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FRACTAL ANALYSIS OF INDIAN RHINOCEROS POACHING AT KAZIRANGA

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Abstract

This paper deals with study of fractal properties of poaching statistics for Indian Rhinoceros at Kaziranga National Park. The statistics used for study comprises time series of total number of incidents of poaching of Indian Rhinoceros at Kaziranga yearly from 1965- 2016. The significance of studying poaching statistics of Indian Rhinoceros at Kaziranga lies in planning of conservation efforts at the national park for the ensuring the effective growth of species. Indian Rhinoceros according to IUCN Red list fall in the category of vulnerable species. The conservation efforts to promote their growth is severely impacted by the instants of poaching of Indian Rhinoceros due to growing demand of their horn in international market. The number of poaching incidents reported in 1992 was 49 which is the highest post 1965 which reduced to 3 during 2011. Despite of being in news for a successful conservation story the threat to Indian Rhinoceros posed by poaching persists as from 2012 the number of poaching incidents increased to 27 in 2013 and remaining at 19 in 2016. The Hurst exponent calculated for the times series is observed to be in range 0.5 which falls in the persistence range clearly indicating towards the increase in the incidents of poaching from 2012 onwards. It is concluded that a situation of dichotomy exists where on one side the species population growth is being encouraged while on the other side the menace of poaching in a persistent manner is posing severe threat to the species according to which the conservation efforts are to be taken more effectively to curb poaching menace.

Keywords and phrases: Kaziranga, Indian Rhino, Poaching, R/S Analysis, Dispersional Analysis, Fractal Dimension.
2010 Mathematics Subject Classification: 37C45

1 Introduction

Functional unit of nature where interactions between different species and the surrounding environment occur is defined as an Ecosystem. Evolution of the dynamics in an ecosystem is governed by the various species interaction. In an ecology, every species interaction has direct and indirect dependence on each others population growth with its own specific coefficient. In

nature the ecological cycles are getting affected and thus conservation of biological diversity has become a serious issue which requires immediate attention. In food chain every species has a crucial role and if a single species becomes extinct the whole food chain gets affected which disturbs the ecological cycles in nature. In developing nations like India, the issue of disturbance of ecological cycles day by day are becoming an alarming situation because due to rise in the human population and urban development, the forest covers are shrinking resulting either the wildlife species being extinct or endangered or vulnerable. In order to save these species and to maintain the biodiversity, national parks, wildlife sanctuaries and bio-reserves has been developed across the globe. In 1972, the first wild life protection act was enacted by the Indian Parliament enacted for the protection of plant and animal species with development of national parks in early 20th century A.D. For the conservation of one horned Indian Rhinoceros Kaziranga national park was developed in 1968 under Assam National Park Act of 1968 and is one of the oldest national park in India. The national park has an area of 430 square kilometer and is located in Assam, India 26o 40N 93o21E . In this national park almost two third of worlds great one horned rhinoceros are conserved and now it is a declared world heritage site. Four major rivers including the Brahmaputra and several small water bodies traverse the region of this national park. It has a marshland, dense tropical forest and huge stretch of tall elephant. Achieving success in wildlife conservation in 2006, it was also declared as Tiger reserve. In Kaziranga National park, along with Bengal Tiger and Indian Rhinoceros, Swamp Deer, Sambar Deer, Hog deer, Asian Elephant, Wild Buffalo and Wild Boar are the other major species which constitute the fauna of this ecosystem. In 1908 for the cause of rhino protection Kaziranga was the first area in Assam gazetted. As per the estimates obtained from census by Kaziranga Forrest, Assam Government website from 366 in 1966 to an estimated 2401 in 2016 Rhino numbers have risen. As two-thirds of the area in Kaziranga is covered with nutrient-rich grassland (Forest Department of Assam, 1993)it serves as an ideal habitat for Indian Rhinoceros.Kaziranga holds more rhinos than any other park or sanctuary in Asia and is the heaven for them due to its size and high carrying capacity. The two kilometer-wide Brahmaputra River on the northern side of the park acts acts as the boundary. As there are no natural barrier and borders of the park being porous, poachers enter Kaziranga easily as a result of which Rhinos arent safe anymore in this heaven. Most of the rhinos are killed with guns for the Rhino horn which has demand in international market due to its utilization in preparation of traditional medicines and therapy and thus is sold illegally at high prices causing these incidents of poaching. Post 1997 a reduction in incidents of poaching was observed due to increase in conservation efforts for saving the Rhinos from poaching which included increase in fencing and patrolling. As a result the incidents of poaching were brought in control and reduced to three incidents per year in 2003 as reported in [14]. But again 2007 it rose to 16 incidents per year while in 2013 it was 27 incidents. The reflection of this increase in incidents of poaching as discussed in [13]. At present from 17 incidents in 2015 the number of poaching incidents went up to 19 in 2016. The continuous increasing and decreasing trends in incidents of poaching with the growing time scale shows an impression of uncertain time series with abrupt high and low. Thus it is significant to study the properties of the time series of incidents of Rhino poaching to understand the evolution of the time series and dynamics that phenomenon of Poaching contains. The analysis of fractals has been used to study the time series helps in deciphering the dynamical properties inherent within the

