Appendix 1.

Evaluating the use of local ecological knowledge to monitor hunted tropical-forest wildlife over large spatial scales

Luke Parry and Carlos A. Peres

METHODS

Assessing depletion

On arriving in settlements we first sought out the elected community leader or, when not available, other informal leaders such as life-long residents, locally-born school teacher, etc. We conducted separate interviews at the level of settlement and household concerning hunting as well as the drivers of settlement growth and rural-to-urban migration (see Parry et al. 2010*a,b*). We only conducted interviews after we had explained the objectives of our research, giving full assurance of confidentiality, and then obtaining verbal consent to participate. The vast majority of interviewees were *caboclos*, the mixed descendants of Amerindians, European colonists and African slaves. Amazonas State's rural population of 735,000 people (IBGE 2007) includes indigenous peoples, *caboclos* and more recent colonists from other regions of the country. Interviews lasted around 1 hour, in total. When estimating depletion distances based on travel time, we discounted rest time if the location mentioned by hunters was distant. When an animal was detected close to a settlement, hunters pointed to a landmark (such as a tree) and we visually estimated a distance. Using this method we identified areas wholly depleted of a given species, which can be distinguished from the use of relative depletion when a species may be at reduced abundance, though still present.

Explanatory variables

Human population density was derived from the estimated number of people living within a 5 km radius of settlements. This population data was calculated from our own field surveys of settlement size and location with additional settlement data (on size and location) from the Brazilian Federal Epidemiological Vigilance database for malaria (SIVEP-MALÁRIA), high resolution images (IKONOS imagery) from Google Earth (where available), and municipal health secretariat databases. When additional settlement data only provided households, we assumed a mean of 5 persons per household (SIVEP MALARIA 2007). Settlement growth was the change in number of households between 1991 and 2007 and was established during interviews. Interviewees informed us of the approximate age of their settlement. We calculated the travel distance from each riverine settlement to its local urban center using the Network Analysis extension in ArcGIS 10.1 (ESRI, Redlands, California; see Parry et al. 2010*a*). Distance to primary forest was estimated based on the reported walking time from the center of the settlement, assuming a mean travel velocity on foot of 4 km/hr. We calculated the percentage of unflooded upland *terra firme* (as opposed to floodplain *várzea*) around each settlement (within a 5 km radial buffer) using a basin-wide raster image reflecting inundation at high water levels (Hess 2003). We did this due to the known differences in abundance of some game species between these forest habitat types (Haugaasen & Peres 2005).

Accuracy of census sector population data

There was a highly significant relationship between the 2007 census data collected by IBGE and our own 2007 field data obtained along the surveyed rivers for those census sectors that were entirely surveyed (Fig. A2). Accuracy appeared to be maintained even in remote areas as there was no significant correlation between fluvial distance from the town within a given sector and the percentage difference between the two population density estimates (Pearson correlation: $R^2 = 0.207$, $n = 52$, $p = 0.141$).

Hierarchical portioning

To minimize the constraints of multicollinearity amongst predictors (Table A2), we used hierarchical partitioning (Chevan & Sutherland 1991) to examine the independent effects of the settlement and landscape variables on depletion distances. Hierarchical partitioning is useful for exploratory analysis and identifying variables likely to be important in regression (e.g. Radford & Bennett 2007). All possible model combinations are considered in order to partition a measure of association into a variable-specific (independent) component and a joint component that is due to the co-action of two or more variables (MacNally 2000). Patterns of depletion were modelled using quasi-poisson errors and a goodness of fit based on r-square. The significance of independent effects was calculated using a randomization test with 100 iterations (MacNally 2002). These tests were implemented using the *hier.part* package in R (Walsh & MacNally 2003). Hierarchical partitioning only partitions the variance explained by selected predictor variables, so we also calculated a measure of overall model fit for the depletion of each species, based on the R^2-values of a Generalized Additive Model (GAM). We fitted GAMs using the *mgcv* package (Wood 2006), as they allow for non-linear trends in responses. We specified a quasi-poisson error and a log link function.

Predicting depletion at settlement and census sector-scales

During model fitting we used manual stepwise removal of the least significant interaction or variable one at a time, until only significant predictors remained. Quasi-poisson error distributions were specified. Where a given species was never observed around a visited settlement, we estimated a minimum depletion of 12.5 km, the maximum inland distance from a settlement that we estimate hunters to travel. On this basis we also capped very large depletion estimates at 12.5 km as larger buffers overlapped proximate locations around which the presence of a species had been reported during interviews. We then combined the revised buffers of reported depletion and predicted depletion (visited and unvisited settlements) to calculate the total proportional depletion zones for all species within visited census sectors. For census sector depletion models, we specified a quasi-binomial error distribution because values of the dependent variable were bound between 0 and 1.

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Table A1. Large vertebrate species for which the depletion zone (distance to nearest direct or indirect encounter within 12 months) was assessed using interviews with rural hunters in Amazonas State, Brazil. The known geographic range of the study species is indicated in relation to the rivers surveyed (taken from natureserve.org and iucnredlist.org). River numbers refer to those shown in a map of the study region (Fig. 1A).

