), illustrating optimal conditions for percent food and cover.

Table 1. Moose Habitat Factors and variables.

Habitat Factor	Variable	Provincial Forest Types PFTs*
Productive food		
Productive food - hardwood	pf_hw	MIX, POP, BWT, TOL < 20 years
Productive food - all	pf_all	MIX, POP, BWT, TOL, PWR, PJK, MCU, MCL < 20 years
Food & Cover		
Food & cover - all hardwood	fc_ahw	POP, BWT, TOL > 35 years
Food and cover - intolerant hardwoods and mixedwoods	fc_ihwm	POP, BWT, MIX > 35 years
Food & cover - tolerant hardwoods	fc_thw	TOL >= 35 years
Food & cover - mixedwood	fc_mix	MIX >= 35 years
Upland Cover		
Upland protective cover	upc	MCU, PWR, PJK >= 35 years
Lowland thermal cover, thermal regulation, and aquatic food		
Low-land thermal cover	lltc	MCL >= 35 years
Alder and brush thermal cover	abtc	BSH
Bog and fen thermal regulation	bftc	TMS
Aquatic food & thermal regulation	aftc	OMS

* MCU – pure black spruce and conifer mixes including balsam fir, cedar, and jackpine; PJK – relatively pure jackpine stands; PWR – red and white pine dominated stands; MCL –wet, lowland areas (including some bogs and swamps) dominated by merchantable, mature black spruce and larch; POP – aspen and balsam poplar dominated stands; TOL – mature tolerant hardwoods; BWT – White birch dominated hardwood stands; MIX – mixes of both conifer and hardwood; BSH – wetlands dominated by alder and other shrubs; TMS – treed wetlands (muskeg), but where trees are small and non-merchantable; OMS – open marsh, including shallow marshes dominated by cattail, bulrush, and sedges.

Table 2. Habitat characteristics underlying areas for the top 25% of predicted moose density.

Habitat Factor	Variable	25th Percentile (Boreal)	75th Percentile (Boreal)	25th Percentile (GLSL)	75th Percentile (GLSL)
Productive food variables					
productive food - hardwood	pf_hw	1.4%	6.6%	**0.4%**	**3.9%**
productive food - all	pf_all	**5.2%**	**22.1%**	1.0%	6.9%
Food and cover variables					
food & cover - all hardwood	fc_ahw	**2.4%**	**13.6%**	**17.6%**	**48.1%**
food and cover - intolerant hardwoods and mixedwoods	fc_ihwm	14.6%	40.3%	15.6%	36.7%
food & cover - tolerant hardwoods	fc_thw	0.0%	0.1%	1.6%	28.2%
food & cover - mixedwood	fc_mix	**9.5%**	**27.1%**	**4.1%**	**17.0%**
Upland cover					
upland protective cover	upc	**10.9%**	**21.3%**	**8.4%**	**32.2%**
Lowland thermal cover, thermal regulation and aquatic food					
low-land thermal cover	lltc	**0.4%**	**1.9%**	**0.4%**	**3.6%**
alder and brush thermal cover	abtc	**0.7%**	**3.4%**	**0.7%**	**2.6%**
bog and fen thermal regulation	bftc	**0.3%**	**1.4%**	**0.5%**	**1.9%**
aquatic food & thermal regulation	aftc	**1.5%**	**3.6%**	**2.6%**	**6.1%**
Interspersion of food and cover					
Contrast weighted edge density+	edge (m/ha)	**9.2**	**21.0**	**3.0**	**10.6**

+ Descriptive only. Not used in model development

References

Aldous, S. E., and L. W. Krefting. 1946. The present status of moose on Isle Royale. American Wildlife Institute.

Allen, A. W., P. A. Jordan, and J. W. Terrell. 1988. Habitat suitability index models: moose, Lake Superior region. Volume 82.US Department of the Interior, Fish and Wildlife Service, Research and ….

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McNicol, J. 1990. Moose and their environment. Ontario Ministry of Natural Resources. The moose in Ontario, Book 1:11-18.

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Van Ballenberghe, V., and W. Ballard. 1998. Population dynamics. Ecology and Management of the North American Moose. Smithsonian Institution Press, Washington, DC, USA:223-245.

Appendix A. Details of model development, including model selection and variable descriptions.

