Appendix 1

Simulation results for gradients in K, λ, σ and ϵ and a mixed fragmentation gradient in K and μ

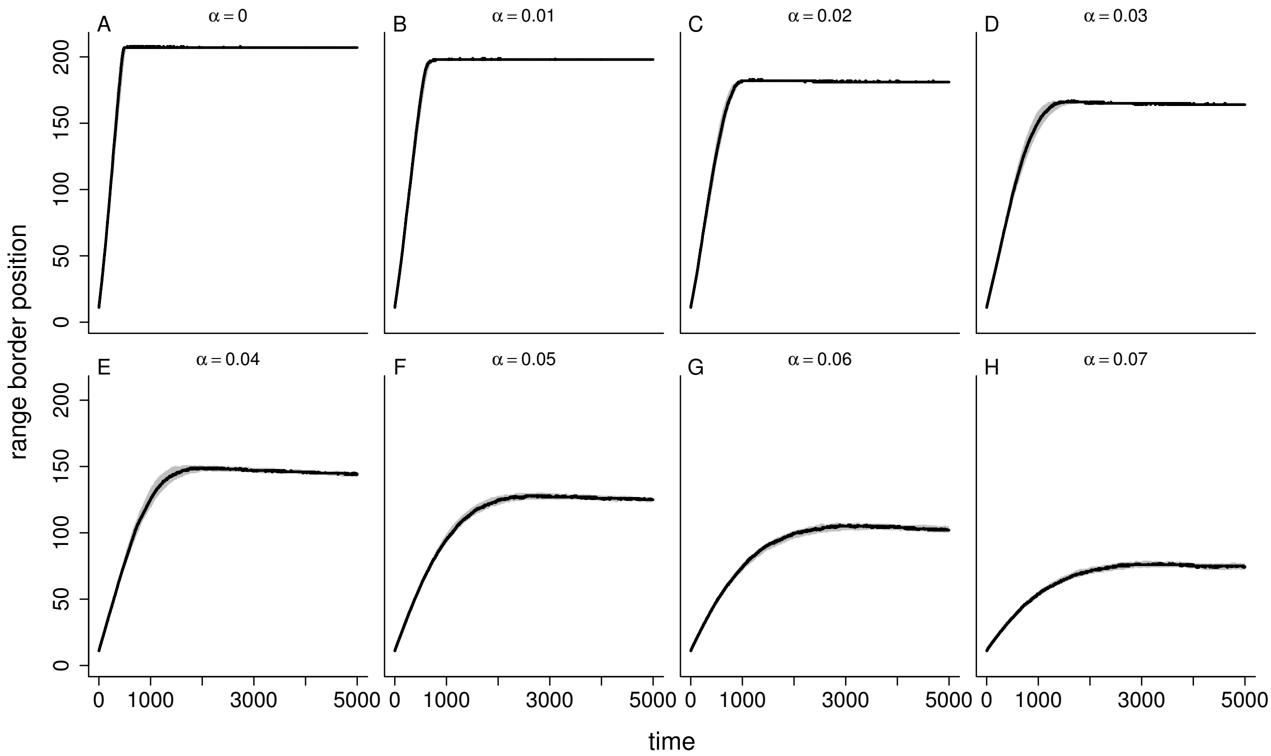

Figure A1: Range border position as a function of simulation time for a gradient in patch size (K). Patch size decreases from $K_{x=1} = 100$ to $K_{x=200} = 0$. Allee effect strength increases from the top left to the bottom right panel. For parameter values see main text. The black lines show the median values of 50 replicate simulations, the shaded grey areas denote 25% and 75% quantiles.

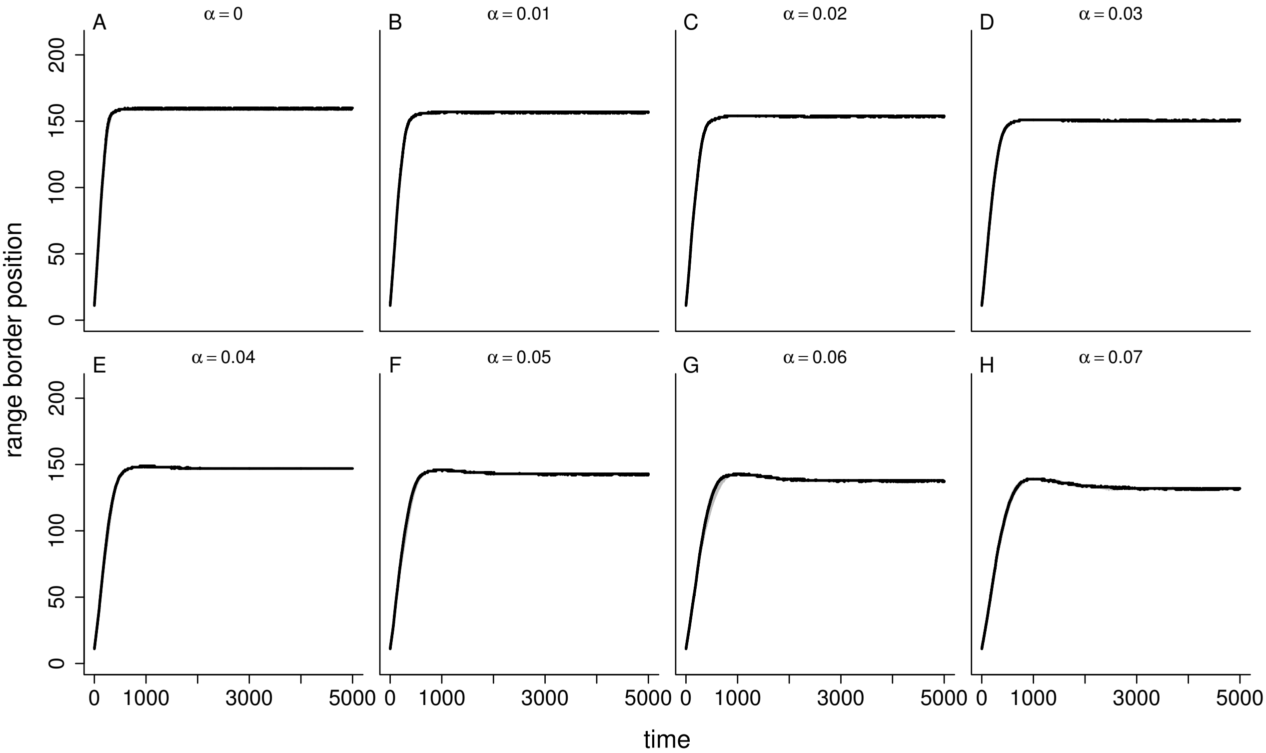

Figure A2: Range border position as a function of simulation time for a gradient in growth rate (λ). Growth rate decreases from $\lambda_{x=1} = 4$ to $\lambda_{x=200} = 0$. Allee effect strength increases from the top left to the bottom right panel. For parameter values see main text. The black lines show the median values of 50 replicate simulations, the shaded grey areas denote 25% and 75% quantiles.

