



A Bibliometric Approach to Understanding the Recent Development of Publication About the Silver Carp *Hypophthalmichthys molitrix* Between 2003 and 2023

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ABSTRACT

Aquaculture of the silver carp (*Hypophthalmichthys molitrix*) is one of the most important species for ensuring food security. This analysis study aimed to comprehend the conceptual framework of the recent research for it, based on 959 Scopus-indexed core collection papers from 446 publications produced by 139 authors from 57 countries between 2003 and 2023. VOSViewer was used to conduct this bibliometric analysis, which looked into the fundamental profile of the chosen fields. Of the ten authors, Luo Yongkang emerged as the most productive author in the field, with an h-index of 58, 268 articles, and 268 documents. China and the USA were found to have the strongest teamwork and the most productive nations, producing 437 and 262 papers, respectively. The most frequently mentioned journals that addressed the research topic were Food Hydrocolloids (411) and Food Chemistry (391, 341, 321, and 196, respectively), which dealt with the research topic the most. As a result, this bibliometric analysis offers thorough details on the field of study and research landscape around silver carp and indicates interest in the subject matter. In addition, it identifies crucial areas for further investigation and makes it easier to map possible authors, organizations, and nations for partnerships.

INTRODUCTION

Over the past two decades, aquaculture has become a more significant contributor to the world's fish production. Production peaked in 2014 at 73.8 million tons, or approximately 44% of the world's total fish production. Aquaculture accounted for almost half of the historic high of 179 million tons of production from catch fisheries and aquaculture combined in 2018. Additionally, aquaculture has been the fastest-growing animal food industry for the last 10 years, producing 52% of fish for human consumption. A larger share of this development in aquaculture output can be attributed to production in Asia and Africa. Even in countries where the economy has been difficult and

environmental issues continue, aquaculture helps support livelihoods, economic growth, poverty reduction, and human food security, in addition to generating income. The aquaculture industry must keep expanding in order to provide for the growing demand for fish. But without a major improvement in planning and administration, development would not be sustainable. To address issues related to the environment, society, economy, health, and welfare of animals, planning and management at the local, national, and international levels are required (Salin & Arome Ataguba, 2018; FAO, 2020; Dang, 2023).

More than 80% of fish raised for food are carps, which include the common carp, silver carp, and grass carp, as well as minor and exotic carps including the rohu, catla, and mrigal. Over the past decade, carp production has increased by nearly two million tons, largely due to enhanced aquaculture practices. Fish are the dominant product in this sector, with the common and silver carp being the two most significant species by volume. For example, in 2018, global production of the silver carp reached 4,822,794 tons. The leading producers of these species include China, India, Bangladesh, and Iran (Molnár *et al.*, 2018; FAO, 2022).

Table 1. Global production of 12 major cultured carp species

Species	Production (1000) tonnes		% of total carp production	
Grass carp (<i>Ctenopharyngodon idella</i> (Valenciennes, 1844))	2698	5704	21.12	19.76
Silver carp (<i>H. molitrix</i> (Valenciennes, 1844))	3007	4789	23.54	16.59
Common carp (<i>Cyprinus carpio</i> (Linnaeus, 1758))	2185	4190	17.1	14.51
Bighead carp (<i>H. nobilis</i> (Richardson, 1845))	1424	3144	11.15	10.89
Catla (<i>Gibleon catla</i> (Hamilton, 1822))	555	3041	4.35	10.54
Carassius spp.	926	2772	7.25	9.6
Roho labeo (<i>Labeo rohita</i> (Hamilton, 1822))	660	2017	5.17	6.99
Wuchang bream (<i>Megalobrama amblycephala</i> (Yi, 1955))	403	784	3.16	2.71
Black carp (<i>Mylopharyngodon piceus</i> (Richardson, 1846))	138	692	1.08	2.4
Cyprinids nei* (Cyprinidae)	43	654	0.33	2.27
Mrigal carp (<i>Cirrhinus cirrhosus</i> (Bloch, 1795))	500	501	3.91	1.74
Silver barb (<i>Barbonymus schwanenfeldii</i> (Bleeker, 1854))	69	380	0.54	1.32

