Zebrafish in Brazilian Science: Scientific Production, Impact, and Collaboration

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Abstract

By means of scientometric indicators, this study investigated the characteristics of scientific production and research collaboration involving zebrafish (*Danio rerio*) in Brazilian Science indexed by the *Web of Science* (WoS). Citation data were collected from the WoS and data regarding Impact Factor (IF) were gathered from journals in the *Journal Citation Reports*. Collaboration was evaluated according to coauthorship data, creating representative nets with VOSviewer. Zebrafish has attained remarkable importance as an experimental model organism in recent years and an increase in scientific production with zebrafish is observed in Brazil and around the world. The citation impact of the worldwide scientific production is superior when compared to the Brazilian scientific production. However, the citation impact of the Brazilian scientific production is consistently increasing. Brazil does not follow the international trends with regard to publication research fields. The state of Rio Grande do Sul has the greatest number of articles and the institution with the largest number of publications is Pontifícia Universidade Católica do Rio Grande do Sul. Journals' average IF is higher in Brazilian publications with international coauthorship, and around 90% of articles are collaborative. The Brazilian institutions presenting the greatest number of collaborations are Pontifícia Universidade Católica do Rio Grande do Sul, Universidade Federal do Rio Grande do Sul, Fundação Universidade Federal de Rio Grande, and Universidade de São Paulo. These data indicate that Brazilian research using zebrafish presents a growth in terms of number of publications, citation impact, and collaborative work.

Introduction

ZEBRAFISH (*DANIO RERIO*) has attained remarkable importance as an experimental model organism in recent years. The similarity between zebrafish and human genes stimulates its use as a complementary/alternative model organism in scientific research. In Brazil, zebrafish is popularly known as “paulistinha,” “peixe zebra,” or even zebrafish.¹ This study aimed to identify, through the use of scientometric indicators, some characteristics of the scientific production, research collaboration, and impact of zebrafish articles in Brazilian Science indexed by the *Web of Science* (WoS).

Danio rerio (Hamilton 1822) is a fish that belongs to the *Cyprinidae* family.² Its genetic information is decoded, presenting a high level of homology (around 70%) to the human counterparts.³ As drug discovery and potential technological innovation for drugs synthesis still depend on biological trials, zebrafish includes significant features for meeting the three Rs criteria (*replacement, refinement, reduction*). Due to its evolutionarily conserved genetic and biochemical mechanisms, the use of zebrafish in screening reduces the use of

larger size animals, in a first instance, as well as the amount of compounds required for trials (since those can be administered intraperitoneally at a lower dose).⁴

The Brazilian Council for Animals Testing (CONCEA, *Conselho Nacional de Controle de Experimentação de Animais*), an agency associated with the Ministry of Science, Technology and Innovation, established in 2014 the Normative Resolution, number 17, which regulates the recognition of alternative methods for the use of animals in researches throughout Brazil. Alternative methods defined by CONCEA include procedures that may replace, reduce, or refine (three Rs) animal use.⁵

The first researcher to use the zebrafish in scientific community was the biologist George Streisinger, from Oregon University, United States. His article entitled *Production of clones of homozygous diploid zebrafish (Brachydanio rerio)*, published in 1981, in the journal *Nature*, is considered “the milestone in translational medicine”.¹

Scientometric analyses can be used to measure the impact of the scientific literature in science development. Technological advances have stimulated the use of metric parameters

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to measure production, impact, investments, and human capital.⁶ Scientometric indicators are the core of discussions to evaluate science and technology development and also to (re)set public policies.⁷ Methodological–theoretical basis for scientometric methods arise from bibliometrics, as it is associated to production process measurement, communication, and use of registered information.⁸

Tague-Sutcliffe⁹ defines bibliometrics as the study of quantitative aspects of production, dispersion, and use of registered information. It uses mathematical models and standards. Scientometrics is defined as the study of science quantitative aspects, as a discipline or economic activity,⁹ which analyzes scientific production evolution from publication indicators.¹⁰

