Performance of Reviews in Aquaculture during 2009-2019: A Bibliometric Analysis

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Abstract

Reviews in Aquaculture (RAQ) is one of the world-leading international peer-reviewed scientific journal in the field of aquaculture, whose first issue was published in 2009 and has become a key academic outlet over the years. Motivated by its 10th anniversary in 2019, this study aimed to provides a bibliometric analysis of RAQ, focusing on (1) the publication trends of the journal articles during 2009-2019; (2) the dynamics and trends of the research literature production, and (3) the more prolific authors, institutions and countries. The number of published papers, country and institute productivity, Lotka equation, and the Bradford model were used to assess the productivity status of the journal/contributors. According to the results, authors from 44 countries and 197 institutes contributed to papers published in the journal. Australia-, Mexico-, and USA-based authors had highest rates of contribution and the Wageningen University & Research, Auckland University of Technology, and Ghent University ranked the first three most productive universities. The average number of citations received by papers published in RAQ was 34.88± 62.94. The papers published during 2009-2019 covered studies on 15 aquatic animal groups but no papers have been published on cods, eels, haddock, hake, halibut, and sea bass. The papers were mostly devoted to shrimps followed by salmon. In total, this article gives a comprehensive snapshot of the journal through learning which publications are most influential, and also future authors and readers of the journal will know whom and what subject they should explore and undergo.

Keywords: Aquaculture; Bibliometric; Shrimp; Fish; Bradford model; Subramanyam's degree

1. Introduction

Aquaculture is the fastest growing food producing sector in the world, and through the wide range of protein-rich products such as fish and shrimp, it plays an important role in providing the food resources needed by human societies [1-4]. It is also make major efforts for economic development by providing food security through primary production, improving revenues, creating employment opportunities and generating significant export earnings [5-7]. Currently, many studies have been conducted around this concept on various topics and different aquatic species. One of the common signs of the development of a field is a journal, which shows the coherence of the authors and the topics surrounding a new area of study [8]. In addition, we can start weaving disciplinary history by examining the evolution of key journals in a specialized field. Reviews in Aquaculture (RAQ) is one of the world-leading international peer-reviewed scientific journal in the field of aquaculture which

published by Wiley. RAQ started publishing in 2009 and has become a key academic outlet over the years. Professor Sena S. De Silva from the Deakin University and Professor Albert G.J. Tacon from the Universidad Tecnológica del Mar de Tamaulipas Bicentenario are the current editors of the journal. The main goal of RAQ is to provide a forum of reviews on developments in aquaculture techniques, policies and planning. The journal publishes fully peer-reviewed review papers on all aspects of the aquaculture, including, for instance, trends in production and marketing, technological developments in aquaculture, interactions between aquaculture and environment, developments in feeds and feeding, genetics, health management in aquaculture, native and alien species, policy developments relating to aquaculture and socio-economics impacts. RAQ ranked 1 out of 52 in the subject category of ''Fisheries'' according to the Thomson Reuters Journal Citation Reports (JCR) with an impact factor of 7.190 in 2019, which means that a

citable article published in the last two years has received at least 7.190 citations in 2018. This journal is listed in all major databases, including Science Citation Index Expanded (Clarivate Analytics), SCOPUS (Elsevier), Veterinary Bulletin (CABI) and Web of Science (Clarivate Analytics). In 2019, RAQ celebrated its tenth anniversary. This turning point encouraged an interest in conducting a general bibliometric analysis of the main trends in the journal during this period. Organizing a special activity is very common when a journal is celebrating its anniversary, including an editorial [9], a special issue [10] or a review [11]. An interesting review that often take place at an anniversary event is a bibliometric overview of the journal. The most important advantage of this approach is the development of a retrospective evaluation that identifies past and present trends of the journal [12]. Bibliometric is the field of research in the library and information sciences that uses quantitative methods to study bibliographic material [13]. Over the years, bibliometric has become very popular for classifying bibliography and developing representative summaries of outstanding results. A few decades ago, much time was required for data classification because the process of gathering information was manually [14].However, today, thanks to the dramatic improvement of computers and the internet over the years, it is very easy to analyze this data [15]. In the literature, there are many bibliometric studies on a variety of subjects, including topics [16], journals [9], universities [17] and countries [18]. There have been limited bibliometric analyses in the field of aquaculture, including the studies by Natale, et al. [19] of mapping the research on aquaculture, by Jarić, et al. [20] of the patterns and trends in fisheries science from 2000 to 2009 and by Guo, et al. [21] of the oyster research from 1991 to 2014. As the first retrospection of RAQ's content during 2009-2019, our study presents insights that may be useful for RAQ's editorial board to craft the future policy and strategy of the journal. This study primarily serves two different group of audiences. First, the current authors and readers of RAQ. Second, the prospective authors and readers of the journal i.e., scholars in the aquaculture discipline, the potential contributors to the journal. For the first group, the article is informative as it provides which subareas of aquaculture are on the rise and which are declining. Therefore, this study aimed to provides a bibliometric analysis of RAQ, focusing on (1) the publication trends of the journal articles during 2009-2019; (2) the dynamics and trends of the research literature production, and (3) the more prolific authors, institutions and countries. We also highlight the major themes discussed in RAQ and visualized the content of published articles. In total, this article gives a comprehensive snapshot of the journal through learning which publications are most influential, and also future authors and readers of the journal will know whom and what subject they should explore in deciding which research projects they should undergo.

2. Materials and Methods

2.1. Data collection

RAQ has been launched at 2009. Free access to some earlier issues is available from the Wiley Online Library. Volumes 1-11 were considered for this study. For each paper, the details including the paper title, journal name, author names, publication year, volume/issue, pages and abstract were downloaded and saved in the EndNote format. Accordingly, information on number of authors, first author affiliations (institute and country) and number of citations were extracted online from the journal webpage and citation counts were retrieved from the Google Scholar. In the case of multiple affiliation of the first author, the first mentioned one was used for the analyses. Editorials and Chinese abstracts were not included in the database.

2.2. Metrics

The bibliometric indicators fall into four categories including productivity, authorship, citation and topic analysis. The number of published papers, country and institute productivity, the Lotka equation [22] and the Bradford model [22] were used to assess the productivity status of the journal/contributors. The authorship trends were evaluated by comparing annual mean number of authors per paper, the Subramanyam's degree of collaboration [23] and collaborative percentage [22]. Also, the visualization of similarities (VOS) approach was used to assess the present the link map of all authors. The VOS is an ordination method which allocates samples in such a way that their relatedness is presented as accurately as possible. The largest set of connected items was allowed for each case. VOSviewer® was used for mapping data. Citation metrics consisted of number of citations received by 2019, the Normalized Citation Impact Index (NCII= Total citation per referenced publication/ Publication Longevity), the immediacy index (number of citations received at the first year of publication, [22]), the research potential realized (ratio of cited articles [24]), and the corrected quality ratio [25]. The corrected quality ratio (CQ) was calculated as follows:

$$CQ = (\frac{C^3}{P})^{\frac{1}{2}}$$

where
C = total citations (on annual basis)
P = total number of papers (on annual basis)
Two approached were used for topic analysis of papers including the predetermined topic search and the text mining approach. Selections of research topics and study animals followed [19]. In doing so, 22 target species and 6 topic categories were considered. Simultaneous abstract and title analyses was performed for text mining. The binary counting method (i.e., presence/absence) was applied and 60% of the most relevant items were used to produce maps.

