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Scientific collaboration in Zika: identification of the leading research groups and researchers via social network analysis

Colaborações científicas em Zika: identificação dos principais grupos e pesquisadores através da análise de redes sociais

Colaboraciones científicas en Zika: identificación de los principales grupos e investigadores mediante el análisis de redes sociales

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Abstract

The association between Zika and microcephaly drew international attention to Brazil. The emergency situation demanded speed and collective effort by researchers worldwide, and Science was quick to investigate the disease and publish the results. Scientific knowledge was created and disseminated through collaboration in this process. Publications are still the best way of disseminating scientific knowledge. They allow to record progress in a field of studies and observe how scientists collaborate to produce advances as new knowledge and technologies are generated. An effective way to map such advances is to analyze scientists' Social Networks (relationship and collaboration networks), since collaboration is currently an intrinsic characteristic of modern science. Co-authorship of publications is thus an important indicator of scientific collaboration for understanding progress in various areas of Science. The current study aimed to use a generalizable method for mapping and analyzing the Scientific Social Network formed in the domain of Zika, demonstrating how scientists collaborated to produce the main research results, identifying the leading research groups on Zika and the most influential researchers. Social Network Analysis was applied to the co-authorship networks formed from 2015 to 2016. The study showed that a Zika researcher's influence is basically determined by three factors: (a) number of publications; (b) diversified partnerships; and (c) the links established with the research area's pioneers.

Zika Virus; Authorship and Co-authorship in Scientific Publications; Social Networking; Cooperative Behavior

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Introduction

The Zika virus (ZIKV) epidemic emerged in 2015 in Brazil as a new phenomenon that continues to demand responses by science on unprecedented issues such as the significant number of microcephaly cases and other neurological alterations in newborns. Zika was previously confined to a limited region of Africa, with a history of benign, uncomplicated clinical evolution [1]. It was only after the outbreaks on Yap Island, Micronesia, in 2007 and later in French Polynesia in 2013 and Brazil in 2014 that it became urgent to study the disease and seek answers to this international health problem.

On Yap Island, approximately 73% of the inhabitants were infected and presented mild, short-lived symptoms, with many asymptomatic cases [2].

In late 2013, a new epidemic occurred in French Polynesia [3], where the outbreak was larger, as shown by retrospective epidemiological studies that indicated the occurrence of approximately 30,000 infections and cases of Guillain-Barré syndrome associated with ZIKV infection, as well as reports of the first cases of perinatal transmission. Retrospective analysis of live births in this outbreak in French Polynesia identified, from March 2014 to May 2015, 17 cases of central nervous system malformations, including microcephaly in fetuses and newborns [4].

According to Massad et al. [5], the virus was introduced into Brazil between October 2013 and March 2014, coming from French Polynesia.

In the latter half of 2014, a new febrile illness was reported in the cities of Natal, state capital of Rio Grande do Norte, and Recife, state capital of Pernambuco. Following investigation of the cases, the circulation of ZIKV was also confirmed in the state of Bahia, in the city of Camaçari [6,7].

In 2015, the uncommon occurrence of microcephaly in newborns began to be detected in Pernambuco, with an unusual incidence rate. Studies on the association between Zika and microcephaly began in Brasil [8]. However, the association was confirmed by the United States Centers for Disease Control and Prevention (CDC), which announced on April 13, 2016, the confirmation of the relationship between ZIKV and microcephaly in infants of mothers infected with the virus.

The emergency situation demanded speed and collective effort by researchers worldwide, and science hastened to investigate the disease and publish the results.

Publications are still the principal mechanism for the dissemination of scientific knowledge. Thus, research productivity and advances by universities and research institutes in state-of-the-art research are assessed by metrics directly related to the number of citations (e.g.: impact factor, i10-index, h-index, among others). Such metrics aim to estimate researchers' reputation and academic productivity, as well the impact of their research, based on their publications [9]. However, these metrics have been criticized from various angles. Some criticisms emphasize the fact that impact measures based on these indicators overlook the more subtle and informal aspects of academic influence, such as community engagement, participation in research groups, and dissemination beyond the scientific community [10].

As important as analyzing researchers' output is to analyze their engagement in the scientific community, their role in the creation and dissemination of knowledge, and the ways that groups in a given field of science evolve [11,12]. In particular, metrics from Social Network Analysis (SNA) can be used to explore the relationships in networks of scientific collaboration, also known as Scientific Social Networks (SSN) [11,13]. In studies focused on co-authorship, this relationship can be measured as the proportion with which the same groups of authors publish articles in common, where such publications can be used to measure the strength of links between researchers. Co-authorship networks and most social structures are usually represented by graph structures. SNA consists of applying a set of metrics and algorithms to analyze the existing relations in these graph structures [14].

This study aims to map and analyze SSN on Zika research, revealing how scientists collaborated to produce the leading results. The study addressed the following questions: "Who are the most influential researchers in terms of activity and collaboration in studies on Zika?", and "What are the leading collaborative groups?". Using SNA metrics together with productivity metrics, the goal is to better understand the representativeness and recognition of Zika researchers to present to the scientific community the most outstanding names in studies related to the disease at present.

Related studies

One pioneering study on scientific collaboration networks was by Newman [15], who explored the PubMed/MEDLINE database and extracted publications and analyzed SSN in various themes in Biomedicine using metrics that examine networks from a macro/global perspective. The study analyzed 2,163,923 publications and identified 1,520,251 researchers. The study also showed a mean of 6.40 articles per researcher, 3.75 researchers per article, and mean collaboration of 18.10. Contrasting with the work by Newman, the current study analyzed SSN from a multidimensional perspective, considering different levels/metrics, in addition to the global metrics explored by that author.

Freeman [16] demonstrated mathematically how it is possible to calculate the centralization of vertices based on the absolute or relative position in relation to other vertices in a social network, allowing the attribution of scores (degree, closeness, and betweenness) for each vertex. Yan & Ding [17] proposed a method to calculate researchers' influence in SSN, applying the centralization metrics as proposed by Freeman [16] together with PageRank [18] in the field of Library Science and Information Science to analyze the network structure at the "micro" level, that is, examining in depth the SSN structure aided by the four metrics. Meanwhile, Liu et al. [19] used the four previous metrics similarly, but the authors proposed a new metric similar to PageRank to assist their analyses, but taking edge weights into account. Their method was applied to the networks of authors that published in the main digital libraries in Computer Science domain. As with Yan & Ding [17] and Liu et al. [19], this study examined in detail the structural aspects of SSN at the micro level (considering researchers and their relational dynamic), but in the current study's method, the combined use of metrics allows the more accurate identification of the most influential researchers.

In the Brazilian scenario, Morel et al. [12] studied scientific productivity and the ways co-authorships are formed between Brazilian researchers in the Web of Science database. Based on this, they were able to map the SSN and analyze the formation of clusters of authors that published international articles on seven neglected tropical diseases from 2001 to 2008. Using keywords extracted from the articles, the authors inferred important co-authorships between the researchers, such as clusters formed in dengue research and the bridges between institutions and groups in tuberculosis research. Besides the way Morel et al. [12] analyzed co-authorships, another difference between that study and the current one is the fact that it automated the process of data retrieval, treatment, and integration and construction of the SSN.

Albuquerque et al. [11] analyzed scientific collaboration between Brazilian researchers that participated in the National Institute of Science and Technology for Cancer Control (INCTCC). The authors conducted social network analysis using a multidimensional model, also analyzing the time series of publications by the group members based on information retrieved from the Lattes and PubMed platforms. Unlike the method used here, which can be generalized to other scenarios and databases, the method presented in that study is limited to the Brazilian scenario, since it uses the Lattes database to extract information and map relations in SSN.

Building the Scientific Social Network

The SSN analysis in this study employed connectivity [20] and centrality [16] metrics, namely degree, betweenness, and closeness, to study how and with whom the researchers establish co-authorships. The study also used a fourth centrality metric, PageRank [18], which measures the relevance of network nodes based on the relevance of other nodes linked to them.

Centrality metrics were chosen according to the definition of "Prestige" in Wasserman & Faust [20]. Degree Prestige is associated with the number of direct links to a researcher in the network. The more links the researcher has in the SSN, the higher his or her Degree Prestige. Closeness Prestige considers as most "central" the researcher with a shorter mean distance in relation to all the others in the network. Researchers that collaborate with more central researchers in the SSN have higher Closeness Prestige. Betweenness Prestige considers as the researchers with the higher prestige those that act as bridges, connecting different research groups. In addition, higher prestige was attributed to the researchers oftener referenced in the SSN, using the PageRank metric [13].