Macias-Chapula proposed some scientometric indicators: production (number of publications), citation impact (the number of citations of publications), and coauthorship (publications with national or international collaboration).⁷ In addition, the Journal Impact Factor (IF) is an indicator used for evaluating scientific journals. IF measures the number of citations of articles 2 years after their publication (*Journal Citation Reports [JCR], Thompson Reuters*).¹¹ Journal IF was created by Garfield and Sher,¹² in 1963, as a way to measure journals' quality. IF is measured by the number of citations received divided by the number of articles published by the journal. Brazilian development agencies, such as *Coordenação de Aperfeiçoamento de Pessoal Nível Superior* and *Conselho Nacional de Desenvolvimento Científico e Tecnológico* (CNPq), use IF to evaluate the researchers community.¹¹

The citation impact is a measurement of scientific publications usability.^{7,13} Among the several uses for citations, which were identified by Weinstock,¹⁴ in 1971, we emphasize paying homage to pioneers, giving credit to related work, identifying methodology, offering background reading, validating data, substantiating claims, analyzing previous work, informing researchers of forthcoming work, rectifying ones' own work, rectifying the work of others, identifying the original publications in which an idea or concept is discussed, identifying original publications that describe concepts or eponym terms, disputing work or idea of others, and disputing the primacy of others' claims.⁷

Coauthorship action arises from affinities and common goals to be reached. Collaboration levels can be recognized as “Intra” or “Inter.” The first one includes national collaboration established among individuals of the same group, department, institution, sector, or nation. The last one includes international collaboration, with the same characteristics of national collaboration.¹⁵

Production is related to scientific findings disclosure, acknowledgment, and intellectual property. Published articles reflect a country's science products (ideas),⁷ and scientific research is essential to stimulate and share information worldwide.¹⁰ Considering that zebrafish use has substantially increased in scientific research, the current report can serve as a basis for resetting public policies for the development of new scientific centers of zebrafish research and/or for investing in improvements on the existing ones. As there are no scientometric studies involving Brazilian studies with zebrafish, this study can be useful to the scientific community with regard to understanding some characteristics of Brazilian scientific production and its development.

Materials and Methods

This research consists of a scientometric study using production, impact, and collaboration indicators,⁷ collected from scientific zebrafish-related publications, having at least one author from a Brazilian institution.

Data were collected from the WoS database, which belongs to the *Institute for Scientific Information*, of the group *Thompson Reuters*, on March 3rd, 2015, using access by “Web of Science Main Collection.” The term selected in the search field was “Zebrafish” and, as a second field option, the Boolean operator “OR” with the term “*Danio rerio*”. The types of documents selected were *articles*, *proceeding paper*, and *review*. The period of this study is from 1955 to 2014. The results covered 25,480 publications, matching worldwide scientific production. Then, the option “Refine results” for delimiting search by country was selected, in this case “Brazil.” The results showed 318 publications with researchers stating connection to Brazilian institutions in their affiliation. The amplitude of indexed work containing the terms that are investigated in this article motivated the choice for WoS. All data collected were imported and normalized in Microsoft MSeExcel®.

For determining the citation impact of the Brazilian and worldwide scientific production, a period of 3 years was selected following the JCR methodological criteria: the sum of citations divided by the number of publications. In this study, the citation impact corresponds to the years of 1999, 2002, 2005, 2008, 2011, and 2014.

We identified the research fields of Brazilian and worldwide scientific production. These fields were obtained from the WoS categories. The objective was to observe if Brazil follows the same worldwide research trends. In addition, we identified the main journals used for publication by both communities.

Hereinafter, we focused on the characteristics and trends of Brazilian scientific production. To identify scientific communication tendencies, the origin of the journals was checked, considering if the publications were from Brazilian or foreign journals.

We have also identified corresponding Brazilian authors to their institutional affiliation obtained through *Instituição de Ensino Superior* (Higher Education Institution) and the institution's Federal State. The analysis was performed using corresponding authors because of their significant role as mediators (research team and editing journals), as researchers responsible for possible reviews and, in some cases, for a project.

Then, we evaluated the IF of journals covered in the JCR. The IF collected refers to the year 2013. We divided the whole sample into three groups for calculating IF as follows: group A—production with Brazilian corresponding author without international coauthorship; group B—production with Brazilian corresponding author with international coauthorship; and group C—production with international corresponding author with national coauthorship. The establishment of these groups permitted the evaluation of the connection between IF and the type of coauthorship established: national or international.

To better express the coauthorship and to visualize the institutions involved, we opted for a division by periods (1996–2000, 2001–2005, 2006–2010, and 2011–2014).