2.3. Data analyses

One-way ANOVA was used to analyze citation metrics (i.e. mean total citations, corrected quality

ratio, and NCII). Data were log(x+1) transformed to meet the assumptions of normality. Temporal trends in mean number of authors per paper was analyzed by performing Kruskal-Wallis test followed by the Dunn-Bonferroni post hoc method. The topic analysis was performed by applying single-linkage clustering method. The association strength was used as similarity measure and the clustering was performed on the distance matrix.

3. Results

3.1. Productivity

RAQ generally publishes four issues per year. Total number of paper published annually was nearly consistent from 2009-2017 and nearly tripled during 2018 and 2019 (Fig. 1). This was due to higher number of papers published per volume. The SCImago portal lists 65178 documents published during 2016-2018 in the "Aquatic Science" category. Accordingly, the RAQ journal belonged to the zone 3 of the classic 3 zone Bradford model (Fig. 1). The ratio between the number of journals in subsequent zones was found to be 1:3.63:182.90. Authors from 44 countries and 197 institutes contributed (as the first author) to papers published in the journal during 2009-2019. Australia-, Mexico-, and USA-based authors had highest rates of contribution (Fig. 1) and the Wageningen University & Research- the Netherlands, Auckland University of Technology-New Zealand, and Ghent University-Belgium ranked the first three most productive universities.
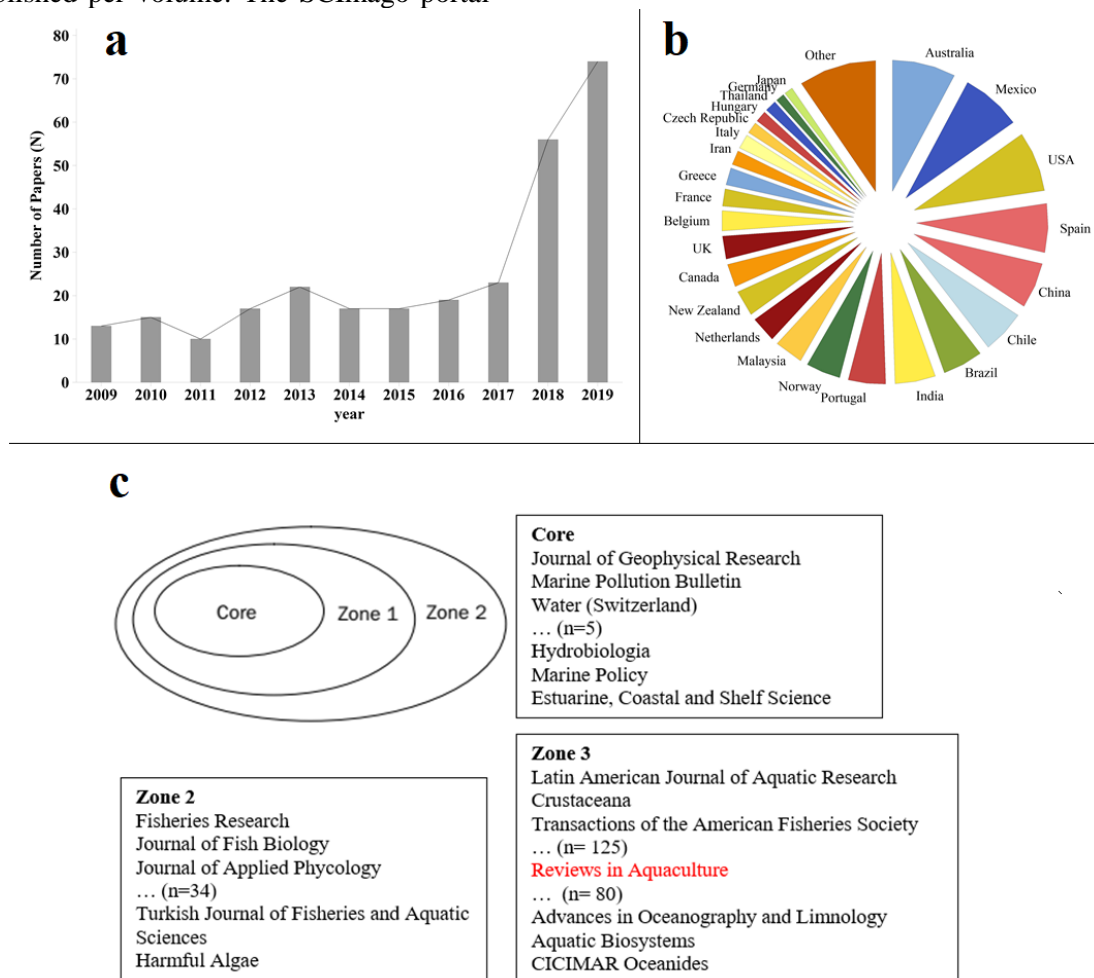

Fig 1. (a) Annual publication counts of *RAQ*, (b) a pie chart of country contribution rates (based on first author nationality), (c) the Bradford zones in the "Aquatic Science" category the SCImago portal

In terms of author productivity, the calculated exponent term in Lotka's author productivity equation was 3.32 and the theoretical equation was found to be:

$$y_x = 0.88x^{3.32}$$

where

$x = number\ of\ papers$

$y_x = number\ authors\ that\ prodice\ x\ papers$

3.2. Authorship

The distribution of number of authors per paper did not follow either Normal (Mean± SD= 4.15± 2.98, KS=0.21, p< 0.01) or Poisson (Median= 4.00, Chi-square=43.48, DF=8, p< 0.0001) distribution patterns. Mean number of authors varied significantly as a factor of year. Highest and lowest number of authors were found during 2013 and 2009, respectively (Fig 2a). Of the 283 articles published during 2009-2019, 24 (~8.5%) were single-authored and the highest ratio of single-authored papers was found in the 2009 volume (Fig. 2b). The increased number of authors during 2013 coincided with international collaboration among authors (expressed as collaborative percentage,