biological signals. The fractal properties of the climate dynamics were studied using R/S Analysis in [12]. The dynamics of river water quality parameters were studied in [2]. In this research work Brownian motion was observed in different water quality parameters through fractal analysis. Similarly besides environmental sciences even in agricultural food prices the monofractal and multifractal analysis method was used in [18] in which weekly data of agricultural product price time series in China from 2003-2014 was studied. Fractal Analysis as another alternative and strong method for analyzing time series data was discussed in [3].Since the last decade fractal analysis has been used to analyze animal movements[15].The method has been applied in case of studying the animal movement patterns in response to environmental factors [19] and locomotion foraging behavior of wild primates[10]. The effect of poaching on metapopulation viability has been discussed in [5] through mathematical modelling and simulation. In this paper to study the fractal nature of the time series of the incidents of Rhino poaching in Kaziranga National Park, Assam both R/S Analysis and Dispersional analysis have been used to assess the complexity of the situation on ground and future conservation purpose.

2 Methodology

To study the fractal properties of time series of incidents of rhino poaching in Kaziranga in this paper both Dispersional Analysis and R/S Analysis methods have been employed . R/S Analysis Method is a nonparametric statistical method widely used for unifractal and monofractal analysis . The modern R/S analysis method is used for computing Hurst Exponent whose steps are as follows:

1. **Step1:** Split Time series $L = Lt,\ t = 1,\ 2, ...A$ into non overlapping segments $Da(a = 1, 2, A)$ of size or scale n, yielding A segments altogether. Denote every segment by li where $i = 1, 2, 3, ..n$ and denote the mean by $\bar{l}a$.
2. **Step2:** Calculate the cumulative deviation in each segment $Da(a = 1, 2, A)$ as follows:

$$L\hat{\beta}, a = \sum_{i=1}^{\beta}(L_{i,a} - \bar{L}_a), \beta = 1, 2, ..., n. \tag{2.1}$$

3. **Step3:** Find the Range R_a and Standard Deviation S_a of each segment given as follows:

$$R_a = \max(L_{\hat{\beta},a}) - \min(L_{\hat{\beta},a}), \tag{2.2}$$

$$S_a = \sqrt{\frac{\sum_{i=1}^{n}(L_{i,a} - \bar{L}_a)^2}{n}}. \tag{2.3}$$

4. **Step4:** Finally the rescaled range is averaged over all segments given as follows:

$$\left(\frac{R}{S}\right)_n = \frac{1}{A}\sum_{a=1}^{A}\left(\frac{R_a}{S_a}\right). \tag{2.4}$$

5. **Step5:** From power law $\left(\frac{R}{S}\right)_n = H^n$ where Hurst Exponent is represented by H while C is a constant and so from linear regression slope of $\log\log\left(\frac{R}{S}\right)_n$ and $\log(n)$, H is calculated from which fractal dimension D by relation $D = 2 - H$ is determined.

In Dispersional analysis standard deviation or variance is measured at successive different levels of resolution. Adjacent data points are grouped to create different levels. On taking successively larger groups with each data point replaced with the average of the group the resolution reduces. The steps for the method are as mentioned as follows:

1. **Step 1:** For $m = 1$ group size calculate the Standard deviation (SD) for Time series $L = L_t, t = 1, 2, ...A$.
2. **Step 2:** For $\tau = 2\Delta t$ binning period or group size $m = 2$, first create groups consisting of two adjacent data points. Calculate the SD of the means of the groups after evaluating the mean for each pair.
3. **Step 3:** Repeat the same procedure for $m = 4, 8, 16$, etc. till the number of groups, $n \leq 4$.
4. **Step 4:** After calculating SD for each m plot log $SD(m)$ versus $\log m$. If the signal is a simple fractal the plot gives a straight line. From slope of the plot evaluate $H = 1$+slope and then from H evaluate D (Fractal Dimension).