The process used (Figure 1), adapted from Maia & Oliveira [13] and Maia & Yagui [21], is responsible for: (i) retrieving data on the researchers in publications on Zika extracted from PubMed; (ii) building a co-authorship SSN based on the retrieved data; (iii) applying SNA metrics to this SSN; and (iv) identifying important researchers and their roles in the Zika SSN, based on their productivity and influence in the research networks to which they belong.

Using the search mechanism for PubMed (https://www.ncbi.nlm.nih.gov/pubmed/advanced) and as search string the term "Zika" applied in the filters "title", "abstract" and "text", on December 21, 2016, data were extracted from 1,932 publications on Zika. To use these data, a workflow was prepared with the Knime tool (https://www.knime.org/about) in order to integrate data on authors and publications to generate the SSN and upload it into the SNA tool called Cytoscape (http://www.cytoscape.org/what_is_cytoscape.html). Next, a collaboration graph was generated to view the resulting network, in which the authors are the nodes and the publications are the edges. This allowed applying SNA metrics and analyzing the SSN at three different levels: global, local, and individual.

Global analysis

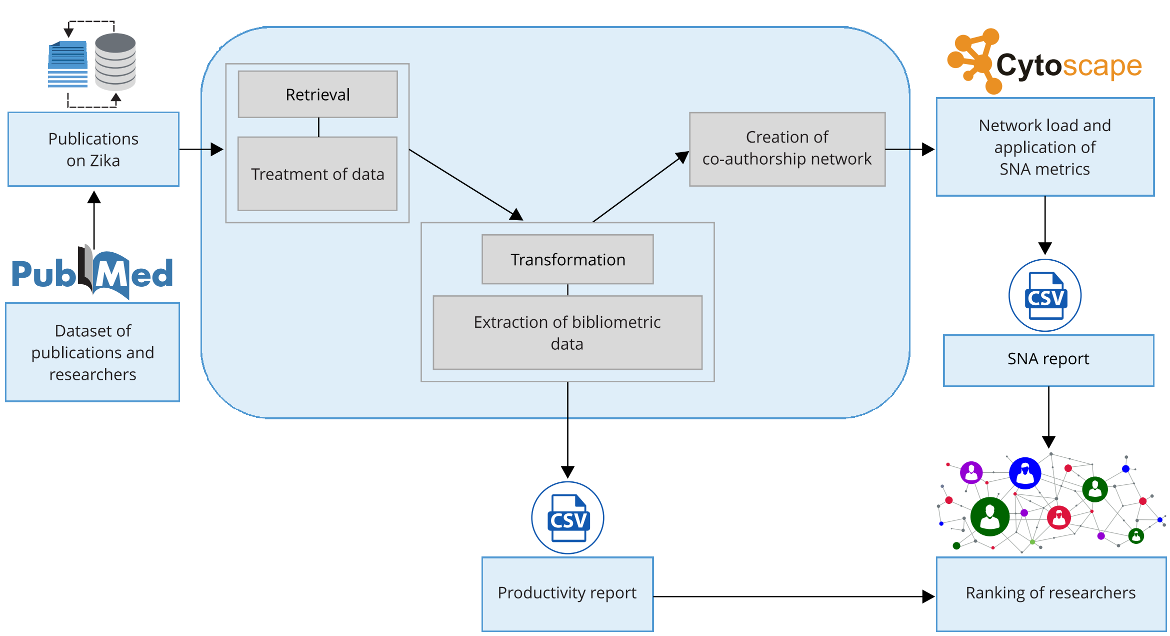
At this level of analysis, the behavior of global publishing on Zika was analyzed based on a preliminary bibliometric analysis correlating data on researchers and publications. Table 1 summarizes the results of this analysis.

As shown in Table 1, this analysis identified 6,808 researchers in the Zika SSN, in which a researcher published an average of 1.49 articles, the articles have an average of 5.20 researchers, and a researcher collaborates, on average, with 6.12 researchers.

Observing the results of the study by Newman [15] and the current study's preliminary bibliometric analyses, some comparisons can be made. For example, the average number of publications per

Figure 1

Proposed architecture for this study (adapted from Maia & Oliveira [13] and Maia & Yagui [21]).



SNA: Social Network Analysis.

Table 1

Global analysis: bibliometric data of the Scientific Social Network on Zika.

Metric	Result
Number of researchers in the network	6,808
Number of publications in the network	1,932
Sum of publications considering each researcher individually	10,160
Sum of researchers considering each publication individually	10,060
Mean publications per researcher	1.49
Mean researchers per publication	5.20
Mean collaboration (mean degree)	6.12

researcher is low when compared to the overall publications in Biomedicine. Only 37 researchers among the 6,808 that were identified had published more than 10 articles on Zika. This indicates that until a few years ago the theme received little attention from the biomedical community, which can be explained by the fact that the interest in studying the disease in greater depth only emerged after the outbreaks in 2013 [22]. On the other hand, the average number of researchers per publication is 5.20, namely 39% higher than the mean observed in Biomedicine publications. By way of example, this study identified 322 publications in which 10 or more authors participated in the research, that is, a sixth of the entire sample. This indicates that the theme tends to form research groups with many members. Finally, the mean collaboration of 6.12 is low (three times lower) when compared to research groups in Biomedicine. This shows that ZIKV researchers tend to collaborate less at the global level.

In the next stage, in order to facilitate identification of the most influential researchers, the network's isolated components and weak links were eliminated (researchers that published without coauthors and links with only one publication in common). The following parameters were used for this purpose: (i) weights for the nodes/researchers, where the weight corresponds to that node's number of edges; (ii) weights for the edges, where the weight corresponds to the number of publications in common; (iii) the occurrence of an edge conditioned on the existence of two or more publications in common; and (iv) removal of isolated nodes from the SSN. The graph visualization thus becomes less polluted and the identification of the important components becomes easier.

After the adjustment, a collaboration graph was projected in which it is possible to identify 1,025 nodes and 3,608 edges, or 8,650 edges if one considers the weight as a function of those that are repeated, that is, 8,650 publications in common were mapped among the 1,025 researchers.

Having done this, it was possible apply connectivity metrics in the SSN to identify the groups of nodes/researchers that stand out in the observed structure.

Local analysis

At this level of analysis, the largest components/clusters were identified, with 208, 133, and 96 nodes, corresponding to 20.29%, 12.97%, and 9.36% of all the researchers in the SSN. Among the other components identified, the fourth, fifth, sixth, seventh, and eighth largest had 37, 23, 22, 22, and 21 nodes, respectively. All the other components had less than 20 nodes each. Table 2 shows the connectivity metrics for the eight largest clusters in the SSN.

Based on these numbers (especially nodes and network diameter) for this study, only the three largest clusters identified in the SSN (hereinafter subnetwork 1, subnetwork 2, and subnetwork 3) were considered in the individual analysis (437 nodes). Figure 2 illustrates the distribution of the scientific collaborations in Zika and highlights the three main clusters/subnetworks that were identified.

Table 2

Local analysis: connectivity metrics for the eight largest clusters in the Scientific Social Network on Zika.

Cluster	Nodes	Mean degree	Network diameter	Density
Giant cluster	208	6.92	12	0.03
Second largest cluster	133	10.38	6	0.079
Third largest cluster	96	7.31	9	0.077
Fourth largest cluster	37	9.35	5	0.26
Fifth largest cluster	23	5.83	4	0.25
Sixth largest cluster	22	9.91	4	0.45
Seventh largest cluster	22	10.00	2	0.47
Eighth largest cluster	21	7.36	3	0.35

Individual analysis

After identification of the most important subsets of researchers, the centrality metrics explained in section *Building the Scientific Social Network* were applied to analyze the individual properties of the three subnetworks and identify the most influential researchers. The analyses at this level were adapted from the work by Maia & Oliveira [13], which incorporated the concepts of centrality applied to the work by Freeman [16], Yan & Ding [17], and Liu et al. [19]. Based on these proposals, the current analysis extracted the degree, closeness, and betweenness to find the most central nodes, and PageRank was used to compare these nodes with the most frequently referenced nodes.

Research productivity analysis

An important initial criterion is the Number of Publications (NP) by each researcher, since quantification of productivity (despite criticisms) is still an essential factor in the academic community for determining whether a researcher is leading progress in his or her field of work or in specific areas, such as Zika. Thus, each researcher's NP was extracted and a ranking was created based on the number times that researcher published. This ranking only took into account those who had published at least five times, excluding the researchers with lower output and reducing the scope of the next analysis. In addition, as a way of facilitating the identification of the most productive researchers and improving the numbers' visualization, four color categories were defined based on each researcher's NP, according to the criteria listed in Table 3.