Fig. 3a). A map of all-author connections revealed 16
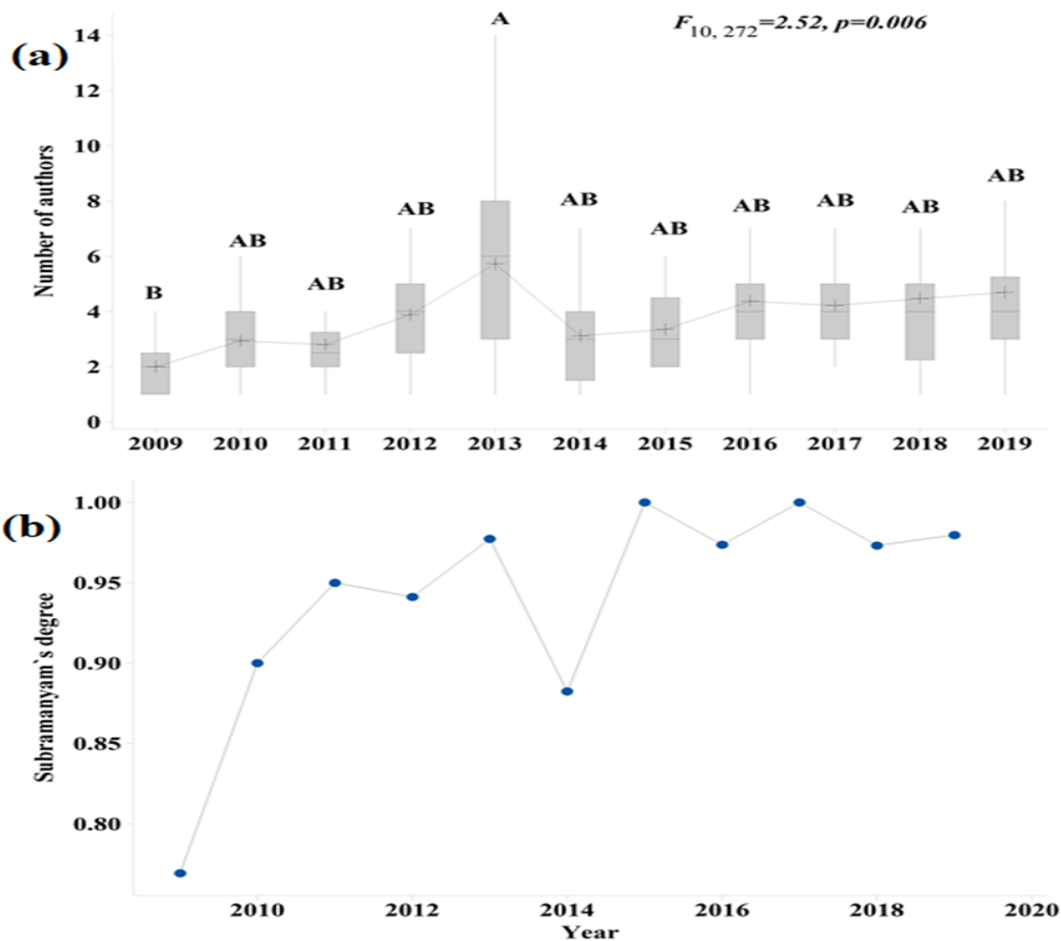clusters of linked authors (Fig. 3b).

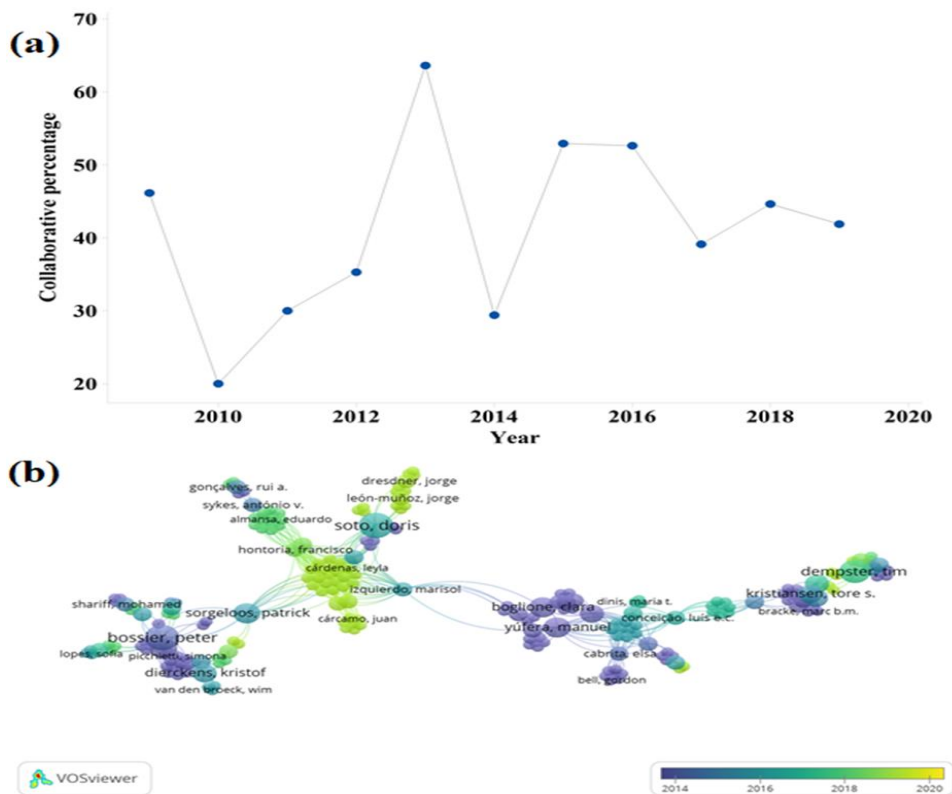**Fig 2. Time period variations in the mean number of authors (a) and Subramanyam's degree (b) in *RAQ*.**

Fig 3. Temporal changes in collaborative percentage contributions to *RAQ* (a) and VOS map of linked authors (d).