Species		IUCN threat status	Rivers
Primates			
Spider monkeys	*Ateles belzebuth* (É. Geoffroy, 1806)	Endangered	1
	A. chamek (Humboldt, 1812)	Endangered	3-7
Woolly monkeys	*Lagothrix cana* (Humboldt, 1812)	Endangered	2-7
	L. poeppigii (Schinz, 1844)	Vulnerable	spatial model only
	L. lagothricha (Humboldt, 1812)	Vulnerable	spatial model only
Saki monkeys	*Pithecia irrorata* (Gray, 1842)	Least concern	2-3,5-8
	P. albicans (Gray, 1860)	Vulnerable	3-4
Capuchin	*Cebus apella* (L., 1758)	Least concern	1-7
Ungulates			
South American tapir	*Tapirus terrestris* (L., 1758)	Vulnerable	1-7
White-lipped peccary	*Tayassu pecari* (Link, 1795)	Vulnerable	1-7
Collared peccary	*Pecari tajacu* (L., 1758)	Least concern	1-7
Red brocket deer	*Mazama americana* (Erxleben, 1777)	Data deficient	1-7
Birds			
Curassow	*Mitu tuberosum* (Spix, 1825)	Least concern	2-7
	Mitu tomentosum (Spix, 1825)	Near threatened	1
	Crax globulosa (Spix, 1825)	Endangered	possibly 3-7
	Crax alector (L., 1766)	Vulnerable	1
Reptiles			
Tortoises	*Chelonoidis denticulata* (L. 1766)	Vulnerable	1-7?

Table A2. Correlation matrix of settlement-scale predictors of depletion of hunted species, with correlation coefficients (r_s) shown in bottom left, and P-values in top right. Sample sizes are shown in parentheses beneath coefficients.

	No. households	City distance (km)	Population density (km^{-2})	% unflooded	Primary forest distance (km)	Settlement age (years)	Settlement growth (no. hh)
No. households		0.007	0.362	0.127	0.223	0.001	0.000
City distance (km)	-0.211 (161)		0.026	0.000	0.000	0.000	0.085
Population density (km^{-2})	0.720 (161)	-0.175 (161)		0.140	0.078	0.945	0.916
% unflooded	-0.121 (161)	0.721 (161)	-0.117 (161)		0.000	0.001	0.496
Primary forest distance (km)	0.102 (144)	-0.332 (144)	0.147 (144)	-0.438 (144)		0.010	0.443
Settlement age (years)	0.264 (159)	-0.305 (159)	0.006 (159)	-0.253 (159)	0.280 (142)		0.073
Settlement growth (no. households)	0.931 (158)	-0.137 (158)	-0.008 (158)	0.055 (158)	0.065 (141)	0.144 (156)	

Table A3. Results of minimal Generalized Linear Models of settlement-scale faunal depletion distances. These results were used to predict depletion distances around non-visited communities along seven rivers in Amazonas State, Brazil. A quasi-poisson error structure was specified. Significance levels refer to: $p < 0.1$ (.); $p < 0.05$ (*); $p < 0.01$ (**); $p < 0.001$ (***).

Variables	Coefficient	t	p	Significance
Tapirus terrestris				
(Intercept)	3.263	17.240	<2e-16	***
settlement size (no. households)	0.034	4.199	4.54e-05	***
city distance	-0.023	-8.320	4.66e-14	***
% unflooded	-0.016	-3.391	0.0009	***
settlement size:% unflooded	-0.0009	-4.048	8.21e-05	***
city distance: % unflooded	0.0002	6.737	3.14e-10	***
Null deviance = 1262.8 (157 df)				
Residual deviance = 399.6 (152 df)		$R^2 = 0.68$		
Tayassu pecari				
(Intercept)	3.045	10.292	<2e-16	***
settlement size	0.0214	1.954	0.052713	.
city distance	-0.015	-3.411	0.000850	***
population density	-0.028	-2.387	0.018324	*
% unflooded	-0.033	-4.107	6.84e-05	***
settlement size: city distance	-0.0008	-2.520	0.012867	*
city distance: population density	0.005	2.436	0.016122	*
city distance: % unflooded	0.0002	3.575	0.000484	***
population density: % unflooded	0.0003	1.751	0.082171	.
Null deviance = 1304.39 (146 df)				
Residual deviance = 653.9 (138 df)		$R^2 = 0.50$		
Pecari tajacu				
(Intercept)	2.691	5.650	7.49e-08	***
city distance	-0.017	-2.524	0.01260	*
population density	0.006	2.376	0.01874	*
% unflooded	-0.027	-2.306	0.02244	*
city distance: % unflooded	0.0002	2.698	0.00776	**
Null deviance = 1132.6 (159 df)				
Residual deviance = 644.4 (155 df)		$R^2 = 0.43$		
Mazama americana				
(Intercept)	2.206	7.586	2.99e-12	***
city distance	-0.010	-2.464	0.014841	*
population density	0.010	7.094	4.54e-11	***
% unflooded	-0.053	-6.342	2.43e-09	***
city distance: % unflooded	0.0002	3.799	0.000209	***
Null deviance = 797.9 (157 df)				
Residual deviance = 266.3 (153 df)		$R^2 = 0.67$		
Crax/Mitu spp.				
(Intercept)	1.095	6.020	1.26e-08	***
settlement size	0.007	4.605	8.66e-06	***
city distance	-0.005	-4.161	5.29e-05	***

