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One Health and research with freshwater fish: A systematic review

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Abstract

Background and Aim: The concept of One Health, which aims to establish the association between human, animal, and environmental health, is dedicated to finding solutions to challenges such as the spread of zoonotic diseases. This study focuses on the conservation of freshwater fish and underscores the need for multi-and transdisciplinary approaches that emphasize the objective established by the concept.

Materials and Methods: In this context, this study conducted a systematic review, employing criteria for article selection and exclusion, where publications spanning from 1990 to 2022 were analyzed using the electronic databases Scopus, Web of Science, PubMed, SciELO, and Literatura Latino-Americana e do Caribe em Ciências da Saúde.

Results: Using the keywords "One Health," "fish," and "freshwater," a comprehensive collection of 2392 articles was identified. However, after a meticulous evaluation, only 12 articles fully satisfied the review criteria. These selected articles, published between 2015 and 2022, were primarily concentrated in Asia and Africa. Notably, the focal points of these articles addressed antimicrobial resistance, parasites, and heavy metals, which are challenges associated with consuming contaminated fish.

Conclusion: Thus, the One Health approach is the most efficient method for managing environmental risks. By harnessing the collaborative efforts of diverse professionals and experts in the fields of environmental, human, and animal health, this approach serves as a robust framework for addressing challenges involving the triad of human, animal, and environmental spheres.

Keywords: animal health, antimicrobial resistance, heavy metals, human health, parasites.

Introduction

The concept of One Health presents an inseparable triad between humans, animals, and environmental health, serving as a strategy response to mitigate complex environmental challenges. For example, we understand that the way we use land can contribute to public health challenges due to exposure to infectious bacteria and agents while preventing the spread of zoonotic diseases [1, 2]. By uniting several fields of science, this approach presents an interdisciplinary and multisectoral character, facilitating communication among professionals from various fields [1].

It is significant to recognize that aquatic environments carry various types of infections by human pathogens, which also affect organisms [3, 4]. Modern-day environmental challenges, such as climate change, biodiversity loss, flooding, and acid rain, are characterized by human intervention in the natural environment. Consequently, freshwater fish are also potential victims of this human intervention [3], being able to carry pathogens that reach the human species through consumption or the intricate web of the food chain. For example, diphyllobothriasis, a disease caused by a freshwater or saltwater fish parasite (*Diphyllobothrium latum*), and anisakiasis, a zoonosis caused by the nematodes *Anisakis simplex*, *Pseudoterranova decipiens,* and *Contracaecum osculatum* [5], are both capable of attacking human beings.

In addition, we can mention the involvement of nematodes belonging to the genus *Eustrongylides*, which are dispersed across all continents [6]. With indirect life cycles and wide distribution, these parasites have birds as definitive hosts, and fish and oligochaetes as secondary hosts [7]. *Eustrongylides* spp. also have a zoonotic importance because it triggers symptoms such as gastritis and intestinal perforation [8].

Another challenge to consider in the One Health approach is the introduction of invasive species, especially in freshwater ecosystems. Fish play an essential

role in determining the distribution of other organisms, aligning with water quality and the overall ecosystem. Thus, the introduction of invasive species and the ensuing interspecific competition results in the extinction of natives fluently influencing socioeconomic dimensions allied with human communities, which depend on the aquatic ecosystem for survival [9].

Sultana and Hashim [10] reported that eight common fish, including *Carassius auratus*, *Cyprinus carpio*, *Oncorhynchus mykiss*, *Oreochromis mossambicus*, *Poecilia reticulata*, *Salmo salar*, *Salmo trutta,* and *Salvelinus fontinalis* are the invading alien fish on all continents, except in the Antarctic. In contrast, in several cases, exotic fish also positively impacted aquaculture production and effective management. Galvão *et al.* [11] reported that non-native species such as *C. carpio* and *Oreochromis niloticus* in Brazil are invasive and deleterious species with a high potential for native fish diversity, according to ecological risk assessment studies.

With this in mind; and understanding the importance of establishing a relationship between the triad determined by the One Health approach, especially concerning freshwater fish, this study conducted a systematic review of the literature, including criteria for selection and exclusion of articles to assess the existence of studies addressing freshwater environment fish from the One Health perspective.

