A Global Perspective of Vibrio Species and Associated Diseases: Three-Decade Meta-Synthesis of Research Advancement

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A Global Perspective of *Vibrio* Species and Associated Diseases: Three-Decade Meta-Synthesis of Research Advancement

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ABSTRACT: Outbreaks of *Vibrio* infections have a long history of global public health concern and threat to the aquaculture industry. This 3-decade (1990-2019) meta-synthesis of global research progress in *Vibrio* species and associated disease outbreaks was undertaken to generate the knowledge needed to design effective interventions with policy implications. Using PRISMA protocol, we obtained data on the online version of the Institute for Scientific Information (ISI), Web of Science (WOS), and Scopus from January 1990 to September 2021 by title search of the keywords "*Vibrio* species OR *Vibrio* spp. OR vibriosis." On the 3-decade survey, the result has shown that a total of 776 publications document types were published on the subject, with an average of 24.25 ± 13.6 published documents per year with an annual growth rate of 4.71%. The year 2020 recorded the highest output of 52 published documents accounting for 6.70% of the total. The most prolific author, Blanch A., published 12 articles on the subject and has received citations of 1003 with an h-index of 10. While the most global cited paper author is the journal of J. Bacteriol (Bassler et al), receiving total citation (TC) (550) and per Year (22). The top active corresponding authors country is the United States of America with (92) articles, freq. 12.40%; TC of 3103. The observations in this study, such as the collaborations network map, and index, which have outlined a big difference between countries based on economic status, have underscored the need for a sustained research mentorship program that can define future policies.

KEYWORDS: Global perspective, ***Vibrio*** species, meta-synthesis

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Introduction

The members of the *Vibrio* genus are spread worldwide, being autochthonous in marine, coastal, and riverine environments.[1,2] Some *Vibrio* species (*Vibrio* spp.) are potentially pathogenic and lives freely in the surface waters. Ample studies have been done on *Vibrio* cholerae, the etiologic agent of cholera.[3-6] There is scanty information on other human pathogenic *Vibrio* spp., including the emerging vibriosis of economic importance such as those caused by *Vibrio fluvialis* and *Vibrio mimicus*.[3,7-9] Human pathogenic *Vibrio* cause: foodborne illness, outbreaks, watery diarrheal, gastro-intestinal disease, septicemia, and wound infections.[6,10] These are usually associated with the use of contaminated water, and eating contaminated undercooked seafood. *Vibrio* spp., are Gram-negative, comma-shaped bacteria that occur naturally in the aquatic environment, and they possess a single polar flagellum for motility.[11,12] In water, their abundance is associated with temperature, salinity, the concentration of organic matter and the presence of zooplankton,[3,13,14] which enable the genus to survive in both culturable and non-culturable[15,16] form. Most *Vibrio* infections occur during the summer and decline during winter. Hygiene and water quality are positive contributing factors to the public health burden of vibriosis.[14,17-19] *Vibrio* was first reported in 1718 by Colwell and Grimes 1984.[20] It was reported as *Vibrio* infection in fishes by Canestrini 1893. It became a threat to fish farming in North America, Europe, and Japan.[21] Infections by *Vibrio* spp., are named after their discoveries (winter ulcer disease caused by *V. viscosus* named after *moritella viscosa*, *Vibrio wodanis* named after *aliivibrio* wodanis). Investigations have implicated dozens of *Vibrio* genera in human disease conditions.[19,22,23] The human pathogenic *Vibrio* spp. of clinical relevance include *Vibrio* (V.) parahaemolyticus, V. cholerae, *Vibrio* vulnificus, V. tubiashi, and V. fluvial, which are transmitted via contaminated water and seafood. Also, V. parahaemolyticus, V. vulnificus, and V. mimicus are foodborne pathogens.[24] The halophilic, V. alginolyticus, V. fluvialis, and V. metschnikovii are human pathogenic,[19] while V. anguillarum, parahaemolyticus, *alginolyticus*, *vulnificus*, *harveyi*, and others are also potentially pathogenic to aquatic animals.[19,23,25] Over 100 species of the *Vibrio* genus have been found in surface waters, estuarine, and marine bodies, with the unending list due to discovering new potential pathogenic species.[2,26,27] Among the health conditions associated with human pathogenic *Vibrio* spp. of significant health concern is cholera infection characterized by painless watery diarrhea and vomiting.[28,29] World Health Organization (WHO) classified 51 countries endemic to cholera in 2017. About 1.4 to 4.3 million cholera cases occur worldwide every year, with a mortality rate ranging from 28 000 to 142 000. Low and middle income countries share an enormous two-thirds volume. Sub-Saharan Africa is one endemic region with sporadic high mortality of malaria,[30] human immunodeficiency virus/acquired immunodeficiency syndrome (HIV/AIDS)[31] and cholera infection.[32,33] Uganda is one of the 51 endemic countries where cholera outbreaks[28,34-36] is still very rampant. Uganda has suffered repeated cholera cases and deaths since 1998[33,37,38] communities most vulnerable to cholera outbreaks in Uganda are situated along the lakes.[3,32,39,40] Lack of safe drinking water and poor sanitation contribute to the high cholera burden in Uganda, where 8% of people depend on surface waters for commercial/domestic and agricultural uses while 7% do not have access to proper basic sanitation.[41] The burden of cholera outbreaks is worst along the Western border with the Democratic Republic of Congo (DRC), the Karamoja region to the north, and Kampala city slums.[28] Surprisingly, there is a lack of regular surveillance and research to monitor the presence of potentially pathogenic species of *Vibrio* spp. on water bodies in this region.

V. parahaemolyticus is not an invasive pathogen; they take advantage of breached barriers and cause infection primarily affecting the colon, causing gastroenteritis.[4,24,42] V. parahaemolyticus and V. vulnificus cause wound infection and sepsis in the blood[24] and are the 2 most common *Vibrio* infections reported in the United States between 1997, States between 2006. V. vulnificus infections account for 95% of *Vibrio* related deaths in the United States.[9] V. fluvialis is pathogenic to fish and crustaceans.[10,23] V. fluvialis causes gastroenteritis and extraintestinal infections, such as hemorrhagic cellulitis and cerebritis,[43] peritonitis,[44] acute otitis,[45,46] biliary tract infection,[47] bacteremia,[48] and even ocular infections.[49] V. mimicus had been implicated with sporadic cholera-like diarrhea.[50] V. anguillarum is the causative agent of a fatal hemorrhagic septicemic disease that also infects fish, mollusks, and crustaceans.[9,19,25,51,52] V. alginolyticus is an opportunistic halophilic (grow in 10% NaCl) vibriosis[19,53] and causes septicemia and skin ulcers.[9,19,25,52] Also implicated in gastroenteritis, otitis media, wound infection, and endophthalmitis.[10,19,54-57]

There is no updated report of outbreak incidence, especially in low resource settings and on other potentially pathogenic species. Surveillance and incidence of other vibriosis-related foodborne diseases, outbreaks, gastroenteritis, and extraintestinal infections remain poorly reported.[1] Despite the progress in *Vibrio* spp., research, there is a dearth of knowledge needed to reduce the foodborne and waterborne hazard burden posed by the pathogens. The outcome and recommendation of 3-decade research in *Vibrio* species and associated diseases summarized in 1 paper will be profoundly significant to the stakeholder and policy markers in a combined effort to mount effective intervention. This study will also help health care providers and planners in developing country settings to harmonize available skills to harness limited resources in designing and implementing effective control.

In this review, we map and evaluate the relevant titled publication documents (PD) for a 3-decade global analysis of activities to reveal the cooperation network map among various countries, institutions, and individuals on the *Vibrio* spp. research in order to suggest the scientific reference for the establishment of the relevant policy.

Methods

Data retrieval

Specific title published articles on *Vibrio* spp., between January 1990 and September 2021, were retrieved from online version 5.34 of the ISI (Institute for Scientific Information) Web of Science and Scopus databases of a rapid science citation index (SCI) of a multidisciplinary database. The keywords "*Vibrio* species OR *Vibrio* spp* OR vibriosis" were the title-specific search terms for documents within the timespan 1990 to 2021 following PRISMA guidelines.[58,59]

On December 31, 2019, the complete metadata for each original published article was collated and updated on September 15 2021, from Web of Science and Scopus databases. Titles and abstracts were reviewed for relevance by 2 independent authors, and papers judged relevant by 1 author were assessed in full by both authors. The title search yielded 776 document types extracted and imported in BibTxt, and CSV file formats, then normalized using ScientoPy R-package,[60] and duplicates were removed using bibliometric and fBasics R-package[61,62] on Rstudio versions 4.0.5,[61,63] as shown in Figure 1.