*Not elsewhere included (Miao & Wang, 2020)

Generally speaking, the East Asian freshwater cyprinid known as the silver carp, *H. molitrix* (Valenciennes 1844), is widely available, inexpensive to produce aquaponically, has a high feed efficiency ratio, and is nutritionally valuable. It has also been introduced

to other parts of the world for the purpose of aquaculture and the control of algal blooms (Kootenaie *et al.*, 2017; Froese & Pauly, 2020). Proteins, polyunsaturated fatty acids, lipid-soluble vitamins, and minerals are among its well-known nutritional benefits (Siddaiah *et al.*, 2001; Rezaei & Shahbazi, 2018). The Asian carp of the genus *Hypophthalmichthys* are important for aquaculture worldwide as well as in eastern and southern Asia, where they are regarded as common species (Kolar *et al.*, 2007). Due to the biological characteristics of *Hypophthalmichthys* spp., a planktivorous fish species, which include rapid growth and reproduction, a wide tolerance to environmental changes, and general eating preferences, the Asian carp are now considered invasive in many of the territories where they have been introduced, particularly in Canada (Bonebrake, 2013), and Europe (Molnár *et al.*, 2018; Jawdhari *et al.*, 2022), and the USA (Molnár *et al.*, 2021).

Studies in the past have looked at how plankton communities in aquatic environments are affected by filter-feeding fish (Zhang *et al.*, 2006; Milstein *et al.*, 2008; Yan *et al.*, 2009; Wahab *et al.*, 2011). The culture of the silver carp in a cage has shown an excellent output without external feeding since this species can horizontally filter plankton from the water body (Roy, 2015). However, in regions where it has been introduced, it is thought that native planktivorous fish, including juvenile fish of almost all species, bigmouth buffalo (*Ictiobus cyprinellus*), paddlefish (*Polyodon spathula*), and gizzard shad (*Dorosoma cepedianum*), compete with this plankton-feeding species (Willink, 2009; Minder & Pyron, 2018).

They can occasionally be employed to successfully control the quality of water, particularly in the control of poisonous blue-green algae (cyanobacteria), because they graze on plankton. Some blue-green algae species, most notably the frequently poisonous microcystis, can pass through silver carp's intestines intact and absorb nutrients. As a result, the silver carp have been known to sometimes worsen the blue-green algal blooms, as well as increasing the microcystis toxin production. Despite having built-in defenses against their toxins, these carp have occasionally levels of algae toxins in their bodies that make them dangerous to consume (Willink, 2009).

Neff and Corley (2009) indicate that bibliometric analysis is a potent instrument that makes it possible to evaluate research priorities across disciplines. It will provide researchers with a reliable source of data that may aid their understanding of the current areas of focus for aquaculture research, as well as other significant scientific metrics. Nonetheless, a large body of literature has been written about a variety of species, including the salmon, trout, shad, eel, and lamprey (Nikolic *et al.*, 2011) in addition to the zebrafish (*Danio rerio*) (Abdel-Aziz *et al.*, 2021), and the grass carp (Sayed-Lafi, 2024).

This paper represents the first comprehensive bibliometric analysis of articles related to the silver carp. The findings highlight global research trends on the silver carp,

a species that is not only one of the most significant in aquaculture but also poses environmental challenges in many countries. This analysis aimed to inspire innovative scientific concepts for future studies, helping organize, illuminate, and foster advanced interconnected research.

The study provides background information and sets clear objectives: to track the development of research, analyze trends, assess author productivity, explore theme evolution, and identify key keywords in the scientific literature related to the silver carp. By doing so, it offers academics access to essential bibliometric data, serving as a reliable resource for understanding the current focus of aquaculture research.

MATERIALS AND METHODS

A search for relevant literature in the Scopus database was conducted for this study between November 2003 and 2023. The data curation process begins with the Scopus database. The Scopus database was chosen over other databases because of its superior scientific quality and coverage (Mongeon *et al.*, 2016; Pham-Duc *et al.*, 2020). In Scopus, the identical processes were rewritten. To identify relevant publications on silver carp research, the search utilized the terms "silver carp," "silvercarp," and "Hypophthalmichthys molitrix" specifically in the article titles. The highest most cited articles were noted after the retrieved documents were arranged in decreasing order of citation counts. Regarding publication date, status, language, document type, or source type, there were no limitations.

