Winter 12-9-2015

Scientometric Analysis of Seaweed Research with reference to Web of Science

Ramasamy Kumaresan
Fisheries College and Research Institute, rkumaresansamy@gmail.com

Krishnan Vinitha
St. Mary's College (Autonomus), Thoothukudi, vinithaksmc@gmail.com

Kattari Kannan
Manonmanium Sundaranar University, Tirunelveli, drlkkannan@gmail.com

Scientometric Analysis of Seaweed Research with reference to Web of Science

Ramasamy Kumaresan[1], Krishnan Vinitha[2] and Kattari Kannan[3]

1 Deputy Librarian, Fisheries College and Research Institute, Tamil Nadu Fisheries University, Thoothukudi – 628 008, Tamil Nadu, India.
E-mail: rkumaresansamy@gmail.com
2 Librarian, St. Mary's College (Autonomus), Thoothukudi – 1, Tamil Nadu, India
3 Assistant Librarian, Manonmanium Sundaranar University, Tirunelveli, Tamil Nadu

Abstract

A total of 5814 publications were published in seaweed research globally during the study period 2005 – 2014. The highest number of publications was published in 2014 with 883 (15.19%). The highest Total Local Citation Scores (TLCS) and Total Global Citation Scores (TGCS) were recorded in 2008, 2460 (14.99%) and 9724 (15.50%) respectively. The mean relative growth of seaweed research is 0.1015 and the average doubling time is 8.532. The collaborative research is predominant in seaweed research globally. The degree of collaboration is 0.947. Jeon, Y. J secure first position with 51 contributions (0.90%). Chinese Academy of Sciences, China contributed 172 publications and score first rank. Research articles were predominant than any other document types. Journal of Applied Phycology contributed 390 (6.71%) publications and score first position. USA contributed 645 (11.10%) publications and place first position. English is most preferred language of seaweed research publications. DuBois, Michel**,** K. A. Gilles, J. K. Hamilton, P. A. Rebers, Fred. Smith. (1956). Colorimetric Method for Determination of Sugars and Related Substances. *Anal. Chem., 28* (3), pp 350–356, DOI 10.1021/ac60111a017 was cited in 239 publications and score first position. Chinese Academy of Sciences, China had 172 Publications with 29455 bibliographic coupling with other institutes.

Keywords: Seaweed, Literature productivity, Scientometrics, Bibliographic coupling.

1. Introduction

The word seaweed is the popular term that is loosely applied to the larger, more complex marine algae; also called macroalgae. Because all seaweeds are marine algae, the two terms will be used interchangeably. Seaweeds are divided into three main groups' viz., green algae, red algae and brown algae. Seaweeds are found in all coastal areas of the world, in all climate zones from the warm tropics to the icy polar regions. There are about 10,000 different species (Mouritsen, 2013)[11]. Seaweed

is a rich source of nutrients included in Asian traditional cuisine and is being extensively explored for its other merits as a food. Apart from its proven nutritional properties, bioactive molecules found in seaweeds have attracted the interest of health conscious societies, as seaweed is regarded as a remarkable marine medicinal food (Rajapakse and Kim, 2011)[14]. Carbohydrates, proteins, lipids, and vitamins are provided to the human body through different food sources. Like most of the terrestrial plants, marine algae are also a rich source of above nutritional elements. In composition with many common vegetables, high levels of fiber, minerals, omega-3 fatty acids, and moderate concentrations of lipids and proteins available in most edible seaweeds (Murata and Nakazoe, 2001)[12]. It is primarily known as a source of iodine. The highest iodine content is found in brown algae ranging from 1500 – 8000 ppm (parts per million). Seaweed is one of the richest plant sources of calcium; one gram of dried seaweed provides 70 mg of calcium. Seaweed contains significant amount of protein i.e., up to 20% of dry matter. Spirulina, a micro-alga, is a well kwon source for protein. It contains 70% of dry matter. Seaweed contains vitamins, such as Provitamin A, vitamin C and B_{12}. Seaweed has very little fat, ranging from 1 – 5% of dry matter. Seaweed has high fiber content, from 32% to 50% of dry matter (Dharmananda, 2002)[2].

1.1. Seaweed

Seaweed is a macroscopic, multicellular, marine algae that lives near the seabed. The term includes some members of the red, brown, and green algae. Seaweeds can also be classified by use. The study of seaweed is known as Phycology.

Scientometrics is the study of measuring and analysing science research. We global literature productivity of seaweed and report the findings in this paper.