Null deviance = 464.4 (154 df)				
Residual deviance = 323.1 (152 df)		R^2 = 0.30		
Chelonoidis spp.				
(Intercept)	1.393	2.869	0.00497	**
settlement size	0.058	2.622	0.01001	*
city distance	-0.003	-2.159	0.03309	*
% unflooded	0.028	2.601	0.01061	*
settlement size: % unflooded	-0.002	-2.600	0.01063	*
Null deviance = 1855.8 (111 df)				
Residual deviance = 1659.6 (107 df)		R^2 = 0.11		
Alouatta spp.				
(Intercept)	0.0561	4.119	6.13e-05	***
city distance	-0.002	-2.767	0.00633	**
Null deviance = 177.5 (158 df)				
Residual deviance = 163.0 (157 df)		R^2 = 0.08		
Pithecia spp.				
(Intercept)	-0.194	-0.616	0.53888	ns
city distance	-0.005	-3.176	0.00184	**
% unflooded	0.013	1.711	0.08939	.
Null deviance = 148.2 (141 df)				
Residual deviance = 127.5 (139 df)		R^2 = 0.14		
Cebus apella				
(Intercept)	-0.366	-1.239	0.217387	ns
city distance	-0.008	-5.269	5.06e-07	***
population density	0.004	1.695	0.092298	.
% unflooded	0.023	3.470	0.000692	***
Null deviance = 180.2 (143 df)				
Residual deviance = 125.0 (140 df)		R^2 = 0.31		
Ateles spp.				
(Intercept)	1.646	7.744	8.89e-12	***
population density	0.013	1.796	0.0756	.
Null deviance = 1150.0 (99 df)				
Residual deviance = 1102.6 (98 df)		R^2 = 0.04		
Lagothrix spp.				
(Intercept)	1.932	8.207	6.14e-13	***
settlement size	0.037	4.004	0.000117	***
city distance	-0.005	-3.770	0.000270	***
population density	0.010	2.451	0.015900	*
Null deviance = 870.5 (108 df)				
Residual deviance = 491.8 (105 df)		R^2 = 0.44		

Table A4. Results of minimal Generalized Linear Models of proportional faunal depletion of census sectors, for those sectors for which field surveys allowed a full census of the human population (n=41). A quasi-binomial error structure was specified. Significance levels refer to: p < 0.1 (.); p < 0.05 (*); p < 0.01 (**); p < 0.001 (***).

Variables	Coefficient	t	p	Significance
Tapirus terrestris				
(Intercept)	1.9656	2.20	0.034	*
city distance (km)	-0.0081	-4.22	0.000	***
population density (-km2)	0.7065	4.68	0.000	***
terra firme (%)	-3.1436	-2.67	0.011	*
Null deviance = 28.3 (40 df)				
Residual deviance = 3.3 (37 df)		R^2 = 0.88		
Tayassu pecari				
(Intercept)	1.2301	0.92	0.364	ns
population density (-km2)	0.9530	3.60	0.001	***
terra firme (%)	-4.2309	-2.70	0.011	*
Null deviance = 26.8 (40 df)				
Residual deviance = 6.1 (38 df)		R^2 = 0.77		
Pecari tajacu				
(Intercept)	3.5157	3.16	0.003	**
city distance (km)	-0.0005	-0.18	0.860	ns
population density (-km2)	-0.8943	-1.91	0.065	.
terra firme (%)	-8.2043	-4.18	0.000	***
city distance:pop density	-0.0025	-2.78	0.009	**
pop density: terra firme	2.9696	3.41	0.002	**
Null deviance = 19.6 (40 df)				
Residual deviance = 2.0 (35 df)		R^2 = 0.90		
Mazama americana				
(Intercept)	1.8195	1.39	0.172	ns
population density (-km2)	-1.4137	-2.91	0.006	**
terra firme (%)	-6.7794	-3.48	0.001	**
pop density: terra firme	3.0504	3.48	0.001	**
Null deviance = 10.0 (40 df)				
Residual deviance = 4.3 (37 df)		R^2 = 0.58		
Crax/Mitu spp.				
(Intercept)	1.8656	1.04	0.307	ns
city distance (km)	0.0351	2.18	0.036	*
population density (-km2)	-1.8255	-3.05	0.004	**
terra firme (%)	-7.3161	-2.53	0.016	*
city distance: terra firme	-0.0365	-1.96	0.058	.
pop density: terra firme	4.2198	3.64	0.001	***
Null deviance = 22.4 (40 df)				
Residual deviance = 5.2 (35 df)		R^2 = 0.77		
Pithecia spp.				
(Intercept)	-2.9186	-1.35	0.185	ns
city distance (km)	0.0742	3.16	0.003	**
population density (-km2)	-0.7883	-1.66	0.107	ns

terra firme (%)	-1.4343	-0.45	0.657	ns
city distance:pop density	-0.0037	-2.35	0.025	*
city distance: terra firme	-0.0838	-3.03	0.005	**
pop density: terra firme	2.3592	2.50	0.017	*
Null deviance = 14.7 (39 df)				
Residual deviance = 4.5 (33 df)		R^2 = 0.70		
Cebus apella				
(Intercept)	0.7842	0.37	0.717	ns
city distance (km)	0.0526	2.19	0.036	*
population density (-km2)	-1.8957	-2.83	0.008	**
terra firme (%)	-7.5062	-2.22	0.033	*
city distance:pop density	-0.0058	-2.88	0.007	**
city distance: terra firme	-0.0527	-1.98	0.056	.
pop density: terra firme	4.8127	3.48	0.001	**
Null deviance = 15.0 (40 df)				
Residual deviance = 5.8 (34 df)		R^2 = 0.61		
Ateles spp.				
(Intercept)	3.7744	2.44	0.021	*
population density (-km2)	0.7124	2.24	0.033	*
terra firme (%)	-6.2561	-3.52	0.001	**
Null deviance = 15.2 (32 df)				
Residual deviance = 4.3 (30 df)		R^2 = 0.72		
Lagothrix spp.				
(Intercept)	5.2049	5.47	0.000	***
city distance (km)	-0.0108	-5.62	0.000	***
terra firme (%)	-5.1973	-3.71	0.001	***
Null deviance = 15.2 (32 df)				
Residual deviance = 4.3 (30 df)		R^2 = 0.89		
Chelonoidis spp.				
(Intercept)	1.6997	0.87	0.392	ns
city distance (km)	0.0298	2.87	0.007	**
population density (-km2)	0.8847	3.11	0.004	**
terra firme (%)	-3.0733	-1.34	0.187	ns
city distance: terra firme	0.1875	-2.91	0.006	**
Null deviance = 21.3 (40 df)				
Residual deviance = 3.9 (36 df)		R = 0.82		

