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Scientometric profiling of reservoir fisheries research in India during 1998-2019, in comparison to the global scenario

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Abstract

Reservoirs are major inland water resources benefitting society through multiple ecosystem services, including fish production. However, the scope of the reservoirs in India is yet to be explored for its full fisheries potential and the scientific/management personnel are engaged in bridging the yield gap. This paper reviews the research progress made in Indian reservoir fisheries from 1998 to 2019 as a case and compares with global studies using bibliometric indicators extracted from the Web of Science (WoS) database. A total of 7607 papers published globally, mainly by the USA (2662 papers), Brazil (874 papers), and People's Republic China (678 papers) were considered. India produced 162 publications (2.13% of total papers) during the period mainly authored by research institutes of Indian Council of Agricultural Research (ICAR). The predominant research subjects both globally and in India were 'Environmental Sciences, Ecology, Marine and Freshwater Biology, and Fisheries', though the composition varies. The trend in the reservoir research output indicated a shift towards applied research such as spatial planning and cage culture which offers scope for the international scientific fraternity to collaborate with Indian counterparts to solve common researchable issues. Indian authors have collaborated with 29 countries on various researchable issues, and preferred Indian journals for publications. The reservoir research in India is mainly funded by public sources and the extent of work carried out on a particular geographical area depends on the nearness to laboratories and availability of the infrastructure. This study advocates that creation of research network at pan-India level in collaboration with international partners would benefit the reservoir fisheries research in the future. This analysis including the trend and dynamics of Indian reservoir fisheries portrayed as a case study would aid in prioritising research efforts for the development of the sector in India and elsewhere.

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Introduction

Reservoirs are man-made eco-systems that provide multiple services, including domestic, agriculture, and industrial water supply, power generation, flood control and recreation (Sugunan 1995, 2000; Nilsson 2013; Su *et al.,* 2017). The coexistence of riverine and lacustrine characters with accumulated nutrients supports rich biodiversity and productivity in its water spread (Banerjee *et al.*, 2016). The Global Georeferenced Database of Dams reports the existence of more than 38,000 dams and associated catchments globally with the highest density found in Asian countries such as China and India (Mulligan *et al.*, 2020). Reservoirs of various categories *viz.* small (<1000 ha), medium (1000 to 5000 ha) and large (>5000 ha), occupy 3.42 million ha of area (19,386 numbers) in India (Sarkar *et al.*, 2017). They are built mainly for irrigation and to supply drinking water along with other specific utilities for industries and power generation (Banerjee *et al.*, 2016). Reservoirs and their biological productivity in terms of fisheries are often under-utilised *vis-a`-vis* their production potential (Sugunan, 1995; Sarkar *et al.*, 2017), and hence referred to as the "sleeping giants".

Research on physical, chemical and biological sub-systems of Indian reservoirs started as early as 1940 by Ganapati (1940) in Red Hills Lake, Tamil Nadu to holistically understand a unique eco-system (Banerjee *et al.*, 2016). Further, feasibility studies for fishery development, stock management and enclosure fish culture were also conducted in some selected reservoirs to assess fisheries potential (Sugunan and Yadava, 1991; Sugunan, 2013). The Government of India (GoI) is prioritising enhancement of fisheries production by utilising the inland open waters to harness their estimated fisheries potential *i.e.* 17 million t) (DoF, 2020). However, considering the geo-spatial variations in ecological dynamics of an individual reservoir (Sugunan, 2000; Banerjee *et al.*, 2016; Sarkar *et al.*, 2018), a common management strategy cannot be adopted for the same. Though, tremendous progress has been made in reservoir research in India, which resulted in innovative management strategies, there is a need to review the research efforts taken up in the past few decades.

Bibliometric studies have been widely used to assess the research efforts of a particular country or organisations in a specific domain in a quantitative and qualitative manner using various research paper indicators (Swinbanks *et al.*, 1997; Annibaldi *et al.*, 2010). Apart from this, the frequency of keywords occurrence in research publications indicates the dynamics and emerging substitutes in the research field (Neff and Corley, 2009). Recently, Ho and Goethals (2020) have assessed the research hotspots and challenges of lakes and reservoirs through bibliometric analysis. A handful of studies were already taken up to analyse the fisheries research with reference to the Indian context (Jayashree and Arunachalam, 2000; Arunachalam and Jeyashree, 2001; Vivekanandan *et al.*, 2009; Sab *et al.*, 2016; Singh *et al.*, 2019; Bhoomaiah *et al.*, 2020a, b; Rathinam *et al.*, 2022).

The present study was undertaken to examine the research efforts on reservoir fisheries in India during 1998-2019. For this purpose, data extracted from the Web of Science (WoS) database were used, with special emphasis on (i) the distribution of publication output of India *vis-a-vis* the most productive countries in the world, (ii) Quantification and qualitative analysis of the research on Indian reservoir fisheries, (iii) Identification of most productive authors and institutions relating to the research, (iv) Understanding the interlinkage and collaboration amongst Indian authors and countries for undertaking the research, (v) Identifying the subject-wise and state-wise contribution of the research on the reservoir and its fishery. As the reservoir eco-systems contribute to fisheries production, ascertaining livelihood and food security, there is a scope to develop an inventory of the reservoir fisheries research in India. This study helps to understand the gaps in the research field that impede policy development for reservoir management and sustainable utilisation. In this study, the results from India are represented as a case, for drawing implications by inference to the rest of the world to comprehend the outputs and impacts to design the future research strategy that would help the policymakers launch targeted reservoir fisheries development programmes.

Materials and methods

Search strategy and data collection

The bibliometric data on 'Reservoir fisheries in India' was collected from the Web of Science (WoS) database using the methods adopted by previous studies (Zyoud *et al.*, 2015; Yao *et al.*, 2018; Ho and Goethals, 2019; Bhoomaiah *et al.*, 2020b). Before the data extraction, keywords were carefully selected through self-expertise and after evaluating the published papers on the similar subject (Ho and Goethals, 2020). A preliminary search was conducted using the name variants of reservoirs and the research field of interest *i.e.* fisheries as: ("Reservoir" AND "Fish*"), ("Reservoir" AND "Fisheries"), [("Reservoir" AND "Fish*") OR ("enclosure fish culture")], ("culture-based fish*" AND "reservoir"), ("fish* enhancement" AND "reservoir") (Table 1). Careful observation of the keyword groupings aided to shortlist the right combination of keywords as follows: ("Reservoir*" AND "Fish*") OR ("Dam" AND "Fish*") to retrieve reservoirs related publications associated with fisheries. The keywords were connected with logical connectors like Boolean operators AND/OR to ensure that at least one search term appeared. Quotation marks ("...") were added to the keywords, to separate the individual words. Asterisks (*) were used to include all the multiple related terms *i. e.,* "fish*" represents "fishery", "fisher" and "fisheries" (Li *et al.*, 2017).

The publication search was conducted in the "TOPIC" field of the database, which covers the title, abstract and keywords (both authors supplied and WoS assigned (keywords plus) of each publication during June 2020. 'Topic Search' was preferred as against the 'Title Search' as it retrieves the data from the fields like Title, Abstract, Keywords and Keywords Plus of the publication (Bhoomaiah *et al.*, 2020a; Liu *et al.*, 2019; Vanzetto and Thome, 2019). In order to understand the temporal research trends and gaps, the data pertaining to the publications for a 20-year period (1998-2019) was used in this study.

