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Mapping the research impact of collaboration and networking of ICAR fisheries research institutes in India: A scientometric study

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ABSTRACT

The eight National Fisheries Research Institutes under the Indian Council of Agricultural Research (ICAR) play a significant role in driving fisheries development in the country by advancing knowledge through basic and applied research; technology development and extension/outreach. Collaboration and networking among researchers and institutes are fundamental to address the multi-faceted issues confronting the fisheries sector in India. Collaborative research pattern among ICAR-Fisheries Research Institutes (IFRIs) and with R&D organisations in other countries was studied for a period of 20 years (2000-2019). Research productivity and focus areas of research of these institutes were also assessed through bibliometrics of publications extracted from the Web of Science (WoS) database. The search yielded 4,557 publications and a significant increase in the number of publications from 2000 to 2019 was evident . Major chunk of these papers (87%) was published in collaboration with National Institutes while only 10.6% had international collaboration especially with the United States of America (USA), Australia and Japan. A positive correlation ($p<0.01$) was observed between the extent of collaboration (both national and international) and the average citation per paper. The average impact factor of the journals carrying fisheries research papers with at least one international author was higher than those in which the papers were with only Indian authors. This leads us to hypothesise that the network of IFRIs with international research institutions aids in increasing the quality, visibility and impact of research. The co-authorship pattern revealed a gradual reduction in single and two-authored papers during the last 20 years, while multi-authored papers exhibited an increasing trend. The study showed that the collaboration network in fisheries research is growing fast; collaborating countries in the network increased gradually, and the number of authors and publications increased almost exponentially, as indicated by the growth rate and doubling time in research publications. The present study provides a multi-dimensional overview of the impact of research publications from IFRIs and provides specific insights in to the research managers to plan and strategise their collaborations to enhance the influence of fisheries research in India.

Keywords: Collaborative index, Collaboration coefficient, Doubling time, Research productivity

Introduction

Fisheries and aquaculture constitute an important sector under agriculture which have a pivotal contribution to ensuring food, nutritional and livelihood security to millions globally. Research on various basic and applied aspects of fisheries are in progress at different public and private research organisations in India (Bhoomaiah *et al.,* 2020a). Fisheries research in India got a significant momentum ever since the opening of India's first Fisheries Research Center, Central Marine Fisheries Research Station (now ICAR-Central Marine Fisheries Research Institute) on 03 February 1947 (Silas, 2003). Presently, there are eight fisheries institutes under ICAR with pan-India scope and specific subject focus *viz,* freshwater, brackishwater and marine aquaculture, cold-water fisheries, fish-harvest and post-harvest technologies, genetic resources mapping and management as well as human resource development (Ayyappan and Diwan, 2006; Murthy, 2015). The ICAR has also established research complexes such as Central Island Agricultural Research Institute, Port Blair, Andaman; Central Coastal Agricultural Research Institute, Goa; ICAR Research Complex for the North-east Hill Region, Umiam, Meghalaya and ICAR Research Complex for Eastern Region, Patna, Bihar to undertake location-specific agricultural research in an integrated way. Some of the ICAR crop institutes are also undertaking fisheries research as a part of integrated farming system (IFS). State Agricultural Universities (SAUs) and traditional universities have

also contributed to the extension of fisheries research knowledge (Jayashree and Arunachalam, 2000). However, the eight ICAR-Fisheries Research Institutes play a substantial role in generating knowledge and developing technology required to propel and sustain fisheries development in India (Lakra and Gopalakrishnan, 2021)

Globally, collaboration and networking are considered as the major drivers of research outcome (Thorsteinsdottir, 2000; Lee and Bozeman, 2005; Bhoomaiah *et al.,* 2020b). Collaborative research papers are on the rise in many research fields, as reflected by the surge in papers published with increasing number of co-authors from both National and International Institutions (Gupta 1993; Gupta *et al*., 2002; He *et al*., 2009; Dutt and Nikam, 2014; Prakasan *et al*., 2014) and fisheries science is no exception. Advancement in fisheries science research demands collaboration of expertise from various disciplines, regions of the country and abroad. The researchers with the same or different specialisations collaborate for sharing knowledge, resources such as expensive research instruments, funding assistance and logistics support (Lee and Bozeman, 2005; Ceballos *et al*., 2017) and collaborations lead to saving time and money and most often, breakthrough research outcomes (Bansal *et al*., 2019). Enhanced funding support for collaborative research and specific fellowships or grants for travel have facilitated international collaboration, particularly among the researchers in many developing countries like India (Gupta *et al*., 2002; Bhoomaiah *et al*., 2020b). Ebadi and Schiffauerova (2015) recognised the influence of collaboration for getting more funding support. Some of the funding agencies also evaluate the research proposals based on proposed collaborative research partners while screening (Ubfal and Maffioli, 2011).

Fundamentally, assessing the collaboration patterns helps us to derive new strategies for formulating effective research collaborations for increasing research productivity (Lee and Bozeman, 2005). Assessment of research collaboration patterns and trends is important for the allocation of funds and resources (Prakasan *et al*., 2014). A critical analysis of the pattern and trends in collaboration would help to decide with whom to collaborate in the future across various fields of research for optimal benefits (Lee *et al*., 2013; Ceballos *et al*., 2017). Studying collaborative research networks' nature and research dynamics is also crucial for structuring and strengthening the innovation system (Toivanen and Ponomariov, 2011) and for formulating national policies that result in gainful collaboration (Abramo *et al*., 2009).

Against this background, the present study was undertaken to evaluate the research productivity, trends and pattern of collaboration network and research focus of ICAR-Fisheries Research Institutes by mining the research paper metrics pertaining to these institutions from Web of Science (WoS) database for the period of 20 years (2000-2019). The study also critically analyses the impact of collaborations in terms of enhancing research influence as indicated by the citation patterns. This study provides a multidimensional overview of the fisheries research and insights to the research managers for forging gainful collaboration among the potential national and international research organisations so as to increase the productivity and research influence of ICAR-Fisheries Research Institutes in India.

Materials and methods

Data collection

The study was carried out using the bibliometric data pertaining to 8 Fisheries Research Institutes functioning under the ICAR *viz*, ICAR-Central Inland Fisheries Research Institute (CIFRI), Barrackpore; ICAR-Central Marine Fisheries Research Institute (CMFRI), Kochi; ICAR-Central Institute of Fisheries Technology (CIFT), Kochi; ICAR-National Bureau of Fish Genetic Resources (NBFGR), Lucknow; ICAR-Central Institute of Fisheries Education (CIFE), Mumbai; ICAR-Central Institute of Brackishwater Aquaculture (CIBA), Chennai; ICAR-Central Institute of Freshwater Aquaculture (CIFA), Bhubaneshwar and ICAR Directorate of Coldwater Fisheries Research (DCFR), Bhimtal, retrieved from the Web of Science [v.5.34] Core Collection. An 'Advanced Search' was performed during January 2020, to obtain the publication records of selected Institutes for 20 years' period (2000-2019), by applying query in the 'Organisation-Enhanced' mode as follows; (NAME OF THE INSTITUTE_1 OR NAME OF THE INSTITUTE_2 OR….NAME OF THE INSTITUTE_8).

The search yielded a total of 4557 records. The present study considered the journal publications which are indexed by Science Citation Index Expanded (SCI-Expanded), Conference Proceedings Citation Index (CPCI-S) and Science and Emerging Sources Citation Index (ESCI). The detailed schematic overview of data extraction strategy is depicted in Fig. 1.

All the Fisheries Institutes analysed in the present study except ICAR-CIFE have a specialised research focus such as marine and inland fisheries, mariculture, fish genetic resources management, cold water fisheries, freshwater and brackishwater aquaculture, harvest and post-harvest technology. ICAR-CIFE, being a Deemed University under ICAR, undertakes fisheries research on all aspects, cutting across the disciplines to facilitate the human resource management in fisheries. The present study includes fisheries research publications only from

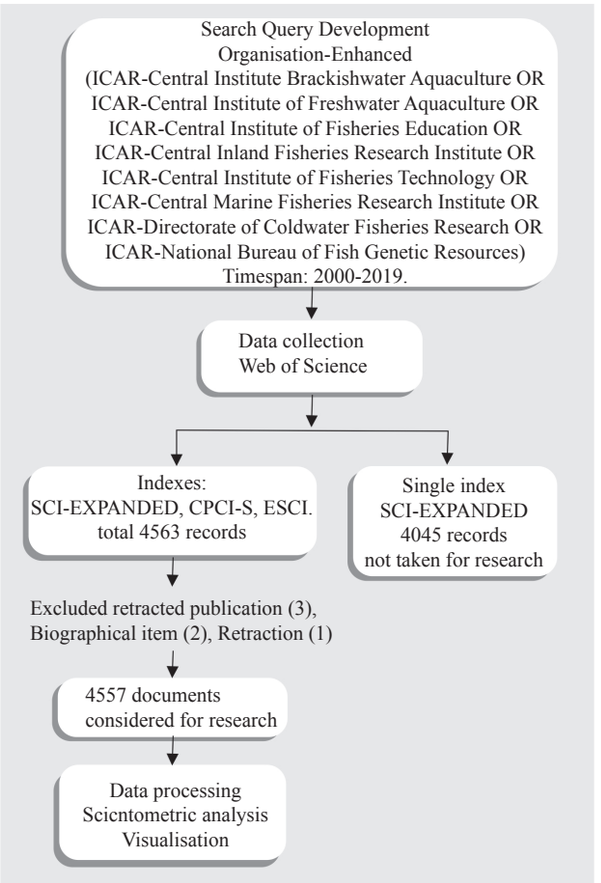

Fig. 1. Schematic overview of data extraction strategy

the eight ICAR fisheries research institutes and not from research complexes under ICAR, universities and other academic institutions across the country.