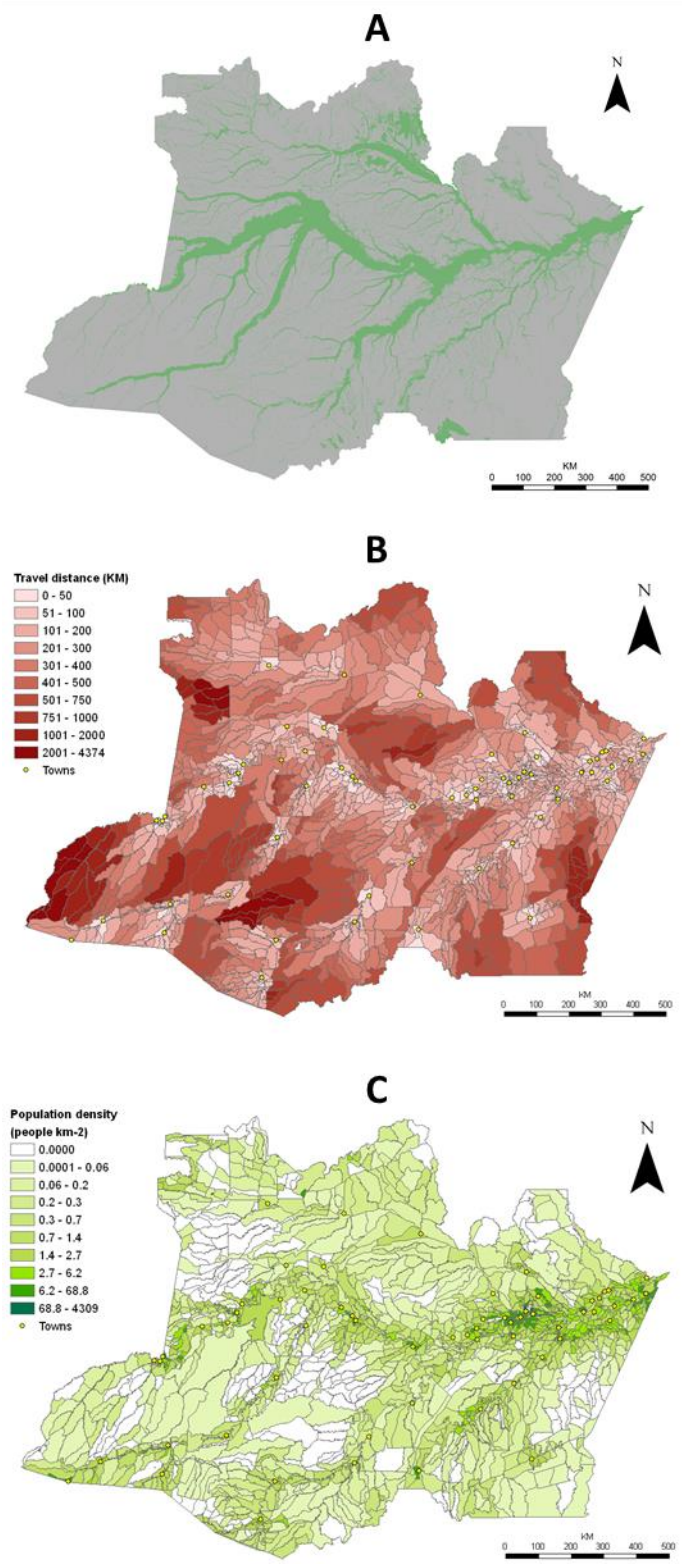


Figure A1. Variables assigned to census sectors: (A) Land-form based on coverage of flooded *várzea* (green) and unflooded *terra firme* (gray); (B) Travel distances to the local urban center (calculated from network analysis; Parry et al. 2010a), and (C) Human population density calculated from the IBGE 2007 population census.

