

**Fig. 1.** Minimum species richness required for multifunctionality. At this richness, half of all communities (experimental plots) exceed multifunctionality thresholds ( $T$ ) of 30% (A), 40% (B), and 50% (C) for every function considered. Missing values indicate that 50% of communities did not meet the given  $T$  at any richness level; y-axis scales differ among panels. Points are offset slightly along the x axis for clarity. See *Methods* for details.

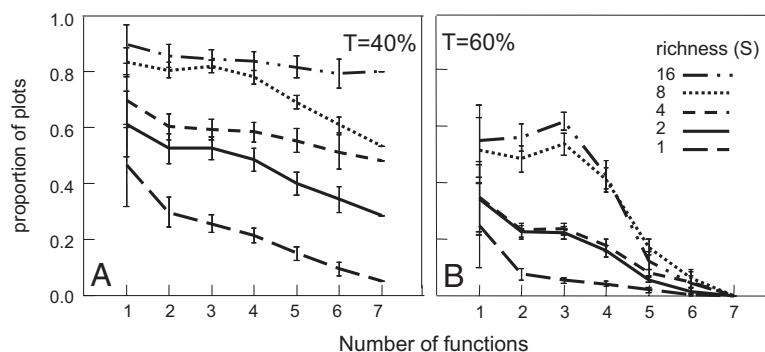
more than four functions. At  $T = 60\%$  in 2000 and  $T = 50\text{--}60\%$  in 2002, a significant interaction emerged between species richness and the number of considered functions (ANOVA;  $p_{2000} < 0.001$ ;  $p_{2002} = 0.024$ ;  $p_{\text{richness} \times \text{functions}} > 0.4$  for all other values of  $T$ ). This reflects the fact that at  $T = 60\%$  in 2000 and  $T = 50\text{--}60\%$  in 2002, communities of higher richness were significantly more likely to

provide threshold levels of multifunctionality for up to four functions simultaneously but less likely to provide those levels for five or more functions (Fig. 2). However, the more diverse communities did provide higher functioning, on average, for one through six functions, and a small number of species-rich plant assemblages were able to provide fairly high levels of all seven functions in some years (Table 1).

This finding likely reflects our approach of measuring multifunctionality in real communities, where tradeoffs limit the ability of most assemblages to provide high levels of several functions at one time. These tradeoffs include tradeoffs within species that hinder the simultaneous provision, for example, of high productivity and high drought tolerance (12, 13). Another tradeoff is in the composition of species assemblages, which can contain functionally similar species that all provide high levels of a few functions or functionally diverse species that all provide high levels of a different function but not both of these. Species interactions might hinder or enhance the ability of real communities to simultaneously provide many functions, but in our study, they did not affect the overall finding that most assemblages can provide high levels of only a limited number of ecosystem functions.

In our data set, we could detect direct tradeoffs among individual functions as a proxy for within species and among species tradeoffs in functionality. Of 21 total pair-wise combinations of two functions (28 in 2002), significant negative correlations occurred between two pairs of functions in 1998, two pairs in 2000, and two pairs in 2002, such that increases in the level of one function necessarily came at the cost of reduced levels of the second function. Total plant  $N$  and invasion resistance were negatively correlated across all communities in all 3 yr ( $P < 0.01$ ), as were total plant  $N$  and root biomass in both 1998 and 2000 ( $P < 0.05$ ). In 2002, soil-nitrate use was negatively correlated with insect richness ( $P < 0.001$ ).

Higher species richness, however, reduced the degree of tradeoff among pairs of functions in certain cases. In 2000, the negative correlation between total plant  $N$  and invasion resistance declined with increasing richness and became positive at the highest richness level ( $P > 0.001$ ;  $r^2_{\text{adj}} = 0.99$ ). The relationship between plant  $N$  and root biomass in 1998 and 2000 followed a similar, but not significant, pattern (1998 had  $P = 0.09$  and  $r^2_{\text{adj}} = 0.544$ ; 2000 had  $P = 0.30$  and  $r^2_{\text{adj}} = 0.13$ ). The negative correlation between insect richness and soil-nitrate use in 2002 also declined significantly with increasing richness ( $P = 0.015$ ;  $r^2_{\text{adj}} = 0.862$ ), but it remained negative at all richness levels. Richness did not affect the relationship between other negatively correlated functions. Although considering larger numbers of functions makes it increasingly difficult for any assemblage at any richness level to provide threshold levels of every function, we still see some evidence that higher



**Fig. 2.** Effects of species richness and number of functions on the proportion of communities that achieve multifunctionality thresholds ( $T$ ) of 40% (A) and 60% (B). Data are included for all possible combinations of each number of functions (x-axis values). Data are shown for the year 2000. Results were similar in 2002 but not in 1998, when species richness did not significantly affect the proportion of communities achieving threshold levels of multiple functions.



For each richness level, we tallied the proportion of communities exceeding  $T$  values from 10% to 90% for all possible combinations of 1–7 (8 in 2002) functions. We conducted ANOVA on the proportion of communities in each year that met or exceeded  $T$  of 30–60% with species richness and number of functions as factors and an interaction term. The dependent variables (proportion of communities) were arcsine transformed for each of these four tests (for  $T = 30\%$ , 40%, 50%, and 60%) to improve data conformation with the assumptions of a parametric test. We did not perform post hoc tests on the results of these ANOVAs.

We computed Pearson correlation coefficients for all pairs of ecosystem functions for each year and across all richness levels to identify negatively correlated pairs. We then computed Pearson correlation coefficients within each richness level for those functions in negatively correlated pairs. We used ordinary least squares regression of correlation coefficients on richness level

to test the effect of species richness on degree of tradeoff between negatively correlated pairs of functions. We used Bonferroni-adjusted  $P$  values to account for multiple tests.

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