Oikos

OIK-05941

Berec, L. 2019. Allee effects under climate change. –

Oikos doi: 10.1111/oik.05941

Appendix 1

Temperature-independent carrying capacity in model (1)

Here I examine impacts of warming when the prey carrying capacity K in model (1) in the main text is temperature-independent. This is formally achieved by setting $E_K = 0$ in formula (3) in the main text. Results are plotted in Fig. A1 and discussed in the main text.

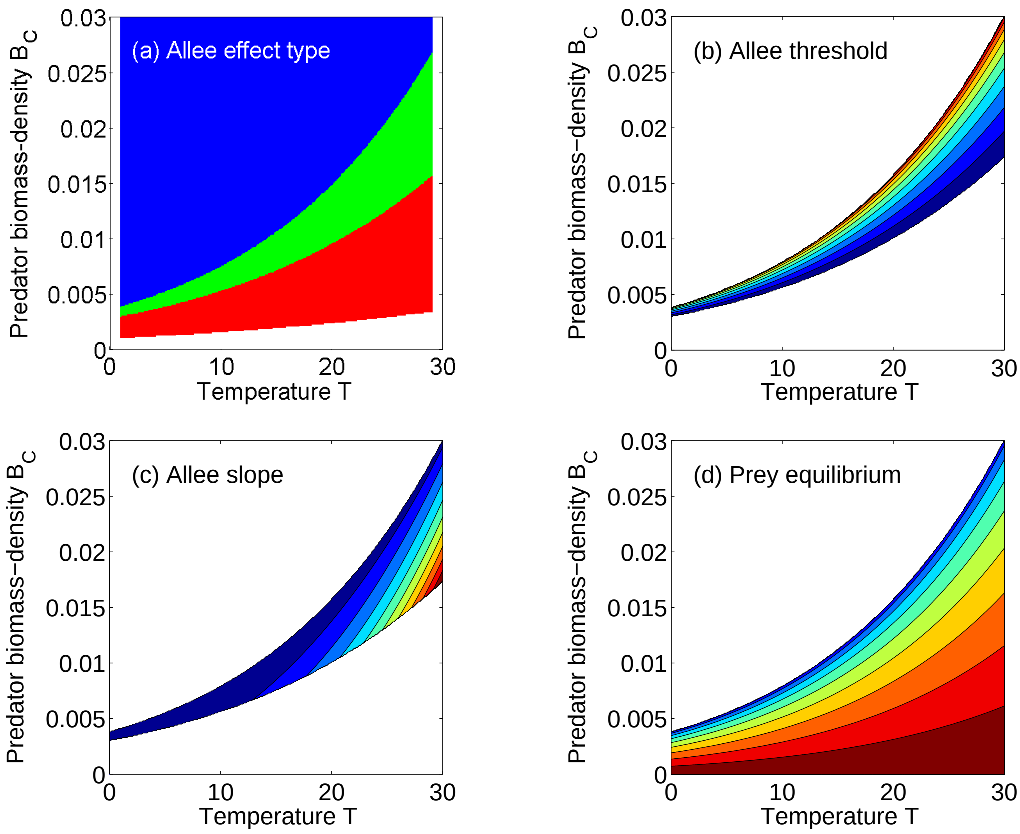

Figure A1. Dependence on the temperature T and the predator biomass-density B_C of the (a) Allee effect type, (b) Allee threshold, (c) Allee slope, and (d) prey positive stable equilibrium, when the prey carrying capacity K is temperature-independent (formally achieved by setting $E_K = 0$ in formula (3) in the main text). Other parameters as in Table 1; $m_R = 10^{-4}$g, $m_C = 10^{-3}$g. Color legend in panel (a): white = logistic-like growth, red = weak Allee effect, green = strong Allee effect, blue = fatal Allee effect. Color legend in panels (b), (c) and (d): the respective variable increases in the direction from dark blue to dark red.

Positively temperature-dependent carrying capacity in model (1)

Here I examine impacts of warming when the prey carrying capacity K in model (1) in the main text is positively temperature-dependent. This is formally achieved by setting $E_K = 0.58$ in formula (3) in the main text. This value was used by Osmond et al. (2017) in their study of predator-prey dynamics. Results are plotted in Fig. A2 and discussed in the main text.