Data analysis and visualisation

Research productivity assessment

The year-wise research productivity of ICAR-Fisheries Research Institutes (IFRIs) was assessed in terms of publication trend (number of papers and growth rate), citation [total citations, self-citation and average citations per paper (ACPP)] and collaboration (collaboration index, degree of collaboration and modified collaborative coefficient).

The relative growth rate (RGR) represented the increase in the number of articles or pages per unit of time. The mean RGR for the specific period of the time interval can be calculated using the equation:

$$1 - 2\bar{R} = \frac{Log_{e2}W - Log_{e1}W}{2^T - 1^T}$$

where,

$1\text{-}2\bar{R}$ = Mean relative growth rate over the specific period of time interval

$Log_{e1}W$ = log of the initial number of articles or pages

$Log_{e2}W$ = log of the final number of articles or pages after a specific period of time interval

$2^T - 1^T$ = Unit difference between initial and final time

The year was taken here as the unit of time. The RGR for both articles and pages should be calculated separately, wherein $1\text{-}2\ R^{(aa\text{-}1Year\text{-}1)}$ represented the mean relative growth rate per unit of articles per unit of a year over a specific period of time interval and $1\text{-}2\ R^{(pp\text{-}1Year\text{-}1)}$ represented the mean relative growth rate per unit of pages per unit of a year over a specific period of time interval.

Publication characteristics assessment

The publication and citation-based indicators such as the number of publications, total citations, self-citations percent, ACPP and *h*-index were used to gauge the research performance and impact (Li and Ho, 2008; Carpenter *et al.,* 2014). The *h*-Index measures the scientific productivity of an author, institute, or journal based on the number of most cited papers and the citations recorded (Hirsch, 2005; Baldock *et al.,* 2009). The data on publication page details were compiled from the bibliography datasets extracted from WoS and were used for calculating average pages per author (APA) and average pages per paper (APP) of IFRIs publications.

Apart from this, the details of top journals carrying research papers from IFRI were extracted from WoS database and impact factors of those journals were retrieved from Journal Citation Reports (JCR 2019). The details on funding sources (names of funding agencies and their programs), extracted through the WoS database from the research paper's 'Funding Text', were manually reviewed for repetition and further validated and confirmed through web searches following Wang and Shapira (2011). The information on country-wise funding sources was also collected through web searches (Alvarez-Bornstein *et al*., 2017).

Collaboration pattern between researchers and institutions

The year-wise authorship pattern of IFRIs publications was studied to know the trend in collaborative research undertaken by these institutes during 2000-19. The extent of collaboration was ascertained based on authorship details of these publications using various indices *viz.,* Degree of collaboration (DC), a measure of the fraction of multiple-authored papers; Collaborative index (CI), a measure of the mean number of authors; and Modified collaborative coefficient (MCC), a quantitative measure of collaborative strength (Savanur and Srikanth, 2010).

$$\text{Degree of collaboration (DC)} = 1 - \frac{f_1}{N}$$

$$\text{Collaborative Index (CI)} = \frac{\sum_{j=1}^{A} j f_j}{N}$$

$$\text{Modified Collaborative Coefficient (MCC)} = \frac{A}{A-1}\left\{1 - \sum_{j=1}^{A} \frac{(1/j) f_j}{N}\right\}$$

where,

f_i = Number of papers having 'j' authors in 'collection/year (K)'

N = Total number of papers in 'K'. $N = \sum_j f_i$

A = Total number of authors in collection 'K'

Co-authorship network mapping

VOSviewer (v 1.6.14) was used for co-authorship network analysis of IFRIs publications (Van Eck and Waltman, 2013). The input data (co-authors) were extracted from the bibliographic data of the WoS publication collections. The 'fractional counting method' was adopted 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 maps were carefully prepared by referring to the manual as well as the other published references (Van Eck and Waltman, 2013; Yeung *et al*., 2017; Yu and Hayes, 2018; Aleixandre-Tudo *et al*., 2018; Mohan and Kumbar, 2020). In the network mapping, the items were grouped into clusters of various colours as determined by VOSviewer based on its association with other items. The size of balls in the network map is proportionate to the quantum of the unit taken for analysis (documents), while the weight of edges between balls is proportional to the collaboration volume.

Statistical analysis

The temporal data collected for different features such as publications number and papers with various co-authors, as well as different measures of collaboration (CI, DC, MCC) and growth (RGR, DT), were statistically analysed using trend analysis techniques. Various measures were tested for the presence of a monotonic trend using the Mann-Kendall test (Mann, 1945; Kendall, 1975), which is a rank-based non-parametric test for assessing the monotonic trend. Subsequently, the magnitude of the slope was estimated using Sen's slope estimator (Sen, 1968).

Results and discussion

The present study reports the trends in research productivity of ICAR-Fisheries Research Institutes (IFRIs) during the past 20 years (2000-2019) with special focus in terms of the collaboration patterns, focus areas of research and also their influence. The research collaborations were broadly classified into intra-organisation collaboration, where the researchers from various divisions/sections of a particular institute collaborate and inter-institute collaboration where researchers collaborated with various domestic or international organisations as validated by at least one co-author from other departments, organisations or countries (Iglic *et al.,* 2017).

Research productivity of ICAR-Fisheries Research Institutes (2000-2019)

Trend of research productivity

Research productivity was measured in terms of the quality and quantity of the publications generated by the researchers in the form of research publications in academic journals, conference proceedings, books, book chapters, monographs, patents and commentaries (Creswell, 1986). As per the WoS database, the IFRIs have published a total of 4,557 peer-reviewed articles attracting 36,779 citations during the study period (2000-2019) (Table 1). There is a temporal rise in the number of publication records annually (Fig. 2) with the maximum number of papers (511) published in 2019. Earlier bibliometric analyses of fisheries research have been based on subject-specific keyword searches (Aksnes and Browman, 2016; Chaman *et al*., 2016; Jan and Ridwana, 2017). Previous scientometric studies on 'fish and aquaculture' recorded 2,454 publications from India during 1994-99 (Jayashree and Arunachalam, 2000). Vinitha *et al*. (2018) reported 2,639 publications from Indian research institutes during 1992-2016 based on Web of Science-based study using the search keywords 'Fisheries' and 'India'. Singh *et al*. (2019) used 'Fisheries', 'Fishery', and 'Aquaculture' as keywords in the 'Scopus' database and reported 10,999 papers from India. The difference in publications number could be due to the time period, databases used, the search keywords used and methodology as demonstrated by Fu and Ho (2015). The present study has not used any keyword-based search but covers the scholarly outputs of the IFRIs.

The increase in research productivity could be attributed to the need for scientific evidence for fisheries management and to the growing importance and prevalence of aquaculture (Link, 2010; Natale *et al*., 2012; FAO, 2012). Several researchers have reported the steadily increasing efforts in fisheries and aquaculture research in India over the years (Vinitha *et al*., 2018; Singh *et al*.,

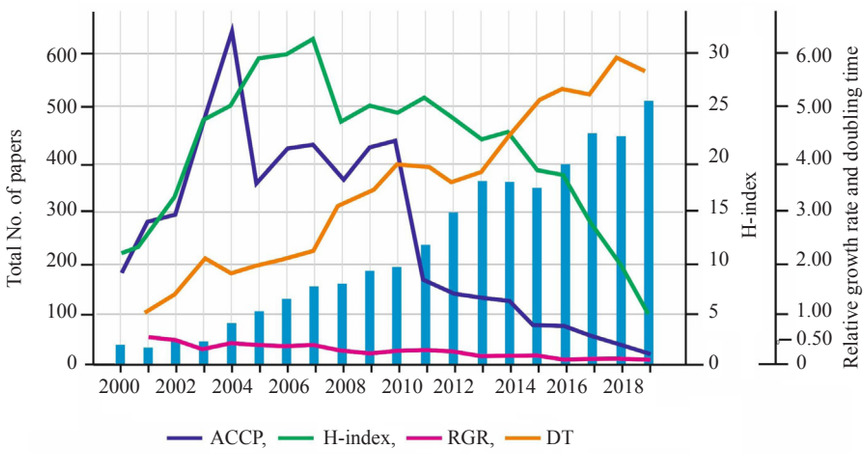

Fig. 2. Year-wise research productivity of ICAR Fisheries Research Institutes (N = 4557)

Table 1. Year-wise research productivity of ICAR Fisheries Research Institutes (N = 4557)