3.3. Citation analysis

The average number of citations received by papers published in RAQ was 34.88± 62.94 (mean± SD). Raw number of citations received by papers varied among years and a decreasing trend could be detected (Fig. 4a). Yet, when normalized to the paper age, no significant difference was detected among different volumes ($F_{10, 265}= 1.7$, $p> 0.05$). In average, 21% of papers published from 2009 to 2018, get cited during the first year of their publication with >20% of their total citations gained in the given year. Values of the immediacy index was highest for papers published in the 2015 to 2018 volumes (Fig. 4b). In contrast, the values of research potential realized and the composite indicator showed a decreasing trend (Fig. 4c, d).
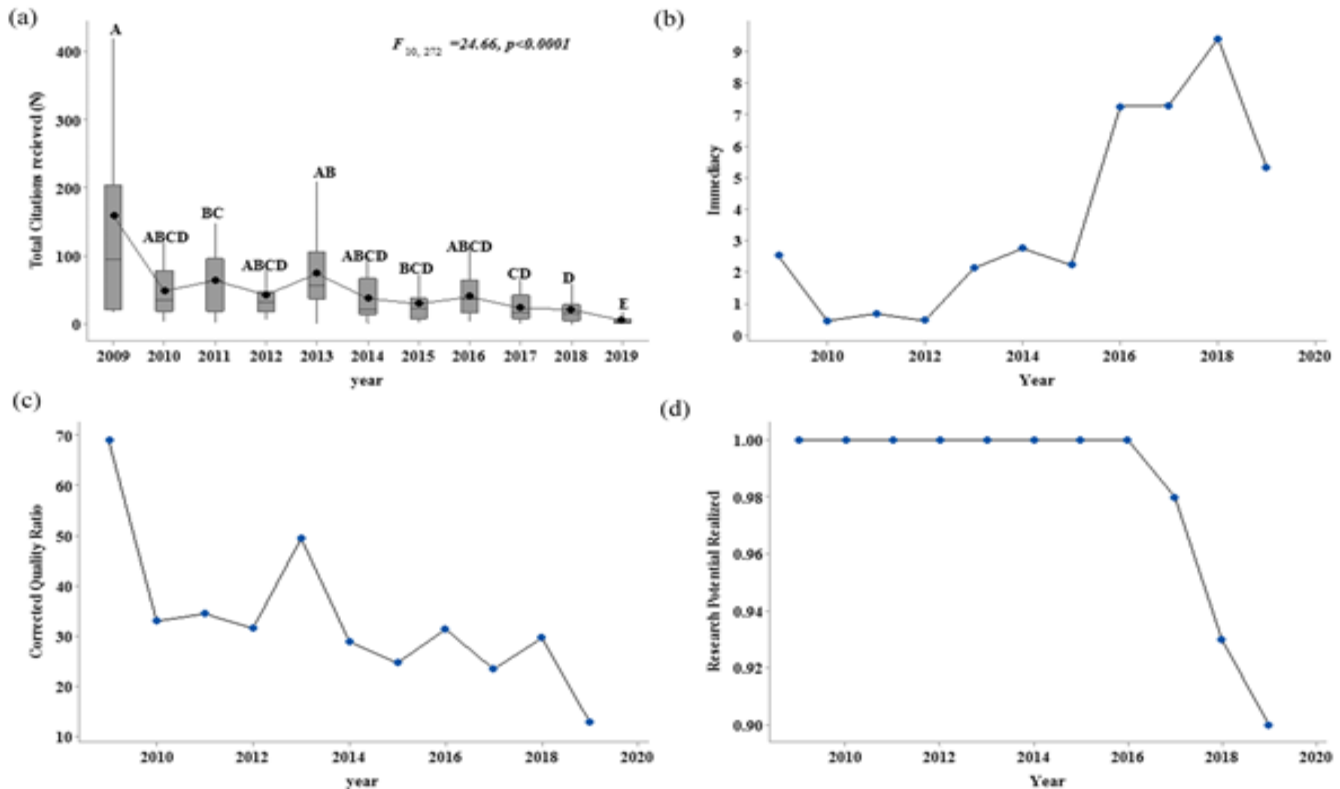

Fig 4. Temporal trends in mean number of citations (a), immediacy (b), quality ratio (c), and research potential realized levels of papers (d) published during 2009-2019 in *RAQ*.

3.4. Content analysis

The papers published in RAQ during 2009-2019 covered studies on 15 aquatic animal groups but no papers have been published on cods, eels, haddock, hake, halibut, and sea bass. The papers were mostly devoted to shrimps followed by salmon (Fig. 5). Nearly, all aspect of shrimp and salmon aquaculture were covered in the journal. The papers on other species were mostly devoted to genetics, reproduction, farming systems, and environmental studies.
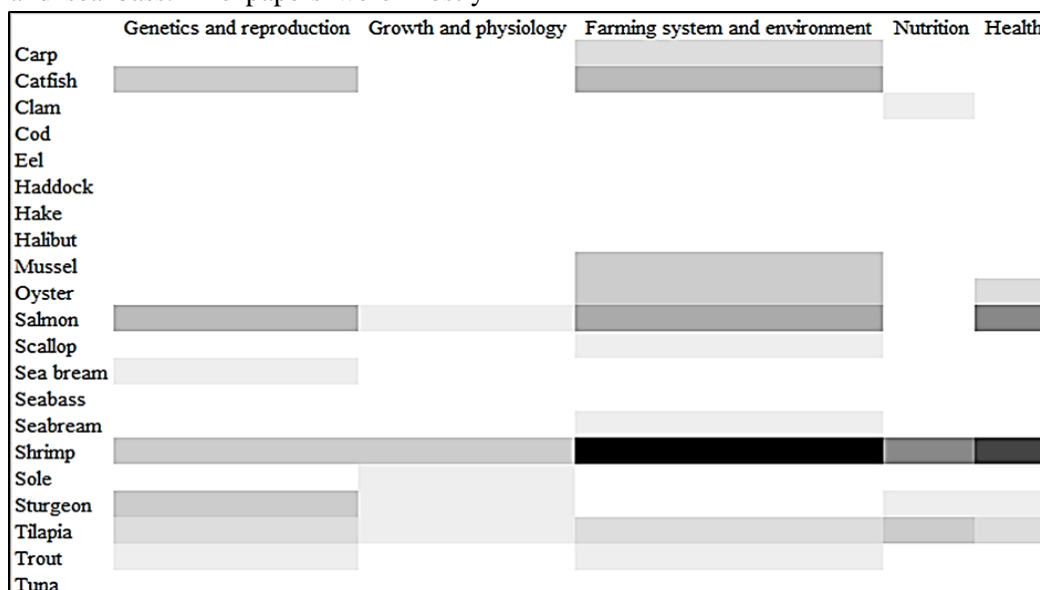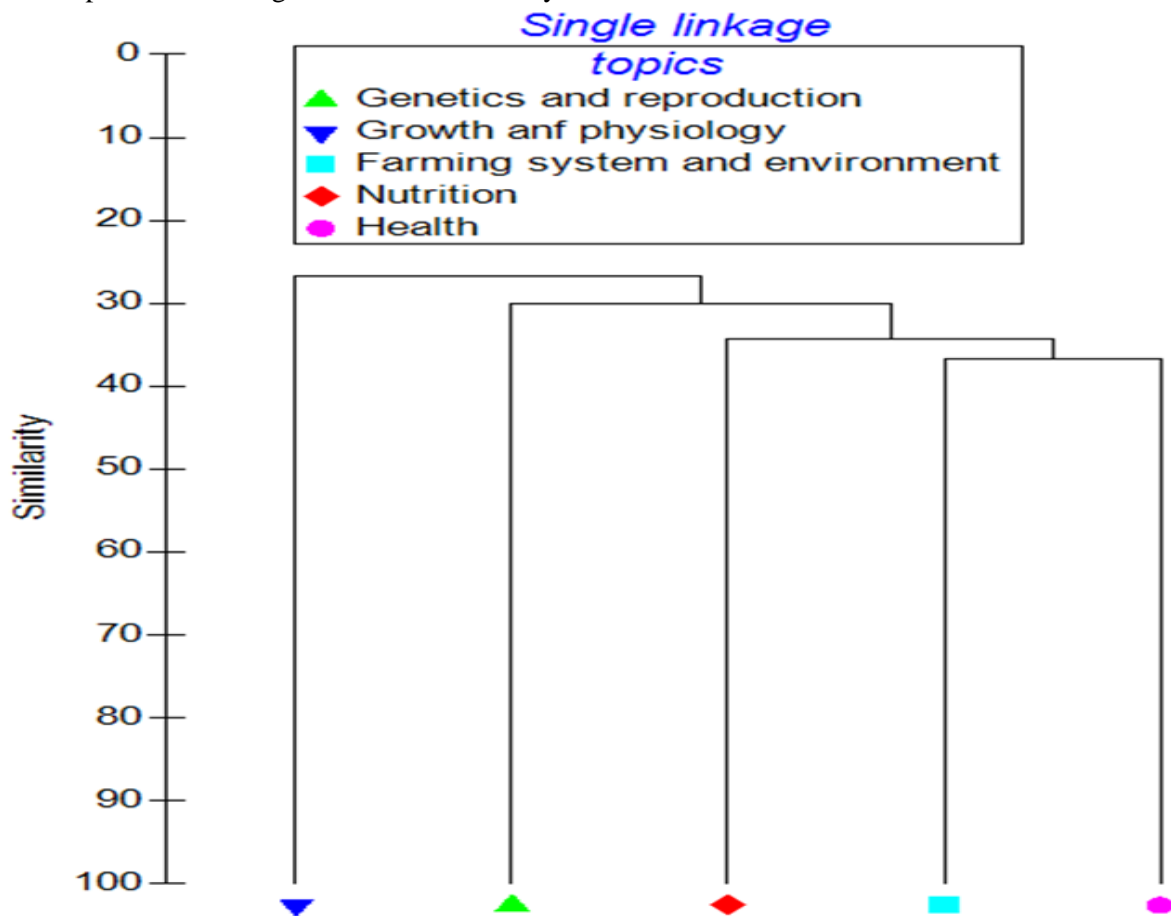
Fig 5. Heat map of topic distribution in papers published during 2009-2019 in *RAQ*. Darker color indicates relevance.