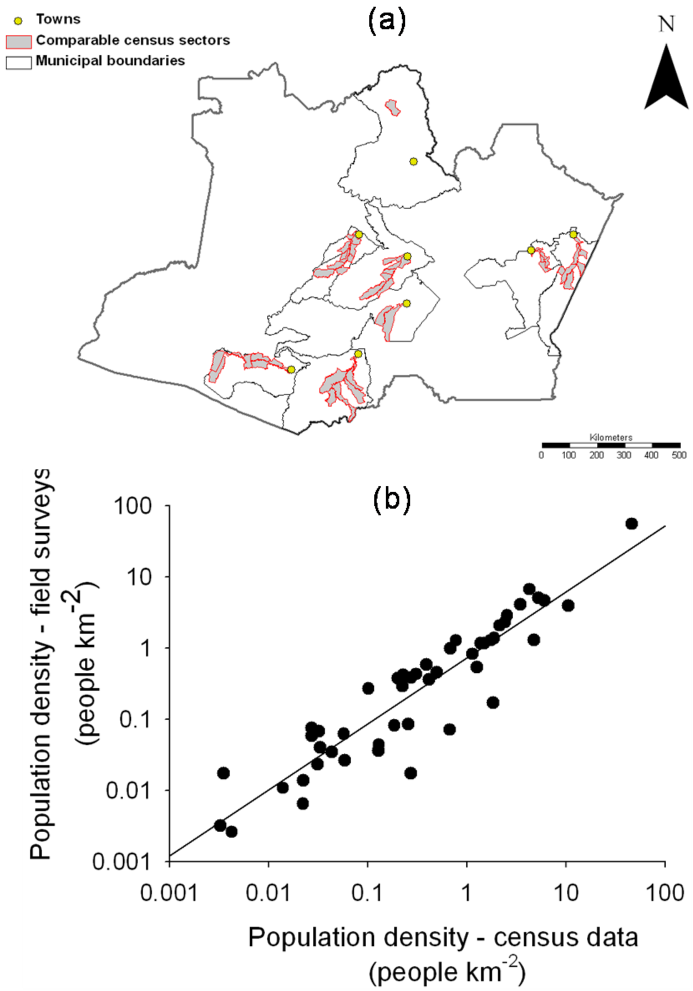


Figure A2. (A) Map of Amazonas state, Brazil, showing census sectors for which we compared governmental 2007 census data and our own surveys, based on field observations, interviews, and local and state health databases. Note this also includes population data from the R. Maués (far right), collected during a pilot study. (B) Comparison of 2007 population density estimates from the national census of the Brazilian Institute of Geography and Statistics (IBGE) and our field surveys. Pearson correlation (log(POPibge+1) ~ log(POPfield+1))= 0.983, n = 52, $p < 0.001$.