Materials and Methods

Ethical approval

Ethical approval was not required for this study, because it was based on a literature review.

Study period and location

Data were extracted and interpreted from June 2022 to August 2022 at Paulista University.

Experimental design

This systematic review employed specific criteria for selecting and excluding articles. The scope of the analysis involved publications spanning from 1990 to 2022. These studies were assessed using electronic databases of indexed journals such as Scopus, Web of Science, PubMed, SciELO, and Literatura Latino-Americana e do Caribe em Ciências da Saúde. We chose to use the Preferred Reporting Items for Systematic Reviews and Meta-Analyses recommendation, namely a checklist with 27 items and 1 flowchart to help authors improve the quality of their systematic reviews and meta-analyses [12]. The keywords involved were "One Health", "fish" and "freshwater" (Table-1).

Inclusion and exclusion criteria (Table-1)

The inclusion criteria were articles and periodicals published between the years 1990 and 2022, with access and download free of charge and in English, which addressed freshwater fish in a One Health context. Articles in languages other than English were excluded, which did not cover the topic addressed.

Statistical analysis

To facilitate the process of article screening, StArt (State of the Art through Systematic Review; created by the Research Laboratory in Software Engineering, located at the Federal University of São Carlos (UFSCar), São Carlos, São Paulo, Brazil) 3.0.3 software was used. This software was used to screen the information obtained according to the inclusion and exclusion criteria of the protocol adopted in the review. Thus, the software guided the evaluation process through two main stages: Selection and extraction, during the selection phase, all articles found through the application of keywords were exported, and only primary studies were subjected to screening. The extraction stage, in contrast, consists of the final selection of articles that aligned with the selection criteria. The publications were obtained with the subsidy of Portal de Periódicos da Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES) due to the agreement of the Universidade Paulista, which allowed access to journals.

Results

With the adoption of the aforementioned keywords, a total of 2392 articles were identified (Table-2). After careful search and screening measures, 11 articles were rejected due to duplicate attributes. Among the resulting articles, 2361 addressed other biological groups from non-objective perspectives imposed by the study. Among the remaining 20 articles that employed intrinsic relationships between One Health and fish, eight were reviews rather than primary ones. Consequently, 12 final articles met all the criteria pre-established by this systematic review (Figure-1 and Table-3) [12–23].

The places of publication varied relatively, reflecting a notable focus on the Asian (n = 4; 33.33%) and African (n = 3; 25%) continents. Noteworthy, contributors included countries such as China (n = 2;

Table-1: Combination of terms used in searches performed in databases, in the fields "title," "abstract," and "author keywords," along with the selection and exclusion criteria adopted in the review.

Keywords	Inclusion criteria	Exclusion criteria
(One Health) AND (fish) AND (freshwater)	Primary study Written in Portuguese or English Approach about fish from a One Health perspective	Preprint Do not present summary in the established databases Meta-analysis, review article, gray literature, book chapter or Other Do not approach about fish Published in languages other than those selected

16.67%), the United States, Brazil, and Italy, each contributing an article (8.33%). The distribution between regions is shown in Figure-2.

Examining the years of publication, an increase in the number of studies with freshwater fish was observed (among other aquatic organisms) from a One Health perspective from 2015, with the largest number of studies (n = 4; 33.33%) published in 2020. The selected articles predominantly addressed three thematic axes: Antimicrobial resistance (AMR), conducted in seven studies (58.33%); parasites (n = 3; 25%); and heavy metals, featured in three articles, one of which was inserted within the context of AMR (16.67%). Notably, all of these studies were inherently linked with the consumption of contaminated fish.