Year	Publication trends				Citation			h-index	Collaboration		
	TP	% share	RGR	DT	TC	Self-citations	ACPP		DC	CI	MCC
2000	39	0.86	-	-	371	0	9.51	11	0.90	0.59	0.60
2001	32	0.70	0.60	1.16	474	1	14.81	12	0.88	0.54	0.56
2002	46	1.01	0.50	1.39	689	0	14.98	16	0.93	0.61	0.63
2003	45	0.99	0.33	2.13	1091	0	24.24	18	0.93	0.65	0.66
2004	78	1.71	0.39	1.76	2481	12	31.81	24	0.96	0.64	0.65
2000-04	240	5.26	-	-	5106	13	21.28	37	0.98	0.69	
2005	104	2.28	0.36	1.92	1813	9	17.43	25	0.99	0.71	0.70
2006	127	2.79	0.31	2.21	2749	9	21.65	29	0.99	0.71	0.72
2007	160	3.51	0.29	2.37	3525	14	22.03	33	0.96	0.67	0.71
2008	163	3.58	0.23	3.02	2879	4	17.66	23	0.98	0.68	0.68
2009	181	3.97	0.21	3.37	2190	6	12.10	25	0.98	0.73	0.69
2005-09	735	16.12	-	-	13156	42	17.9	53	0.95	0.69	
2010	190	4.17	0.18	3.89	2371	2	12.48	24	0.99	0.75	0.73
2011	237	5.20	0.19	3.74	2216	13	9.35	26	0.97	0.73	0.70
2012	300	6.58	0.19	3.57	2654	30	8.85	24	0.99	0.76	0.75
2013	357	7.83	0.19	3.64	2509	24	7.03	22	0.99	0.77	0.73
2014	358	7.86	0.16	4.32	2502	37	6.99	23	0.98	0.78	0.76
2010-14	1442	31.64	-	-	12252	106	8.5	43	0.98	0.77	
2015	346	7.59	0.13	5.18	1725	17	4.99	19	0.99	0.78	0.77
2016	391	8.58	0.13	5.24	1873	26	4.79	18	0.99	0.80	0.78
2017	448	9.83	0.13	5.22	1448	47	3.23	14	0.90	0.59	0.77
2018	444	9.74	0.12	5.96	940	63	2.12	10	0.88	0.54	0.79
2019	511	11.21	0.12	5.83	279	77	0.55	5	0.93	0.61	0.80
2015-19	2140	46.96	-	-	6265	230	2.93	24	0.93	0.65	
Total	4557	100	-	-	36779	391	8.07	66			

TP-Total publication; RGR – Relative growth rate; DT – Doubling time; TC-Total citation; ACPP – Average citations per paper; DC – Degree of collaboration; CI – Collaboration index; MCC- Modified collaboration coefficient

2019). An increase in the number of publications over the years can also be explained by expansion or additions in the coverage of scientometrics database. For example, journals such as *Iranian Journal of Fisheries Sciences* and *Indian Journal of Fisheries* were added to WoS-database in 2007 and 2009, respectively. This expansion resulted in substantial increase in the relative numbers of publication appearing in the WoS database in later years (Aksnes and Browman, 2016). The overall increase in the number of papers may also be due to the increased research efforts

of these institutes which are linked to the Science and Human Resource (HR) development policies of the country, increase in the size of scientific force, availability of advanced infrastructure facilities, improved networking among the peers, increased utilisation of ICT facilities as well as sensitisation on research communication. A comprehensive assessment on publication patterns (1900-2013) of over 40,000 researchers indicated the increase in the number of publications and average number of co-authors in recent decades (Fanelli and Lariviere, 2016).

The share of IFRIs research papers to the total decadal publications increased from 21.3% (1st decade: 2000-2009) to 78.6% (2nd decade: 2010-2019). The RGR and DT for publications and citations were first used by Mahapatra (1994). The year-wise research productivity of papers from the IFRIs in terms of RGR and DT is given in Table 1 and 2. The decreasing trend in RGR and increasing trend in DT of publications suggested that the growth is neither exponential nor linear. A similar trend for RGR and DT was reported in the scientometric analysis of the Mechatronics research trend and productivity (2000-2017) using Web of Science (Anandhalli and Achha, 2018).

The ACPP of IFRIs publication was the highest (31.81) for the papers published in 2004. The maximum citations (3,525) and highest *h*-index (33) were recorded for the research papers published in 2007 (Fig. 2). This could be attributed to the sudden increase in the number of papers (especially during 2004), quality and focus of the research work and availability of time for the citations for those papers published during 2000-2009, to accrue. The citations during 2000-2004 and 2005-2009 were more than the subsequent periods as the citations tend to increase with time. The shifting momentum in the *h*-index for the publications from 2004 was attributed to the increasing total number of publications apart from citation aspects (Hirsch, 2005; Bornmann and Leydesdorff, 2014). However, the number of citations decreased from 13,156 to 12,252 in the later year which led to the decrease in the h-index from 53 to 43. *h*-index is approximately proportional to the square root of the total citation counts and linearly proportional to the total number of publications and to increase it by 1, it is needed to get 2h+1 extra citations (Franceschini and Maisano, 2010).

Publication metrics of ICAR-Fisheries Research Institutes

The number of total publications and citation metrics are widely used in scientometric studies to gauge the research performance. The relationship between the different research paper metrics of ICAR-Fisheries Research Institutes' publications (2000-2019) are depicted in Fig. 3. ICAR-CMFRI had published maximum number of papers (1,145) with highest total number of pages (8906) and average page count per paper (APP) for these publications is 7.78, while recording the least ACPP (5.7). Conversely, the publications from ICAR-CIFA and ICAR-CIFE received the highest ACPP of 15.54 and 10.55 and highest APP of 8.15 and 7.89, respectively. We observed a positive relationship between the number of citations with average number of pages per paper (APP) and number of authors except for ICAR-CMFRI where the APP and number of authors are more but the citations are less than ICAR-CIFA. Our results are in line with the findings of Fox *et al.* (2016), where they found that the research papers with a greater number of pages and authors tend to receive more citations.

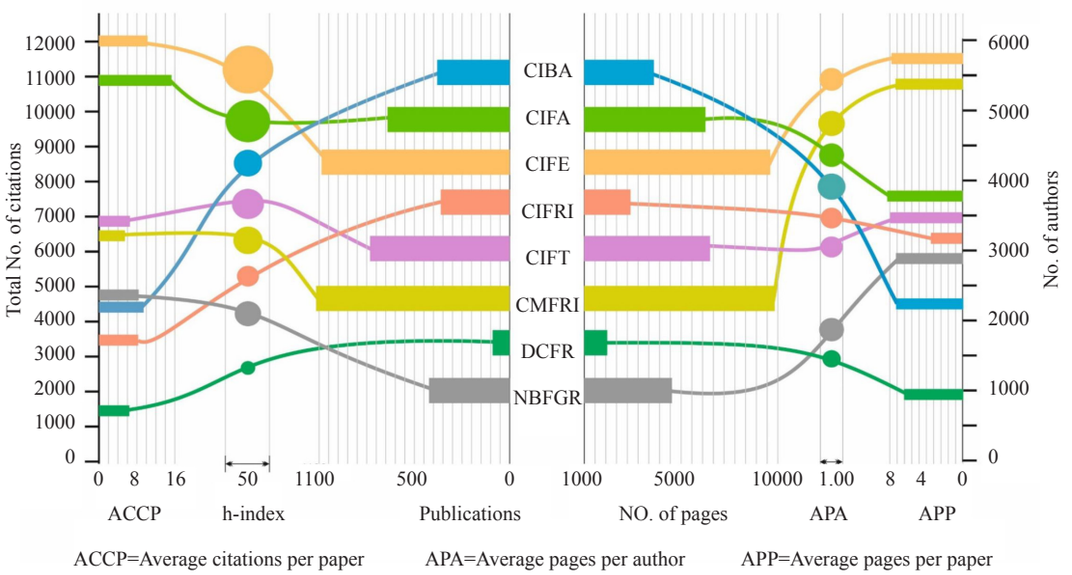

Fig. 3. Publication metrics of the ICAR Fisheries Research Institutes during 2000-2019

Table 2. Temporal trends (Institute-wise) in the productivity metrics of research papers published by ICAR Fisheries Research Institutes

A) Relative growth rate

Year	Relative growth rate								
	ICAR	CMFRI	CIFE	CIFA	CIBA	CIFT	CIFRI	NBFGR	DCFR
2000	3.66	1.61	2.20	2.40	1.79	1.79	0.69	0.69	NA
2001	0.60	0.47	0.64	0.60	0.41	0.61	0.41	1.10	NA
2002	0.50	0.56	0.50	0.64	0.29	0.49	NA	0.51	NA
2003	0.33	0.31	0.41	0.37	0.51	0.11	NA	0.26	NA
2004	0.39	0.55	0.44	0.28	0.44	0.41	0.85	0.14	NA
2005	0.36	0.29	0.35	0.22	0.30	0.68	0.76	0.29	NA
2006	0.31	0.44	0.23	0.24	0.34	0.41	0.47	0.34	0.00
2007	0.29	0.30	0.26	0.28	0.14	0.41	0.12	0.43	0.69
2008	0.23	0.29	0.15	0.20	0.15	0.35	0.23	0.26	NA
2009	0.21	0.28	0.17	0.19	0.11	0.19	0.34	0.32	1.61
2010	0.18	0.24	0.16	0.12	0.20	0.16	0.19	0.31	0.34
2011	0.19	0.31	0.17	0.11	0.24	0.11	0.23	0.30	0.41
2012	0.19	0.26	0.21	0.16	0.22	0.11	0.13	0.35	0.54
2013	0.19	0.20	0.22	0.13	0.15	0.17	0.28	0.23	0.49
2014	0.16	0.20	0.21	0.13	0.13	0.11	0.25	0.18	0.24
2015	0.13	0.13	0.15	0.09	0.14	0.13	0.25	0.15	0.33
2016	0.13	0.16	0.13	0.12	0.14	0.14	0.18	0.13	0.17
2017	0.13	0.15	0.14	0.11	0.18	0.12	0.21	0.11	0.12
2018	0.12	0.16	0.14	0.06	0.11	0.08	0.26	0.07	0.11
2019	0.12	0.16	0.13	0.09	0.15	0.09	0.19	0.10	0.06

