## Solving the SLOSS debates on designing natural reserves under the evolving metacommunity framework


### Abstract

After the theory of island biogeography, Diamond proposed a classic design of natural reserves in 1975 and he believed it would be better to build a single large reserve, rather than several small ones, which further triggered the SLOSS debate (Single Large or Several Small?). Here, the SLOSS debate argues whether a single large natural reserve is better than several small reserves as SL > SS, or otherwise, as SL < SS. This debate remains unresolved. However, the strategy of designing a single large natural reserve has been usually adopted in all practices. During the early stages of the debate, there was little mechanistically understanding of general patterns of biodiversity in community ecology at large spatial scales, which is the cornerstone in solving the debate. For decades, with the shift in community ecology from local to regional scales and the development of evolutionary ecology, modern theories such as metacommunity ecology and rapid evolution have been proposed, and provide foundational theoretical guidance for resolving the SLOSS debate.

Under the evolving metacommunity framework, we developed an individual-based model in Python for simulating community assembly with population demography and genetics of multi-species in a metacommunity landscape. Three spatial scales are assumed in the model, from locally to regionally in the metacommunity, i.e., habitats scales, patches scales and global scales. Two dispersal pathways are assumed, i.e., dispersal among patches and dispersal within a patch. Setting different degrees of the fragmentation of the landscape as a parameter in the model, we tackled the SLOSS debate by simulating the model in a parameters space of multiple dispersal levels, cross-habitat heterogeneity levels, and patch disturbance levels. We found that (1) when the level of dispersal among patches is close to that of dispersal within a patch, SL ≈ SS. (2) When the level of dispersal within a patch is weigh higher than that of dispersal among patches, there exist two circumstances. If the organisms undergo asexual reproduction, SL>SS. If the organisms undergo sexual reproduction, it is tended to be SL<SS. (3) If the cross-habitat heterogeneity in a metacommunity landscape is low, then SL>SS, otherwise, SL<SS. (4) From low, intermedium to high levels of disturbance in the patches of the landscape, it is tended to be SL>SS, SL=SS or SL<SS, respectively.

The mechanisms and eco-evolutionary processes underlying the results patterns could be (1) the monopolization effect (i.e., priority effect mediated by evolution) and the spatial spread of monopolization species from local to regional scales is the main factor in reducing biodiversity in a metacommunity; (2) under sexual reproduction, species are more prone to rapid evolution, exacerbating the monopolistic effect; (3) if there are more transitional habitat types between patches, these habitats can act as "stepping stones" for the spatial and evolutionary spread of monopolization species; (4) under conditions where monopolization effects are likely, several small patches can hinder the spatial spread of monopolization species; (5) several small patches have a risk-sharing effect, which is beneficial for biodiversity protection when patches are subject to strong disturbances. This study showed that the answer to SLOSS debate is context-dependent. The optimal natural reserves not only depend on reserve area but also on life-history, evolution, and dispersal of the organisms.



**Keywords**: Evolving metacommunity, reserves design, individual-based modeling, SLOSS, monopolization effects