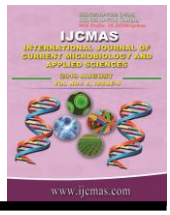
Int.J.Curr.Microbiol.App.Sci (2019) *8*(8): 336-345

International Journal of Current Microbiology and Applied Sciences
ISSN: 2319-7706 **Volume 8 Number 08 (2019)**
Journal homepage: http://www.ijcmas.com



Original Research Article https://doi.org/10.20546/ijcmas.2019.808.038

Research on Climate Change and Fisheries: A Scientometric Analysis

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Keywords

Scientometrics, Climate Change, Fisheries, Publish or Perish

Article Info

Accepted:
04 July 2019
Available Online:
10 August 2019

A B S T R A C T

Climate change has become one of the most contentious as well as pressing issue of our times. Changes and variations in rainfall pattern and temperature have already begun to adversely affect capture and culture fish production. The impactful scientific literature produced on climate change in relation to fisheries was tracked for period since 1990 till 2018. The open source freeware *Publish or Perish (PoP)* desktop application was used to retrieve the scientific articles, which were then subjected to scientometric study. Several relevant word combinations of 'climate change', 'fisheries', 'aquaculture', 'fish', and 'aquatic environment' were used as search terms in PoP. After repeated screening, a total of 1,221 articles on climate change and fisheries were collated and then subjected to descriptive statistical analysis using MS-Excel and the data visualization software Power Bi. The results showed that output of scientific literature on 'climate change and fisheries' significantly increased *after* 2005. The five journals *Journal of Coastal Research, Natural Hazards, Ocean and Coastal Management, Journal of Coastal Conservation and Sustainability Science* were the top most preferred journals by authors for publishing 'climate change in fisheries' related studies. The 3 most impactful articles on 'climate change in fisheries' were authored by EH Allison, WWL Cheung and JM Roessig who were affiliated to institutions in USA and Canada. One third of the publications had single authors while 21% had two authors. In India, E. Vivekanandan (7; CMFRI), R.S. Mahendra (6; INCOIS) and A. S. Rajawat (SAC) are the ones with most publications. Climate science in India is still at nascent stage and increased funding and attention would be essential to evolve evidence based climate change adaptation strategies.

Introduction

Scientometrics is a quantitative method of investigating the development of science as an information process (*Nalimov and Mulchenko, 1969*). Scientometrics measures the scientific disciplines' growth, structure, interrelation, and productivity *(Tague-Sutcliffe, 1992).* The main areas covered by scientometrics are individual scientific documents, authors, scientific institutions, academic journals and regional scientific aspects *(Stock and Sonja, 2006).* Scientometric studies are available for many disciplines and are based on the scientific literature available in the public domain, which the citations databases such as

Scopus, Web of Science and *Publish or Perish* usually cover. Climate change affects the fisheries and aquaculture through ocean acidification, changes in seawater temperatures and sea-level rise. This has implications such as reduced fish productivity, habitat destruction and threat to fishers' livelihoods (Daw *et al.,* 2009; Badjeck *et al.,* 2010). The Kyoto Protocol in 1997 and its subsequent ratification by most countries have given a fillip to research studies on climate change and its impacts. Climate action is now one of the Sustainable Development Goals. Importance of climate change studies in fisheries and aquaculture is now receiving increased attention among the researchers in the aftermath of many climate-induced calamities such as tsunami, cyclonic floods, erratic rainfall and frequent droughts. In this scenario, an attempt was made to track the impactful scientific literature produced on climate change in relation to fisheries during the last three decades i.e. from 1990 till 2018. The specific research questions were as follows: How does India compare with other countries in growth of science?; What are the most published thematic areas; What are the top Journals publishing on a theme; What are the top institutions researching on a theme at global level and in India; Who are the top most and impactful articles / authors researching on a theme globally and locally; and What is the extent of collaboration among authors / institutions, authors count, etc.