(B) Doubling time (DT)

Year	Doubling time (DT)								
	ICAR	CMFRI	CIFE	CIFA	CIBA	CIFT	CIFRI	NBFGR	DCFR
2000	0.19	0.43	0.32	0.29	0.39	0.39	1.00	1.00	NA
2001	1.16	1.47	1.09	1.16	1.71	1.14	1.71	0.63	NA
2002	1.39	1.24	1.39	1.08	2.41	1.41	NA	1.36	NA
2003	2.13	2.27	1.71	1.87	1.36	6.58	NA	2.64	NA
2004	1.76	1.26	1.59	2.45	1.58	1.71	0.82	4.84	NA
2005	1.92	2.41	1.99	3.14	2.28	1.02	0.91	2.41	NA
2006	2.21	1.59	2.99	2.86	2.04	1.69	1.47	2.06	NA
2007	2.37	2.29	2.70	2.45	4.88	1.69	5.88	1.62	1.00
2008	3.02	2.39	4.50	3.47	4.62	1.98	3.01	2.62	NA
2009	3.37	2.52	4.13	3.68	6.42	3.71	2.01	2.18	0.43
2010	3.89	2.94	4.44	5.76	3.54	4.41	3.66	2.23	2.06
2011	3.74	2.25	4.15	6.06	2.89	6.53	3.01	2.30	1.71
2012	3.57	2.66	3.25	4.24	3.19	6.60	5.40	1.97	1.29
2013	3.64	3.51	3.09	5.32	4.68	3.98	2.46	2.97	1.40
2014	4.32	3.45	3.34	5.47	5.37	6.15	2.79	3.94	2.89
2015	5.18	5.32	4.53	7.38	4.88	5.52	2.77	4.64	2.12
2016	5.24	4.35	5.17	5.98	4.91	4.78	3.92	5.23	4.13
2017	5.22	4.75	5.04	6.18	3.81	5.83	3.33	6.55	5.67
2018	5.96	4.35	4.96	11.64	6.20	8.85	2.64	9.75	6.36
2019	5.83	4.37	5.33	7.99	4.78	7.62	3.71	6.63	11.08

The high number of national collaborative papers by ICAR-CMFRI is partly justified by its network of research stations along coastal India which might have enabled them to form a network with other research institutes/ universities/laboratories situated in the vicinity. Likewise, ICAR-CIFE being a deemed university in fisheries science, the network formed by the research scholars during their study programmes and abroad visit for higher education/training might have resulted in the generation of more international collaborative papers. This study reports

more citations for the publications of ICAR-CIFA and ICAR-CIFE which have higher APP. The higher citation metrics for the national collaboration papers published by ICAR-CIFA could be attributed to greater network among the researchers in addressing issues having particular relevance to the local conditions.

Characteristics of collaborative research papers

The temporal trends in the bibliometric indicators of the collaborative research papers published by the IFRIs are presented in Table 3. During the study period, IFRIs had published 3,981 papers (87.36% of the total publications) with all authors from India and 486 papers (10.66% of the total publications) with at least one international collaborator. More than a 10-fold increase in the number of national co-authorship papers was observed from the base year (2000), while it was 30-fold higher for the papers with at least one international co-authorship. The number of international collaborative papers increased significantly ($p<0.01$) after 2010. There was a significant ($p<0.01$) increase in the number of collaborative research papers with all authors from India (excluding single-author papers and papers with at least one international author) during the study period. Sangam and Aral (2016) suggested positive relationship between collaboration and growth of publications in the genetics field.

The increase in collaboration could be attributed to several factors such as, expertise and knowledge which is not otherwise available but important to the research outcomes (Thorsteinsdottir, 2000), easier access to public financing, objectives for greater prestige and wide visibility resulting from collaboration with renowned/ reputed research groups, and the opportunities to attain higher productivity (Lee and Bozeman, 2005). Prakasan *et al*. (2014) reported overall 14.58% of international collaborative publication records in Indian S&T research during 1991-2010, ranging in different subjects from 23.18% (Physics) to 2.26% (Environmental sciences).

Citation count analysis of publications with national and international collaboration showed that the number of total citations received by national collaborative papers (32,215) was more than the citations received by international collaborative papers (6,981) due to difference in the number of papers. However, the high ACPP value of international collaborative papers (14.36) over national collaborative papers (8.09) is attributed to the extent of research problems undertaken, quality of the research and content of research paper, visibility and rapid diffusion of research results through high impact journals (Pasterkamp *et al*., 2007; Tahamtan *et al*., 2016; Adams and Gurney, 2018; Zahedi and Haustein, 2018). The year-wise

Table 3. Publication characteristics of collaborative research papers from ICAR Fisheries Research Institutes (N=4557)

Year	Papers with all authors from India excluding those with single author						Papers with at least one author from outside India					
	Papers		Citations			*h*-index	Papers		Citations			*h*-index
	No.	% share	Total	SC	ACPP		No.	% share	Total	SC	ACPP	
2000	33	0.72	296	0	8.97	9	2	0.04	24	0	12.00	2
2001	23	0.50	356	1	15.48	8	5	0.11	145	0	29.00	4
2002	38	0.83	504	0	13.26	12	5	0.11	169	0	33.80	5
2003	38	0.83	926	0	24.37	16	4	0.09	136	0	34.00	4
2004	71	1.56	2435	11	34.30	24	4	0.09	77	0	19.25	4
2005	97	2.13	1812	9	18.68	24	5	0.11	45	0	9.00	3
2006	117	2.57	2679	8	22.90	30	9	0.20	154	1	17.11	7
2007	138	3.03	3062	12	22.19	30	20	0.44	587	2	29.35	16
2008	147	3.23	2462	4	16.75	21	10	0.22	551	0	55.10	8
2009	164	3.60	1961	5	11.96	23	15	0.33	344	1	22.93	11
2010	158	3.47	1848	1	11.70	21	28	0.61	631	1	22.54	15
2011	178	3.91	1399	7	7.86	17	47	1.03	805	3	17.13	17
2012	263	5.77	2152	26	8.18	21	33	0.72	654	2	19.82	12
2013	312	6.85	2029	21	6.50	20	36	0.79	656	1	18.22	15
2014	311	6.82	2113	28	6.79	21	41	0.90	589	5	14.37	14
2015	311	6.82	1676	15	5.39	18	30	0.66	223	1	7.43	7
2016	337	7.40	1694	18	5.03	19	48	1.05	424	3	8.84	12
2017	403	8.84	1422	45	3.53	15	38	0.83	354	0	9.32	10
2018	393	8.62	982	52	2.50	10	46	1.01	260	5	5.65	10
2019	449	9.85	407	54	0.91	6	60	1.32	153	8	2.55	5
Total	3981	87.36	32215	317	8.09	-	486	10.66	6981	33	14.36	-

high-values of *h*-index of national collaborative papers are justified by the high number of total papers published and the citations received (Hirsch, 2005). The total citation did not show any statistically significant trend in both the cases. The *h*-index of papers with at least one author from outside India showed a significant ($p<0.01$) positive trend whereas papers with only Indian authors did not show any significant ($p>0.05$) trend.

International collaborations result in a deeper and more thorough interpretation of data because of different cultural exposure and experiences. Further, collaborative research publications are expected to bring more citations as they get more visibility globally than the research papers without collaboration (He *et al*., 2009). Tahamtan *et al.* (2016) also suggested international collaboration as the stronger predictors for citation. It has been confirmed that, type of collaboration is associated with the quality of research as can be measured by direct citations (Oliveira Junior *et al*., 2016). Collaboration with highly productive scientists tends to increase personal productivity (Marmolejo-Leyva *et al*., 2015) and *vice versa* (Katz and Martin, 1997). The self-citations for the national and international collaborative papers during the study period (2000-19) were 0.98% (317 citations of 32,215) and 0.47% (33 citations of 6,981), respectively. The higher self-citation (%) of recent year publications may be linked to the continuity of ongoing research work of a particular individual researcher or the work of collaborators (Garfield and Merton, 1979). In general, self-citations of a research paper are of recent years, have a shorter half-life than citations from other papers and stabilise within 3-4 years after publication (Wallace *et al*., 2012).

Among the IFRIs, the number of national collaborative papers was the highest in ICAR-CMFRI (1,051 papers), which was followed by ICAR-CIFE (938 papers) and ICAR-CIFT (747 papers) (Table 4). The citation impact or research influence (measured based on total citations, ACPP and *h*-index) of papers with national-level collaboration was found to be highest for the research papers published by ICAR-CIFA and ICAR-CIFE. ICAR-CIFE had the highest number of publications (153) with international collaboration and also recorded the highest *h*-index (30) and maximum citations. ICAR-DCFR had the least number of papers with international collaboration but the highest ACPP (21.22) which shows the impact of research done by ICAR-DCFR.

Authorship-based collaboration analysis of ICAR-Fisheries Research Institutes

Trend of authorship-based collaboration

The collaboration generally occurs in various forms such as between individuals, groups, divisions, organisations, sectors and countries (Katz and Martin, 1997). In this study, 98.03% of the total authors (22,942 authors) had been found to be involved in the publication of collaborative research papers. The block-wise distribution of authorship metrics of these publications reveals a shifting pattern in the 'number of authors' over the study period (Fig. 4). During the block period of 2000-04, most of the research papers had 2 authors, which subsequently increased to 5 authors during the block period, 2015-19.