Data processing and analysis

To import and manage the metadata from Web of Science and Scopus, we utilized bibliometrix version 1.7,[61] an R-Tool of R-Studio version 4.0.1[63] for comprehensive science mapping analysis, and biblioshiny, the shiny interface offering a web interface for bibliometrix. The main characteristics, scientific production, author's impact, corresponding author's country, most cited countries, sources impact, most global cited documents, the total number of publications, citations count with total citations (TC), average article citations (AAC), the number of citing articles, journal sources, keywords, countries/regions, and author-level metrics such as h-, m-, and g indexes were all included in the baseline metadata analysis. H-index measures the number of papers published

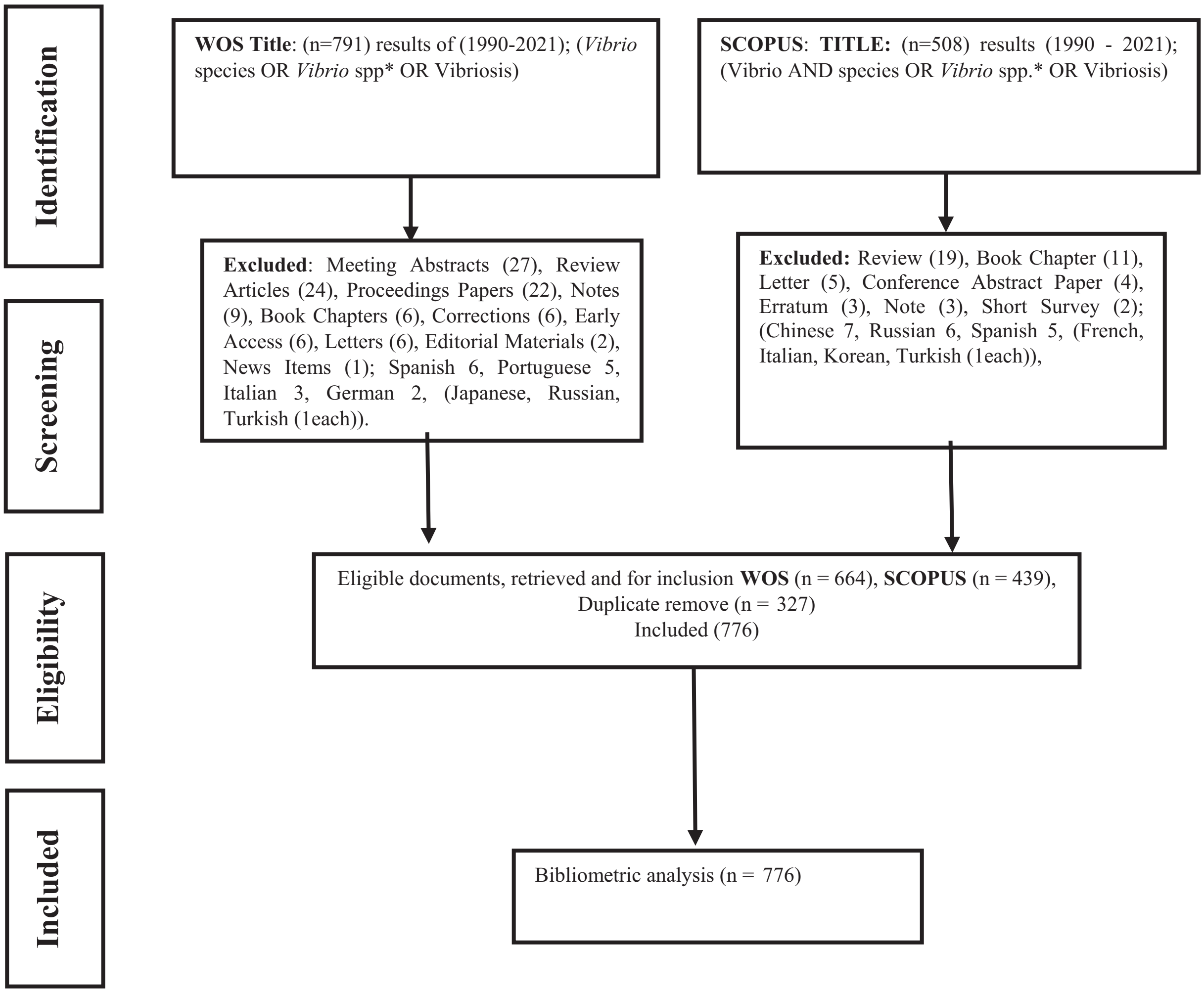

Figure 1. PRISMA process of searching, reviewing, and selecting research articles.

with at least 1 citation.[64,65] It is often used to evaluate the impact of a scientist on his or her peers. The m-index or m-quotient (ie, the h-index divided by the number of years from the author's first publication [m-quotient = h-index/n, n = number of years since the scientist's first published article]) was used since the h-index does not consider the author's career span. Furthermore, the g-index, which grants credit for the most highly cited papers in a data set, was also employed to account for the citation evolution of the most cited works of a specific author over time. The annual growth rates of scientific publications were calculated by applying a calculator (CAGR) at www.investopediacom.com/calculator.

The authors, institutions and countries network analyses were used as collaboration indicators. In addition, the keywords network from the bibliographic data collection was used to map the conceptual structure framework with a dimensionality reduction technique and Multiple Correspondence Analysis (MCA), which are connected in groups of papers expressing similar ideas. Categorical variables were reported as frequency and percentage, and continuous datasets were presented as medians with maximum and minimum values.

Results

Global publication performance and growth rate on a 3-decade survey of Vibrio *spp., research Landscape*

A global evolution trend of research titled *Vibrio* spp., a 3-decade timespan study, was carried out. A total of 1299 documents were published during the survey period, while 776 research articles types were included in this review, and their characteristics are presented in Table 1. We obtained a collaboration index of 3.81, which implies moderate involvement of co-authorship per document[16,66,67] and 2917 authors per document of 3.76 and co-authors per document of 5.12. Citations per document were 24.7 on average. Fourteen (14) authors were involved in single-authored documents, while 2903 authors were involved in multi-authored documents. The values obtained from the present study suggest a positively skewed distribution of citations of a single author and multiple authors among the published documents in this study.[68,69]

The results depict a rapid increase of research articles in some years of the study period with fluctuations in overall production between 1990 and 2021. There was a tremendous increase in PD in 2010 (n = 37) compared to the previous years in the first 2

Table 1. Descriptive data of retrieved information on *Vibrio* spp.

DESCRIPTION	RESULTS
Timespan	1990:2021
Sources (Journals, Books, etc)	290
Documents	776
Average years from publication	11
Average citations per document	24.7
Average citations per year per doc	2.113
References	25606
Document types	
Articles	776
Document contents	
Keywords Plus (ID)	4407
Author's Keywords (DE)	1581
Authors	
Authors	2917
Author Appearances	3974
Authors of single-authored documents	14
Authors of multi-authored documents	2903
Authors collaboration	
Single-authored documents	14
Documents per Author	0.266
Authors per Document	3.76
Co-Authors per Documents	5.12
Collaboration Index	3.81

decades. In 2012 (n = 28), PD dropped in the third-decade survey with a rising gain of 52 in 2020. The mean of total citation per article (meanTCperArt) is depicted through a line graph plotted on the secondary axis indicating 1999 published documents receive the highest mean citation of 89.4, as presented in Figure 2. The result shows that the rapid increase beginning from the end of the second decade (2000-2010) may be primarily due to the seafood outbreak associated with *Vibrio* spp., specifically, *V. parahaemolyticus* and *V. vulnificus* 2009 to 2010 in a developed country such as the USA, developing nation Mexico, and mid-range economy Spain. More specifically, developed countries with high per capita income are expected to control their disease and outbreaks better than developing countries.[70,71] Thus, during the seafood disease outbreak, the developed country, (USA) should usually control the outbreak better than Spain, and Mexico, lending credence to the role of economic status as a driver of effective disease control programs.[70,71] Articles in the first decade (1990-2000) gain more citations than other decades due to high-quality journals and considerable years of publication. The citable year continues to decline from 1990 (30) to 2020 (3) and is lower than the previous years because most freshly published publications had not been cited extensively at the time of data extraction for our analysis. However, over the last 30 years, the results revealed 2 distinct growth dynamics: increasing article production and decreasing mean TC per articles, as it takes time for new studies to gain appreciable citations.

The total number of publications per year, mean total citation per year and articles, and citations years, with an annual growth rate of 4.71%.

The 3-decade evolution survey of authors productive on Vibrio *spp*

The most productive researchers in the evolution of *Vibrio* spp., studies revealed 2 prolific authors, Blanch A from the University

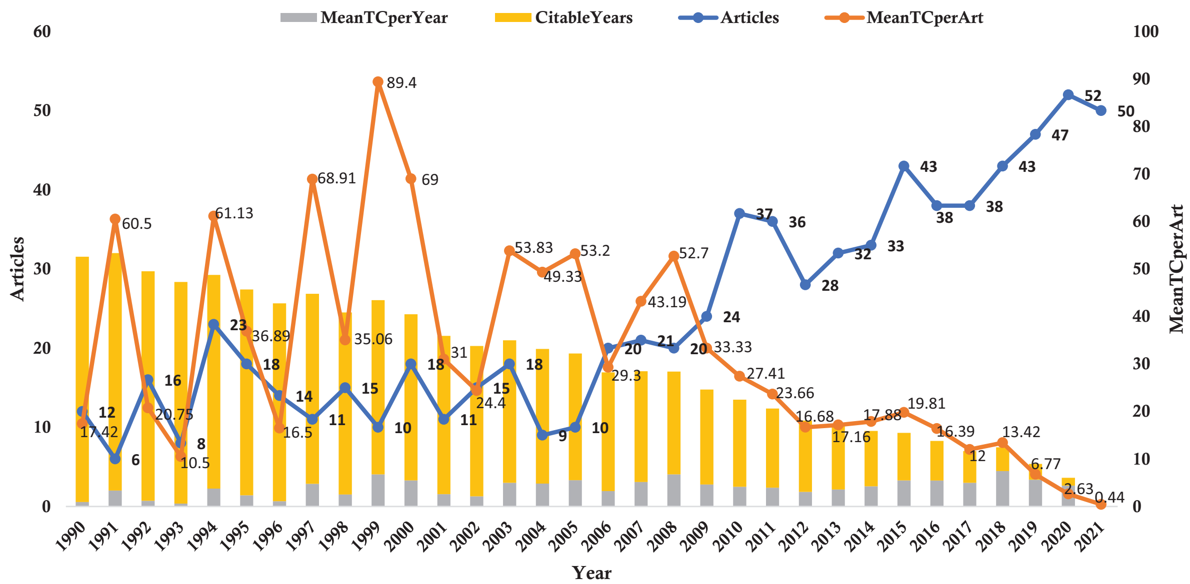

Figure 2. Three-decade scientific research output on *Vibrio* spp. and associated infections.
Abbreviations: Doc, documents; TC, total citation.