The citation metrics were calculated using Harzing's Publish or Perish (www.harzing.com). Additionally, Microsoft Excel 2016 was employed to analyze citation characteristics—including authors, titles, publication years, journals, and citation counts—and to create a visual bibliometric network using VOSviewer software version 1.6.15 (Center for Science and Technology Studies, Leiden University, Netherlands). The network was semantically represented through a co-occurrence map, incorporating validated terms from the selected papers. Each term in the search string was treated as a significant unit of analysis for the bibliometric study, with some minor adjustments made during the process. The initial search yielded a total of 1,349 articles. Relevant keywords included "Phaethys molitrix," "silver carp," "Cyprinidae," "carp," "animals," "Cyprinid," "carps," "fish," "invasive species," "lakes," "aquaculture," and "fish culture." Ultimately, 959 articles were retained for analysis, with the subsequent discussion focusing on the source types (journal articles, conference proceedings, book series, books, and trade journals).

RESULTS AND DISCUSSION

1. Publications and citations

The results of the present analysis indicated that over the past 20 years, research on the silver carp has accumulated a total of 20,474 citations, with both an h-index and g-index of 100 (Table 2). From 2003 to 2023, there were 959 publications related to silver carp, with 94 published in 2023 alone, a notable increase from just 11 in 2003 (Fig. 2). The research was primarily published in English (807), but other languages included Chinese (52), Persian (6), German (2), and Arabic (1). The majority of the publications appeared in journals (941), followed by conference proceedings (9) and book series (7).

The silver carp is recognized as one of the most productive and cost-effective species for aquaculture, largely due to its rapid growth rate and ability to thrive on phytoplankton without additional feeding. This efficiency is reflected in the substantial number of publications and high citation counts associated with the species (**Jawdhari et al., 2022**).

Table 2. Main information regarding the collection

Publication years	2003-2023
Citations	20474
Cites/year	1023.20
Cites/paper	102.32
Authors/paper	1.00
Papers/ Author	200
h-index	100
g-index	100

Fig. (1) illustrates the ranking of countries that have published research on silver carp, using a gradient scale from white to dark blue to indicate the number of publications, ranging from one to 437. A total of 57 countries contributed relevant articles, with the top two countries—China and the USA—accounting for 59.23% of all publications. Specifically, China leads with 437 publications, while the USA follows with 262. The average number of publications for the remaining countries stands at 8.74. This highlights China's prominent role in advancing research on the silver carp (Fig. 2).

Various metrics, such as citation frequency, publication count, and h-index, provide a comprehensive assessment of a country's academic influence on this topic (Yi-Run *et al.*, 2022).