2. Review of Literature

Kumaresan et al (2014)[7] studied the global literature productivity on WSSV based on Web of Science database and inferred China as the top literature productive country, followed by India. Chinese Academy of Sciences, Beijing stood first place followed by National Taiwan University, Taipei. C. F. Lo contributed more literature on WSSV. Kumaresan et al., (2014)[8] studied the research trends in fish stock assessment during 1999 – 2013 and the original articles were predominant,

collaborative research is dominant over solo research and the degree of collaboration was 0.88. Dastidar et al. (2013)[1] studied global shrimp disease research productivity. Though it is practiced in around 70 countries, it is primarily dominated by China, Thailand, Indonesia, Vietnam, Ecuador and India. The study highlighted the role of research in the development of the industry by taking examples of *Penaeus vannamei* and *P. monodon*. Dias et al. (2012)[3] studied global literature productivity on net cages in fish farming using Thomson Reuters Database (Web of Knowledge) from 1990 to 2009 and selected 238 articles published during this study period. There was a temporal increase in the number of articles published. Jaric et al (2012)[5] investigated the trends in fisheries science research from 2000 to 2009 based on the Web of Science database and the results indicate that the most frequently studied group of species was *Salmonidae*. The United States was the most productive country over the last few decades with a gradually increasing output over the time. Jaric and Gessner (2012)[4] analysed the world literature productivity on Sturgeon. Sturgeon species are among the commercially most valuable and the most endangered groups of fish. The analysis was performed based upon articles obtained from the ISI Web of Knowledge online database. White sturgeon (*Acipenser transmontanus*) was the most frequently studied species, but it was recently surpassed by Persian sturgeon (*A. persicus*). A steady increase in the number of published articles over time was observed. During the period reviewed, sturgeon research published in peer reviewed journals dominantly originated from the USA and EU. International and inter-institutional collaboration both tended to increase the impact of the research. Mohn and Ravi (2007)[10] studied the seaweed research is studied by systematic analysis and the flow of literature productivity is mapped using CD-ROM version of ASFA database over the period of nine years, 1988-1996. The study is analyzed on the quantum of research output, most productive institutions globally as well as India in terms of publications. This paper also analyses the choice of the journals, authorship pattern, and their productivity. Source and subject wise distribution of seaweed research literature are explored.

Very few studies were conducted at national level. Kumaresan et al. (2014)[9] analysed the Indian contribution in the Aquaculture journal during 1972 – 2011. During this period 374 publications were contributed by Indian authors. The percentage of Indian contribution was 2.74 during this study period. A. S. Sahul

Hameed scored first rank with 27 publications. Central Institute of Freshwater Aquaculture (ICAR), Bhubaneswar, Odisha scored first rank with 40 publications among Indian Institutions. Tamil Nadu secured first position with 133 contributions. The publication of I. Karunasagar et al. (1994) has highest citation both in SCOPUS database (240) and Google Scholar database (380). Ponnudurai and Shabu (2013)[13] studied the research productivity on fish and fishing industry in India and found that fish research output increased from 370 in 1980 to 3971 in 2009. Jayashree and Arunachalam (2000)[6] did mapping of fish research in India and found out that 460 papers came from India every year, of which 82% were journal articles. About 70% of journal articles were published by 113 Indian journals. About 61% of the publications were contributed by government laboratories and over 25% by academic Institutions. Tamil Nadu and Kerala were the leading states in literature contributions. Rana and Agarwal (1994)[15] studied authorship trends in Indian wildlife and fisheries literature. The data were collected from Wildlife Review and Fish Review published from 1980 to 1989. This study revealed that single authored papers decreased from 63.68% in 1980 to 52.74% in 1989. During the same period, there was an increase in the average number of authors per paper from 1.57 in 1980 to 1.70 in 1989. The degree of collaboration also increased from 0.36 to 0.47.

3. Objective of the study

The main objective of this study is to analyse the global literature productivity on seaweed during the period of study (2005 – 2014) and the objectives are to:

i) quantify the global literature productivity,
ii) study the year-wise distribution of literature,
iii) identify the document type,
iv) study the high productive journals in seaweed research,
v) identify the high productive institutions and
vi) identify the high productive country and language.

4. Methodology and source of data

The required data were collected from Web of Science databases such as Science Citation Index Expanded (SCI-Expanded), Social Sciences Citation Index (SSCI), Conference Proceedings Citation Index - Science (CPCI-S), Conference Proceedings Citation Index - Social Sciences & Humanities (CPCI-SSH) and Index Chemicus (IC) for the period of 10 years (2005 – 2014). Nearly 5814 bibliographic records were retrieved on seaweed. Advance search was employed TS = “Seaweed”.

The downloaded 5814 bibliographic records were analysed using HistCite software (developed by Thomson Reuter), VOSviwer (developed by Universiteit Leiden, Netherlands) and Pajek (Pajek is developed by Vladimir Batagelj and Andrej Mrvar. Some procedures were contributed also by Matjaž Zaveršnik.

5. Limitation of the study

This study confined to Web of Science Database only and the period of study is also limited to ten years (2005 – 2014). This should not give complete picture of literature productivity in Seaweed research globally.

6. Result and discussion

The analysis of data was done to measure the global literature contribution in seaweed research. The analysis was done year-wise distribution, author's productivity, collaborative patterns, institutional productivity, document type, journal-wise distribution, country-wise distribution, language-wise distribution, highly cited articles and institutional bibliographic coupling etc.

