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Recent trends in the use of social media in parasitology and the application of alternative metrics

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ABSTRACT

In recent times, the use of social media for the dissemination of "news and views" in parasitology has increased in popularity. News, Twitter and Blogs have emerged as commonplace vehicles in the knowledge dissemination and transfer process. Alternative metrics ("altmetrics"), based on social media mentions have been proposed as a measure of societal impact, although firm evidence for this relationship is yet to be found. Nevertheless, increasing amounts of data on "altmetrics" are being analysed to identify the nature of the unknown impact that social media is generating. Here, we examine the recent, and increasing use of social media in the field of parasitology and the relationship of "altmetrics" with more traditional bibliometric indicators, such as article citations and journal metrics. The analyses document the rise and dominance of Twitter as the main form of social media occurring in the discipline of parasitology and note the contribution to this trend of Twitter bots that automatically tweet about publications. We also report on the use of the social referencing platform Mendeley and its correlation to article citations; Mendeley reader numbers are now considered to provide firm evidence on the early impact of research. Finally, we consider the Twitter profile of 31 journals publishing parasitology research articles (by volume of papers published); we show that 13 journals are associated with prolific Twitter activity about parasitology. We hope this study will stimulate not only the continued and responsible use of social media to disseminate knowledge about parasitology for the greater good, but also encourage others to further investigate the impact and benefits that altmetrics may bring to this discipline.

1. Introduction

Defining research impact is of considerable importance, especially in current times when research assessment is carried out in numerous ways by Institutions and Governments alike (Greenhalgh et al., 2016). In the past, academics were groomed during their training to believe in publication citations and journal impact factors, but ideas have changed enormously in recent times about impact. The Australian Research Council defines research impact as "the contribution that research makes to the economy, society, environment or culture, beyond the contribution to academic research" (https://www.arc.gov.au/policies-strategies/strategy/research-impact-principles-framework), while the U.K. Research Excellence Framework (REF) defines impact as "an effect on, change or benefit to the economy, society, culture, public policy or services, health, the environment or quality of life, beyond academia" (https://re.ukri.org/research/ref-impact/). Implicit in these definitions are the contributions to Society that exist beyond academic work. The paybacks of research come in many forms; knowledge, training, changes to policy, monetary and economic benefits and so on (Milat et al., 2015; Greenhalgh et al., 2016; Kamenetzky & Hinrichs-Krapels, 2020). Within the many impact assessment frameworks evolving to measure research impact, social media is acknowledged as a relatively recent avenue for knowledge dissemination and transfer (Cruz Rivera et al., 2017). Thelwall (2020a, b) provides an excellent overview of current thinking on the value of altmetrics and research assessment.

The alternative metrics (or altmetrics for short) consists of data gathered from social media websites about mentions of published scientific papers. The Altmetric Attention Score (AAS), along with its colourful, instantly recognisable donut, is a weighted score automatically calculated by Altmetric from mentions on News, Blogs, Policy

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documents, Patents, Wikipedia, Twitter and F1000, and it has gained considerable popularity for quickly assessing research impact in a dynamic way that is almost in real time. The sources of these data include real-time feeds from English and non-English news outlets as well as a manually curated list of blogs. Data are also collected *via* an API from Twitter, Facebook, Mendeley, Web of Science plus others (a detailed summary is provided here: https://help.altmetric.com/support/solutions/articles/6000060968-what-outputs-and-sources-does-altmetric-track-).

The use of altmetrics lay in the studies of Priem and colleagues who explored social media for its impact on scholarship (Priem et al., 2010, 2012; Priem, 2013). Sites such as altmetric.com aggregate such data from a range of sources by tracking these engagement events. The challenges of working with this kind of data has already been recognised and include confusing terminology, data collection, processing and integrity issues (Erdt et al., 2016). Nevertheless, previous studies record the emergence and value of altmetrics for highlighting the attention research is receiving in social media. Whilst altmetrics are not considered a replacement for traditional bibliometric methods (such as citation analyses), they are regarded as a complement with their own pros and cons (Williams, 2017). Their real value in determining impact is still under investigation (Bornmann et al., 2019; Thelwall, 2020a, b).

