**Appendix S3.** Calculating the Wildlife Picture Index (WPI) with a multi-season multi-species occupancy model.

As an alternative to solely using species richness for monitoring large mammals with camera traps, [O'Brien *et al.* (2010](#_ENREF_2)) proposed the Wildlife Picture Index (WPI). The WPI is calculated as the geometric mean of relative occupancy probabilities. [O'Brien *et al.* (2010](#_ENREF_2)) estimated occupancy for each species independently with a single-species occupancy model ([MacKenzie *et al.* 2002](#_ENREF_1)). Confidence intervals for the index were calculated in a second step using a generalized additive model (GAM) and a nonparametric bootstrapping methods ([O'Brien & Kinnaird 2013](#_ENREF_3)). The errors of the occupancy estimates are not being considered in this method and species that were not detected during a survey are considered to be absent. The authors noted that for several species occupancy could not be estimated due to scarcity of data. The multi-species occupancy models proposed here seem ideal for calculating the WPI with full error propagation while also accounting for the probability of undetected species being present. We illustrate this using the three years of survey data from the Los Amigos surveys.

### Calculation

To obtain the WPI for year *t*, an index of relative occupancy is first calculated for every species *i* by dividing the occupancy value of year *t* by the occupancy value of the first year of the time series:

*oit = ψit / ψi1*.

The WPI of a community is then calculated as the geometric mean of these values

where *n* is the total number of species for all years combined. For species with *ψ*=0 we adjusted the estimate

where *x* is the number of camera trap stations ([O'Brien & Kinnaird 2013](#_ENREF_3)).

We compared two different options of dealing with undetected/absent species. First we calculated the WPI based on the probability of the species being present estimated by the model (*wit*). If *wit*=0 for a particular run of the model then *ψit*=0.01 to avoid divisions by zero, else *ψit* is was estimated by the model based on information from the other surveys. Second we calculated the WPI only for the species that were detected during all three surveys. We show the median and credible intervals for both calculations.

### Results

Figures 1 and 2 show the WPI for the two options chosen to deal with missing species. Estimates and confidence intervals were very different and the inclusion of missing species in the analysis lead to very imprecise estimates of the WPI.



Figure 1: The Wildlife Picture Index calculated using a multi-species occupancy model for three camera trap surveys from the Peruvian Amazon. We included 27 species and for undetected species we estimated the probability of their presence using the model.



Figure : The Wildlife Picture Index calculated using a multi-species occupancy model for three camera trap surveys from the Peruvian Amazon. We included 21 species, omitting species that were not detected during one of the surveys.

### Discussion

Our multi-species occupancy model allows the calculation of the WPI with full error propagation eliminating the use of a second step (GAM with bootstrapping) for estimating confidence intervals. For both estimates the WPI increases over the three-year period, but we see a large difference in the confidence intervals depending on how undetected species were dealt with. When including undetected species with the estimated probability that the species was present confidence intervals increase substantially compared to the case were we only use species that were detected in all surveys. This is understandable given the calculation of *oit = ψit / ψi1*. If *ψi1*=0.01 and *ψit*>0 then *oit* can become very large. This seems to be an unresolved issue with the WPI for species that are not detected consistently.

### Literature cited

MacKenzie, D.I., Nichols, J.D., Lachman, G.B., Droege, S., Royle, J.A. & Langtimm, C.A. (2002) Estimating site occupancy rates when detection probabilities are less than one. *Ecology,* **83,** 2248-2255.

O'Brien, T.G., Baillie, J.E.M., Krueger, L. & Cuke, M. (2010) The Wildlife Picture Index: monitoring top trophic levels. *Animal Conservation,* **13,** 335-343.

O'Brien, T.G. & Kinnaird, M.F. (2013) The Wildlife Picture Index: A biodiversity indicator for top trophic levels. *Biodiversity Monitoring and Conservation: Bridging the Gap between Global Commitment and Local Action* (eds B. Collen, N. Pettorelli, J. Baillie & S.M. Durant), pp. 45-70.Wiley, London.