6.1. Year-wise distribution of publication on Seaweed research

Sl. No.	Years	No. of Publications	Percentage	TLCS	%	TGCS	%
1	2005	320	5.50	1958	11.93	7232	11.53
2	2006	397	6.83	2323	14.15	8366	13.33
3	2007	422	7.26	2319	14.13	7582	12.09
4	2008	544	9.36	2460	14.99	9724	15.50
5	2009	524	9.01	2000	12.18	7950	12.67
6	2010	506	8.70	1581	09.63	6532	10.41
7	2011	691	11.89	1978	12.05	6820	10.87
8	2012	731	12.57	1094	06.67	4717	7.52
9	2013	796	13.69	618	03.77	2898	4.62
10	2014	883	15.19	82	0.50	914	1.46
	Total	5814	100.00	16413	100.00	62735	100.00

Table. 1. Year-wise distribution of publication on Seaweed research

A total of 5814 publications were published on seaweed during 2005 – 2014 globally. Table 1 shows the year-wise distribution of publication on Seaweed research. The maximum number of publications 883 (15.19%) were recorded in 2014 with a Total Local Citation Scores (TLCS) 82 and Total Global Citation Scores (TGCS) 914. The minimum number of publications 320 (5.50%) were recorded in 2005 with 1958 TLCS and 7232 TGCS. The maximum TLCS 2460 (14.99) were

recorded in 2008 and minimum 82 (0.50%) in 2014. The maximum TGCS 9724 (15.50%) were recorded in 2008 and minimum 914 (1.46%) in 2014.

5.2. Relative Growth Rate of literature on Seaweed

Sl. No.	Years	No. of Publications	W_1	W_2	R(a)= (W_2-W_1)	Mean R(a)	D_t = 0.693/R(a)
1	2005	320	-	5.768	-		-
2	2006	397	5.768	5.984	0.216		03.21
3	2007	422	5.984	6.045	0.061		11.36
4	2008	544	6.045	6.299	0.254		02.73
5	2009	524	6.299	6.261	-0.038		18.24
6	2010	506	6.261	6.227	-0.034	0.1015	20.38
7	2011	691	6.227	6.538	0.311		02.23
8	2012	731	6.538	6.594	0.056		12.38
9	2013	796	6.594	6.680	0.086		08.06
10	2014	883	6.680	6.783	0.103		06.73
	Total	5814			1.015		85.32

Table 2. Relative growth rate and doubling time on Seaweed research

Table 2 shows the growth rate and doubling time on seaweed research globally. It is observed that, the maximum relative growth rate were recorded in 2008 (0.254) and minimum relative growth rate were recorded in 2010 (-0.034). The mean relative growth rate is 0.1015. The doubling time has increased from 2.23 in 2011 to 20.38 in 2010. The average doubling time is 8.532.

6.3. Authorship pattern and degree of collaboration in Seaweed research

Sl. No.	Authorship pattern	No. of publications	Cumulative publications	Percentage (%)	Cumulative percentage (%)
1	Single author	308	308	05.30	05.30
2	Two authors	834	1142	14.34	19.64
3	Three authors	1129	2271	19.42	39.06
4	Four authors	1057	3328	18.18	57.24
5	Five authors	889	4217	15.29	72.53
6	Six authors	591	4808	10.17	82.70
7	Seven authors	390	5198	06.71	89.41
8	Eight authors	233	5431	04.01	93.42
9	Nine authors	156	5587	02.68	96.10
10	Ten authors	77	5664	01.32	97.42
11	More than ten authors	150	5814	02.58	100.00
	Total	5814		100.00	

Table 3- Authorship pattern in seaweed research

Table 3 shows the authorship pattern in seaweed research globally. There were 14805 authors contributed 5814 publications. Out of 5814 publications, 1129 (19.42%) publications were contributed by three authors, followed by 1057 (18.18%) publications were contributed by four authors, whereas single author publications were 308 (5.30%) only. "Cock JM, Sterck L, Rouze P, Scornet D, Allen AE, et al. The Ectocarpus genome and the independent evolution of multicellularity in brown algae NATURE. 2010 JUN 3; 465 (7298): 617-621", was contributed by 77 authors. The degree of collaboration is 0.947. Multiple authorship is predominant in seaweed research.

Degree of collaborations:

The Degree of Collaboration (DC) is measured by proportion of multiple authored papers derived by Subramanyam (1983)[16] as,

$$DC = \frac{N_m}{N_m + N_s}$$

Where, DC = degree of collaboration in a discipline.

N_m = Number of multiple-authored research papers in the discipline published during a year.

N_s = Number of single-authored research papers in the discipline published during the same year.

