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Research Output of Biological Science during 1901-1945: A Scientometric Analysis

Sanku Bilas Roy

Jadavpur University, Kolkata - 700 032, India
E-mail: sankub.roy@jadavpuruniversity.in

ABSTRACT

A scientometric evaluation of India's scientific productions in the field of biological science during 1901-1947 has been performed. The growth rate, authorship pattern, collaboration trend, and prolific researchers (male and female) of biological science literature is investigated. From the result it is found that the mean relative growth rate and duplication time is 0.615 and 1.007 respectively for the period 1901-1945. The calculated results follow the spirit of the 'Price Law' i.e. the coefficient of determination of the exponential plot is greater than that of the linear plot. About 75 per cent papers are single-authored and the degree of collaboration is 0.249. The Collaborative author index (CAI) for single author shows decreasing trend while for two author and more than two author shows increasing trend. The data set derived from this study follows Lotka's law of author productivity. The productivity of ten most productive researchers together contributed 15 per cent publication share. It is also found that the productivity of women researchers together contributed 0.62 per cent publication share in biological science research.

Keywords: Relative growth rate; Duplication time; Co-authorship index; Degree of collaboration; Lotka's law; Price law; Botany; Zoology.

1. INTRODUCTION

India has got a very old history of development in science. The scientific studies of the flora in India were carried out by the Portuguese during the sixteenth century. The Dutch Governor of Malabar, Henry Van Rheede spent a lot of years on scientific studies of Indian plants and thereby made significant contribution between 1686 and 1703 by publishing twelve volume under the title '*Hortus Malabaricus'*. However, with the arrival of J. G. Koenig, a Company's Natural Historian under the Madras Governemnt in 1768, scientific botany in India started to work. He founded the 'Society of United Brothers' for the promotion of natural history in India. By 1757, British supremacy was established in the country. The botanical garden at Shibpur, Calcutta was established in 1786 by the initiative of Colonel Robert Kyde, an army officer of British origin. With the establishment of the three universities in India in 1857, the science of biology took a new turn.

The Agri-Horticultural Society which was established by William Carey in 1820 is the landmark of the botanical research in India. Indian Forest Department (1864), Forest Research Institute at Dehradun (1870), the Botanical Survey of India (1889) played a vital role in the field of botanical research. The famous scientists of this period were William Roxburgh (1793), Buchanan Hamilton (1815), N. Wallich (1816), W. Griffith(1842), Hooker (1850-52), T. Anderson, G. B. Clarke(1890) and others. The foundation of the Indian Botanical Society in 1921 and the publication of its journal has been an additional stimulus to the progress of botany in India[1]. A considerable amount of work on the Indian plants had been done during the first half of twentieth century. Of these, the work of Bose, Iyenger, Bharadwaja, Agharkar, Sabnis, Dastur, Maheswari, Johri, Joshi, Banerji, Biswas, Bhaduri and Richaria may be mentionable.

The foundation of systematic zoology was organised by a handful of European ex-servicemen and amateur naturalists. Dutch naturalists like Artedi, Gronow, Lacepede, etc. made a significant contribution on Indian fishes during the eighteenth century. Thereafter, a long line of competent and devoted zoologists from Buchanan, McClelland, Sykes, Blyth, Day, Hodgson, to Falconer, Blanford, and Cautley raised Indian zoology to International standard[2]. In the initial phase, the Asiatic Society of Bengal and the Bombay Natural History Society were the pioneer organisation for proliferation of research activities in zoology. Then a number of collateral scientific institutes worked in fishery, sericulture, lac research, marine studies and a host of agricultural problems, were established. The Zoological Survey of India (ZSI) was established in Calcutta in 1916 where extraordinary work of much depth and dimension in identifying the animals by the handful of British naturalists as well as Indian zoologists. The contributions of Annandale, Chaudhuri, Hora, Bahl, Bhaduri, Mani, Mukherji, Pruthi, Aiyar, Mookerjee, Panikkar, Ramaswami and Ray among others during the first half of the twentieth century were notable one. After Second World War, some rapid development was observed in zoology in India.

The word "Biology", from Greek "life discourse", was introduced around 1800 by several authors to denote "the

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science of life", or "everything that pertains to living bodies"[3]. What we now call biology or the life sciences comprises a rich variety of research traditions and practices. The present study tried to depict a bird's eye view on the contribution of Indian researchers in the biological science disciplines exclusively in botany and zoology for the period between 1901 and 1947.

