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Letter to the Editor

Negative correlation between dynamical complexity and metapopulation persistence: A reply

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Zhang et al. argue that the overcrowding effect with high intensity ($D \gg 40$, see Hui and Li, 2003 for definition) can stabilize the dynamics. Therefore, they insisted that the overcrowding effect can destabilize the dynamics when the intensity D is low and stabilize the dynamics when the intensity D is high. I agree with them about the lack of clarity with regard to the correlation between the overcrowding effect and its intensity D . However, I would like to stress in the following that the overcrowding effect is still “the key to incur chaos and increase the dynamical complexity”. A uniform correlation between dynamical complexity and metapopulation persistence will be obtained.

The definition of the overcrowding effect in a metapopulation is an overcompensating density-dependent rate of local extinction (Hui and Li, 2003). In terms of metapopulation, the extinction rate influenced by the overcrowding effect is $(e + (1 - e)p^D)p$, in which p is the metapopulation size (Fig. 1A). As Zhang et al. argued, the intensity D of the overcrowding effect loses its real meaning in the density-dependent extinction rate when $D \gg 40$. The term $1/D$ was proposed to be the index of the overcrowding effect. However, the term $1/D$ still cannot grasp the characteristic of the overcrowding effect. After reanalysis of the previous overcrowding effect, the real problem is an increasing equilibrium of the metapopulation size with the intensity D ($0 \leq D \leq 40$) [note that the equilibrium stop increasing if $D \gg 40$] (Fig. 1A). The contribution of Zhang et al. highlights the difficulty of introducing the overcrowding effect in metapopulation model. However, finding a problem is not the same as solving it.

Here, I give a new extinction rate of metapopulation that influenced by the overcrowding effect, $e(1 - e/c)^{1-b}p^b$ ($b \geq 1$) (b

is the intensity of overcrowding effect; see Fig. 1B). The equilibrium of metapopulation size no longer changes with the intensity b . Moreover, when the metapopulation size is larger than the equilibrium (i.e. when the extinction rate is higher than the colonization rate), the extinction rate with higher intensity b exceeds the rate with low intensity (Fig. 1B), which shows a stronger overcompensation caused by the overcrowding effect. Therefore, this new form of overcrowding effect properly solves the problem mentioned above.

The bifurcation diagram of the metapopulation size shows that the intensity of overcrowding effect, b , increases the dynamical complexity and decreases the mean of the metapopulation size (Fig. 2). This result confirms that the overcrowding effect is still the key to incur chaos in metapopulation dynamics (Hui and Li, 2003). Tests on other effects (including patch loss, patch isolation, habitat decay, Allee effect, and rescue effect) that associate with the new overcrowding effect do not change the primary results in Hui and Li (2003). Only the correlation between the overcrowding effect and metapopulation persistence should be updated to negative (see Table 1 in Hui and Li, 2003). Our previous conclusion is that “there is no uniform correlation between dynamical complexity and metapopulation persistence” because the dynamical complexity and metapopulation persistence oppositely respond to the change of other effects but respond equally to the overcrowding effect (Table 1 in Hui and Li, 2003). Now, a strong conclusion emerges, i.e. dynamical complexity is negatively correlated with metapopulation persistence. Empirical evidence has shown that endangered species fluctuate before going extinct, and the conclusion here gives a potential explanation.

(A)

(B)

Fig. 1 – The colonization rate (black lines) and the extinction rate (red lines) of metapopulation. (A) The colonization rate is $cp(1-p)$; the extinction rate is $(e + (1-e)p^D)p$ (Hui and Li, 2003). (B) The extinction rate is $e(1-e/c)^{1-b}p^b$. Parameter values: $c = 0.5$ and $e = 0.1$ (for interpretation of the references to colour in this figure legend, the reader is referred to the web version of the article).

Fig. 2 – The bifurcation diagram of the overcrowding effect (described by the intensity parameter b) in metapopulation ($c = 0.5$ and $e = 0.1$). Red line indicates the mean of the metapopulation size (for interpretation of the references to colour in this figure legend, the reader is referred to the web version of the article).

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