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Inequality in resource allocation among individuals and population dynamics models

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The Hassell equation is a classic discrete-time population model which has been widely used to model population dynamics of species with seasonal reproduction. This equation is a generalization of the Beverton-Holt equation with an additional exponent, and can describe various types of reproduction curves exhibiting from exact-compensation (contest competition) to over-compensation (scramble competition) depending on the value of the exponent. The value of the exponent and the resulting density dependence is thought to be related to the degree of inequality in resource allocation among individuals; contest curves result from unequal resource allocation, and scramble curves, from equal allocation. However, as the model is a phenomenological one at the population level, this relation between the exponent and the inequality in resource allocation has mostly been discussed only phenomenologically. Although some authors have actually derived the Hassell equation from first-principles by considering specific competition models among individuals, the exponent of the derived models does not match the naive expectation above. This study explores whether it is possible to derive from first-principles such a Hassell model that its exponent is related to the inequality in resource allocation by considering resource competition among individuals. I demonstrate that such a Hassell model can indeed be derived by assuming that each individual obtains a constant amount of resources (a resource unit) at a time, and that the competition for such a discrete resource unit among individuals is repeated many times. Different sizes of the resource unit generate different degrees of inequality, and the exponent of the derived model turns out to depend on that size, thus being related to the degree of the inequality. The derived model reduces to the Beverton-Holt model when the inequality is highest, and to the Ricker model when the inequality is lowest. Finally, I discuss how replacing an assumption on fecundity with more realistic one changes the functional form of the derived model, and the extension to two-species competition models as well.

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