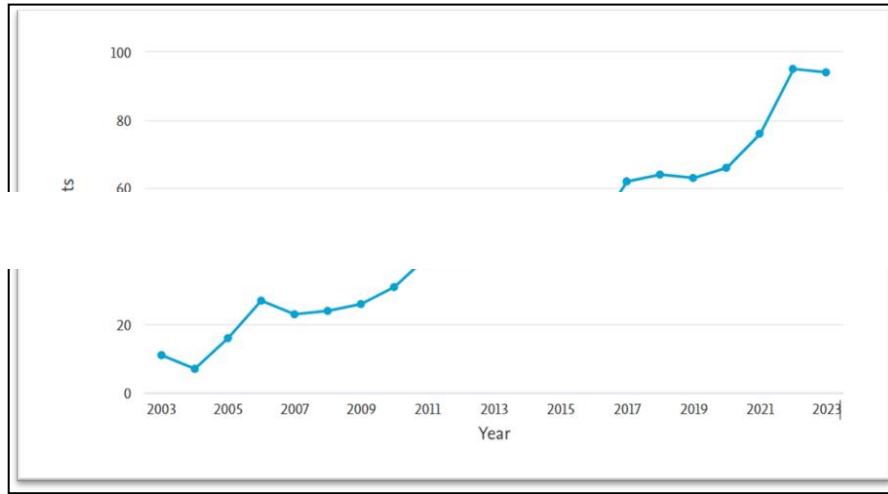


Fig. 1. Number of research articles regarding silver carp published since 2003

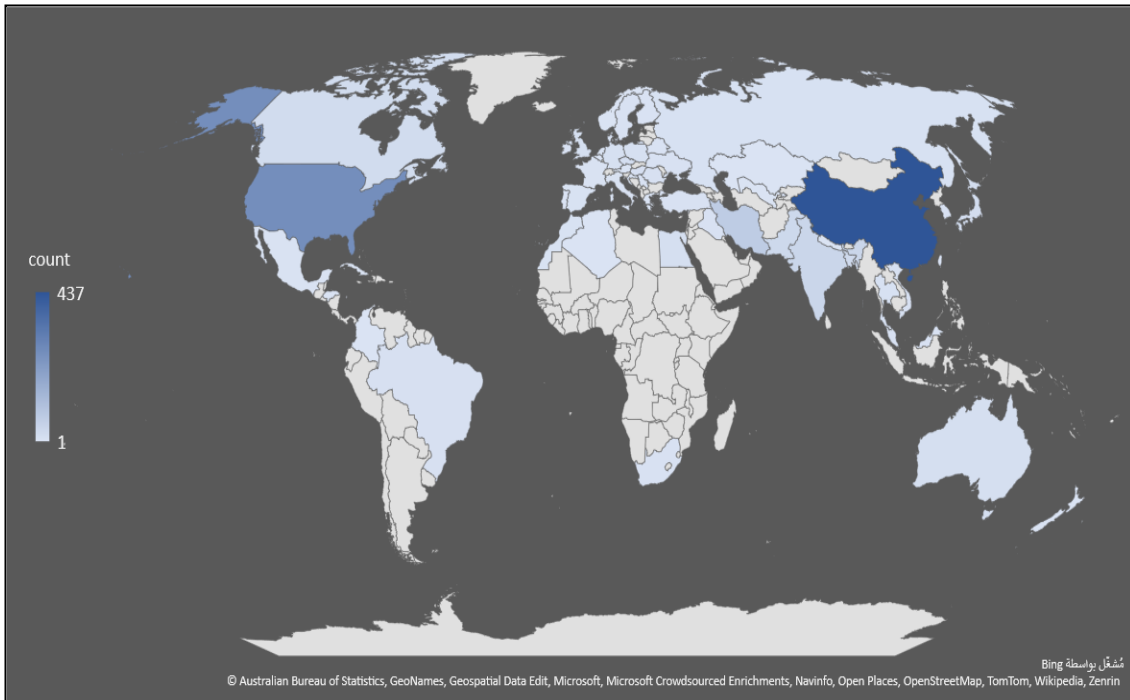


Fig. 2. Total number of publications from various nations worldwide. Lighter hues indicate fewer articles, whereas dark blue indicates the greatest amount of publications overall