Several Indian researchers published their research work in journals that are non-indexed by the above indices and thus were not visible in the WoS database. With the opinion of the subject experts in the field, *Journal of Inland Fisheries Society of India*, a popular non-indexed journal publishing a range of studies on the subject since 1969 (http://www.cifri.res.in/ifsi/journal/about_journal.htm) was considered to cover the wholesome of the research studies that happened in Indian context. The details were manually collected from the journal website and included in the analysis to supplement the study. The country-wise research publication counts on reservoir fisheries (1998-2019) were also obtained from

Table 1. Search Query used for data collection in Web of Science database

Search Query used in Web of Science database	Reference
Topic Search of the keywords so as to ascertain the complete publication output on the reservoir and its fisheries which covers title, abstract and keywords of each publication	Bhoomaiah *et al.* (2019)
TS = (reservoir*)	Ho and Goethals (2019)
TS = (fish*)	Nikolic *et al.* (2011); Jaric *et al.* (2012)
TS = (dam*)	Jiang *et al.* (2016b); Ding *et al.* (2018)
Based on the above search queries, final keyword for the advanced search is arrived as TS = (reservoir* AND fish*) OR TS= (Dam AND fish*)	
Refined by: RESEARCH AREAS=(Environmental Sciences Ecology OR Physiology OR Fisheries OR Marine Freshwater Biology OR Reproductive Biology OR Water Resources OR Forestry OR Zoology OR Engineering OR Construction Building Technology OR Biodiversity Conservation OR Veterinary Sciences OR Life Sciences Biomedicine Other Topics OR Remote Sensing OR Toxicology OR Social Sciences Other Topics OR Science Technology Other TopicS OR Parasitology OR Microbiology OR Agriculture OR Biochemistry Molecular Biology OR Arts Humanities Other Topics OR Biotechnology Applied Microbiology OR Genetics Heredity OR Government Law OR Public Environmental Occupational Health OR Thermodynamics OR Evolutionary Biology OR Public Administration OR Meteorology Atmospheric Sciences OR Developmental Biology OR Computer Science OR Immunology)	
Languages=(English) And Document Types= (Article) And Countries/Regions = (India)	

the database to study the research progress and map the research productivity and collaboration network in the international arena. The citation details of top-cited papers were also extracted from the Google Scholar database (GS) in April 2021. The Impact Factor (IF) details of the journals were extracted from Journal Citation Reports (JCR, 2020).

Data analysis and visualisation

Research productivity of India and the world in the field of reservoir fisheries were analysed in terms of publication trend (number of papers), citation (total citations, self-citation, and average citation per paper), and *h*-index. The *h*-index is used to quantify the scientific research output based on the most cited papers and the number of citations received (Hirsch, 2005). The datasets were also analysed to characterise the most productive institutions, authors, and highly cited papers in India on reservoir fisheries research. Apart from WoS based research area, the publications were manually sorted into broader thematic areas (12 nos.) and the study area location to assess the spatio-temporal dynamics of research interests among the Indian researchers over the time period (Table 2).

Table 2. Broader thematic areas considered for sorting the publications in the present study

Thematic area	Sub-topics	Reference for the Research areas
Environment and Ecology	Eutrophication studies, Physico-chemical parameters, Eco-modelling, Trophic studies, Climate change	Haasan *et al.* (2014); Wang *et al.* (2014), Ho and Goethals (2019); Li *et al.* (2020)
Biodiversity and Conservation	Ichthyofauna, Phytoplankton, Zooplankton, Biodiversity, conservation issues	Liu *et al.* (2011)
Aquatic animal health and Physiology	Fish diseases/Immunology	Bandara and Wijewardene (2018), Ho and Goethals (2019)
Anthropogenic activities and Pollution	Heavy metal, Urbanisation	Li *et al.* (2020)
Harvest and Post-harvest studies	Integrated development of Processing units, Retail outlets Kiosks and Fish storage facilities	Operational Guidelines of Pradhan Mantri Matsya Sampada Yojana, Dept. of Fisheries, Govt. of India
Genetics and Biotechnology	Fish genetics, Biotechnology	Jaric *et al.* (2011)
Management and Governance	Leasing and Licensing, Fisheries management, Policy development and implementation	Bandara and Wijewardene (2018), Ho and Goethals (2019)
Gear and Craft	Mesh size of nets, Types of crafts	Operational Guidelines of Pradhan Mantri Matsya Sampada Yojana, Dept. of Fisheries, Govt. of India
Stock assessment and Stocking	Stocking of fingerlings in the reservoirs	
Cage culture	Aquaculture	DoF (2020)
Remote sensing	GIS, Remote sensing	Duan *et al.* (2020)
General*	*Publications which include issues pertaining to Reservoir and its fisheries	

All the graphs in the study were plotted using MS Excel and VOS viewer (Leiden University, Leiden, Netherlands), an open-source software for analysing and visualising relationships between authors, countries, and keywords *i. e*., for constructing and visualising the bibliographic information thus helping in effective interpretation of the research outputs. The input data were extracted from the bibliographic data of the WoS publication collections. The 'fractional counting method' was adopted in the present study to ensure equal weightages to all components taken for the analysis irrespective of the number of documents, authors, citations, or references of a publication (Perianes Rodriguez *et al.*, 2016). The minimum threshold value of documents was fixed based on the range/extent of occurrences of selected items before each analysis for better visualisation of networks. The network visualisation was used for the co-authorship and keyword co-occurrence analysis. In the network mapping, the items were grouped into clusters of various colours as determined by VOS viewer based on their association with other items. The size of the circle in the network map is proportionate to the quantum of the unit taken for analysis (documents), while the weight of lines between circles is proportional to the intensity of collaboration. The distance between the two circles represents the relatedness and similarity between the clusters and items (van Eck *et al.*, 2010; Waltman *et al.*, 2010). Overlay visualisation method was used for co-authorship-based countries analysis where in the colour of the countries *i.e.* blue with lowest score to green as medium to yellow with highest score.

Statistical analysis

One-way ANOVA was performed to statistically test the significance of variations in publication and citation counts over time. Pearson's correlation was used to determine the strength of funding agencies' influence on the reservoir and fisheries research in India. Paired 't' test was used to test the null hypothesis that the mean score obtained between the pairs of observations is zero. All statistical analyses were performed using SPSS version 21.0 statistical package (SPSS, 2021).

Results and discussion

Global research output on reservoir fisheries

The Web of Science (WoS) based research output assessment on reservoir fisheries during 1998-2019, recorded a total of 7607 publications at the global level (Table 3). The top three countries *viz.* USA (2662 papers; 34.99%), Brazil (874 papers; 11.49%), and the People's Republic of China (678 papers; 8.91%) contributed about 55% to the total global publications on reservoir fisheries. India produced 162 publications with a share of 2.13% during the period. These countries also top in the list with highest number of dams in the world and India has 4,407 dams occupying third place (ICOLD, 2022). Overall, a marked increase in publications count on reservoir fisheries was observed for all countries while a few *viz.* Turkey (26 folds), China (14.44 folds), Brazil (11.5 folds) and India (11 folds) have shown more than 10 folds increase in their publication count from the base year of analysis (*i. e.* 1998). The consistent increase in production and demand for freshwater fish must have contributed to increase in reservoir related research in China (Kang *et al.*, 2017). Hao *et al.* (2021) observed that the researchers from Western countries mostly focused on the river restoration and management including research on fish way and fish pass (Brito-Santos *et al.*, 2021), while China focussed on the eco-modelling, climate change and reservoir operations. Inland fisheries contributes significantly for aquaculture production in India, Brazil and Turkey and the reservoirs offer good scope to enhance culture-based fisheries, triggering a focussed research in these countries on reservoir fisheries (Syed *et al.*, 2019). Various development schemes implemented by the Govt. of India during the last decade focussed on the stocking of fingerlings and cage culture in the reservoirs as well as integrated reservoir development plans. The recently launched fisheries development scheme, Pradhan Mantri Matsya Sampada Yojana (PMMSY) also has dedicated components to develop reservoir fisheries in India (NFDB, 2020).

The citation rate is one of the proxy measures of the scientific impact and research evaluation (Wouters *et al.*, 2015) and the total and average citations per paper (ACPP) are the most used indicators for the evaluation of publications (Waltman, 2016). In the present study, the ACPP ranged from 5.91 to 28.19 during 1998-2019. Italy registered the highest citation impact with 28.19 ACPP, followed by Germany (25.55) and France (24.79), despite having very little publication share.

Among the countries, the USA had the highest *h*-index (83), and ranked 10th in terms of ACPP (19.11) (Table 3). The current study revealed that the contribution of Western and South Asian countries to the research on reservoir fisheries is significantly higher ($p<0.01$) when compared to India and this can be attributed to the research focus, type of publications and intended readers. The papers of the researchers from tropical developing countries focus on regional researchable and relevant issues and are published in easy-to-publish local journals than in international journals (Collazo-Reyes, 2014; Oliveira Jr. *et al.*, 2016).The present study revealed that the WoS database had classified global reservoir fisheries research outputs under 84 broader research areas of which 'Environmental Sciences Ecology' (35.13%), 'Marine Freshwater Biology' (28.21%), and 'Fisheries' (26.52%) contributed about 90% to the total publications. Generally, the research subjects under inland fisheries are evolving and diversifying over the period to meet the requirement of a particular geographical area (Alves and Minte-Vera, 2013).