Degree of Collaboration:

$$DC = \frac{5506}{5506 + 308} = 0.947$$

6.4. Most productive authors in seaweed research

Sl. No.	Name of the author	No. of contribution	Percentage (%)	TLCS	TGCS
1	Jeon, Y. J	51	0.90	368	1049
2	Pereira, R. C	43	0.74	139	404
3	Critchley, A. T	38	0.65	261	465
4	Jha, B	37	0.64	136	459
5	Miyashita, K	34	0.58	376	848
6	O'Doherty, J. V	30	0.52	157	261
7	Hosokawa, M	29	0.50	351	800
8	Teixeira, V. L	29	0.50	93	241
9	Hong, Y. K	28	0.48	94	209
10	Kim, S. K	28	0.48	120	390

Table 4. Most productive authors in seaweed research

Table 4 shows that there were 14805 authors contributed 5814 publications in seaweed research globally. Out of these 14805 authors, Jeon, Y. J contributed 51 (0.90%) publications and secured first position with 368 TLCS and 1049 TGCS, followed by Pereira, R. C contributed 43 (0.74%) publications with 139 TLCS and 404 TGCS and Critchley, A. T contributed 38 (0.65%) publications with 261 TLCS and 465 TGCS and secured second and third position respectively.

6.5. Most prolific contributing Institution in Seaweed research

Sl. No.	Name of the Institution	No. of contribution	Percentage (%)	TLCS	TGCS
1	Chinese Academy of Sciences, China	172	2.958	676	2065
2	Pukyong National University, South Korea	111	1.909	373	1164
3	Russian Academy of Sciences, Moscow	87	1.496	456	995
4	Ocean University of China,	80	1.376	215	722
5	University of São Paulo, Brazil	80	1.376	293	705
6	Unknown	70	1.204	8	400
7	Hokkaido University, Japan	64	1.101	440	1332
8	Federal Fluminense University, Brazil	64	1.101	178	541
9	University of Paris VI, France	61	1.049	249	1520
10	Jeju National University, South Korea	60	1.031	372	1150

Table 5. Most prolific contributing institution in seaweed research

Table 5 shows the most prolific institutions were contributed more than 60 publications. There were 3658 institutions contributed 5814 publications during the study period. Out of 3658 institutions, Chinese Academy of Sciences, China contributed 172 (2.958%) publications with 676 TLCS and 2065 TGCS scored first position, followed by Pukyong National University, South Korea were contributed 111 (1.909%) publications with 373 TLCS and 1164 TGCS and Russian Academy of Sciences, Moscow were contributed 87 (1.496%) with 456 TLCS and 995 TGCS were secured second and third places respectively. Central Salt and Marine Chemical Research Institute were contributed 56 (0.96%) with 258 TLCS and 615 TGCS were placed in 12th position from India.

6.6. Source-wise distribution of publications in seaweed research

Sl. No.	Document type	No. of Publications	Percentage (%)	TLCS	TGCS
1	Article	4963	85.363	14258	53004
2	Review	255	4.386	1499	7178
3	Meeting Abstract	187	3.216	15	20
4	Proceedings Paper	160	2.752	48	136
5	Article; Proceedings Paper	127	2.184	385	1538
6	News Item	33	0.568	4	46
7	Editorial Material	27	0.464	8	62
8	Review; Book Chapter	23	0.396	142	411
9	Letter	20	0.345	43	224
10	Correction	11	0.189	0	3
11	Article; Book Chapter	4	0.069	11	113
12	Biographical-Item	2	0.034	0	0
13	Book Review	1	0.017	0	0
14	Software Review	1	0.017	0	0
	Total	5814	100.00	16413	62735

Table 6. Source-wise distribution of publication in seaweed research

Table 6 shows the source-wise distribution of publications in seaweed research globally. There were 14 types of sources contributed 5814 publications. Out of 14 sources, articles were major source of contribution 4963 (85.363%) with 14258 TLCS and 53004 TGCS, followed by review 255 (4.386%) with 1499 TLCS and 7178 TGCS and meeting abstract 187 (3.216%) with 15 TLCS and 20 TGCS.

6.7. Journal-wise distribution of publication in seaweed research

Sl. No.	Name of the journal	No. of publications	Percentage (%)	TLCS	TGCS
1	JOURNAL OF APPLIED PHYCOLOGY	390	6.71	1485	3370
2	JOURNAL OF PHYCOLOGY	121	2.08	440	1263
3	BOTANICA MARINA	114	1.96	396	971
4	MARINE ECOLOGY PROGRESS SERIES	89	1.53	342	1266
5	CARBOHYDRATE POLYMERS	85	1.46	407	1250
6	PHYCOLOGIA	85	1.46	52	243
7	AQUACULTURE	83	1.43	573	1454
8	FOOD CHEMISTRY	81	1.39	760	2050

9	PLOS ONE	75	1.29	0	567
10	BIORESOURCE TECHNOLOGY	73	1.26	490	2208

Table 7 – Top ten highly contributing journals in seaweed research

Table 7 shows the top ten most productive journals in seaweed research globally. There were 1419 journals published 5814 publications in seaweed research. Out of these 1419 journals, Journal of Applied Phycology were contributed 390 (6.71%) publications with 1485 TLCS and 3370 TGCS and secured first position, followed by Journal of Phycology were contributed 121 (2.08%) with 440 TLCS and 1263 TGCS, Botanica Marina were contributed 114 (1.96%) with 396 TLCS and 971 TGCS and scored second and third position respectively.