The coauthorship net was created using VOSviewer. Using a symmetrical matrix, this tool provides data relative to the

FIG. 1. Increase in the number of scientific production using the “zebrafish” term as subject worldwide (1955–2014) and in Brazil: shows the increase in scientific production on zebrafish in Brazil and in the world from 1955 to 2014. On the *left (black)*, the *line* represents the increase in number of publications worldwide. On the *right (gray)*, the *line* represents the increase in number of publications in Brazil.

number of links of the institutions. It is possible to visualize the established coauthorship nets using net figures. Institutions with greater amount of links are prominent in the net figures. The analysis emphasizes the three Brazilian institutions with the greatest number of collaborations. The Brazilian institution names are abbreviated. The foreign institution names are written in full, specifying the country.

Results and Discussion

The worldwide scientific production on the subject zebrafish comprises 25,480 publications (Fig. 1). The first article dates from 1955.¹⁶ The countries with greater production on the subject are the United States (11,107), Germany (2889),* and China (2638). Brazil is at the 20th position (318). From 1955 to the end of the 1980s, we did not verify a significant increase in the global scientific production, which intensely increased since the 1990s.

Brazilian scientific production on zebrafish started in 1996.¹⁷ From this year to 2014, the number of publications was 318, with an increasing number of articles up to 2007. Only in 2014, 75 articles were published, a 56% increase compared to the previous year.

Figure 2 shows the citation impact in the world and Brazil, using a 3-year window. The periods analyzed are 1999, 2002, 2005, 2008, 2011, and 2014. From the 2002 period, we excluded an article¹⁸ of the Brazilian production, which was responsible for 62% of all citation impact.

The citation impact of the worldwide scientific production is higher compared to that of the Brazilian production.

However, over the course of the analyzed periods, we have observed that the citation impact of the scientific production in Brazil is constantly increasing, with a relatively superior growth rate than that of the worldwide production's citation impact. This citation impact growth trend minimizes the differences with regard to visibility and research results impact in the scientific community. In addition, it reveals that the research results are been used as reference for other studies.

We have established a comparative study of the research fields (obtained from the WoS categories), utilizing only the fields that were individually responsible for more than 10% of all the publications in Brazil and in the world (Table 1).

FIG. 2. Citation impact: Brazilian and worldwide scientific production. Citation impact data were collected from 1999 to 2014.

TABLE 1. WEB OF SCIENCES PUBLICATIONS CATEGORIES IN BRAZIL AND THE WORLD

Country	Web of Sciences categories	Number of publications
Brazil	TOXICOLOGY	74
	NEUROSCIENCES	51
	BIOCHEMISTRY	46
	MOLECULAR BIOLOGY	
	ENVIRONMENTAL SCIENCES	44
	ZOOLOGY	42
	DEVELOPMENTAL BIOLOGY	32
	PHARMACOLOGY	32
World	PHARMACY	
	DEVELOPMENTAL BIOLOGY	5344
	BIOCHEMISTRY	4017
	MOLECULAR BIOLOGY	
	CELL BIOLOGY	3066
	GENETICS HEREDITY	2603

Comparative study of the research fields (Web of Science Categories) individually responsible for more than 10% of the publications in Brazil and in the world.

We have observed that the publications in Brazil are concentrated in seven research fields, while in the world they are concentrated in four. In addition, according to the results, Brazilian research does not follow the same publication field trends as the worldwide scientific production.

Two research fields are observed in both communities: Biochemistry Molecular Biology and Developmental Biology. Therefore, in Brazil, there are five predominant research fields that are not represented in the main categories of the worldwide scientific production, including the two containing the most publications: Toxicology and Neuroscience. This exclusive prevalence of these two important research categories in Brazil probably reflects the global increase in

number of Brazilian publications in the fields Toxicology¹⁹ and Neuroscience.^{20,21}

From 1996 to 2014, Brazilian researches were published in 155 journals, with 97% of them being foreign journals. The other countries' studies, corresponding to the worldwide scientific production, were published in 2266 journals. In Brazilian scientific production, eight journals published, each one, more than 2%, representing, in its totality, 5.16% of all the publications. In the worldwide production, five journals published, each one, more than 2% of all publications, representing, in its totality, 0.22% of publications (Table 2). Thus, the Brazilian research publications are concentrated in a larger number of journals than the international ones. The journal *PLoS One* stands out among the most used by researchers from both communities. We have observed that the Brazilian researchers publish in journals with lower IF than scientists from other countries.