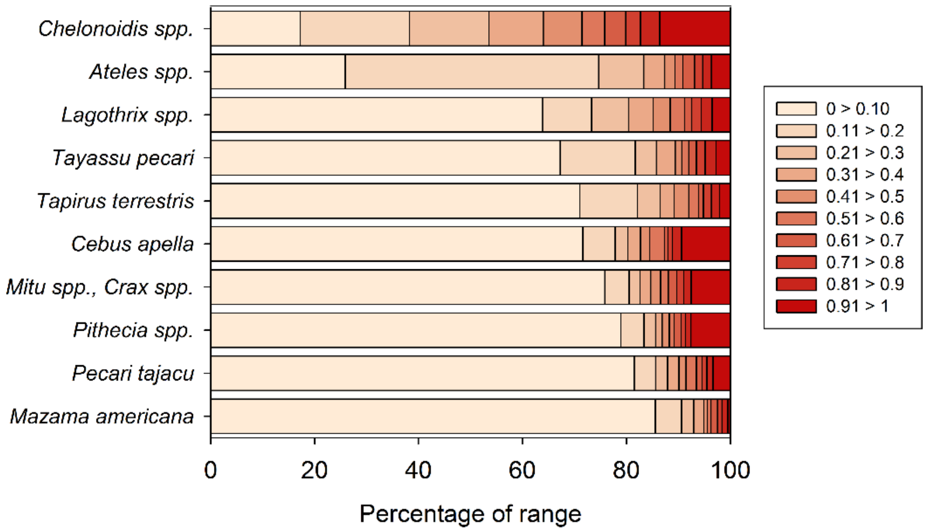
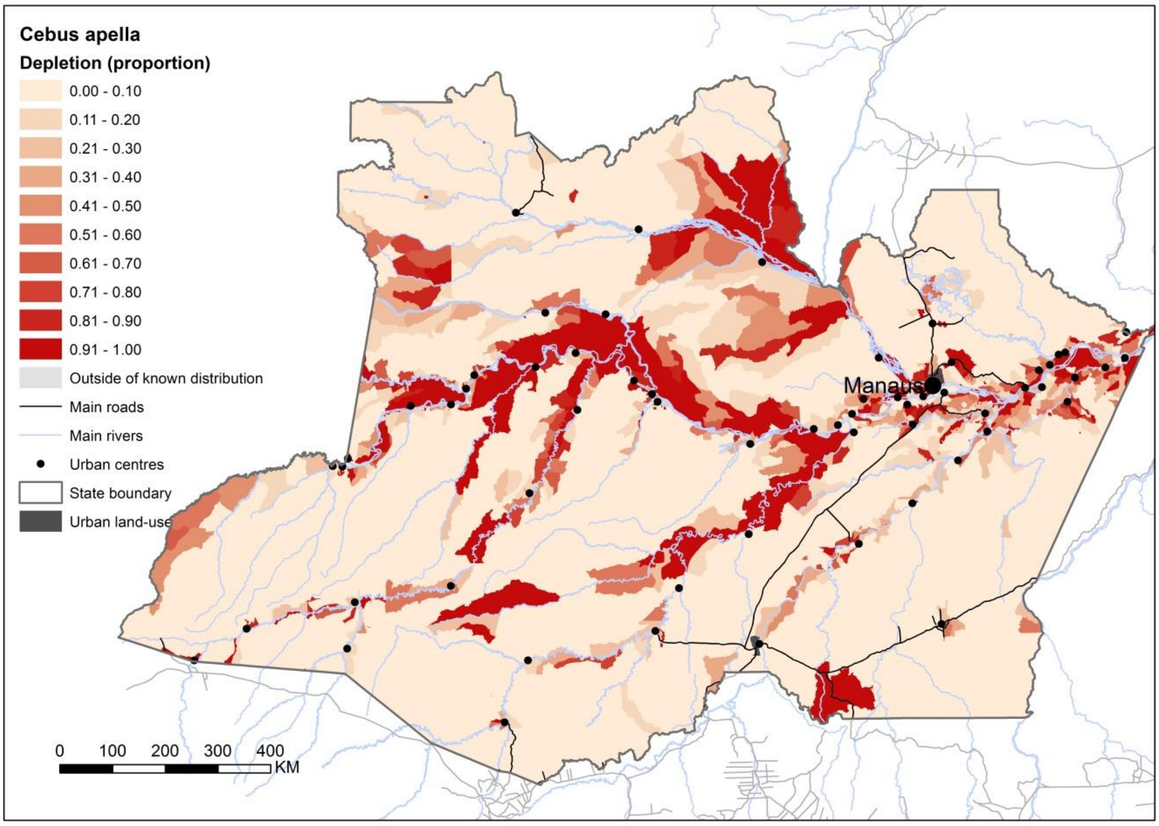
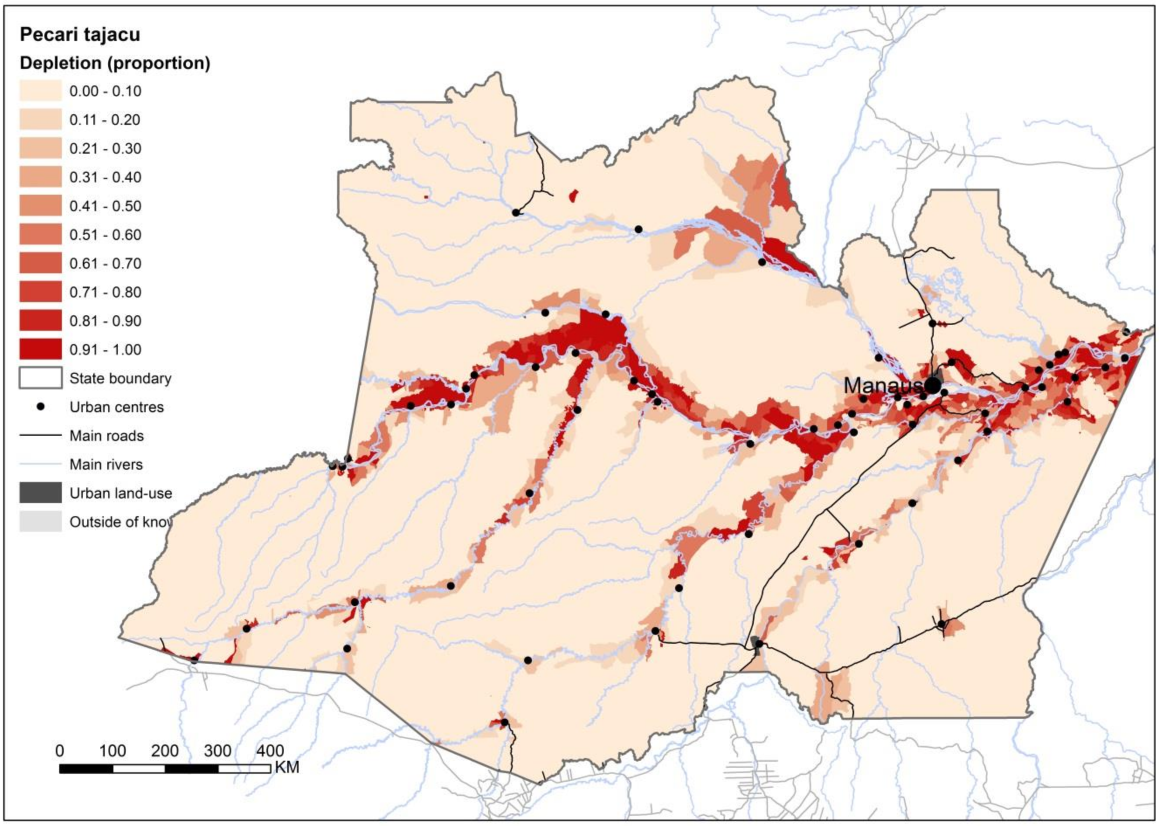
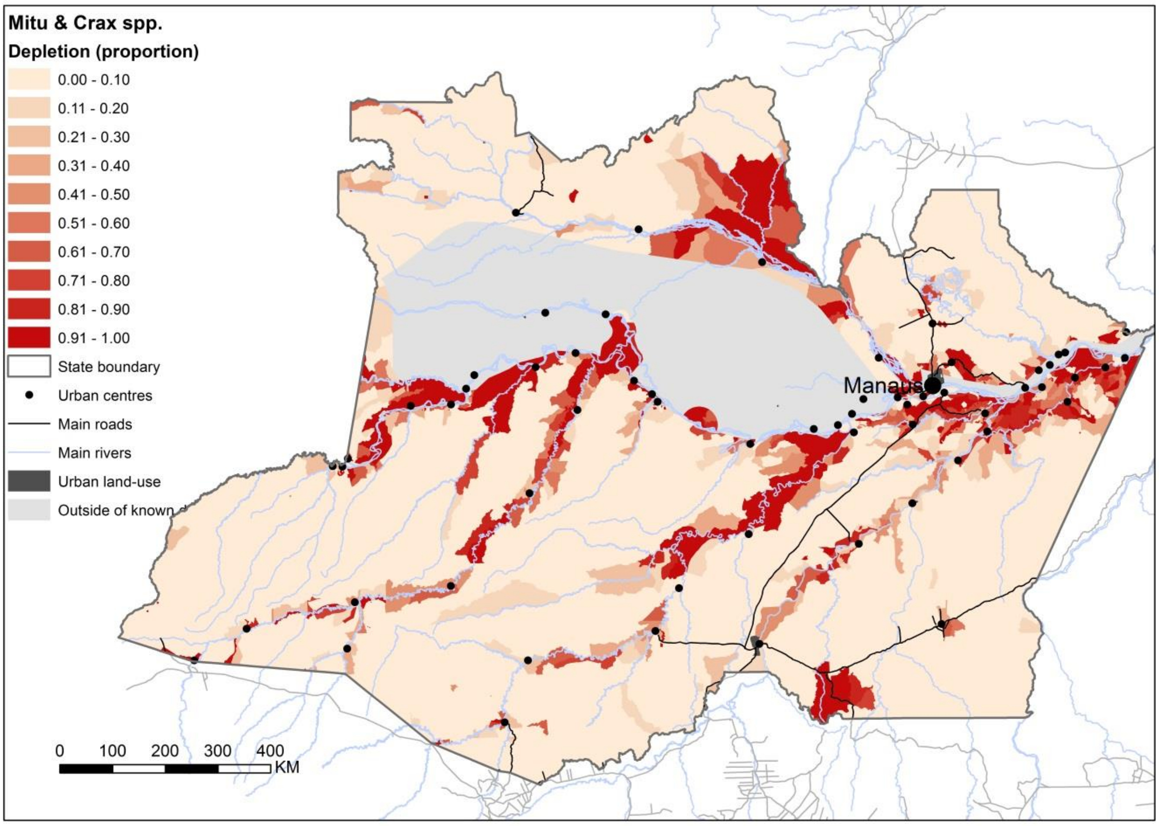
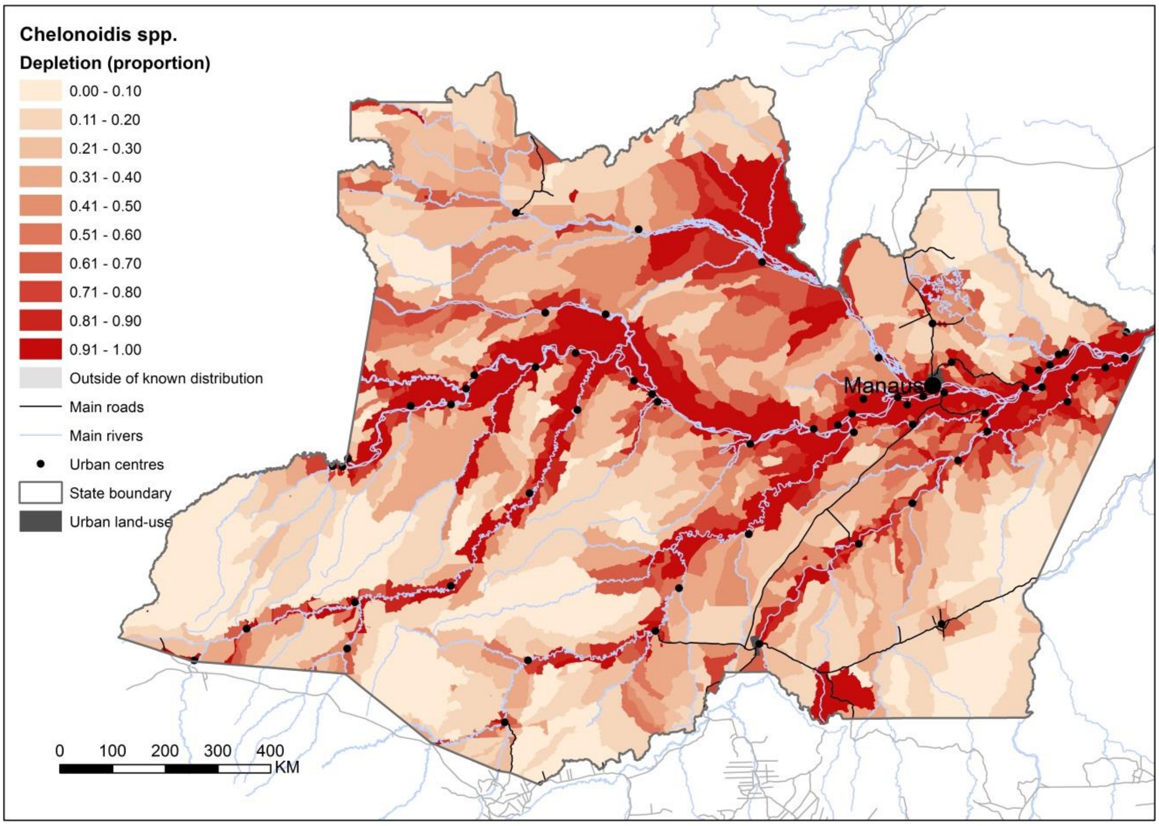