6.8. Country-wise contribution of publications in seaweed research

Sl. No.	Name of the country	No. of publications	Percentage (%)	TLCS	TGCS
1	USA	645	11.10	1796	8946
2	Peoples Republic of China	544	9.40	1596	5517
3	South Korea	537	9.20	1523	5383
4	Japan	514	8.80	1450	4988
5	Brazil	395	6.80	1163	3526
6	Spain	381	6.60	970	4524
7	India	371	6.40	1200	4074
8	UK	337	5.80	1071	5397
9	France	301	5.20	985	5017
10	Canada	275	4.70	1147	3735

Table 8 – Top ten most productive countries in seaweed research

Table 8 shows the most productive countries in seaweed research globally. There were 106 counties contributed 5814 publications in seaweed research globally. Out 106 countries, USA were contributed 645 (11.10%) publications with 1796 TLCS and 8946 TGCS and scored fist place, followed by People Republic of China were contributed 544 (9.40%) with 1596 TLCS and 5517 TGCS and South Korea were contributed 537 (9.20%) with 1523 TLCS and 5383 TGCS and secured second and third places respectively. India secured 7th position with 371 publications.

6.9. Language-wise distribution of publications in seaweed research

Sl. No.	Language	No. of Publications	Percentage (%)	TLCS	TGCS
1	English	5674	97.59	16370	62531

2	Japanese	38	0.65	4	34
3	Portuguese	26	0.45	13	54
4	Spanish	23	0.40	9	27
5	Polish	14	0.24	3	8
6	Chinese	13	0.23	3	35
7	French	10	0.17	4	10
8	Korean	5	0.08	0	6
9	German	2	0.03	0	0
10	Russian	2	0.03	0	7
11	Turkish	2	0.03	0	2
12	Czech	1	0.02	1	3
13	Dutch	1	0.02	3	6
14	Greek	1	0.02	1	9
15	Italian	1	0.02	0	0
16	Malay	1	0.02	2	3
		5814	100.00	16413	62735

Table 9 - Language-wise distribution of publications in seaweed research

The table 9 shows the language-wise distribution of publication in seaweed research. There were 5814 publications were published in 16 languages. Out 16 languages, English was the most preferred language for publication in seaweed research. English language publications were contributed 5674 (97.59%) with 16370 TLCS and 62531 TGCS, followed by Japanese (38) and Portuguese 23) publications.

6.10. Highly cited references in seaweed research

Sl. No.	**Author/year/Journal**	No. of citation
1	DuBois, Michel**,** K. A. Gilles, J. K. Hamilton, P. A. Rebers, Fred. Smith. (1956). **Colorimetric Method for Determination of Sugars and Related Substances.** *Anal. Chem.*, *28* (3), pp 350–356, DOI 10.1021/ac60111a017	239
2	Davis, T. A., B. Volesky and A. Mucci. 2003. **A Review of the Biochemistry of Heavy Metal Biosorption by Brown Algae**. *Water Research*, 37(18), pp. 4311-4330. doi:10.1016/S0043-1354(03)00293-8	140
3	Smit, Albertus J., (2004). **Medicinal and pharmaceutical uses of seaweed natural products: A review**. *Journal of Applied Phycology*, 16(4), pp 245-262. DOI 10.1023/B:JAPH.0000047783.36600.ef	131
4	Cumashi, A., Ushakova, N.A., Preobrazhenskaya, M.E., D'Incecco, A., Piccoli, A., Totani, L., Tinari, N., Morozevich, G.E., Berman, A.E., Bilan, M.I., Usov, A.I., Ustyuzhanina, N.E., Grachev, A.A., Sanderson, C.J., Kelly, M., Rabinovich, G.A., Iacobelli, S. and Nifantiev, N.E., (2007). **A**	127

	Comparative Study of the Anti-Inflammatory, Anticoagulant, Antiangiogenic, and Antiadhesive Activities of Nine Different Fucoidans from Brown Seaweeds. *Glycobiology*,17(5), pp541-552. doi: 10.1093/glycob/cwm014	
5	Bradford, Marion M. (1976). **A rapid and sensitive method for the quantitation of microgram quantities of protein utilizing the principle of protein-dye binding**. *Analytical Biochemistry*, 72(1–2), pp248-254. doi:10.1016/0003-2697(76)90527-3	116
6	Fleurence, Joël . (1999). **Seaweed proteins: biochemical, nutritional aspects and potential uses**. *Trends in Food Science & Technology*, 10(1), pp 25–28. doi:10.1016/S0924-2244(99)00015-1	108
7	Rupérez, Pilar, Oussama Ahrazem and J. Antonio Leal. (2002). **Potential Antioxidant Capacity of Sulfated Polysaccharides from the Edible Marine Brown Seaweed Fucus vesiculosus**. *J. Agric. Food Chem*., 50 (4), pp 840–845. DOI: 10.1021/jf010908o	106
8	Lüning, Klaus, Charles Yarish and Hugh Kirkman. (1990). **Seaweeds: Their Environment, Biogeography, and Ecophysiology**. New York: John Wiley & Sons, Inc.	105
9	Mabeau,Serge and Joël Fleurence. (1993). **Seaweed in food products: biochemical and nutritional aspects**. *Trends in Food Science & Technology*, 4 (4), pp 103-107. doi:10.1016/0924-2244(93)90091-N	104
10	Dodgson, K. S. and R. G. Price. (1962). **A note on the determination of the ester sulphate content of sulphated polysaccharides**. *Biochem J*., 84(1): 106–110	103
11	Amir Neori, Thierry Chopin, Max Troell, Alejandro H. Buschmann, George P. Kraemer, Christina Halling, Muki Shpigel, Charles Yarish. (2004). **Integrated aquaculture: rationale, evolution and state of the art emphasizing seaweed biofiltration in modern mariculture**. *Aquaculture*, 231(1–4), pp 361–391. doi:10.1016/j.aquaculture.2003.11.015	101