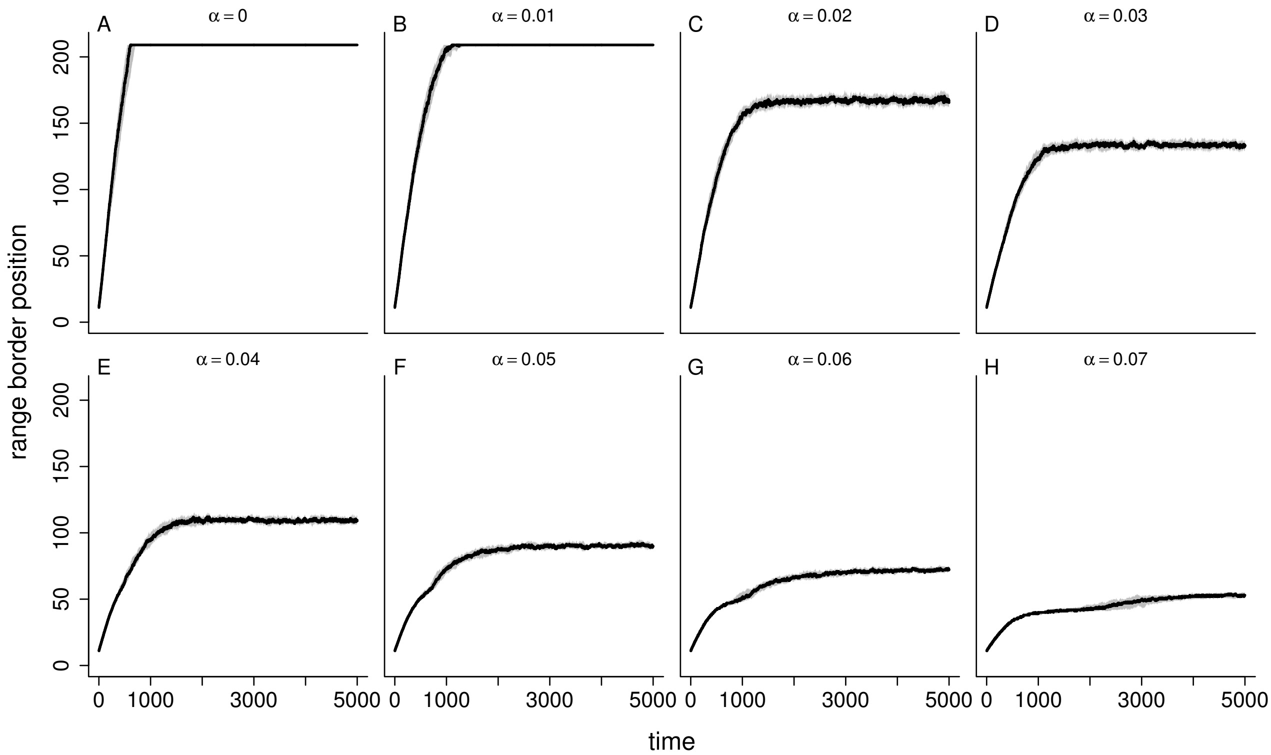

Figure A3: Range border position as a function of simulation time for a gradient in demographic stochasticity (σ). Demographic stochasticity increases from $\sigma_{x=1} = 0$ to $\sigma_{x=200} = 10$. Allee effect strength increases from the top left to the bottom right panel. For parameter values see main text. The black lines show the median values of 50 replicate simulations, the shaded grey areas denote 25% and 75% quantiles.

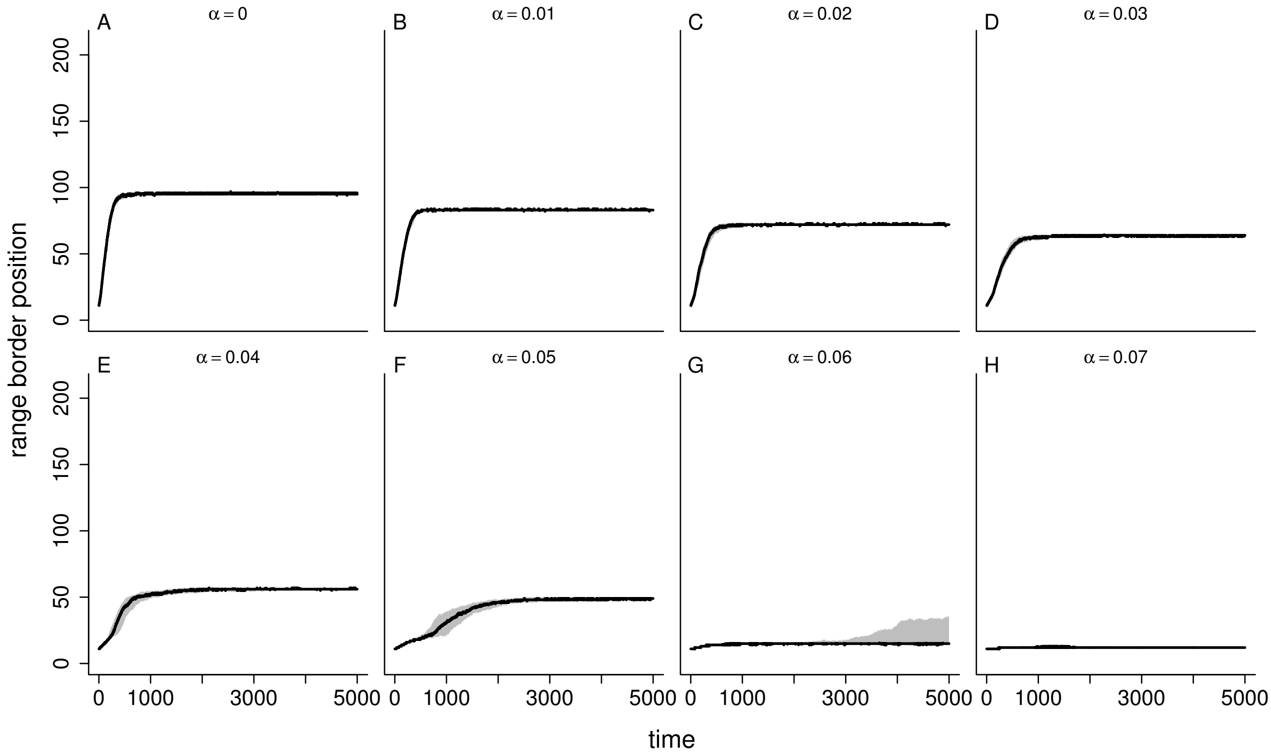

Figure A4: Range border position as a function of simulation time for a gradient in catastrophic extinction risk (ϵ). Extinction risk increases from $\epsilon_{x=1} = 0$ to $\epsilon_{x=200} = 1$. Allee effect strength increases from the top left to the bottom right panel. For parameter values see main text. The black lines show the median values of 50 replicate simulations, the shaded grey areas denote 25% and 75% quantiles.