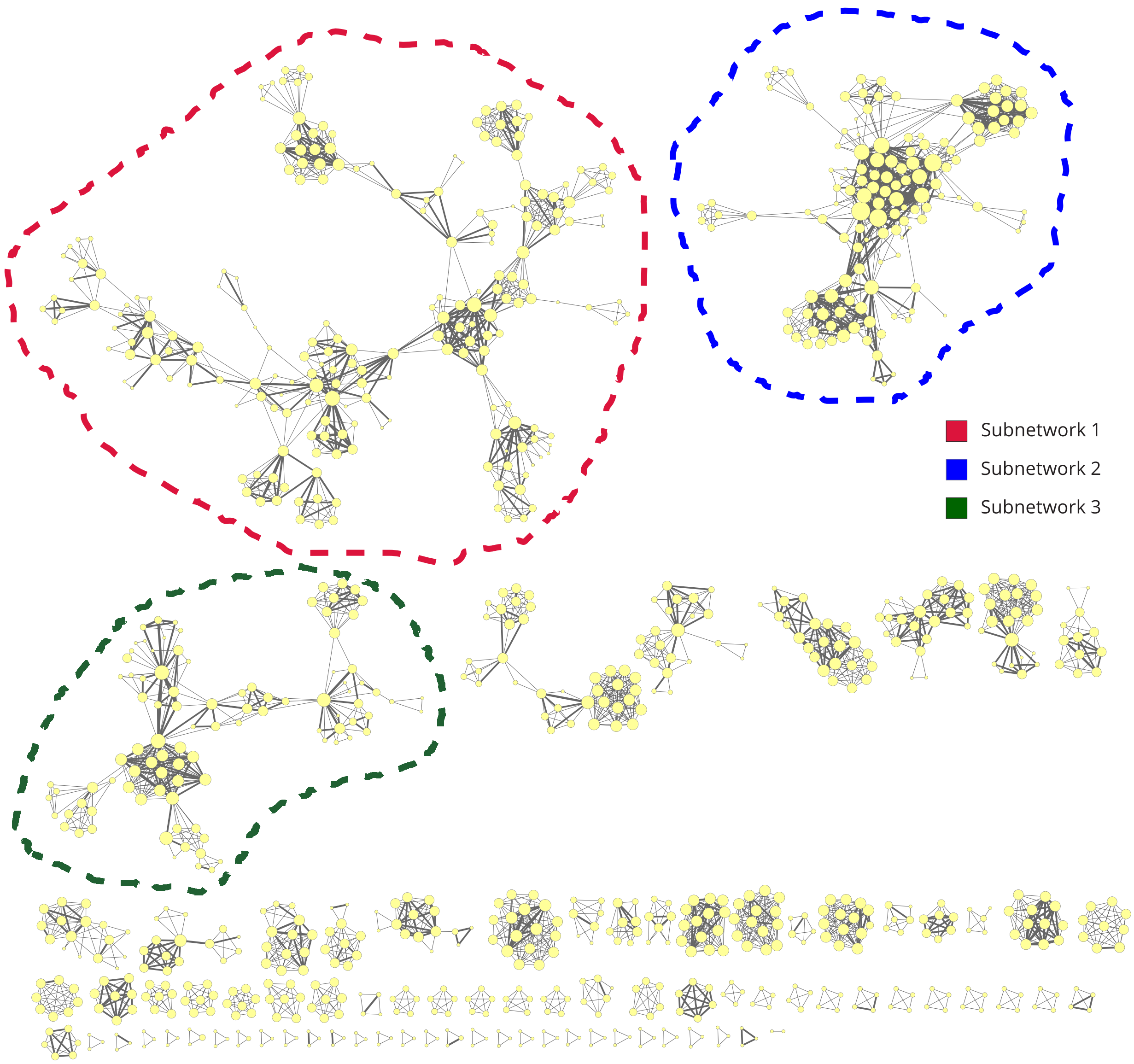
Having defined these criteria, we found that among the researchers who have published the most, 133 are in the red category, 24 in the purple, 21 in the blue, and 16 in the green. Table 4 shows the researchers with the most publications (category green) in the three main clusters/subnetworks.

The results in Table 4 show that these names are actually researchers that belong to networks of scientific collaboration with strong geopolitical/institutional references. Well-defined clusters are seen in this group, for example, the one formed by researchers from the Institut Louis Malardé – ILM (Tahiti/French Polynesia), consisting of Didier Musso (MUSSO D) and Van-Mai Cao-Lormeau (CAO-LORMEAU VM) and Isabelle Leparc-Goffart (LEPARC-GOFFART I), that belongs to the French National Reference Center for Arboviruses – NRCA and to the Institut de Recherche Biomédicale des Armées – IRBA (Marseille/France).

These researchers began to publish in 2014, following the ZIKV outbreak in French Polynesia in 2013. Didier Musso and Cao-Lormeau have a strong partnership with Duane Gubler from Duke-NUS Medical School (Singapore) and from Partnership for Dengue Control (Lyon/France), which although not among the most productive researchers, nevertheless reinforces the link with another French institution in this co-authorship network.

Figure 2

Collaboration graph of the Scientific Social Network on Zika, highlighting the three main clusters of researchers that were identified (subnetwork 1, subnetwork 2, and subnetwork 3).



Note: the co-authorship graph with the Zika researchers' names is available at: https://luisfmpm.github.io/CSP/. The co-authorship graph also highlights the weights applied to the nodes and edges, in which the size of the nodes varies according to each researcher's number of co-authorships, and the size of the edges varies according to the number of co-authorships between two researchers.

This group of 11 researchers also features a strong cluster from CDC (Atlanta/United States), namely Mark Fischer (FISCHER M), Denise J. Jamieson (JAMIESON DJ), Margareth A. Honein (HONEIN MA), and J. Erin Staples (STAPLES JE). Based on the capillarity of CDC in terms of partnerships and research development, this cluster showed highly significant productivity based on publishing. Mark Fischer, for example, was one of the first to publish on the ZIKV epidemic on Yap Island in 2007 [23].

Table 3

Color categories based on the number of publications (NP).

Category	Condition
Red	If NP ≥ 5 or NP < 8
Purple	If NP ≥ 8 or NP < 10
Blue	If NP ≥ 10 or NP < 15
Green	If NP ≥ 15

Table 4

Researchers who have published the most in the 3 subnetworks.

Researcher	Publications
MUSSO D	33
JAMIESON DJ	21
LEPARC-GOFFART I	20
FISCHER M	19
HONEIN MA	18
WEAVER SC	17
STAPLES JE	16
VASILAKIS N	16
DIAMOND MS	16
CAO-LORMEAU VM	16
QIN CF	15

Scott Weaver (WEAVER SC) and Nikos Vasilakis (VASILAKIS N) from the University of Texas – UT (United States) lead another important group in publishing on Zika. In addition to UT, other smaller groups from Washington University, with Michael S. Diamond (DIAMOND MS), from Johns Hopkins University, and others confirmed the strong participation by the United States on Zika research.

Cheng-Feng Qin (QIN CF), from the Department of Virology at the Beijing Institute of Microbiology and Epidemiology (Beijing/China), shows strong participation in the network of publications on Zika, mainly with Chinese partnerships.

Ranking of Freeman's metrics

In this analysis, each researcher's degree, closeness, and betweenness were extracted. Next, the researchers were ranked individually (on their subnetworks) based on these measures, where the higher their score in a metric, the better their ranking in that metric. Only the 100 highest ranking in each metric were considered in this process.

We then totaled the researchers' ranks in the three metrics, where the most influential ones are listed in ascending order according to the values in the column "Score". Researchers with low productivity (Table 3) or low scores, namely betweenness or closeness or degree below the first 100, were excluded from this ranking. Next, a specific ranking was created for the network's researchers with less centrality (low scores in one of the three metrics), according to the same criteria as in the previous ranking. These researchers (underlined) appear right below the more central researchers in the subsequent tables.

Tables 5, 6, and 7 show the highest-ranking researchers in the three subnetworks according to these criteria, in addition to the color/productivity categories (Table 3). The degree and the number of publications were used as a tie-breaking criterion.

Comparative ranking (PageRank)

In this stage, PageRank was calculated for each researcher. According to the criteria for prestige defined in section *Building the Scientific Social Network*, the higher the PageRank value, the more the researcher is related to high prestige or widely referenced nodes. This metric was thus used complementarily to verify the reliability of the centrality ranking, since higher prestige researchers should also be expected to score better on PageRank.

With this in mind, the rankings in Tables 5, 6, and 7 were compared to the 100 most productive researchers (Table 3) in the three subnetworks in PageRank (Tables 8, 9, and 10). Only 2 researchers from the Freeman ranking did not appear in the comparative ranking. Meanwhile, 9 researchers from the comparative ranking did not appear in the Freeman ranking. However, in their respective clusters, these 11 nodes are linked to the high prestige nodes in the Freeman ranking. Comparative Tables 8, 9, and 10 show the researchers listed in descending order according to PageRank.