Materials and Methods

Open source software *Publish or Perish* (PoP) desktop application was used to retrieve the scientific articles available in the public domain. This application uses the Google Scholar to obtain the raw citations. Several relevant word combinations namely 'climate change', 'fisheries', 'aquaculture', 'fish', 'aquatic studies', 'global warming', 'vulnerability', 'fishers livelihood' 'fisherwomen' 'fishermen' 'fish farm' and 'aquatic environment' were used as search terms in PoP application. Search was done for every individual year, at three-year intervals and by keeping all the years (1990-2018). Published scientific literature was collected for 28 years (1990-2018). Collected articles were then subjected to descriptive statistical analysis using MS-Excel. The data visualization software Power Bi was used to graphically represent the data. In addition, the open source content analysis tool '*Word It Out'* was used to assess the popular themes covered in the published scientific literature.

Results and Discussion

Scientific publications on "Climate Change & Fisheries" from 1990 to 2018

A total of 1221 scientific publications (articles) got published during 1990-2018, as seen from the *Publish or Perish* (Fig. 1). The results showed that output of scientific literature on climate change and fisheries significantly increased since 2005. The growth of scientific literature in the discipline can be better understood if we divide the study period (1990-2018) into 2, almost equal, distinct phases keeping 2004 as the dividing year. The first phase i.e. 1990-2004 can be seen as the formative period for climate change and fisheries studies with the number of publications averaging about 10 per year. During this period, 2 milestone events happened that had implications on climate change studies. The global Earth Summit held at Rio de Janeiro in 1992 had brought the entire world leadership (178 countries participated) on one stage to take note of the pressing environmental issues including global warming and address them head-on, thus bringing the concerns of environment that were hitherto on the margins into the global mainstream debate. The second major milestone was the signing of Kyoto Protocol

that set targets for reduction of greenhouse gases by both developed and developing countries, and bound the industrialised west to take major responsibility for sharing the cost of this reduction. As one of the spinoffs, 37 countries had agreed to start climate change studies and it helped subsequent increase in scientific literature. The massive Tsunami that hit the Indian Ocean in 2004 was a turning point that forced both leaders and researchers to action as the threat of climate change was felt real and immediate having tremendous implications for the future of humanity. As evidenced, the output of scientific literature shot up nearly 7 times since 2005 with an average of nearly 75 publications per year on 'climate change and fisheries' during 2005 to 2018. It is interesting how one cataclysmic event can turn the tide of R&D focus across the globe.

Top 10 cited publications

The citation analysis has revealed that EH Allison, WWL Cheung and JM Roessig are the top 3 most cited authors working on climate change and fisheries as on date. As could be expected, these authors were affiliated to institutions in USA and Canada. It was also found that top cited publications are mainly focused on a macro-level studies i.e. global, regional or country level, and mainly covered the physical aspects like implications of rise in sea surface temperature, sea level changes, coastal erosion, etc. Almost all the authors of the most cited articles are from economically developed countries (Table 1).

Top 10 journals publishing 'Climate Change and Fisheries' related studies

As many as 866 scientific journals have published the 1221 articles found in the *Publish or Perish* during 1990 to 2018, with an average of 1.4 articles per journal. The large number of journals indicates a highly diverse journals publish studies on 'climate change and fisheries'. This diversity is in terms of journals thematic coverage as well as their geographical location. The 6 journals namely *Journal of Coastal Research, Natural Hazards, Ocean and Coastal Management, Journal of Coastal Conservation, Sustainability Science* and Marine Policy, with at least 10 articles each (Table 2), were the most preferred journals by authors for publishing climate change & fisheries related studies. These together have published 142 articles which are 11% of total articles published on the theme. One can infer that there exists both few numbers of specialized journals as well as diverse set of non-specialised journals that publish 'climate change and fisheries' related studies, which is a healthy sign.