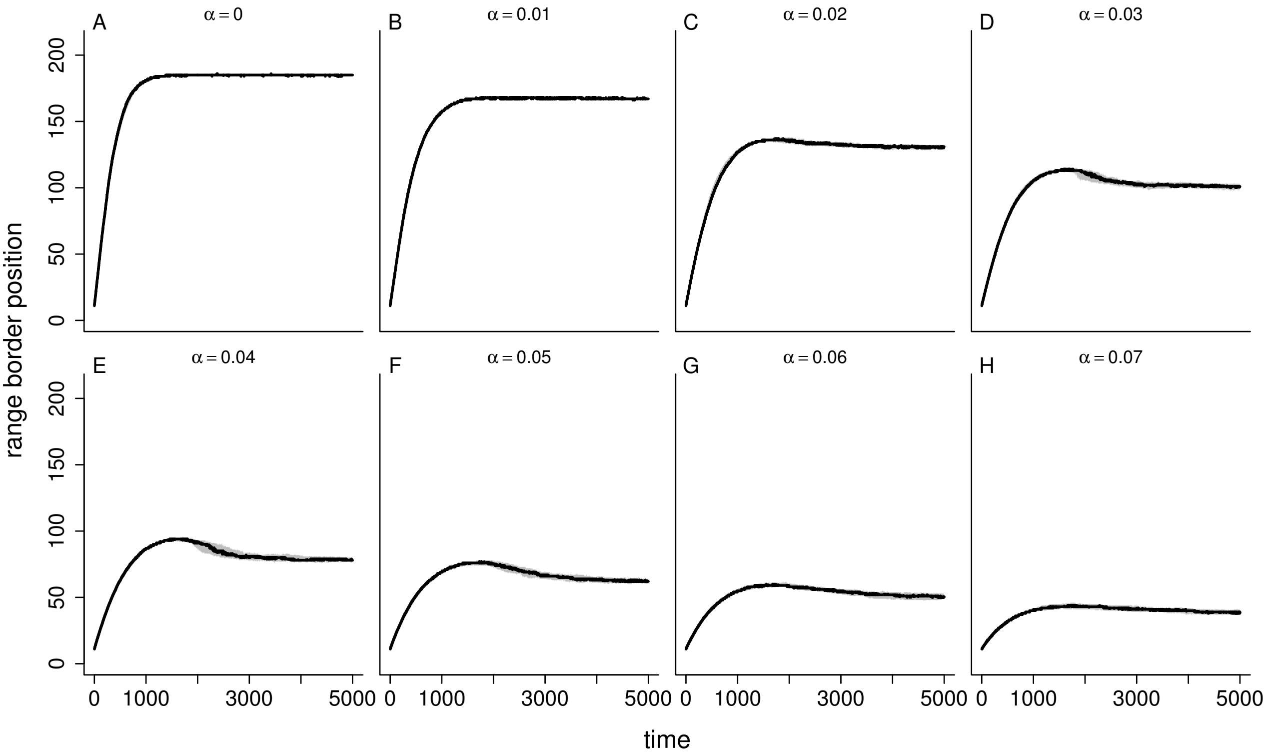

Figure A5: Range border position as a function of simulation time for a gradient in both patch size (K) and dispersal mortality (μ). Patch size decreases from $K_{x=1} = 100$ to $K_{x=200} = 0$ and dispersal mortality increases from $\mu_{x=1} = 0.2$ to $\mu_{x=200} = 1$. Allee effect strength increases from the top left to the bottom right panel. For parameter values see main text. The black lines show the median values of 50 replicate simulations, the shaded grey areas denote 25% and 75% quantiles.

Appendix 2

Simulation results for all gradients assuming the evolution of a negative exponential dispersal kernel

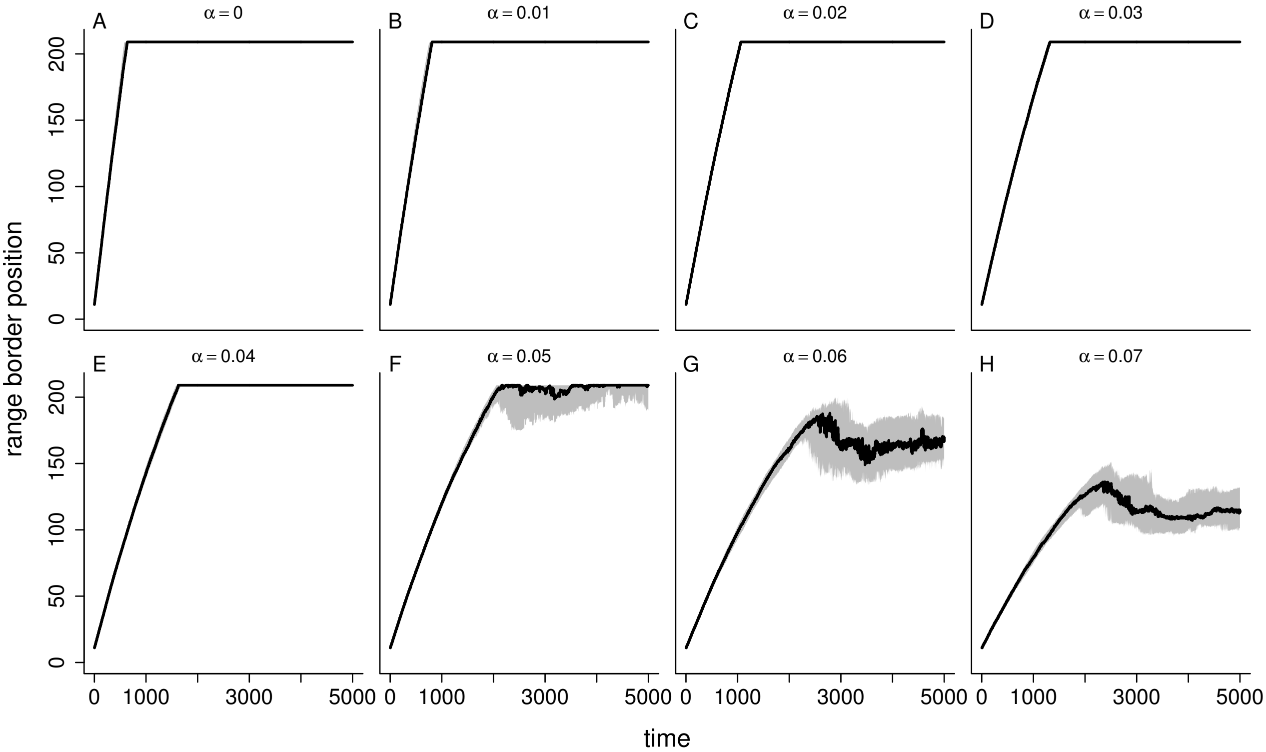

Figure A6: Range border position as a function of simulation time for a gradient in dispersal mortality (μ) assuming the evolution of a negative exponential dispersal kernel instead of emigration propensity. Dispersal mortality increases from $\mu_{x=1} = 0.2$ to $\mu_{x=200} = 1$. Allee effect strength increases from the top left to the bottom right panel. For parameter values see main text. The black lines show the median values of 50 replicate simulations, the shaded grey areas denote 25% and 75% quantiles.