Thus, based on the productivity (publications) and prestige criteria (betweenness, closeness, degree and PageRank), of the 437 nodes identified in the individual analysis, the 106 most influential researchers were mapped, of which 54 in subnetwork 1, 34 in subnetwork 2, and 18 in subnetwork 3, as shown in Figures 3, 4, and 5.

The most influential researchers in the three subnetworks

Concerning the mapping of researchers according to their influence in the Zika SSN during the study period, the results support the idea that the most productive researchers are also the most influential.

- **Subnetwork 1**

Subnetwork 1, the largest cluster of researchers identified by this study, is characterized by the strong participation by Chinese researchers, with Cheng-Feng Qin (the most influential in the subnetwork 1). For example, according to Table 5, 8 of the 14 most influential researchers are Chinese.

Scott Weaver and Nikos Vasilakis, from the UT, who ranked first in Tables 5 and 8, lead a diverse group consisting of Brazilian researchers and several Chinese researchers who conduct studies in the United States and also in Beijing/China. In these co-authorship links, an important node is Pei-Yong Shi (SHI PY), from UT, connecting to the group in China via Cheng-Feng Qin.

Co-authorship with Brazilian researchers occurred through the partnership with Albert Icksang Ko (KO AI) from the Yale School of Public Health (United States) who is a collaborating researcher with the Gonçalo Moniz Institute (IGM) of the Oswaldo Cruz Foundation (Fiocruz), in Salvador, Bahia, Brazil.

Subnetwork 1 is the one with the most ranked Brazilian researchers. They are distributed across research groups linked to two key state capitals for the epidemic, Salvador and Recife, both in Northeast Brazil, and with Fiocruz Research Centers, namely the IGM in Salvador, Bahia, and the Aggeu Magalhães Institute (IAM) in Recife, Pernambuco.

Guilherme de Sousa Ribeiro (RIBEIRO GS) of IGM/Fiocruz is the highest-ranking Brazilian researcher among the most influential researchers. A closer look at Figure 3 shows that he is a bridge between several groups from important nodes, which also explains his high betweenness score. These results are due to his partnership with UT and Albert Ko, yielding 7 publications for him in co-authorship with Scott Weaver and Nikos Vasilakis, Gúbio Soares Campos (CAMPOS GS) (Federal University of Bahia – UFBA), Bruno de Paula Freitas (DE PAULA FREITAS) (Roberto Santos General Hospital – HGRS), *Mittermayer Galvão Reis* (*REIS MG*), and Federico Costa (IGM/Fiocruz), who published 4 times on ZIKV.

Close to this group, there is also a group of 7 nodes to which Gúbio Soares (UFBA) belongs, the bridge between this group and that of Guilherme Ribeiro. With 7 publications, Gúbio has a

Table 5

Ranking of the most influential researchers in subnetwork 1 based on the Freeman metrics, which also covers the color categories based on the number of publications (Table 3).

Researcher	Publications	Betweenness/Rank	Closeness/Rank	Degree/Rank	Score
QIN CF	15	0.4374/2	0.2900/1	26/2	5
WEAVER SC	17	0.2603/5	0.2638/4	27/1	10
VASILAKIS N	16	0.2548/6	0.2638/5	22/3	14
DENG YQ	10	0.1486/11	0.2737/3	17/8	22
LIU X	5	0.2378/7	0.2441/11	19/5	23
SHI PY	12	0.4961/1	0.2815/2	12/22	25
YE Q	9	0.0326/32	0.2450/8	20/4	44
ZHAO H	5	0.1884/9	0.2383/16	13/19	44
GAO GF	7	0.2856/3	0.2441/10	10/33	46
KO AI	10	0.2805/4	0.2343/24	13/20	48
LI XF	9	0.0368/30	0.2605/6	14/15	51
TESH RB	11	0.0285/33	0.2444/9	15/10	52
RIBEIRO GS	7	0.1260/12	0.2265/31	12/23	66
LI C	6	0.0467/25	0.2372/17	10/34	76
DIAMOND MS	16	0.1082/15	0.1998/80	18/6	101
ZHANG S	7	0.0489/24	0.2027/67	15/11	102
BELFORT R JR	9	0.1254/13	0.2017/71	12/24	108
MAIA M	7	0.1254/14	0.2017/72	12/25	111
FERNANDEZ E	7	0.00011/81	0.1986/22	12/26	129
GARCIA-BLANCO MA	5	0.0219/37	0.0242/13	7/79	129
LIU ZY	5	0.0002/68	0.2328/26	10/36	130
XIE X	8	0.0014/52	0.2430/12	8/69	133
LI J	5	0.0348/45	0.2265/66	11/31	142
SHAN C	5	0.0013/53	0.2422/14	7/79	146
SONG H	6	0.2107/8	0.2071/63	7/86	157
LI D	5	0.0022/51	0.2017/75	10/39	165
JIANG T	5	0.0002/71	0.2320/28	7/80	179
CAMPOS GS	7	0.0557/21	0.1869/93	8/74	188
ROSSI SL	5	0.0003/65	0.2129/45	7/82	192
SALL AA	11	0.00006/78	0.2130/49	8/72	199
DIALLO M	7	0.00005/73	0.2129/50	8/79	202
QIAN X	5	0.1793/10		16/9	19
LI Y	9	0.074/19		18/7	26
RAMOS RC	9	0.1025/16		14/16	32
VAN DER LINDEN V	8	0.0579/20		15/12	33
YANG H	5	0.0911/18		11/32	50
VENTURA CV	10	0.0219/36		12/27	63
OGDEN SC	5	0.0009/56		15/13	69
HAMMACK C	5	0.00089/57		15/14	71
DOWD KA	5	0.0187/40		10/41	81
ROCHA MA	7	0.0151/42		10/40	82
PIERSON TC	8	0.0186/41		10/42	83
CORDEIRO MT	9	0.0501/23		9/63	86
RODRIGUES LC	11	0.0426/27		8/77	104
WANG Z	7	0.00004/82		10/45	127
DE PAULA FREITAS B	5	0.0040/47	0.1962/88		135

Note: this ranking also includes 15 researchers (underlined) which, according to the target centrality criteria, can be considered influential but less central in subnetwork 1. In case of tie consider: 1st - higher degree; 2nd - number of publications.

Table 6

Ranking of the most influential researchers in subnetwork 2 based on the Freeman metrics, which also cover the color categories based on the number of publications (Table 3).

Researcher	Publications	Betweenness/Rank	Closeness/Rank	Degree/Rank	Score
JAMIESON DJ	21	0.1966/2	0.5111/1	43/1	4
ODUYEBO T	13	0.2031/1	0.4808/3	38/3	7
HONEIN MA	18	0.1336/5	0.5018/2	38/2	9
POWERS AM	14	0.1806/3	0.4742/4	30/5	12
FISCHER M	19	0.1311/6	0.4509/6	31/4	16
MEANEY-DELMAN D	13	0.1076/8	0.4584/5	29/7	20
PETERSEN EE	13	0.0457/16	0.4466/7	30/6	29
RIVERA-GARCIA B	11	0.1639/4	0.4070/18	26/9	31
STAPLES JE	16	0.0304/20	0.4326/8	24/10	38
HILLS SL	7	0.0500/15	0.4169/12	18/15	42
RASMUSSEN SA	11	0.0179/26	0.4312/9	26/8	43
MUNOZ-JORDAN J	8	0.1105/7	0.3865/25	24/11	43
RUSSELL K	8	0.0206/22	0.4259/10	20/13	45
PEREZ-PADILLA J	8	0.0515/14	0.3920/24	18/16	54
MEAD P	7	0.0129/30	0.4000/20	19/14	64
BROOKS JT	7	0.0157/29	0.4119/15	16/22	66
VILLANUEVA J	5	0.0039/43	0.4181/11	16/21	75
SHAPIRO-MENDOZA CK	5	0.0189/23	0.4156/13	12/42	78
MOORE CA	7	0.0298/21	0.3865/26	15/32	79
VALENCIA-PRADO M	5	0.0180/24	0.3854/28	12/45	97
POLEN KN	6	0.0012/48	0.4023/19	13/37	104
OSTER AM	5	0.0074/36	0.3942/23	11/49	108
LANCIOTTI RS	7	0.0121/32	0.3424/50	7/30	112
ELLINGTON SR	6	0.0007/54	0.4107/17	12/44	115
RYFF KR	5	0.0102/35	0.3179/74	21/12	121
PETERSEN LR	13	0.0178/27	0.3865/27	7/67	121
SIMEONE RM	5	0.0068/37	0.3833/29	9/59	125
JOHANSSON MA	5	0.0116/34	0.3822/30	7/68	132
RENQUIST CM	5	0.0010/51	0.3801/32	11/51	134
HENNESSEY M	6	0.0030/45	0.3520/42	10/57	144
SHARP TM	7	0.0019/47	0.3157/79	15/33	159
RIVERA A	5	0.0044/42	0.3136/83	15/34	159
PASTULA DM	8	0.0430/17	0.3108/86	10/58	161
KUEHNERT MJ	6	0.0172/28	0.3209/73	6/92	193

Note: in case of tie consider: 1st – higher degree; 2nd – number of publications.

co-authorship network with *Silvia Sardi* (*SARDI SI*) (UFBA), Antonio C. Bandeira (BANDEIRA AC) (Santa Helena Hospital, Camaçari/Bahia), Guilherme Ribeiro, and other researchers from IGM, in addition to partnerships with Charles Y. Chiu and Samia Naccache (2 publications) from the University of California (United States).