The year-wise authorship pattern of publications from IFRIs showed that there is a significant increase in the number of publications with ≥5 authors over the study period (Table 5). While no paper from the fisheries institutes had >10 authors during 2000, it increased to 19 by 2019. About half of the total publications had 3-5 authors while 37% of the publications had >5 researchers. This indicates the teamwork spirit among researchers of IFRIs and also a way for promoting improvement in quality of the research as the collaboration positively correlated with the quality of research, though this relationship is not

Table 4. Institute-wise publication characteristics of papers from ICAR Fisheries Institutes

Name of the institute	Papers with all authors from India including those with single author				Papers with at least one author from outside India			
	TP	h-index	TC	ACPP	TP	h-index	TC	ACPP
ICAR-CIBA	369	24	2734	7.41	90	25	1757	19.52
ICAR-CIFA	626	46	9461	15.11	72	20	1384	19.22
ICAR-CIFE	938	46	9021	9.62	153	30	2493	16.29
ICAR-CIFRI	363	21	3033	8.36	54	12	547	10.13
ICAR-CIFT	747	35	6016	8.05	24	8	191	7.96
ICAR-CMFRI	1051	29	5659	5.38	94	17	872	9.28
ICAR-DCFR	156	15	873	5.60	9	5	191	21.22
ICAR-NBFGR	467	26	3720	7.97	67	16	946	14.12
Total	4717*	-	40517	-	563*	-	8381	-

**The papers with authors from more than one ICAR fisheries research institutes are counted against each of the respective institutes and hence the total exceeds the actual number of papers published (N=4557)*

universal (Smart and Bayer, 1986; Muriithi *et al*., 2013; Koseoglu, 2016).

The number of papers with 1-3 authors was found to decrease after 2014 and the average page counts per article were ranging from 6.17 (2002) to 8.51 (2018) (Table 5). Except for single-author papers, the number of papers with different combinations of multi-author papers (2 to ≥10) showed a significant ($p<0.05$) increase. The total number of authors showed a significant ($p<0.05$) increase over time with an increase of about 150 authors per year. Single authorship paper reflects the strength and authority of a person in his/her domain and the current trend could be attributed to the multi-dimensional and transdisciplinary research. The single-authored papers contribute 0.2 and 0.7% of total fisheries research publications in China and Brazil, while for countries like the USA, Canada, Norway, and the UK it was reported at about 5% (Syed *et al*., 2019).

Rana and Agarwal (1994) reported change in the % composition of authorship pattern of single and multi-

Table 5. Authorship pattern of publications from ICAR Fisheries Institutes during 2000-2019

Year	Single	Two	Three	Four	Five	Six	Seven	Eight	Nine	Ten	> Ten	TP	TA	APPA
2000	4	12	8	10	3	1	0	1	0	0	0	39	121	7.67
2001	4	13	8	4	2	0	1	0	0	0	0	32	87	6.50
2002	3	17	9	6	5	3	1	0	0	1	1	46	160	6.17
2003	3	12	7	8	8	1	4	2	0	0	0	45	174	6.98
2004	3	21	24	14	8	5	2	0	0	1	0	78	267	7.15
2005	2	23	24	15	11	18	1	9	1	0	0	104	414	7.48
2006	1	26	28	22	18	15	4	5	0	0	8	127	543	7.84
2007	2	29	33	37	24	20	8	4	2	1	0	160	663	7.53
2008	6	32	51	30	14	12	9	3	1	4	1	163	633	8.04
2009	3	41	41	44	19	19	9	3	2	0	0	181	698	7.34
2010	3	23	47	36	27	18	17	8	5	1	5	190	875	7.56
2011	12	37	51	33	38	34	13	4	3	5	7	237	1058	7.36
2012	4	35	51	48	42	36	36	14	8	15	11	300	1653	7.39
2013	9	45	55	63	67	46	31	18	7	6	10	357	1792	6.99
2014	5	22	70	58	63	47	33	26	13	9	12	358	1861	8.43
2015	4	23	44	56	67	62	43	16	12	7	12	346	1900	7.60
2016	6	17	58	60	66	69	45	28	17	7	18	391	2266	7.82
2017	7	31	46	70	98	73	54	29	19	8	13	448	2415	8.16
2018	5	30	30	72	87	73	71	29	23	9	15	444	2558	8.51
2019	4	23	49	63	70	89	79	34	31	14	55	511	2804	7.15
Total	90	512	734	749	737	641	461	233	144	88	168	4557	22942	7.67
%	1.97	11.24	16.11	16.44	16.17	14.07	10.12	5.11	3.16	1.93	3.69	100	100	-

TP-Total publications; TA-Total authors; APPA-Average number of pages per article

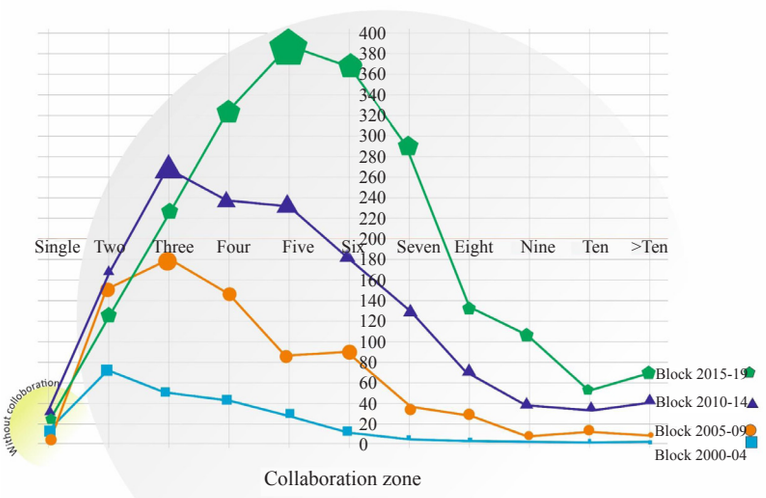

Fig.4. Distribution of authorship pattern for the period of 20 years in block of 5 years

authored papers which was attributed to the advent of multidimensional fields, like biodiversity, habitats, and eco-development. Vinitha *et al*. (2018) analysed 25 years (1992-2016) of India's fisheries research based on WoS and found that three authored publications were predominant and were followed by two and four authored publications. Jan and Ridwana (2017) observed that the publications with >3 authors contributed maximum articles that appeared in the *Indian Journal of Fisheries* during the period 1999-2012. This trend is not universal and the relationship would vary based on the inherent characteristics of the research field (Ball, 2008; Falagas *et al*., 2013; Ahmed *et al*., 2016). The publication's co-authorship-based assessment indicators can only partially represent the collaboration activity (Bush and Hattery, 1956) as there could be other factors like ease of executing the research, value-addition, ease of publications, evolving career assessment policies emphasising on number of research papers and consequent practices of gift authorship (Schofferman *et al*., 2015; Bhoomaiah *et al.,* 2020a). Thus, a detailed internal survey among the Indian researchers would aid in understanding the factors influencing the current trend of enhanced research network collaboration in the field of fisheries research in India.

Collaborative measures *viz*, DC, CI and MCC were used to analyse the degree of research collaboration. CI calculates the mean number of authors per paper and DC measures the fraction of two or multi-authored papers and these two are being used to measure the collaboration strength (Savanur and Srikanth, 2010). The extent of collaboration can be measured using these parameters at the institute level (Yadav *et al.,* 2020) or field of study (Jeyshankar and Nishavathi, 2018).

The degree of collaboration (DC) value was ≥ 0.9 during the entire study period except for the year 2001 and 2018. The highest value of the collaboration index (0.8) was reported in 2016. Both DC and CI values were reported to be lower during the last block of the study period (2015-19). The modified collaboration coefficient (MCC) was recorded in the range of 0.56 -0.80 (Table 1). The institute-wise temporal trends in the collaboration metrics of research papers published by the respective institute are shown in Fig. 5. The CI for IFRIs (comprising all 8 Fisheries institutes) was observed as 5.04, while among the individual institutions, it varied from 4.41 (ICAR-CIFT) to 5.69 (ICAR-CIFRI). There was no significant ($p>0.05$) difference among the individual fisheries institutes and the IFRIs with respect to DC and MCC (Fig. 5). All the three measures of collaboration showed a significantly ($p<0.01$) increasing trend for the IFRIs. While the mean number of authors (CI) showed a positive temporal trend in all IFRIs, the fraction of two

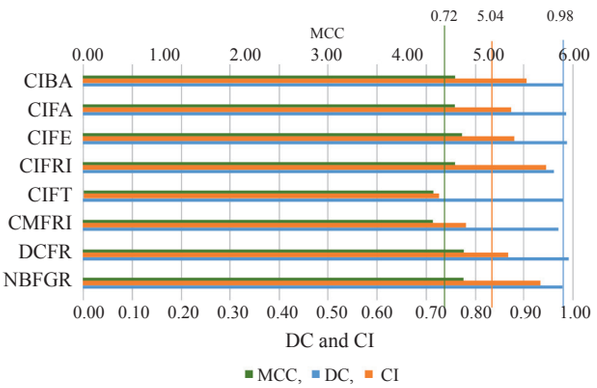

Fig. 5. Institute-wise collaborative measures during 2000-2019. Vertical lines represent ICAR

or multi-authored papers (DC) did not show any temporal trend among the IFRIs, except NBFGR (decreasing) and DCFR (increasing). The overall strength of collaboration as measured by MCC was observed to increase temporally among all the IFRIs, except CIFRI, NBFGR and CIFT.