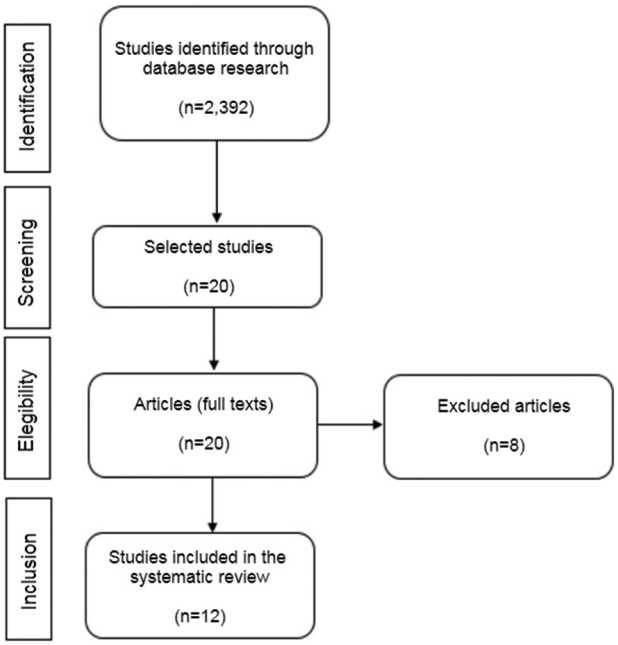

Figure-1: Flow chart of search and analysis of articles found.

Table-2: Distribution of the articles found and selected in the first moment (selection stage) by the databases.

Databases	Articles found
Scopus	389
Web of science	1.132
PubMed	866
SciELO	5
LILACS	0
Total	2.392

LILACS=Literatura Latino-Americana e do Caribe em Ciências da Saúde

Discussion

This review report underscores the existence of 12 articles on freshwater fish and their conservation from a One Health perspective. Interestingly, even among the vast diversity of species, certain countries have shown limited attention to this subject. For instance, despite Brazil possessing over 2400 freshwater fish species until 2007 [25], only one study centered on this theme. Likewise, countries such as India (n = 1003), the United States (n = 963), Vietnam (n = 731), Nigeria (n = 311), and Uganda (n = 274) each exhibited only one study with freshwater fish. In contrast, China and Thailand showed the presence of two studies, with 1621 and 828 species, respectively [26].

Antimicrobial resistance and its relation to freshwater fish in the context of One Health

Antimicrobial resistance refers to the capability of microorganisms, whether bacteria, viruses, fungi, or parasites, to grow and multiply in the presence of an antimicrobial. This phenomenon can occur naturally due to mutations or under certain selective pressure [27, 28].

Alhaji *et al*. [12] addressed AMR in freshwater fish farms. For approximately 2 years, the authors conducted a survey of fish farmers in urban and rural areas. As a result of the questionnaire distributed among the participants, 78.1% (118/151) of the respondents reported using antimicrobials in their fish farming activities.

Regarding the indiscriminate use of antimicrobials in aquaculture systems, Brunton *et al*. [13] examined two aquaculture systems in Vietnam, which cultivate *Plotosus lineatus* (catfish-eel-striped) and *Litopenaeus vannamei* (white-legged shrimp) to

Table-3: Articles selected for review according to their respective authors, places of study, journals and databases where they are indexed.

Author, year	Place of publication	Journal	Database
Alhaji *et al*. 2021 [12]	Nigeria, West Africa	Food control	Scopus
Brunton *et al*. 2019 [13]	Vietnam, Southeast Asia	Science of the total environment	Scopus
Sapugahawatte *et al*. 2022 [14]	Hong Kong, China	Antibiotics	PubMed
Das *et al*. 2020 [15]	Khorda, India	JMIR research protocols	Scopus
Cerdeira *et al*. 2020 [16]	Belém, Brazil	Genomics	Scopus
Minja *et al*. 2021[17]	Tanzânia, East Africa	Antibiotics	Scopus
Sapugahawatte *et al*. 2020 [18]	Hong Kong, China	mSphere	PubMed
Pace *et al*. 2020 [19]	Naples, Italy	Animals	Web of science
Sripa *et al*. 2015 [20]	Northeastern Thailand, Thailand, Southeast Asia	Acta Tropica	PubMed
Sripa *et al*. 2017 [21]	Thailand, Southeast Asia	Parasitology international	PubMed
Melnyk *et al*. 2021 [22]	Maine, United states	Science of the Total environment	PubMed
Andrew *et al*. 2016 [23]	Uganda, East Africa	Cogent Food and agriculture	PubMed