Table 3. Publication output and citation analysis of high-profile countries on reservoir fisheries research during 1998-2019 (n=7,607)

No.	Country	1998				2019				1998-2019					
		TP	TC	ACCP	*h*-index	TP	TC	ACCP	*h*-index	TP	% Share to n	TC	ACCP	*h*-index	WSC
1	USA	59	1872	31.73	25	207	302	1.46	5	2662	34.99	50877	19.11	83	44535
2	Brazil	8	519	64.88	7	92	165	1.79	5	874	11.49	13670	15.64	52	10511
3	People's R China	9	78	8.67	5	130	306	2.35	6	678	8.91	9746	14.37	46	8653
4	Canada	19	630	33.16	13	32	108	3.38	3	424	5.57	8798	20.75	45	8410
5	Turkey	1	5	5	1	26	17	0.65	2	329	4.32	3594	10.92	27	3174
6	France	7	181	25.86	6	19	21	1.11	3	277	3.64	6868	24.79	41	6682
7	Australia	5	106	21.2	4	23	31	1.35	3	247	3.25	5812	23.53	37	5592
8	Czech Republic	9	132	14.67	5	19	29	1.53	3	242	3.18	3695	15.27	32	2929
9	Spain	4	139	34.75	4	16	41	2.56	3	225	2.96	5149	22.88	36	5004
10	England	2	28	14	2	16	90	5.63	3	200	2.63	4902	24.51	38	4829
11	Germany	9	190	21.11	7	19	97	5.11	4	197	2.59	5034	25.55	38	4885
12	South Africa	2	77	38.5	2	15	26	1.73	3	193	2.54	3306	17.13	27	2977
13	Poland	5	73	14.6	3	17	6	0.35	1	191	2.51	2048	10.72	24	1859
14	Russia	5	32	6.4	3	21	7	0.33	1	175	2.30	1035	5.91	18	999
15	Japan	4	131	32.75	4	11	9	0.82	2	165	2.17	2983	18.08	28	2885
16	India	2	0	0	0	22	78	3.55	2	162	2.13	1179	7.28	15	1147
17	Norway	4	341	85.25	4	17	15	0.88	2	130	1.71	2818	21.68	27	2756
18	Portugal	3	81	27	2	12	15	1.25	3	118	1.55	2379	20.16	29	2276
19	Italy	3	98	32.67	2	11	91	8.27	4	96	1.26	2706	28.19	30	2675
20	Mexico	2	26	13	1	15	88	5.87	3	95	1.25	1034	10.88	18	1002

TP-Total papers, TC-Total citations, ACPP-Average citations per paper, WSC-Without self-citations, N-Total number of publications by all countries

Research output on Indian reservoir fisheries

Major research focus areas

The WoS based research area-wise breakup of the papers (162 nos.) from India yielded 'Fisheries' (47 papers; 29.01%), 'Environmental Sciences Ecology' (43 papers; 26.54%), and 'Marine Freshwater Biology' (20 papers; 12.34%) as the top three areas, contributing 67.90% to the total publications (Fig. 1). After the individual evaluation of research papers, it was found that the papers under theme 'Fisheries' cover diverse subjects including stock assessment, productivity, stocking, fishing gear and craft. The findings of the present study also support similar scientometric studies and other related topics which recorded diverse subjects in fisheries research in the Indian context (Sab *et al.*, 2016; Bhoomaiah *et al.*, 2020b). Though Fisheries, has the highest number of research papers, the ACPP of Environmental Sciences Ecology was 8.3 with an *h*-index of 11 with highest citations *i.e.* 357. This indicates that studies dealing with reservoir's ecology and environmental aspects attract more readers than the other subjects. The reason for this is the need to document the fish diversity and habitat conditions of reservoirs.

Temporal research dynamics

The manual evaluation and classification of publications pertaining to WoS based research themes *viz.* 'Fisheries', and 'Marine Fresh Water Biology' under broader thematic areas (13 nos.; 116 papers) revealed the temporal transformation in the subjects (Table 4). The predominant thematic areas in India's reservoir fisheries were 'Biodiversity and Conservation', 'Environment and Ecology', and 'Stock Assessment' especially during 1990's and early 2000s. Subject areas which are directly linked to the reservoir management like 'Aquatic Animal Health', 'Physiology', 'Stock assessment, and stocking' have shown an increase in the number of publications in the later period. It is also inferred that many publications were

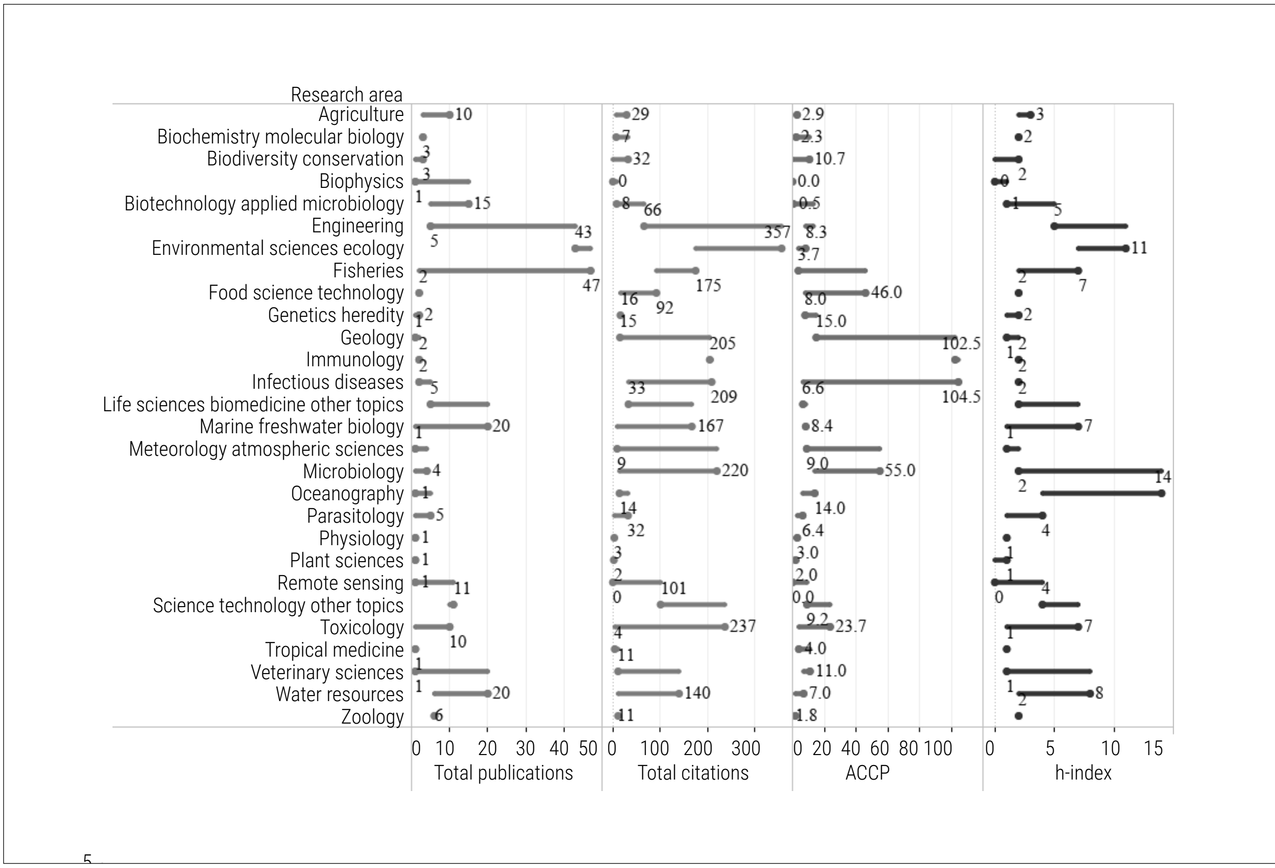


Fig. 1. Contribution of the research areas to the research on Reservoir Fisheries in India during 1998-2019

