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Science Maps of Global and Indian *Wildlife Forensics*: A Comparative Analysis

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Abstract

Science map is a useful tool to understand the structure of a discipline, research networks and collaborations. Wildlife forensics is an emerging field of Forensic Sciences, where science is applied to legal cases involving wildlife. This study is aimed at creating science maps of Wildlife Forensics, both at global level and regional (i.e. India) level using *PubMed* database. A total of 303 records pertaining to global and 29 records pertaining to India published between 2001 and 2015 are obtained from the *PubMed*. These bibliometric data are analysed and maps are constructed using MS-Excel spreadsheets, *VOSviewer* and *Pajek* software. The study shows the global Wildlife Forensics literature growth showed exponential trend while the contemporary Indian literature showed linear growth trend. Globally A.M. Linacre and N. Mukaida share the first rank while among the Indian authors S.P. Goyal receives the first place. The degree of collaboration is more than 0.9. The journal *Forensic Science International* is the top ranking journal both internationally and nationally. The research trends in Wildlife Forensics are also found from the study.

Keywords: Forensic Science, Wildlife Forensics, Scientometrics, Science maps, Research trends, *PubMed*.

Introduction

Scientometrics is a discipline that has emerged from metadata based domain visualisation used to map the growing domain structure of scientific disciplines. Science mapping or bibliometric mapping is a spatial representation of how disciplines, fields, specialties, and individual authors or documents are related to one another (Small, 1999). Science maps are useful tools to understand the state-of-the-art disciplinary structure within an academic field as well as to analyse the emergence of research networks among institutions and authorship collaborations.

Science Mapping

The origin of the term *scientometrics* goes back to the year 1969, when two Russian scientists Nalimov and Mulechenko coined the Russian term *naukometriya* the Russian equivalent of scientometrics (Nalimov and Mulechenko, 1969). Scientometrics is the quantitative study of science and technology. It is the study of quantitative aspects of science as a discipline or economic activity (Tague-Sutcliffe, 1992). Scientometric techniques have wide applications in identifying the author productivity, authorship pattern, core periodicals, research trends in a subject, research collaboration and impact of research, etc. Hence it is of great use to identify the emerging research areas within a given subject.

Alan Pritchard in the year 1969 coined the term *bibliometrics* to replace the term *statistical bibliography*. However, some give the credit to Paul Otlet, who used the French term *bibliometrie* in the year 1934. Pritchard (1969) defines bibliometrics as “to shed light on the processes of written communication and of the nature and course of development of a discipline, by means of counting and analyzing the various facets of written communication

… the application of mathematics and statistical methods to books and other media of communication…”

The techniques of scientometrics and bibliometrics are closely similar and overlap each other. Nevertheless, their roles are distinguished by their very different contexts. Bibliometrics stresses the material aspects of the analysed unit such as a paper, citation or any other information irrespective of the subject orientation. Scientometrics on the other hand emphasizes the measurement of specific information related to its scientific value (Brookes, 1990). Scientometrics includes all quantitative aspects and maps related to the production and dissemination of scientific and technological knowledge.

Wildlife Forensics

The Latin word *forensis* means *forum*, *public* or *market-place*. In the Roman Empire, the Senate used to conduct its meetings in a public place called the *forum* and any one could listen to the debates and watch the actions of the government. The term forensic means *of the forum*, in the broadest sense, and forensic science can be defined as the methods of science applied to public matters. Hence, forensic science does not necessarily have to do with crime, but the term has evolved in modern times to refer to the application of science to court or criminal matters.

Since *forensic* sciences refer to science applied to criminal and civil law any science can be a forensic science if it has some application to justice (Siegel & Mirakovits, 2016). A plethora of sciences have application to law and therefore we have endless list of specialties in forensic sciences starting from forensic accounting and ending with forensic zoology. In between these two are a number of specialties such as, forensic art, forensic anthropology, forensic ballistics, forensic biology, forensic entomology, forensic pathology, forensic psychology, forensic odontology, forensic serology, forensic toxicology, forensic chemistry, and so on.

Wildlife forensics is an emerging specialty of Forensic Sciences (Jeyasekar, 2015). It is the application of science to legal cases involving wildlife. When scientific principles are used to investigate crimes related to wildlife it is known as Wildlife Forensics. Wildlife Forensics includes investigation involving the exotic pets and their illegal trade, poaching, other illegal hunting activities, and oil spills which affect the flora and fauna. Poaching or killing wild animals that are protected from hunting by laws is one of the most serious crimes investigated by Wildlife Forensic Scientists. Other crimes against wildlife include buying and selling protected animals, and their products like hides, claws, nails, teeth, etc. The aim of Wildlife Forensics is to use scientific procedures to examine, identify, and compare evidence from crime scenes, and to link this evidence with the suspects and the animal victims. The development of Wildlife Forensics as a field is vital for successful management of the many social and ecological conservation issues related to the illegal wildlife trade and wildlife law enforcement.