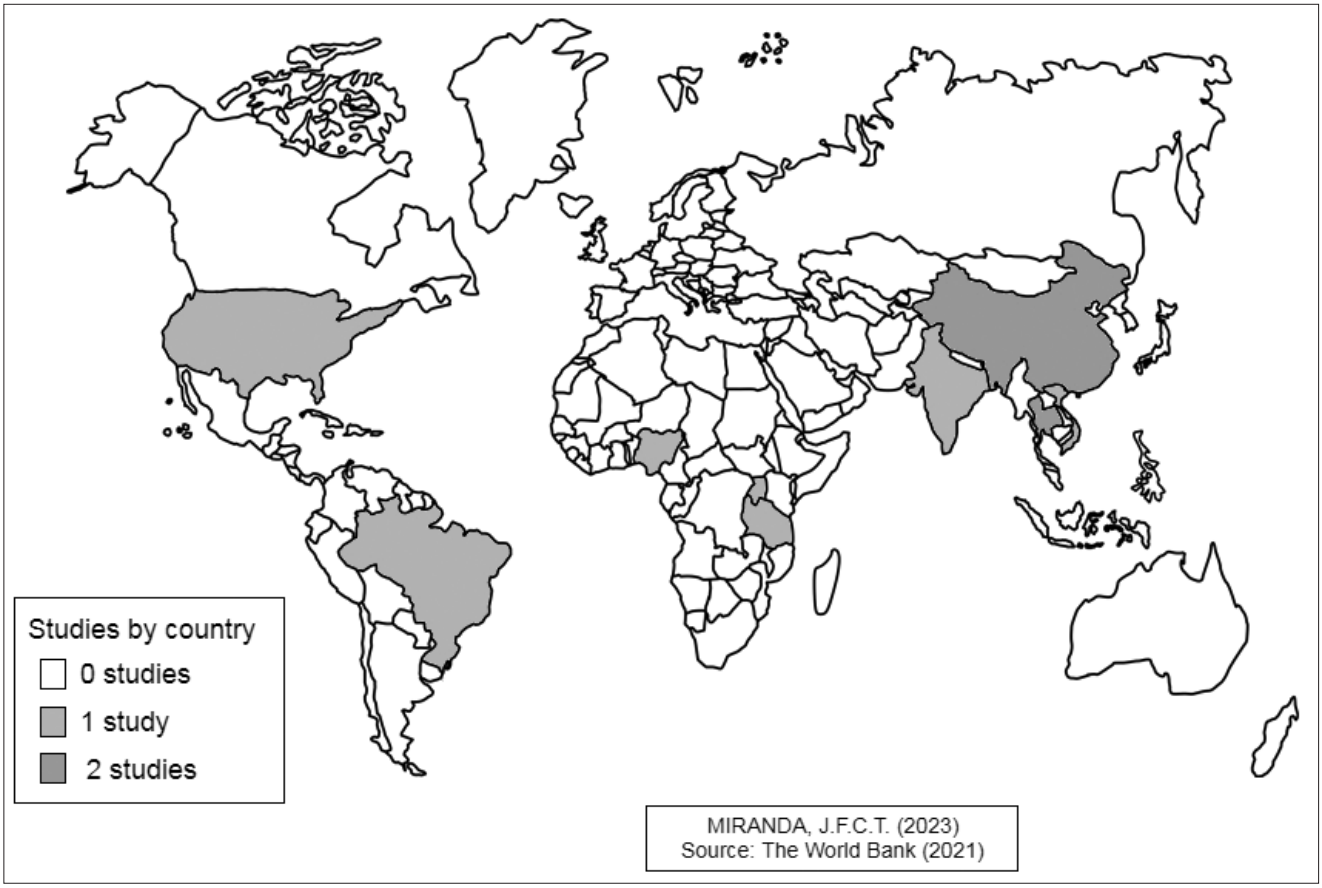

Figure-2: Number of publications distributed by continent and countries between 1990 and 2022 [Source: https://maps.worldbank.org/].

identify emergency hotshots of antibiotic-resistant bacteria attributed to human exposure. Thus, the results revealed that the growth stage of individuals is crucial for the emergence of highly resistant bacteria due to the exacerbated use of antimicrobials and the consequent exposure to contaminated water.