Table 4. Major subject areas on reservoir fisheries research during 1998-2019 (n=162)

No.	Subject area	1998-2002	2003-07	2008-12	2013-17	2018-19	Total
1	Environment and Ecology	2	1	5	6	3	17
2	Biodiversity and Conservation	2	4	6	10	10	32
3	Aquatic Animal Health and Physiology	3		1	4	2	10
4	Anthropogenic activities and Pollution		1	2	4		7
5	Harvest and Post-harvest studies			1	1	1	3
6	Genetics and Biotechnology			1	1		2
7	Management and Governance			2	3	1	6
8	Gear and Craft			1		1	2
9	Stock assessment and Stocking		2	4	5	6	17
10	Cage culture		1			2	3
11	Remote sensing				3	2	5
13	General*	1	1	3	4	3	12
Total		8	10	26	41	31	116**

*Indicates publications that mentioned the keyword, "Reservoir" and the publications are of general interest.
**No. of publications which are directly involved in the field of reservoir and its fisheries.

focussed on the reservoir management and governance. A transition to the subjects of the 'Genetics and Biotechnology', 'Harvest and Post-harvest', and 'Governance' was observed from 2008. The shift in the research from the environmental related aspects towards the management and governance aspects could be attributed to the complex institutional arrangements and ownership of Indian reservoirs involving large group of stakeholders at administrative, managerial, research and end user levels. The remote sensing research on reservoir fisheries emerged as a thematic area in Indian reservoir fisheries since 2013. Overall, it is observed that a multi-disciplinary approach is being given more attention in the recent times. Jaric *et al.* (2012) reported 'Genetics' as the most rapidly growing area of research in fisheries science during 2000-2009. The change in research focus could be attributed to support the goals of the Govt. of India to increase the reservoir productivity and applying improved scientific approach to plan and implement the development schemes like fingerling stocking in the reservoirs.

A detailed analysis of the papers published by the *Journal of Inland Fisheries Society of India*, a non-indexed journal, indicated that 57 papers were published during the contemporary period, on Reservoirs Fisheries. These papers were predominantly published during 2000-2010. During the late 1990's, the research focus was more on the basic domain such as limnological and stock assessment related aspects while productivity evaluation and environmental quality related studies dominated post-2000 (Table 5). These observations confirm the WoS based analysis, inferring that there is no major difference in the research focus between the two groups of information.

In general, the focus of the central fisheries institutes in India was to study the reservoir eco-system as a whole including the limnology, ecology and socio-economic aspects and publish in the form of bulletins, policy briefs and newsletters to reach the administrators/beneficiaries to manage and augment the reservoir fish production scientifically as observed by Vivekanandan (2001). For instance, the Central Inland Fisheries Research Institute, Barrackpore under the Indian Council of Agricultural Research has studied 81 reservoirs in India and published around 17 bulletins during 1998-2014 (http://www.cifri.res.in).

Table 5. Major research thematic areas on Reservoir Fisheries Research published by Journal of Inland Fisheries Society of India during 1998-2014

Subject area	1998-2002	2003-2007	2008-2012	2013-2014	Total
Environment and Ecology	6	6	2		14
Biodiversity and Conservation	5	4	5	1	15
Aquatic animal health and Physiology	3	3	1		7
Anthropogenic activities and Pollution		1	1		2
Management and Governance	1	1	2	1	5
Stock assessment and Stocking	3	6	2	1	12
General	2				2
Total	20	21	13	3	57

Research publication metrics assessment

A gradual increase in the number of papers with a significant difference ($p<0.01$) in the total number of papers and *h*-index between the two decades was observed (Table 6). Indian reservoirs fisheries papers have received a total of 1,179 citations, with the maximum citation of 273 in the year 2009 (Table 6). About 2.47% of the research papers (4 nos.) had received more than 50 citations, while 17.90% of the papers recorded 10-49 citations (Table 7). It is also evident that, about 79.63% (129 of 162) of the papers received <10 citations and this may be attributed to the nature of research problem selected, geographical area, and lack of associated value in terms of economics. For instance, Bhoomaiah *et al.* (2020b) reported higher citation of Indian research papers on White Spot Syndrome Virus, a devastating pathogen that wrecked huge monetary losses to the shrimp farming sector around the world.

In the present study, no significant difference ($p>0.05$) in the ACCP amongst the two decades was found and the maximum ACPP was recorded for the papers published in 2009 followed by 2010 (Table 6). The ACPP depends on many factors such as the age of publication, publication types such as a review or original article, the importance and application of the research work (Aksnes, 2003; Aksnes *et al.*, 2019). It has been observed that reviews tend to gain more citations, on an average, 3 times more than that of original research articles (Miranda and Garcia-Carpintero, 2018). The publications providing core information, *i. e.* water quality, plankton diversity and productivity are of high interest considered for citation. However, updated technologies like usage of geospatial tools in planning, impact studies related to various policies have less representation in the articles due to which frontier knowledge is less available for citations (Cole, 2000).

Major reservoir research organisations in India

The study showed that research institutions under Indian Council of Agricultural Research (ICAR) *viz.* ICAR-Central Inland Fisheries Research Institute (ICAR-CIFRI) and ICAR-Central Institute of Fisheries Education (ICAR-CIFE) accounted for the maximum share of the reservoir fisheries research publications in India. Apart from these central institutions, the contribution by State Agricultural University (SAU) such as Govind Ballabh Pant University of Agriculture Technology, Pantnagar is also evident as observed by Jayashree and Arunachalam (2000) (Table 8). Previous scientometric studies on various aspects of Indian fisheries research

Table 6. Trend of research on reservoir fisheries in India during 1998-2019

Year	Papers with authors from India					Papers with at least one author from other countries				
	Papers		Citations			Papers		Citations		
	No.	% Share	Total citations	ACCP	*h*-index	No.	% Share	Total citations	ACCP	*h*-index
1998	2	1.23	0	0	2	0	0	0	0	0
1999	0	0.00	0	0	4	0	0	0	0	0
2000	3	1.85	4	1.33	3	0	0	0	0	0
2001	2	1.23	18	9.00	4	0	0	0	0	0
2002	1	0.62	0	0	4	0	0	0	0	0
2003	2	1.23	17	8.50	4	0	0	0	0	0
2004	2	1.23	24	12.00	4	1	3.70	12	12.00	1
2005	1	0.62	2	2.00	4	0	0	0	0	0
2006	3	1.85	18	6.00	6	0	0	0	0	0
2007	3	1.85	5	1.67	5	0	0	0	0	0
2008	6	3.70	62	10.33	4	1	3.70	27	27.00	1
2009	8	4.94	273	34.13	4	2	7.41	233	116.5	2
2010	9	5.56	144	16.00	2	1	3.70	11	11.00	1
2011	10	6.17	103	10.30	1	3	11.11	55	18.33	3
2012	8	4.94	35	4.38	1	2	7.41	4	2.00	2
2013	16	9.88	49	3.06	2	3	11.11	24	8.00	2
2014	8	4.94	57	7.13	2	2	7.41	34	17.00	2
2015	12	7.41	131	10.92	0	1	3.70	15	15.00	1
2016	11	6.79	67	6.09	2	4	14.81	54	13.50	4
2017	13	8.02	50	3.85	1	3	11.11	15	5.00	2
2018	20	12.35	42	2.10	0	2	7.41	5	2.50	2
2019	22	13.58	78	3.55	0	2	7.41	70	35.00	1
Total	162	100	1179	152.34		27	100	559	282.83	

Table 7. Citation trend of Indian reservoir fisheries research papers during 1998-2019

No. of citations	Papers with authors from India		Papers with at least one author from other countries	
	Number	%	Number	%
0	51	31.48	0	0
1 to 9	78	48.15	11	40.74
10 to 19	22	13.58	9	33.33
20 to 49	7	4.32	5	18.52
>50	4	2.47	2	7.41
Total	162	100	27	100

shows the predominant contribution of research institutes on their mandated subject area. For instance, the contribution by ICAR-Central Institute of Brackishwater Aquaculture (ICAR-CIBA), Chennai in WSSV research (Bhoomaiah *et al.*, 2020b) and ICAR-Central Marine Fisheries Research Institute ICAR-CMFRI), Kochi in the research on coral reef ecosystem (Mohan *et al.*, 2011). Similarly, ICAR-CIFRI, Barrackpore is mandated for fisheries research on inland waterbodies such as reservoirs, wetlands, and estuaries in India. The key drivers for the growth in publications are the capacity and motivation of the researchers and the institutional culture (Hiruy *et al.*, 2019).