Institute-wise co-authorship-based network analysis

The VOSviewer based co-authorship network analysis of papers published by IFRIs indicates the large cluster size of ICAR-CMFRI, ICAR-CIFE and ICAR-CIFA. The close proximity of all 8 Fisheries Institutes of ICAR in the network map suggested the existence of strong mutual collaboration between and among these institutes, apart from their research collaboration with State Agriculture Universities (SAUs), other universities and research organisations (Fig. 6).

The domestic research collaboration of any organisation depends on its mutual agreement/understanding with other organisations working in the same line in addition to the specific geographical advantages, the expertise of manpower and research focus and infrastructure facilities (Iglic *et al*., 2017). Recently, ICAR has developed Scientific Equipment Policy-2021 to ensure the sharing of equipment within and across other national institutions and universities which will further augment the collaborative research (ICAR, 2021). Singh *et al.* (2019) listed 15 clusters of authorship collaboration at the intra- and inter-institutional levels in Indian fisheries research during 2007-2016. The collaboration intensity can also be indicated by the total link strength (TLS) of (VOSviewer) selected factors such as organisations/countries (Zhai and Di, 2019). The total citations and link strength were higher for ICAR-CIFE, a Deemed University under ICAR for fisheries science education. The collaboration established with other research institutes for students' research and universities might have facilitated the high TLS and citations of this

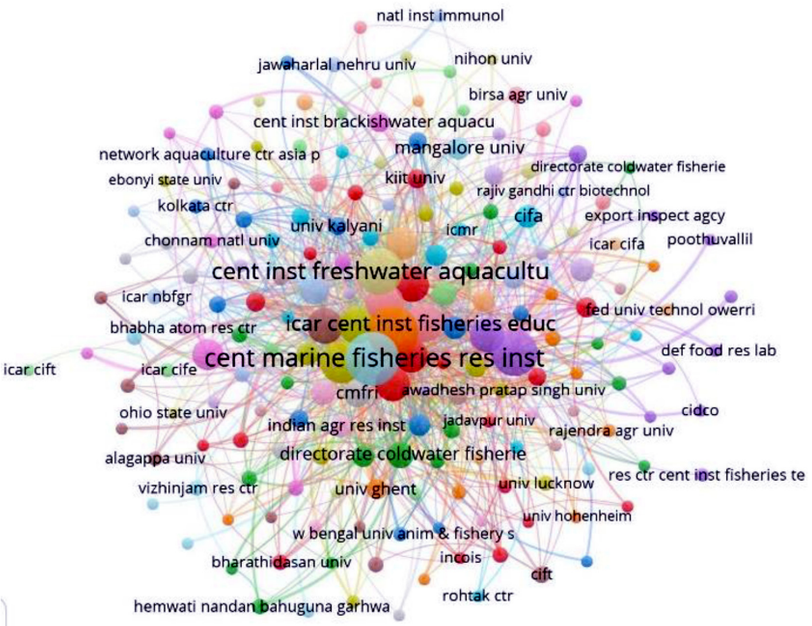

Fig. 6. Co-author network map of Fisheries Research Institutes in India during 2000-19

institute as observed by NSB (2008). The same is also true for research collaboration observed between these organisations with State Agriculture Universities (SAUs) and other universities.

Inconsistent pattern in writing the affiliation in research papers with multiple names of a single institute was observed. For instance, ICAR-CMFRI has been depicted with multiple names *i.e.,* 'cent marine fisheries res inst', 'cmfri', 'vizhinjam res cntr'. Similarly, ICAR-CIFA has been depicted with multiple names *i.e.*, 'cent inst freshwater aquaculture', 'cifa', 'icar cifa' (Fig. 6). To resolve the ambiguity in multiple variants of an organisation's affiliation, WoS has introduced the 'Organisations Enhanced' search option in 2013. However, these functions may not cover all organisations indexed and sometimes the organisations are expected to request for inclusion with known name variants (Goodwin, 2014).

Co-authorship based network of international collaboration papers

Co-authorship networks and social network analysis are successful tools to analyse the collaboration trends and identifying the leading scientists and institutions in the particular research field (Stefano *et al*., 2013). These tools are widely used by many researchers for the collaboration assessment of various disciplines, organisations and journals (Kumar and Garg, 2005; Gupta and Bala, 2011; Sagar *et al*., 2014; Marisha, 2019).

The publication characteristics (Fig. 7) and co-authorship-based network (Fig. 8) of international collaboration papers of IFRIs explains that the fisheries science research network is expanding geographically and also becoming more intensive. During the study period, Indian fisheries research institutes had collaborated with 76 countries and published 486 papers. The publication characteristics of top 15 countries which published >10 papers in collaboration with India are depicted in Fig. 7. The number of collaborative papers were the highest with the USA (101 documents; 2025 citations), followed by Japan (52 documents; 992 citations) and Australia (52 documents; 783 citations), which together accounted for >30% of the total international collaborative papers published by IFRIs. The highest ACPP value was reported for the collaborative research publications with Italy (26.88) followed by People's Republic of China (24), Canada (20.8) and USA (20.05), while the *h*-index was the highest in case of research papers published in collaboration with authors from USA (24), Japan (20) and Australia (17) (Fig. 7). This is also evident through the co-authorship-based network visualisation map made from VOSviewer. A total of 4 clusters were formed in 'Red colour' being the dominant one which includes the countries such as the USA, Japan, Australia, Belgium, Norway, Thailand, Nigeria, Germany and Saudi Arabia (Fig. 8).

The results of the scientometric analysis on Indian fisheries and aquaculture research papers during 2007-2016 showed the USA, South Korea and the UK as top collaborating countries (Chaman *et al*., 2016; Vinitha *et al*., 2018; Singh *et al*., 2019). At the global level, Syed *et al*.

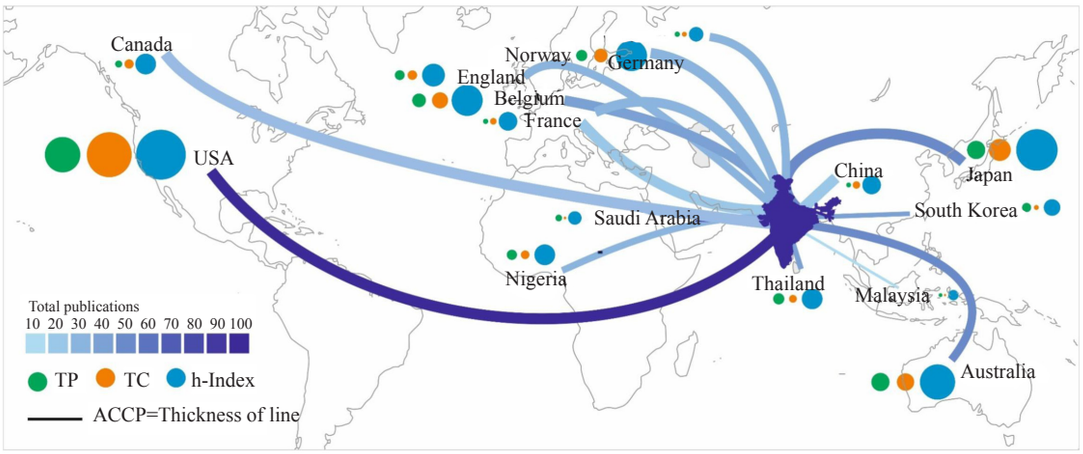

Fig. 7. Publication characteristics of the top15 collaborating countries with ICAR Fisheries Research Institutes during 2000-2019

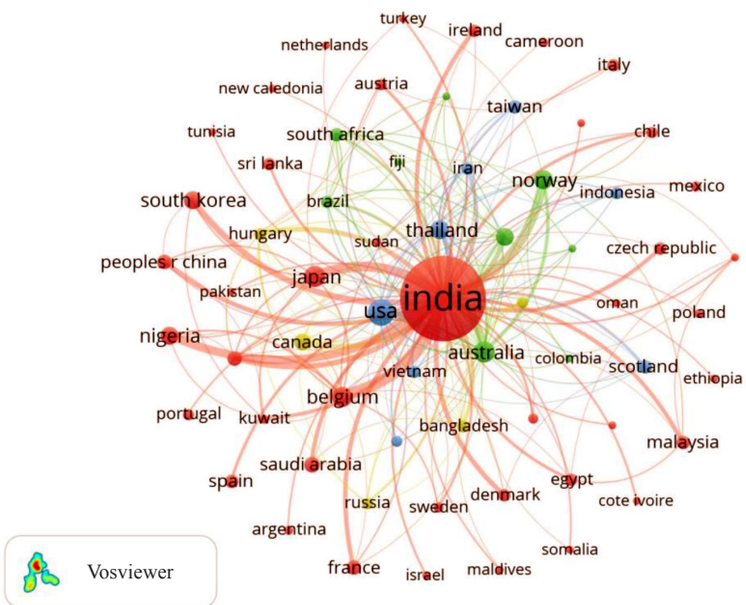

Fig. 8. Co-author network map of international fisheries collaboration research papers of ICAR Fisheries Institutes during 2000-19

(2019) found repeated collaboration in fisheries research rather than broad-style collaboration which is expected to increase the knowledge base on a particular subject. They also reported a mutual collaboration between the traditional fisheries research countries (*e.g.,* Japan, USA, Canada, UK, Australia, Norway) with developing countries like India. The collaboration between the top two aquaculture countries, *i.e.,* India and People's Republic of China was weak as indicated by the low number of collaborative research papers (14) during the study period. A similar pattern in collaboration was seen with India's other neighbouring and adjoining maritime countries, as also reported by Bhoomaiah *et al.* (2020b).