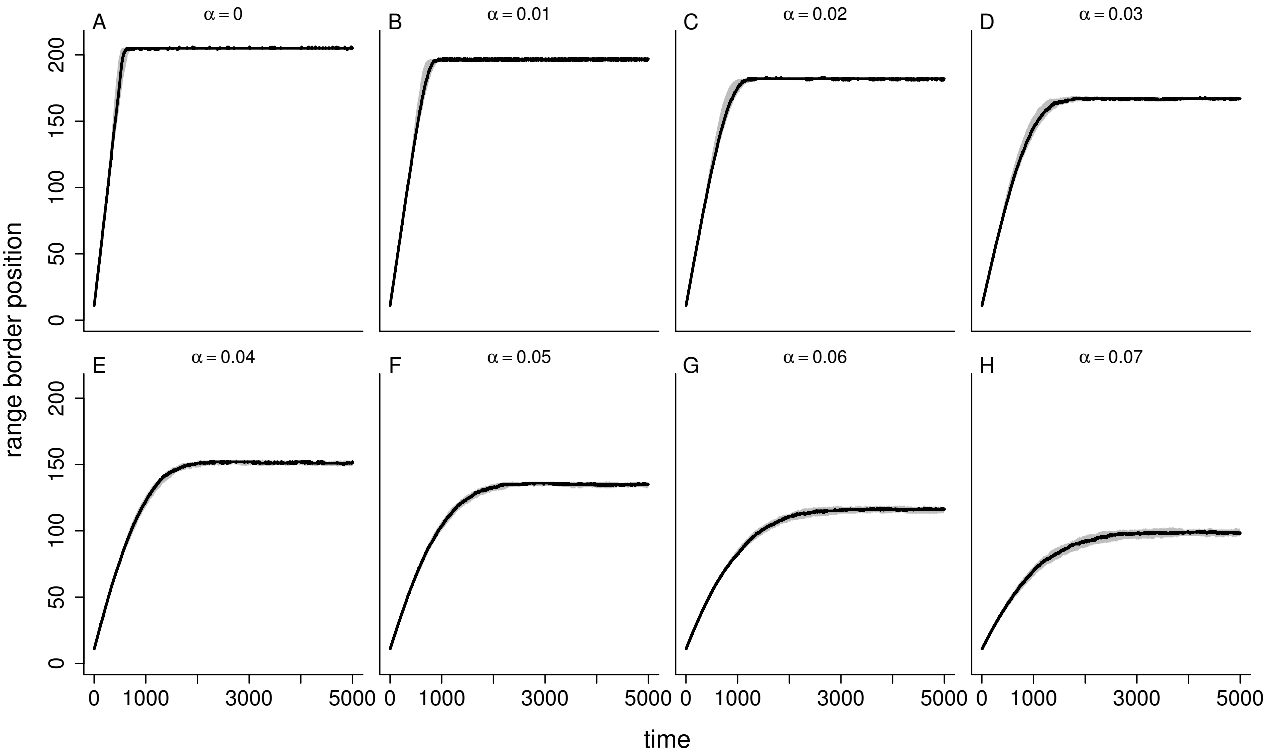

Figure A7: Range border position as a function of simulation time for a gradient in patch size (K) assuming the evolution of a negative exponential dispersal kernel instead of emigration propensity. Patch size decreases from $K_{x=1} = 100$ to $K_{x=200} = 0$. Allee effect strength increases from the top left to the bottom right panel. For parameter values see main text. The black lines show the median values of 50 replicate simulations, the shaded grey areas denote 25% and 75% quantiles.

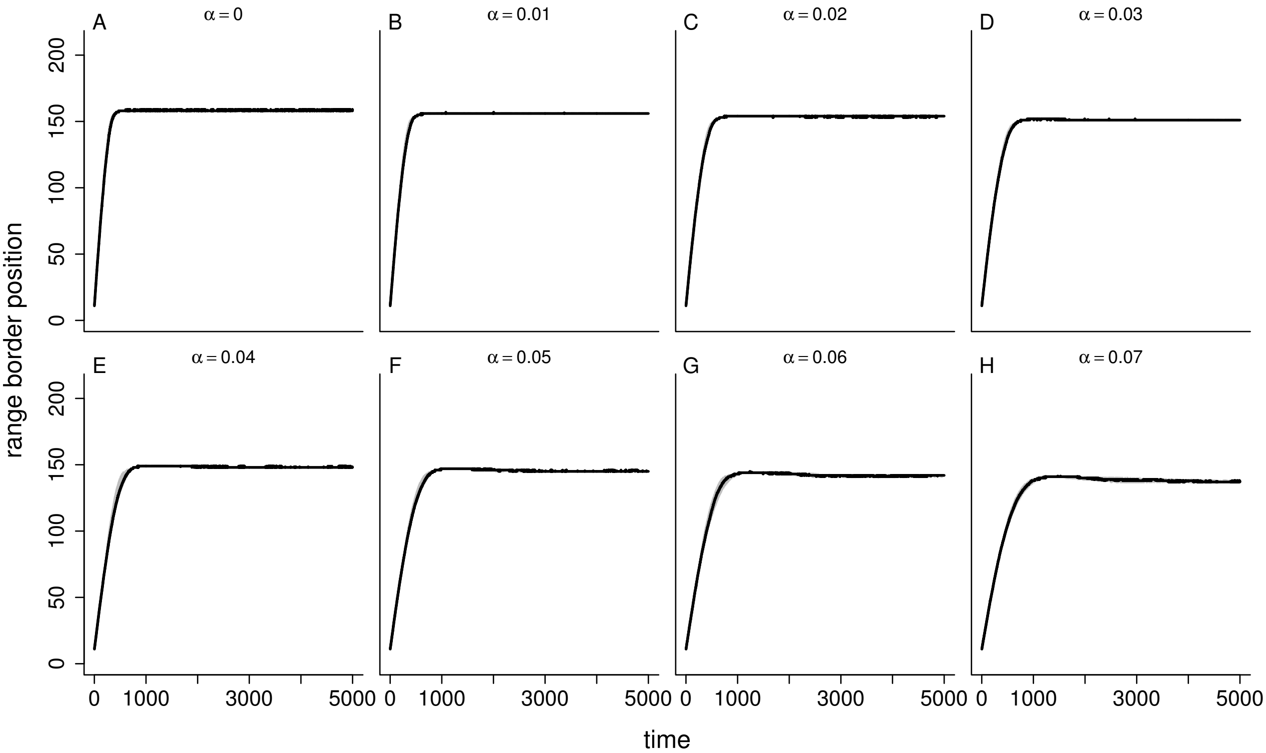

Figure A8: Range border position as a function of simulation time for a gradient in growth rate (λ) assuming the evolution of a negative exponential dispersal kernel instead of emigration propensity. Growth rate decreases from $\lambda_{x=1} = 4$ to $\lambda_{x=200} = 0$. Allee effect strength increases from the top left to the bottom right panel. For parameter values see main text. The black lines show the median values of 50 replicate simulations, the shaded grey areas denote 25% and 75% quantiles.