Review of Literature

Most highly cited articles, most prolific authors and impact factors of Forensic Sciences literature have been examined by Jones (1993, 1999, 2003, 2004, 2005a, 2005b & 2007). Scientometric Studies on global and Indian Forensic Science using Indian Citation Index (*ICI*), *SCOPUS*, *PubMed*, and Web of Science (*WoS*) have also been conducted (Jeyasekar & Saravanan, 2012a, 2012b, 2014a, 2014b & 2015a; Kumbar & Biradar, 2015). Few single journal studies have also been conducted (Jones, 2002; Shammim, 2013; Jeyasekar & Saravanan, 2013, 2014b, 2014c & 2014d) in the area of Forensic Sciences. Savageau, Desnoyers and Godin (2009) have mapped two North American Forensic journals.

The three Forensic specialties, viz., Forensic Odontology (Jeyasekar & Saravanan, 2015b), Forensic Anthropology (Gauldi-Russo & Fonti, 2013) and Forensic Psychology (Black, 2012) have also been scientometrically mapped.

Need and Significance

Scientific literature is the mirror of scientific activity of a country or of a particular field of study. Hence examining the literature provides the structure of the field and the quantity and quality of the scientific activity in the geographical area studied. The emerging field of Wildlife Forensics is of great importance to science policy makers since wildlife, ecology, climate change and sustainable growth all go hand in hand. Hence the present study is conducted.

Objectives of the Study

The objectives of the study are

1. To study the growth of wildlife forensics literature.
2. To examine the contributions of the most prolific authors and also to construct co-author maps.
3. To find the top ranking journals and their contributions.
4. To analyse the keywords used.

Materials and Method

The data for this study is obtained from *PubMed*. *PubMed* is a search engine accessing primarily the Medline database of references and abstracts on life sciences and biomedical topics. The data related to the years 2001 to 2015 were downloaded in *MS-Excel* worksheets, cleaned and checked for duplicates. The final number of bibliographic records obtained pertaining to global Wildlife Forensics was 303 and Indian Wildlife Forensics was 29. These data were analyzed using *MS-Excel* and the results obtained compared and studied according to the established principles and practices. *VOSViewer* and *Pajek* software were used to visualize and map the literature.

Results and Discussion

Literature Growth

The year-wise break-up of the number of papers in the field of Wildlife Forensics, both global and Indian, obtained from *PubMed* database and the percentage analysis done are presented in Table 1. The cumulative growth of the number of papers is also calculated and given in the same table.

Table 1: Year-wise growth of Wildlife Forensics Literature

Year	Global	Per cent	Cumulative Growth	Per cent	India	Per cent	Cumulative Growth	Per cent
2001	6	1.98	6	1.98	0	0	0	0
2002	10	3.30	16	5.28	0	0	0	0
2003	4	1.32	20	6.60	1	3.45	1	3.45
2004	6	1.98	26	8.58	1	3.45	2	6.90
2005	11	3.63	37	12.21	2	6.90	4	13.79
2006	20	6.60	57	18.81	2	6.90	6	20.69
2007	12	3.96	69	22.77	0	0	6	20.69
2008	17	5.61	86	28.38	2	6.90	8	27.59
2009	22	7.26	108	35.64	5	17.24	13	44.83
2010	32	10.56	140	46.20	2	6.90	15	51.72
2011	30	9.90	170	56.11	4	13.79	19	65.52
2012	26	8.58	196	64.69	2	6.90	21	72.41
2013	29	9.57	225	74.26	3	10.34	24	82.76
2014	51	16.83	276	91.09	4	13.79	28	96.55
2015	27	8.91	303	100	1	3.45	29	100
Total	303	100			29	100		

It is found from the table that the global literature growth is steady although there are some downward trends occasionally. But the growth of Indian Wildlife Forensics literature's case is not so and it is very irregular. Globally the highest number of papers (51), which is about 17 per cent of the total output during the period of study, has been published during 2014. The maximum number (5) of Indian Wildlife Forensics papers has been published in the year 2009. This is approximately 14 per cent of the total output of India in Wildlife Forensics literature.