As the result of their widespread use and availability, the use of altmetrics to measure research impact has been the basis of many research studies, including their comparison to traditional bibliometrics (Bar-Ilan, 2012; Li et al., 2012; Thelwall et al., 2013). Correlations to metrics such as citations have generally proven to be very low (Costas et al., 2015), although citation counts were shown to be correlated with the use of a social reference manager (i.e. number of Mendeley readers) (Bornmann, 2015; Thelwall, 2018). A Mendeley reader count represents the number of people that have bookmarked a document in Mendeley and assumes that most of these users read or intend to read the document (Mohammadi et al., 2016). Current thinking suggests that Mendeley readers provide evidence for early academic research impact (Maflahi & Thelwall, 2016). Further, the suggestion that altmetrics may be an indicator of societal impact of research has not been proven (Bornmann et al., 2019). Despite this, the benefits of real-time dissemination of research to a diverse audience of scholars (including non-publishing authors) and the general public is seen as an attractive communication strategy for a range of reasons, including content and promotional reasons (Holmberg & Vainio, 2018).

The purpose of this study was to investigate and highlight the use of social media for disseminating information about parasitology research; in addition, we investigate recent trends in altmetric data (sourced from Altmetric Explorer) that arise from the use of social media on parasitology. We hope this study will encourage not only the responsible use of social media to convey knowledge about parasitology for the greater good, but also to encourage others to investigate the impact and benefits that altmetrics may provide to this discipline.

2. Materials and methods

2.1. Data collection

This study used the Dimensions database (https://app.dimensions.ai/discover/publication); a search used the term “parasite” in the title and abstract of publications. Searches were time restricted (e.g. by year or time frame) and limited to articles. Search results were exported to the Altmetric Explorer (https://www.altmetric.com/explorer/login) directly from Dimensions for production of altmetric data. Searches of the Altmetric database were also conducted using Altmetric Explorer directly using the same search term.

2.2. Correlation analyses

Descriptive statistics of altmetric data from Altmetric were generated in Excel using the Data Analysis add-in. The relationship between the citations to articles (from Dimensions) and the main contributors to altmetrics were investigated in a number of ways. First, scatter plots were created to identify any major trends and interquartile ranges were calculated (in Excel using the quartile function); correlations were performed using Spearman’s rank correlation coefficient as most bibliometric analyses use the latter because of the sparseness of the data (Erdt et al., 2016). Spearman’s correlations (and *P*-values) were calculated with Python 3.8.3 using the algorithms found in either the *numpy* or *scipy* packages. Distribution of data as percentile ranges was determined in Excel using the percentile function.

Several analyses were also performed using Python run in a Jupyter notebook (v6.0.3). These included determination of the Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy and Bartlett’s test of sphericity using the Python module factor_analyzer in Python 3.8.3. Principal components analysis (PCA) was performed using scikit-learn (https://scikit-learn.org/stable/). Data preprocessing (for 44,377 publications) was performed using the StandardScaler utility from the scikit-learn preprocessing module, which scales data to have zero mean and unit variance.

2.3. Twitter Index of parasitology journals

A Twitter Index of parasitology journals was formulated for 2019. Briefly, articles from a search of Dimensions were identified with “parasite” in the title and abstract of publications. The search results from those journals with greater than 100 publications in 2019 were exported to Altmetric Explorer and altmetrics gathered. If 80% or more of the articles in a journal received a tweet, the journals were further analysed. The number of tweets per journal were normalised by calculating percentiles using the formula of Hazen as suggested (Bornmann & Haunschild, 2016). Journals were then ranked by their tweet median percentile value. The Twitter citation rate was calculated as the mean number of tweets received by articles in a journal (number of tweets/number of articles).

The metrics Scimago Journal Rank (SJR), Journal Impact Factor (JIF), H-index, Source Normalised Impact per Paper (SNIP) and CiteScore were obtained from either Scimagojr (https://www.scimagojr.com/), InCites Journal Citation Reports (https://clarivate.com/webofsciencegroup/solutions/journal-citation-reports/) or letPub (https://www.letpub.com/). Spearman's correlations were investigated amongst these metrics for 2019 and altmetric data for individual journals in the following way: for 2019 a search of Dimensions using the term “parasite” in the title and abstract of publications (as described above) was performed. Journals were ranked according to volume of papers published. The top ten core parasitology journals (i.e. publishing only parasitology papers, such as *Parasitology*) were identified along with the top ten multidisciplinary journals publishing parasitology papers (e.g. *Scientific Reports*). Altmetrics data for these journals were sourced from Altmetric Explorer. Analyses were performed in Excel.