2. RESEARCH QUESTIONS

Data on 47-years period (1901–1947) for Indian researchers in biological science research is used to address the following research questions:

- What is the growth rate of biological science literature?
- Is Price's law of exponential growth applicable for the present study?
- What is the research profile of Indian researchers?
- What is the collaboration scenario among Indian researchers?
- What is the author productivity pattern in the field of study?
- Is the author productivity patterns follows the Lotka's law?
- Who are the most prolific researchers (male and female) in the field of study?

3. METHODOLOGY

The data for this study was collected from the Biographical Memoirs of the Fellow of the Indian National Science Academy, Indian Science Abstract (1935-1939), Biological Abstract, and the Zoological Record of the Zoological Society of London databases for the period of 1901 to 1947. The bibliographical points of all relevant articles/papers on the concerned aspects were noted and put into Excel sheets from which a simple working database was prepared. The data was tabulated and then analysed by various quantitative methods with the aid of MS-Excel and SPSS in order to satisfy the above mentioned objectives of this study. An extensive manual scrutiny of the collected bibliographic data had been done in order to eradicate ambiguities in case of author name and co-author name. The bibliometric indicators used in this study includes: Relative growth rate, Duplication time, Price's law, authorship pattern, Degree of collaboration, Co-authorship index, and Lotka's law.

4. LITERATURE REVIEW

There are various aspects of literature available on the origin and development of biological science in India. Noteworthy studies are by Kapil[4] who studied history of life sciences in India from the Ancient period to British period. Jaggi[5] revealed the aims of invasion of the Europeans particularly the British in India. The propagation of the fields like agriculture, zoology, veterinary sciences, mathematics, physics, chemistry, geography, archaeology, etc. as well as the development of technical and engineering education and research in India was also mentioned by the author. Bhattacharyya[6] observed the role of the Dutch and the British in case of modern botanical study of Indian plants during the seventeenth and eighteenth centuries. Jain[7] described the development and rise of the modern life sciences in India during the eighteenth and nineteenth centuries. Mathew[8] described the emergence of various botanical technologies such as botanical illustrations, economic botany especially regarding tea, rubber, sandalwood, tobacco, cotton, etc., botanical gardens and horticulture, forestry, ecology and conservation, pharmacology, museums and other education aids during the eighteenth-nineteenth centuries. Gopal and Zutshi[9] provided an overview of a historical perspective and progress in hydro-biological studies in India during the twentieth century. They mainly focused on gradual advancement of hydro-biological studies in India from the beginning of the 20th century to after independence period. Majumdar[10] illustrated the emergence and developments of botanical sciences from the period of Indus Valley civilisation to the twentieth century. Patra and Muchie[11] studied growth trends, authorship pattern, prolific authors, level of collaboration among authors as well as institutions and productive journals in pre-independent India on the basis of Scopus database.

In general, these studies present an overview of the evolution and transmission of knowledge of biological sciences in India over the period.

A number of bibliometric/scientometric analysis were carried out to investigate the status of biological science research in general as well as on its various branches.

Maheswarappa and Ningoji[12] analysed the growth trend of literature in biology in India for the period of 1965-89. The Indian Science Abstract was the source database for this study. The relative growth rate of biological science literature has consistently declined from 0.70 in 1966 to 0.06 in 1989. The doubling time of literature had increased consistently from 0.88 year in 1966 to 11.56 year in 1989. The growth of biological science literature in India (1965-89) follows neither modified exponential, logistic nor the linear pattern.

The trends of research in botany in India and abroad on the basis of different bibliometric aspects such as growth rate, authorship pattern, dynamics of collaboration, geographical distribution, citation pattern, etc. have been highlighted in a number of writings Maheswarappa[13], Mahapatra and Kaul[14], Sangam and Pratap[15], Varma[16], Mumtaz[17], Joshi, Kshitij, and Garg[18], Kumbar and Kumar[19,] Thanuskodi[20], Banateppanvar, Biradar and Kannappanavar[21].

There are various sorts of works on the research scenario of zoology in India and abroad analysed through the use of quantitative indicators. The noteworthy contributions made by Ghosh[22], Begum and Rajendra[23], Ramakrishna and Pangannaya[24], Nandi and Bandyopadhya[25], Banateppanvar[26], *et al.*, Garg and Kumar[27], Lakshmanan[28], and Sarvanan and Radhakrishnan[29].