The data presented earlier show some characteristics and trends of the Brazilian and worldwide scientific production. The Brazilian scientific production with zebrafish distinguishes itself from the worldwide scientific production in three aspects: (1) the citation impact improvement over the last 15 years; (2) use of different journals for research results publication; and (3) different field research trends.

Hereinafter, we describe other characteristics and trends of Brazilian scientific production. The following aspects were observed: (1) corresponding authors with higher productivity, institutional bond, and cities where they work; (2) connection between the IF of the journals and international and national coauthorship; and (3) Brazilian institutions with the largest number of established collaborations.

Among 318 publications, 257 pointed to a Brazilian researcher as the corresponding author. In the other 61 publications, the corresponding authors came from the following countries: the United States (26), England (7), Holland (5), Scotland (4), Spain (4), Portugal (3), Germany (3), Canada

TABLE 2. JOURNALS RESPONSIBLE FOR MORE THAN 2% OF ALL PUBLICATIONS IN BRAZIL AND IN THE WORLD (1996–2014)

Country	Title journal	Journal country territory	Number of publications	Impact factor (2013)	%
Brazil	<i>PLoS One</i>	United States	12	3.534	5.16%
	<i>Zebrafish</i>	United States	11	1.772	
	<i>Comparative Biochemistry and Physiology C Toxicology Pharmacology</i>	United States	11	2.829	
	<i>Aquatic Toxicology</i>	Netherlands	10	3.513	—
	<i>Zygote</i>	United States	9	1.323	
	<i>Progress in Neuro Psychopharmacology Biological Psychiatry</i>	England	9	4.025	
	<i>Bulletin of Environmental Contamination and Toxicology</i>	United States	7	1.216	—
	<i>Behavioural Brain Research</i>	Netherlands	7	3.391	
	8 journals		76	—	—
	Total				
World	<i>Development</i>	England	1115	6.273	0.22%
	<i>PLoS One</i>	United States	988	3.534	
	<i>Developmental Biology</i>	United States	987	3.637	
	<i>Developmental Dynamics</i>	United States	730	2.668	
	<i>PNAS</i>	United States	489	9.809	
Total	5 journals		4309	—	—

Journals most used by the Brazilian and worldwide scientific community. In the Brazilian scientific production, 8 journals published each one, more than 2% of all publications. Meanwhile, in the worldwide production 5 journals published, each one, more than 2% of all publications.

TABLE 3. SCIENTIFIC PRODUCTION, COLLABORATION AND NUMBER OF INSTITUTIONS

Periods	Publications	National collaboration	International collaboration	Without collaboration	Number of institutions		
					Brazilian	Foreign	Total
1996–2000	7	3 (43%)	4 (57%)	0 (0%)	5	9	14
2001–2005	17	12 (70%)	3 (18%)	2 (12%)	14	6	20
2006–2010	95	45 (47%)	31 (33%)	19 (20%)	35	60	95
2011–2014	199	122 (61%)	66 (33%)	11 (6%)	73	165	238
Total	318	182 (100%)	104 (100%)	32 (100%)	127	240	367
%	100	57	33	10	35	65	100

Brazilian researchers with the greatest scientific production on the zebrafish subject and who are corresponding authors in the publications. Most researchers are affiliated with Pontifícia Universidade Católica do Rio Grande do Sul (PUC-RS), one of the pioneer institutions on studies with zebrafish in Brazil.

(3), Argentina (2), France (2), Austria (1), and Japan (1). Among the 257 publications with Brazilian corresponding authors, the researchers standing out with the greatest number of publications are specified in Table 3.

The institutions to which the corresponding authors are affiliated are Pontifícia Universidade Católica do Rio Grande do Sul (PUC-RS, 53 publications), Fundação Universidade Federal de Rio Grande (FURG, 30), Universidade de São Paulo (USP, 20), Universidade Federal do Rio Grande do Sul (UFRGS, 19), Universidade Estadual Paulista (UNESP, 18), Universidade Federal do Rio de Janeiro (UFRJ, 15), Universidade Federal do Pará (UFPA, 12), Universidade de Passo Fundo (UPF, 9),

Fundação Oswaldo Cruz (Fiocruz, 8), and Universidade Federal de São Carlos (UFSCar, 7). Two are private institutions (PUC-RS and UPF) and the others are public.

