ilies[5]. Second, yuccas control larval densities of pollinators more effectively than they do non-pollinators. Because about 90% of pollinated flowers abscise[6], and because abscission of flowers can be selective[7], pollinators experience high larval mortality. By ovipositing in young fruit, of which only about 10% abscise, non-pollinators frequently have a greater impact on seed production than do pollinators. It is of continuing interest to determine the mechanisms regulating the frequency and impact of this and other forms of 'cheating' (see ref. 8) in yucca/yucca moth mutualism.

John F. Addicott
Department of Biological Sciences,
University of Alberta,
Edmonton, Alberta T6G 2E9, Canada

1. Davis, D. R. *U.S. natn. Mus. Bull.* **255,** 1–170 (1967).
2. Riley, C. V. *Proc. biol. Soc. Wash.* **7,** 81–104 (1892).
3. Miles, N. J. *J. Lepid. Soc.* **37,** 207–216 (1983).
4. Addicott, J. F. *Oecologia* **70,** 486–494 (1986)
5. Bronstein, J. L. in *Insect–Plant Interactions* Vol. 4 (ed. Bernays, E. B.) 1–43 (CRC Press, Boca Raton, FL, 1992).
6. Addicott, J. F. in *The Biology of Mutualism* (ed. Boucher, D. H.) 217–247 (Croom Helm, London, 1985).
7. Pellmyr, O. & Huth, C. J. *Nature* **372,** 257–260 (1994).
8. Addicott, J. F. & Tyre, A. J. *Oikos* **72,** 382–394 (1995).

● See also the Letter to Nature on page 155.

Atlantic forest extinctions

SIR — High estimates of future extinction rates[1] derived from deforestation figures appear to be seriously undermined by data from South America's Atlantic forests[2]. Here, nearly 90% of the rainforest has been cleared, yet no bird species has so far been shown to be extinct[3]. Is the forest-loss-to-species-loss extrapolation "simply wrong"[2], because forest species survive in disturbed habitats[3]? Could extinctions have occurred historically, but unnoticed, as on Pacific islands[4]? Or is there a time-lag between deforestation and extinction[1], with many species now in serious danger?

The species–area relationship, $S = cA^z$, predicts how many species, S_n, of an original pool, S_o, survive a reduction in forest area from A_o to A_n; c and z are case-specific constants. Thus, $S_n = S_o(A_n/A_o)^z$. For reasons justified elsewhere[5], we set $z = 0.25$ and consider only endemic species. Non-endemics would survive elsewhere were the region entirely deforested[1,5]. Using published estimates of S_o and A_n/A_o for the entire Atlantic forest[3,6] and for endemic bird areas[3,7] within it, we predict the number of extinctions, S_e, from $S_e = S_o - S_n$. The box above compares these predictions with the latest counts[8] of how many endemic birds from each area are threatened by habitat loss (S_t). These threatened species were identified independently of species–area predictions, and have "a high probability of extinction in the medium-term future"[8]. We include Alagoas curassow, *Mitu mitu*, listed as "extinct in the wild", but exclude any species threatened solely by tiny ranges, direct exploitation or future (rather than current) deforestation.

Do endemic bird areas hold threatened species simply in proportion to the numbers of their endemics ($S_t \propto S_o$)? The data reject this hypothesis. In endemic bird areas with 12–20% forest remaining (B51/52 and B54), 29 endemics are threatened (32 are not), whereas in areas with 2–6% forest (B47 and B48), 11 endemics are threatened, but only 2 are not ($\chi^2 = 5.93$; 1 d.f.; $P < 0.02$). The alternative hypothesis is that the proportions of threatened species, S_t/S_o, correlate with the proportions of extinctions predicted from deforestation S_e/S_o. They do; $r = 0.72$. Consequently, for the two groups of endemic bird areas, the data do not reject the hypothesis that S_t and the non-threatened species $S_o–S_t$ equal the independently derived S_e and $S_o–S_e$, respectively ($\chi^2 = 4.01$; 2 d.f.; $P > 0.1$). Finally, as found elsewhere[1], more endemics restricted to single endemic bird areas are threatened (40 of 74) than ones found more widely within the region (20 of 140; $\chi^2 = 38$; 1 d.f.; $P < 0.01$).