5. ANALYSIS AND INTERPRETATION

For the period 1901 to 1947, 5610 record were collected from different databases (print as well as online) as mentioned in the scope of this study.

5.1 Relative Growth Rate and Duplication Time

Relative growth rate (RGR) refers to the value of the present growth in comparison with that of the previous year. The basic concept of RGR is based on work of Hunt[30] and Blackman[31] in Plant growth analysis. The mean relative

Table 1. Relative growth rate and duplication time

Period	No. of paper	Cumulative no. of paper	W1	W2	RGR	Mean RGR	DT	Mean DT
1901-05	11	11	-	1.041	-			
1906-10	27	38	1.431	1.579	1.579		0.438	
1911-15	66	104	1.819	2.017	0.585	1.082	1.183	0.811
1916-20	115	219	2.061	2.341	0.521		1.331	
1921-25	271	490	2.432	2.691	0.629	0.575	1.101	1.216
1926-30	451	941	2.654	2.973	0.541		1.281	
1931-35	1084	2025	3.035	3.306	0.652	0.569	1.062	1.171
1936-40	1529	3554	3.184	3.551	0.515		1.343	
1941-45	1515	5069	3.181	3.704	0.521	0.518	1.331	1.337

growth rate [R (1-2)] over a specified period of interval can be calculated from the following equation.

$$\text{Relative Growth Rate (RGR)} = \frac{W2-W1}{t2-t1}$$

where W1 – Log of initial number of papers; W2 – Log of final number of papers; t1 – Initial year/period; t2 – Final year/period

On the other hand, Duplication time refers to the time (years) it takes a subject to duplicate its production. The equation for the duplication time is viz.:

Duplication time (DT) = 0.693/R

It is seen from the (Table 1) that the mean relative growth for the first ten year (i.e. 1906-1915) showed a growth rate of 1.082 whereas for the last ten year (i.e. 1936-1945) it was reduced to 0.518. The corresponding mean duplication time for the period increased from 0.811 to 1.337.

5.2 Application of Price Law

Price's Law[32] is broadly used indicator of productivity used in assessing the productivity of a particular discipline or country. To evaluate exponential trend of growth of any scientific output, this law can be used. The main factor of fulfillment of this law is the situation when the coefficient of determination of the linear plot is less than that of the exponential plot.

The quinquennial distribution of the publication exhibits a more or less steady growth in the numbers of papers in biological science research during the period under study (Fig. 1).

The equation y = 0.0887x + 1.1807 based on linear adjustment of the collected data and the equation $y = 1.0743e^{-0.094x}$ based on exponential adjustment are calculated for the verification of validity of Price's law in case of scientific productivity of the present study.

As can be seen from the Fig. 1, the value of R i.e. Coefficient of Determination are 0.3752 and 0.3606 for exponential and linear trends of growth respectively. We can claim that growth trend of biological science literature exhibits exponential trend. Therefore, the price law is satisfied in case of present study.

5.3 Authorship Pattern

Table 2 presents the output in terms of several authorship patterns for the period under study. The authorship pattern grouped in five year periods. The last decade is the only exceptional, which includes seven year periods. The highest 75 per cent paper were single-authored, followed by 22 per cent paper with double authored during the period under study. It is found that papers with more than two authors have only 3 per cent contribution. It is also seen that the period 1940-1947 was the most productive period.