Table A1. Names and descriptions of all variables used in the LSL models.

Field_Name	**Description**
Area	Forest Management Unit
ModelYear	Year of Inventory
Scenario	Scenario name
Stat_Area	The area the output represents
MEA_ID	Moose Emphasis Area
Label	Moose Emphasis Area Name
n	n for proportions fields is based upon the 500 ha scale; n for area fields is based upon the 16 ha scale
pmdenAll	Mean predicted Moose Density at the 500 ha scale
ppfhw5	Mean proportion of productive food - hardwood at the 500 ha Scale
ppfall5	Mean proportion of productive food - all hardwood and softwood at the 500 ha Scale
pfcahw5	Mean proportion of food & cover - all hardwood at the 500 ha Scale
pfcihwm5	Mean proportion of food and cover - intolerant hardwoods and mixedwood at the 500 ha Scale
pfcthw5	Mean proportion of food & cover - tolerant hardwoods at the 500 ha Scale
pfcmix5	Mean proportion of food & cover – mixed hardwood and softwood at the 500 ha Scale
pupc5	Mean proportion of upland protective cover at the 500 ha Scale
plltc5	Mean proportion of low-land cover at the 500 ha Scale
pabtc5	Mean proportion of alder and brush thermal cover at the 500 ha Scale
pbftc5	Mean proportion of bog and fen thermal regulation at the 500 ha Scale
paftc5	Mean proportion of aquatic food & thermal regulation at the 500 ha Scale
tforest	Total Forest Area (ha)
pf_hw	Total area (ha) of productive food - hardwood
pf_all	Total area (ha) of productive food - all: MIX, POP, BWT, TOL < 15 years
fc_ahw	Total area (ha) of food & cover - all hardwood and softwood: MIX, POP, BWT, TOL, PWR, PJK, MCU, MCL < 15 years
fc_ihwm	Total area (ha) of food & cover - all hardwood: POP, BWT, TOL > 35 years
fc_thw	Total area (ha) of food and cover - intolerant hardwoods and mixedwoods: POP, BWT, MIX > 35 years
fc_mix	Total area (ha) of food & cover - tolerant hardwoods: TOL > 35 years
upc	Total area (ha) of food & cover – mixed hardwood and softwood: MIX > 35 years

lltc	Total area (ha) of upland protective cover: MCU, PWR, PJK > 35 years
abtc	Total area (ha) of alder and brush thermal cover: BSH
bftc	Total area (ha) of bog and fen thermal regulation: TMS
aftc	Total area (ha) of aquatic food & thermal regulation: OMS
FORLT20	Total area (ha) of forest < 20 years old
UPCGT35	Total area (ha) of upland conifer forest >= 35 years old
LLCGT35	Total area (ha) of lowland conifer forest >= 35 years old
HWDGT35	Total area of hardwood forest >= 35 years old
MIXGT35	Total area (ha) of mixedwood forest >= 35 years old

Table A2. Boreal model selection* using AIC.

1. High production food model (hpfm): Start model selection by selecting the best model (lowest AIC from set of candidate models) that identifies young forest types that moose use as highly productive food habitat. Statistically test if initial model performs well.		
1.1. pf_hw	13856.2	
1.2. pf_all	**13828.0+**	
2. Food & Cover model		
2.1. Boreal (hpfm + fcm): Now test if in addition moose are using landscapes that contain older food and cover habitat. Select model if drop in AIC relative to best hpfm is > 2.		
2.1.1. hpfm + fc_ahw	13768.5	59.5
2.1.2. hpfm + fc_mix	13420.4	407.6
2.1.3. hpfm + fc_ahw + fc_mix	13421.9	**406.1**
3. Upland protective cover model (hpfm + fcm + **upcm**): Now test if in addition moose are also using landscapes with habitat that provide upland protective cover habitat:		
3.1. hpfm + fcm + upc	13423.9	-2.0
3.1. hpfm + fcm + upc + upc^2	13299.6	**124.3**
4. Lowland thermal cover model (hpfm + fcm + upcm + ltcm): Now test if in addition moose are also using landscapes with habitat that provide low-land thermal cover and/or alder brush thermal cover:		
4.1. hpfm + fcm + upcm + lltc	12796.8	502.8
4.2. hpfm + fcm + upcm + abtc	13301.5	-1.9
4.3. hpfm + fcm + upcm + lltc + abtc	12766.9	**532.7**
5. Aquatic food and thermal regulation (hpfm + fcm + upcm + ltcm + aftr): Now test if in addition moose are also using landscapes with habitat that provides both aquatic food and some degree of thermal regulation in summer. Statistically test if final selected model performed well.		
5.1. hpfm + fcm + upcm + ltcm + aftc	12762.7	34.2
5.2. hpfm + fcm + upcm + ltcm + bftc	12724.2+	**72.7**
5.3. hpfm + fcm + upcm + ltcm + aftc + bftc	12725.5	71.4