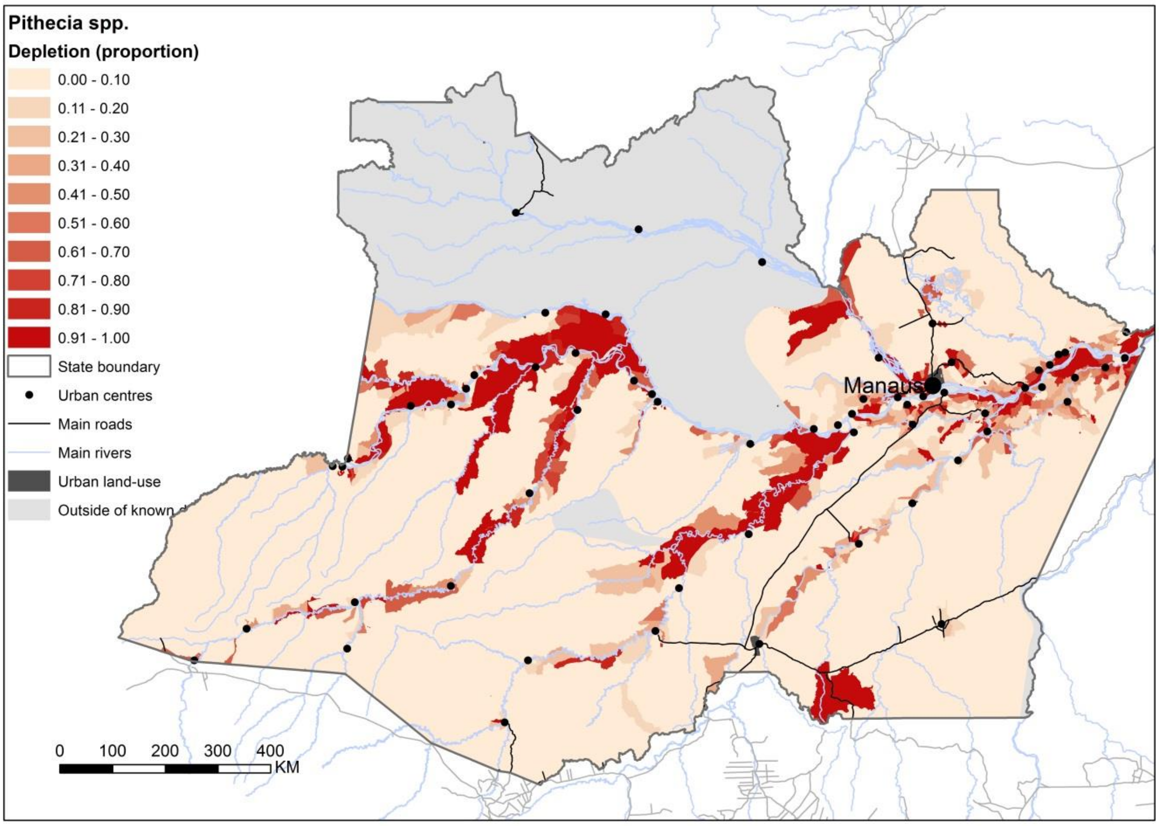
Figure A3. Depletion levels estimated for 10 species of large vertebrate, within their known geographic range distribution within Amazonas state, Brazil.