Another group linked by Brazilians includes Rubens Belfort Jr. (BELFORT R JR) and Maurício Maia (MAIA M), both from the Department of Ophthalmology and Visual Sciences at the São Paulo Medical School, Federal University of São Paulo (UNIFESP), with 9 and 7 publications, respectively, with studies on visual disorders in children with microcephaly. Both also scored well on the Freeman ranking and PageRank, which translates as partnerships in co-authorships they developed with researchers from Recife and Salvador. This partnership includes Vanessa Van Der Linden (VAN DER LINDEN V) from Barão de Lucena Hospital – HBL (Recife), Regina Coeli Ferreira Ramos (RAMOS RC) from Federal University of Pernambuco – UFPE, Camila Ventura (VENTURA CV)

Table 7

Ranking of the most influential researchers in subnetwork 3 based on the Freeman metrics, which also cover the color categories based on the number of publications (Table 3).

Researcher	Publications	Betweenness/Rank	Closeness/Rank	Degree/Rank	Score
CAO-LORMEAU VM	16	0.4071/2	0.3968/3	26/1	6
MUSSO D	33	0.3281/3	0.4291/1	24/2	6
LEPARC-GOFFART I	20	0.4585/1	0.3448/10	21/3	14
DESPRES P	7	0.1825/5	0.3571/7	15/6	18
MALLET HP	8	0.1616/6	0.3921/4	13/20	30
SIMON-LORIERE E	5	0.0997/8	0.3154/19	21/4	31
TEISSIER A	8	0.0990/9	0.4032/2	11/21	32
SAKUNTABHAI A	5	0.0809/10	0.3144/20	20/5	35
GAREL C	5	0.0801/11	0.3472/9	9/24	44
ROCHE C	6	0.0067/23	0.3571/8	8/27	58
BESNARD M	5	0.0070/22	0.3205/17	9/25	64
BROULT J	5	0.0081/20	0.3355/14	7/38	72
DE LAMBALLERIE X	9	0.0028/26	0.2631/64	10/23	113
MAQUART M	9	0.0074/21	0.2680/53	6/44	118
BAUD D	11	0.0034/30	0.3048/37	5/56	123
VOUGA M	7	0.00007/34	0.3039/39	4/64	137
ROUSSET D	5	0.0587/13	0.2624/65	4/71	149

Note: in case of tie consider: 1st – higher degree; 2nd – number of publications.

from UNIFESP, Bruno Freitas from HGRS, *Liana Maria Vieira de Oliveira Ventura* (*VENTURA LO*), coordinator of the Department of Pediatric Ophthalmology and Strabismus from the Pernambuco Eye Hospital, and Albert Ko from IGM/Fiocruz.

This group with the most links to Brazilians also features Vanessa Van Der Linden of HBL, with 8 publications, and Regina Ramos from UFPE, with 9 publications. Both have high betweenness and PageRank scores, indicating their links to important nodes (explained in the previous paragraph) and their action as mediators between other nodes of researchers that are more isolated in the network. Camila Ventura from UNIFESP, with 10 publications, Marli T Cordeiro (CORDEIRO MT) from IAM/Fiocruz, with 9 publications, Maria Ângela Wanderley Rocha (ROCHA MA) from Oswaldo Cruz University Hospital (Recife), with 7 publications, Bruno Freitas from HGRS, with 5 publications, and Laura Cunha Rodrigues (RODRIGUES LC) from the London School of Hygiene and Tropical Medicine – LSHTM (United Kingdom), with 11 publications, complete the body of influential researchers in subnetwork 1, but most of whom did not score on the closeness metric, indicating that this group has a more isolated position in the network (as indicated in section *Ranking of Freeman's Metrics*).

Interestingly, the majority of these researchers are linked to the Microcephaly Epidemic Research Group (MERG), coordinated by Dr. *Celina Maria Turchi Martelli* (*MARTELLI CM*), who does not appear in the Freeman ranking but scored well in the PageRank metric. This research group belongs to IAM/Fiocruz and works in partnership with various Brazilian and international institutions, including University of Pernambuco – UPE, UFPE, Pernambuco State Health Department – SES-PE, LSHTM (United Kingdom), University of Pittsburgh (United States), Altino Ventura Foundation – FAV, Disabled Child Care Association – AACD, and the Professor Fernando Figueira Integral Medicine Institute – IMIP.

Among many articles produced from 2015 to 2016, one was quite special. In June 2016, the group published an article entitled *Microcephaly in Infants, Pernambuco State, Brazil, 2015* [24], of major international importance, since it reported the first research confirming in a case-control study that the microcephaly epidemic resulted from congenital ZIKV infection.

Table 8

Comparative ranking of subnetwork 1, which includes the researchers' PageRank position (PRP), the Freeman ranking position (FRP) and the color categories based on the number of publications (Table 3).

Researcher	PageRank	PRP	FRP	Researcher	PageRank	PRP	FRP
WEAVER SC	0.0165	1	2	ZHAO H	0.0072	28	8
VASILAKIS N	0.0148	2	3	SHI PY	0.0071	29	6
DIAMOND MS	0.0135	3	15	LI XF	0.0071	30	11
QIN CF	0.0130	4	1	*GOVERO J*	0.0070	31	
VAN DER LINDEN V	0.0113	5	34	*MARTELLI CM*	0.0068	32	
RAMOS RC	0.0107	6	35	LI J	0.0065	35	23
LI Y	0.0106	7	33	GARCIA-BLANCO MA	0.0058	42	20
LIU X	0.0096	8	5	CAMPOS GS	0.0057	43	28
YE Q	0.0096	9	7	YANG H	0.0056	44	36
TESH RB	0.0095	10	12	LI C	0.0056	45	14
KO AI	0.0095	11	10	SONG H	0.0056	46	25
VENTURA CV	0.0092	12	37	LI D	0.0055	49	26
DENG YQ	0.0089	13	4	*REIS MG*	0.0054	51	
ZHANG S	0.0087	14	16	XIE X	0.0053	52	22
BELFORT R JR	0.0086	15	17	*VENTURA LO*	0.0052	54	
MAIA M	0.0086	16	18	SALL AA	0.0051	56	30
FERNANDEZ E	0.0084	17	19	DIALLO M	0.0051	57	31
QIAN X	0.0081	18	32	WANG Z	0.0051	59	45
GAO GF	0.0081	19	9	LIU ZY	0.0051	62	21
CORDEIRO MT	0.0079	20	43	ROSSI SL	0.0050	67	29
RIBEIRO GS	0.0077	21	13	SHAN C	0.0046	80	24
ROCHA MA	0.0075	22	41	*FAYE O*	0.0045	88	
RODRIGUES LC	0.0075	23	44	*DIALLO D*	0.0045	90	
OGDEN SC	0.0074	24	38	*BANDEIRA AC*	0.0045	92	
HAMMACK C	0.0074	25	39	*SARDI SI*	0.0045	95	
DOWD KA	0.0072	26	40	**DE PAULA FREITAS B**			46
PIERSON TC	0.0072	27	42	**JIANG T**			27

Note: this ranking also includes 2 researchers that did not score on PageRank (in **bold**), 8 that did not appear in the Freeman ranking (in *italics*), and the 15 researchers (underlined) that are influential, but less central according to the Freeman ranking.

However, the media credits this discovery to CDC, which published a press note in April 2016 stating that "[they] *...have concluded, after careful review of existing evidence, that Zika virus is a cause of microcephaly and other severe fetal brain defects. In the report published in the* New England Journal of Medicine*, the CDC authors describe a rigorous weighing of evidence using established scientific criteria*" [25].

The work by the MERG was acknowledged by *Nature*, one of the world's most prestigious scientific publications, which listed Dr. *Celina Turchi Martelli* as one of the ten most notable people in science in 2016.