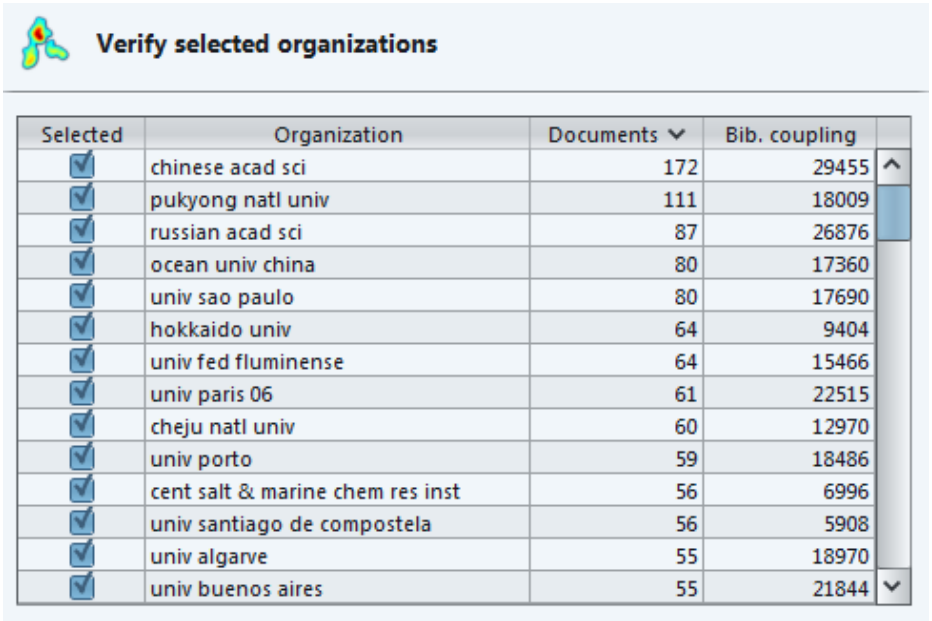
Table 10. Top eleven highly cited references in seaweed research

Table 10 shows the highly cited references in seaweed research publications. There were 135168 references were cited in the 5814 publications in seaweed research globally. Out of 135168 references DuBois, Michel**,** K. A. Gilles, J. K. Hamilton, P. A. Rebers, Fred. Smith. (1956). **Colorimetric Method for Determination of Sugars and Related Substances.** *Anal. Chem., 28* (3), pp 350–356, DOI 10.1021/ac60111a017 were cited 239 times, followed by Davis, T. A., B. Volesky and A. Mucci. 2003. **A Review of the Biochemistry of Heavy Metal Biosorption by Brown Algae**. *Water Research*, 37(18), pp. 4311-4330. doi:10.1016/S0043-1354(03)00293-8 were cited 140 times and Smit, Albertus J.,

(2004). **Medicinal and pharmaceutical uses of seaweed natural products: A review**. *Journal of Applied Phycology*, 16(4), pp 245-262. DOI 10.1023/B:JAPH.0000047783.36600.ef were cited 131 times.

6.11. Bibliographic coupling of Institution in seaweed research

The bibliographic coupling can be defined as "papers are bibliographically coupled when different authors cite one or more papers in common" (Garfield, 2001). The Web of Science source ".txt" data file was exported to VOSviewer to prepare the institutional bibliographical coupling. VOSviewer is used for analysing institutional bibliometrics networks. Fig. 1 shows the institutional-wise bibliographic coupling in seaweed research globally. The institutional network on seaweed research was prepared using Pajek. Bibliographic coupling was estimated with following criteria, minimum number of documents of an institute 20 or above. Out of 3658 institutions, 92 institutions meet the threshold. For each of the 92 institutes, the number of bibliographic coupling link was calculated. The institutes with the largest number of link were selected. Full count method was applied. Chinese Academy of Sciences, China had 172 Publications with 29455 bibliographic coupling with other institutes. Fig. 1 shows the institutional bibliographic coupling in seaweed research globally.