Table 2. Published documents and research impact of top 20 authors in this survey.

RANKED	ELEMENT	PD	H_INDEX	G_INDEX	M_INDEX	TC	PY_START
1	Blanch A	12	10	12	0.357	1003	1994
1	Kim Y	12	7	12	0.304	495	1999
2	Kim H	11	7	11	0.269	207	1996
3	Kim J	10	6	9	0.316	91	2003
5	Gomez-Gil B	9	7	9	0.292	500	1998
6	Kim M	9	5	7	0.192	62	1996
7	Wang Y	9	7	9	0.389	181	2004
8	Choi S	8	7	8	0.438	255	2006
9	Lee K	8	8	8	0.5	236	2006
10	Colwell R	7	7	7	0.35	228	2002
11	Kong I	7	6	7	0.4	105	2007
12	Lee J	7	6	7	0.5	85	2010
13	Lee S	7	6	7	0.3	145	2002
14	Nishibuchi M	7	7	7	0.226	731	1991
15	Okoh A	7	5	7	0.357	178	2008
16	Oliver J	7	7	7	0.304	307	1999
17	Wang X	7	4	7	0.182	65	2000
18	Zhang X	7	5	7	0.294	72	2005
19	Igbinosa E	6	5	6	0.357	172	2008
20	Jung Y	6	6	6	0.857	75	2015

Abbreviations: PD, number of published documents; TC, total citation.
Ranked based on the PD.

Barcelona in Spain and Kim Y of the Pukyong National University in South Korea, shared the first position with (nPD = 12; 1.55%), and h-index of 12, 7 respectively. Also, where the most impactful authors among the top 20 productive authors. The ranking was based on the number of published articles in the studied period. The second leading author is Kim H of the Yonsei University in South Koran with (nPD = 11 1.42%) and an h-index of 7, while the third prolific author is Kim J of the Sogang University in South Koran (nPD = 10; 1.29%) and an h-index of 6 as indicated in Table 2.

The most cited papers on *Vibrio* spp., global research survey, are shown in Table 3. The paper author by Bassler BL, 1997, published in J Bacteriol, has received a TC and TC per Year of (550 and 22) emerged as the most cited study. Seconded by Kim YB, 1999, published in J Clin. Microbiol. (387 and 16.82). Alsina M, 1994, published in J Appl. Bacteriol. been the third most cited study in the survey with TC and TC per year of (285 and 10.18). Due to the importance of vibriosis to public health, research related to this illness has been widely accepted in established and reputable journals. However, researchers tend to cite papers in high-impact factor journals more often than those in other journals. This is because these papers are more detailed and influential.

The evolution of corresponding author's countries and most cited countries of the 3-decade global survey on Vibrio *spp., research*

Table 4 shows the various countries that participated in the *Vibrio* spp., global research survey. The USA is associated with 92 articles. Out of these, 87 were single country publications (SCP), and only 5 were multiple country publications (MCP). Similarly, developing countries such as China (77, 70, 7) and India (62, 61,1), while Japan (56, 52, 4); South Korea (51, 49, 2); Spain (44, 40,4) were the top productive corresponding author's country. The frequency of publications among the top countries ranges from 12.40% to 5.93%. At the same time, the USA top in country total citation (TC) (3103) and average articles citation (AAC), 33.73 followed by Japan (2083; 37.2), Spain (1767; 40.16) India (1585; 25.56), China (1280; 16.62), Italy (1115; 30.97).

Table 3. The most cited papers on *Vibrio* spp., in this survey.

PAPER	TC	TC PER YEAR
Bassler et al,[72] J Bacteriol.	550	22
Kim et al,[73] J Clin Microbiol.	387	16.82
Alsina and Blanch,[74] J Appl Bacteriol.	285	10.18
Nandi et al,[75] J Clin Microbiol.	270	12.27
Alsina and Blanch,[74] J Appl Bacteriol.	251	8.96
Kirstein et al,[76] Mar Environ Res.	236	39.33
Vaseeharan and Ramasamy,[77] Lett Appl Microbiol.	221	11.63
Brackman et al,[78] Bmc Microbiol.	199	14.21
Hikima et al,[79] Gene	163	8.58
Panicker et al,[80] Appl Environ Microbiol.	156	8.67
Cervino et al,[81]Appl Environ Microbiol.	141	7.83
Adams,[82] Fish Shellfish Immunol.	138	4.45
Baker-Austin et al,[83] Nat Rev Dis Primers	132	33
Okuda et al,[84]Microb Pathog.	125	4.63
Porsby et al,[85] Appl Environ Microbiol.	121	8.65
Zorrilla et al,[86]J Fish Dis.	117	6.16
Gomez-Gil et al,[54] Aquaculture	115	4.79
Gopal et al,[87] Int J Food Microbiol.	114	6.71

The most relevant sources of the 3-decade global survey on Vibrio *spp., research*

The top academic journals publishing papers relevant to *Vibrio* spp., research in the survey period are presented in Table 5. Applied and Environmental Microbiology top the list of journal sources impact 46 articles, 2136 citations, and an h-index of 28. Similarly, Aquaculture (20; 399 and 11), Journal of Applied Microbiology (20, 649, and 15), Journal of Food Protection (18, 359, and 12), Journal of Bacteriology (17, 1149, and 13), and Letters in Applied Microbiology (15 articles, 408 citations, and 7 h-index) respectively.

Table 6 lists the most frequently keywords used in the 3-decades global survey on *Vibrio* spp., research including both author keywords (AK) and Keywords-Plus (KP). Five among the top 20 keywords found in publications about *Vibrio* spp. research in the author keywords includes: *Vibrio* (n = 608; 78.35), vibriosis (n = 283; 36.47), *Vibrio parahaemolyticus* (n = 281; 36.21), *Vibrio cholerae* (n = 275; 35.44), non-human (n = 235; 30.28), *Vibrio vulnificus* (n = 193; 24.87). While the 5 top KP includes; *Vibrio* (n = 158; 20.36), *Vibrio* spp., (n = 69; 8.89), *Vibrio parahaemolyticus* (n = 48; 6.19), *Vibrio cholerae* (n = 35; 4.51), *Vibrio* species (n = 29; 3.74).

The 3-decade global use of keywords and topic/stream on Vibrio *spp., research survey*

The K-means clustering shows 4 clusters of 4 thematic concepts frequently linked to *Vibrio* spp., research. The thematic conceptual landscapes in *Vibrio* spp., research are shown in Figure 3. The identified 4 conceptual thematic frameworks (CTF) includes: CTF#1 (green cluster), involving the sequences analysis, nucleotide sequence, *Vibrio* strain/bacterial protein and genes, phylogeny as the modern bacterium evolution to understand vibriosis pathogenicity. This cluster received the most excellent attention. The pathogenic strain pointed in CFT#1 is *V. mimicus*. The conventional detection methods involve DNA extraction and sequencing genomes for genetic examination. In addition, therapeutic management includes unclassified drugs. The second CTF#2 highlights the emerging strains of public concern. The strains mentioned are *V. alginolyticus, harveyi*, *vulnificus*, *parahaemolyticus*, and *cholerae* and their molecular characterization by polymerase chain reaction (PCR). These species are implicated in several infectious diseases, food poison and outbreaks due to their expression of virulence toxins example, *V. parahaemolyticus, cholerae*. Also, they are widely distributed in aquaculture, water and seafood. Third, CTF#3 centered on the pathogenicity to humans, animals and the microbiological methods of isolation and purification. The 4 cluster CTF#4 focuses on identifying the pathogenic *V. parahaemolyticus* and *vulnificus*.

Figure 4, shows the collaboration network between; (A) Authors, the author's name is represented by a circle, with the size of each circle indicating the total number of publications present in the network collaboration with other authors. Connecting lines represent collaboration pathways between authors. The thick/bold lines and names indicate the highest number of collaborations and co-authorships. (B) Institution, each institution is represented by a circle, with the size of each circle indicating the total number of publications connected with interlinked pathways lines networks. The thickest lines and names represent the institutions with greater strength in collaborations with other institutions. (C) Countries, each nation is represented by a circle, with the size of each circle indicating the total number of publications connected with interlinked pathways lines networks; the thickest lines and names represent the nations with more outstanding strength in collaborations with other countries

Discussions

This study's findings reveal that the number of publications, contributing countries, and the average number of authors per document increased over time on the subject of *Vibrio* spp. However, the number of countries that made significant contributions was restricted to developing countries, as was the average number of citations per document and the number of publications that made significant contributions. Vibriosis

Table 4. Corresponding author's countries and most cited countries on this survey.

