Tree Species Diversity in Logged Rainforests

C. H. Cannon *et al.* report an increase in tree diversity 8 years after selective logging in Borneo (*1*). These results accord with theoretical expectations (*2*) and with previous observations in Borneo and elsewhere (*3*); however, the significance of these findings is debatable.

Cannon *et al*. detect increased stem diversity with the use of a "species-to-stems" ratio. The comparisons between logged and unlogged forests are, however, confounded by differences in stem counts per sample because species-individual ratios decline with increasing stem numbers in any community (*4*). Cannon *et al*. note the value of rarefaction as an alternative approach (figure 1 in the report), but do not provide the appropriate evaluations for their small samples. Thus, the finding of a general increase in stem-diversity remains unsubstantiated.

A greater concern arises from the assertion by Cannon *et al*. that such diversity patterns have some previously unrecognized conservation significance. Species are not equivalent, and species counts do not represent any inherent conservation value or provide a measure of ecological integrity. It is no paradox that habitat deterioration may be marked by a transient rise in stem diversity. Selective logging is known to be a relatively nonselective agent of short-term tree mortality (*3*). Stems from all the species that are present before logging will usually persist at reduced densities after harvesting is completed. In addition, logging increases the heterogeneity of forest microhabitats and provides considerable space for colonisation by immigrant species. These additions are predominantly good dispersers and "disturbance dependent" species rather than the more vulnerable and restricted taxa which characterise old-growth vegetation (*2*). Periods as short as 8 years [or 17 years (*5*)] actually tell us little about the long-term maintenance of species in managed systems where some stems have the potential to live for centuries. While production forests have numerous conservation values (*6*), any benefits from post-logging increases in tree diversity remain doubtful.

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3. K. Kartawinata, *Biotrop. (suppl.)* **3**, 27 (1977); R. Abdulhadi, K. Kartawinata, S. Sukardjo, *Malay For.* **44**, 407 (1981); A. D. Johns, *Biotropics* **20**, 31 (1988).
4. S. H. Hurlbert, *Ecology* **52**, 577 (1971). A simpler approach might compare Z = log(species counts)/log(stem counts), assuming $S = N^z$, where S = species counts and N = stem counts. Cannon *et al.*'s comparison of data from 1 year to that of 8 years after logging does have similar stem counts, but is not strictly relevant, as unbiased comparison to unlogged forest is still needed. This study is pseudoreplicated—the 1-year and 8-year sites are not replicated at the treatment level. Correct controls for each would use samples taken from within each treatment area, not a combination of both.
5. C. H. Cannon, D. P. Peart, M. Leighton, K. Kartawinata, *For. Ecol. Manage.* **67**, 49 (1994). Cannon *et al.*'s "8-year" site was also logged 17 years previously, which likely contributed further to forest heterogeneity.
6. J. A. Sayer and T. C. Whitmore, *Biol. Conserv.* **55**, 199 (1991); J. A. Sayer, P. A. Zuidma, M. H. Rijks, *Commonw. For. Rev.* **74**, 282 (1995).
7. We thank P. Macoun and M. Spilsbury for their comments.

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Response: Sheil *et al*. point out that the relationship between the number of species encountered and the number of stems is nonlinear, which confounds direct tests of species per individual ratios from samples of different sizes. As suggested, we applied a transformation that linearizes a power function, by testing l*n*(number of species)/l*n*(number of individuals), instead of direct measures. We again found that the number of tree species in a sample of stems 20 cm dbh or larger is greater in selectively logged forest 8 years after the harvest than in nearby unlogged forest (t test, d.f. = 19, $P = 0.025$).

However, we are not suggesting with this evidence that tree species diversity has been increased or forest quality improved by selective logging. On the contrary, we observed (*1*) a dramatic reduction in stem density and a lowering of tree species richness per unit area. The effects of logging are a compound result of several processes, including the selective harvest of the dominant species, indirect damage to unharvested trees, and the recruitment of trees less than 20 cm dbh into the larger diameter size classes. The steeper increase (after logging) in number of species with the number of stems in the sample is important, because it indicates that the losses associated with logging are no more than would occur as a result of random mortality of trees.

Sheil *et al*. suggest that an influx of pioneer or invasive species could be responsible for the high species richness in the 8-year forest, but this pattern was not seen in our sample. Roadsides and skidtrails were dominated by a mixture of small trees of *Trema orientalis* (Ulma.), *Glochidion* spp. (Euphorb.), *Neolamarckia cadamba* (Rubia.), *Macaranga* spp. (Euphorb.), climbers of *Uncaria* spp. (Rubia.) and *Gleichenia* sp. ferns, but only two individuals of species recognized as gap colonizers, species of *Macaranga* and *Vitex* (Verben.), were large enough to be included in our sample. All other species are commonly encountered in closed mature forest, both at this research site and other locations around the island (*2*). Sheil *et al*. note that there was a light harvest of the 8 year site prior to the primary harvest (*3*). The lack of trees over 20 cm dbh of pioneer species indicates earlier disturbance was minimal.

These selectively logged forests possess great conservation value. In general, forests suffer episodic and severe damage through natural processes such as wind storms (*4*) and fires (*5*) and recover through natural mechanisms of growth and succession. Given the rapidly changing situation across much of Southeast Asia, where increasingly smaller areas of protected mature forests are surrounded by expanding landscapes of highly modified forests, selectively logged forests represent conservation and research opportunities that may not be available in the near future.

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