

Evolutionary dynamics of predator in a community of interacting species

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Motivation and Aim: This paper proposes an ecological-genetic model of “predator-prey” community that explicitly describes the Mendelian inheritance mechanism for a trait of predator lifecycle. When modeling, we were motivated by the “arctic fox – mouse-like rodents” community which is an example of interspecies interaction of “prey – predator” type. To describe such a community, one has to consider along with ecological variables the predator genetic structure as well, as litter size being one of the most important traits of arctic fox lifecycle is genetically determined by a single diallelic locus [1]. Thus using a single locus diallelic model of inheritance is not unnatural for the considered case. With limited food resources, which corresponds to a low density of rodent population, pups' survival in large and small litters of Arctic foxes differs, therefore the considered locus determines both the birth rate of Arctic fox population and the survival rate of its offspring. At the same time, the survival rate of Arctic foxes, especially in large litters, significantly depends on prey population size as their food supply. To model it, we introduce a functional dependence of the fitness of predator genotypic groups on the prey population size instead of the constant ones used in classical papers [2, 3]. This study focuses on the explicit dependence of predator genotype composition and, accordingly, its birth rate on the prey abundance.

Methods and Algorithms: We propose a discrete-time model of predator-prey dynamics with Holling type II response function and Verhulst low of density limitation of each population in the community [4]. Predator evolution is considered by taking into account Mendelian inheritance of a lifecycle trait of the diploid predator by a single diallelic locus. In accordance with r-K-selection, the predator genotypes' fitnesses functionally depends on the prey abundance, thus its genotypes differing in reproductive potentials adapt unequally to food resource limitation. The proposed model is analytically and numerically studied, including research on stability, the construction of phase and parametric portraits, and bifurcation analysis. We use dynamic mode maps to study stability domains of fixed points, bifurcations, and evolution direction for the model.

Results: The proposed model demonstrates periodic, quasiperiodic and chaotic oscillations as well depending on the values of model parameters. Bistability of the monomorphic states is shown to appear provided a reduced fitness of the heterozygote, thus current genetic composition of the predator determines not only direction of its genetic evolution but the mode of population dynamics too. The model also demonstrates multistability with several alternative coexisting attractors, and initial conditions determine which of them attracts the system trajectory. Note that the attraction basins of coexisting monomorphic states can show fractal structure. Thus even little variation of predator or prey abundance due to accidental external influence can change the dynamics

mode of the community populations' numbers. Such a variation does not change the evolution direction, because it does not influence the predator genetic composition. However, a drastic change in the predator abundance with restructuring of its genetic structure can shift the evolution direction. The possibility of polymorphism existing at reduced heterozygote fitness with fluctuations of both the community populations' sizes and predator genetic composition turned out to be unexpected, because this phenomenon violates the classical evolutionary scenario. Such a polymorphism appears due to the genotype fitness dependence on a current prey abundance that can either stabilize or fluctuates about equilibrium changing the genotypes' fitnesses. With a heterogeneous predator in its fertility and adaptation to limited food resources, different phases of prey dynamics correspond to opposite direction of natural selection in the predator population. Thus fluctuating prey abundance can result in oppositely directed natural selection in the predator population that alters the ratio of its genotypes' fitnesses. Here one can see radically different scenarios of the predator evolution caused by various birth rate of the prey. Note that such a phenomenon is seemed to be characteristic for natural populations when more fecund genotypes of the predator require more food resources like in arctic fox populations, for instance. So, with a low birth rate in the prey population, eliminating of homozygotes with high reproductive potential and food requirements occurs in the predator population with monomorphism establishment to follow. A higher birth rate of the prey reverses the natural selection direction against those homozygotes that were winners in the previous conditions, and more fecund prey creates conditions for the predator to fix both its alleles. Such a polymorphism is characterized by long processes of elimination and accumulation of alleles without complete loss of any of them, in addition, one can see significantly different dynamics of the population sizes in the different phases of the process, which can be recognized by an observer as a change in the population dynamics mode of any species of the community.

Conclusion: Such a fluctuating polymorphism seems to exist in natural populations of inland arctic fox, because recessive inheritance type of small litters in this species excludes possibility of overdominance resulting in stable polymorphism, and only vast fluctuations of rodents' abundance being the main food of arctic foxes change natural selection direction in predator population and prevent loss of its genetic variety. At the same time, in the opposite dynamics phases of predator genetic composition, its consumption affects the prey population in different ways, which can already change the prey dynamics mode. It is an influence which can be a reason for the observed change in the dynamics mode in natural populations of rodents.

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