Sapugahawatte *et al*. [14] isolated 252 strains of *Streptococcus agalactiae* from 992 individuals of freshwater fish and 361 pigs purchased from wet markets in Hong Kong. This study highlighted the presence of *S. agalactiae* in fish intended for human consumption. As a methodology, the authors adopted the use of antibiotics such as ciprofloxacin, levofloxacin, gentamicin, and others, and observed that AMR was scarce in fish, but significant in pigs.

Das *et al*. [15] conducted a surveillance protocol aimed at documenting patterns of infection and resistance of some bacteria (n = 7) in the host groups such as humans, cattle, birds, and freshwater fish, as well as the risks offered by microorganisms from a one health perspective. The findings showed that the use of antibiotics for therapeutic purposes between organisms, and non-therapeutics (for livestock), can allow the establishment of a relationship with the pattern of resistance, and intervention actions regarding public, animal, and environmental health.

A study conducted by Brazilian researchers [16] sought to characterize the AMR burden of pathogens critical to the World Health Organization (WHO) [28] a strain of *Klebsiella pneumoniae* isolated from an Amazonian freshwater species (*Brachyplatystoma filamentosum*). After microbiological analysis, it was determined that native freshwater fish sold in wet markets, especially in Amazonian regions, are potential propagators of bacteria with multidrug resistance to humans.

Regarding bacterial enzymes, Minja *et al*. [17] studied plasma carriers of beta-lactamase blaCTX-M-15 from both humans and animals, which also include freshwater fish, determining conjugation frequencies to understand the spread of genes highly resistant to various antibiotics and thus establish a relationship with the circulation of bacterial species between humans and animals. As a result, the bacterium *Escherichia coli* was the dominant species in all samples collected, indicating a public health challenge because the interaction between animals, humans, and the environment allows the exchange and reserve of resistant pathogens.

In addition, on beta-lactamases, Sapugahawatte *et al*. [18] examined 730 animal samples, among these, 411 samples were obtained from two freshwater species, and the remaining 339 samples were from pigs. The focus of the study was on animals carrying beta-lactamase-producing bacteria, specifically *Enterobacteriaceae* (ESBLs and

carbapenemase-producing *Enterobacteriaceae*. This study demonstrated the presence of ESBL-E genes in fish from the Hong Kong wet market. Thus, the authors highlighted the need for monitoring and control of AMR in aquaculture, as well as detailed analyses of these genes to assess the potential zoonotic spread between animals and humans.

Parasites and freshwater fish in the context of One Health

Parasitism in freshwater fish has a high economic impact on fish farming [29]. As highlighted by Pace *et al*. [19], an alarming statistic reveals that approximately half a billion people are at risk of infections caused by flukes, which are transmitted through improper fish consumption. The severity of these infections depends on various factors, including the parasite species and the specific location within the host organism. Notably, the gills of fish are particularly vulnerable to infection, which can lead to critical outcomes like asphyxia and even death. Several parasites of freshwater fish have been described worldwide, most of which are easily and rapidly transmitted, especially in small environments such as tanks [29].

The study conducted by Pace *et al*. [19] in Italy extends its focus beyond fish's economic and food power but also those used in the laboratory, such as *Danio rerio* (zebrafish), commonly affected by *Centrocestus formosanus*, a generalist parasite capable of inducing death to the animal. Recognizing this concern, the researchers devised an innovative technique to identify *C. formosanus* within the laboratory environment, thereby, providing a faster and more effective discovery of the protozoan and intervention measures that minimize infection by other organisms.

The study addressed in the work by Sripa *et al*. [20] in Thailand describes *Opisthorchis viverrini*, as a significant zoonotic worm, commonly referred to as human liver worm. Poor public health conditions, contaminated food sources, inadequate sanitation, and the lack of preventive and socioenvironmental measures have created a concerning situation. People in this region are at risk due to the consumption of fish infected with these worms, which can ultimately lead to severe liver ailments such as cancer. The study aims to raise awareness regarding environmental concerns and come up with a project with intervention measures on Lake Lawa as an alert on environmental concerns and to search for preventive measures that can restore the balance of ecosystem health, drawing the attention of the WHO to the challenges involved in One Health.

