Appendix C. Detailed description of methods and results for estimating density-dependence of emigration rate, and for estimating dispersal range from covariance structure in abundance.

C.1 Density-Dependence of Emigration Rate. We fitted a Poisson GLMM to assess the nature of density-dependence on emigration at time *t* in low- and high-connectivity landscapes. Abundance of adults in the matrix at time *t* was regressed against the fixed effect, the abundance of live adult beetles in patches at time *t*, along with random landscape and time effects. The GLMM was implemented within a Bayesian framework. Models were fitted in R using add-on library R2WinBUGS with 3 parallel chains. Specification for prior and hyper prior, iterations, burn-in, thinning rate and convergence checking were as in Govindan and Swihart (2012).

C.2. Estimation of Mean Dispersal Range. Accounting for the geometry of subpopulations, we followed the approach of Schneeberger and Jansen (2006) to estimate the dispersal rate, the fraction of total population that disperses from one patch to another in coupled populations experiencing equilibrium, and the per capita growth rate from the time series data on abundance. Specifically we assumed that connectivity of patch i in a homogenous landscape followed a negative exponential dispersal kernel such that each off diagonal element in the connectivity matrix, $c_{ij} = \exp(-\alpha d_{ij})$ for $i \neq j$, where α is the dispersal range of species, a parameter that defines the distribution of dispersal distance of focal species and d_{ij} are the inter-patch distances. Additionally, for each row of the connectivity matrix, the diagonal element c_{ii}(i.e., $i = j$) was set as $-(\sum c_{ij})$. Accordingly, c_{ij} denotes the proportion of dispersers moving from patch i to patch j and c_{ii} denotes the proportion reflected on the boundaries and remain in the focal patch i. For heterogeneous landscapes, we modified $c_{ij} = \exp(-\alpha d_{ij})\ A_j$, for all i and j, to explicitly account for the differences in contribution of individuals from neighboring patches with markedly different carrying capacity (area). Random values of α constrained to approximate the mean dispersal distance for beetles between 0 and 42 cm (maximum d_{ij} in constructed landscape) were used in the stochastic first order auto regressive model of the variances and covariances of the transformed abundances of time series fitted against the eigenvalues generated from the connectivity matrix, to arrive at the best fit estimate of dispersal range. For homogeneous landscapes, estimates of dispersal rate and related parameters were based on time series of abundance for the first 15 time steps to better approximate the assumption of equilibrium in metapopulations (data for $t = 1$ to 24 time steps were used for heterogeneous landscapes). Confidence intervals for the dispersal rate were estimated following the bootstrap approach (1000 runs) of Schneeberger and Jansen (2006) . Reliable estimation of dispersal range of beetles in a landscape required an estimate of dispersal rate to be significant (confidence interval excluded zero). Estimated dispersal range for each replicate treatment landscape (for only those estimates that were significant) was used in the computation of λ_M and other derived parameters for the appropriate replicate.

C.3 Dispersal Range, Dispersal Rate and Per Capita Growth Rate. Estimates of per capita growth rate (Table C1), were influenced by the interaction effect of resource structure and patch dynamics (Table C2; $P = 0.04$). Growth rate in landscapes with fast (vs. slow) dynamic patches was 2 times lower for homogeneous than heterogeneous resources. Growth rate was also negatively affected by connectivity (Table C2; $P = 0.04$); it was 30% higher in low (0.52 ± 0.04) versus high (0.40 ± 0. 03) connectivity landscapes (Table C1). For a given resource structure, landscapes with low connectivity and slow dynamics had the highest growth rates, with beetle populations in heterogeneous landscapes growing slightly faster ($P < 0.10$). The low connectivity and slow dynamic landscapes exhibited greater growth rates ($P < 0.05$) than any other treatment containing homogeneous resources (Table C1).

Our estimate of species' dispersal rate was significant (95% confidence interval excluded zero) for all replicate homogeneous landscapes. In contrast, except for the high connectivity slow dynamic counterpart, only two of three replicates for each of the heterogeneous landscape treatments were different from zero. For the corresponding heterogeneous treatments, nonsignificant replicates were ignored while computing metapopulation capacity and derived parameters. Resource structure had a negative effect ($P \ll 0.001$) and connectivity a positive effect ($P = 0.04$) on patch-specific dispersal rate (Table C2). Dispersal rate of beetles was significantly lower in heterogeneous (0.04 ± 0.01) than homogeneous (0.11 ± 0.01) landscapes and in low (0.05 ± 0.01) than high connectivity (0.09 ± 0.01) landscapes (Table C1). Consistent with these results and differences in growth rates evinced in these landscapes, connectivity had a significant effect on adult beetle mortality in the matrix ($P \ll 0.001$) as well as inside the patches ($P \ll 0.001$; Table C1). While mortality in the matrix was 46% higher in high (vs. low) connectivity landscapes, mortality inside the patches was only 20% higher in landscapes with low (vs. high) connectivity.