CORRESPONDING AUTHOR'S COUNTRY						MOST CITED COUNTRIES		
COUNTRY	NPD	%FREQ	SCP	MCP	MR (%)	COUNTRY	TC	AAC
USA	92	12.40	87	5	5.43	USA	3103	33.73
China	77	10.38	70	7	9.09	Japan	2083	37.2
India	62	8.36	61	1	1.61	Spain	1767	40.16
Japan	56	7.55	52	4	7.14	India	1585	25.56
South Korea	51	6.87	49	2	3.92	China	1280	16.62
Spain	44	5.93	40	4	9.09	Italy	1115	30.97
Italy	36	4.85	25	11	30.56	Germany	853	32.81
Germany	26	3.50	21	5	19.23	South Korea	622	12.2
Brazil	22	2.97	21	1	4.55	Belgium	563	62.56
Mexico	22	2.97	19	3	13.64	United Kingdom	517	36.93
France	21	2.83	17	4	19.05	Brazil	487	22.14
Australia	20	2.70	19	1	5	Mexico	454	20.64
Malaysia	16	2.16	15	1	6.25	France	418	19.9
United Kingdom	14	1.89	10	4	28.57	Australia	360	18
Iran	13	1.75	13	0	0	Norway	336	42
Canada	12	1.62	11	1	8.33	Canada	251	20.92
Thailand	12	1.62	9	3	25	Denmark	221	44.2
South Africa	10	1.35	8	2	20	Thailand	201	16.75
Belgium	9	1.21	8	1	11.11	Tunisia	188	23.5
Nigeria	9	1.21	8	1	11.11	South Africa	185	18.5

Abbreviations: AAC, average articles citations; Freq, frequency; MCP, multiple country publications; MR%, MCP_Ratio %; nPD, number of published documents; SCP, single country publications; TC, total citations.

mainly was linked to the consumption of contaminated water and the consumption of raw/undercook seafood. Most of the literature at the community level, region, and nation focused on the isolated/characterization of strains' prevalence, dispersion, pathogenicity, and antimicrobial resistance, in response to the increasing reports of outbreaks, infections associated with potentially pathogenic *Vibrio* spp., and the emergence of its antimicrobial resistance (AMR) problem.[59,88] The reoccurring and unending global epidemic of *Vibrio* spp., requires a resolution urging member states to develop and adopt a stringent strategy that promotes and minimizes outbreaks and infection and also promote policies to reduce the spread of its resistant strains in the environments. Therefore, this survey aims at arousing the attention of many countries, investigators, academics, and policymakers.

WHO report on the first global burden of foodborne diseases in 2015 show that about 1 in every 10 people worldwide is sickened by the foodborne disease each year, and *Vibrio* spp., is one of the principal causes. It affects 600 million people, of which 420 000 die due to foodborne disease. It is imperative to note that diarrheal disease agents are number 1 among the 31 foodborne hazards global estimates by WHO.[89] Diarrheagenic agents include Campylobacter spp., Cryptosporidium spp., Entamoeba histolytica, norovirus, non-typhoidal Salmonella, pathogenic E. coli, *Vibrio* spp., (V. cholerae, V. parahaemolyticus, V. vulnificus, V. mimicus).[89,90] However, new scientific knowledge is rapidly driving health emergency outbreaks of infection on emerging viral pathogens (Zika, Chikungunya, Ebola viruses, and the likes), reflecting a significant increase in the number of research publications on these subjects.[91] For instance, the Chikungunya virus records only 8 publications in 2005 but gained a significant upsurge to 302 by 2014.[92] In the same vein, the Ebola virus had 43 publications in 2013 prior to the Ebola outbreaks in West Africa, and by 2014 has increased to more than 600 publications in 2014,[93] advancing knowledge in these subjects granting directives to policy markers.

Table 5. Most relevant journal sources on *Vibrio* spp., research.

SOURCES	PD	H_INDEX	G_INDEX	M_INDEX	TC	PY_START
Applied and Environmental Microbiology	46	28	46	0.87	2136	1990
Aquaculture	20	11	19	0.37	399	1992
Journal of Applied Microbiology	20	15	20	0.6	649	1997
Journal of Food Protection	18	12	18	0.38	359	1990
Journal of Bacteriology	17	13	17	0.42	1149	1991
Letters in Applied Microbiology	15	7	15	0.24	408	1993
Journal of Fish Diseases	14	8	14	0.27	300	1992
Food Control	13	10	13	0.5	345	2002
Systematic and Applied Microbiology	13	9	13	0.32	429	1994
Microbial Ecology	12	10	12	0.31	386	1990
FEMS Microbiology Letters	11	8	11	0.28	220	1993
International Journal of Food Microbiology	11	8	11	0.33	471	1998
Plos one	11	7	11	0.64	211	2011
Scientific Reports	10	6	10	1	228	2016
Journal of Microbiological Methods	9	4	9	0.17	83	1998
Microbial Pathogenesis	8	6	8	0.22	334	1995
BMC Microbiology	7	7	7	0.5	387	2008
FEMS Microbiology Ecology	7	6	7	0.21	280	1994
Fish and Shellfish Immunology	7	6	7	0.19	379	1991
Frontiers in Microbiology	7	6	7	0.86	133	2015

The topmost active authors regarding h_index (total citations) were affiliated with institutions in developed nations, including the USA, Germany, Japan, South Korea; developing nations China and India; mid-economy nations Spain and Italy. This attribute is due to advanced technology and intense research coupled with funding to ensure the safety of drinking water, foods, and aqua agricultural products that are not contaminated with *Vibrio* spp. Interestingly, a Spanish researcher shares the first position spotlight with a South Koran researcher on *Vibrio* infection. This may be because the *Vibrio* outbreak in Spain and Mexico must have encouraged the Spanish researcher to do more research on *Vibrio* than others. It is unclear why USA authors are missing from the first position spotlight. This study has summarized the research findings that will advance our knowledge in *Vibrio* spp., pathogenicity. The magnitude of disease distribution and the rapidity of the onset, with the worldwide spread of disease associated with *Vibrio* spp. have been widely covered in this 3-decade study. Lineage and clade identity, molecular epidemiology, and global geographical niche directed distribution has been fully reported. Thus, our knowledge has been advanced, and we are better equipped to face the next generation challenges regarding *Vibrio* spp., and related infections.

Disease management programs are structured treatment plans that help people improve the management of chronic diseases on a long- and short-term basis. This requires an established health care system, resources, and policies to implement recommended interventions. High-income countries are expected to offer sustainable and more effective health delivery services than their middle or low-income countries counterparts. Therefore, it is safe to infer that a high-income country with the most necessary resources to implement health services will perform better than middle and low-income countries' counterparts. Again, the Centers for Disease Control and Prevention (CDC) is the gold standard for a global disease control pattern. All counties have a CDC modeled after the CDC in the USA to mount a unified uniformed response again health emergencies.

In Africa, only 2 authors, Okoh A. I. (South Africa) and Igbinosa E. O. (Nigeria), were listed in the top 20 authors global 3-decade evolution survey of authors productive on *Vibrio* spp. This may indicate that many countries in Sub-Saharan Africa, among the 51 regions with endemic *Vibrio* cholera, gastroenteritis, septicemia, and hemorrhagic infections associated with other *Vibrio* spp., lack regular water surveillance. This may be due to a lack of research mentorship,

Table 6. Top 20 most relevant keywords related to *Vibrio* spp. on this survey.

S/N	KEYWORD PLUS	OCCURRENCES		AUTHORS KEYWORDS	OCCURRENCES	
1.	*Vibrio*	608	78.35	*Vibrio*	158	20.36
2.	Vibriosis	283	36.47	*Vibrio* spp	69	8.89
3.	*Vibrio parahaemolyticus*	281	36.21	*Vibrio parahaemolyticus*	48	6.19
4.	*Vibrio cholerae*	275	35.44	*Vibrio cholerae*	35	4.51
5.	Nonhuman	235	30.28	*Vibrio* species	29	3.74
6.	*Vibrio vulnificus*	193	24.87	*Vibrio vulnificus*	25	3.22
7.	Bacterial	130	16.75	Aquaculture	23	2.96
8.	Controlled study	124	15.98	Vibriosis	23	2.96
9.	Priority journal	122	15.72	Shrimp	22	2.84
10.	Polymerase chain reaction	119	15.34	PCR	21	2.71
11.	Bacteria (microorganisms)	116	14.95	Virulence	20	2.58
12.	*Vibrio alginolyticus*	114	14.69	*Vibrio* harveyi	18	2.32
13.	DNA	110	14.18	Antibiotic resistance	17	2.19
14.	Animals	98	12.63	Multiplex PCR	17	2.19
15.	Microbiology	98	12.63	Identification	16	2.06
16.	*Parahaemolyticus*	97	12.50	Seafood	15	1.93
17.	Phylogeny	97	12.50	*Vibrio alginolyticus*	15	1.93
18.	Genetics	92	11.86	*Vibrios*	15	1.93
19.	Virulence	81	10.44	Fish	14	1.80
20.	*Vibrio* harveyi	79	10.18	*Vibrio* sp.	14	1.80

Abbreviations: DNA, deoxyribonucleic acid; PCR, polymerase chain reaction; spp/sp, species; *V*, *Vibrio*.