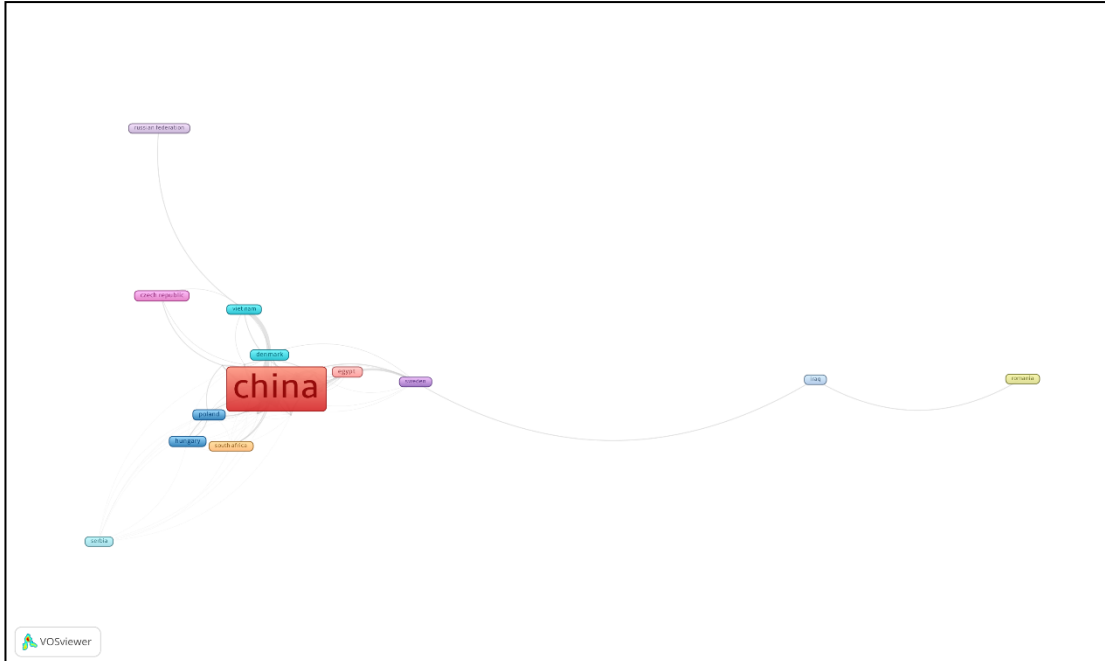


Fig. 3. Visualization map of international collaboration (co-authorship) by country for publications on silver carp

2. Productive and characteristics of journals

The top 10 journals for silver carp research articles are shown in Table (3). We found relevant papers from 466 journals in total. Food Chemistry had the highest number of publications (41), followed by aquaculture (33), and the North American Journal of Fisheries Management (40). Due to their low publication count, the remaining journals were left out. But Food Chemistry (16.3), which is Q1, had the highest Cite Score (2023), followed by LWT (16.3), which is also Q1. The research articles used in this study were taken from the Scopus databases and were chosen for their thorough and multidisciplinary coverage. Some of the most widely used databases in the world, Scopus is recognized for publishing high-caliber research publications and is said to cover over 7000 publishers and over 84 million records from 240 disciplines (Li *et al.*, 2018; Omotehinwa, 2022; Fernandes & Sukthankar, 2024).

Table 3. The top 10 highly productive journals on silver carp in the period (2003-2023)

Journal title	TP	TC	ND	Cite Score (2023)	Publisher
Food Chemistry (UK)	102 72	167 849	41	16.3 (Q1)	Elsevier (Netherlands)
North American Journal of Fisheries Management (USA)	554	142 0	40	2.6 (Q2)	John Wiley & Sons (USA)
Aquaculture (Netherlands)	480 3	412 68	33	8.6 (Q1)	Elsevier (Netherlands)
Biological Invasions (Switzerland)	998	601 9	28	6.0 (Q1)	Springer Nature (Germany)
Aquaculture Research (UK)	186 3	853 6	20	4.6 (Q2)	Hindawi (UK)
Hydrobiologia (Netherlands)	113 2	613 3	15	4.5 (Q1)	Springer Nature (Germany)
Environmental Biology of Fishes (Netherlands)	518	134 5	14	2.6 (Q2)	Springer Nature (Germany)
LWT (USA)	653 2	773 48	14	11.8 (Q1)	Elsevier (Netherlands)
Journal Of Aquatic Food Product Technology (USA)	315	109 1	13	3.5 (Q3)	Taylor & Francis (UK)
PLoS ONE (USA)	624 63	384 633	13	6.2 (Q1)	Public Library of Science (USA)

TP=Total publications; TC= Total citation; ND= Number of documents

3. Highest citation of journals

On the other hand, the article "Novel colorimetric films based on starch/polyvinyl alcohol incorporated with roselle anthocyanins for fish freshness monitoring" received the highest citation (411), followed by articles published in Food Chemistry (391, 341, and 321), which were related to the silver carp and the top 10 articles that were taken into consideration. When a journal is indexed in Scopus, it becomes available to a vast audience of academics and researchers who are actively searching for high-quality research articles. Thus, the study conducted inside Scopus concentrated on prominent scientists around the world who published in credible journals (such as Food Hydrocolloids, Food Chemistry, Aquaculture, and Nature). Since Scopus is a curated database, content is selected for inclusion through a rigorous procedure in which publishers and editors submit serial content (such as journals) to be considered for inclusion in the database. Strict and superior scientific criteria are used to evaluate and select the content (Baas *et al.*, 2020). Every journal is in Q1, except the Journal of Fish Biology, located in Q2.