Dispersal range of beetles in the landscape tended to be affected by an interaction of resource structure and patch connectivity ($P = 0.05$) and also by resource structure and patch dynamics ($P = 0.09$) (Table C2). Lower connectivity as well as slower dynamics dampened the dispersal range in heterogeneous resource landscapes as opposed to their homogeneous counterparts. α in heterogeneous versus homogeneous resource landscapes was 2.2 times less with low than high patch connectivity. Similarly, α in landscape with heterogeneous versus homogeneous resource was 2.4 times less with low than high connectivity.

Landscapes with heterogeneous resources, low connectivity and slow patch dynamics exhibited the highest per patch growth rate, an intermediate and less variable α and lowest dispersal rate (Table C1). α in this landscape was distinctly lower than that in other heterogeneous landscapes ($P < 0.01$) except for the analogous fast dynamic landscape ($P = 0.43$; Table C1). In contrast, it was not different from homogeneous landscapes except for the low connectivity slow dynamic counterpart, that exhibited the highest dispersal range, highest growth rate and lowest dispersal rate ($P = 0.01$; Table C1) among homogeneous ones.

LITERATURE CITED

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Schneeberger, A., and V. A. A. Jansen. 2006. The estimation of dispersal rates using the covariance of local populations. Ecological Modelling 196:434–446.

TABLE C1. Estimate (mean) of species-specific attributes for the eight treatment landscapes. Standard deviation of estimate is presented in parenthesis. For each parameter, treatment means with same superscript are not different from each other (Tukey sandwich HSD, $P < 0.05$). Abundance data from time steps $t = 0$ to 15 and $t = 0$ to 23 were used in the estimation of species-specific attributes for homogeneous and heterogeneous landscapes, respectively.

Treat-ment #	Resource Structure	Patch Connectivity	Patch Dynamics	Growth Rate	Dispersal Range	Dispersal Rate
1	Homogeneous	High	Fast	0.30[cd] (0.07)	0.04[ab] (0.02)	0.14[c] (0.04)
2	Homogeneous	High	Slow	0.37[cb] (0.03)	0.05[ab] (0.02)	0.10[c] (0.02)
3*	Homogeneous	Low	Fast	0.26[d] (0.06)	0.03[a] (0.00)	0.13[c] (0.04)
4	Homogeneous	Low	Slow	0.50[ab] (0.08)	0.06[b] (0.01)	0.09[bc] (0.04)
5**	Heterogeneous	High	Fast	0.46[b] (0.08)	0.17[c] (0.02)	0.04[ab] (0.03)
6	Heterogeneous	High	Slow	0.49[ab] (0.08)	0.19[c] (0.07)	0.06[abc] (0.04)
7**	Heterogeneous	Low	Fast	0.62[a] (0.04)	0.17[abc] (0.13)	0.02[ab] (0.04)
8**	Heterogeneous	Low	Slow	0.63[a] (0.01)	0.04[a] (0.01)	0.01[a] (0.02)

* or ** Mean± SD is based on two replicates [* One replicate for this treatment (#3) suffered fungal infestation, and ** 95% credible interval for the dispersal rate estimated for one replicate each for these treatments (#5, #7 and #8) contained zero; data from corresponding replicates were not included in analysis].

TABLE C2. AICc based model averaged estimate (± adjusted standard error) of coefficients associated with predictor variables for responses. For each response variable, estimates for only significant predictors ($P \leq 0.05$) are presented.

Response Variables	Intercept	Predictors (Coefficient ± adj.SE)				
		RS	PC	PD	RS X PC	RS X PD
Growth Rate *	0.85 ± 0.02	0.09 ± 0.02	-0.03 ± 0.02	0.05 ± 0.02		-0.05 ± 0.02
Dispersal Rate	0.10 ± 0.01	-0.07 ± 0.02	0.03 ± 0.02			
Dispersal Range **	-3.20 ± 0.27	0.90 ± 0.46			1.04 ± 0.53	-0.94 ± 0.55
Matrix Mortality **	3.43 ± 0.10		1.59 ± 0.12			
Patch Mortality **	5.24 ± 0.08		-0.92 ± 0.10			

RS: Resource Structure; PC: Patch Connectivity; PD: Patch Dynamics;

* log (x + 2) or ** log (x): Log transformed dependent variable X.