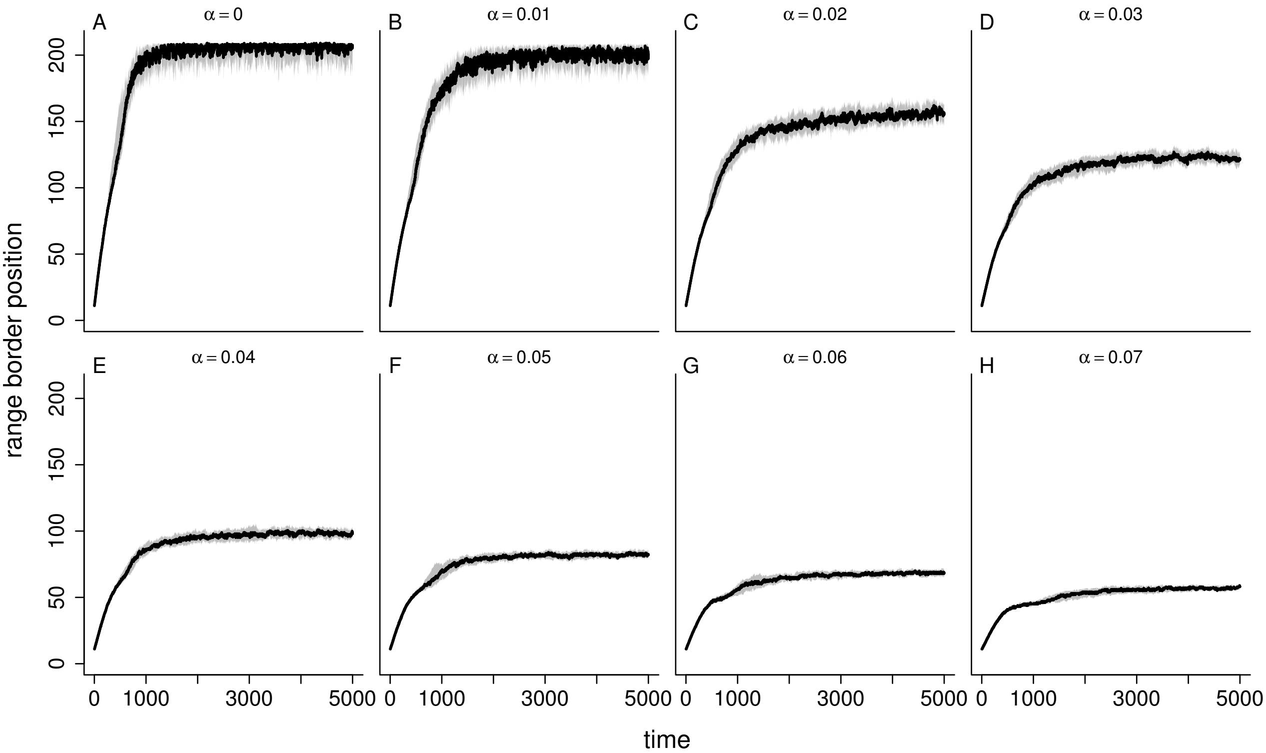

Figure A9: Range border position as a function of simulation time for a gradient in demographic stochasticity (σ) assuming the evolution of a negative exponential dispersal kernel instead of emigration propensity. Demographic stochasticity increases from $\sigma_{x=1} = 0$ to $\sigma_{x=200} = 10$. Allee effect strength increases from the top left to the bottom right panel. For parameter values see main text. The black lines show the median values of 50 replicate simulations, the shaded grey areas denote 25% and 75% quantiles.

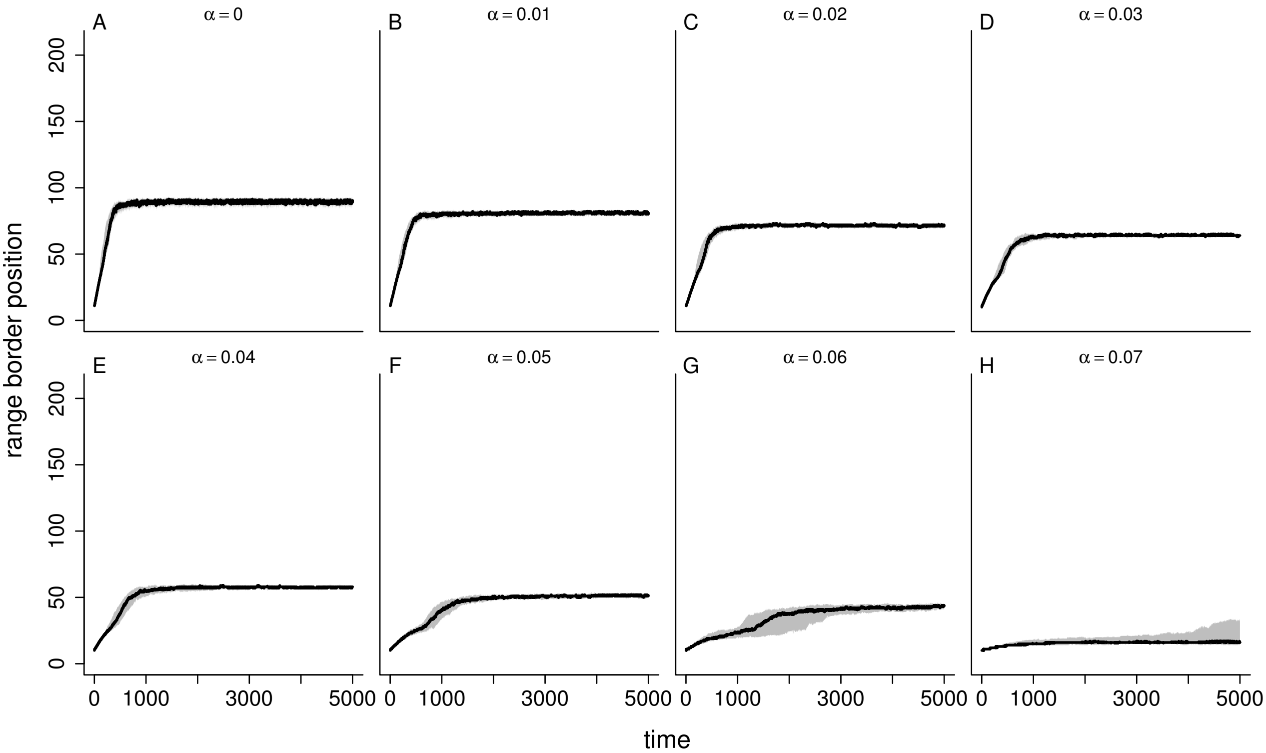

Figure A10: Range border position as a function of simulation time for a gradient in catastrophic extinction risk (ϵ) assuming the evolution of a negative exponential dispersal kernel instead of emigration propensity. Extinction risk increases from $\epsilon_{x=1} = 0$ to $\epsilon_{x=200} = 1$. Allee effect strength increases from the top left to the bottom right panel. For parameter values see main text. The black lines show the median values of 50 replicate simulations, the shaded grey areas denote 25% and 75% quantiles.

