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Effect of functional form of interaction on evolution of cooperation

Intraspecific cooperative interactions are widely observed in various taxonomic groups. Evolutionary processes of cooperative level have been well studied by using adaptive dynamics. Those studies generally assumed that a consequence of cooperation is a function of total investment from interacting players. However, an alternative functional form may be possible depending on substantial relationship among players. For example, the consequence can be summation or products of functions of each individual investment. We investigate the effect of functional form of interaction on evolution of cooperation.

In the analysis, we consider that n individuals interact each other in a local habitat, where i-th individual invest x_i resources for cooperation. The individual investment for cooperation linearly decreases its basal fitness. However, the cooperative investments within the habitat contribute to increase fitness of habitat members. We consider three types of fitness enhancement (benefit) functions, *i.e.* an additive investment ($B(\Sigma x_i)$), an additive effect ($\Sigma B(x_i)$) and a multiplicative effect ($\Pi B(x_i)$).

According to analysis of evolutionary dynamics, we found that evolutionary consequence depends on the functional forms of benefit. In the additive investment and additive effect cases, cooperative level always becomes monomorphic. In the multiplicative effect case, evolution can result in dimorphism in dependence on the functional form of $B(.)$, but never achieve polymorphism with more than two cooperative levels. When the assumption of linear cost is relaxed, it influences the result of additive investment case only, where polymorphism of cooperative level is possible.

Our analysis indicates that the functional form of interaction is an important determinant of evolutionary dynamics of cooperation.