Thus, the analysis of subnetwork 1 clearly shows the leadership of China and the USA in state-of-the-art research in Zika. Although Brazil witnessed the worst epidemic of microcephaly with the occurrence of neurological complications in newborns and produced important scientific research on Zika, Brazilian researchers did not rank in any leading positions.

- **Subnetwork 2**

The most influential researchers in this subnetwork, based on the centrality metrics, all belong to the CDC. Denise Jamieson, Titilope Oduyebo (ODUYEBO T), and Margareth Honein are the three most influential researchers in these rankings and belong to the same research group – The Pregnancy and Birth Defects Task Force for CDC Zika Virus Response, with major scientific output on the theme.

Table 9

Comparative ranking of subnetwork 2, which includes the researchers' PageRank position (PRP), the Freeman ranking position (FRP), and the color categories based on the number of publications (Table 3).

Researcher	PageRank	PRP	FRP	Researcher	PageRank	PRP	FRP
JAMIESON DJ	0.0284	1	1	MOORE CA	0.0108	18	19
ODUYEBO T	0.0236	2	2	VILLANUEVA J	0.0098	22	17
HONEIN MA	0.0236	3	3	SHARP TM	0.0096	23	31
FISCHER M	0.0208	4	5	RIVERA A	0.0095	24	32
POWERS AM	0.0190	5	4	PASTULA DM	0.0087	28	33
PETERSEN EE	0.0190	6	7	POLEN KN	0.0082	29	21
RIVERA-GARCIA B	0.0175	7	8	LANCIOTTI RS	0.0078	34	23
MEANEY-DELMAN D	0.0171	8	6	OSTER AM	0.0078	40	22
RASMUSSEN SA	0.0158	9	11	VALENCIA-PRADO M	0.0076	41	20
STAPLES JE	0.0155	10	10	SHAPIRO-MENDOZA CK	0.0076	43	18
MUNOZ-JORDAN J	0.0151	11	12	ELLINGTON SR	0.0075	46	24
RYFF KR	0.0132	12	25	HENNESSEY M	0.0073	48	30
RUSSELL K	0.0129	13	13	RENQUIST CM	0.0072	50	29
HILLS SL	0.0127	14	10	KUEHNERT MJ	0.0070	53	34
MEAD P	0.0122	15	15	SIMEONE RM	0.0063	72	27
PEREZ-PADILLA J	0.0110	16	14	JOHANSSON MA	0.0055	87	28
BROOKS JT	0.0108	17	16	PETERSEN LR	0.0054	88	26

Table 10

Comparative ranking of subnetwork 3, which includes the researchers' PageRank position (PRP), the Freeman ranking position (FRP) and the color categories based on the number of publications (Table 3).

Researcher	PageRank	PRP	FRP	Researcher	PageRank	PRP	FRP
MUSSO D	0.0397	1	2	GAREL C	0.0132	10	9
LEPARC-GOFFART I	0.0364	2	3	BESNARD M	0.0132	12	11
CAO-LORMEAU VM	0.0257	3	1	MAQUART M	0.0113	28	14
DESPRES P	0.0215	4	4	ROCHE C	0.0113	29	10
SIMON-LORIERE E	0.0184	5	6	BROULT J	0.0111	30	12
DE LAMBALLERIE X	0.0182	6	13	BAUD D	0.0102	36	15
MALLET HP	0.0179	7	5	ROUSSET D	0.0092	46	17
SAKUNTABHAI A	0.0171	8	8	VOUGA M	0.0083	59	16
TEISSIER A	0.0162	9	7	*PANCHAUD A*	*0.0064*	*75*	

Note: this ranking also includes 1 researcher that does not appear in the Freeman ranking (in *italics*).

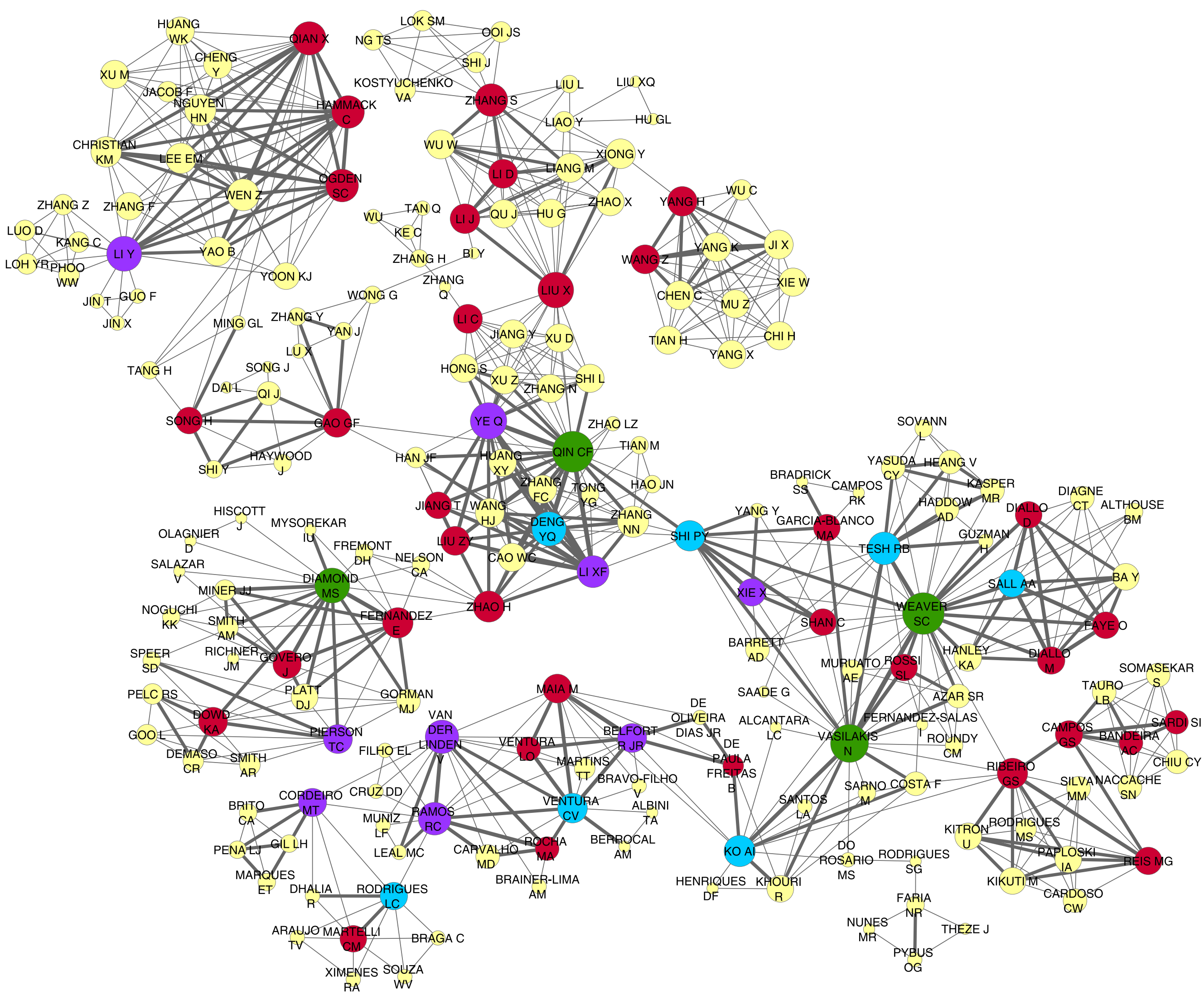
The study of the Zika epidemic in Puerto Rico appears in this network, again demonstrating the formation of subnetworks through geopolitical and institutional relations.

The co-authorship groups are quite interchangeable. Based on the most influential first authors, some co-authorships can be identified:

- Denise Jamieson, Sonja A. Rasmussen (RASMUSSEN AS), Margareth Honein, Lyle R. Petersen (PETERSEN LR), Erin Staples, Mark Fisher.
- Titilope Oduyebo, Mark Fischer, Emily E. Petersen (PETERSEN EE), Carrie K. Shapiro-Mendonza (SHAPIRO-MENDOZA CK), Denise Jamieson, Margareth Honein, Dana Meaney-Delman (MEANEY-DELMAN D).