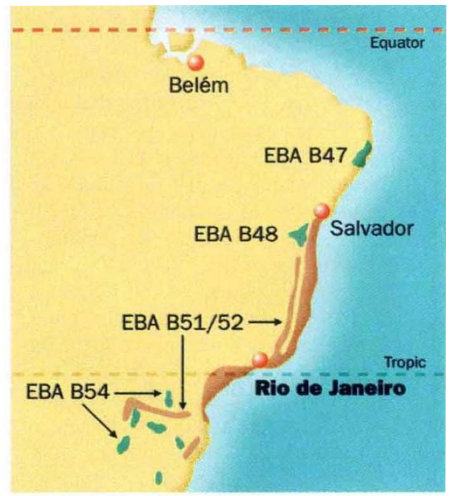
If Atlantic forest endemics were adapted to survive forest fragmentation[2,3], we would count significantly fewer threatened birds than deforestation predicts ($S_e > S_t$). We do not. We would also count fewer threatened species if the forests lost them before they became known to science. The kinglet cotinga, *Calyptura cristata,* has not been recorded this century[8]. Other species may have escaped documentation altogether, but our data suggest that such cryptic losses were rare.

The time-lag between deforestation and extinction is thus the best explanation for the similarity between the observed numbers of threatened Atlantic forest endemics and the numbers expected from deforestation. Forest clearance is leading to bird extinctions in these forests, at levels predicted by simple species–area analyses. Without immediate conservation action, the numerous Atlantic forest birds (and untold numbers of other taxa) currently threatened will soon be extinct.

Thomas Brooks
Department of Ecology and Evolutionary Biology,
University of Tennessee,
Knoxville, Tennessee 37996-1610, USA
Andrew Balmford
Department of Animal and Plant Sciences,
The University of Sheffield,
Sheffield S10 2TN, UK

1. Pimm, S. L., Gittleman, J. G., Russell, G. & Brooks, T. *Science* **269,** 347–350 (1995).
2. Budiansky, S. *Nature* **370,** 105 (1994).
3. Brown, K. S. & Brown, G. G. in *Tropical Deforestation and Species Extinction* (eds Whitmore, T. C. & Sayer, J. A.) 119–142 (Chapman & Hall, London, 1992).
4. Pimm, S. L., Moulton, M. P. & Justice, L. J. *Phil. Trans. R. Soc. Lond.* B**344,** 27–33 (1994).
5. Pimm, S. L. & Askins, R. A. *Proc. natn. Acad. Sci. U.S.A.* **92,** 9343–9347 (1995).
6. Scott, D. A. & Brooke, M. de L. in *Conservation of Tropical Forest Birds* ICBP tech. Publ. 4 (eds Diamond, A. W. & Lovejoy, T. E.) 115–139 (Int. Council Bird Preservation, Cambridge, UK, 1985).
7. Stattersfield, A. J., Crosby, M. J., Long, A. J. & Wege, D. C. *A Global Directory of Endemic Bird Areas* (BirdLife International, Cambridge, UK, in the press).
8. Collar, N. J., Crosby, M. J. & Stattersfield, A. J. *Birds to Watch* Vol. 2 (BirdLife Conserv. Ser. 4, BirdLife International, Cambridge, UK, 1994).

The endemic bird areas (EBAs) of Brazil's Atlantic forests. Data for the various EBAs are given in the table below. In the values for the whole Atlantic forest, S_o equals the sum of endemics from the EBAs (11 + 2 + 57 + 4 = 74) plus 140 endemics found more widely within the region. Similarly, S_t equals the sum of the threatened endemics from the EBAs (9 + 2 + 27 + 2 = 40), plus an additional 20 more widespread threatened endemics. The proportion S_t/S_o is not constant across these areas, but correlates with the proportion of extinctions predicted by deforestation, S_e/S_o.



Name of area	EBA code	Proportion of forest remaining (A_n/A_o)	Endemic bird species (S_o)	Extinctions predicted from forest losses (S_e)	Currently threatened species (S_t)
Alagoan Atlantic slope	B47	0.02	11	7	9
Bahian deciduous forest	B48	0.06	2	1	2
Brazilian lowlands	B51/52	0.12	57	24	27
Araucaria forest	B54	0.20	4	1	2
Whole region		**0.12**	**214 (= 74+140)**	**88**	**60 (= 40+20)**