Highly productive authors and their networking

The top 10 authors contributed 37.03% to the total publications from India. The co-author network map showed 9 clusters, and more than ten authors have collaborated in 5 clusters. It can be inferred that the researchers had collaborated to improve their research with their technical skill to address the researchable issues in reservoir fisheries. The size of the circle and number of lines between the items in each cluster indicates the strength of intra-cluster collaboration (Fig. 2). The network diagrams presented in this study are generated through VOSviewer tool, which uses the

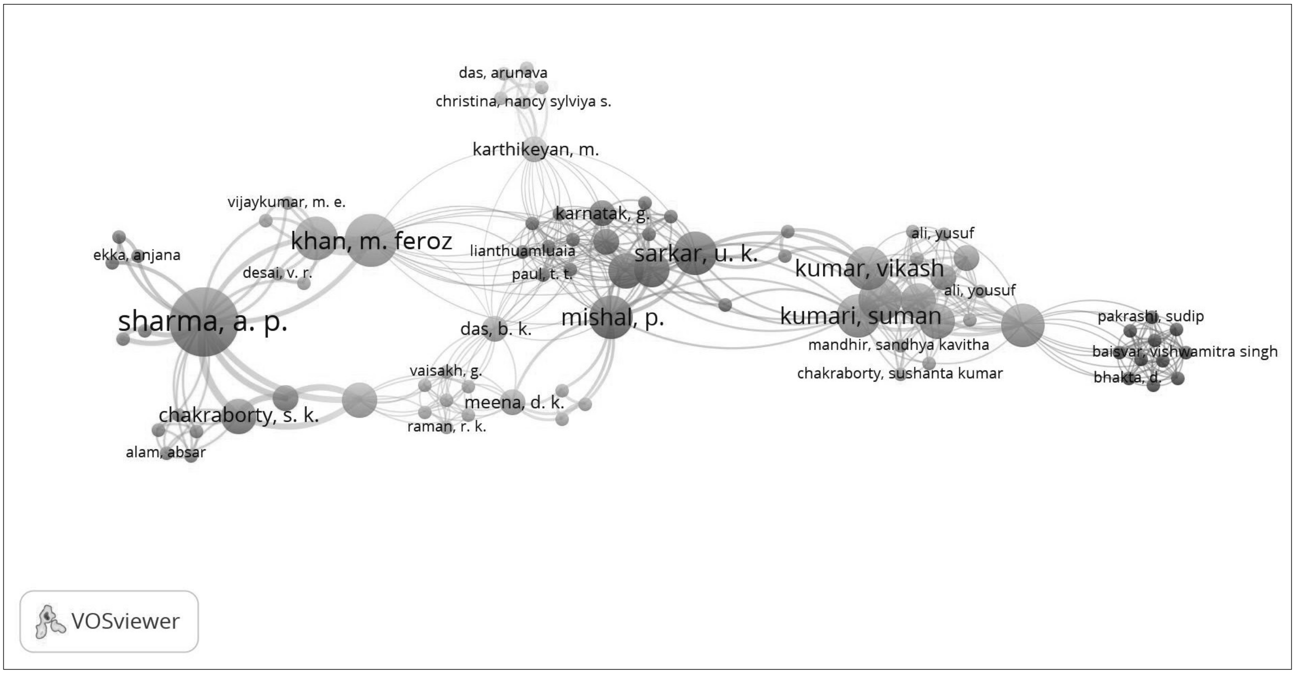


Fig. 2. Network visualisation of author collaboration in research on reservoir fisheries during 1998-2019 in India

bibliography data exported from the WoS database; and thus, this figure represents the details extracted from the Indexed Journal papers available in WoS database only. Most of the scientometric studies have limitations and in the present study, the issue of same author with different written names was encountered (*e. g.* Khan, m.f and Khan, m. feroz). This observation sheds light on the need for sensitisation among the research community to utilise standard citation practices and a unified persistent digital identifier (like ORCID). Over time, the names of the institutions and their affiliations may change, and in the context of advancing digital technology, there is a dire need for developing a unique identifier for all research authors/researchers and organisations.

Highly cited research papers

The highly cited papers are the publications that the researchers in the field most frequently cite. The citations for the top ten papers on Indian reservoir fisheries ranged between 87 (Dhanakumar *et al.*, 2015) to 10 (Hulyal *et al.*, 2008) (Table 9). These papers are mostly published in international journals with impact factors (JCR, 2020) ranging from 0.612 *(Journal of Applied Ichthyology)* to 4.872 *(Ecotoxicology and Environmental Safety)*. The highly cited papers are published in the environment subject related journals. Google Scholar citation data acquired for the top ten papers revealed a higher citation count than WoS database. Lawrence (2001) reported that Google Scholar retrieves citations from non-journal sources hence have a much lower scientific impact than citations found by WoS/ Scopus (Martin-Martin *et al.*, 2018).

Top journals for reservoir fisheries research in India

Research publications from India on reservoir fisheries were published in 79 journals, including 63 international journals (92 papers). The top journals which published ≥5 papers on

Table 8. Research output from organisations in India on reservoir fisheries during 1998-2019 (n=162)

No.	Name of the Organisation	TP	TC	ACPP	*h*-index
1	ICAR-Central Inland Fisheries Research Institute	28	159	5.68	7
2	ICAR-Central Institute of Fisheries Education	13	55	4.23	4
3	Govind Ballabh Pant University of Agriculture Technology	9	5	0.56	1
4	ICAR-Directorate of Coldwater Fisheries Research	8	6	0.75	1
5	ICAR-Central Institute of Freshwater Aquaculture	7	83	11.86	5

Table 9. Top 10 highly cited Indian publications on reservoir fisheries research during 1998-2019

No.	Title	Year	Author	Affiliation	Journal title	Total citations	
						WoS	GS
1	Heavy metal partitioning in sediments and bioaccumulation in commercial fish species of three major reservoirs of river Cauvery delta region, India	2015	Dhanakumar *et al.*	Bharathidasan University, Tiruchirappalli	Ecotoxicology and Environmental Safety	87	185
2	Assessment of impacts of invasive fishes on the food web structure and ecosystem properties of a tropical reservoir in India	2009	Khan *et al.*	Bangalore Regional Center of ICAR-Central Inland Fisheries Research Institute	Ecological Modelling	28	61
3	Impact of urbanisation on the quality of water in a natural reservoir: A case study with the Deepor Beel in Guwahati City, India	2010	Bhattacharyya and Kapil	Guwahati University, Guwahati	Water and Environment Journal	18	32
4	Comparative mass-balanced trophic models to assess the impact of environmental management measures in a tropical reservoir ecosystem	2008	Panikkar *et al.*	Bangalore Regional Center of ICAR-Central Inland Fisheries Research Institute	Ecological Modelling	17	33
5	Indicators and assessment of ecosystem health of Bakreswar Reservoir, India: An approach through network analysis	2017	Banerjee *et al.*	Visva-Bharati University, Santi Niketan	Ecological Indicators	15	27
6	Assessment of genotoxic induction and deterioration of fish quality in commercial species due to heavy-metal exposure in an urban reservoir	2014	Fatima *et al.*	Aligarh Muslim University, Aligarh	Archives of Environmental Contamination and Toxicology	15	40
7	Impact of stocking on yield in small reservoirs in Andhra Pradesh, India	2004	Sugunan and Katiha	Bangalore Regional Center of ICAR-Central Inland Fisheries Research Institute	Fisheries Management and Ecology	12	40
8	Density-dependent growth performance of Indian major carps in rainwater reservoirs	2004	Mohanty *et al.*	ICAR-Water Technology Centre for Eastern Region, Bhubaneswar	Journal of Applied Ichthyology	12	44
9	Water quality assessment of Almatti Reservoir of Bijapur (Karnataka State, India) with special reference to zooplankton	2008	Hulyal *et al.*	Karnataka University, Dharwad	Environmental Monitoring and Assessment	10	39
10	Studies on the growth and mortality of Indian River shad, *Gudusia chapra* (Hamilton, 1822) from Panchet Reservoir, India	2018	Kumari *et al.*	ICAR-Central Inland Fisheries Research Institute, Barrackpore	Environmental Science and Pollution Research	7	11