Research focus of ICAR-Fisheries research institutes

Subject area-wise research focus assessment

An analysis on the areas in which the IFRIs had undertaken research showed that the research publications during the study period represented 112 journal subject areas as classified by the WoS database. The subject areas that accounted for at least 80% of publications from each fisheries research institute during 2000-2019 show their respective research focus (Fig. 9). The major subject areas of the IFRIs were 'Fisheries' and 'Marine and Freshwater Biology', besides 'Environmental Sciences Ecology' and 'Biochemistry Molecular Biology'.

All the IFRIs focused their research on 'Fisheries' as determined by the subject category of journals which carried the publications. The present study also noted the significant contribution of each IFRIs to its dedicated fields of subject areas next to common subject area categories *viz,* 'Fisheries' and 'Marine and Freshwater Biology'. For instance, ICAR-CMFRI had contributed significantly to 'Oceanography', ICAR-NBFGR in 'Genetics and Heredity', ICAR-CIFRI in 'Environmental Sciences Ecology' and ICAR-CIFT in 'Food Science Technology' (Fig. 9).

The findings of the present study were also supported by other scientometric studies on Indian fisheries (Kumerasan *et al*., 2014; Chaman *et al*., 2016; Vinitha *et al*., 2018). The occurrence of a greater number of publications in subject specific journal (Fig. 8) explains that the major research focus of ICAR and its respective fisheries institutes are essentially aligned towards their mandates (Bhoomaiah *et al.,* 2020b). The subject area-wise publication analysis of ICAR-Fisheries Research Institutes based on Scopus journal classification system lists 'Agricultural and Biological Sciences' Genetics and Molecular Biology' 'Biochemistry' and 'Environmental Science' as top 3 subject areas focused by IFRIs (Bhoomaiah *et al.,* 2020a).

Journal preferences

The researchers from IFRIs have published their national collaborative research papers (n=3981) in 545 diverse journals. Among them, the top 3 journals were the *Indian Journal of Fisheries* (613 papers; 15.40%), *Fishery Technology* (380 papers; 9.54%) and *Indian Journal of Geo-Marine Sciences* (172 papers; 4.32%). Likewise, the international collaborative research papers (n=486) were published in 216 journals which included *Aquaculture* (38 papers; 7.82%), *Fish and Shellfish Immunology* (30 papers; 6.17%) and *Aquaculture Research* (21 papers; 4.32%) (Table 6). This demonstrates a journal selection pattern for research papers which in general followed that the national collaborative research papers were predominantly published in journals of Indian origin, whereas the international collaborative research papers were mostly (11 out of 15) published in journals of reputed international publishing houses with relatively higher impact factor. The impact factor (IF) and *h*-index of top journals which carried the research papers with international authors was significantly ($p<0.05$) higher than that those with national collaborators (Table 6).

The scientists from developing countries in tropical regions have a prominent focus and role on regional issues; hence, they may find it difficult to publish their work in international journals (Collazo-Reyes, 2014; Oliveira Junior *et al*., 2016; Syed *et al*., 2019). It is observed that international collaboration directly influences paper visibility, journal placement and citations (Collazo-Reyes, 2014) and without collaboration, scientists may publish their research work generally in national journals (Oliveira Junior *et al*., 2016). The preference given by government fisheries laboratories for publishing their

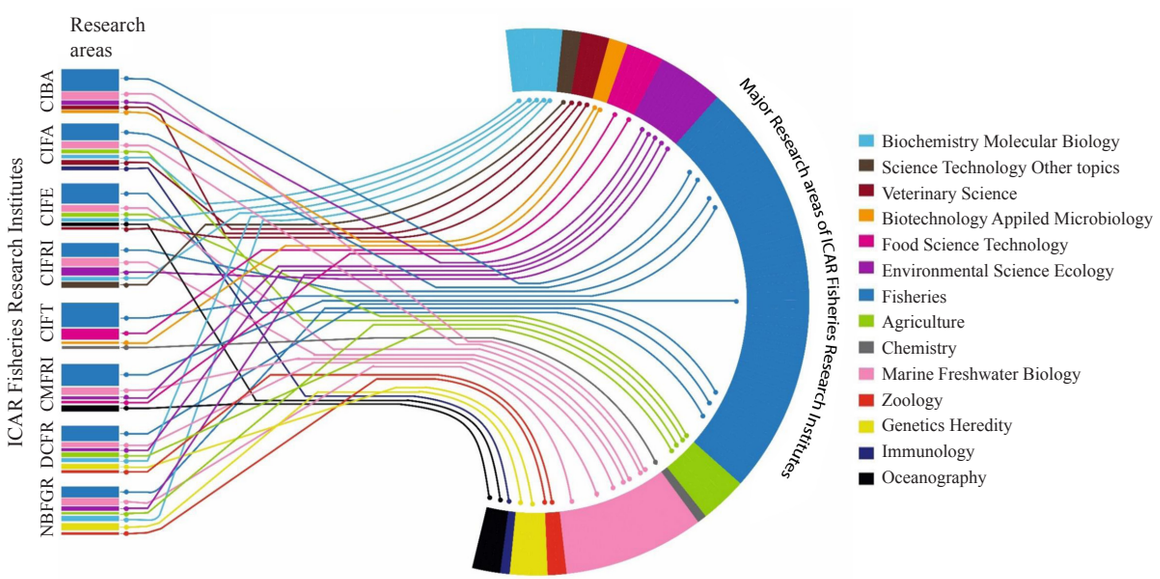

Fig. 9. Institute-wise research focus based on subject area of journals carrying publications from ICAR Fisheries Research Institutes during 2000-2019. (Subject areas which accounted for at least 80% of publications from the respective institutes during 2000-19 were included)

Table 6. Top Journals carrying research papers of ICAR Fisheries Research Institutes with and without any international author (2000-19)

Source titles	Papers with all authors from India				Papers with at least one author from outside India				
	Records	%	IF*	h-Index	Source Titles	Records	%	IF*	h-Index
#Indian Journal of Fisheries	613	15.40	0.293	11	Aquaculture	38	7.82	3.224	164
#Fishery Technology	380	9.54	NA	09	Fish and Shellfish Immunology	30	6.17	3.298	112
#Indian Journal of Geo Marine Sciences	172	4.32	0.328	33	Aquaculture Research	21	4.32	1.748	80
Aquaculture Research	153	3.84	1.748	80	Fish Physiology and Biochemistry	19	3.91	2.242	75
Aquaculture	149	3.74	3.225	164	#Indian Journal of Fisheries	19	3.91	0.293	11
Fish and Shellfish Immunology	90	2.26	3.298	112	Zootaxa	13	2.67	0.955	80
#Indian Journal of Animal Sciences	87	2.18	0.278	21	Aquaculture International	10	2.06	1.363	50
Journal of Applied Ichthyology	82	2.06	0.612	58	Journal of the World Aquaculture Society	10	2.06	1.451	55
#Current Science	71	1.78	0.725	110	Aquaculture Nutrition	8	1.65	2.231	72
#Journal of Environmental Biology	59	1.48	0.781	43	Journal of Fish Diseases	8	1.65	2.318	80
#Journal of Food Science and Technology Mysore	57	1.43	1.946	55	Environmental Monitoring and Assessment	6	1.24	1.903	102
Israeli Journal of Aquaculture Bamidgeh	48	1.21	0.275	27	#Indian Journal of Geo-Marine Sciences	6	1.24	0.328	33
#National Academy Science Letters-India	48	1.21	0.416	16	#Journal of Environmental Biology	6	1.24	0.781	43
Aquaculture International	45	1.13	1.363	50	Developmental and Comparative Immunology	5	1.03	3.192	105
Molecular Biology Reports	43	1.08	1.402	14	#Fishery Technology	5	1.03	NA	09
Mitochondrial DNA Part A	41	1.03	1.073	11	Journal of Fish Biology	5	1.03	1.495	108
Fish Physiology and Biochemistry	40	1.00	2.242	75	Scientific Reports	5	1.03	3.998	179

**Impact Factor as per* JCR, 2019*; #Journals published from India;* NA - *Not Available*

research work in low impact and low visibility journals during late 90s (Jayashree and Arunachalam, 2000) could be attributed to their mandate *i.e.,* to develop need-based technologies and transfer the same to their beneficiaries to increase/sustain fish production (Vivekanandan, 2001). Hence, these research communications are mostly aimed for publication in national journals for dissemination to stakeholders rather than high impact foreign journals (Arunachalam and Jayashree, 2001). This preference for national journals may be attributed to the fact that national journals have a vast local reader-base and thus the researchers can communicate their findings to the relevant stakeholders. Other factor which leads to publication in national journals are time taken for publication, ease of peer review and publication, and lack of relevance to global readers. The institutional policies promoting publication of research papers in in-house society journals also contribute to this trend.

In general, researchers from around the world collaborate for a common researchable issue with global concern which needs special expertise/new techniques/ advanced methodology/state of art' research setup at diverse geographical regimes. The results arising from these research programmes are published in international journals to reach a large mass of readers across the boundary (Bansal *et al*., 2019).