5.3.1 Degree of Collaboration

The degree of collaboration (DC) counted by the formula

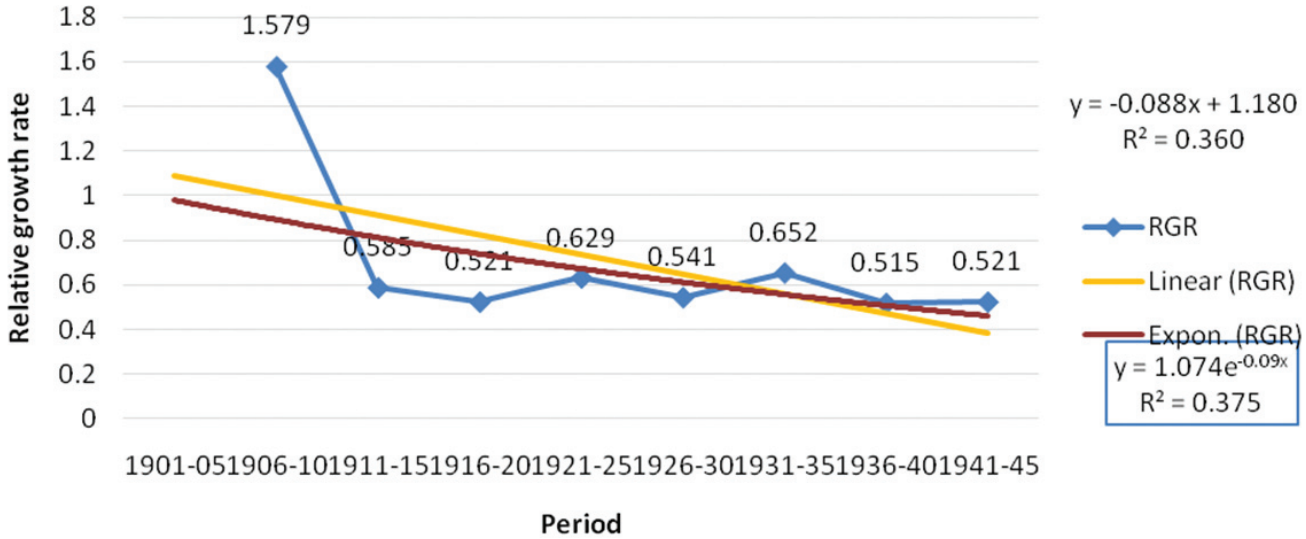

Figure 1. Relative growth rate.

Table 2. Authorship pattern

Period	Single	Double	Triple	Four	Five
1901-05	11	0	0	0	0
1906-10	27	0	0	0	0
1911-15	59	7	0	0	0
1916-20	95	19	1	0	0
1921-25	221	46	2	2	0
1926-30	378	59	10	4	0
1931-35	821	241	18	4	0
1936-40	1129	344	50	6	0
1941-47	1469	513	64	7	3
Total	4210	1229	145	23	3

which is suggested by the Subramanyam[33] as mention below:

$DC = 1 - f1 / N$

where $f1$ = the number of single-authored articles

N = the total number of articles published in a year

Hence, DC for the period 1901-05 is:

$DC = 1 - f1 / N$

$= 1 - 11/11$

$= 1 - 1$

$= 0$

Similarly, the value of DC is calculated for all the corresponding periods.

Table 3 determines the degree of collaboration during the study period. The average degree of collaboration 0.249 has been registered during the period of study. The maximum average degree of collaboration is in the period 1941-47 which is 0.285, followed by 0.261 during the period 1935-40 and 0.242 during the 1931-35 respectively. There was no collaborative study occurred in the first decade of the study period. Therefore, it is concluded that collaborative research is more preferred to solo research among researchers in case of biological science literature on British India.

5.3.2 Co-Authorship Index

CAI is obtained by calculating proportionately the Publication by single, two and multi authored papers. The methodology is similar to one suggested by Price[34] and used to calculate Activity Index (AI) suggested by Frame[35] and elaborated by Schubert and Braun[36]. The following formula suggested by Garg and Padhi[37] has been used for calculating CAI:

$$CAI = \frac{Nij / Nio}{Noj / Noo} * 100$$

where Nij =Number of papers having j authors in block i; Nio =Total output of block i; Noj = Number of papers having j authors for all blocks; Noo =Total number of papers for all authors and all blocks; j = 1, 2, (3, 4) and (>5).

Table 3. Degree of collaboration

Period	Single author	Multi-author	Total	DC
1901-05	11	0	11	0
1906-10	27	0	27	0
1911-15	59	7	66	0.106
1916-20	95	20	115	0.173
1921-25	221	50	271	0.184
1926-30	378	73	451	0.161
1931-35	821	263	1084	0.242
1936-40	1129	400	1529	0.261
1941-47	1469	587	2056	0.285
Total	4210	1400	5610	0.249

For this study, the authors have been classified into three block i.e. Single, Two and more than two author and period of the study during the period 1901-1947.

It is evident from (Table 4) that Co-authorship index for the output of biological research output for the entire study period is varied with higher and lesser than the average. CAI of single author shows decreasing trend (133.2 – 95.2).On the contrary CAI for double author and more than two author shows increasing trend (0 – 113.8) and (0 – 118) respectively.