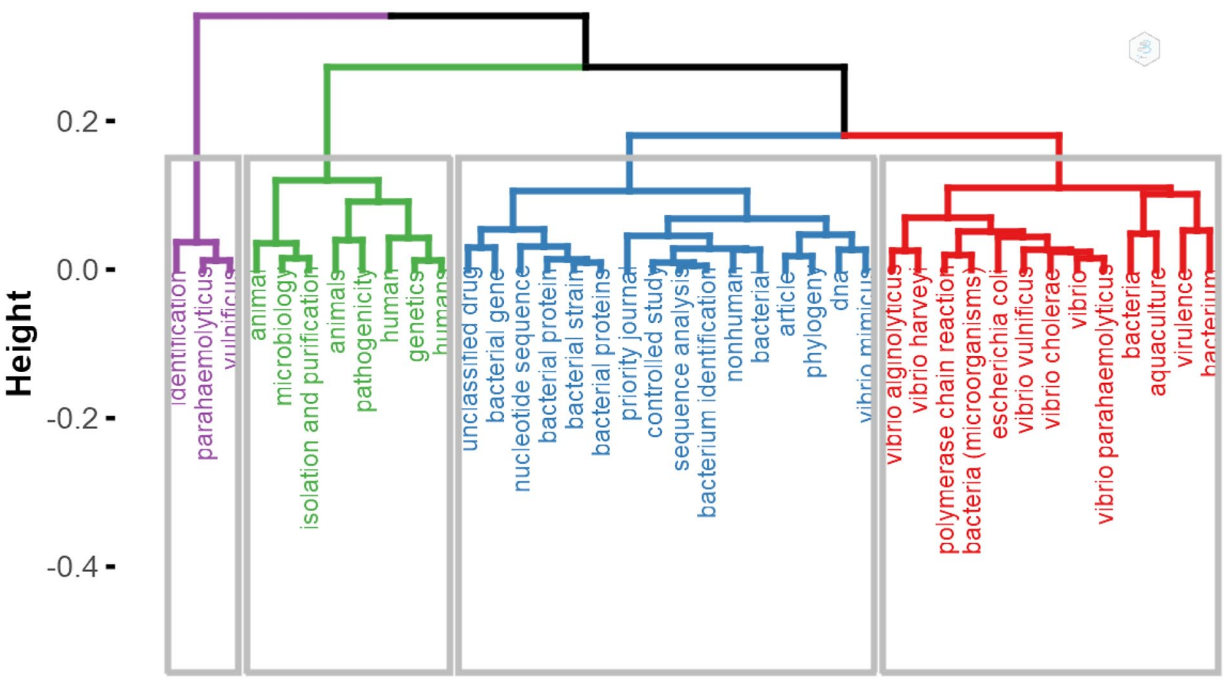

Figure 3. Research topics and conceptual landscapes on *Vibrio* spp.

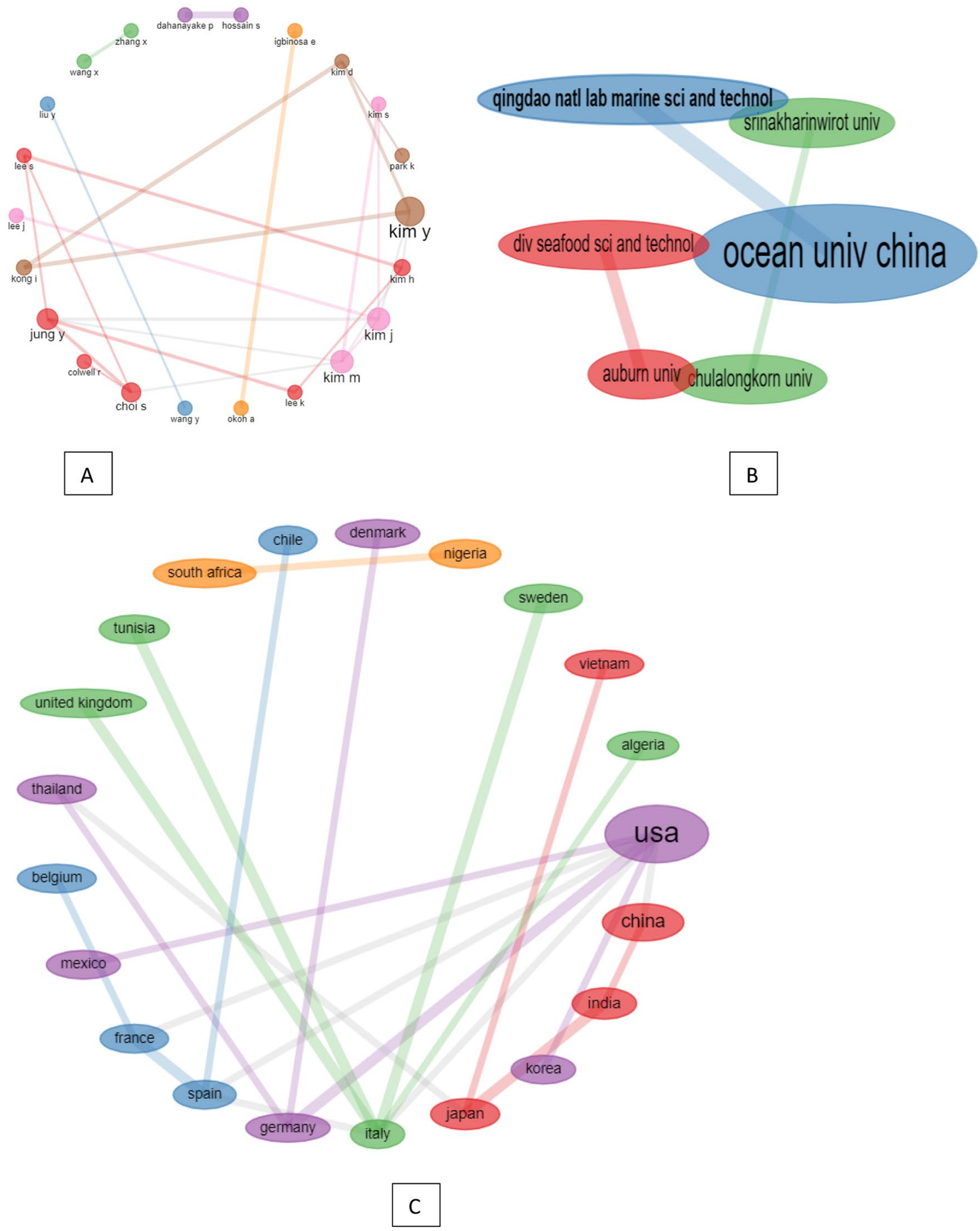

Figure 4. The top authors' (A), institutions (B), and countries (C) collaboration and coupling networks on *Vibrio* spp., research.

technology/advances required or peradventure lack of funding. Even though this study report only 2 authors from Africa, there are studies about *Vibrio* spp. in Africa that are not limited to these 2 authors. There are studies done in Africa concerning *Vibrio* spp., probably without contribution from local investigators or the studies were published in journals not indexed in the 2 databases used for this review. Uganda, for instance, has experienced recurring episodes of *V*. Cholera outbreak from 1998 to date. Unfortunately, the literature remains scant on the investigation of surface water sources (tap water, raw water, surface wells, unprotected springs, lakes, rivers, and boreholes) for the possible contamination with *Vibrio* spp., before usage. In many low resource settings of African countries, outbreaks are contained without a regular surveillance system, leaving the populations in such hard-to-reach areas at high risk of outbreaks of waterborne diseases. As a result, no quality reports of vibriosis mortality and morbidity from such affected areas/regions. Scientific research is not encouraged, with no knowledge, technology transfer, or required resources.

Furthermore, the rank order of these countries differ when productivity is measured based on the number of TC per country, with only the United States maintaining the same positions. Similar results obtained from other parameters and other research areas in the developed, developing, and mid-economy nations such as the United States, China, Japan, India, France, Spain, Brazil, South Korean, Canada, Germany, Mexico, and Australia take the lead in productivity with insufficient research from low-income countries. It has been reported that research output influences a country's development and its economic strength (growth).[69,94] The results also show research and economic disparity where the USA is more successful because of the budget allocation for research compared to Nigeria. This has economic and policy implications concerning research advancement in both *Vibrio* and other research-related policies. Therefore, policymakers should allocate funding systems motivation awards to researchers in affected countries for studies on emerging and re-emerging pathogens.

Keyword analysis provides a research advantage in discovering the path of science, and specifically, the author's keyword gives information on current trends in a subject study.[95,96] Therefore, author's keywords in bibliometrics analysis are recently used to analyze research trends.[31,96] Similarly, our study keywords indicate that vibriosis is ill health caused by infection with one of the several members of the genus *Vibrio* or related genera *Photobacterium*.[97] The Vibrionaceae family has changed several times due to advancements in species identification to new dynamics of family vibrionaceae using multilocus sequence analysis (MLSA) of 8 gene loci; the *ftsZ*, *gapA*, *gyrB*, *mreB*, *pyrH*, *recA*, and *TopA* gene sequences from 96 taxa.[98] Species frequently mentioned in the span time of this review is V. cholerae causes cholera infections. V. parahaemolyticus, is pathogenic to both humans and animals, causes gastroenteritis[42] in humans and acute hepatopancreatic necrosis disease or AHPND, shrimp Asian countries, China, Vietnam, Thailand, and Malaysia,[99] bivalve mollusk and crustaceans, oyster, clam, and shellfish in Asia[100,101] and several European countries.[102] V. vulnificus causes fatal foodborne pathogens in the United States, septicemia or wound infections.[103] V. alginolyticus, formerly regarded as biotype 2 of V. *parahaemolyticus*,[104] is an emerging threat to aquaculture as reported in Mediterranean countries, Tunisia,[105] Turkey,[106] India and Taiwan,[107] Spain and Israel,[86] Saudi Arabia,[108] Uganda.[3] V. harveyi is an emerging opportunistic pathogen affecting many aquatic animals worldwide. The findings also show that *Vibrio* spp. is transmitted as marine bacteria that possess resistance genes, like horizontal gene transfer by which they are resistant to the current antimicrobial agents. PCR is one of the effective tools for characterization and speciation of *Vibrio* spp.