Number of authors in publications

It was found that nearly one third (381; 31%) of the publications are single authored while 21% (260) are double authored publications. It was interesting to find a relationship between citations and number of authors i.e. publications with higher citations had more than 2 authors. This indicates that greater extent of collaboration as well as inter- / multi- disciplinary approach leads not only to more number of authors but significantly, higher number of citations underscoring greater relevance and utility of those publications among the peer group (Fig. 2).

Top 10 authors in 'Climate Change & Fisheries'

Developed countries (in other words consuming West) dominate the landscape of scientific publications on climate change and fisheries, though the theme is equally relevant to the developing countries (in other words producing East). The 9 of the top most authors are from just 3 countries namely United States

of America, Australia and United Kingdom, who have producing 222 articles i.e. 18% of the total publications. This is highly lopsided. As the Table 3 below indicates, these publications have also come from specific institutions to which these authors have long been affiliated to, which indicates concentration of 'climate change & fisheries' studies research in few institutions and lack of diversification even within the developed west.

Top 10 Impactful Authors working on 'Climate change & fisheries'

The total citations count, an accepted measure of an author's impact, of the top 10 authors (as given in Table 3) publishing on this theme were listed in descending order to understand the author wise citation trends (Table 4). It shall be noted that here the total citations count refer to all the publications of respective authors and not just confined to only on 'climate change and fisheries' related studies. The most impactful author, RJ Nicholls, is not only the one with highest total number of publications but also the disproportionately cited author i.e. nearly 3 times more publications but 13 times more cited than the second most published and cited author with nearly 4 times h-index and g-index scores. Interestingly, the differences in the prolificness of authors (column 2 in Table 3 and Table 4) when the total number of publications and those focused on 'climate change and fisheries' were considered has meant that there is no one to one correspondence between the two. However, this observation needs to be qualified as it doesn't take into consideration the length of each author's publishing career.