Selected	Organization	Documents	Bib. coupling
☑	chinese acad sci	172	29455
☑	pukyong natl univ	111	18009
☑	russian acad sci	87	26876
☑	ocean univ china	80	17360
☑	univ sao paulo	80	17690
☑	hokkaido univ	64	9404
☑	univ fed fluminense	64	15466
☑	univ paris 06	61	22515
☑	cheju natl univ	60	12970
☑	univ porto	59	18486
☑	cent salt & marine chem res inst	56	6996
☑	univ santiago de compostela	56	5908
☑	univ algarve	55	18970
☑	univ buenos aires	55	21844

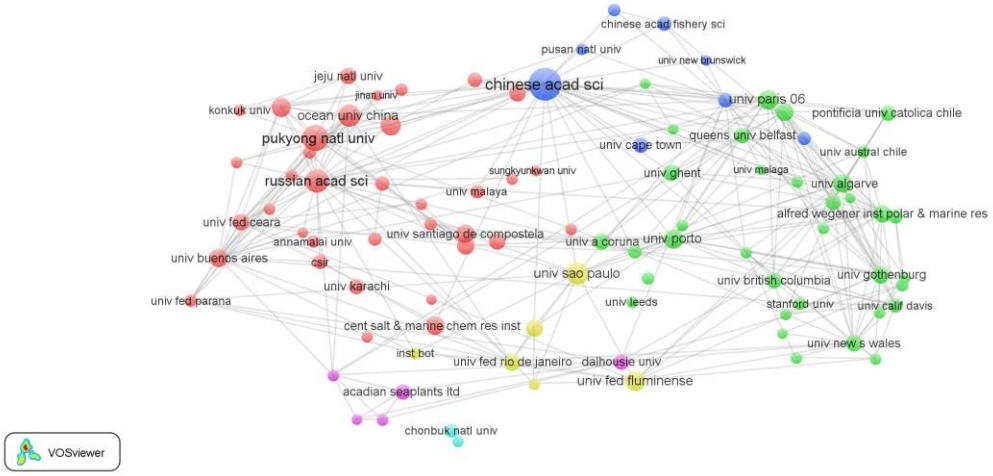


Fig. 1 Bibliographic coupling of institutes using full count method

The institutional network in seaweed research was prepared using Pajek. In VOSviewer, the source file was opened and saved as Pajek ".net" file. Using this ".net" file, institutional network was obtained. Fig. 2 shows the institutional network among the institutions performing research in seaweed.

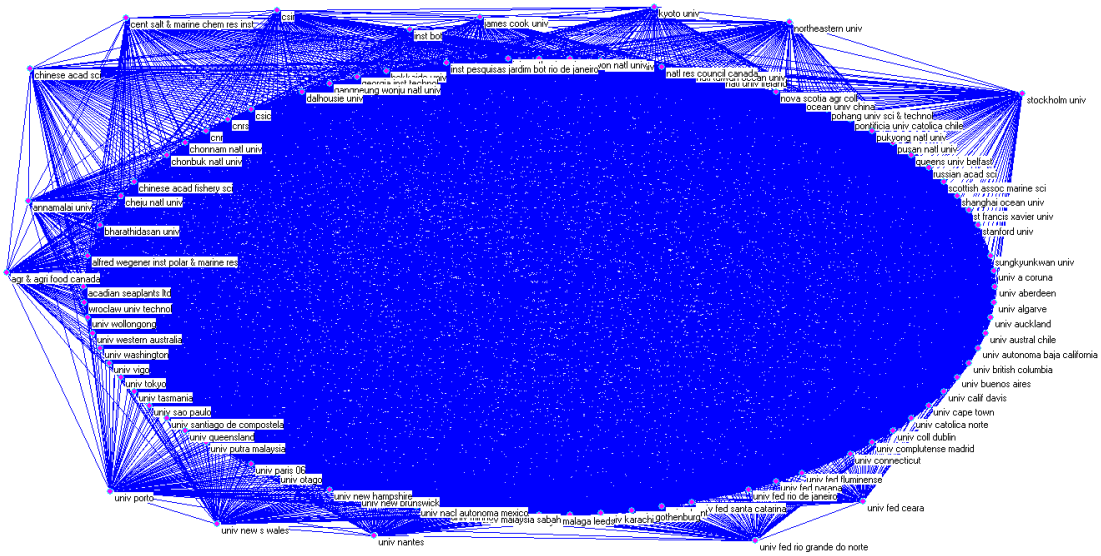


Fig. 2. Institutional network in seaweed research using Pajek

6.12. Conclusion

A total of 5814 publications were published in seaweed research globally during the study period 2005 – 2014. The highest number of publications was published in 2014 with 883 (15.19%). The highest Total Local Citation Scores