* Bolded values indicated selected model.
\+ $p < 0.001$ for omnibus test that all coefficients = 0

Table A3. GLSL model selection* using AIC.

1. Food & Cover model. Start model selection by selecting the best model (lowest AIC among set of candidate models) that identifies forest types that moose use as both food and cover habitat (fcm). Statistically test if initial selected model performs well.		
1.1 fc_thw	6200.1	
1.2. fc_ihwm	6189.2	
1.3. fc_thw + fc_ihwm	6191.2	
1.4. fc_ahw	6208.1	
1.5. fc_ahw + fc_mix	**6159.4+**	
2. High production food model (fcm + hpfm): Now select best model (from set of candidate models) that identifies young forest types that moose use as highly productive food habitat. Select model if drop in AIC relative to best fcm is > 2.		
2.1. fc_m + pf_hw	6107.9	51.5
2.2. fc_m + pf_all	6111.3	48.1
3. Upland protective cover model (fcm + hpfm + upcm): Now test if in addition moose are also using landscapes with habitat that provide upland protective cover habitat:		
3.1. hpfm + fcm + upc	6064.3	43.6
3.1. hpfm + fcm + upc + upc^2	**6028.1**	79.8
4. Lowland thermal cover model (fcm + hpfm + upcm + ltcm): Now test if in addition moose are also using landscapes with habitat that provide low-land thermal cover and/or alder brush thermal cover:		
4.1. hpfm + fcm + upcm + lltc	6021.2	6.9
4.2. hpfm + fcm + upcm + abtc	6029.1	-1.1
4.3. hpfm + fcm + upcm + lltc + abtc	**6023**	5.1
5. Aquatic food and thermal regulation (fcm + hpfm + upcm + ltcm + aftr): Now test if in addition moose are also using landscapes with habitat that provides both aquatic food and some degree of thermal regulation in summer. Statistically test if final selected model performed well.		
5.1. hpfm + fcm + upcm + ltcm + aftc	5950	73
5.2. hpfm + fcm + upcm + ltcm + bftc	5996.3	26.7
5.3. hpfm + fcm + upcm + ltcm + aftc + bftc	**5923.9+**	99.1

* Bolded values indicated selected model.
+ $p < 0.001$ for omnibus test that all coefficients = 0

Table A4. Model coefficients for final selected boreal model.

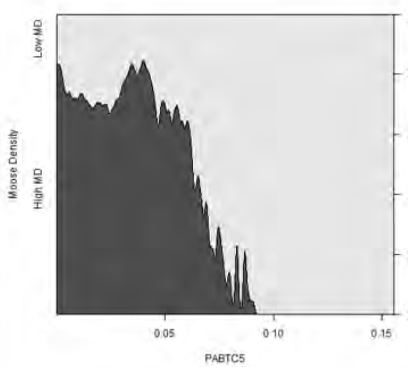
Parameter*	B	Std. Error	Wald Chi-Square	df	Sig.	Effect Size Exp(B)
(Intercept)	1.53196	.0958	255.705	1	0.000	4.627
pf_all	0.00540	.0012	22.053	1	.000	1.005
fc_mix	0.00848	.0015	32.217	1	.000	1.009
fc_ahw	-0.00282	.0015	3.687	1	.055	.997
upc	0.04647	.0049	90.544	1	0.000	1.048
upc_sq	-0.00093	8.63E-05	117.027	1	0.000	.999
lltc	-0.02808	.0013	444.808	1	0.000	.972
abtc	0.02191	.0031	49.453	1	.000	1.022
bftc	-0.01969	.0030	43.500	1	.000	.981

*Variables are arcsine (square root) transformed.