Fig.1 Year wise growth

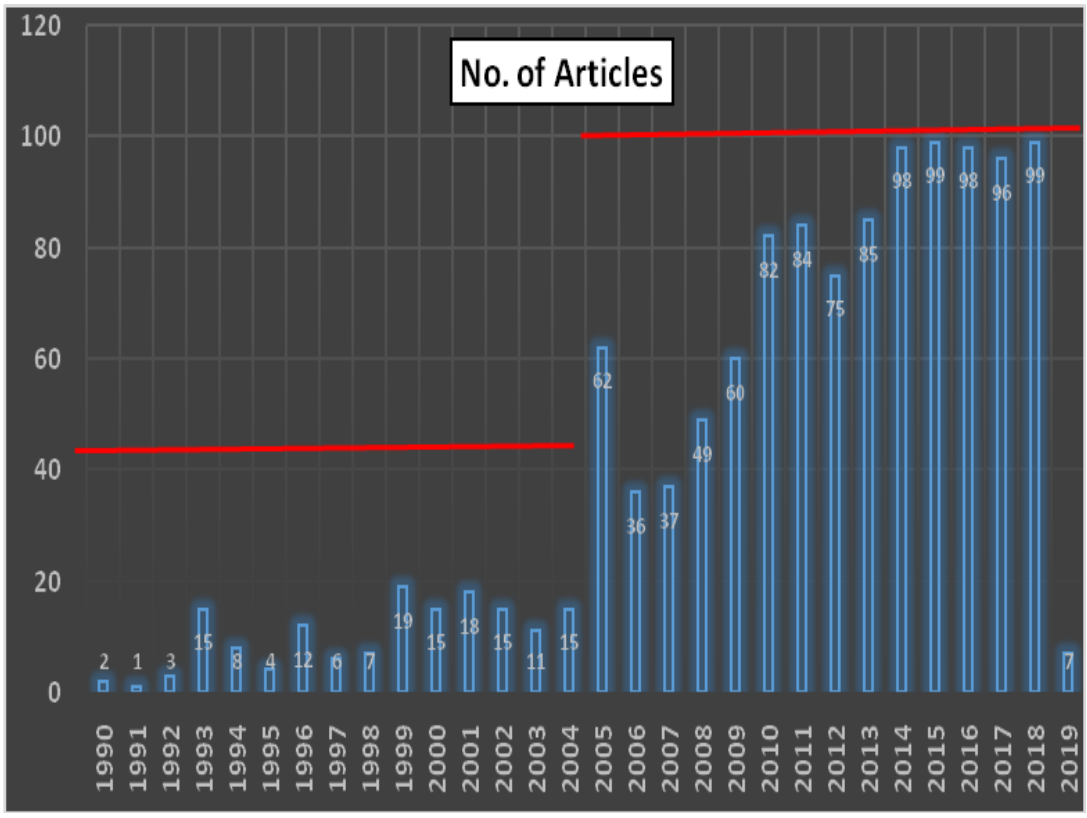

Fig.2 Number of authors in publications

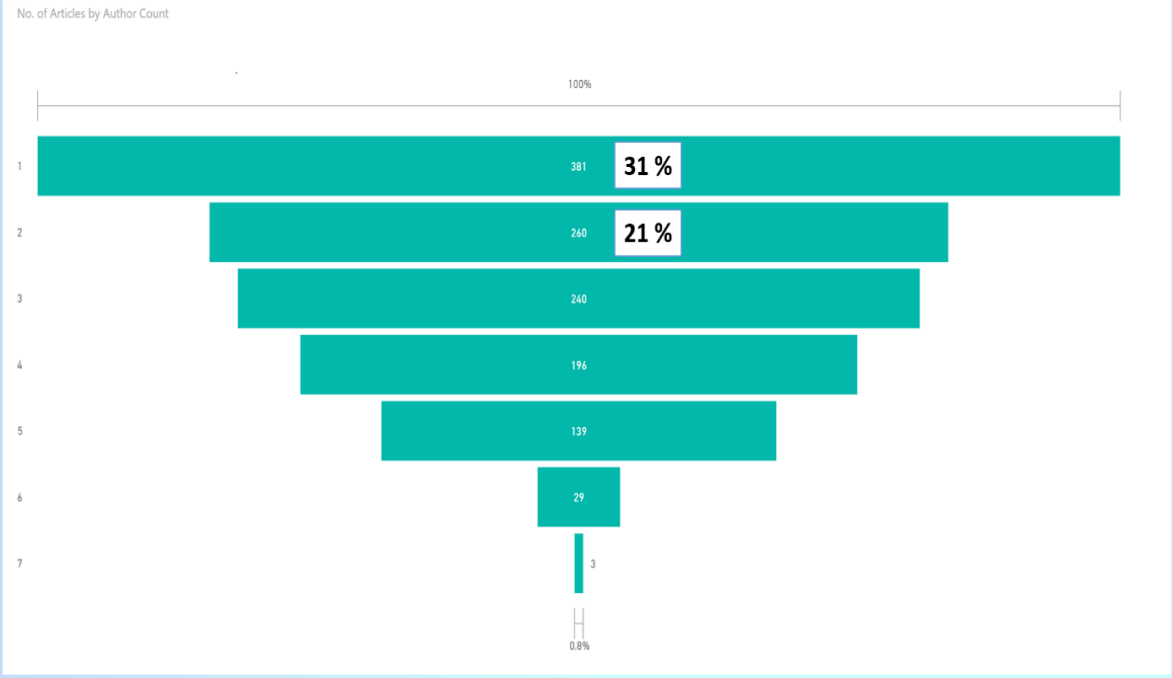

Fig.3 Most published thematic areas within 'Climate Change & Fisheries'