Geographical location appears to have impacted research collaboration because Italy collaborated most with Sweden, the USA with Mexico and Japan with India. However, the study shows more excellent research contributions and collaborations from high-income countries than low-income countries and scanty collaboration with developing countries. Authors, institutes, and countries engaged in research on the subject of *Vibrio* spp. have produced not more than 5 titled research contributions over the 16 years. Nevertheless, the fluctuation in research production is an index of global awareness of vibriosis outbreaks.

Limitations

This analysis quantifies and qualifies the scope and adequacy of research efforts in *Vibrio* spp., disciplines. However, there are limitations to this review, including the use of only 2 databases for the study. There is no doubt that significant data in other databases if included in future studies, may change the narrative of the findings of this present study. The confidence is that even under such a study beyond the scope of this review, the findings of this study will remain relevant and will serve as a pointer to important policy in this field.

Secondly, the use of titled search specificity and refined to only English Language and the exclusion of the document types (book chapter, proceedings paper, correction, letter, meeting abstract, note, review) may have limited the analysis. However, we strongly believe that having based this study on the mainstream search of the ISI WOS and Scopus databases; the excluded book chapter, proceedings paper, correction, letter, meeting abstract, note, review, when included in the future study, will have minimum impact on the findings of this study because there is a strong relationship between book chapter, proceedings paper, correction, letter, meeting abstract, note, review, and articles published in mainstream databases

Conclusion

This analysis reveals the research progress and characteristics of a 3-decade global survey on the subject of *Vibrio* spp. and associated diseases. We have outlined a constant average decade by decade increase in research interest regarding *Vibrio* and associated diseases from this review. This is because research interest doubled from the first decade to the second decade and tripled from the second to the third decade. Geopolitical location impacted research collaboration. The delineated disease distribution pattern also underscores the impact of economic status in disease control, whereby developing countries with the most significant disease burden have less capacity to control the distribution than developed countries counterparts. Increased funding of various emerging research interests irrespective of geographical locations is recommended. Finally, we recommend multifactorial bibliometric analysis to explore emerging themes and recent research focus for future directives.

Author Contributions

OH, and NUU conceived and designed the study. OH, NUU, and AE carried out the study, OH analyzed and interpreted the data, and drafted the manuscript. OH, NUU, and AE edit the manuscript. All authors read and made the final corrections.

Data Availability Statement

The datasets used for this study are available from the corresponding author on reasonable request.

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REFERENCES

1. Senderovich Y, Izhaki I, Halpern M. Fish as reservoirs and vectors of *Vibrio* cholerae. *PLoS One*. 2010;5:e8607.
2. Osunla CA, Okoh AI. *Vibrio* pathogens: a public health concern in rural water resources in sub-Saharan Africa. *Int J Environ Res Public Health*. 2017;14:1188. doi:10.3390/ijerph14101188
3. Onohuean H, Okoh AI, Nwodo UU. Epidemiologic potentials and correlational analysis of *Vibrio* species and virulence toxins from water sources in greater Bushenyi districts, Uganda. *Sci Rep*. 2021;11:22429.
4. Jones JL. Vibrio. In: Dodd CER, Aldsworth T, Stein RA, Cliver DO, Riemann HP, eds. *Foodborne Diseases*. 3rd ed. Academic Press; 2017:243-252.
5. Weekes C, Kotra LP. *Vibrio* infections. In: Enna SJ, Bylund DB, eds. *xPharm: The Comprehensive Pharmacology Reference*. Elsevier; 2007:1-6.
6. Zhang XH, Austin B. Haemolysins in *Vibrio* species. *J Appl Microbiol*. 2005;98:1011-1019. doi:10.1111/j.1365-2672.2005.02583.x
7. Ramamurthy T, Chowdhury G, Pazhani GP, Shinoda S. *Vibrio* fluvialis: an emerging human pathogen. *Front Microbiol*. 2014;5:91. doi:10.3389/fmicb.2014.00091
8. Soumya Haldar SC. *Vibrio* related diseases in aquaculture and development of rapid and accurate identification methods. *J Mar Sci Res Dev*. 2012;s1:1-7. doi:10.4172/2155-9910.s1-002
9. Morris JG, Acheson D. Cholera and other types of vibriosis: a story of human pandemics and oysters on the half shell. *Clin Infect Dis*. 2003;37:272-280.
10. Austin B. *Vibrio*s as causal agents of zoonoses. *Vet Microbiol*. 2010;140:310-317. doi:10.1016/j.vetmic.2009.03.015
11. Yildiz FH, Visick KL. *Vibrio* biofilms: so much the same yet so different. *Trends Microbiol*. 2009;17:109-118. doi:10.1016/j.tim.2008.12.004
12. Acosta-Smith E, Viveros-Jiménez K, Canizalez-Román A, et al. Bovine lactoferrin and lactoferrin-derived peptides inhibit the growth of *Vibrio* cholerae and other *Vibrio* species. *Front Microbiol*. 2017;8:2633. doi:10.3389/fmicb.2017.02633
13. Lipp EK, Huq A, Colwell RR. Effects of global climate on infectious disease: the cholera model. *Clin Microbiol Rev*. 2002;15:757-770.
14. Hasan NA, Grim CJ, Lipp EK, et al. Deep-sea hydrothermal vent bacteria related to human pathogenic *vibrio* species. *Proc Natl Acad Sci USA*. 2015;112:E2813-E2819. doi:10.1073/pnas.1503928112
15. Vezzulli L, Pezzati E, Moreno M, Fabiano M, Pane L, Pruzzo C. Benthic ecology of *Vibrio* spp. and pathogenic *Vibrio* species in a coastal Mediterranean environment (La Spezia Gulf, Italy). *Microb Ecol*. 2009;58:808-818. doi:10.1007/s00248-009-9542-8
16. Chimetto LA, Brocchi M, Thompson CC, Martins RC, Ramos HR, Thompson FL. *Vibrio*s dominate as culturable nitrogen-fixing bacteria of the Brazilian coral Mussismilia hispida. *Syst Appl Microbiol*. 2008;31:312-319. doi:10.1016/j.syapm.2008.06.001
17. Colwell RR. Polyphasic taxonomy of the genus *vibrio*: numerical taxonomy of *Vibrio* cholerae, *Vibrio* parahaemolyticus, and related *Vibrio* species. *J Bacteriol*. 1970;104:410-433. doi:10.1128/jb.104.1.410-433.1970
18. Heidelberg JF, Heidelberg KB, Colwell RR. Seasonality of chesapeake bay bacterioplankton species. *Appl Environ Microbiol*. 2002;68:5488-5497. doi:10.1128/AEM.68.11.5488-5497.2002
19. Pruzzo C, Huq A, Colwell RR, et al. Pathogenic *vibrio* species in the marine and estuarine environment. In: Belkin S, Colwell RR, eds. *Oceans and Health: Pathogens in the Marine Environment*. Springer; 2005:217-252.
20. Colwell RR, Grimes DJ. *Vibrio* diseases of marine fish populations. *Helgoländer Meeresuntersuchungen*. 1984;37:265-287. doi:10.1007/BF01989311
21. Sindermann CJ. *Principal Diseases of Marine Fish and Shellfish. Volume 2. Diseases of Marine Shellfish*. 2nd ed. Academic Press; 1990.
22. Ruby EG, Urbanowski M, Campbell J, et al. Complete genome sequence of *Vibrio* fischeri: a symbiotic bacterium with pathogenic congeners. *Proc Natl Acad Sci USA*. 2005;102:3004-3009.
23. Cavallo R, Acquaviva M, Stabili L, Cecere E, Petrocelli A, Narracci M. Antibacterial activity of marine macroalgae against fish pathogenic *Vibrio* species. *Open Life Sci*. 2013;8:646-653. doi:10.2478/s11535-013-0181-6
24. Ng C, Goh SG, Saeidi N, Gerhard WA, Gunsch CK, Gin KYH. Occurrence of *Vibrio* species, beta-lactam resistant *Vibrio* species, and indicator bacteria in ballast and port waters of a tropical harbor. *Sci Total Environ*. 2018;610-611:651-656. doi:10.1016/j.scitotenv.2017.08.099
25. Romalde JL, Dieguez AL, Lasa A, Balboa S. New *Vibrio* species associated to molluscan microbiota: a review. *Front Microbiol*. 2014;4:413. doi:10.3389/fmicb.2013.00413
26. Lago EP, Nieto TP, Farto Seguín R. Fast detection of *Vibrio* species potentially pathogenic for mollusc. *Vet Microbiol*. 2009;139:339-346. doi:10.1016/j.vetmic.2009.06.035
27. Haldar S, Neogi SB, Kogure K, et al. Development of a haemolysin gene-based multiplex PCR for simultaneous detection of *Vibrio* campbellii, *Vibrio* harveyi and *Vibrio* parahaemolyticus. *Lett Appl Microbiol*. 2010;50:146-152. doi:10.1111/j.1472-765X.2009.02769.x
28. Kwesiga B, Pande G, Ario AR. A community-wide cholera outbreak caused by drinking unsafe water: Kasese District, Western Uganda, February – July 2015. *Pan African Med J Conf Proc*. 2018;2018:1. doi:10.11604/pamj.cp.2017.1.2.6
29. Aktar A, Rahman MA, Afrin S, et al. Plasma and memory B cell responses targeting O-specific polysaccharide (OSP) are associated with protection against *Vibrio* cholerae O1 infection among household contacts of cholera patients in Bangladesh. *PLoS Negl Trop Dis*. 2018;12:e0006399. doi:10.1371/journal.pntd.0006399
30. Onohuean H, Alagbonsi AI, Usman IM, et al. Annona muricata linn and Khaya grandifoliola C.DC. Reduce oxidative stress in vitro and ameliorate plasmodium berghei-induced parasitemia and cytokines in BALB/c mice. *Evid Based Integr Med*. 2021;26:2515690X2110366. doi:10.1177/2515690X211036669
31. Onohuean H, Aigbogun EO Jr, Igere BE. Meta-synthesis and science mapping analysis of HIV/HPV co-infection: a global perspective with emphasis on Africa. *Global Health*. 2022;18:36.
32. Bwire G, Ali M, Sack DA, et al. Identifying cholera 'hotspots' in Uganda: an analysis of cholera surveillance data from 2011 to 2016. *PLoS Negl Trop Dis*. 2017;11:e0006118.
33. Bwire G, Munier A, Ouedraogo I, et al. Epidemiology of cholera outbreaks and socio-economic characteristics of the communities in the fishing villages of Uganda: 2011-2015. *PLoS Negl Trop Dis*. 2017;11:e0005407.
34. Bwire G, Mwesawina M, Baluku Y, Kanyanda SS, Orach CG. Cross-border cholera outbreaks in Sub-Saharan Africa, the mystery behind the silent illness: what needs to be done? *PLoS One*. 2016;11:e0156674.
35. Bwire G, Malimbo M, Maskery B, Kim YE, Mogasale V, Levin A. The burden of cholera in Uganda. *PLoS Negl Trop Dis*. 2013;7:e2545.
36. Oguttu DW, Okullo A, Bwire G, Nsubuga P, Ario AR. Cholera outbreak caused by drinking lake water contaminated with human faeces in Kaiso Village, Hoima District, Western Uganda, October 2015. *Infect Dis Poverty*. 2017;6:146.
37. Brown J, Cavill S, Cumming O, Jeandron A. Water, sanitation, and hygiene in emergencies: summary review and recommendations for further research. *Waterlines*. 2012;31:11-29. doi:10.3362/1756-3488.2012.004
38. Pande G, Kwesiga B, Bwire G, et al. Cholera outbreak caused by drinking contaminated water from a lakeshore water-collection site, Kasese District, southwestern Uganda, June-July 2015. *PLoS One*. 2018;13:e0198431.
39. Alajo SO, Nakavuma J, Erume J. Cholera in endemic districts in Uganda during El Niño rains: 2002-2003. *Afr Health Sci*. 2006;6:93-97.
40. Andrawa M, Anguzu P, Anguaku A, Nalwadda C, Namusisi O, Tweheyo R. Risk factors for repeated cholera outbreak in Arua municipal council, northwestern Uganda. *Int J Infect Dis*. 2010;14:e65.
41. Hirai M, Roess A, Huang C, Graham J. Exploring geographic distributions of high-risk water, sanitation, and hygiene practices and their association with child diarrhea in Uganda. *Glob Health Action*. 2016;9:32833.
42. Jones MK, Oliver JD. *Vibrio* vulnificus: disease and pathogenesis. *Infect Immun*. 2009;77:1723-1733.
43. Janda JM, Powers C, Bryant RG, Abbott SL. Current perspectives on the epidemiology and pathogenesis of clinically significant *Vibrio* spp. *Clin Microbiol Rev*. 1988;1:245-267. doi:10.1128/CMR.1.3.245
44. Ratnaraja N, Blackmore T, Byrne J, Shi S. *Vibrio* fluvialis peritonitis in a patient receiving continuous ambulatory peritoneal dialysis. *J Clin Microbiol*. 2005;43:514-515. doi:10.1128/JCM.43.1.514-515.2005
45. Ceccarelli D, Colwell RR. *Vibrio* ecology, pathogenesis, and evolution. *Front Microbiol*. 2014;5:256.
46. Rodríguez LEC, Monroy SP, Morier L, et al. Severe otitis due to *Vibrio* fluvialis in a patient with AIDS: first report in the world. *Rev Cubana Med Trop*. 57(2):154-155.
47. Liu WL, Chiu YH, Chao CM, Hou CC, Lai CC. Biliary tract infection caused by *Vibrio* fluvialis in an immunocompromised patient. *Infection*. 2011;39:495-496. doi:10.1007/s15010-011-0146-0
48. Lai CH, Hwang CK, Chin C, Lin HH, Wong WW, Liu CY. Severe watery diarrhoea and bacteraemia caused by *Vibrio* fluvialis. *J Infect*. 2006;52:e95-e98.