For the time series of the incidents of poaching of Rhinoceros the Hurst exponent (H) and Fractal Dimension (D) have been calculated using these two method.

3 Results

The data of incidents of Rhino poaching in Kaziranga National Park(KNP) was obtained from year 1965-2016 whose time series has been analyzed using R/S Analysis and Dispersion Analysis. The data ofRhinoceros poaching from 1965-1993 has been obtained from study by [16], from 1993-2005 has been obtained jointly from study in [13,14] while 2005-2015 and 2016 data have been obtained from official website of Kaziranga National Park, Assam Government and Wikipedia respectively.

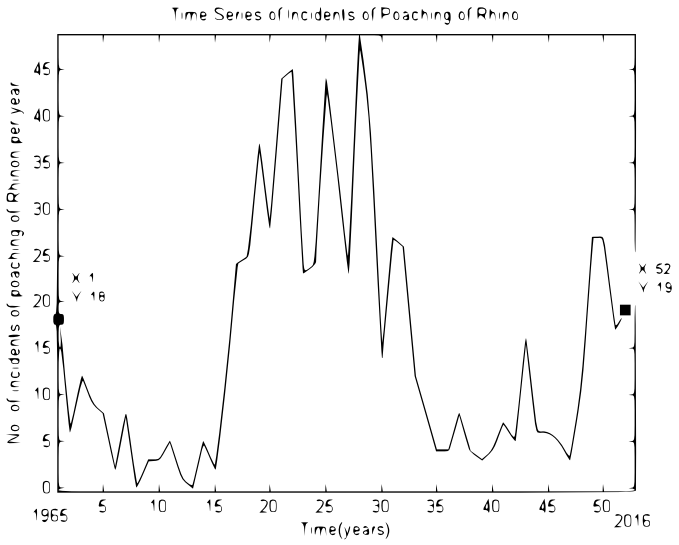

Figure 1: Time Series of Incidents of Rhino Poaching at KNP, Assam (1965-2016)

The time series of the data of incidents of poaching has been plotted in Figure 1. The Statistical properties are given in Table 1 while the fractal properties of the time series is mentioned in Table 2.

Table 1: My captionStatistical Properties of Time series of Incidents of Rhino poaching at KNP(1965-2016)

Variable	Mean	Standard Deviation	Kurtosis	Skewness
Rhino Poaching Incidents per year	15.32692	13.58881	-0.12106	0.957473

Table 2: Fractal Properties of Time series of Incidents of Rhino poaching at KNP(1965-2016)

Method	Hurst Exponet(H)	Fractal Dimension(D)
R/S Analysis	1.0	1.0
Dispersional Analysis	0.9	1.1

4 Discussion with Ecological Significance

Every ecosystem has its own well developed food chain cycles which connects species through interactions of competition and predation. These interactions help maintain a balance of both predator and prey population and thus its continuous and efficient functioning is crucial for the mutual sustenance of species and stability of the ecosystem.In Figure 4 the food cycle for Kaziranga ecosystem and interruption in the function of food chain by poaching activity is schematically shown. Most of the studies conducted till recent have focused mainly on patterns of animal behavior however fractal study of poaching time series in this paper gives a new insight to the persistent behavior of poaching phenomena of Indian Rhino in Kaziranga ecosystem.The activity of poaching of any one species disturbs the whole food cycle and thus destabilizes the whole ecosystem leading to its destruction by making species population vulnerable to level of extinction.

The study in this paper addresses this problem. As the population of the Rhinos reduce the grazing and predation cycles will get affected such that initially the swamp deer and tiger species will show some increase but beyond the carrying capacity the population for both will reduce due to infighting and starvation. Lack of resources force the tiger species to migrate and scatter at distant boundary areas making them more accessible to poachers who take advantage of porous boundaries of the national park. Thus maintenance of rhino population is essential as its continuous poaching affects the food cycle which in turn poses threat of death to other species due to infighting, starvation and poaching.