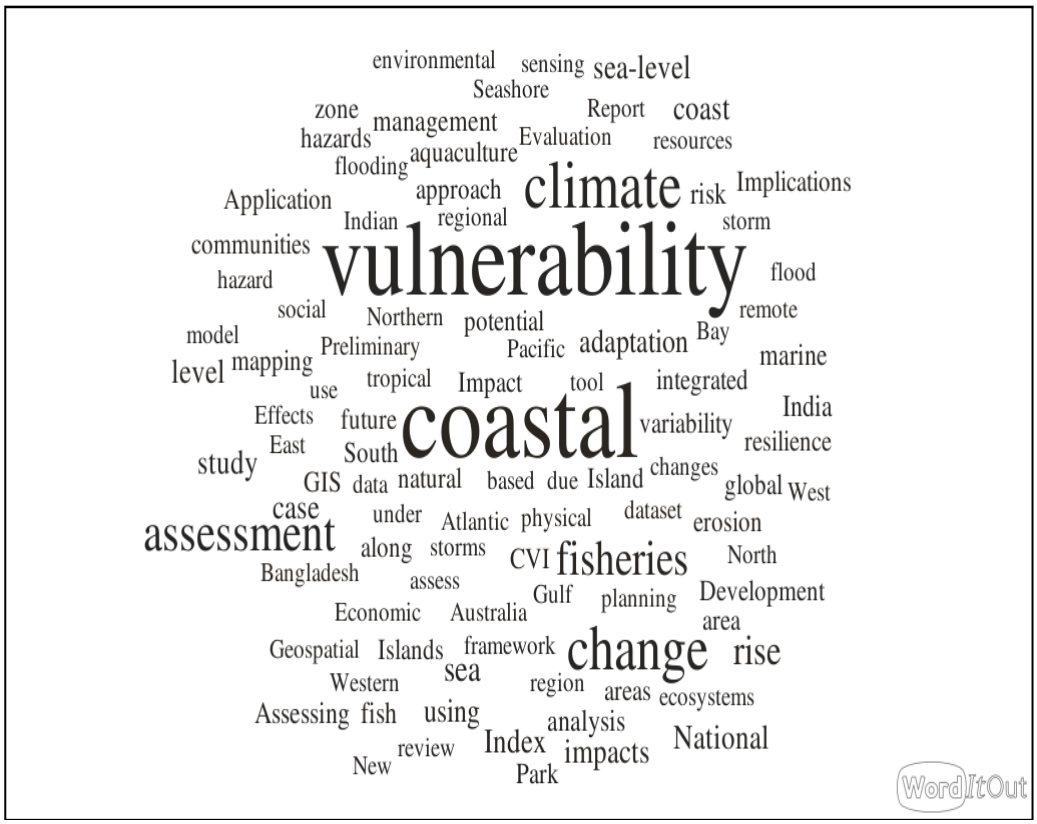

Fig.4 Top countries publishing on 'Climate Change & Fisheries'

Table.1 Top 10 cited publications

Rank	Article	Authors	Journal	Year	Cites	Journal Impact	First author affiliation
1	Vulnerability of national economies to the impacts of climate change on fisheries	EH Allison, AL Perry, MC Badjec	Fish and Fisheries	2009	844	6.9	College of Environment, University of Washington, USA
2	Large- scale redistribution of maximum fisheries catch potential in the global ocean under climate change	WWL Cheung, VWY Lam, JL Sarmiento	Global Change Biology	2010	733	8.9	The University of British Columbia, Canada
3	Effects of global climate change on marine and estuarine fishes and fisheries	JM Roessig, CM Woodley, JJ Cech	Reviews in Fish Biology and Fisheries	2004	523	3.3	Department of Wildlife, USA
4	Climate change and deepening of the North Sea fish assemblage: a biotic indicator of warming seas	NK Dulvy, SI Rogers, S Jennings	Journal of Applied Ecology	2008	520	5.7	Simon Fraser University, Department of Biological Sciences, Canada
5	Assessment of coastal vulnerability to climate change	RJT Klein, RJ Nicholls	Ambio	1999	459	3.6	Potsdam Institute for Climate Impact Research, Germany
6	Climate change impacts on the biophysics and economics of world fisheries	UR Sumaila, WWL Cheung,	Nature Climate Change	2011	349	7.8	Fisheries Centre, University of British Columbia, Canada
7	Erosion hazard vulnerability of US coastal counties	BJ Boruff, C Emrich, SL Cutter	Journal of Coastal Research	2005	334	0.93	University of South Carolina, Columbia, USA
8	National assessment of coastal vulnerability to sea-level rise; US Atlantic Coast	ER Thieler, ES Hammar-Klose	Journal of Coastal Research	1999	318	0.93	U.S. Geological Survey, Woods Hole Science Center, USA
9	A flood vulnerability index for coastal cities and its use in assessing climate change impacts	SF Balica, NG Wright, F van der Meulen	Natural hazards	2012	277	1.90	UNESCO-IHE, Institute for Water Education Delft, The Netherlands
10	Vulnerability of coastal communities to key impacts of climate change on coral reef fisheries	JE Cinner, TR McClanahan, NAJ Graham	Global Environment Change	2012	273	6.37	Australian Research Council Centre, James Cook University, Australia