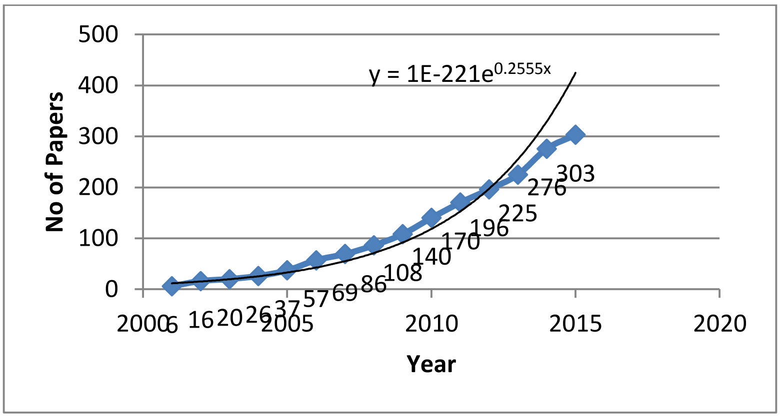

Fig. 1: Cumulative Growth Rate of Global Wildlife Forensics Literature

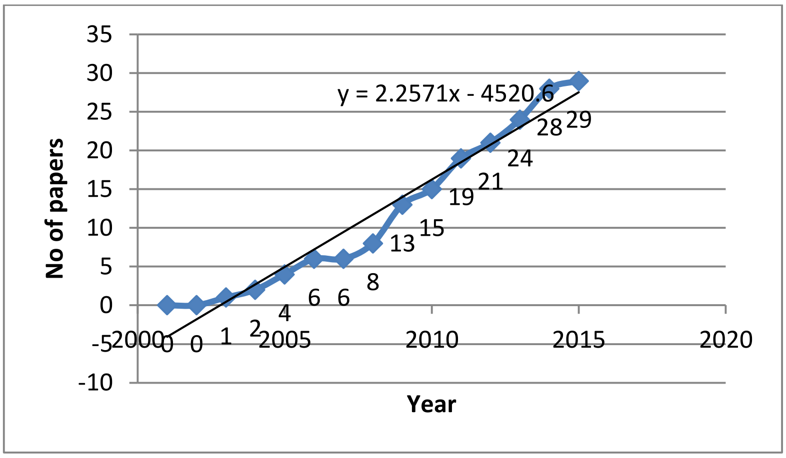

Fig. 2: Cumulative Growth Rate of Indian Wildlife Forensics Literature

The cumulative growth rate of global Wildlife Forensics papers is plotted as a graph in Figure 1. The trend line is also drawn on the graph. This figure clearly shows exponential growth rate. Similarly, the cumulative growth rate of Indian Wildlife Forensics literature is also plotted in Figure 2 and trend line is also drawn. This figure in contrast to the global cumulative growth rate shows linear trend.

Prolific Authors and Their Affiliation

The top contributing authors and their contributions at the global level are analysed and ranked. The results are presented in Table 2.

Table 2: Global Top Ranking Authors

Author	Institution	Contribution	Per cent	Rank
A.M. Linacre	Flinders University, Adelaide, US	10	3.3	1
N. Mukaida	Wakayama Medical University, Wakayama, Japan	10	3.3	1
S.P. Goyal	Wildlife Institute of India, Dehradun, India	8	2.6	3
T. Kondo	Wakayama Medical University, Wakayama, Japan	7	2.3	4
T. Chen	Xi'an Jidotong University, China	6	2.0	5
Y. Ishida	Wakayama Medical University, Wakayama, Japan	6	2.0	5
A. Kimura	Wakayama Medical University, Wakayama, Japan	6	2.0	5
S.B. Li	Xi'an Jidotong University, China	6	2.0	5
V. Sahajpal	Wildlife Institute of India, Dehradun, India	6	2.0	5
L. Singh	Centre for Cellular and Molecular Biology, Hyderabad, India	6	2.0	5
Total		71	23.4	

The table reveals that two authors, namely, A.M. Linacre and N. Mukaida with a contribution of 10 each share the first rank. S.P. Goyal, an Indian author ranks third with a contribution of 8 papers. It is found that the top ranking 10 authors together have contributed 71 papers, which is about 23 per cent of the global Wildlife Forensics literature output. The table also reveals that the top ranking author (A.M. Linacre) belongs to the US. Four authors among the top ten belong to Japan while three are from India and two from China.

The top contributing Indian authors are also ranked according to their contribution and listed in Table 3.