Google Scholar accessed in April 2021

reservoir fisheries from India are summarised in Table 10. The *Indian Journal of Fisheries* contributed 17 papers, followed by *Bioscience Biotechnology Research Communications* with 10 papers. Recent scientometric studies on various aspects of Indian fisheries research and elsewhere concludes that *Indian Journal of Fisheries* as the most preferred journal among the Indian researchers (Jayashree and Arunachalam, 2000; Sab *et al.*, 2016; Bandara and Wijewardene, 2018; Bhoomaiah *et al.*, 2020a). Apart from *Indian Journal of Fisheries*, the other Indian journals mentioned in Table 10 are *Fishery Technology*, *Journal of Environmental Biology* and *Current Science*. The researcher's preference to these journals could be attributed to the journal's scope of research interest that helps the researchers to have broader understanding on location-specific research and its implications. Further, the articles published in these journals will be of greater applicability to the South Asian countries as the reservoirs in these nations share common climatic/weather conditions.

Environmental Science and Pollution Research, Environmental Monitoring and Assessment are among the top 15 journals preferred by the Indian authors. The researchers prefer to publish

Table 10. Research journals which published most papers on reservoir fisheries during 1998-2019 (n=162)

No.	Journal	TP	% Share to n	TC	ACPP	*h*-index	Impact factor*
1	Indian Journal of Fisheries	17	10.49	20	1.18	3	0.29
2	Bioscience Biotechnology Research Communications	10	6.17	2	0.20	1	#
3	Fishery Technology	9	5.56	3	0.33	1	#
4	Journal of Environmental Biology	9	5.56	14	1.56	3	0.78
5	Current Science	7	4.32	32	4.57	3	0.73
6	Environmental Science and Pollution Research	5	3.09	19	3.80	3	3.06
7	Environmental Monitoring and Assessment	4	2.47	25	6.25	3	1.90
8	Indian Journal of Animal Sciences	4	2.47	6	1.50	2	0.28
9	Journal of Applied Ichthyology	4	2.47	17	4.25	2	0.61
10	Aquaculture	3	1.85	62	20.67	3	3.22
11	Ecotoxicology and Environmental Safety	3	1.85	106	35.33	3	4.87
12	Sustainable Water Resources Management	3	1.85	1	0.33	1	#
13	Water Resources Management	3	1.85	44	14.67	3	2.92
14	Agricultural Water Management	2	1.23	3	1.50	1	4.02
15	Aquatic Conservation Marine and Freshwater Ecosystems	2	1.23	7	3.50	2	#

*As per JCR (2020); # Not indexed as per JCR (2020)

their articles in high impact factor (IF) journals to increase their visibility and thus impact citations (Tahamtan *et al.*, 2016). The research published in highly ranked journals might be attracting the elite research fraternity like academicians and researchers thus enhancing the citations. But these publications may end with no access to the general public, start-ups and administrators (Hiruy *et al.*, 2019). The journal accessibility, visibility, international status, impact factor and quality of the journal influences citations' probability (Vinkler, 1987).

It is worth mentioning that, many Indian Journals are not represented in the Web of Science because of not maintaining regular periodicity (Vinitha *et al.*, 2018). The journals like *Journal of the Inland Fisheries Society of India*, *Marine Fisheries Information Service*, and *Mahasagar* publish papers from their respective institutions, and these papers are not indexed by Science Citation Index (SCI). Indian fisheries researchers normally tend to publish their research in the local journals, which their respective institutes administer. This is normally restricted to the subject, which may be of local interest, and secondly, these papers may not be matching the quality demanded by journals having high international impact factor (Jayashree and Arunachalam, 2000; Bhoomaiah *et al.*, 2020a).

Prominent keywords

The analysis of keyword occurrence pattern is highly useful to quantify the focus of research output (Kumaresan *et al.*, 2014). Among the total keywords (1066), 79 keywords were selected (threshold of minimum occurrence of 3), and their network visualisation maps were generated in VOS viewer (Fig. 3). The top keywords include 'reservoir' (14 times), 'diversity' (13 times), 'management (11 times), 'biodiversity' (10 times) and 'conservation' (10 times). Grouping of keywords based on their relevance revealed that 'reservoir' (reservoir, reservoirs, reservoir fisheries, reservoir ecosystem) were represented 25 times, diversity and biodiversity 23 times and plankton (zooplankton, plankton, phytoplankton) 16 times. This observation supports that most of the research in the reservoir fisheries was concentrated on productivity and biodiversity assessment which are necessary for the sustainable utilisation of the resources. Similarly, 'reservoir' and 'fish' are amongst the most popular keywords in reservoir-related publications (Ho and Goethals, 2020).

Keyword co-occurrence analysis has clustered the 79 keywords into 9 major clusters wherein nodes with similar colour belong to the same cluster. The size of the node and word is directly proportional to the weight/frequency of the cluster and the cluster with the largest number of keywords is the most prominent research area (Hu and Zhang, 2015; Bandara and Wijewardene, 2018). The red coloured cluster indicates the main keywords like reservoir, lakes, diversity, phytoplankton, zooplankton and water quality, which indicates the research works related to productivity and water quality of the reservoirs. The occurrence of key words indicated that the research on plankton dynamics, biodiversity, conservation, trophic status, and stocking density are the highly prioritised research areas compared to the less represented topics such as genetics, geo-spatial implications and disease management. Understanding the thematic areas utilising the keywords will help the researchers to have an idea on the focus areas and also the lateral trend/swift in the importance given to the subject areas.

Research funding on reservoir fisheries

A total of 68 funding agencies were shortlisted after removing the repetitions in the names of the institutes. It was observed that data on research funding pertaining to the reservoir fisheries were not provided in some papers. This could be attributed to the practice of the authors in India not to mention the source of funding in case of publications that emerge out of the in-house research projects, undertaken using funds allocated to the respective agencies. The major four funding sources were University Grants Commission, Indian Council of Agricultural Research, Department of Science and Technology, and Department of Biotechnology which together contributed 16.65% to the total publications (Table 11). Non-availability of information on the funding agencies in all the publications was a limitation in the analysis.

International collaboration

International collaboration is an important research output indicator that is useful in understanding the interlinkage of the countries (Bhoomaiah *et al.*, 2020b). The current study revealed that 27 papers were published with at least one author from outside India, which formed 16.67% to the total publications on reservoir fisheries. Overlay visualisation was used for the co-authorship and countries analysis with threshold of at least one publication and one citation per document with fractional counting. The analysis showed a list of 29 countries with whom India has collaborated. An increasing trend over the years was noticed in the collaboration of Indian research with other countries (Fig. 4). However, the observed collaboration is lower, compared to other subject areas *viz.* WSSV (Bhoomaiah *et al.*, 2020b), while higher than the value reported for overall fisheries research (Bhoomaiah *et al.*, 2022).