(TLCS) and Total Global Citation Scores (TGCS) were recorded in 2008, 2460 (14.99%) and 9724 (15.50%) respectively. The mean relative growth is 0.1015 and the average doubling time is 8.532. The collaborative research is predominant in seaweed research globally. The degree of collaboration is 0.947. There were 14805 authors contributed 5814 publications, out of these Jeon, Y. J score first position with 51 contributions (0.90%). There were 3658 institutions contributed 5814 publications globally. Out of these, Chinese Academy of Sciences, China contributed 172 publications and score first rank. Research articles were predominant than any other document types. Fourteen types of documents were identified, out of these 4963 (85.363%) were research articles. There were 5814 publications were published in 1419 journals. Out of these, Journal of Applied Phycology contributed 390 (6.71%) publications and score first position. There were 106 countries contributed seaweed research globally. Among these, USA contributed 645 (11.10%) publications and place first position. English is most preferred language of seaweed publications. There were 5814 publications published in 16 languages. There were 135168 references were cited in 5814 publications. Out of these, DuBois, Michel**,** K. A. Gilles, J. K. Hamilton, P. A. Rebers, Fred. Smith. (1956). **Colorimetric Method for Determination of Sugars and Related Substances.** *Anal. Chem., 28* (3), pp 350–356, DOI 10.1021/ac60111a017 was cited in 239 publications and score first position. Chinese Academy of Sciences, China had 172 Publications with 29455 bibliographic coupling with other institutes. Further depth study will be needed to know the exact literature productivity in seaweed research globally as well as country-wise.

7. References

1. Dastidar, Prabir G., Mallik, Ajoy and Mandal, Nripendranath (2013). Contribution of shrimp diseases research to the development of the shrimp aquaculture industry: an analysis of the research and innovation structure across the countries. *Scientometrics*, 97 (3), 659 – 674.

2. Dharmananda, Subhuti (2002). The nutritional and medicinal value of seaweeds used in Chinese medicine. www.itmonline.org/arts/seaweed.htm (accessed on 07.12.2015)

3. Dias, Juliana Deo, Simoes, Ressye Simoes and Bonecker, Claudia Costa. (2012). Net cages in fish farming: a scientometric analysis. *Acta Limnologica Brasiliensia*, 24 (1), 12-17

4. Jarić, I. and Gessner, J. (2012). Analysis of publications on sturgeon research between 1996 and 2010. *Scientometrics* 90 (2), 715-735. doi:10.1007/s11192-011-0583-7

5. Jarić, Ivan, Cvijanovic, Gorcin, Knezevic-Jaric, Jelena and Lenhardt, Mirjana. (2012). Trends in fisheries science from 2000 to 2009: a bibliometric study. *Reviews in Fisheries Science*, 20(2), 70-79. DOI: 10.1080/10641262.2012.659775

6. Jayashree, B and Arunachalam, Subbiah, 2000. Mapping fish research in India. *Current Science*, 79(5), 613-620.

7. Kumaresan, Ramasamy, Ezhil Rani, Ramasamy and Jayaraman, Ramanujam (2014). Global literature productivity on White Spot Syndrome Virus (WSSV) during 1999 – 2013: a scientometric study, *International Journal of Current Research and Development*, 2(2): 71-83.

8. Kumaresan, Ramasamy, Ezhilrani, Ramasamy, Vinitha,Krishnan, Sivaraman, Periyakarupan and Jayaraman, Ramanujam (2014). Research trends in fish stock assessment during 1999 - 2013: a scientometrics study. *International Journal of Library and Information Science*, 3(2): 24-36.

9. Kumaresan, Ramasamy, Ezhilrani, Ramasamy, Vinitha, Krishnan and Jayaraman, Ramanujam. (2014). Indian research contributions in the *Aquaculture* journal during 1972 – 2011: a scientometric study. *Library Philosophy and Practice (e-journal).* Paper 1185. http://digitalcommons.unl.edu/libphilprac/1185

10. Mohan, V. and Ravi, S., (2007). Mapping of seaweed research: A global perspective. *Kelpro Bulletin*, 11 (1). pp. 1-14.

11. Mouritsen, Ole G. (2013). Seaweeds: edible, available & sustainable. Chicago: The University of Chicago Press.

12. Murata, M. and Nakazoe, J. (2001) Production and Use of Marine Algae in Japan. *Japan Agricultural Research Quarterly*, 35, 281-290.

13. Ponnudurai, R. and Shabu (2013). Research Productivity on Fish and Fishing industry in India. *International Journal of Pharmaceutical & Biological Archives*, 4(4): 747 - 750

14. Rajapakse, Niranjan and Kim, Se-Kwon (2011). Nutritional and digestive health benefits of seaweed. In Se-Kwon Kim, Ed. *Advances in Food and Nutrition Research, Vol. 64. Marine Medicinal Foods: implications and applications, macro and microalgae.* Amsterdam: Elsevier.

15. Rana, Madan S and Agarwal, Sunita. (1994). Authorship trends in Indian wildlife and fisheries literature – a bibliometric study. *Annals of Library Science and Documentation*, 41 (1), 13 – 18.

16. Subramanyam, K, 1983. Bibliometric studies of research collaboration: a review. *Journal of Information Science*, 6(1), 33-38.