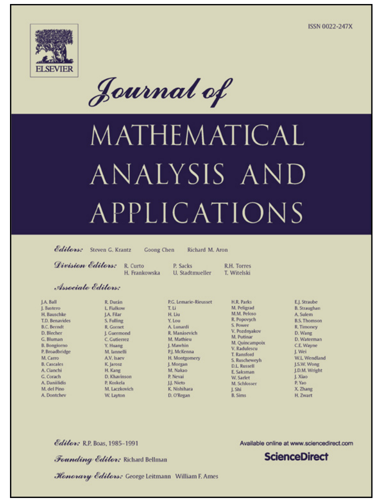


# Ecological Chaos and the Choice of Optimal Harvesting Policy

Ranjit Kumar Upadhyay, S.K. Tiwari

PII: S0022-247X(16)30744-2
DOI: http://dx.doi.org/10.1016/j.jmaa.2016.11.054
Reference: YJMAA 20907

To appear in: *Journal of Mathematical Analysis and Applications*

Received date: 9 May 2016

# Ecological Chaos and the Choice of Optimal Harvesting Policy

Ranjit Kumar Upadhyay*, S. K. Tiwari

*Department of Applied Mathematics*
*Indian Institute of Technology (ISM), Dhanbad–826004*
*Jharkhand, India*

**Abstract**

Harvested populations fluctuate because of two primary reasons: the inherent nonlinearity contained in the interactions among the constituent species and the forces of harvesting acting on the oscillatory dynamics resulting from species interactions. During the course of these fluctuations, population densities make excursions to low densities. When the ecological system executes chaotic motion, extinction–sized densities are common. Thus, it is imperative to design harvesting strategies which aim at maximizing economic gains giving due consideration to the ecological health of the concerned ecological system. The present study was designed and performed to figure out how to set harvesting strategies which optimize the economic gain. The choice of optimal harvesting policy can be made only if dynamical features of the concerned ecological system are well understood. In this paper, we have consider the temporal and spatiotemporal interactions among phytoplankton, zooplankton and fish population with Holling type II and Holling type III functional responses. We have calculated stability analysis of the model system and performed the numerical simulations for both non-spatial and spatial models to figure out the parameters that are responsible for chaotic dynamics the of model system. The temporal model system shows rich dynamics including limit cycles and chaos whereas spatial model shows different types of patterns for population distribution. In this work, we have taken the case study of Sundarban wetland ecosystem. We have carried out the analysis of maximum sustainable yield and identified the parameters that are responsible for good health of wetland ecosystem through numerical simulation results.

*Keywords:* Optimal utilization, Fishery resources, Economic gain, Ecological health
*2010 MSC:* 92D25, 39A30, 35B36

## 1. Introduction

Ecological systems have all the ingredients needed for the chaotic dynamics; e. g., palpable nonlinearity, multi-species interactions and feedback loop [47, 48]. Dynamics of an ecological system in chaotic state makes frequent excursions to low population densities [1]. Therefore, it is not advisable to harvest an ecological system at a constant rate. If the system is harvested at a variable rate then, other problems creep in. Fisheries biologists are interested in quantifying biological risks associated with resources on which related industries are based. Lande and co-authors [30] investigated sustainability of fluctuating populations in variable environments. Authors emphasize on uncertainty in estimation of population sizes and risk of resource collapse while discussing harvesting strategies that maximize yield while accounting for stochastic dynamics of interacting populations. Harvesting above a threshold population size helps to avoid the extinction risk of exploited

*Corresponding author
*Email address:* ranjit_ism@yahoo.com (Ranjit Kumar Upadhyay)