The distribution of general topics was to some extent variable among volumes. The clustering of topic distribution is presented in Fig 6. At 35% similarity level, the growth ad physiology cluster was separated from other topics.

Fig 6. Clustering of study topics according to their distribution in *RAQ* volumes.

The importance of a paper to the development of a field is often assessed by the number of citations that it has attracted, on the basis that subsequent researchers in that field will have cited that paper if, and only if, they found it to be of value in their own research. As for the impact of papers, we calculate the NCII score of each paper, and list the top forty influential papers in Table 1. From the table, we can see that the most influential papers published by authors from different countries mostly Europe (n=20) and Asia (n=10). We can also observe that most papers in top forty are published in 2018 (n=11), whereas only one paper is published in 2015. Turchini, et al. [26] article, titled 'Fish oil replacement in finfish nutrition' is the most influential work, cited 774 times which attracts many following researches. This is followed by Wang, et al. [27] article, accredited with 110 citations which provides an overview of research on fish gut microbiota, including microbial composition,

formation, factors that affect the GI microbes and characteristics of fish intestinal microbiota compared with human and mice. Other influential works include Glencross [28] article, titled 'Exploring the nutritional demand for essential fatty acids by aquaculture species' (NCII: 38.1); Robledo, et al. [29] article, titled 'Applications of genotyping by sequencing in aquaculture breeding and genetics' (NCII: 36.5); and Valladão, et al. [30] article, titled 'South American fish for continental aquaculture' (NCII: 36.0).

Table 1. The 40 most influential papers published in *RAQ*.

Title	First author country	Number of citation	NCII	Reference
Fish oil replacement in finfish nutrition	Australia	774	70.4	[26]
Progress in fish gastrointestinal microbiota research	China	110	55.0	[27]
Exploring the nutritional demand for essential fatty acids by aquaculture species	Australia	419	38.1	[28]
Applications of genotyping by sequencing in aquaculture breeding and genetics	UK	73	36.5	[29]
South American fish for continental aquaculture	Brazil	72	36.0	[30]
Fish larval nutrition and feed formulation: knowledge gaps and bottlenecks for advances in larval rearing	Norway	208	29.7	[31]
Use of lumpfish for sea-lice control in salmon farming: challenges and opportunities	UK	58	29.0	[32]
Feeding behaviour and digestive physiology in larval fish: current knowledge, and gaps and bottlenecks in research	Norway	202	28.9	[33]
Probiotic, prebiotic and synbiotic supplements in sturgeon aquaculture: a review	Iran	109	27.3	[34]
New developments and biological insights into the farming of *Solea senegalensis* reinforcing its aquaculture potential	Spain	100	25.0	[35]
Tilapia lake virus: a threat to the global tilapia industry?	Norway	25	25.0	[36]
Skeletal anomalies in reared European fish larvae and juveniles. Part 2: main typologies, occurrences and causative factors	Italy	174	24.9	[37]
Probiotic application for sustainable aquaculture	Egypt	23	23.0	[38]
Global aquaculture and its role in sustainable development	Italy	248	22.5	[7]
Salmon lice treatments and salmon mortality in Norwegian aquaculture: a review	Norway	22	22.0	[39]
Selection response in fish and shellfish: a review	Norway	43	21.5	[40]
The utilization and mode of action of organic acids in the feeds of cultured aquatic animals	Malaysia	64	21.3	[41]
Coping styles in farmed fish: consequences for aquaculture	Portugal	62	20.7	[42]
Application of zeolites in aquaculture industry: a review	Canada	41	20.5	[43]
Mineral requirements of fish: a systematic review	France	79	19.8	[44]
Showcasing metabolomic applications in aquaculture: a review	New Zealand	38	19.0	[45]
The ecosystem approach to aquaculture 10 years on – a critical review and consideration of its future role in blue growth	UK	19	19.0	[46]
Microbial-based systems for aquaculture of fish and shrimp: an updated review	Mexico	94	18.8	[47]
A review of the nutrition and feeding management of farmed tilapia throughout the culture cycle	Malaysia	127	18.1	[48]
A revisit to fishmeal usage and associated consequences in Chinese aquaculture	China	36	18.0	[49]
Astaxanthin as feed supplement in aquatic animals	Malaysia	35	17.5	[50]
Open-water integrated multi-trophic aquaculture: environmental biomitigation and economic diversification of fed aquaculture by extractive aquaculture	Canada	137	17.1	[51]
Ocean acidification and marine aquaculture in North America: potential impacts and mitigation strategies	Canada	51	17.0	[52]
Application of herbal anaesthetics in aquaculture	Iran	17	17.0	[53]