In Figure 3, we show the Brazilian territory with the geographic location of the states where the researchers (corresponding authors) with the highest number of publications on the zebrafish subject are affiliated. As we can observe, Rio Grande do Sul is the state with the greatest number of corresponding authors, followed by São Paulo and Rio de Janeiro.

To analyze journals' IF, we examined three groups separately. Group A: Brazilian corresponding author without

FIG. 3. Map of Brazil: distribution of corresponding authors by federative states. Brazilian territory and its federative units where the researchers (correspondent authors) with the highest number of publications on zebrafish are located. The state that stands out with the highest number of publications is RS. On the left of the map, we have included the map legend with the complete names of the cities where the researchers are located and the number of publications. RS, Rio Grande do Sul.

TABLE 4. BRAZILIAN CORRESPONDING AUTHORS WITH THE HIGHEST NUMBER OF PUBLICATIONS

<i>Brazilian corresponding authors</i>	<i>Number of publications</i>	<i>Institutions</i>
Bonan, CD	22	Pontifícia Universidade Católica do Rio Grande do Sul (PUC-RS)
Marins, LF	15	Fundação Universidade Federal de Rio Grande (FURG)
Maximino, C	14	Universidade Federal do Pará (UFPA)
Bogo, MR	11	Pontifícia Universidade Católica do Rio Grande do Sul (PUC-RS)
Barcellos, LJG	9	Universidade de Passo Fundo (UPF)
Monsserrat, JM	6	Fundação Universidade Federal de Rio Grande (FURG)
Rosemberg, DB	6	Universidade Federal do Rio Grande do Sul (UFRGS)
Costa, ML	4	Universidade Federal do Rio de Janeiro (UFRJ)
Da Silva, RS	4	Pontifícia Universidade Católica do Rio Grande do Sul (PUC-RS)
Vianna, MR	4	Pontifícia Universidade Católica do Rio Grande do Sul (PUC-RS)

The table shows the number of publications per period of the Brazilian scientific production, the number of collaborations established and the number of Brazilian and foreign institutions involved in studies on zebrafish.

international coauthorship (214 publications—32 publications without any Brazilian collaboration) had an IF average of 2.33. Group B: Brazilian corresponding author with international coauthorship (43 publications) had an IF average of 3.15. Group C, international corresponding author with national coauthorship (61 publications) had an IF average of 4.74.

In an Intra and Inter¹⁵ coauthorship scale, we have identified that 90% of Brazilian scientific production is constituted in collaboration (publications involving more than one author), 33% of publications were in collaboration with foreign researchers (international collaboration), 57% were in national collaboration (among researchers of the same institution and/or among Brazilian institutions), and 10% without collaboration, that is, publications with only one author (Table 4). In Brazilian scientific production, the coauthorships and the institutions involved increased with time (Figs. 4–7). It is important to emphasize that the number of coauthorship per work ranged from 1 to 24 (data not shown).

Figure 4 shows data from 1996 to 2000. We verified a more intense collaboration with foreign institutions than collaborative work between Brazilian institutions. USP/Brazil presented two links, one with the University of Pennsylvania (United States) and one with the Universidad de Malaga (Spain). There were collaborations between UFRJ/Brazil and Institut Pasteur (France) and between the Universidade Federal Rural de Pernambuco (Brazil) and the University St. Andrews (Scotland). We also observed two isolated Brazilian institutions, without any established collaboration: Universidade de São Carlos (UFSCar) and Fiocruz.