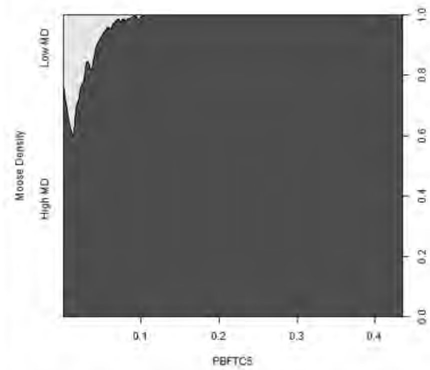
Table 5. Model coefficients for final selected GLSL model.

Parameter*	B	Std. Error	Wald Chi-Square	df	Sig.	Effect Size Exp(B)
(Intercept)	-.197317	.1717	1.320	1	.251	.821
fc_ahw	.023417	.0021	119.812	1	0.000	1.024
fc_mix	.020051	.0025	64.704	1	.000	1.020
pf_hw	.038406	.0036	112.916	1	0.000	1.039
upc	-.037055	.0071	27.209	1	.000	.964
upc_sq	.000983	.0001	57.428	1	.000	1.001
lltc	.011465	.0037	9.648	1	.002	1.012
abtc	-.006647	.0056	1.411	1	.235	.993
aftc	.045690	.0052	75.987	1	.000	1.047
bftc	.032799	.0061	29.041	1	.000	1.033

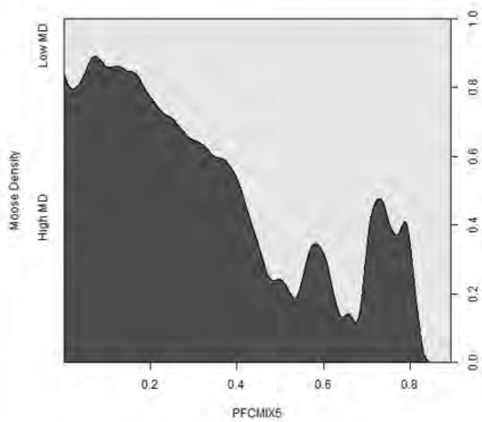
*Variables are arcsine (square root) transformed.