Table 4. Highest citation for silver carp in journals

Journal title	Cite	Year	Research
Food Hydrocolloids (Netherlands)	411 (Q1)	2017	Novel colorimetric films based on starch/polyvinyl alcohol incorporated with roselle anthocyanins for fish freshness monitoring
Food Chemistry (UK)	391 (Q1)	2009	Effects of chitosan coating on quality and shelf life of silver carp during frozen storage
Food Chemistry (UK)	341 (Q1)	2008	The use of a tea polyphenol dip to extend the shelf life of silver carp (<i>Hypophthalmichthys molitrix</i>) during storage in ice
Food Chemistry (UK)	321 (Q1)	2008	Antioxidant and biochemical properties of protein hydrolysates prepared from Silver carp (<i>Hypophthalmichthys molitrix</i>)
Biological Conservation (Netherlands)	321 (Q1)	2015	Quantification of eDNA shedding rates from invasive bighead carp <i>Hypophthalmichthys nobilis</i> and silver carp <i>Hypophthalmichthys molitrix</i>
Food Hydrocolloids	298 (Q1)	2013	Preparation, properties and antioxidant activity of an active film from silver carp (<i>Hypophthalmichthys molitrix</i>) skin

(Netherlands)			gelatin incorporated with green tea extract
Nature (UK)	280 (Q1)	2021	Environmental performance of blue foods
Journal of fish biology (USA)	257 (Q2)	2007	Reduced condition factor of two native fish species coincident with invasion of non-native Asian carps in the Illinois River, U.S.A. Is this evidence for competition and reduced fitness?
Canadian Journal of Fisheries and Aquatic Sciences (Canada)	255 (Q1)	2013	Detection of Asian carp DNA as part of a Great Lakes basin-wide surveillance program
Environmental toxicology (USA)	244 (Q1)	2005	Organ distribution and bioaccumulation of microcystins in freshwater fish at different trophic levels from the eutrophic Lake Chaohu, China
The ISME journal (UK)	232 (Q1)	2014	Fish gut microbiota analysis differentiates physiology and behavior of invasive Asian carp and indigenous American fish
Aquacultural Engineering (Netherlands)	213 (Q1)	2020	Deep learning-based appearance features extraction for automated carp species identification
Biological invasions (Switzerland)	201 (Q1)	2009	Diet overlap among two Asian carp and three native fishes in backwater lakes on the Illinois and Mississippi rivers
Food Chemistry (UK)	196 (Q1)	2016	Determination of the effects of different washing processes on aroma characteristics in silver carp mince by MMSE–GC–MS, e-nose and sensory evaluation

4. Productive authors

In total, the 959 most-cited articles had contributions from 132 academics. However, studies were also done on the most prolific authors in the silver carp industry. The collaborative analysis carried out by the researchers was done with VOSviewer, as

indicated in Table (5) and Fig. (3). A bibliometric examination revealed that the most prolific authors were from China and the USA. "Luo Yongkang" was the most prolific author, with 268 total publications and the highest h-index (9,680 citations). "Xiong, Shanbai" was next, with 305 articles total, an h-index of 51, and 7,793 citations. In contrast, Coulter, Alison of the USA had an h-index of 12, the highest Hirsch index of 15,779 citations, and a total of 447 articles. Therefore, the majority of authors who have written on silver carp are from China or the USA. This is because of the basic circumstances surrounding this species. Due to their ability to filter-feed, bigheaded carp, also known as silver carp, were introduced in the 1970s for the purpose of controlling phytoplankton in aquaculture and wastewater treatment plants (Kolar *et al.*, 2007). As a result of their subsequent escape into natural streams, healthy populations were established, and they aggressively expanded their range northward through the Mississippi River Drainage Basin (Sass *et al.*, 2010), creating an unmanageable environmental issue. Another explanation is that freshwater aquaculture was initially created in China as a substitute for marine catch that was sluggish (Miao & Yuan, 2007). With more than 60% of the world's production (in volume), it is the biggest producer of aquaculture globally (Newton *et al.*, 2021). More than 40% of China's inland aquaculture production is derived from various carp species, making cyprinoids (Cyprinidae), which include silver carp and other species, the most important fish family in terms of commerce (Newton *et al.*, 2021).