Figure 5 shows data from 2001 to 2005. There was an increase in the number of collaborations, compared to 1996 to 2000. Other Brazilian institutions started to publish on zebrafish, as did UFRGS and PUC-RS, with three links, both acting in collaboration. USP expanded its collaborations (six links) with foreign (University of Vienna [Austria, 1], Salk Institute for Biological Studies [United States, 1], and the

FIG. 4. Collaborations established from 1996 to 2000: shows the Brazilian scientific production collaboration network established from 1996 to 2000. In the *center*, we have the international collaboration between the University of Pennsylvania (United States) and USP (Brazil). At the *bottom*, we identify the international collaboration between University of St. Andrews (Scotland) and UFRPE and, at the *top*, between Universidade Federal do Rio de Janeiro and Institut Pasteur (France). Other Brazilian institutions that had publications on the zebrafish subject acted individually (on the *right*): UFSCar and Fiocruz. USP, Universidade de São Paulo; UFRPE, Universidade Federal Rural de Pernambuco; UFSCar, University Federal de São Carlos; Fiocruz, Fundação Oswaldo Cruz.

FIG. 5. Collaborations established from 2001 to 2005: shows the Brazilian scientific production collaboration network from 2001 to 2005. On the *right*, we have USP (Brazil) with an expanded collaboration network with Brazilian and foreign institutions. *Right* above it, there is PUC-RS and UFRGS acting in collaboration. Other Brazilian institutions emerge in this period: UFSC, UFRJ, Fiocruz, Embrapa, UNESP, and PUC-MG. PUC-RS, Pontifícia Universidade Católica do Rio Grande do Sul; UFRGS, Universidade Federal do Rio Grande do Sul; UFSC, Universidade Federal de Santa Catarina; UFRJ, Universidade Federal do Rio de Janeiro; UNESP, Universidade Estadual Paulista; PUC-MG, Pontifícia Universidade Católica de Minas.

University of Washington [United States, 1]) and Brazilian (Universidade Fluminense [UFU, 1], Embrapa [1], and UNESP [1]) institutions.

Figure 6 shows data from 2006 to 2010. PUC-RS (37 links total, 32 with Brazilian institutions), USP (26 links, 18 with Brazilian institutions), and FURG (18 links, 15 with Brazilian institutions) led in links.

Collaborative net analysis revealed the following collaborations:

PUC-RS—Main Brazilian institutions: UFRGS (10) and Instituto Nacional de Ciência e Tecnologia Translacional em Medicina (4). Foreign institutions: National Cancer Institute (United States, 2), National Institutes of Health (United

States, 1), Nestle Purina (United States, 1), and the University of Missouri (United States, 1).

USP—Main Brazilian institutions: their own groups (3), UFPA (5), and Universidade Federal de Santa Catarina (3). Foreign institutions: University of Virginia (United States, 1), Medical University of Vienna (Austria, 1), University of Montreal (Canada, 1), United States Department of Agriculture (United States, 1), Imperial College of Science, Technology and Medicine (England, 1), University of Minnesota (United States, 1), Case Western Reserve University (United States, 1), and University of Pennsylvania (United States, 1).

FURG—Main Brazilian institutions: their own groups (13), PUC-RS (1) and Universidade Federal de Santa Maria

FIG. 6. Collaborations established from 2006 to 2010: shows the Brazilian scientific production collaboration network from 2006 to 2010. We can observe an increase in number of Brazilian institutions. At the *top left*, we identify PUC-RS with the greatest number of established collaborations. On the *right*, we have USP and, in the *center*, we have FURG. FURG, Fundação Universidade Federal de Rio Grande.

FIG. 7. Collaborations established from 2011 to 2014: shows the Brazilian scientific production collaboration network established from 2011 to 2014. In the *center*, PUC-RS stands out with the highest number of established interactions. At the *bottom*, we have UFRGS. At the *top*, FURG.

(1). Foreign institutions: Bodo University College (Norway, 1), Università Politecnica delle Marche (Italy, 1), and Woods Hole Oceanographic Institution (United States, 1).

Figure 7 shows data from 2011 to 2014. A collaborative network involving 238 institutions was observed. Considering that the network is very broad and that many of the institutions presented little collaboration, only the entities with the greatest number of collaborations are specified: PUC-RS (145), UFRGS (84), and FURG (57).

PUC-RS: did not establish any collaboration with foreign institutions. Main Brazilian institutions: its own groups (52), Instituto Nacional de Ciência e Tecnologia Translacional em Medicina (INCT-TM) (32), UFRGS (30), and Instituto Nacional de Ciência e Tecnologia em Excitotoxicidade e Neuroproteção (INCT-EN, 6).