A more recent study offered results obtained up until the year 2017 regarding the Lawa project, where the lake was treated with drugs for the control of worms and constant monitoring of the ecosystem. The project encompassed educational efforts centered on environmental and health awareness, targeting schools and communities in the region. Notably, the prevalence of infections caused by the protozoan *O. viverrini* C, among individuals living around the lake significantly declined due to these interventions. The success of this project stands as a noteworthy example and serves as a blueprint for regions worldwide that require similar attention and care [21].

Heavy metals and freshwater fish in the context of One Health

Cerdeira *et al*. [16] reported for the first time the identification and genomic characteristics of a multiresistant strain of *K. pneumoniae*. This specific strain was traced to freshwater catfish, a stable human consumption in the markets of the Amazon region in Brazil, characterizing a risk to human health. The analysis of this sequencing revealed a large resistome, a set of genes that provide resistance to antibiotics, heavy metals, and disinfectants. Thus, native freshwater fish from the Amazon region can act as a vehicle for transmission of these multidrug-resistant bacteria to humans. The authors also propose that this study can serve as a new vision for the dissemination of pathogens, which is a critical priority of the WHO based on the concept of One Health.

In the study by Melnyk *et al*. [22], the focus was on measuring mercury levels in anadromous fish across two successive spawning seasons, specifically, in 2017 and 2018, to assess their potential risks to humans and wildlife. To achieve this, the researchers selected six species of fish known for their migratory behaviors, covering various trophic levels within the Penobscot River in Maine. Subsequently, the results obtained were compared with the reference doses established by the United States Environmental Protection Agency. The researchers concluded that the higher the trophic level of the species analyzed, the greater the amounts of mercury obtained and bioaccumulated, indicating the high impact of this metal on marine life. Thus, since fish are the main source of fatty acids (Omega 3), this study proposes that all efforts should be made to reduce the sources of mercury disposal, thus seeking to minimize exposure to wildlife and human life.

Andrew *et al*. [2] conducted a comprehensive examination of mercury levels in the musculature, abdomen fat, and liver of two distinct species of tilapia sourced from Lake Albert in Uganda. The study was conducted under the justification that there are not enough studies related to the monitoring of mercury levels in fish species predominantly consumed by fishing communities, so the limits recommended by the Food and Agriculture Organization and WHO may be exceeded. The analyzes indicated that the fish consumed by the fishing communities are smaller, offering less risk of mercury contamination, whereas tilapia accumulated more mercury in the muscle and liver. Thus, the researchers concluded that some species of fish should not be consumed, as a basis for future studies and the development of public policies regarding the absorption of mercury from fish by more vulnerable communities in developing countries.

Conclusion

With the analysis of the 12 selected scientific articles, there is a need for dissemination on One Health, in line with the opening of discussions within the scientific community, and the general population, to reflect the significance that involves the conservation of freshwater fish, their habitats (rivers, streams, lakes, streams, floodplains, and mangroves) and the infeasibility of the spread of diseases and pathogens arising from these organisms and ecosystems.

Environmental diseases primarily stem from the lack of basic sanitation measures, making the scenario conducive to the development of vectors and the emergence of diseases. Contaminated river waters, due to the absence of sewage networks, are also a predisposing factor for the contamination of fish consumed by communities. It is crucial for interdisciplinary involvement and wide dissemination in a simple didactic language, although well elaborated so that the concepts and pillars of One Health are established and there is union and collaboration among the scientific community, population, and government.

The One Health approach is the most efficient method for managing environmental risks because several professionals and experts in environmental, human, and animal health collaborate to solve challenges involving the triad of human, animal, and environment.

Authors' Contributions

WSS: Conceptualization and writing – edition and revision. JFCTM, KFSR, BRRC, JRA, VS: Data collection and writing – original draft. All authors have read, reviewed, and approved the final manuscript.

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Competing Interests

The authors declare that they have no competing interests.

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