Figure 3

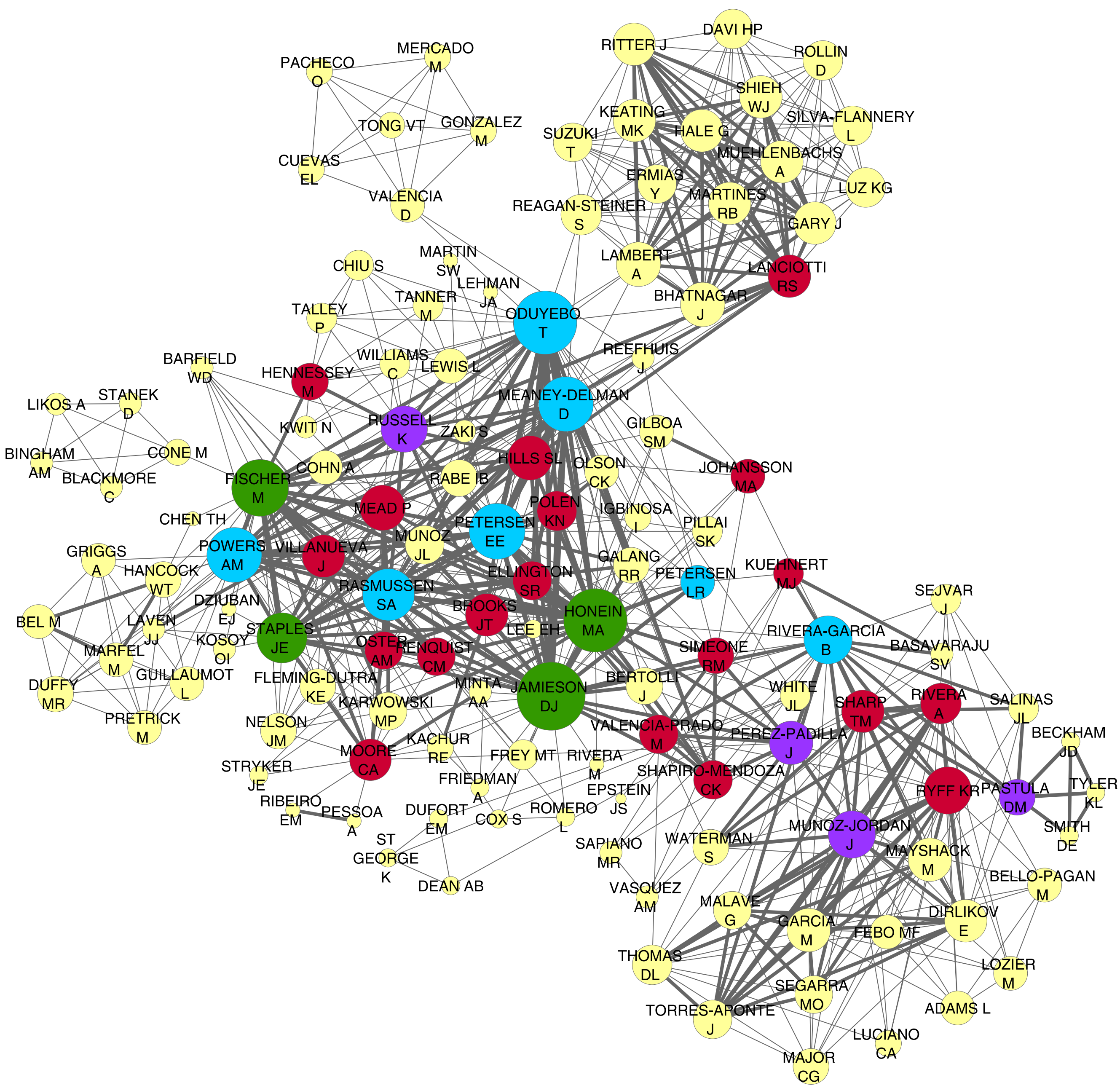
Collaboration graph of the subnetwork 1, highlighting the most influential researchers in this cluster according to the color categories defined in Table 3.



- Mark Fischer, Erin Staples, Cynthia Moore (MOORE CA), Paul Mead (MEAD P), Margareth Honein, Sonja Rasmussen.
- Brenda Rivera-Garcia (RIVERA-GARCIA B), Regina M. Simeone (SIMEONE RM), Carrie Shapiro-Mendonza, Denise Jamieson, Miguel Valencia Prado (VALENCIA-PRADO M), Janice Perez-Padilha (PEREZ-PADILLA J), Sascha R. Ellington (ELLINGTON SR), in the scientific production on Zika in Puerto Rico.
- Tyler M. Sharp (SHARP TM), Aidsa Rivera (RIVERA A), Brenda Rivera-Garcia, also in the scientific production on Zika in Puerto Rico.
- Mark Fisher, Paul Mead, Morgan Hennessey (HENNESSEY M), Kate Russel (RUSSEL K), Susan L. Hills (HILLS SL).

Figure 4

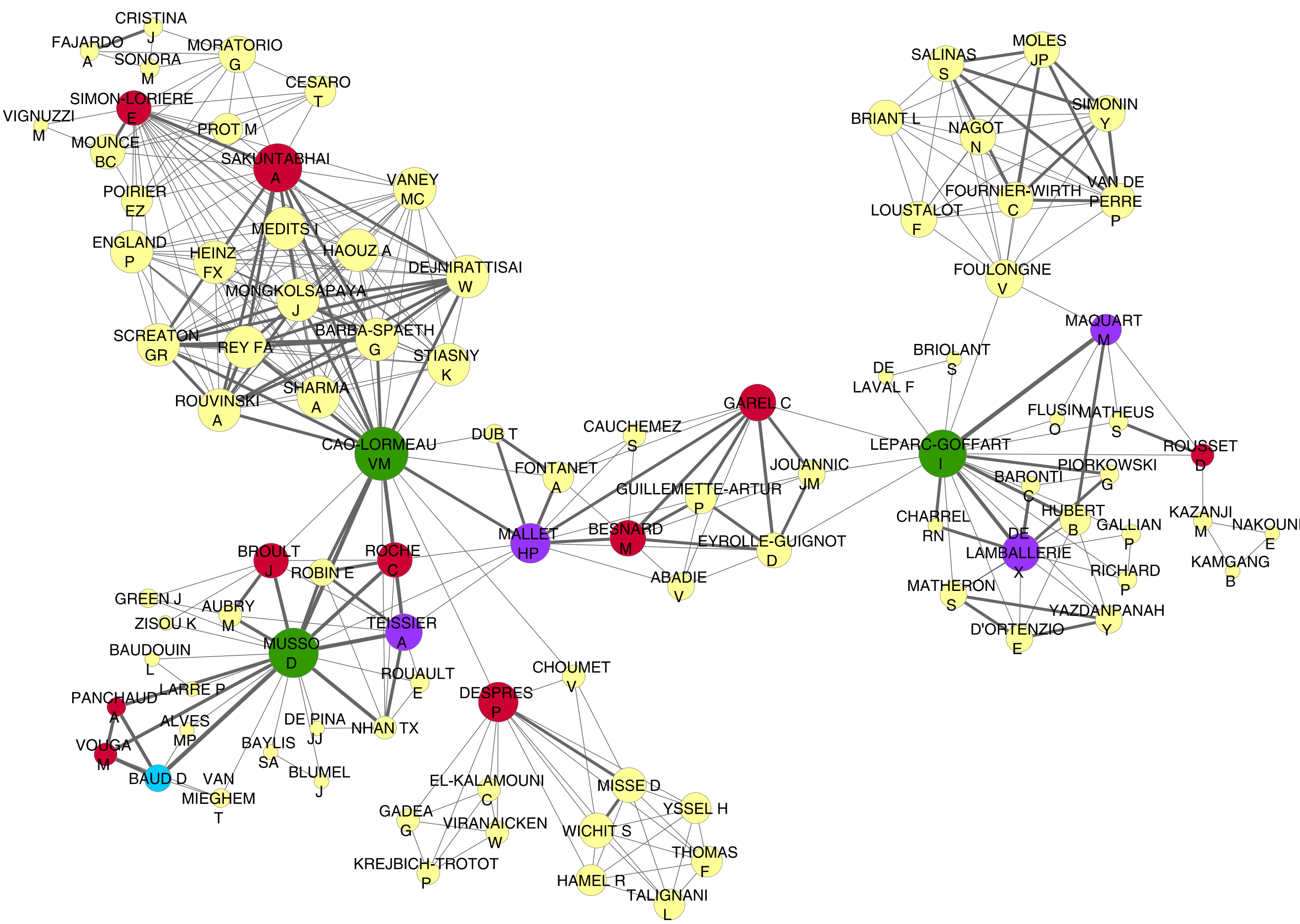
Collaboration graph of the subnetwork 2, highlighting the most influential researchers in this cluster according to the color categories defined in Table 3.



• Titilope Oduyebo, Robert Lanciotti (LANCIOTTI RS), Amy Lambert, Julu Bhatnagar and Kleber Giovanni Luz. This group of coauthors includes a researcher from Federal University of Rio Grande do Norte, another state from Northeast Brazil that also experienced the epidemic, like Bahia and Pernambuco. Kleber Luz appears in subnetwork 2 as coauthor, recording the first cases of microcephaly in the state of Rio Grande do Norte [26]. However, this researcher does not appear among the most influential.