Cebus apella
Depletion (proportion)
0.00 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
Outside of known distribution
Main roads
Main rivers
Urban centres
State boundary
Urban land-use
Manaus
0 100 200 300 400
KM


Pecari tajacu
Depletion (proportion)
0.00 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
State boundary
Urban centres
Main roads
Main rivers
Urban land-use
Manaus
0 100 200 300 400
KM


Mitu & Crax spp.
Depletion (proportion)
0.00 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
State boundary
Urban centres
Main roads
Main rivers
Urban land-use
Manaus
0 100 200 300 400
KM


Chelonoidis spp.
Depletion (proportion)
0.00 - 0.10
0.11 - 0.20
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
Outside of known distribution
Main roads
Main rivers
Urban centres
State boundary
Manaus
0 100 200 300 400
KM



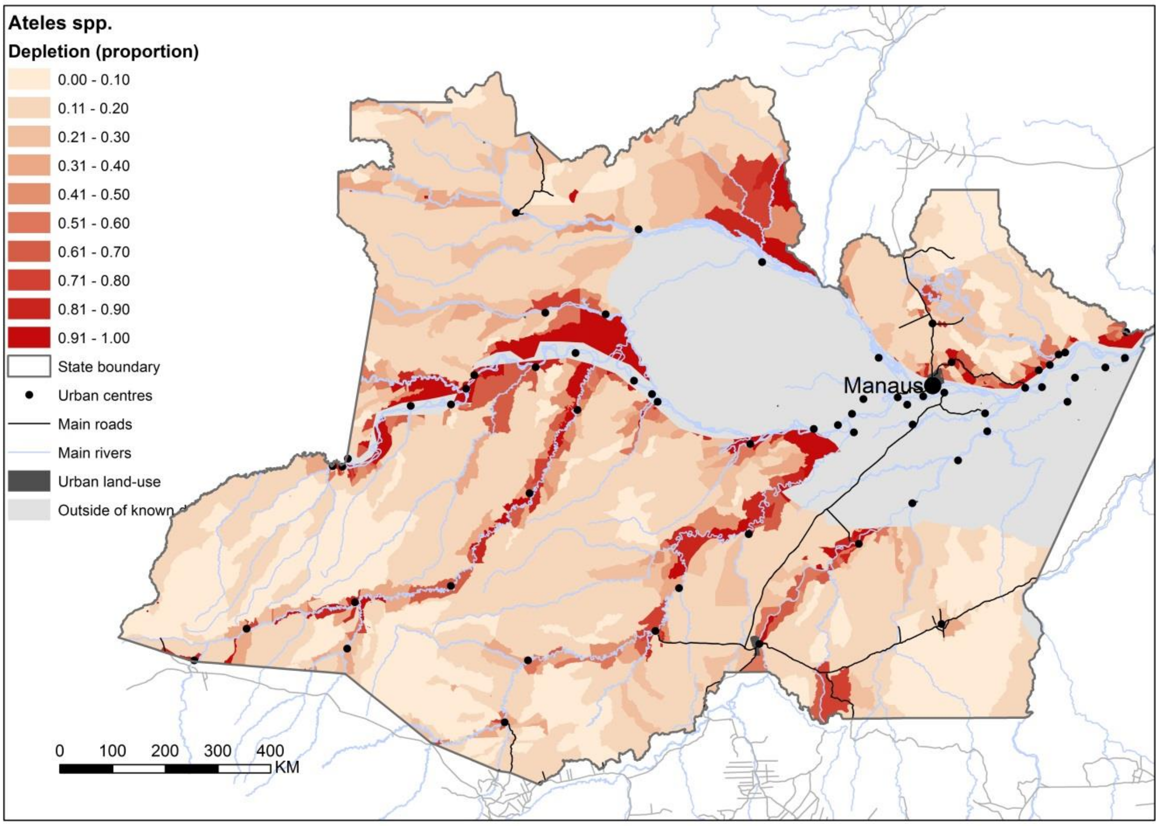


Figure A4. Predicted depletion levels of large vertebrates within census sectors in Amazonas State, Brazil, based on species-specific predictive models that used human population density, coverage of *terra firme* upland, and travel distance to the nearest urban center.