Mathematical Modeling for Variation Factors of Persian Gazelle's Population in a Wildlife Environment

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Abstract

Evaluating Persian Gazelles' population can improve our understanding about the population fluctuations of large mammals in eastern Iran. The present article showed that the most important threatening factors for the population reduction of Persian Gazelle are natural and human-wise parameters. In the present research work, we consider an animal population concluding some parameters in that, such as illegal hunts, preferential migration and road's collision, which have negative impacts on animals' population, all of them are considered as disturbing factors. By constructing some hypothesis, we model a population model of single species. After analyzing the obtained model, we can study the Gazelle's population on the respective hunting prohibited region.

Keywords: Gazelle population, Differential Equations, Equilibrium Point
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1. Introduction

One of the most symbolic species of Iran's wildlife is the Persian Gazelle (Gazella subgutturosa) which its population significantly declined during the last decades due to several factors such as illegal hunts and habitat destruction, so that currently, the mentioned animal has placed among the protected species of Iran's Environmental Protection Agency and has inserted at the Vulnerable Class (VU) of IUCN Red List (Ashouri et al., 2017). Numerous studies have shown that several factors influence its population dynamic changes and even the herds' physiological parameters and its biological reactions may stimulate the population's fluctuation in a distinctive area (Malekian et al., 2020).

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The study district enjoys a semiarid climate with an area of 108,000 hectare of hunting prohibited region located on the east of Khorasan Razavi province and on the border of Iran and Afghanistan. The region consists of two mountainous and plain lands. The predominant vegetation species of the area include Salsola spp, Scariola orientalis, siberi and Euphorbia spp. Lacking the systematic census and only based on the direct observations of rangers, the number of Persian Gazelle in the area is estimated between 350 to 400 animals which despite the supportive strategies, it seems to partially decline due to the shortage or undesirable forage, reduction of drinking water supplies, human interventions and unavoidable migrations. Periodic visits were conducted in accompany with knowledgeable experts and environmental NGO'S, in addition to library studies and questionnaires distributed among the road drivers and local people.

In general, the purpose of this study is to investigate the causes of Gazelle's population changes and modeling the relationship of some of these parameters with the population decline of this species. In an overview, the threatening factors affecting this animal's population included two categories of natural-wise and human-wise reasons. The main natural reasons are: unfavorable habitat, the non-sustainable climate conditions such as the continuation of drought periods, the presence of large carnivores such as leopards and wolves, age and sex structure of the species, reproductive failure rate, physiological weakness leading to natural mortality and preferential migration of herds to neighboring areas such as Afghanistan;

Considering the human-wise reasons, the main causes were: illegal hunts (leading to gender ratio change), destruction of natural habitats (such as expansion of human settlements, roads troubles, innovations and agricultural lands, and intensification of livestock grinder pressure on pastures leading to destructive competition), stray dog attacks especially for young Gazelles near to rural settlements and agricultural fields, road casualties and other human-centered causes such as deer dispersion, falling into a water pools, trapping in enclosed spaces, swallowing deadly waste, etc.

2. Modeling and Discussion

In the following, we consider a single-species model for deer population (Rahmani Doust et al., 2021, 2020 & 2015). In this model, we enter some parameters such as illegal hunts, preferential migration of herds to neighboring habitats and collisions with road vehicles that have a negative impact on animal mortality. It is assumed that deers, in the absence of above factors, have a logistic growth rate, about the two factors of illegal hunts and collisions with road vehicles, although both of them cause animal deaths, the decrease in deer population has no effect on increasing the number of poachers and vehicles. In fact, these two factors appear in the role of disturbing factors. Now, we consider some following hypothesis:

- The independent variable t and dependent variable x represent time and number of Gazelle population, respectively.
- Parameter a shows the exponential growth rate of deer population.

- Parameter b illustrates the logistic growth rate of deer population.
- Parameter c_1 shows the impact factor of road casualties on deer population.
- Parameter c_2 indicates the coefficient of impact of migration on deer population.
- Parameter c_3 demonstrates the impact factor of illegal hunts on deer population.
- Parameter K indicates the maintenance capacity of the environment for the deer population.

By considering the above assumptions, the following model may be obtained:

$$x' = x\left(a - \frac{bx}{K} - c_1 - c_2 - c_3\right) \qquad (1)$$

Since the parameters c_1, c_2 and c_3 are considered constant, after simplifying, model (1) may be written as follow:

$$x' = x(a - \frac{bx}{K} - c) \qquad (2)$$

The above equation has trivial equilibrium point which is origin. Moreover, model (2) has nontrivial equilibrium point which is $x = \frac{K}{b}(a - c)$.

By analyzing the equilibrium points of equation (2), we are able to study the deer population. The analysis of results shows that the situation of Persian Gazelle herds in the study area, like other herds in the protected areas of Khorasan Razavi province, is in a defensive model (WT) and urgent management strategies and supportive mechanisms should be applied and implemented to maintain the population reductive factors at the lowest level of threat (Modoodi et al., 2016).

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