5 Conclusion

The data set for poaching of Rhinos at Kaziranga National Park (KNP), Assam has been obtained for the period of 52 years from 1965-2016. The Statistical properties and Fractal properties for this time series has been evaluated. For the time series of rhino poaching from both R/S Analysis and Dispersion Analysis the Hurst Exponent (H) is observed to be between 0.5 and 1 while Fractal Dimension (D) lies between 1 and 1.5 respectively. This indicate a long term positive correlated behavior which implies series is persistent and has long term memory. This further implies that as 2015 the number of incidents of Rhino poaching has again started increasing in coming years it is expected to increase. A situation of dichotomy exists where on one side the species population growth is being encouraged while on the other side the menace of poaching in a persistent manner is posing severe threat to the species according to which the conservation efforts are to be taken more effectively to curb poaching menace.It is significant that rhino species is conserved so that the food cycle remains unperturbed and functions properly for the stability of ecological system. Thus the conservation policies and measures are to be made considering the persistent increasing trend of the time series of poaching incidents to conserve the vulnerable Rhino species at

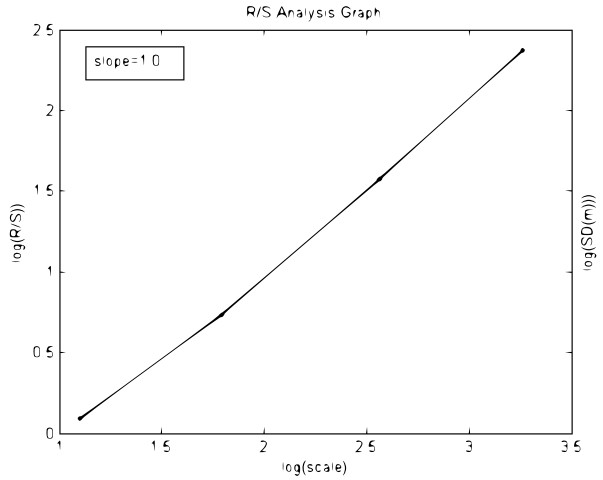

Figure 2: R/S Analysis Plot for Time series of Incidents of Rhino poaching at KNP(1965-2016)

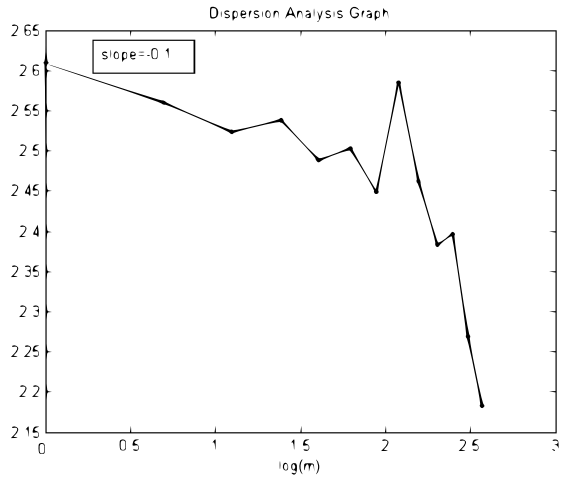

Figure 3: Dispersional Analysis plot for Time series of Incidents of Rhino poaching at KNP(1965-2016)

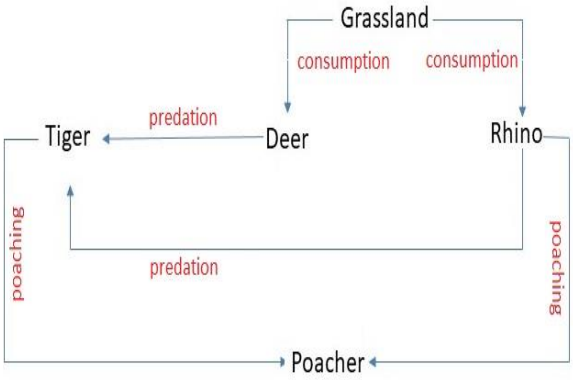

Figure 4: Schematic network diagram for Kaziranga ecosystem food chain

Kaziranga and promote their growth for it continues to keep its stature of being the heaven for Asiatic one horn Rhino.

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