Significance of microalgal–bacterial interactions for aquaculture	Malaysia	99	16.5	[54]
Is integrated multitrophic aquaculture the solution to the sectors' major challenges? – a review	Portugal	66	16.5	[55]
Application of phytochemicals as immunostimulant, antipathogenic and antistress agents in finfish culture	Hungary	147	16.3	[56]
Physiological change and nutritional requirement of Pacific white shrimp Litopenaeus vannamei at low salinity	China	49	16.3	[57]
Application of machine vision systems in aquaculture with emphasis on fish: state-of-the-art and key issues	Czech Republic	49	16.3	[58]
Gamete quality and broodstock management in temperate fish	Scotland	113	16.1	[59]
A review on fish growth calculation: multiple functions in fish production and their specific application	Germany	64	16.0	[60]
Cryopreservation and vitrification of fish semen: a review with special emphasis on marine species	Brazil	32	16.0	[61]
Use of chemicals and biological products in Asian aquaculture and their potential environmental risks: a critical review	Netherlands	126	15.8	[62]
Vitamin C supplementation to optimize growth, health and stress resistance in aquatic animals	Japan	31	15.5	[63]
Probiotics in aquaculture: a current assessment	Spain	92	15.3	[64]

Using VOSviewer, we further analyzed the bibliographic data. The map presented in Fig. 7 shows the most frequent title+ abstract word clusters of papers published in RAQ during 2009-2019. The most pronounced title and/or abstract terms were 'breeding', 'rearing', 'expression', 'sale', 'weight', and 'marker'.
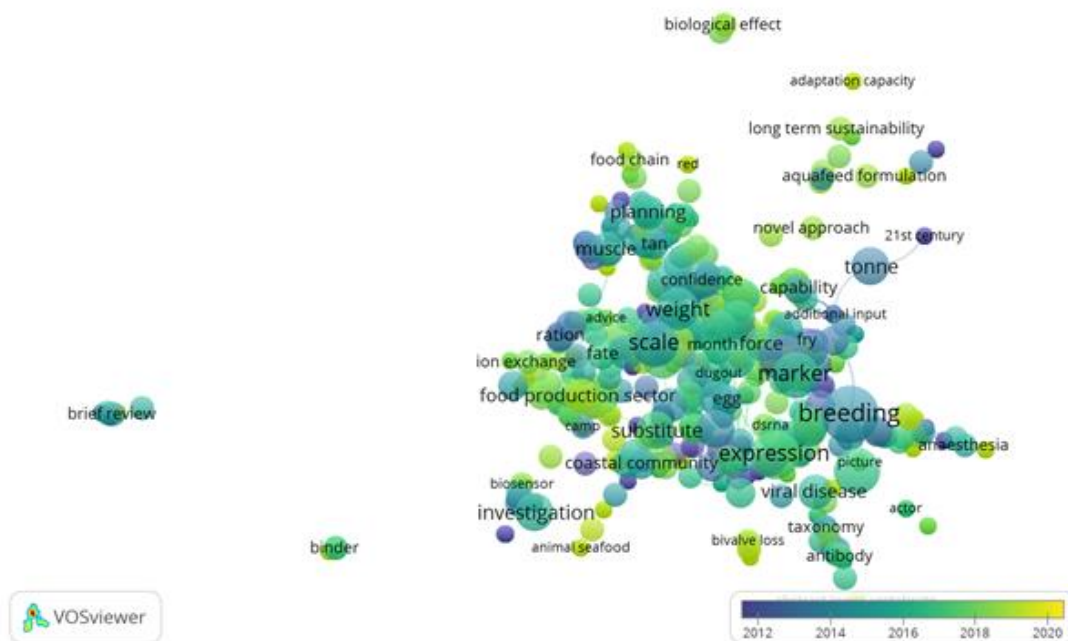

Fig 7. Topic relevance in abstract and titles of papers published in *RAQ* during 2009-2019.

Among the most 60% relevant terms, the largest set of connected items consisted of 69 clusters of items. The first 15 clusters mainly included words about reproduction, disease, and growth (Table 2).

Table 2. Clustering of the most relevant terms in *RAQ* papers (abstract and title). The values in bracket indicate total link strength.

Cluster	Items
1	Controlled condition(102), Sturgeon(99), gonad(70)
2	Viral disease(50), antibody(47), diagnostic(46)
3	Fish spermatozoa(87), nitrite(59), fate(59)

4	Initiation(104), boom(58), bottom(50)
5	Weight(147), platform(70), shrimp pond(67)
6	Biomass yield(83), bioremediation(83), total ammonia nitrogen(83)
7	Salmon industry(95), percentage(66), chemotherap-(53)
8	Female(76), phylogeny(76), fatty acid(66)
9	Gomperts(71), logistic(71), growth model(69)
10	Biomass production(99), multitrophic aquaculture(73), removal efficiency(71)
11	Matter(106), natural ecosystem(57), trophic level(57)
12	Cryopreservation(103), spermatozoa(102), motility(102)
13	Revenue(80), total cost(60), bio-economic analysis(52)
14	Interview(80), water treatment(67), vibrio(65)
15	Damage(82), marine organism(59), methanol(58)

4. Summary and conclusion

In 2019, *RAQ* has celebrated its tenth anniversary. Motivated by this event, this study presents a bibliometric overview of the leading trends that have occurred in the journal during this period of time. In addition to productivity, the journal shows growth in its influence as an important outlet on aquaculture research. In average, 21% of papers published from 2009 to 2018, get cited during the first year of their publication with >20% of their total citations gained in the given year. The papers were mostly devoted to shrimps followed by salmon. Nearly, all aspect of shrimp and salmon aquaculture were covered in the journal. The papers on other species were mostly devoted to genetics, reproduction, farming systems, and environmental studies. In addition, Australia-, Mexico-, and USA-based authors had highest rates of contribution and the Wageningen University & Research- the Netherlands, Auckland University of Technology-New Zealand, and Ghent University- Belgium ranked the first three most productive universities. Furthermore, the most influential papers published by authors from different countries mostly from Europe and Asia.

In conclusion, the past 10 years of *RAQ* have positioned it as a distinct, reputed, and trusted academic journal in aquaculture research frequently pursued for its academic excellence involving topics. The increase in publications and citations indicates *RAQ's* growing stature as a key academic outlet advancing knowledge in multiple terms in aquaculture including reproduction, disease, and growth. The papers covered studies on 15 aquatic animal groups but no papers have been published on cods, eels, haddock, hake, halibut, and sea bass. However, encourage researchers to submit and publish their articles on other species cods, eels, haddock, hake, halibut, and sea bass may fortify *RAQ* as the focal point of aquaculture research in future studies.

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References

1. Khanjani, M.H., Alizadeh, M., and Sharifinia, M. (2020). Rearing of the Pacific white shrimp, Litopenaeus vannamei in a biofloc system: The effects of different food sources and salinity levels. Aquaculture Nutrition 26, 328-337.