Table 3: Top Ranking Indian Authors

Author	Institution	Contribution	Per cent	Rank
S.P. Goyal	Wildlife Institute of India, Dehradun	8	27.6	1
V. Sahajpal	Wildlife Institute of India, Dehradun	6	20.7	2
L. Singh	Centre for Cellular and Molecular Biology, Hyderabad	6	20.7	2
B. Dubey	Central Forensic Science Laboratory, Kolkata	3	10.3	4
S.K. Gupta	Centre for Cellular and Molecular Biology, Hyderabad	3	10.3	4
I. Haque	Central Forensic Science Laboratory, Kolkata	3	10.3	4
R. Jayapal	Wildlife Institute of India, Dehradun	3	10.3	4
P.R. Meganathan	Central Forensic Science Laboratory, Kolkata	3	10.3	4
S.K. Verma	Centre for Cellular and Molecular Biology, Hyderabad	3	10.3	4
Total		38	131	

This table shows that 9 authors have contributed 3 or more papers. S.P. Goyal, the top-most author has 8 papers to his credit and is ranked number one. He is followed by two authors namely V. Sahajpal and L. Singh who have 6 papers each to their credit. These 9 authors together have contributed 38 papers, whereas the total literature output of India is 29 only. This is due to the high degree of collaboration found among the Indian Wildlife Forensics researchers.

Degree of Collaboration

Research collaboration has been a fascinating area of research for many Scientometricians from all over the world. Many Bibliometricians and Scientometricians have attempted to study the average number of authors per paper, the authorship collaboration pattern in a discipline, the proportion of single and multi-author papers, etc. Some of these studies have resulted formulation of indices such as, Collaborative Index

(Lawani, 1980), Degree of Collaboration (Subramanyam, 1983), Collaborative Coefficient (Ajiferuke, Burrell & Tague-Sutcliffe, 1988), Affinity Index (Arunachalam and Doss, 2000) and Authorship Affinity Index (Jeyasekar and Saravanan, 2015c).

Subramanyam propounded the Degree of Collaboration (DC), a measure to calculate the proportion of single and multi author papers and to interpret it as a degree. According to Subramanyam (1983),

$$DC = \frac{Nm}{Ns+Nm}$$

where, Nm is the number of multi-author papers and Ns is the number of single author papers. In simpler terms,

$$DC = \frac{No\ of\ multi\ author\ papers}{Total\ no\ of\ papers}$$

At the global level, the number of single author papers is 23 and the number of multi-author papers is 280. Applying the Subramanyam formula the DC found in the global Wildlife Forensics is 0.92. The number of single author Indian paper is 1 and number of multi-author paper is 28. Hence, according to the same formula the DC of Indian Wildlife Forensics is 0.97.

Co-author Maps

The global co-authors are mapped using VOSviewer and Pajek software, with a threshold value of two, and the resultant network map obtained is illustrated in Figure 3.