Appendix 3

Simulation results for varying spatial and temporal slopes and gradient shapes

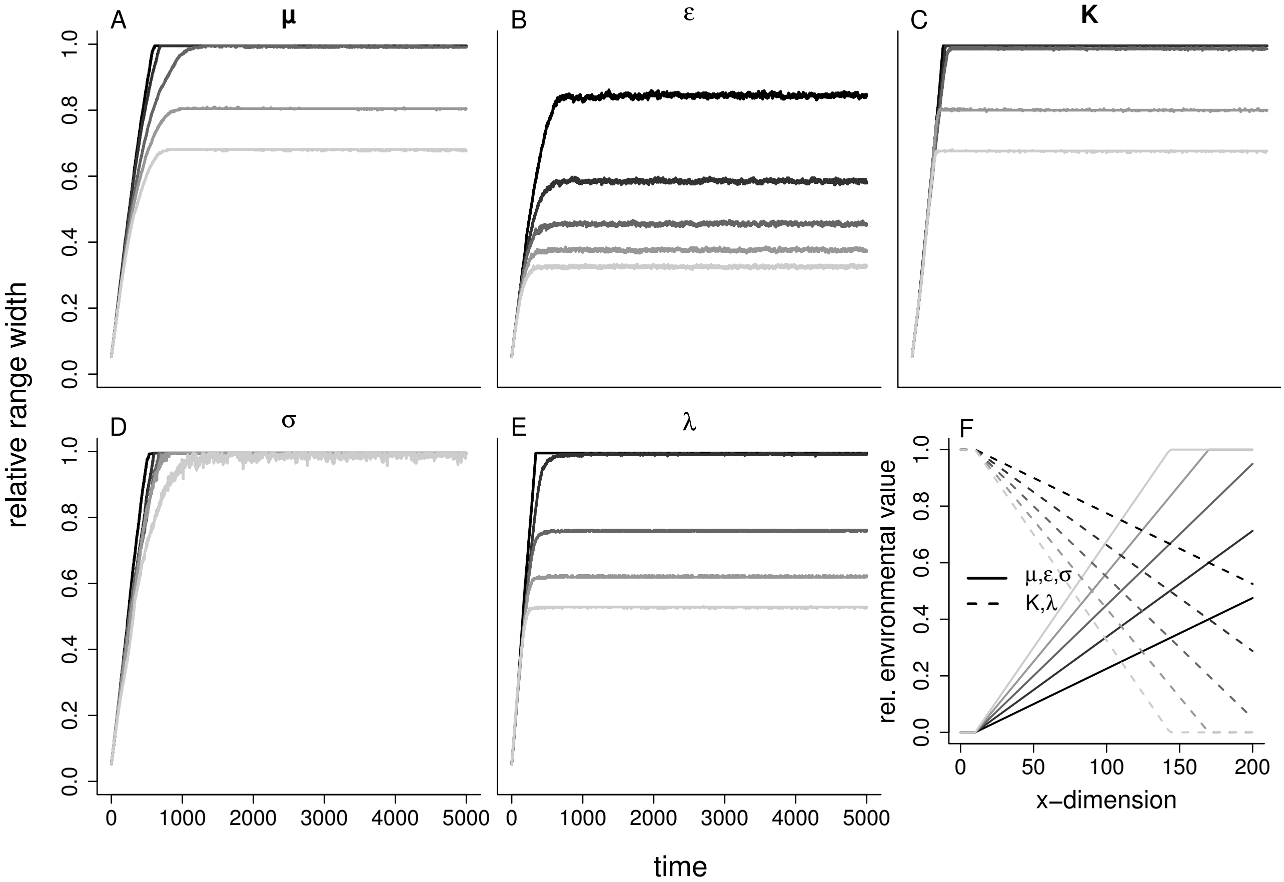

Figure A11: Linear decrease in fitness. Range border position as a function of simulation time for gradients in A) dispersal mortality (μ), B) catastrophic extinction risk (ϵ), C) patch size (K), D) demographic stochasticity (σ) and E) growth rate (λ). The local values of K and λ, $g(x)$, are given by $g(x) = g(x_{max}) - \frac{g(x_{max})}{x_{max}} \cdot \gamma \cdot x$ with $g(x_{max})$ defining the respective environmental value at $x = x_{max} = 200$ and γ giving the slope of the gradients. The local values of μ, ϵ and σ are given by $g(x) = g(x_1) + \frac{g(x_{max})}{x_{max}} \cdot \gamma \cdot x$ with $g(x_1)$ being the respective value at $x = 1$. All extreme gradient values (i.e. $g(x_1)$ and $g(x_{max})$) are the same as in the previous appendix figures. No Allee effect is assumed for these simulations. The gray shadings denote the different slopes of the gradients, which are given by $\gamma = \{0.5, 0.75, 1, 1.25, 1.5\}$ (relative environmental values are shown in panel F). Relative range widths are averaged over 10 replicate simulations.

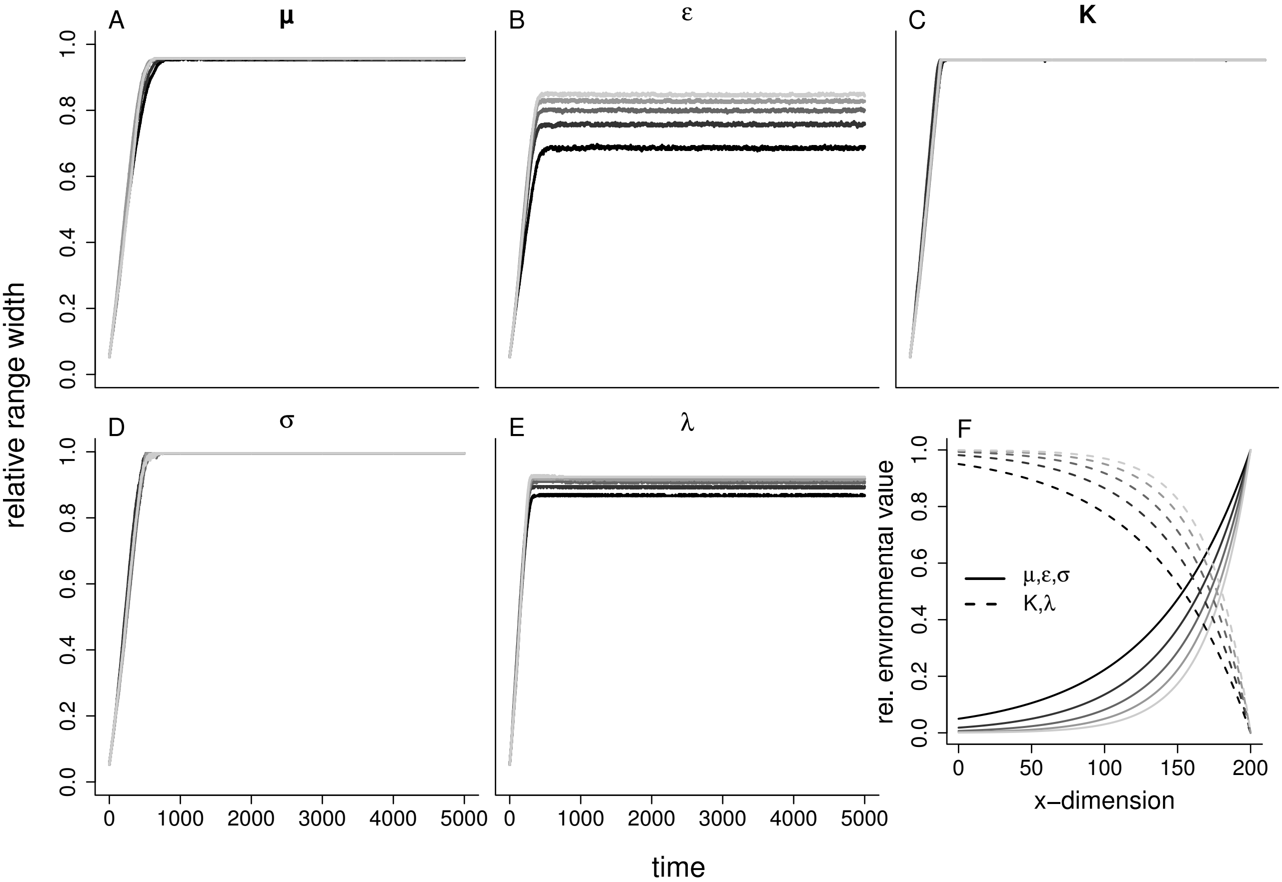

Figure A12: Concave decrease in fitness. Range border position as a function of simulation time for gradients in A) dispersal mortality (μ), B) catastrophic extinction risk (ϵ), C) patch size (K), D) demographic stochasticity (σ) and E) growth rate (λ). The local values of all gradients, $g(x)$, are given by $g(x) = g(x_1) + \frac{(g(x_{max})-g(x_1))\cdot e^{\gamma \cdot x}}{e^{\gamma \cdot x_{max}}}$, with $g(x_{max})$ defining the respective environmental value at $x = x_{max} = 200$, $g(x_1)$ the value at $x = 1$ and γ giving the slope of the gradients. All extreme gradient values (i.e. $g(x_1)$ and $g(x_{max})$) are the same as in the previous appendix figures. No Allee effect is assumed for these simulations. The gray shadings denote the different slopes of the gradients, which are given by $\gamma = \{0.015, 0.02, 0.025, 0.03, 0.035\}$ (relative environmental values are shown in panel F). Relative range widths are averaged over 10 replicate simulations.

