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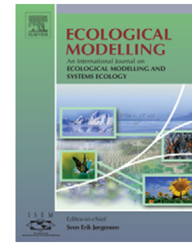

Modeling a wetland system: The case of Keoladeo National Park (KNP), India

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ABSTRACT

A model for the wetland part of KNP is presented and analyzed. Two-dimensional parameter scans suggest that this minimal model possesses dynamical complexities. Per capita availability of water to “bad” biomass (W_1) is one of the most vital parameters. One can ensure good health of the park by restricting the par capita availability of water to low values. Getting the “bad” biomass removed by granting permits to villagers should go hand in hand with water management and conservation activities. The model presented in this paper may be helpful in designing the timing and nature of human interventions in the form of implementation of well worked out policies in future.

1. Introduction

The Ramsar convention adopted the following definition of wetlands. Wetlands are areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary with water that is static or flowing, fresh, brackish or salty including areas of marine water, the depth of which at low tide does not exceed 6 m. This definition suggests that wetlands could give rise to varieties of values. Wetlands also act as pollution assimilation agents for nitrate pollution created by up-stream agriculture. Thus they provide a positive externality benefit. The aquatic system of KNP belongs to such a system.

There are various kinds of wetlands. Some well-known wetland types are (1) fresh water coastal wetlands, (2) flood-plain wetlands and (3) constructed wetlands. The aquatic part of KNP belongs to the second category. It has been found that tourist traffic and ecological value of the park are non-linearly related. Chopra and Adhikari (2004) have shown that conservation efforts increase the attractiveness of the park beyond a certain level. They have also indicated that the impact may be cumulative and, therefore, more than proportionate income is expected.

The Keoladeo National Park is a man-made system. It is located on the Indo-Gangetic Plain near the town of Bharatpur(27°13′N, 77°32′E). It is a Ramsar and designated World Heritage site. It has an interesting history. This man-made park was declared as National Park in 1981. The relative importance of three constituent ecosystems (wetland, grassland and woodland) has evolved over time. This evolution has been primarily driven by human interventions over more

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than hundred years now. The wetland area of the park covers a central depression of about 8.5 km^2, which is divided by dykes into a number of compartments or blocks. Apart from rainfall, the park receives water released into it through the Ghana canal. This canal originates in the Ajanbund, a seasonal reservoir of water to the south of the park. The seasonal floods in the northern rivers upstream cause the annual inundation of the park.

The economic value of the park emanates primarily from the presence of two kinds of birds: resident and migratory. The seasonal rainfall and the water that is let into the park in July–August initiate a period of increased biomass growth. The tourism value of this park is determined by its wetland nature. It provides a large habitat for birds among which the migratory species, namely, the Siberian crane, constitutes the flagship species. The biomass is divided into two categories with reference to the migratory birds: “Good” and “Bad”. In 1985, a report from Bombay Natural History Society suggested that grazing *per se* was not damaging the ecology of the park. On the contrary, the excess growth of *Paspalum* restricted the growth of bulbs, tubers and roots (Vijayan, 1991). Avifauna such as Siberian cranes that fed on these found that their habitat had become less friendly. The probability of grassland fires also increased. This report by BNHS persuaded the management of the park to grant permits for villagers to enter the park for extraction of grasses in summer months. The issuance of permits started in 1986.

In course of time, the cost of the control of bad biomass by non-biotic means arose and the subsidy from the government also arose. This subsidy is viewed as the excess of expenditure over revenue collected by the management of the park. The most expensive item was the creation of open water bodies, which were the required habitats for several bird species including the Siberian crane.

The other notable human intervention that the KNP was subjected to after 80s was intensive agriculture in the catchment. The increased agricultural activities affect the wetland adversely in two respects: (a) a reduction in water flow into the park and (b) the deterioration in the quality of water due to the chemical fertilizer upstream. This also causes deaths of birds due to poisoning (Chopra and Adhikari, 2004). A better understanding of inter-relationships between population of birds and different kinds of biomass and the factors driving their change over time would enable us to take better policy decisions for the management of the park. One of the main objectives of the present paper is to present a model which can link up the ecological and economic values (use and recreation values) in such a way that a balance can be struck between the two. The paper presents a model of the wetland, which provides clear perspectives on future management strategies and policy decisions.

2. The model

A wild grass species *Paspalum distichum* is the most dominant species, which depletes oxygen in the open water bodies in the park. The fishes and the water-fowl are the species most suffered. The other suffered species are that of floating vegetation: *Nymphoides indicum*, *Nymphoides cristatum*, *Nymphaea nouchali* and *Nymphaea stellat* (Shukla and Dubey, 1996). The *Paspalum* and its family acts as a “bad” biomass for the birds (resident and migratory) and floating vegetation. The floating vegetation and other useful species are clubbed together in the category “good” biomass. I propose the following model to describe the temporal evolution of the wetland part of KNP.

$$\frac{dG}{dt} = aG - bG^2 - cGB - d\frac{GP}{G+D} \tag{1}$$

$$\frac{dB}{dt} = eB - \frac{B^2}{W_1} - a_2GB \tag{2}$$

$$\frac{dP}{dt} = -\theta P + \phi\frac{GP}{G+D_1}, \tag{3}$$

where a is the reproductive growth rate of the “good” biomass (G) and b measures the severity of the intra-specific competition among individuals of “good” biomass. The ratio of a to b defines carrying capacity to good biomass. The carrying capacity is neither constant nor a continuously varying function; instead, takes a discrete set of values in simulations reported in the present paper. The d is the maximum of the rate at which the bird population (P) consumes the “good” biomass. D is a measure of the half-saturation constant. Similarly, e represents the rate of reproductive growth for the “bad” biomass (B) and W_1 denotes the per capita water availability for B. The parameters c and a_2 measure the intensity of competition between “good” and “bad” biomasses. The θ and ϕ are mortality rates and conversion coefficients for the bird species (resident as well as migratory). D_1 is the half-saturation constant appearing in the numerical response of the predator P. It may be noted that dynamics of G and P is cast as that of a system known as R–M system (Rosenzweig and MacArthur, 1963; Rai, 2004).

The underlying assumptions of the model are the following:

(1) The growth rate of the bad biomass is limited by the per capita availability of water.
(2) “Good” and “bad” biomasses are in competition for resources like nutrients, water, light, etc.
(3) The bird population dies out exponentially in the absence of the “good” biomass.

The second assumption represents a fact of KNP as both are part of aquatic fauna inhabiting the same wetland. The third assumption implies that birds feed only on “good” biomass. They hardly feed on any species, which have been clubbed in “bad” biomass. This assumption serves as a foundation stone

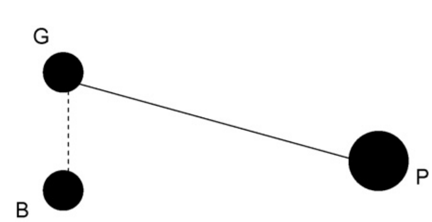

Fig. 1 – The basic interactions between the different components of the model.