International collaboration on policy matters, governance issues and spatial planning is always a welcoming subject to bring out innovative and updated methodologies in reservoir fisheries research. A co-authorship-based network of international collaboration papers was generated (Fig. 5) and the USA (14.81%) exhibited major author collaboration with India followed by England and Germany (Table 12). Generally, USA accounts for more collaborations with India in fisheries research (Sab *et al.*, 2016; Vinitha *et al.*, 2018; Singh *et al.*, 2019; Bhoomaiah *et al.*, 2020b, 2022). Papers with international collaboration had significantly ($p<0.01$) higher citations than the papers only with Indian authors (Fig. 6). This may be due to the nature of research problem, quality of work (extent of data collection, analysis and way

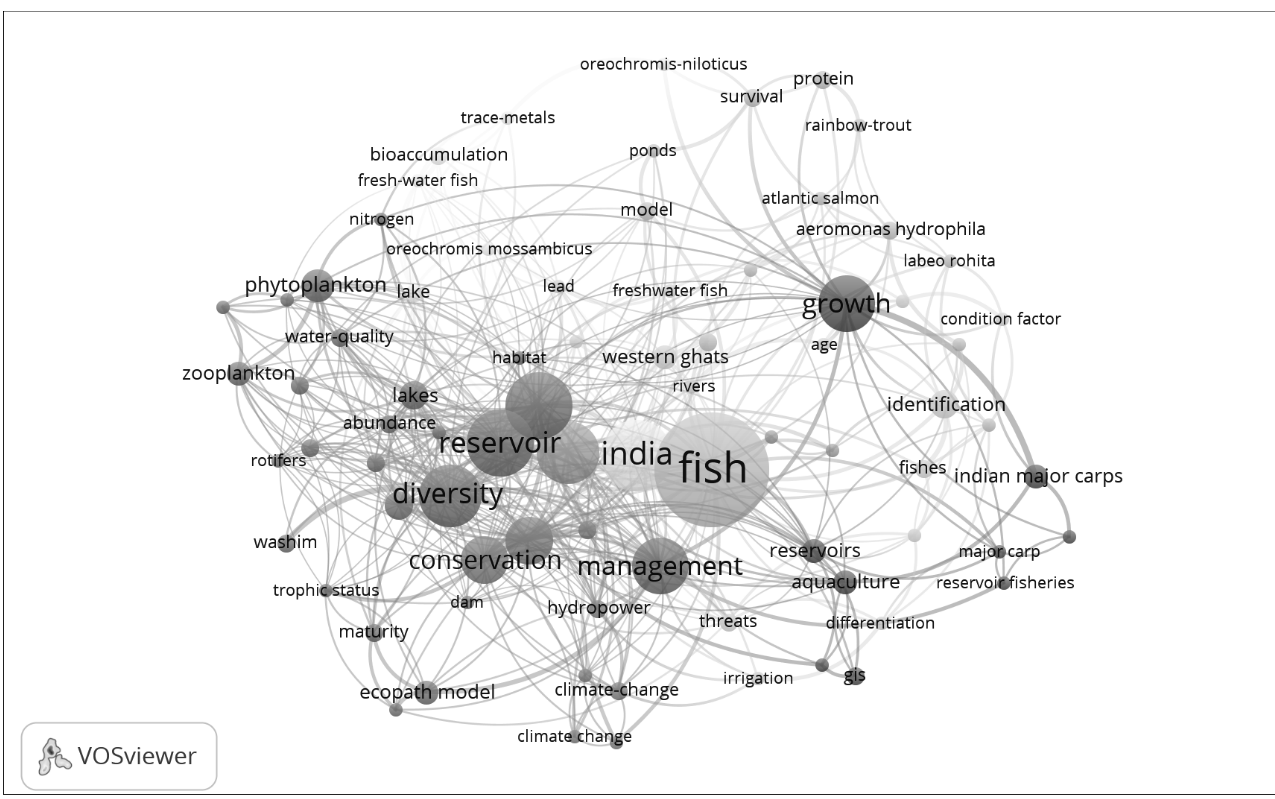


Fig. 3. Co-occurrence network of "keywords" used in Indian research publications on reservoir fisheries during 1998-2019 (n clusters=9, links=1032)

Table 11. Contribution of top 10 funding agencies on reservoir fisheries during 1998-2019

No.	Funding Agency	TP	% Share of total publications from India (n=162)
1	University Grants Commission	9	5.55
2	Indian Council of Agricultural Research	8	4.937
6	Department of Science Technology, India	6	3.703
5	Department of Biotechnology, India	4	2.469
3	Council of Scientific Industrial Research, India	2	1.235
4	Czech Academy of Sciences	2	1.235
7	Grant Agency of The Czech Republic	2	1.235
8	Indian Council of Medical Research	2	1.235
9	Ministry of Environment, Forest and Climate Change, Govt. of India	2	1.235
10	National Fisheries Development Board, India	2	1.235

of presentation) and wider publicity (Aksnes and Sivertsen, 2004; Lancho-Barrantes *et al.*, 2012).

States focused on reservoir fisheries research in India

The examination of relevant reservoir fisheries papers (116) revealed Uttarakhand (16 papers), Maharashtra (15 papers), and Tamil Nadu (13 papers) as leading states (Fig. 7) undertaking research in reservoir fisheries. This could be attributed to the presence of Central Fisheries institutes and State Agricultural Universities, which carry out the reservoir

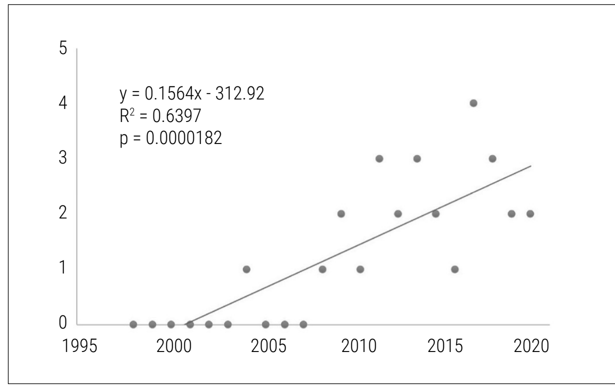


Fig. 4. Trend in papers with at least one author from other countries

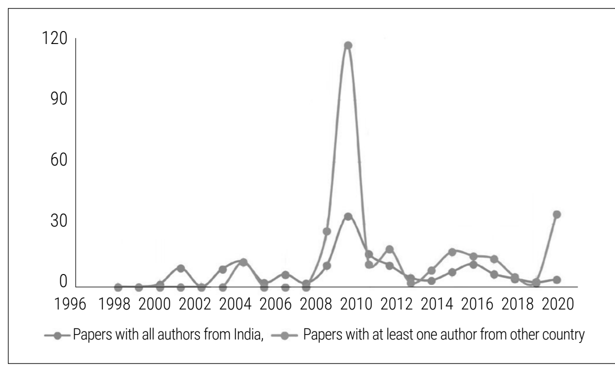


Fig. 6. Citation of papers with all authors from India and at least one author from another country

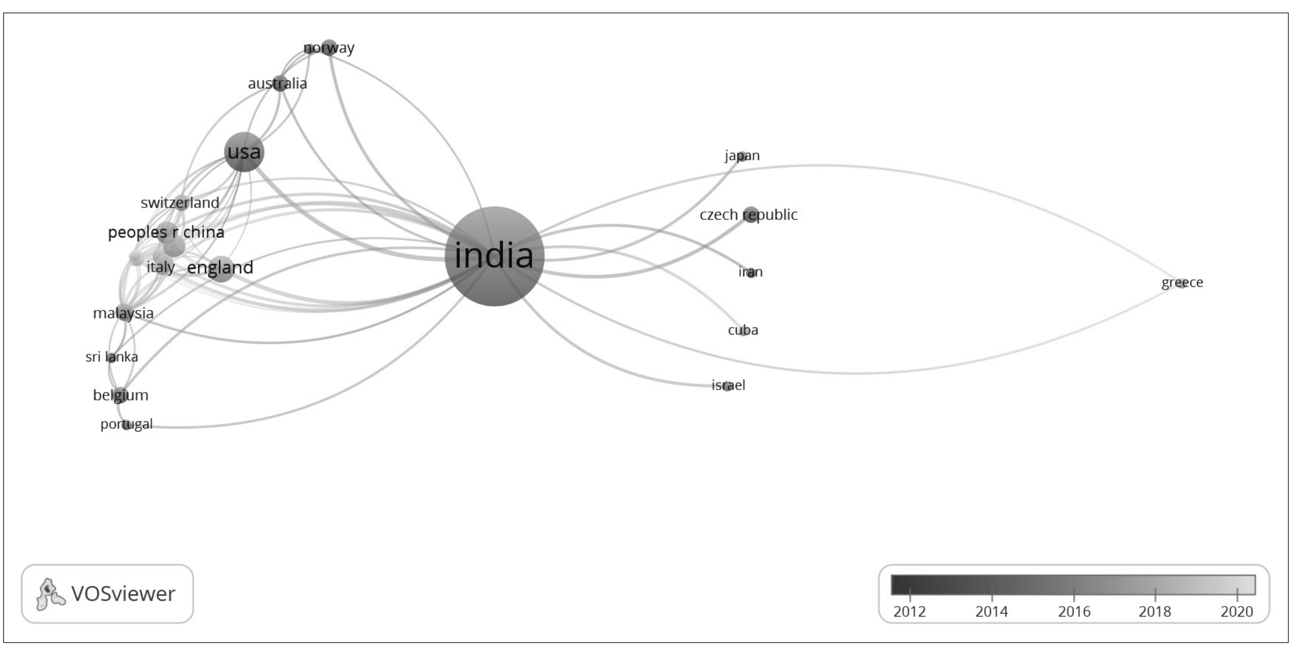


Fig. 5. Overlay visualisation of author collaboration between India and other countries on reservoir fisheries during 1998-2019