5.3.3 Lotka's Law

Lotka conducted an experiment on the author productivity.

The simplest equation to represent Lotka's law is:

$x^a y = c$

where x stands for the contributions; y stands for the number of authors, and c is constant.

Using the above equation, the value of c will be determined according to Sen's method[38].

Table 4. Co-authorship index

Year	Single author	CAI	Double authors	CAI	More than two authors	CAI	Total
1901-05	11	133.2	0	0	0	0	11
1906-10	27	133.2	0	0	0	0	27
1911-15	59	119.1	7	48.4	0	0	66
1916-20	95	110.1	19	75.4	1	28.5	115
1921-25	221	108.6	46	77.4	4	48.4	271
1926-30	378	111.6	59	49.5	14	101.8	451
1931-35	821	100.9	241	101.4	22	66.5	1084
1936-40	1129	98.3	344	102.6	56	120.1	1529
1941-47	1469	95.2	513	113.8	74	118	2056
Total	4210		1229		171		5610

Table 5. Verification of Lotka's law

Number of papers (x)	Number of author (y) (observed)	Number of author (y) (expected) with the value a=1.884
1	757	757
2	205	205
3	117	96
4	58	56
5	47	37
6	41	29
7	32	19
8	25	15
9	14	12
10	11	10
11	11	8
12	6	7
13	6	6
14	8	5
15	5	5
16	7	4
17	5	4
18	6	3
19	2	3
20	1	3
21	4	2
22	5	2
23	1	2
24	4	2
25	1	2
26	1	1
28	4	1
29	4	1
30	6	1
31	1	1
32	3	1
38	1	1
39	1	1
50	1	0.5
51	1	0.5
53	1	0.5
55	1	0.4
56	2	0.4
58	1	0.4
60	1	0.3
65	1	0.3
68	1	0.3
75	1	0.2
275	1	0.02

Taking in account the value of as given in the first row of the Table 5, we get

1^a. 757 = c [as $1^a = 1$]

757 = c

Now, using the data of the second row (Table 5), we can find out the value of *a*.

2^a. 205 = 757

- $2^a = 3.692$
- $a \log 2 = \log 3.692$
- 0.301 = 0.567
- $a = 0.567/0.301$
- $a = 1.884$

Using the value of *a* the expected values of *y* has been determined in the Table 5. It may be observed from table that the value of *y* are quite close to the actual values when calculated with $a = 1.884$.

Hence, it may be said that by and large the data set derived from this study follows Lotka's law.

5.3.3.1 Goodness-of-Fit Tests

There are several statistical tests available for goodness of fit tests. Among those tests, we used the t-test as goodness-of-fit tool.

From Table 6 it is seen that for a two-tailed test with 86 Degree of freedom (df), we can read the critical value at the 0.05 level is 1.9879. Our computed critical value of 't' is 1.9879; hence it is significant conveying that the differences between means are significant. Thus, the Lotka's law does fit in the observed given author productivity distribution of the first authors.

5.4 Most Prolific Researchers

In biological science research, the productivity of ten most productive researchers (Table 7) varied from 54 to 276 and together contributed 15 per cent publication share.

The most productive author was S. L. Hora from Zoological Survey of India (ZSI), Calcutta with 276 (4.91 %)

Table 6. Statement of t-Test

	Variable 1	Variable 2
Mean	32.09090909	29.67772727
Variance	13795.85201	13767.43652
Observations	44	44
Pooled Variance	13781.64427	
Hypothesized Mean Difference	0	
df	86	
t Stat	0.09641639	
P(T<=t) one-tail	0.461707103	
t Critical one-tail	1.66276545	
P(T<=t) two-tail	0.923414206	
t Critical two-tail	1.987934166	

Table 7. Most prolific researchers

Name	Publications	Per cent of share in total Contribution	Rank	Affiliation
Hora, Sunder Lal	276	4.91	1	Calcutta, ZSI
Prashad, B	75	1.33	2	Calcutta, ZSI
Pruthi, Hem Singh	68	1.21	3	Pusa (Bihar), IARI
Bose, Sahay Ram	65	1.15	4	Calcutta, Carmichael Medical College
Biswas, Kalipada	62	1.11	5	Calcutta, Royal Botanic Garden
Bose, Jagadis Chunder	61	1.08	6	Calcutta, Bose Institute
Husain, M A	60	1.06	7	Lahore, Panjab University
Singh, B N	58	1.03	8	Banaras Hindu University
Mookerjee, Himadri Kumar	58	1.03	8	University of Calcutta
Maheswari, Panchanan	54	0.96	9	Dacca University