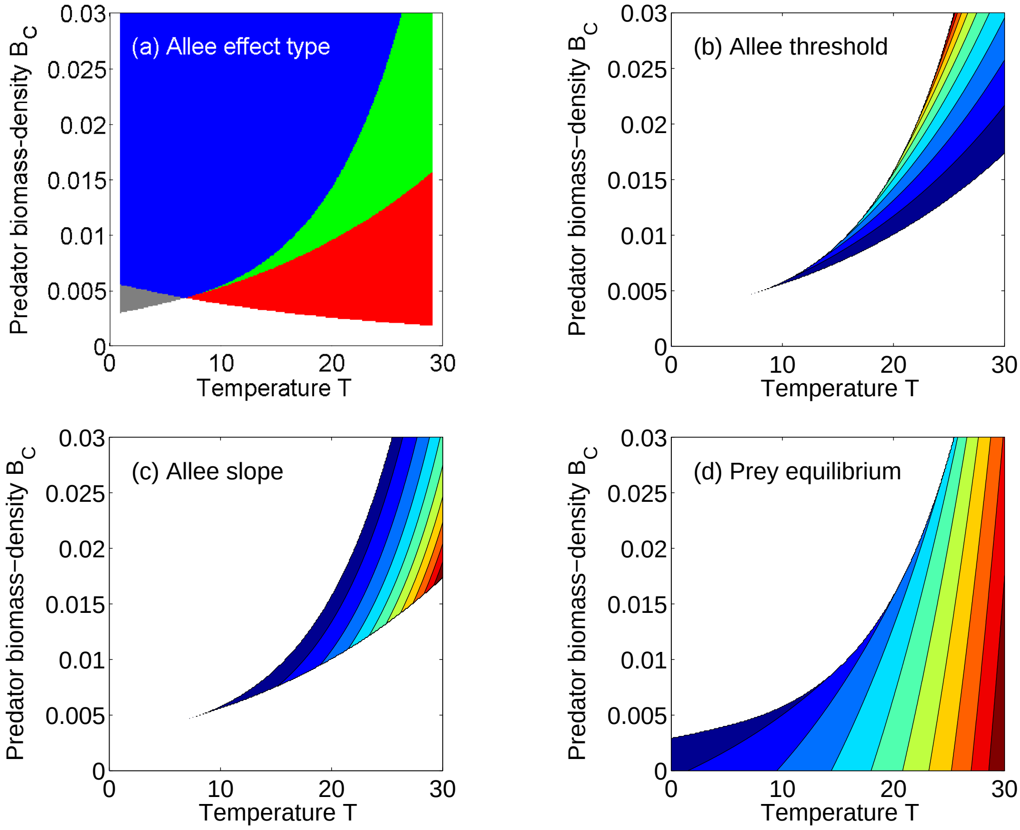

Figure A2. Dependence on the temperature T and the predator biomass-density B_C of the (a) Allee effect type, (b) Allee threshold, (c) Allee slope, and (d) prey positive stable equilibrium, when the prey carrying capacity K is temperature-independent (formally achieved by setting $E_K = 0.58$ in Eq. 3 in the main text). Other parameters as in Table 1; $m_R = 10^{-4}$g, $m_C = 10^{-3}$g. Color legend in panel (a): white = logistic-like growth, red = weak Allee effect, green = strong Allee effect, blue = fatal Allee effect, grey = decreasing per capita prey growth rate $g(B_R)$ (Eq. 7 in the main text) with all values negative. Color legend in panels (b), (c) and (d): the respective variable increases in the direction from dark blue to dark red.