UFRGS: Main Brazilian institutions: its own groups (7), PUC-RS (30), INCT-EN (7), and INCT-TM (5). Foreign institutions: University of San Diego (United States, 4), Universidad Complutense Madrid (Spain, 1), Ctr Higher Profess Training (Spain, 1), University of Peshawar (Pakistan, 1), and Tulane University (United States, 1).

FURG: Main Brazilian institutions: its own groups (18), PUC-RS (4), Universidade Federal de Pelotas (4), and CNPq (4). Foreign institutions: Universidad de Buenos Aires (Argentina, 1), Bodo University College (Norway, 2), Universidad Nacional de Luján (Argentina, 2), University of Nordland (Norway, 1), Nanotek AS (Argentina, 1), and Universidad Tecnológica Nacional (Argentina, 1).

Coauthorship indicators point to collaborative social networks (national or international) established among researchers, institutions, and countries.¹³ The number of collaborations established by period shows some position alterations of institutions that presented a greater number of collaborative studies. During the last period (2011 to 2014), PUC-RS, UFRGS, and FURG were the institutions with the highest number of collaborations, while USP had more collaborations in the first three periods analyzed. However, USP was

the university presenting the most collaboration with foreign institutions.

Although there has been growth in Brazilian scientific production with zebrafish each 4-year period, these periods distinguish themselves by the type of collaborations established. With time, there has been an increased national collaboration trend, while the international interactions followed the opposite path. Regardless of the collaborations being national or international, 90% of the Brazilian scientific production was identified as made in collaboration (Table 4).

By means of the net (Figs. 4–7), we identified the Brazilian institutions that excelled with the greatest number of collaborations. Thereby, each analyzed period presented itself differently due to the increase in number of national and international institutions involved in zebrafish studies and the consequent expansion of the established collaborations.

Thus, we specifically observed a decentralization process of the involvement of Brazilian institutions researching with zebrafish, since new Brazilian institutions emerged along the time periods. This phenomenon could be related to the exchange processes established between Brazilian researchers and to their own repositioning processes. Many researchers start to act as researchers in other universities as they are awarded with doctorates, thereby creating laboratories and following up on the studies with zebrafish as an experimental model.

Conclusion

This study portrayed some aspects of the Brazilian scientific production with zebrafish, its impact, the tendencies of scientific communication, and the collaboration established by Brazilian researchers. It also presented a comparative study of the characteristics and trends of the Brazilian and worldwide scientific production.

We identified a growth of global and Brazilian scientific production starting in the 90s. In Brazil, the scientific production started many years after the international production.

The Brazilian scientific production with zebrafish presents different characteristics than that of the world scientific community. The citation impact of the worldwide scientific production is much superior to that of the Brazilian publications. However, the Brazilian scientific production is constantly increasing. This tendency indicates that the Brazilian scientific production is being used as reference for other studies and is contributing to scientific progress.

With regard to the research fields, Brazil does not follow the same worldwide publication trends. A significant part of the Brazilian scientific production is concentrated in the categories Toxicology and Neuroscience, whereas the worldwide production is concentrated in the fields Developmental Biology and Biochemistry Molecular Biology.

In addition, the Brazilian community uses different journals for the publication of research results. The internationalization of Brazilian scientific production is observed by the great predominance of publications in foreign journals.

Furthermore, 90% of the Brazilian scientific production was identified as made in collaboration. Around 33% of Brazilian scientific production with zebrafish was made in collaboration with foreign researchers. Collaboration with foreign groups affected positively the IF of the journals, especially when the correspondent author is a foreign researcher.

Publications with national coauthorship predominated as scientific work practice in Brazil. Importantly, we detected an impressive growth of interactions between Brazilian groups with time, which could be related to the substantial growth of Brazilian scientific production with zebrafish. This phenomenon could be related to the professional path of researchers who have contributed to the decentralization of the researches with zebrafish in Brazil.

Disclosure Statement

No competing financial interests exist.