Table 8. Contribution of women researchers

Name	Affiliation	Publications	Subject
Ammal, E K Janaki	Coimbatore	18	Botany
Rathnavathy, C K	Madras University	3	Zoology
Parukutty, P R	Benaras	3	Botany
Nalini, K P	Madras University	2	Zoology
Kamath, H Sunanda	Coimbatore	1	Botany
Karnad, R	Bangalore, IIS	1	Botany
Khosla, Shanti	Coimbatore	1	Botany
Shah, R	Nagpur	1	Botany
Bana, R N	Bombay, Royal Institute of Science	1	Zoology
Mahadevan, G	Madras	1	Zoology
Radha, K S	Bombay	1	Zoology
Subhapradha, C K	Madras, Presidency college	1	Zoology
Varde, M R	Bombay	1	Zoology

papers followed by B. Prashad with 75 papers (1.33 %) from ZSI and H. S. Pruthi with 68 papers (1.21 %) from Indian Agricultural Research Institute (IARI), Pusa respectively.

5.5 Contribution of Women Researchers

Here, an attempt has been made to explore the contribution scenario of women researchers during the period under study. As whole 13 women researchers were traced (Table 8) out having interest in biological science research during the period under study.

The productivity of women researchers varied from 01 to 18 and together contributed 0.62 per cent publication share in biological science research. It is seen that Dr. E K Janaki Ammal of Sugarcane Breeding Station, Coimbatore was contributed highest number of research papers (18 paper). She is the first Indian woman who awarded PhD degree in the field of botany. The other most prolific women researchers were C. K.Rathnavathy (3 papers) of Madras University in the field of zoology, P. R. Parukutty (3 papers) of Benaras Hindu University in botany, and K. P. Nalini of Madras University in zoology accounted with 2 paper respectively.

6. FINDINGS AND CONCLUSIONS

The present study tries to focus on the basic features of research scenario in biological science created by native Indian researchers during 1901-1947. The growth rate of research activities in India during the early decades of the twentieth century was slow in nature.

This is because there were almost no dedicated research institutions which could permit Indian to do research. After the establishment of some notable scientific research institutions like Indian Institute of Science (1909), Calcutta University College of Science (1916), etc. pave the way to participate the native Indian researchers in the arena of scientific research. With the birth of the Indian Science Congress (1914), zoology and botany came to occupy its rightful place amongst the science subjects taught in the universities. The mean relative growth rate and duplication time are 0.615 and 1.007 respectively for the period 1901-1945. This research demonstrated that the growth of biological science related literature favours an exponential path. The calculated results follow the spirit of the 'Price Law' i.e. the coefficient of determination of the exponential plot is greater than that of the linear plot.

About 75 per cent papers are single-authored and the Degree of Collaboration is 0.249. So it is evident from the results that there was a prevalence of solo research during the period of study. The Collaborative author index (CAI) for single author shows decreasing trend while for two author and more than two author shows increasing trend.

The data set derived from this study follows Lotka's law of author productivity. The productivity of ten most productive researchers together contributed 15 per cent publication share. The most productive author was S. L. Hora from Zoological

Survey of India (ZSI), Calcutta with 276 (4.91 %) papers. It is also found that the productivity of women researchers together contributed 0.62 per cent publication share in biological science research and EK Janaki Ammal of Sugarcane Breeding Station, Coimbatore has contributed highest number of research papers.

Interested people could gather some basic knowledge about research conditions in biological science in British India as well as the level of research performance of the then researchers from the outcome of this study. Thus, this study provides a helpful reference for biological science researchers and other academics.

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CONTRIBUTOR

Dr. Sanku Bilas Roy did his MLIS, MPhil, and PhD in Library and Information Science from University of Calcutta. He also did MA (English) from IGNOU. He is presently working as the Librarian in Jadavpur University, Kolkata. He has published more than 15 paper in journals, edited books and conference proceedings. His areas of interest are: Scientometric analysis, bibliometric analysis, Information seeking behaviour, public library system, Community information service, etc.