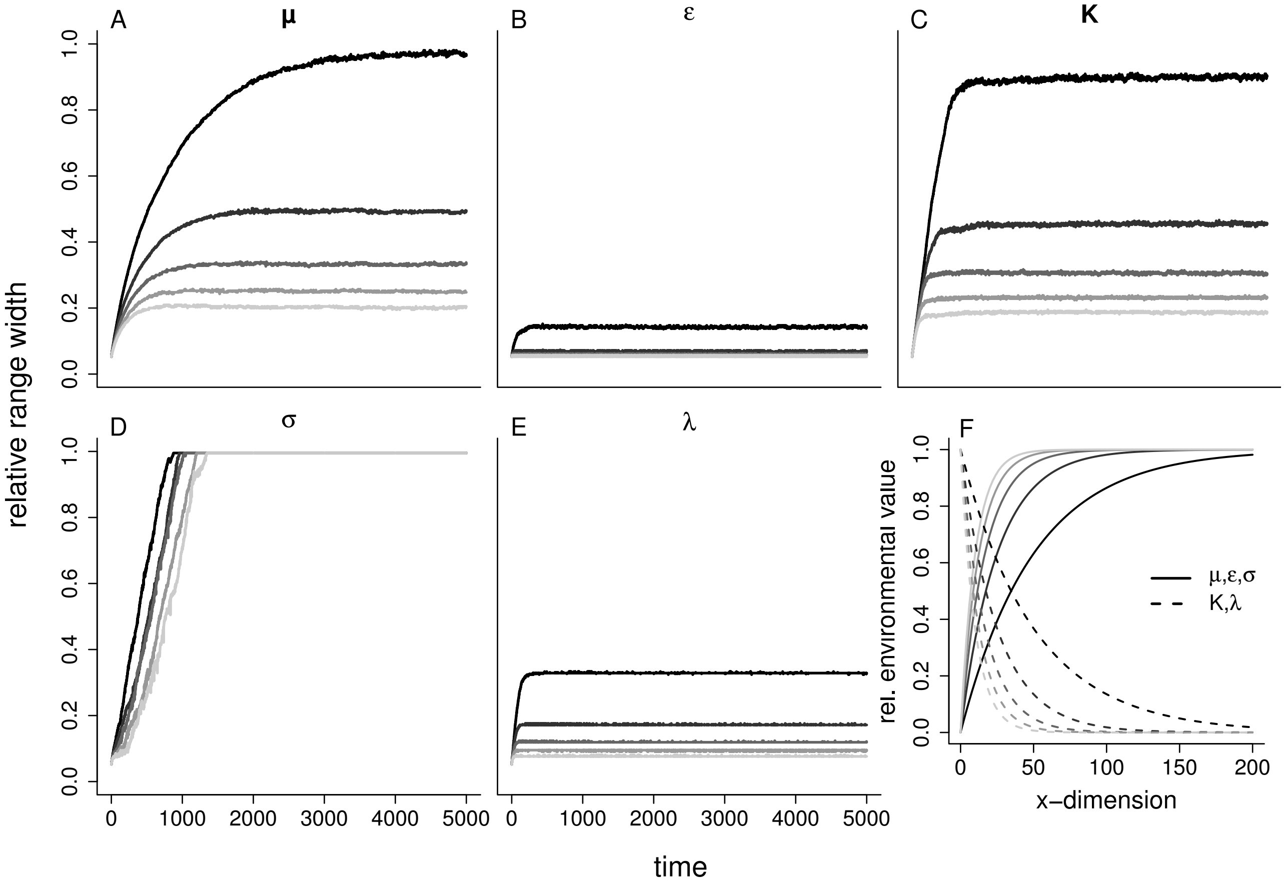

Figure A13: Convex decrease in fitness. Range border position as a function of simulation time for gradients in A) dispersal mortality (μ), B) catastrophic extinction risk (ϵ), C) patch size (K), D) demographic stochasticity (σ) and E) growth rate (λ). The local values of all gradients, $g(x)$, are given by $g(x) = g(x_1) + (g(x_{max}) - g(x_1)) \cdot (1 - e^{-\gamma \cdot x})$, with $g(x_{max})$ defining the respective environmental value at $x = x_{max} = 200$, $g(x_1)$ the value at $x = 1$ and γ giving the slope of the gradients. All extreme gradient values (i.e. $g(x_1)$ and $g(x_{max})$) are the same as in the previous appendix figures. No Allee effect is assumed for these simulations. The gray shadings denote the different slopes of the gradients, which are given by $\gamma = \{0.02, 0.04, 0.06, 0.08, 0.1\}$ (relative environmental values are shown in panel F). Relative range widths are averaged over 10 replicate simulations.