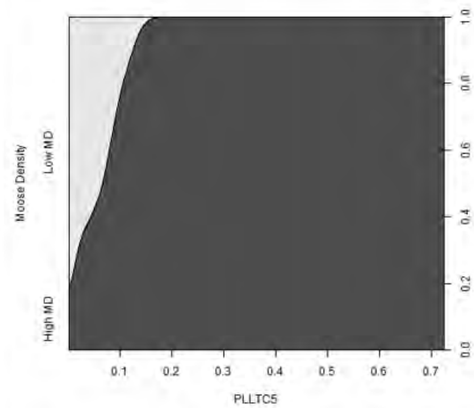
A. Alder and brush thermal cover



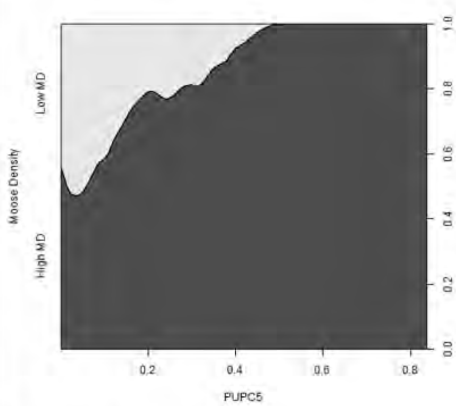
B. Bog and fen thermal regulation



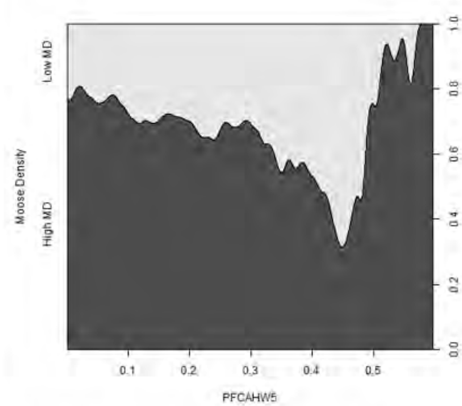
C. Food & cover - mixedwood



D. Low-land thermal cover



E. Upland protective cover



F. Food & cover - all hardwood

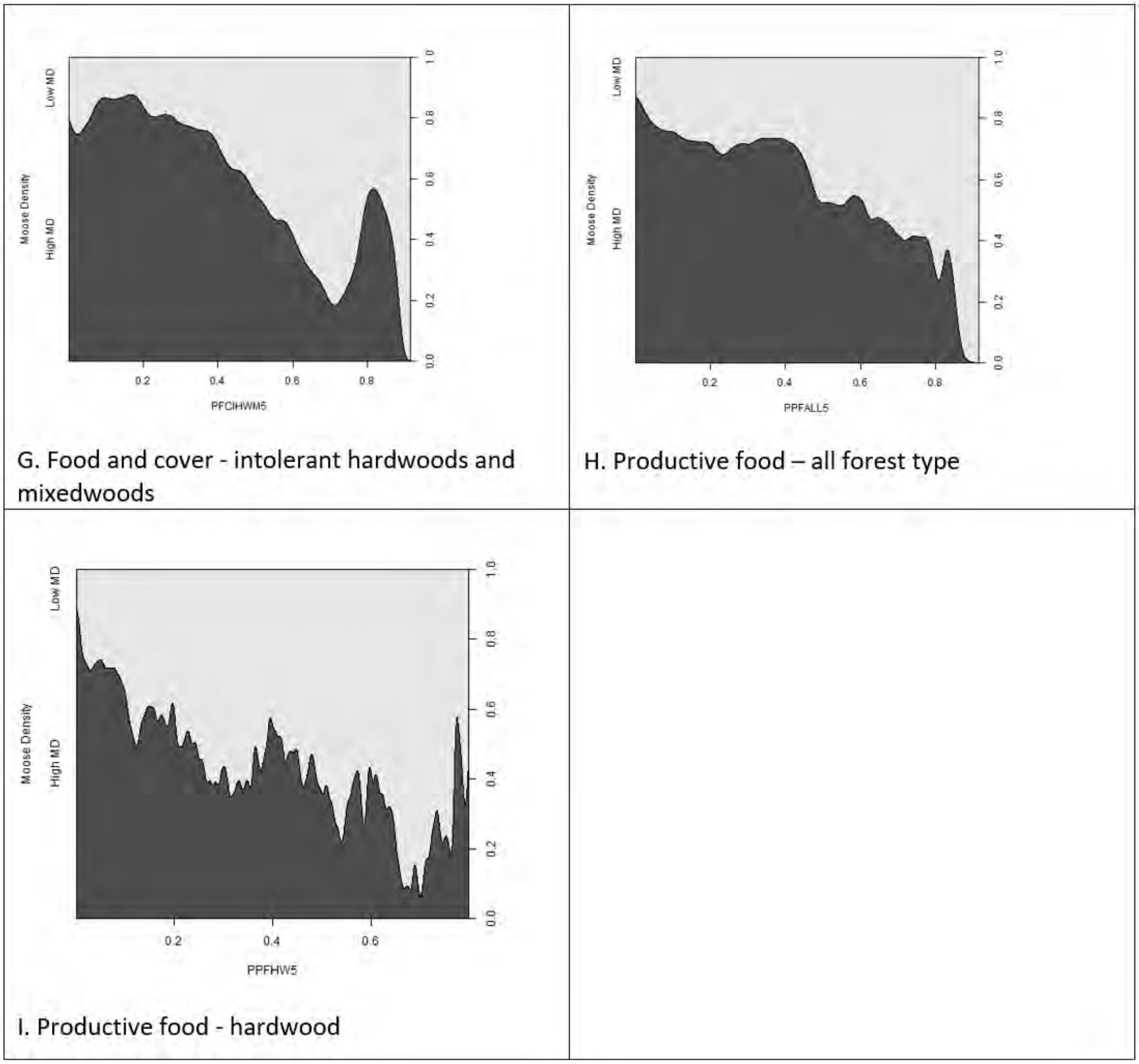


Figure A1: Conditional density plots illustrating the change in probability of an area providing high moose capability as a function of model variable (holding other variables constant) for landscape guide region 3W.