Table 5. Top 10 authors based on total publications in the silver carp fields

Author	Year of 1st Publication	TP	h-Index	Current Affiliation	Country
Luo, Yongkang	2001	268	58	China Agricultural, Beijing, China	China
Xiong, Shanbai	2006	305	51	Key Laboratory of Environment Correlative Dietology, Wuhan, China	China
Coulter, Alison	2013	40	12	South Dakota State University, Brookings, United States	USA
Chapman, Duane	1995	68	24	Columbia Environmental Research Center, Columbia, United States	USA
Lamer, James Thomas	2008	47	12	Illinois Natural History Survey, Champaign, United States	USA
Garvey, James E.	1995	102	33	Southern Illinois University Carbondale, Carbondale, United States	USA
Hong, Hui	2012	172	39	China Agricultural University,	China

				Beijing, China	
Yin, Tao	2013	122	24	Key Laboratory of Environment Correlative Dietology, Wuhan, China	China
You, Juan	2015	100	29	Key Laboratory of Environment Correlative Dietology, Wuhan, China	China
Xie, Ping	1994	447	65	Institute of Hydrobiology, Chinese Academy of Sciences, Wuhan, China	China

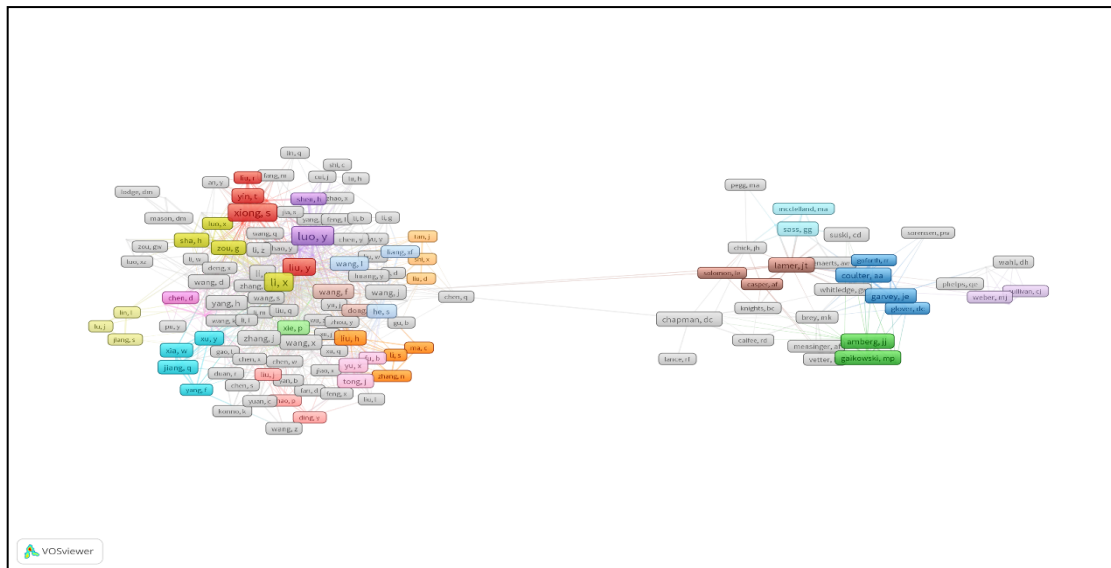


Fig. 4. Visualization map of analysis results of productive authors in silver carp

5. Articles by subject

The article percentages by subject are displayed in Fig. (5). It is observed that the top four specializations are 42.3% for Agriculture and Biological Sciences ($n = 714$); 18.1% for Environmental Science ($n = 306$); 8.5% for Biochemistry, Genetics, and Molecular Biology ($n = 144$); and 6.5% for Chemistry ($n = 109$). The remaining specializations have varying percentages. Every original research publication, in general, provides fresher viewpoints, research findings, methodological insights, and improved comprehension (Dutta, 2019). Finding relevant, current evidence and impact have become increasingly difficult due to the massive volume of information generated every day worldwide (Bahishti, 2021).