Table.2 Top 10 journals publishing on climate change & fisheries

S. N	Journal Name	Publications	Impact Factor
1	Journal of Coastal Research	53	0.93
2	Natural Hazards	26	1.90
3	Ocean and Coastal Management	25	2.27
4	Journal of Coastal Conservation	17	1.16
5	Sustainability Science	11	3.85
6	Marine Policy	10	2.10
7	Fish and Fisheries	9	6.9
8	International Journal of Disaster Risk Reduction	7	1.96
9	Ambio	6	3.61
10	Environmental Science and Policy	6	3.82
11	Estuarine, Coastal and Shelf Science	5	2.61
12	Journal of Environmental Planning	5	1.70
13	Journal of Marine Science and Engineering	5	1.71

Table.3 Top 10 authors in 'Climate Change & Fisheries'

S. No	Authors	Article Numbers	Country	Affiliations
1	EA Pendleton	57	USA	U.S. Geological Survey, Woods Hole Science Center
2	ER Thieler	51	USA	U.S. Geological Survey, Woods Hole Science Center
3	SJ Williams	26	USA	U.S. Geological Survey, Woods Hole Science Center
4	ES Hammer-Klose	23	USA	U.S. Geological Survey, Woods Hole Science Center
5	RJ Nicholls	19	UK	University of Southampton
6	N Harvey	16	Australia	Department of Geography and Environmental Studies, University of Adelaide
7	CD Woodroffe	12	Australia	School of Earth and Environmental Sciences, University of Wollongong
8	RJT Klein	11	Germany	Potsdam Institute for Climate Impact Research, Telegrafenberg
9	L Mcfadden	10	UK	Flood Hazard Research Centre (FHRC), Middlesex University
10	M Barange	7	UK	GLOBEC International Project Office

Table.4 Top 10 Impactful authors working on 'Climate change & fisheries'

S. No	Authors	Article	Citations	h-index	g-index
1	RJ Nicholls	950	55475	118	212
2	ER Thieler	328	4620	33	64
3	RJT Klein	120	6967	30	83
4	SJ Williams	140	2308	27	46
5	WWL Cheung	61	3558	22	59
6	M Barange	59	1374	15	37
7	EA Pendleton	67	446	12	20
8	ES Hammer-Klose	44	679	8	26
9	N Harvey	20	304	8	17
10	L Mcfadden	10	379	7	10

Table.5 Top 6 Indian authors publishing on 'Climate Change & Fisheries'

S. No	Authors	Article Numbers	Affiliations
1	E. Vivekanandan	7	CMFRI, Cochin
2	R.S. Mahendra	6	Indian National Centre for Ocean Information Services (INCOIS), Hyderabad
3	A. S. Rajawat	6	Marine and Earth Sciences Group, Space Applications Centre, Ahmedabad
4	S. Kaliraj	5	ESSO - National Centre for Earth Science Studies (NCESS), Thiruvananthapuram
5	P.K. Bhaskaran	5	Department of Ocean Engineering and Naval Architecture, Indian Institute of Technology Kharagpur
6	N. Chandrasekar	4	Center for Geo Technology, Manonmaniam Sundaranar University Tirunelveli

