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Modelling the trait in fear of predators

Recent fields experiments on fear effect of prey due to predators show that anti-predator defence may reduce the reproduction of prey. Based on these observations, a predator-prey model is proposed which incorporates the cost of fear in prey production. Mathematical analysis show that high levels of fear (or equivalently strong anti-predation behaviours) can stabilize the predator-prey system by excluding the existence of periodic solutions. However, relatively low levels of fear can induce multiple limit cycles via subcritical Hopf bifurcations, leading to a bi-stability phenomenon. Compared to classic predator-prey models ignoring the cost of fear where Hopf bifurcations are typically supercritical, Hopf bifurcations in our model can be both supercritical and subcritical by choosing different sets of parameters. Numerical simulations are conducted to explore relationships between fear effect and other biologically related parameters, which further demonstrate the roles that fear play in predator-prey interactions. For example, it is found that under the conditions for existence of a Hopf bifurcation, increase of fear level may alter the direction of Hopf bifurcation from supercritical to subcritical when the birth rate of prey varies accordingly. Simulations also show that the prey is less sensitive in perceiving predation risks with increasing birth rate of prey or increasing death rate of predators, but demonstrates stronger anti-predation defense with larger attacking rate by predators.