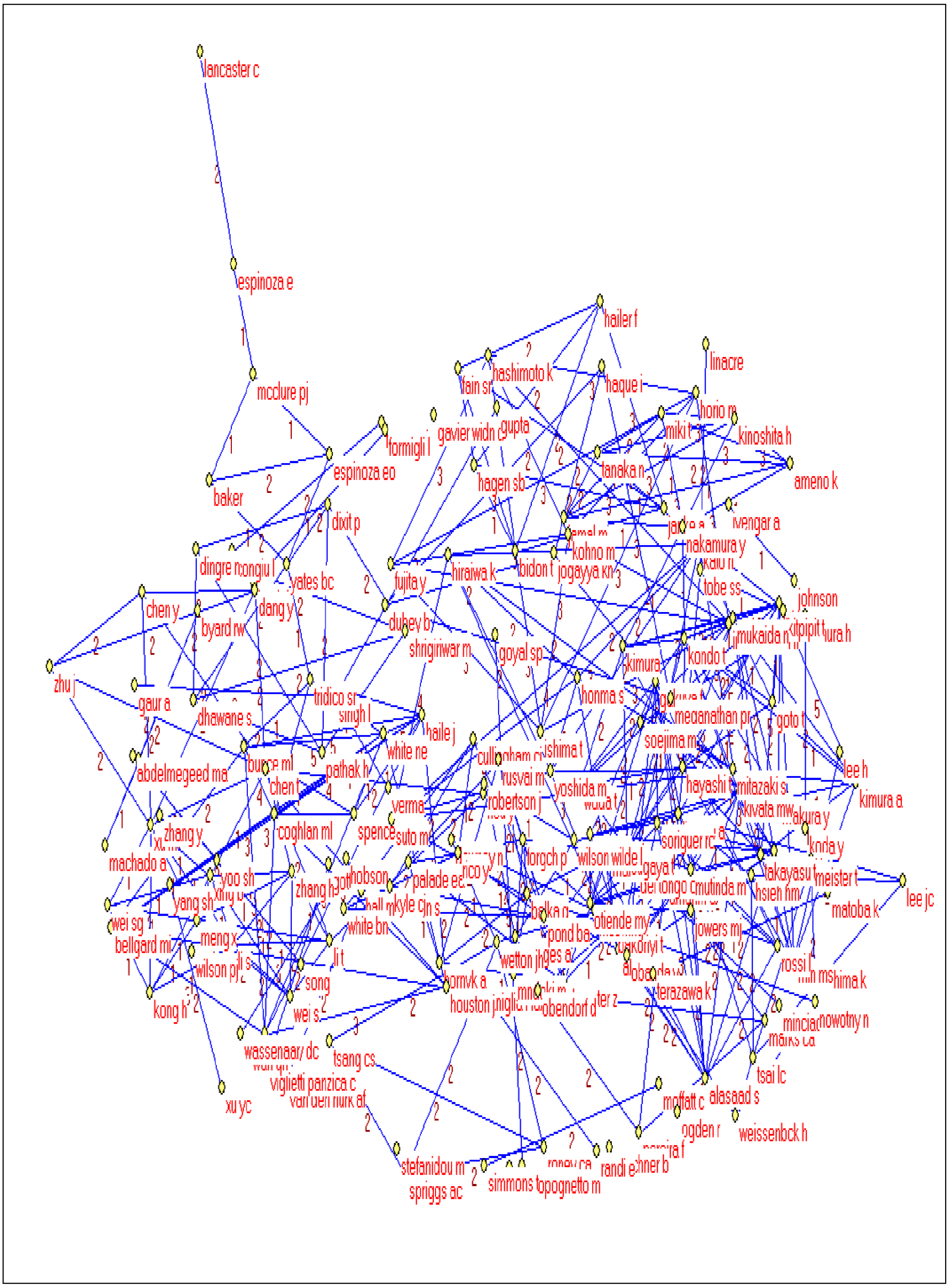

Fig. 3: Co-author Map (Global)

This map shows 169 nodes, each node representing an author. The values marked over the lines connecting the nodes represent the link strength, which is the number of papers both of them have co-authored. The shortest line is between M.J. Jowers and M. Mutinda. The longest line is between S.P. Goyal and V. Sahajpal.

Similar to Figure 3, all the authors affiliated to Indian institutions are mapped and presented in the co-author map in Figure 4.