Disregarding prey carrying capacity

Whereas all the other temperature-dependent parameters of model (1) in the main text describe a specific process, this is not the case of prey carrying capacity K. In particular, K is not a parameter linked to a specific process, but rather a complex outcome of population dynamics. Hence, its postulated temperature dependence may be controversial. I reformulate model (1) by assuming that the prey population grows exponentially. This is not a problem in the context of this study, since Allee effects affect population dynamics predominantly at low (biomass-)densities where within-species competition is likely comparably weak. I thus assume the population model

$$\frac{dB_R}{dt} = rB_R - \frac{aB_R}{1 + ahB_R} B_C. \tag{A1}$$

This model has one positive equilibrium, given by the formula

$$B_R = \frac{aB_C - r}{rah}, \tag{A2}$$

provided that $aB_C > r$ (predation is intense enough) and no positive equilibrium provided that $aB_C < r$ (predation is relatively weak). When the positive equilibrium exists, it is unstable and corresponds to the Allee threshold; prey are thus subject to a strong Allee effect. The case with no positive equilibrium corresponds to a weak Allee effect.

Using temperature dependences of the parameters r, a and h described in the main text, the Allee effect characteristics vary with the temperature T and the predator biomass-density B_C as plotted in Fig. A3. In particular, the effect of temperature is to weaken Allee effects from strong to weak and the effect of predator biomass-density is to strengthen Allee effects from weak to strong (Fig. A3a). Note that only weak or strong Allee effects may occur here, but otherwise the results stay comparable to those corresponding to model (1) with logistic prey growth. This is because the temperature at which strong Allee effects become weak corresponds to where the per-unit-biomass prey growth rate evaluated at the zero prey biomass-density, $g(0) = r - aB_C$, changes sign from negative to positive, and this critical value is not affected by presence of absence of the prey carrying capacity K.

Similarly to when the prey carrying capacity is present, when the Allee effect is strong, the Allee threshold is smaller (Fig. A3b) and the Allee slope is steeper (Fig. A3c) at higher temperatures. As a consequence, smaller Allee thresholds are more clearly distinguished: prey populations with biomass-densities just above those thresholds grow faster and hence escape from staying close to them more easily. On the contrary, larger Allee thresholds are more blurred: prey populations with biomass-densities just above those thresholds grow slowly and are thus vulnerable to extinction for a prolonged period of time, especially when subject to repeated perturbations (Meyer 2016).

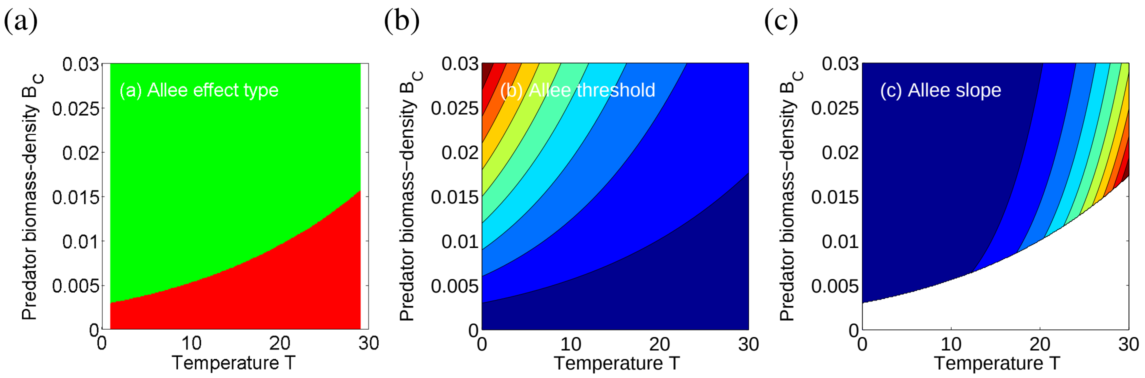

Figure A3. Dependence on the temperature T and the predator biomass-density B_C of the (a) Allee effect type, (b) Allee threshold and (c) Allee slope for the model (A1). Parameters as in Table 1 in the main text; $m_R = 10^{-4}$g, $m_C = 10^{-3}$g. Color legend in panel (a): red = weak Allee effect, green = strong Allee effect. Color legend in panels (b) and (c): the respective variable increases in the direction from dark blue to dark red.

References

Meyer, K. 2016. A mathematical review of resilience in ecology. – Natural Resource Modeling 29: 339–352.

Osmond, M. M., Barbour, M. A., Bernhardt, J. R., Pennell, M. W., Sunday, J. M. and O'Connor, M. I. 2017. Warming-induced changes to body size stabilize consumer-resource dynamics. – American Naturalist 189.