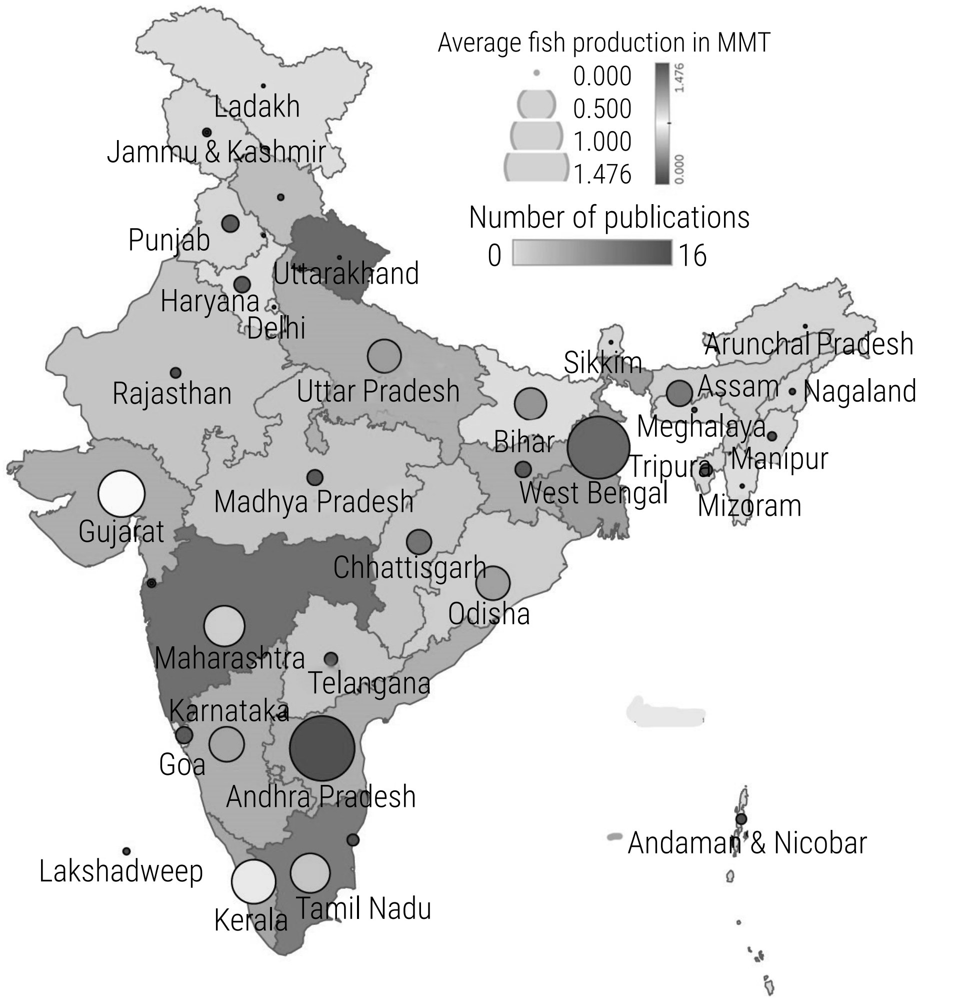
Table 12. Countries with which Indian researchers collaborated on reservoir fisheries during 1998-2019.

No.	Country	Papers		Citations		ACPP	*h*-index
		Total	% Share	Total citations	Self-citations (%)		
1	USA	8	14.81	353	0	44.13	6
2	England	4	7.41	120	0	30.00	3
3	Germany	3	5.56	85	1.18	28.33	2
4	People's Republic China	3	5.56	72	0	24.00	2
5	Sweden	3	5.56	279	0	93.00	3
6	Australia	2	3.70	231	0	115.50	2
7	Belgium	2	3.70	22	0	11.00	2
8	Canada	2	3.70	72	0	36.00	2
9	Czech Republic	2	3.70	13	0	6.50	2
10	Italy	2	3.70	79	0	39.50	2
11	Malaysia	2	3.70	83	0	41.50	2
12	Netherlands	2	3.70	83	0	41.50	2
13	Norway	2	3.70	232	0	116.00	2
14	Switzerland	2	3.70	95	0	47.50	2
15	Austria	1	1.85	69	0	69.00	1
16	Brazil	1	1.85	69	0	69.00	1
17	Cuba	1	1.85	11	0	11.00	1
18	Denmark	1	1.85	205	0	205.00	1
19	Egypt	1	1.85	12	0	12.00	1
20	Greece	1	1.85	2	0	2.00	2
21	Iran	1	1.85	24	0	24.00	24
22	Israel	1	1.85	8	0	8.00	1
23	Japan	1	1.85	2	0	2.00	1
24	Mexico	1	1.85	69	0	69.00	1
25	New Zealand	1	1.85	2	0	2.00	1
26	Portugal	1	1.85	8	0	8.00	1
27	Sri Lanka	1	1.85	14	0	14.00	1
28	Vietnam	1	1.85	69	0	69.00	1
29	Zambia	1	1.85	69	0	69.00	1
	Total	54*	100	2452		1307	73

*Includes double counting of some papers that have more than one country collaboration

fisheries research on diverse aspects, in these states. Overall, this leads us to hypothesise that the extent of research work carried out in a particular geographical area depends on the proximity to research laboratories. Lack of available research infrastructure also contributes for less research in the states irrespective of its potential. Creating a network of research collaboration among the researchers working in different institutes at pan-India level would aid in addressing this issue and strengthen reservoir fisheries research in the future. Further, establishing the linkage with international research laboratories will help to navigate through the hurdles in reservoir fisheries management and sustainable utilisation. Irrespective of the geographical setting of the states, the dominant areas of research observed during the study period were biodiversity, stocking, environmental and ecological studies (Table 4).

The study undertook an analysis of publications on reservoir fisheries research in India as well as in the world. India stands 16th in terms of the total number of publications with 162 papers



Map based on Longitude (generated) and Latitude (generated) and Latitude (generated). For pane Latitude (generated): Color shows sum of Number of publications. Details are shown for Name of the State. For pane Latitude (generated) (2): Color shows sum of Average Fish production in MMT. Size shows sum of Average Fish production in MMT. The marks are labeled by Name of the State.

Fig. 7. Publication output (1998-2019) and fish production of States (for the year 2019) in reservoir fisheries research in India

and the transition in the research areas indicates a shift towards management of reservoirs. The preference of the researchers to publish their work in non-SCI-indexed/institutional/society journals may be a reason for the low representation of Indian publications and citations in the database such as WoS or Scopus. The publications related to reservoirs in India do not have significant international researcher collaboration as compared to general fisheries research in India and there is a need to strengthen collaboration among the researchers in India with researchers from other countries. In the current study, the publications on reservoir fisheries were extracted from the WoS database and also from the prominent journal on inland fisheries published from India. Similar research papers on reservoir fisheries in non-indexed journals published from other countries could not be analysed due to lack of access. National governments may consider developing databases and repositories of all publications and provide open access to the same. This will provide an opportunity to conduct comprehensive scientometric analyses and aid in better understanding of the research trends in different subject areas in a country. However, in a broader sense, this study throws light on the status of research productivity and spatio-temporal dynamics on the reservoir fisheries publications, which would help the academicians and policymakers in understanding the current research focus and trends in this field and plan the course of research for better reservoir management.

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