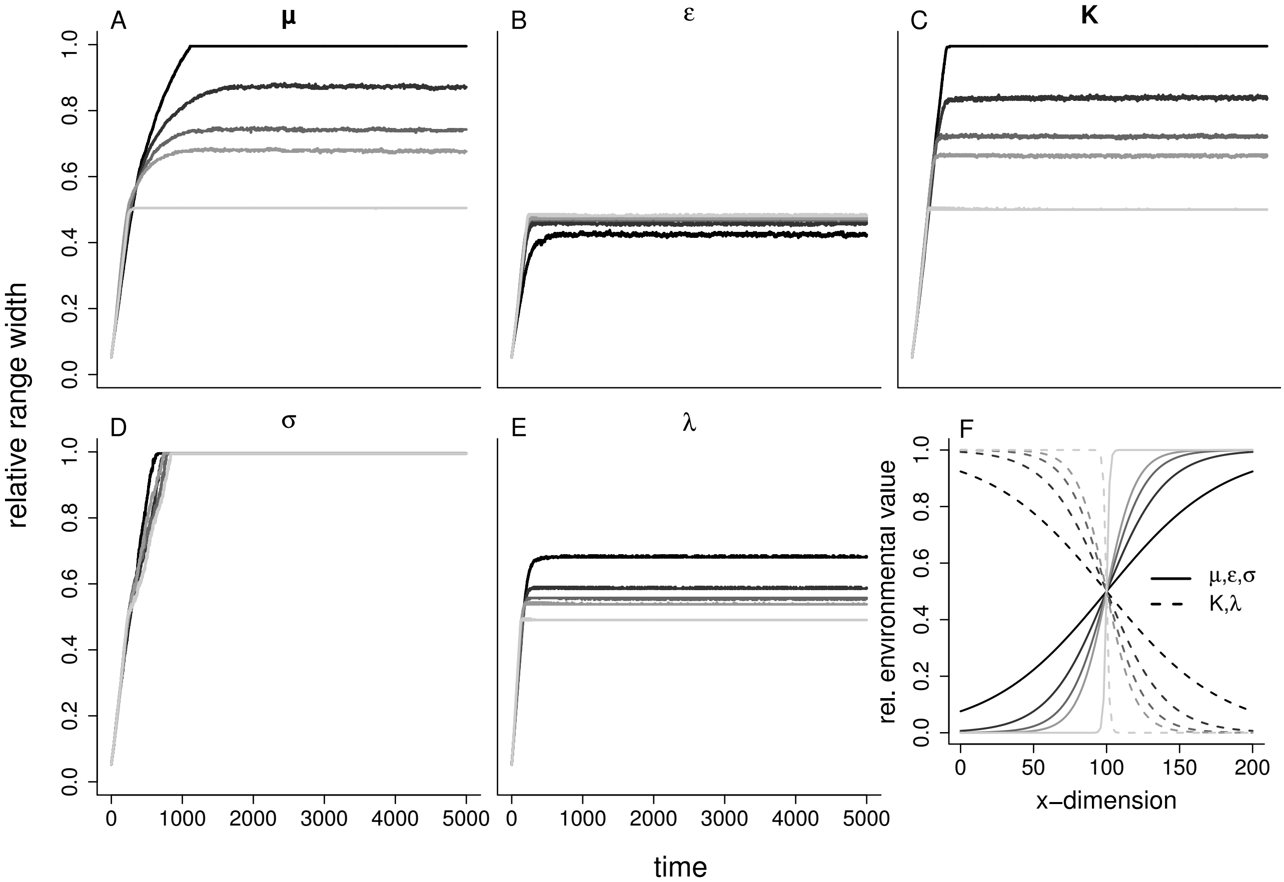

Figure A14: Sigmoid decrease in fitness. Range border position as a function of simulation time for gradients in A) dispersal mortality (μ), B) catastrophic extinction risk (ϵ), C) patch size (K), D) demographic stochasticity (σ) and E) growth rate (λ). The local values of all gradients, $g(x)$, are given by $g(x) = g(x_1) + \frac{g(x_{max})-g(x_1)}{1+exp(-\gamma \cdot (x-0.5x_{max}))}$, with $g(x_{max})$ defining the respective environmental value at $x = x_{max} = 200$, $g(x_1)$ the value at $x = 1$ and γ giving the slope of the gradients. All extreme gradient values (i.e. $g(x_1)$ and $g(x_{max})$) are the same as in the previous appendix figures. No Allee effect is assumed for these simulations. The gray shadings denote the different slopes of the gradients, which are given by $\gamma = \{0.025, 0.05, 0.075, 0.1, 1\}$ (relative environmental values are shown in panel F). Relative range widths are averaged over 10 replicate simulations.

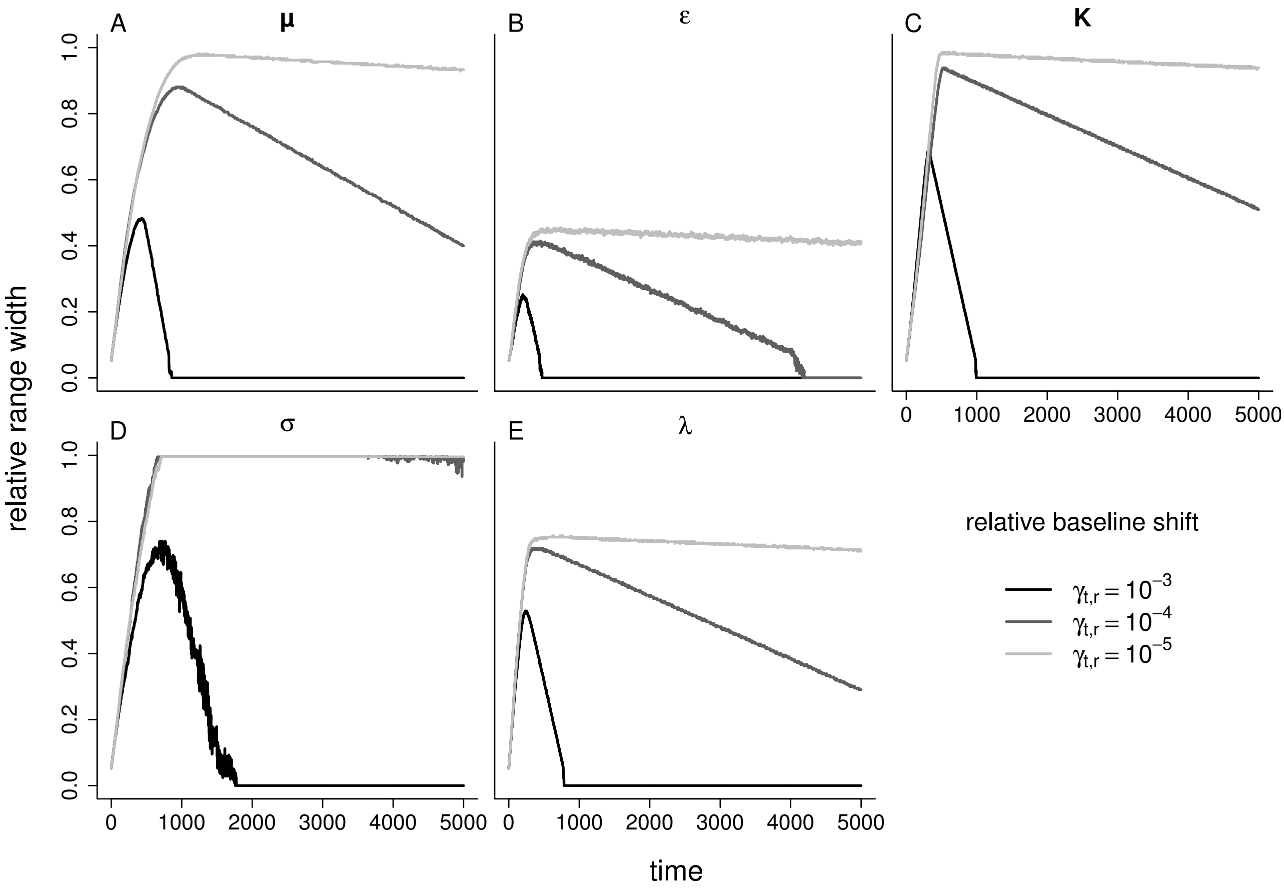

Figure A15: Temporal changes in linear gradients. Range border position as a function of simulation time for gradients in A) dispersal mortality (μ), B) catastrophic extinction risk (ϵ), C) patch size (K), D) demographic stochasticity (σ) and E) growth rate (λ). The local values of all gradients are initialized with the same values as in figures A1 - A10. Each generation, the local environmental conditions are added a number g_t (baseline shift), which is calculated as $g_t = \gamma_{t,r} \cdot (g(x_{max}) - g(x_1))$ with $\gamma_{t,r}$ thus defining the relative baseline shift. All extreme gradient values (i.e. $g(x_1)$ and $g(x_{max})$) are the same as in the previous appendix figures. No Allee effect is assumed for these simulations. The gray shadings denote the different slopes of the gradients, which are given by $\gamma = \{0.025, 0.05, 0.075, 0.1, 1\}$ (relative environmental values are shown in panel F). Relative range widths are averaged over 10 replicate simulations.