References

1. Silveira TR da, Schneider AC, Hammes TO. Zebrafish: modelo consagrado para estudos de doenças humanas. *Ciência e Cultura* 2012;64:4–5.
2. Eschmeyer WN, Fricke R. (eds). *Catalog of Fishes: Genera, Species, References*. [This version was edited by Bill Eschmeyer]. Available at: <http://researcharchive.calacademy.org/research/ichthyology/catalog/fishcatmain.asp> (accessed September 3, 2015).
3. Howe K, Clark MD, Torroja CF, Torrance J, Berthelot C, Muffato M, *et al.* The zebrafish reference genome sequence and its relationship to the human genome. *Nature* 2013;496:498–503.
4. Rosemberg DB, Rico EP, Mussulini BHM, Piato AL, Calcagnotto ME, Bonan CD, *et al.* Differences in spatio-temporal behavior of zebrafish in the open tank paradigm after a short-period confinement into dark and bright environments. *PLoS One* 2011;6:1–11.
5. BRASIL: Ministério da Ciência, Tecnologia e Inovação. Conselho Nacional de Controle de Experimentação Animal. Resolução Normativa No. 17. *Diário Oficial da União*, Brasília, DF, 2014;4:pp. 51–52.
6. Mugnaini R: 40 anos de Bibliometria no Brasil: da bibliografia estatística à avaliação da produção científica nacional. In: *Bibliometria e cientometria: reflexões teóricas e interfaces*. Hayashi MCPI and Leta J (eds), pp. 37–58, Pedro e João Editores, CAPES, São Carlos, SP, 2013.
7. Macias-Chapula CA. O papel da informetria e da cientometria e sua perspectiva nacional e internacional. *Ciência da Informação* 1998;27:134–140.
8. Maricato JM, Noronha, DP: Indicadores bibliométricos e cientométricos em CT&I: apontamentos históricos, metodológicos e tendências de aplicação. In: *Bibliometria e cientometria: reflexões teóricas e interfaces*. Hayashi MCPI and Leta J (eds), pp. 21–41, Pedro e João Editores, CAPES, São Carlos, SP, 2013.
9. Tague-Sutcliffe J. An introduction to informetrics. *Inform Process Manage* 1992;28:1–3.
10. Spinak E. Indicadores cientométricos. *Ciência da Informação* 1998;27:141–148.
11. Strehl L. O fator de impacto do ISI e a avaliação da produção científica: aspectos conceituais e metodológicos. *Ciência da Informação* 2005;34:19–27.
12. Garfield E, Sher IH. New factors in the evaluation of scientific literature through citation indexing. *American Documentation* 1963;14:195–201.
13. Vanti N. A cientometria revisitada à luz da expansão da ciência, da tecnologia e da inovação. *Ponto de Acesso* 2011; 5:5–31.
14. Weinstock, M. Citation indexes. In: *Encyclopedia of library and information science*. Kent A, Lancour H (Ed.), pp. 16–40, v. 5, New York, M. Dekker, 1971.
15. Katz JS, Martin BR. What is research collaboration? *Res Policy* 1997;26:1–18.
16. Halstead BW, Chitwood MR, Modglin RB. The anatomy of the venom apparatus of the zebrafish, *Pterois volitans* (Linnaeus). *Anat Rec* 1955;122:317–333.
17. Vieira VLA, Johnston IA. Muscle development in the tambaqui, an important Amazonian food fish. *J Fish Biol* 1996;49:842–853.
18. Gripp KW, Wotton D, Edwards MC, Roessler E, Ades L, Meinecke P, *et al.* Mutations in TGIF cause holoprosencephaly and link NODAL signalling to human neural axis determination. *Nat Genet* 2000;25:205–208.
19. Loregian B. Produção e colaboração científica brasileira em Toxicologia nos anos de 2006–2012 representada na Web of Science. Universidade Federal do Rio Grande do Sul/Faculdade de Biblioteconomia e Comunicação 2014. Available at: <http://lume.ufrgs.br/handle/10183/102295> (accessed March 26, 2016).
20. Hoppen NHF. A Neurociências no Brasil de 2006 a 2013, indexada na Web of Science: produção científica, colaboração e impacto. Universidade Federal do Rio Grande do Sul/Faculdade de Biblioteconomia e Comunicação, Programa de Pós-Graduação em Comunicação e Informação 2014. Available at: <http://lume.ufrgs.br/handle/10183/107958> (accessed March 26, 2016).
21. Guimarães TT, Monteiro-Junior RS, Deslandes AC. A evolução da neurociência no Brasil: uma comparação com os países da América Latina nos últimos 16 anos. *Revista Neurociências* 2014;22:359–364.

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