2. Khanjani, M.H., Sharifinia, M., and Hajirezaee, S. (2020). Effects of different salinity levels on water quality, growth performance and body composition of Pacific white shrimp (Litopenaeus vannamei Boone, 1931) cultured in a zero water exchange heterotrophic system. Annals of Animal Science, https://doi.org/10.2478/aoas-2020-0036.

3. Galappaththi, E.K., Ichien, S.T., Hyman, A.A., Aubrac, C.J., and Ford, J.D. (2020). Climate change adaptation in aquaculture. Reviews in Aquaculture, https://doi.org/10.1111/raq.12427.

4. Yeganeh, V., Sharifinia, M., Mobaraki, S., Dashtiannasab, A., Aeinjamshid, K., Borazjani, J.M., and Maghsoudloo, T. (2020). Survey of survival rate and histological alterations of gills and hepatopancreas of the Litopenaeus vannamei juveniles caused by exposure of Margalefidinium / Cochlodinium polykrikoides isolated from the Persian Gulf. Harmful Algae 97, 101856.

5. Khanjani, M., and Sharifinia, M. (2020). Biofloc technology as a promising tool to improve aquaculture production. Reviews in Aquaculture. https://doi.org/10.1111/raq.12412.

6. Rimmer, M.A., Sugama, K., Rakhmawati, D., Rofiq, R., and Habgood, R.H. (2013). A review and SWOT analysis of aquaculture development in Indonesia. Reviews in Aquaculture 5, 255-279.

7. Subasinghe, R., Soto, D., and Jia, J. (2009). Global aquaculture and its role in sustainable development. Reviews in Aquaculture 1, 2-9.

8. Sugimoto, C.R., and Weingart, S. (2015). The kaleidoscope of disciplinarity. Journal of Documentation.

9. Cancino, C., Merigó, J.M., Coronado, F., Dessouky, Y., and Dessouky, M. (2017). Forty years of Computers & Industrial Engineering: A bibliometric analysis. Computers & Industrial Engineering 113, 614-629.

10. Meyer, R., and Winer, R.S. (2014). Introduction to the JMR 50th anniversary special section. Journal of Marketing Research 51, 83-83.

11. Donthu, N., Kumar, S., and Pattnaik, D. (2020). Forty-five years of Journal of Business Research: A bibliometric analysis. Journal of Business Research 109, 1-14.

- 12. Schwert, G.W. (1993). The journal of financial economics: A retrospective evaluation (1974–1991). Journal of Financial Economics 33, 369-424.
- 13. Broadus, R.N. (1987). Toward a definition of "bibliometrics". Scientometrics 12, 373-379.
- 14. Ding, Y., Rousseau, R., and Wolfram, D. (2016). Measuring scholarly impact, (Springer).
- 15. Merigó, J.M., Gil-Lafuente, A.M., and Yager, R.R. (2015). An overview of fuzzy research with bibliometric indicators. Applied Soft Computing 27, 420-433.
- 16. Yu, D. (2015). A scientometrics review on aggregation operator research. Scientometrics 105, 115-133.
- 17. Merigó, J.M., Muller, C., Modak, N.M., and Laengle, S. (2019). Research in production and operations management: A university-based bibliometric analysis. Global Journal of Flexible Systems Management 20, 1-29.
- 18. Baccini, A., De Nicolao, G., and Petrovich, E. (2019). Citation gaming induced by bibliometric evaluation: A country-level comparative analysis. PLoS One 14, e0221212.
- 19. Natale, F., Fiore, G., and Hofherr, J. (2012). Mapping the research on aquaculture. A bibliometric analysis of aquaculture literature. Scientometrics 90, 983-999.
- 20. Jarić, I., Cvijanović, G., Knežević-Jarić, J., and Lenhardt, M. (2012). Trends in fisheries science from 2000 to 2009: a bibliometric study. Reviews in Fisheries Science 20, 70-79.
- 21. Guo, L., Xu, F., Feng, Z., and Zhang, G. (2016). A bibliometric analysis of oyster research from 1991 to 2014. Aquaculture international 24, 327-344.
- 22. Andrés, A. (2009). Measuring academic research: How to undertake a bibliometric study, (Elsevier).
- 23. Subramanyam, K. (1983). Bibliometric studies of research collaboration: A review. Journal of information Science 6, 33-38.
- 24. Raisig, L.M. (1960). Mathematical Evaluation of the Scientific Serial. Science 131, 1417-1419.
- 25. Prathap, G. (2010). Going much beyond the Durfee square: enhancing the h T index. Scientometrics 84, 149-152.
- 26. Turchini, G.M., Torstensen, B.E., and Ng, W.K. (2009). Fish oil replacement in finfish nutrition. Reviews in Aquaculture 1, 10-57.
- 27. Wang, A.R., Ran, C., Ringø, E., and Zhou, Z.G. (2018). Progress in fish gastrointestinal microbiota research. Reviews in Aquaculture 10, 626-640.
- 28. Glencross, B.D. (2009). Exploring the nutritional demand for essential fatty acids by aquaculture species. Reviews in Aquaculture 1, 71-124.
- 29. Robledo, D., Palaiokostas, C., Bargelloni, L., Martínez, P., and Houston, R. (2018). Applications of genotyping by sequencing in aquaculture breeding and genetics. Reviews in Aquaculture 10, 670-682.
- 30. Valladão, G.M.R., Gallani, S.U., and Pilarski, F. (2018). South American fish for continental aquaculture. Reviews in Aquaculture 10, 351-369.
- 31. Hamre, K., Yúfera, M., Rønnestad, I., Boglione, C., Conceição, L.E., and Izquierdo, M. (2013). Fish larval nutrition and feed formulation: knowledge gaps and bottlenecks for advances in larval rearing. Reviews in Aquaculture 5, S26-S58.
- 32. Powell, A., Treasurer, J.W., Pooley, C.L., Keay, A.J., Lloyd, R., Imsland, A.K., and Garcia de Leaniz, C. (2018). Use of lumpfish for sea-lice control in salmon farming: Challenges and opportunities. Reviews in aquaculture 10, 683-702.
- 33. Rønnestad, I., Yúfera, M., Ueberschär, B., Ribeiro, L., Sæle, Ø., and Boglione, C. (2013). Feeding behaviour and digestive physiology in larval fish: current knowledge, and gaps and bottlenecks in research. Reviews in Aquaculture 5, S59-S98.
- 34. Hoseinifar, S.H., Ringø, E., Shenavar Masouleh, A., and Esteban, M.Á. (2016). Probiotic, prebiotic and synbiotic supplements in sturgeon aquaculture: a review. Reviews in Aquaculture 8, 89-102.
- 35. Morais, S., Aragão, C., Cabrita, E., Conceição, L.E., Constenla, M., Costas, B., Dias, J., Duncan, N., Engrola, S., and Estevez, A. (2016). New developments and biological insights into the farming of Solea senegalensis reinforcing its aquaculture potential. Reviews in Aquaculture 8, 227-263.
- 36. Jansen, M.D., Dong, H.T., and Mohan, C.V. (2019). Tilapia lake virus: a threat to the global tilapia industry? Reviews in Aquaculture 11, 725-739.
- 37. Boglione, C., Gisbert, E., Gavaia, P., E. Witten, P., Moren, M., Fontagné, S., and Koumoundouros, G. (2013). Skeletal anomalies in reared E uropean fish larvae and juveniles. Part 2: main typologies, occurrences and causative factors. Reviews in Aquaculture 5, S121-S167.
- 38. Dawood, M.A.O., Koshio, S., Abdel-Daim, M.M., and Van Doan, H. (2019). Probiotic application for sustainable aquaculture. Reviews in Aquaculture 11, 907-924.
- 39. Overton, K., Dempster, T., Oppedal, F., Kristiansen, T.S., Gismervik, K., and Stien, L.H. (2019). Salmon lice treatments and salmon mortality in Norwegian aquaculture: a review. Reviews in Aquaculture 11, 1398-1417.
- 40. Gjedrem, T., and Rye, M. (2018). Selection response in fish and shellfish: a review. Reviews in Aquaculture 10, 168-179.
- 41. Ng, W.K., and Koh, C.B. (2017). The utilization and mode of action of organic acids in the feeds of cultured aquatic animals. Reviews in Aquaculture 9, 342-368.
- 42. Castanheira, M.F., Conceição, L.E., Millot, S., Rey, S., Bégout, M.L., Damsgård, B., Kristiansen, T., Höglund, E., Øverli, Ø., and Martins, C.I. (2017).