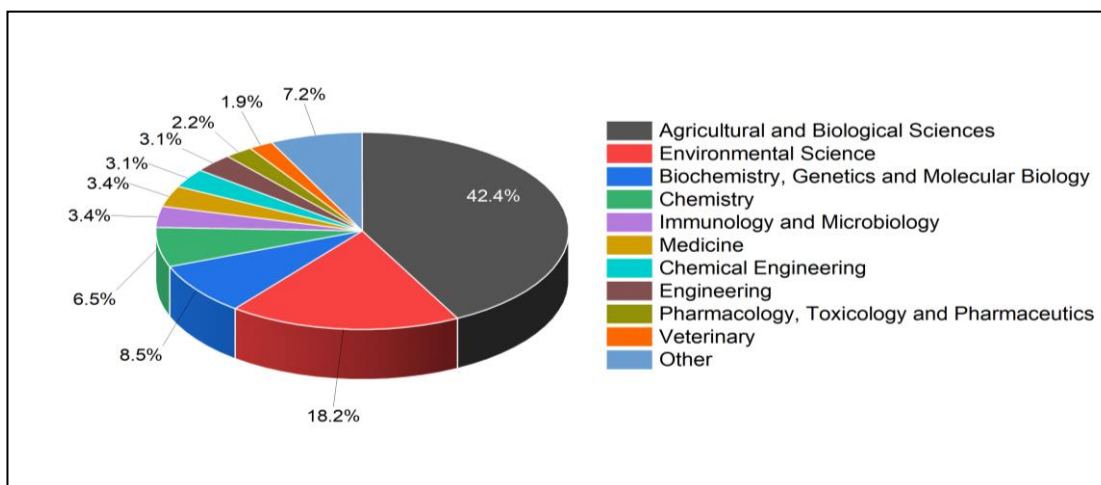


Fig. 1. The percentages of publications on the subject of silver carp

6. Top 10 Institutions

Furthermore, nations and organizations can provide more thorough information regarding studies conducted on the subject, including major research institutes and their partnerships (Yi-Run *et al.*, 2022). Thus, Table (4) suggests that the USA and China are at the top of the global silver carp research productivity scale. Publications on the topic were produced in collaboration with other governmental and academic institutions. Broadly speaking, nations and organizations can provide more in-depth information regarding studies conducted on the subject, including major research institutions and their partnerships (Yi-Run *et al.*, 2022). Universities and public research organizations are widely recognized as vital sources of innovation because they offer both technical people and cutting-edge scientific information (Whittington *et al.*, 2009).

Table 6. The top 10 research institutions in silver carp fields

Institutions	Country	ND
United States Geological Survey	USA	64
Ministry of Education of the People's Republic of China	China	61
Chinese Academy of Fishery Sciences	China	59
Chinese Academy of Sciences	China	58
Huazhong Agricultural University	China	57
Illinois Natural History Survey	USA	53
China Agricultural University	China	49
Ministry of Agriculture of the People's Republic of China	China	48
Institute of Hydrobiology, Chinese Academy of Sciences	China	43
Shanghai Ocean University	China	42

ND= Number of documents

CONCLUSION

This study represents the first bibliometric analysis of the silver carp research, highlighting the increasing number of experts in the field. This growth relates both to enhancing individual production and addressing the impacts of introducing a species often viewed as invasive, particularly in the context of fish from the USA. The findings provide a valuable resource for future research efforts, outlining key journals, influential authors, highly cited publications, and related topics of interest. Additionally, this analysis identifies potential collaborators among authors, institutions, and countries, guiding future scholarly endeavors in silver carp research.

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