Most published thematic areas within 'Climate Change & Fisheries'

In order to find out the major thematic areas of research within 'climate change and fisheries' related studies, the titles of all the 1,221 published articles were taken and analysed through an online content analysis tool called *Word It out*. The results (Fig. 3) showed that *vulnerability, coastal, climate, fisheries, change, CVI, Impacts, Sea-level, GIS* are the most published thematic areas, in that order of frequency, within the broader discipline of 'climate change and fisheries' related studies. One can argue that the scientific research so far is focused predominantly on climate change induced sea-level rise and its attendant implications for coastal (marine) fisheries and population. In other words, the climate change implications on inland fisheries, has not received much attention.

Top countries publishing on 'Climate Change & Fisheries'

The analysis of country wise publication trends showed that most of the publications originated from North America, Europe and Australia, further buttressing the inferences made in the foregoing discussion. China and India, though being the top two fish producing as well as most populous countries with significant coastline, have been largely absent so far in production of impactful scientific literature on the subject so far (Fig. 4). This is a serious lacunae and needs to be corrected with adequate funding for focused research on 'climate change and fisheries' related studies.

Top 6 Indian Authors Publishing on 'Climate Change & Fisheries'

The publishing trend on the subject in India is not entirely gloomy as the analysis has borne out. As the Table 5 below indicates, many authors have turned their attention on the subject of 'climate change and fisheries' with E. Vivekanandan (7; CMFRI), R.S. Mahendra (6; INCOIS) and A. S. Rajawat (6; SAC) being the top 3 Indian authors publishing on the subject. It is possible to surmise that the number of publications as retrieved from India might be an underestimate with many studies being published in local journals and conference proceedings that are not indexed on global data bases on which tools like *Publish or Perish* depend. However, this is no justification for not allocating more resources and attention on climate change and fisheries studies.

A total of 1,221 articles were published by 2,372 number of authors on 'climate change and fisheries' related studies during 1990 to 2018, while annual output increased 7 times for the period after 2005. Journal of Coastal Research, Natural Hazards, Ocean and Coastal Management, Journal of Coastal Conservation, and Sustainability Science were the most preferred journals by authors while EH Allison, WWL Cheung and JM Roessig are most cited authors working on climate change and fisheries related studies. The majority (381; 31%) of the publications are single authored while 21% (260) are double authored publications. The author impact results showed RJ Nicholls as the most published / cited author (h index - 118) while E. Vivekanandan (7; CMFRI), R.S. Mahendra (6; INCOIS) and A. S. Rajawat (6; SAC) are the top Indian authors publishing on 'climate change and fisheries'. Climate science in fisheries is still tilted towards global/regional/macro level with thematic coverage on physical aspects of sea surface temperature, sea level rise, coastal erosion and fisheries. Climate science in India is at the beginning stage though location specific studies are beginning to receive attention. There is a need to emphasis more on micro level (communities / household/village) studies and core aspects of fisheries by allocating more resources and reorienting R & D programs for producing relevant and impactful research and evolving evidence based climate change adaptation strategies.

Acknowledgements

The study was conducted as a part of the doctorial research in ICAR-Central Institute of Fisheries Education, Mumbai, India. The Authors duly acknowledge the fellowship and support provided by the Institute for the conduct of the study.

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How to cite this article:

Velumani, T., P.S. Ananthan, P. Krishnan and Lloyd Chrispin, C. 2019. Research on Climate Change and Fisheries: A Scientometric Analysis. *Int.J.Curr.Microbiol.App.Sci*. 8(08): 336-345. doi: https://doi.org/10.20546/ijcmas.2019.808.038