Funding of ICAR-fisheries institutes' collaborative research

Information on the funding status of the research work extracted from a scientific publication is considered as a possible indicator to assess the quality and to track the impact of research by funders and status of funding (public/private or national/international) on a particular field of study or institute (Boyack and Jordan, 2011; Wang and Shapira, 2011; Lakshman and Devi, 2020). The ICAR, New Delhi is the apex body controlling fisheries research in its constituent institutes through direct funding and also other sponsored programmes (Consortia Research Platform, Outreach programmes, All India Coordinated Research Projects, Network projects, Tribal Sub-Plan). Likewise, Department. of Biotechnology (DBT), New Delhi, and Department of Science and Technology (DST), New Delhi support research programmes in diverse scientific fields through their stated scholarship programmes and project funding.

The study showed that among the multi-authored collaborative research papers published by the IFRIs, 41.32% of the national collaboration papers and 63.79% of the international authorship collaboration papers carried funding particulars. This indicates that these studies are necessarily supported by the grants received from various funding agencies which automatically insists them to

acknowledge the source of funding in the research papers coming out of that particular project (Alvarez-Bornstein *et al*., 2017). The manual sorting of funding agency details revealed that a total of 182 funding agencies/components had funded research themes of 1,645 papers. It is pertinent to note here that the funding information data in WoS database records were added only since August 2008, prior to which the coverage was reported to be extremely low (Paul-Hus *et al*., 2016; Clarivate-Analytics, 2020).

The top funding agencies of the national collaboration publication records were ICAR, New Delhi (1,281 papers); DBT, New Delhi (223 papers) and DST, New Delhi (176 papers) (Table 7). The results from the present study are in accordance with similar scientometric studies performed on Indian fisheries research (Vinitha *et al*., 2018). The present study also reports the name variants of funding agencies and their programmes in the extracted data as noted by Begum and Lewison (2017). There is a need to have a unique ID globally for each funding agency and to develop more detailed funding acknowledgement guidelines to overcome the issues arising from the data inadequacy in providing the necessary funding acknowledgement details (Alvarez-Bornstein *et al*., 2017).

The present study also reports generous financial support from international funding sources *viz,* US National Institutes of Health (NIH) (21 papers); Ministry of Education, Culture, Sports, Science and Technology (MEXT), Japan (17 papers) and World Bank, Washington DC, USA (12 papers). It is pertinent to mention here that a few national funding sources, such as National Agricultural Innovation Project (NAIP), National Agricultural Technology Programme (NATP) and Chilika Development Authority (CDA), Bhubaneswar did not yield research papers with international collaborations. The variation reported in the contribution of international co-authorship papers to total sponsored publication records of funding agencies may be attributed to the nature of the subject area (*e.g*. Coordinated research with bordering countries by CMLRE and INCOIS), type of funding (*e.g*. DBT, DST and UGC international scholarship programme), geographical regime of the funding source (*e.g*. Chilika Development Authority (CDA) and national level agriculture programmes *viz*, NAIP and NATP).

In the present study, publications of students/ in-service candidates, scholarship-based foreign-Ph.D. program, which lead to research papers with at least one international author, are classified as international collaboration. The limitations of the funding analysis of the present study include inconsistency in nomenclature; lack of standardisation of the acknowledgment text; use of terms like "support" which do not exactly indicate whether financial support was involved; lack of countries' names in the records; lack of names of funding agencies and various schemes under these agencies in the journal database, as

Table 7. Major funding agencies which supported ICAR Fisheries Research Institutes (2000-19)#

No.	Name of the funding agency	Total no. of records	% of international collaboration papers
1	Indian Council of Agricultural Research (ICAR), New Delhi	1281	10.07
2	Department of Biotechnology (DBT), New Delhi	223	19.28
3	Department of Science and Technology (DST), New Delhi	176	15.34
4	Department of Animal Husbandry Dairying and Fisheries (DAHDF) / National Fisheries Development Board, Hyderabad	84	2.38
5	University Grants Commission (UGC), New Delhi	59	15.25
6	Ministry of Earth Sciences, Govt. of India	50	8.00
7	Centre for Marine Living Resources and Ecology (CMLRE), Kochi	46	26.08
8	Council of Scientific and Industrial Research (CSIR), New Delhi	49	10.20
9	National Agricultural Innovation Project (NAIP)	30	-
10	Board of Research in Nuclear Sciences/ Department of Atomic Energy (DAE), Govt. of India	21	71.42
11	*US National Institutes of Health (NIH)	21	90.47
12	Indian National Centre for Ocean Information Services (INCOIS), Hyderabad	19	21.05
13	*Ministry of Education, Culture, Sports, Science and Technology (MEXT), Japan	17	100.00
14	National Agricultural Technology Programme (NATP)	15	-
15	*World Bank, Washington DC, USA	12	25.00
16	Chilika Development Authority (CDA), Bhubaneswar	12	-

**International funding source*

#Only those which yielded at least 10 research publications during the period.

also reported by earlier researchers (Alvarez-Bornstein *et al*., 2017; Lakshman and Devi, 2020). Table 8 provides the detailed funding information of top funding agencies which had yielded at least 5 research papers during the study period.

The current study shows a significant increase in the overall collaboration research output in Indian fisheries research by ICAR-Fisheries Research Institutes during 2000-19. The temporal increase in the number of authors per publication of IFRIs demonstrate the increasing trend in teamwork and networking. The study establishes that collaboration increases the chance of getting the paper published in relatively higher impact factor journals, which could be considered as an indirect metric for publication quality. During the study period, Indian fisheries research institutes had collaborated with 76 countries and published 486 papers. The study showed that the fisheries science research network is expanding geographically and also becoming more intensive. It has been observed that the papers with a greater number of pages and authors recorded higher citations compared to shorter papers with less number of authors, which could be attributed to intense and elaborate discussions on results and greater visibility of the research through multiple author networks. The researchers had greater preference

Table 8. Top funding sources which supported ICAR-Fisheries Research Institutes #

No.	Name of the funding agency	Papers with all authors from India	International collaboration papers	Total records
1	Indian Council of Agricultural Research (ICAR), New Delhi	1152	129	1281
2	Department of Biotechnology (DBT), India	180	43	223
3	Department Of Science and Technology (DST), New Delhi	149	27	176
4	Department of Animal Husbandry Dairying and Fisheries (DAHDF) / National Fisheries Development Board	82	2	84
5	University Grants Commission (UGC), New Delhi	50	9	59
6	Ministry of Earth Sciences, Govt. of India	46	4	50
7	Centre for Marine Living Resources and Ecology (CMLRE), Kochi	34	12	46
8	Council of Scientific and Industrial Research (CSIR), New Delhi	38	5	49
9	National Agricultural Innovation Project (NAIP)	30		30
10	Board of Research in Nuclear Sciences/ Department of Atomic Energy(DAE), Govt. of India	6	15	21
11	US National Institutes of Health (NIH)	2	19	21
12	Indian National Centre for Ocean Information Services (INCOIS), Hyderabad	15	4	19
13	Ministry of Education, Culture, Sports, Science and Technology, Japan	-	17	17
14	National Agricultural Technology Programme (NATP)	15	-	15
15	World Bank, Washington DC, USA	9	3	12
16	Chilika Development Authority (CDA), Bhubaneswar	12	-	12
17	US Department of Health and Human Services (US DOHHS)	15	10	10
18	Kerala State Council for Science, Technology and Environment (KSCSTE)	10	-	10
19	Research Council of Norway (RCN)	-	9	9
20	King Saud University (KSU), Riyadh, Saudi Arabia	-	8	8
21	Ministry of Water Resources, River Development and Ganga Rejuvenation, Govt. of India	7	1	8
22	Australian Research Council	-	7	7
23	US National Science Foundation (NSF)	-	7	7
24	Global Environment Facility (GEF), Washington DC, USA	3	4	7
25	Australian Government	-	6	6
26	Japan Society for the Promotion of Science, Tokyo	-	6	6
27	National Institute of Food and Agriculture, USDA	-	6	6
28	Tamil Nadu Dr. J. Jayalalithaa Fisheries University (TNJFU), Nagapattinam	6	-	6
29	Ministry of Environment, Forest and Climate Change (MoEFCC), Govt. of India	5	1	6
30	Australian Centre for International Agricultural Research (ACIAR), Canberra	-	5	5
31	Eastern New Mexico University (ENMU), New Mexico	-	5	5
32	Taiwan Ministry of Science and Technology (MOST)	-	5	5
33	United States-India Educational Foundation	-	5	5
34	UP Council of Science and Technology (UPCST)	5	-	5

#Only those which yielded at least 5 research publications during the period.

to publish in Indian journals which possibly could be due to the scope/utility of the study, targeted reader-base and relative ease of publication.

The evaluation of journal subject area of publications shows that the research focus of IFRIs is towards 'Fisheries' and 'Marine and Freshwater Biology'. However, detailed scientometric analysis on specific subject area is required to study the relationship between the institute mandate and research outputs from the respective institutes. The visualisation and mapping of Indian fisheries research in the present study is expected to help the policymakers, science administrators and researchers to understand the collaboration pattern and dynamics of collaborative research for framing future programmes and policies to improve the research productivity and boost the prospects of the ongoing blue revolution mission. The study also demonstrates lack of adequate collaborative research among the South Asian countries, which are the major producers of fish through aquaculture. This leads us to hypothesise that strengthening collaboration among these countries that are located adjacently and also produce similar species would aid in enhanced research impact on fisheries development. Programmes could be drawn to build the capacities of the researchers from this region in a time-bound manner in this regard.

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