Figure 5

Collaboration graph of the subnetwork 3, highlighting the most influential researchers in this cluster according to the color categories defined in Table 3.



Compared to subnetwork 1, this cluster is denser and shows higher correlation between the four centrality metrics analyzed.

- **Subnetwork 3**

This cluster consists mainly of authors affiliated with Institut Pasteur (Paris/France), Institut Pasteur (French Guiana), ILM (Tahiti), Aix-Marseille Université – AMU (Marseille), NRCA-IRBA (Marseille) and École de Pharmacie Genève-Lausanne, Université de Genève (Geneva/Switzerland).

As shown in Tables 7 and 10, the principal nodes are Didier Musso and Cao-Lormeau from ILM (Tahiti); and Isabelle Leparc-Goffart from NRCA-IRBA (Marseille). These three authors began to publish on Zika in the year 2014, when the outbreak occurred in French Polynesia [27].

One can observe two distinct groups in this subnetwork, one led by Didier Musso and Cao-Lormeau and the other by Leparc-Goffart.

The strongest co-authorship group in this subnetwork is linked to Didier Musso and Cao-Lormeau, with strong participation by Anita Teissier (TEISSIER A), also from ILM, and Henry-Pierre Mallet (MALLET HP) from the French Polynesia Ministry of Health.

Leparc-Goffart has strong links in co-authorships with Xavier de Lamballerie (DE LAMBALLERIE X) from AMU (Marseille) and Marianne Maquart (MAQUART M) from NRCA-IRBA. Dominique Rousset (ROUSSET D) from Institut Pasteur (French Guiana) also appears as a coauthor linked to Leparc-Goffart, but with a weaker link.

In this subnetwork, Marianne Besnard (BESNARD M) (Hôpital Du Taaone, Tahiti) and Catherine Garel (GAREL C) (Hôpital Armand Trousseau, Assistance Publique-Hôpitaux de Paris, Université Pierre et Marie Curie, Paris-France) are important nodes that link the group of Leparc-Gofart to the group of Didier Musso and Cao-Lormeau.

Three authors from Swiss institutions, *Alice Panchaud* (*PANCHAUD A*) of Geneva and David Baud (BAUD D) and Manon Vouga (VOUGA M) of Lausanne are linked to Didier Musso.

Final remarks

This study aimed to identify the principal research groups in Zika, as well as the researchers with the most publications and the highest prestige/status on this subject. To achieve this, the study analyzed scientific interactions in the Zika SSN at three levels: global, local, and individual.

The global analysis provided a macro view of this field of study via bibliometric indicators. According to this analysis, compared to other studies conducted in the PubMed/MEDLINE database on various themes in Biomedicine, collaboration and publishing output by Zika researchers is smaller than other themes in public health, reflecting the limited importance assigned to ZIKV in the international scenario until the recent epidemics [22].

The local analysis identified the three main clusters of researchers in the SSN, with 208, 133, and 96 nodes, respectively, which include the most important research groups in this area.

The individual analysis identified the 106 most influential researchers – in terms of activity and collaboration – in research on ZIKV.

The observation of these names and research groups shows that they are the researchers who are spearheading significant strides on Zika research, exercising leadership in renowned research institutions and coordinating joint efforts between different institutes and research groups, favoring the exchange of knowledge.

The study also found that in general the researchers with the most publications were among the most influential in their respective subnetworks. In this sense, it is interesting to note that many of these cases (researchers with high influence and productivity) are people that belong to well-defined research groups with strong geopolitical and institutional references, responsible for considerable strides in studies on ZIKV. These results stand out when analyzing who are the researchers in Table 4, that shows the 11 most productive ones in the 3 subnetworks.

The study's data signal that a researcher's influence in Zika SSN is basically determined by three factors: (a) whether their efforts are translated as results corroborated by their publications (productivity); (b) whether their publications are the result of partnerships between different research groups, favoring exchange of knowledge; and (c) the amount of links established, more specifically with groups/researchers that are or have been pioneers in the search for answers to solve the problem [28].

Although Brazilian researchers have played a relevant role in identification of neurological damage related to congenital Zika and in the subsequent investigation, the Brazilian research networks do not stand out in the analyses performed here.

Importantly, thus far no national or international mapping or studies have been published on how scientific interactions on the disease occurred (studying in depth the Zika SSN). This study is thus pioneering on the subject as an important element for studying the evolution of research on Zika. The methodology can also be applied to the study of other areas of science.

The results can be used to understand and improve the scientific collaboration between research groups in ZIKV.

Future studies should continue with analysis of the impact and social recognition of researchers and their discoveries through alternative metrics (*altmetrics* [13]).

Contributors

L. F. M. P. Maia was the principal researcher in charge of the study's conception and working project, creation of the computational architecture, data capture and treatment, and data analysis and interpretation, and was the principal author, responsible for writing most of the text. M. Lenzi was responsible for contextualization of the disease, writing, and qualitative validation, thus guaranteeing the results' precision and integrity. E. T. Rabello was responsible for revision of the article and the qualitative data analysis. J. Oliveira was responsible for the study's conception, definition of the methodology, and final revision.

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Resumo

Devido à associação entre Zika e microcefalia, o Brasil recebeu atenção neste cenário. A situação de emergência exigiu rapidez e esforço coletivo dos pesquisadores de todo o mundo, e a Ciência se apressou nas investigações e publicação dos resultados. A partir das interações formadas, criou-se e se disseminou conhecimento científico. Publicações ainda são a melhor forma de divulgar o conhecimento científico. Através delas é possível registrar os progressos realizados em um campo de estudos e observar como os cientistas colaboram entre si para conduzir avanços à medida que novos conhecimentos e tecnologias são engendrados. Um modo eficaz de mapear esses avanços é analisar as Redes Sociais (redes de relacionamentos e colaboração) dos cientistas, já que atualmente a colaboração constitui uma característica intrínseca da Ciência moderna. Desse modo, a coautoria em publicações se apresenta como um importante indicador de colaboração científica na compreensão dos progressos realizados em diversas áreas da Ciência. Este trabalho objetiva, por um método generalizável, mapear e analisar a Rede Social Científica formada no domínio de Zika, mostrando como os cientistas colaboraram entre si para conduzir os principais avanços de pesquisa, identificando os principais grupos de pesquisa em Zika, além dos pesquisadores mais influentes. Para isso, utilizaram-se técnicas de Análise de Redes Sociais nas redes de coautoria formadas entre os anos de 2015 e 2016. Os dados deste estudo sinalizam que a influência de um pesquisador em Zika é basicamente motivada por três fatores: (a) quantidade de publicações; (b) parcerias diversificadas; e (c) os vínculos estabelecidos com os pioneiros da área.

Zika Vírus; Autoria e Coautoria na Publicação Científica; Rede Social; Comportamento Cooperativo

Resumen

Debido a la asociación entre el Zika y la microcefalia, Brasil, como país, llamó la atención sobre este campo de estudio. La situación de emergencia ocasionada exigió rapidez y un esfuerzo colectivo de los investigadores de todo el mundo, asimismo, la ciencia se apresuró en ofrecer investigaciones y la publicación de resultados sobre este tema. Debido a las interacciones surgidas, se creó y diseminó conocimiento científico. Las publicaciones hoy en día todavía son la mejor forma de divulgar conocimiento científico. Gracias a ellas, es posible registrar los progresos realizados en un campo de estudio y observar cómo los científicos colaboran entre sí para llevar a cabo avances, a medida que se generan nuevos conocimientos y tecnologías. Un modo eficaz de mapear estos avances es analizar las Redes Sociales (redes de relaciones y colaboración) de los científicos, ya que actualmente la colaboración constituye una característica intrínseca de la ciencia moderna. De este modo, la coautoría en publicaciones se presenta como un importante indicador de la colaboración científica en la comprensión de los progresos realizados en diversas áreas de la ciencia. El objetivo de este trabajo, como método generalizable, es mapear y analizar la Red Social Científica, formada en el campo de Zika, mostrando cómo los científicos colaboraron entre sí para llevar a cabo los principales avances en investigación, identificando los principales grupos de investigación sobre Zika, además de a los investigadores más influyentes. Para ello, se utilizaron técnicas de Análisis de Redes Sociales, en redes de coautoría formadas entre los años de 2015 y 2016. Los datos de este estudio señalan que la influencia de un investigador en Zika está básicamente motivada por tres factores: (a) cantidad de publicaciones; (b) colaboraciones diversificadas; y (c) vínculos establecidos con los pioneros del área.

Virus Zika; Autoría y Coautoría en la Publicación Científica; Red Social; Conducta Cooperativa

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