49. Penland RL, Boniuk M, Wilhelmus KR. *Vibrio* ocular infections on the U.S. Gulf Coast. *Cornea*. 2000;19:26-29. doi:10.1097/00003226-200001000-00006
50. Chowdhury G, Joshi S, Bhattacharya S, et al. Extraintestinal infections caused by non-toxigenic *Vibrio* cholerae non-O1/non-O139. *Front Microbiol*. 2016;7:144.
51. Dorsch M, Lane D, Stackebrandt E. Towards a phylogeny of the genus *Vibrio* based on 16S rRNA sequences. *Int J Syst Bacteriol*. 1992;42:58-63.
52. Powell JL. *Vibrio* species. *Clin Lab Med*. 1999;19:537-552.
53. Chen CY, Wu KM, Chang YC, et al. Comparative genome analysis of *Vibrio* vulnificus, a marine pathogen. *Genome Res*. 2003;13:2577-2587. doi:10.1101/gr.1295503
54. Gomez-Gil B, Tron-Mayén L, Roque A, Turnbull JF, Inglis V, Guerra-Flores AL. Species of *Vibrio* isolated from hepatopancreas, haemolymph and digestive tract of a population of healthy juvenile Penaeus vannamei. *Aquaculture*. 1998;163:1-9. doi:10.1016/S0044-8486(98)00162-8
55. Gomez-Gil B, Soto-Rodríguez S, García-Gasca A, et al. Molecular identification of *Vibrio* harveyi-related isolates associated with diseased aquatic organisms. *Microbiology*. 2004;150:1769-1777.
56. Sawabe T, Ogura Y, Matsumura Y, et al. Updating the *Vibrio* clades defined by multilocus sequence phylogeny: proposal of eight new clades, and the description of *Vibrio* tritonius sp. Nov. *Front Microbiol*. 2013;4:414.
57. Chimetto LA, Brocchi M, Gondo M, Thompson CC, Gomez-Gil B, Thompson FL. Genomic diversity of *vibrio*s associated with the Brazilian coral Mussismilia hispida and its sympatric zoanthids (Palythoa caribaeorum, Palythoa variabilis and Zoanthus solanderi). *J Appl Microbiol*. 2009;106:1818-1826.
58. Moher D, Shamseer L, Clarke M, et al. Preferred reporting items for systematic review and meta-analysis protocols (PRISMA-P) 2015 statement. *Rev Esp Nutr Humana y Diet*. 2016;20:148-160.
59. Onohuean H, Agwu E, Nwodo UU. Systematic review and meta-analysis of environmental *Vibrio* species – antibiotic resistance. *Heliyon*. 2022;8:e08845.
60. Ruiz-Rosero J, Ramirez-Gonzalez G, Viveros-Delgado J. Software survey: ScientoPy, a scientometric tool for topics trend analysis in scientific publications. *Scientometrics*. 2019;121:1165-1188. doi:10.1007/s11192-019-03213-w
61. Aria M, Cuccurullo C. Bibliometrix: an R-tool for comprehensive science mapping analysis. *J Inform*. 2017;11:959-975.
62. Kassambara A. ggpubr: 'ggplot2' based publication ready plots. *R Package version 040*. https://cran.r-project.org/web/packages/ggpubr/index.html accesse
63. Rstudio Team. *RStudio: Integrated Development for R*. RStudio Team PBC. 2020. Accessed December 15, 2021. http://www.rstudio.com/
64. Hirsch JE. An index to quantify an individual's scientific research output. *Proc Natl Acad Sci USA*. 2005;102:16569-16572.
65. Nerli R. H-index. *J Sci Soc*. 2014;41:1. doi:10.4103/0974-5009.126686
66. Siamaki S, Geraei E, Zare-Farashbandi F. A study on scientific collaboration and co-authorship patterns in library and information science studies in Iran between 2005 and 2009. *J Educ Health Promot*. 2014;3:99.
67. Ekundayo TC, Okoh AI. A global bibliometric analysis of Plesiomonas-related research (1990–2017). *PLoS One*. 2018;13:e0207655.
68. Olisah C, Okoh OO, Okoh AI. Global evolution of organochlorine pesticides research in biological and environmental matrices from 1992 to 2018: a bibliometric approach. *Emerg Contam*. 2019;5:157-167.
69. Olisah C, Okoh OO, Okoh AI. A bibliometric analysis of investigations of polybrominated diphenyl ethers (PBDEs) in biological and environmental matrices from 1992–2018. *Heliyon*. 2018;4:e00964.
70. Garas A, Guthmuller S, Lapatinas A. The development of nations conditions the disease space. *PLoS One*. 2021;16:e0244843.
71. Ismahene Y. Infectious diseases, trade, and economic growth: a panel analysis of developed and developing countries. *J Knowledge Econ*. Published online July 21, 2021. doi:10.1007/s13132-021-00811-z
72. Bassler BL, Greenberg EP, Stevens AM. Cross-species induction of luminescence in the quorum-sensing bacterium *Vibrio* harveyi. *J Bacteriol*. 1997;179:4043-4045. doi:10.1128/jb.179.12.4043-4045.1997
73. Kim YB, Okuda J, Matsumoto C, Takahashi N, Hashimoto S, Nishibuchi M. Identification of *Vibrio* parahaemolyticus strains at the species level by PCR targeted to the toxR gene. *J Clin Microbiol*. 1999;37:1173-1177.
74. Alsina M, Blanch AR. A set of keys for biochemical identification of environmental *Vibrio* species. *J Appl Bacteriol*. 1994;76:79-85.
75. Nandi B, Nandy RK, Mukhopadhyay S, Nair GB, Shimada T, Ghose AC. Rapid method for species-specific identification of *Vibrio* cholerae using primers targeted to the gene of outer membrane protein OmpW. *J Clin Microbiol*. 2000;38:4145-4151.
76. Kirstein IV, Kirmizi S, Wichels A, et al. Dangerous hitchhikers? Evidence for potentially pathogenic *Vibrio* spp. on microplastic particles. *Mar Environ Res*. 2016;120:1-8.
77. Vaseeharan B, Ramasamy P. Control of pathogenic *Vibrio* spp. by Bacillus subtilis BT23, a possible probiotic treatment for black tiger shrimp Penaeus monodon. *Lett Appl Microbiol*. 2003;36:83-87. doi:10.1046/j.1472-765X.2003.01255.x
78. Brackman G, Defoirdt T, Miyamoto C, et al. Cinnamaldehyde and cinnamaldehyde derivatives reduce virulence in *Vibrio* spp. by decreasing the DNA-binding activity of the quorum sensing response regulator LuxR. *BMC Microbiol*. 2008;8:149.
79. Hikima S, Hikima JI, Rojtinnakorn J, Hirono I, Aoki T. Characterization and function of kuruma shrimp lysozyme possessing lytic activity against *Vibrio* species. *Gene*. 2003;316:187-195.
80. Panicker G, Call DR, Krug MJ, Bej AK. Detection of pathogenic *Vibrio* spp. un shellfish by using multiplex PCR and DNA microarrays. *Appl Environ Microbiol*. 2004;70:7436-7444. doi:10.1128/AEM.70.12.7436-7444.2004
81. Cervino JM, Hayes RL, Polson SW, et al. Relationship of *Vibrio* species infection and elevated temperatures to yellow blotch/band disease in Caribbean corals. *Appl Environ Microbiol*. 2004;70:6855-6864. doi:10.1128/AEM.70.11.6855-6864.2004
82. Adams A. Response of penaeid shrimp to exposure to *Vibrio* species. *Fish Shellfish Immunol*. 1991;1:59-70. doi:10.1016/S1050-4648(06)80020-3
83. Baker-Austin C, Oliver JD, Alam M, et al. *Vibrio* spp. infections. *Nat Rev Dis Primers*. 2018;4:8.
84. Okuda J, Kurazono H, Takeda Y. Distribution of the cytolethal distending toxin A gene (cdtA) among species of Shigella and *Vibrio*, and cloning and sequencing of the CDT gene from Shigella dysenteriae. *Microb Pathog*. 1995;18:167-172. doi:10.1016/S0882-4010(95)90022-5
85. Porsby CH, Nielsen KF, Gram L. Phaeobacter and Ruegeria species of the Roseobacter clade colonize separate niches in a Danish turbot (scophthalmus maximus)-rearing farm and antagonize *Vibrio* anguillarum under different growth conditions. *Appl Environ Microbiol*. 2008;74:7356-7364. doi:10.1128/AEM.01738-08
86. Zorrilla I, Arijo S, Chabrillon M, et al. *Vibrio* species isolated from diseased farmed sole, Solea senegalensis (Kaup), and evaluation of the potential virulence role of their extracellular products. *J Fish Dis*. 2003;26:103-108. doi:10.1046/j.1365-2761.2003.00437.x
87. Gopal S, Otta SK, Kumar S, Karunasagar I, Nishibuchi M, Karunasagar I. The occurrence of *Vibrio* species in tropical shrimp culture environments; implications for food safety. *Int J Food Microbiol*. 2005;102:151-159. doi:10.1016/j.ijfoodmicro.2004.12.011
88. Onohuean H, Okoh AI, Nwodo UU. Antibiogram signatures of *Vibrio* species recovered from surface waters in South Western districts of Uganda: implications for environmental pollution and infection control. *Sci Total Environ*. 2022;807:150706.
89. WHO. WHO's first ever global estimates of foodborne diseases find children under 5 account for almost one third of deaths. 2015. Accessed April 15, 2022. https://www.who.int/news/item/03-12-2015-who-s-first-ever-global-estimates-of-foodborne-diseases-find-children-under-5-account-for-almost-one-third-of-deaths
90. Onohuean H, Igere BE. Occurrence, antibiotic susceptibility and genes encoding antibacterial resistance of *Salmonella* spp. and Escherichia coli from milk and meat sold in markets of Bushenyi District, Uganda. *Microbiol Insights*. 2022;15:1-8. doi:10.1177/11786361221088992
91. Albuquerque PC, Castro MJ, Santos-Gandelman J, Oliveira AC, Peralta JM, Rodrigues ML. Bibliometric indicators of the Zika outbreak. *PLoS Negl Trop Dis*. 2017;11:e0005132.
92. Vera-Polania F, Muñoz-Urbano M, Bañol-Giraldo AM, Jimenez-Rincón M, Granados-álvarez S, Rodriguez-Morales AJ. Bibliometric assessment of scientific production of literature on chikungunya. *J Infect Public Health*. 2015;8:386-388.
93. Cruz-Calderón S, Nasner-Posso KM, Alfaro-Toloza P, Paniz-Mondolfi AE, Rodríguez-Morales AJ. A bibliometric analysis of global Ebola research. *Travel Med Infect Dis*. 2015;13:202-204.
94. Zhang C, Fang Y, Chen X, Congshan T. Bibliometric analysis of trends in global sustainable livelihood research. *Sustainability*. 2019;11:1150.
95. Zhao F, Du F, Zhang J, Xu J. Trends in research related to Keratoconus from 2009 to 2018: a bibliometric and knowledge mapping analysis. *Cornea*. 2019;38:847-854.
96. Chiu WT, Ho YS. Bibliometric analysis of tsunami research. *Scientometrics*. 2007;73:3-17. doi:10.1007/s11192-005-1523-1
97. Noga EJ. *Fish Disease: Diagnosis and Treatment*. 2nd ed. Wiley-Blackwell; 2010.
98. Sawabe T, Kita-Tsukamoto K, Thompson FL. Inferring the evolutionary history of *vibrio*s by means of multilocus sequence analysis. *J Bacteriol*. 2007;189:7932-7936. doi:10.1128/JB.00693-07
99. De Schryver P, Defoirdt T, Sorgeloos P. Early mortality syndrome outbreaks: a microbial management issue in shrimp farming? *PLoS Pathog*. 2014;10:e1003919.
100. Yu SC, Fen SY, Chien CL, Wong HC. Protective roles of katG-homologous genes against extrinsic peroxides in *Vibrio* parahaemolyticus. *FEMS Microbiol Lett*. 2016;363:201.
101. Kang CH, Shin Y, Jang S, et al. Characterization of *Vibrio* parahaemolyticus isolated from oysters in Korea: resistance to various antibiotics and prevalence of virulence genes. *Mar Pollut Bull*. 2017;118:261-266.
102. Ottaviani D, Leoni F, Rocchegiani E, et al. An extensive investigation into the prevalence and the genetic and serological diversity of toxigenic *Vibrio* parahaemolyticus in Italian marine coastal waters. *Environ Microbiol*. 2013;15:1377-1386.