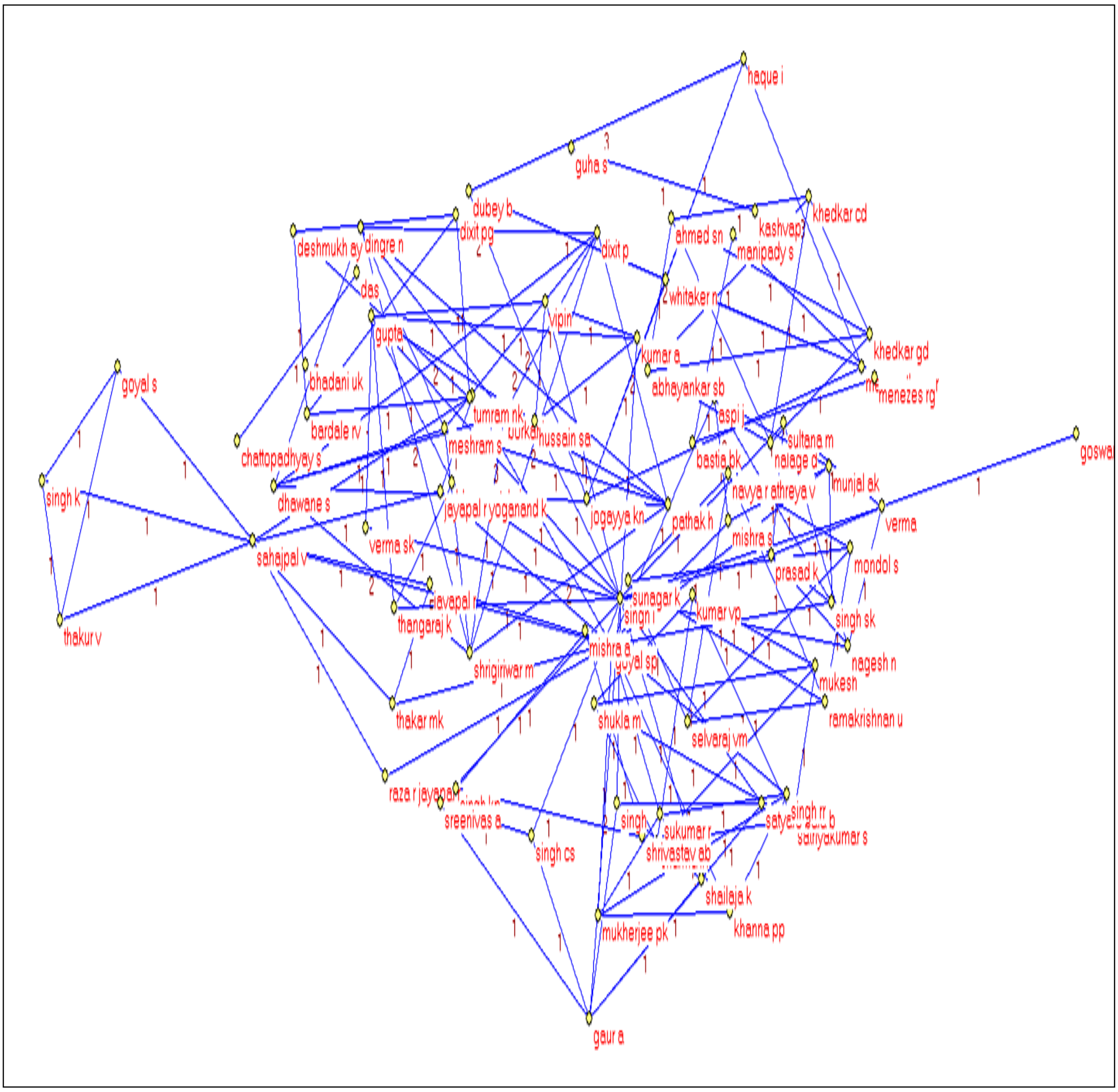

Fig. 4: Co-author Map (Indian)

The map illustrated in Figure 4 reveals 79 nodes, each representing a different author as indicated in the labels. The link strength values represent the number of co-authored papers. The closest vertex is between Thakar and N.K. Tumram. The smallest angle is between K.N. Jogayya, N. Whitaker and I. Haque. The shortest line is between K. Shailaja and B. Satayare Bala. The longest line is between Thakar and S.P. Goyal.

Ranked List of Journals

The top contributing journals are examined with respect to their number of papers in the field of Wildlife Forensics during the study period both at the global and regional level and ranked accordingly. This ranked list is presented in Table 4.

Table 4: Journal Ranking

Journal	Global	Rank	Per cent	India	Rank	Per cent
Forensic Science International	31	1	10.23	7	1	24.14
Forensic Science International: Genetics	26	2	8.58	1	6	3.45
Forensic Science, Medicine & Pathology	18	3	5.94	0		0
Journal of Forensic Science	18	4	5.94	3	3	10.34
PLoS One	11	5	3.63	1	6	3.45
Forensic Science Review	8	6	2.64	0		0
Rapid Communication Mass Spectrometry	6	7	1.98	0		0
Science & Justice	6	7	1.98	5	2	17.24
Veterinary Microbiology	6	7	1.98	0		0
Investigative Genetics	5	10	1.65	0		0
Legal Medicine	5	10	1.65	1	6	3.45
BMC Genetics	3		0.99	2	4	6.90
Journal of Forensic & Legal Medicine	4		1.32	2	4	6.90
Total	147		48.51	22		75.87

The table clearly reveals that 'Forensic Science International' is the number one journal this field of study at both levels, globally and regionally. However, when a percentage analysis is done, this journal accounts for 24 per cent of the Indian contribution while just 10 per cent of the global contribution. Globally, 'Forensic Science International: Genetics' is the journal ranked second, whereas it ranks sixth as per the Indian contributions. Globally third ranked journal 'Forensic Science, Medicine & Pathology' does not have any Indian contribution. Another noteworthy fact is that about 76 per cent of the Indian contribution is concentrated in just 8 journals.