Coping styles in farmed fish: consequences for aquaculture. Reviews in Aquaculture 9, 23-41.

- 43. Ghasemi, Z., Sourinejad, I., Kazemian, H., and Rohani, S. (2018). Application of zeolites in aquaculture industry: a review. Reviews in Aquaculture 10, 75-95.

- 44. Antony Jesu Prabhu, P., Schrama, J.W., and Kaushik, S.J. (2016). Mineral requirements of fish: a systematic review. Reviews in Aquaculture 8, 172-219.

- 45. Alfaro, A.C., and Young, T. (2018). Showcasing metabolomic applications in aquaculture: a review. Reviews in Aquaculture 10, 135-152.

- 46. Brugère, C., Aguilar-Manjarrez, J., Beveridge, M.C., and Soto, D. (2019). The ecosystem approach to aquaculture 10 years on–a critical review and consideration of its future role in blue growth. Reviews in Aquaculture 11, 493-514.

- 47. Martínez-Córdova, L.R., Emerenciano, M., Miranda-Baeza, A., and Martínez-Porchas, M. (2015). Microbial-based systems for aquaculture of fish and shrimp: an updated review. Reviews in Aquaculture 7, 131-148.

- 48. Ng, W.K., and Romano, N. (2013). A review of the nutrition and feeding management of farmed tilapia throughout the culture cycle. Reviews in Aquaculture 5, 220-254.

- 49. Han, D., Shan, X., Zhang, W., Chen, Y., Wang, Q., Li, Z., Zhang, G., Xu, P., Li, J., and Xie, S. (2018). A revisit to fishmeal usage and associated consequences in Chinese aquaculture. Reviews in Aquaculture 10, 493-507.

- 50. Lim, K.C., Yusoff, F.M., Shariff, M., and Kamarudin, M.S. (2018). Astaxanthin as feed supplement in aquatic animals. Reviews in Aquaculture 10, 738-773.

- 51. Chopin, T., Cooper, J.A., Reid, G., Cross, S., and Moore, C. (2012). Open-water integrated multi-trophic aquaculture: environmental biomitigation and economic diversification of fed aquaculture by extractive aquaculture. Reviews in Aquaculture 4, 209-220.

- 52. Clements, J.C., and Chopin, T. (2017). Ocean acidification and marine aquaculture in North America: potential impacts and mitigation strategies. Reviews in Aquaculture 9, 326-341.

- 53. Hoseini, S.M., Taheri Mirghaed, A., and Yousefi, M. (2019). Application of herbal anaesthetics in aquaculture. Reviews in Aquaculture 11, 550-564.

- 54. Natrah, F.M., Bossier, P., Sorgeloos, P., Yusoff, F.M., and Defoirdt, T. (2014). Significance of microalgal–bacterial interactions for aquaculture. Reviews in Aquaculture 6, 48-61.

- 55. Granada, L., Sousa, N., Lopes, S., and Lemos, M.F. (2016). Is integrated multitrophic aquaculture the solution to the sectors' major challenges? a review. Reviews in Aquaculture 8, 283-300.

- 56. Chakraborty, S.B., and Hancz, C. (2011). Application of phytochemicals as immunostimulant, antipathogenic and antistress agents in finfish culture. Reviews in Aquaculture 3, 103-119.

- 57. Li, E., Wang, X., Chen, K., Xu, C., Qin, J.G., and Chen, L. (2017). Physiological change and nutritional requirement of Pacific white shrimp Litopenaeus vannamei at low salinity. Reviews in Aquaculture 9, 57-75.

- 58. Saberioon, M., Gholizadeh, A., Cisar, P., Pautsina, A., and Urban, J. (2017). Application of machine vision systems in aquaculture with emphasis on fish: state-of-the-art and key issues. Reviews in Aquaculture 9, 369-387.

- 59. Migaud, H., Bell, G., Cabrita, E., McAndrew, B., Davie, A., Bobe, J., Herraez, M.P., and Carrillo, M. (2013). Gamete quality and broodstock management in temperate fish. Reviews in Aquaculture 5, S194-S223.

- 60. Lugert, V., Thaller, G., Tetens, J., Schulz, C., and Krieter, J. (2016). A review on fish growth calculation: multiple functions in fish production and their specific application. Reviews in Aquaculture 8, 30-42.

- 61. Magnotti, C., Cerqueira, V., Lee-Estevez, M., Farias, J.G., Valdebenito, I., and Figueroa, E. (2018). Cryopreservation and vitrification of fish semen: a review with special emphasis on marine species. Reviews in Aquaculture 10, 15-25.

- 62. Rico, A., Satapornvanit, K., Haque, M.M., Min, J., Nguyen, P.T., Telfer, T.C., and Van Den Brink, P.J. (2012). Use of chemicals and biological products in Asian aquaculture and their potential environmental risks: a critical review. Reviews in Aquaculture 4, 75-93.

- 63. Dawood, M.A., and Koshio, S. (2018). Vitamin C supplementation to optimize growth, health and stress resistance in aquatic animals. Reviews in Aquaculture 10, 334-350.

- 64. Pérez-Sánchez, T., Ruiz-Zarzuela, I., de Blas, I., and Balcázar, J.L. (2014). Probiotics in aquaculture: a current assessment. Reviews in Aquaculture 6, 133-146.