103. Raszl SM, Froelich BA, Vieira CR, Blackwood AD, Noble RT. *Vibrio* parahaemolyticus and *Vibrio* vulnificus in South America: water, seafood and human infections. *J Appl Microbiol*. 2016;121:1201-1222.
104. Chart H. *Vibrio*, mobiluncus, gardnerella and spirillum. In: Greenwood D, Barer M, Slack R, Irving W, eds. *Medical Microbiolology*. Churchill Livingstone; 2012:314-323.
105. Ben Kahla-Nakbi A, Chaieb K, Bakhrouf A. Investigation of several virulence properties among *Vibrio* alginolyticus strains isolated from diseased cultured fish in Tunisia. *Dis Aquat Org*. 2009;86:21-28.
106. Korun J, Karaca M. Antibiotic resistance and plasmid profile of *Vibrio* alginolyticus strains isolated from cultured European sea bass (Dicentrarchus Labrax, L.). *Bull Vet Inst Pulawy*. 2013;57:173-177.
107. Rameshkumar P, Nazar AKA, Pradeep MA, et al. Isolation and characterization of pathogenic *Vibrio* alginolyticus from sea cage cultured cobia (Rachycentron canadum (Linnaeus 1766)) in India. *Lett Appl Microbiol*. 2017;65:423-430.
108. Al-Sunaiher A, Ibrahim A, Al-Salamah A. Association of *Vibrio* species with disease incidence in some cultured fishes in the Kingdom of Saudi Arabia. *World Appl Sci J*. 2010;8:653-660.