Co-word Maps

Cluster Analysis is a multivariate procedure of detecting natural groupings in data (Wulder, 2014). Cluster Analysis is used to group objects, people, countries or other entities on the basis of shared characteristics (McCain, 1990). Grouping the entities together on the basis of similarities and differences is possible by Cluster Analysis (Tryon & Bailey, 1970). The similarity strength between the entities, in this case the key terms used in the abstracts of the bibliographic records, are analysed and then they are represented graphically.

Cluster Analysis is carried out with the aid of *VOSviewer* to find the sub-fields found in the global Wildlife Forensics literature during the period of study. The abstracts of all the 303 papers are subjected to cluster analysis and the map created using the software is presented in Figure 5.

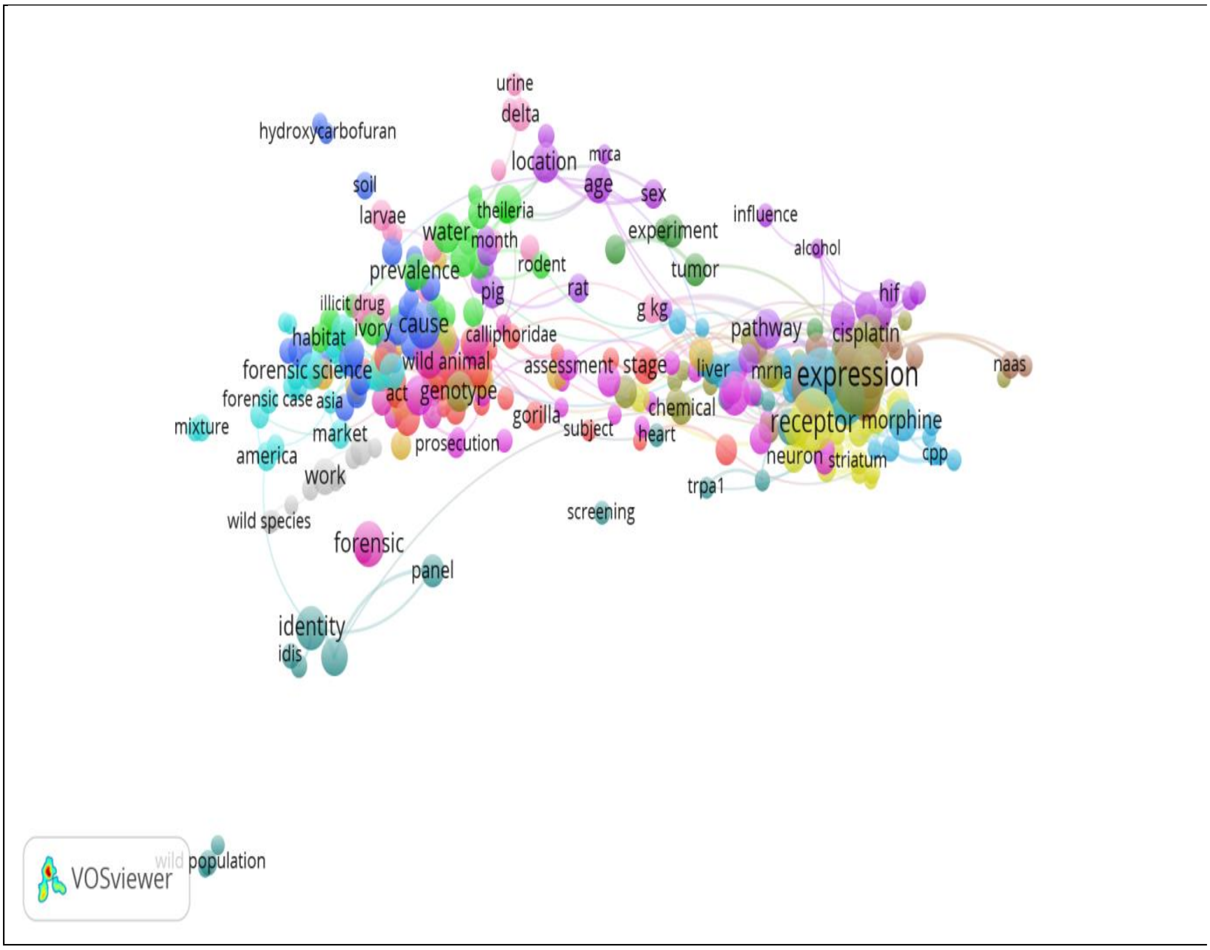

Fig. 5: Co-word Map (Global)

The cluster map of the co-words reveals 334 items grouped in 17 clusters. Each cluster is differentiated by a different cluster colour. Cluster number 1 has 32 items and the last cluster, i.e., cluster number 17 has 6 items. Some of items with high frequencies are fish, pig, rat, mouse, rodent, sheep, wild boar, gorilla, red deer, maggot, larvae, domestic cat, wolf, diptera, polar bear, horse, lion, rhinoceros, wild bird and agar wood. This is an indication of high rate of crime investigation related to these wild lives. Geographical terms with high frequencies found are America, Canada, Europe, Italy, Germany, Israel, Hungary, Taiwan and the world. It is inferred that most of the Wildlife Forensics research or wildlife are from these parts of the world. Body parts like head, brain, cerebellum, heart liver, pancreas, and kidney are found with high frequency. Other important terms observed in the map include, injury, wound, tumour, age, alcohol, drugs, pesticide, farm, ecology, DNA, mitochondrial, cytochrome, gene expression, collagen, estimate, parasite, ivory, saliva, food and water. Age estimation, pathological examination of injuries and wounds and DNA analysis of the wildlife victims of crime are major areas of research in Wildlife Forensics.

The abstracts of all the 29 papers of Indian origin are also subjected to cluster analysis using VOSviewer and the map obtained is given in Figure 6.

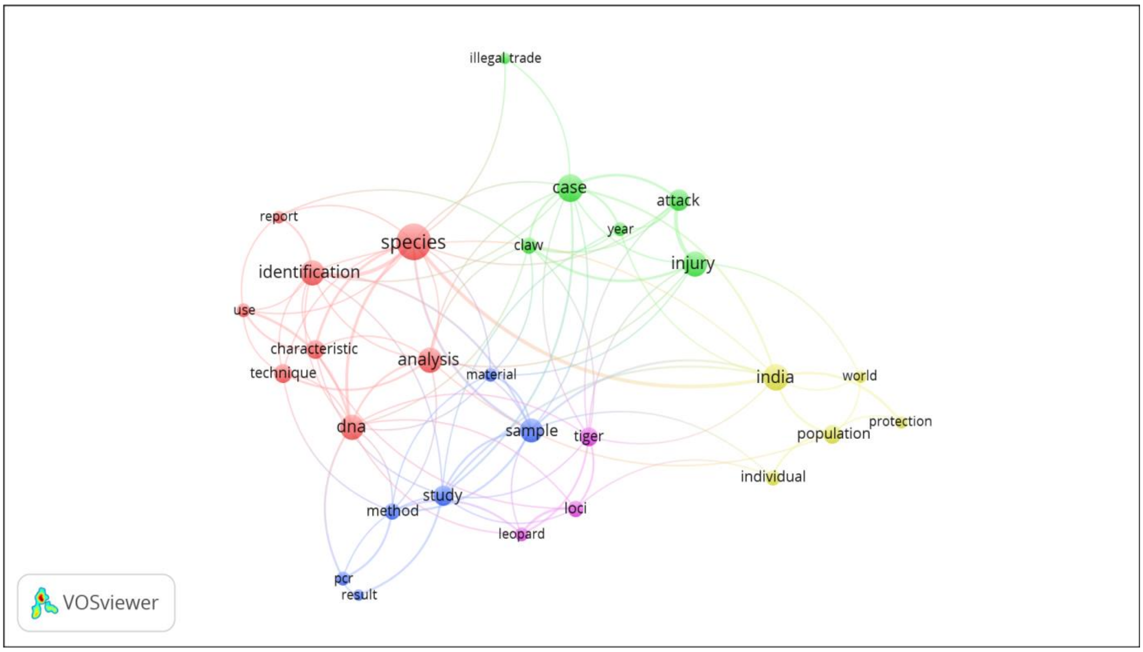

Fig. 6: Co-word Map (Indian)

Altogether 28 items in 5 clusters resulted from this analysis. The wild animals found in this map are tiger, and leopard. The major areas of research studies found are DNA, PCR (Polymerase Chain Reaction), illegal trade, claw, injury, attack, protection, population, and identification.

Conclusion

The study revealed that global Wildlife Forensics literature grew exponentially during the study period, while the Indian literature of the same field grew linearly. A.M. Linacre from the US and N. Mukaida from Japan share the first rank among the most prolific authors. The most prolific Indian author is S.P.Goyal. Degree of Collaboration of global Wildlife Forensics literature is 0.92 while it is 0.97 in India's case. *Forensic Science International* is the top contributing journal at both the levels. The most common research trends in Wildlife Forensics are age estimation, pathology and DNA analysis.

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