As the database search using a keyword has the potential to induce bias into the data analysed, a Twitter Index of journals publishing parasitology articles was also formulated using journals present in the Parasitology category of Scimago Journal & Country Rank (https://www.scimagojr.com/). The journals in the Parasitology category were ranked by either SJR or H-index and the top 20 journals selected; the lists were combined to provide a list of 28 unique journals for analysis. Three additional journals identified in the above studies (*Scientific Reports*, *PLoS One*, *PLoS Neglected Tropical Diseases*) were added to the list for completeness. For articles in the Dimensions database from 2019, the numbers of publications for each of the 31 journals was obtained using the filter “Source Title”; altmetrics data were collected from each of these searches using Altmetric Explorer.

2.4. Analyses of terms in journal article titles

GATE was used with ANNIE and the TermRaider plugin (https://gate.ac.uk/projects/neon/termraider.html) to perform term extraction

(Maynard et al., 2008; Cunningham et al., 2013). This pipeline uses the processing resources of ANNIE for tokenising, sentence splitting, language recognition through the ANNIE gazetteer and POS tagging. TermRaider extracts important nouns or noun phrases from the text. The titles of the peer-reviewed papers from 2019 that received at least one tweet were investigated for the main topics present by determining the frequency of the words. Term frequency was determined in TermRaider for nouns and noun phrases. Word clouds were generated from term frequencies using WordClouds.com.

3. Results

3.1. General observations using Altmetric Explorer

A search in Altmetric Explorer (accessed 21 May 2020) using “Parasite” in the title identified ~169,000 total mentions with social media making up the vast majority of mentions. Such a search is not restricted to peer-reviewed papers and encompasses a wide selection of media sources, including policy documents. Within the social media category, Twitter was by far the most common form of communication with 136,439 mentions (> 80%) followed by Facebook (6,380 mentions). News and blogs made up ~7% of the activities with news (7,560 mentions) being more than twice as common as blogs (3,708 mentions). Patents and policy made up ~5% mentions with patents (6,727 mentions) being three times more common than policy documents (2,016 mentions). Of the other sources, Wikipedia was most commonly represented with 3,930 mentions (~2.5%).

On the day this search was conducted, the top five mentions from this search include reference to bird behaviour (https://www.nature.com/news/city-birds-use-cigarette-butts-to-smoke-out-parasites-1.11952), the award of Nobel prize for antiparasitic drugs (https://www.nature.com/news/anti-parasite-drugs-sweep-nobel-prize-in-medicine-2015-1.18507), and mentions to peer-reviewed journal articles including one on the spread of drug-resistant malaria (Imwong et al., 2017). The most mentioned article, however, was published in 2020 and reports on a cnidarian parasite of salmon that lacks a mitochondrial genome (Yahalomi et al., 2020), mentioned by 138 news outlets and 643 tweeters. More recently (accessed 3 September 2020), a paper entitled “The immunogenetics of sexual parasitism” (Swann et al., 2020) has emerged with an AAS of 961, with News, Twitter, Blogs and Facebook mentions.

The main sources of mentions on Twitter are summarised in Table 1 and include many Twitter bots, that represents bot software that controls a Twitter account *via* the Twitter API (Haustein et al., 2016). Most Twitter activity originates from the USA and UK (which together make up greater than 25% of the activity), along with various other European countries (e.g. France, Germany, Spain), Australia, Canada and Japan. The World Health Organisation is the main source of mentions in policy documents, while two news outlets dominate: phys.org (UK, https://phys.org/) and EurekAlert (American Association for the Advancement of Science, https://www.eurekalert.org/).

3.2. Timeline for the uptake of social media

If we consider the timeline of the use of social media in parasitology, we can see a significant change in trends (Fig. 1). For 2000–2001, the mentions were predominantly made up by patents and policy documents; Wikipedia emerges in 2006–2007; and Twitter activity takes off from 2010. For 2018–2019, this amounts to ~55,000 tweets. Over the entire time period, 136,439 tweets occurred by 51,124 unique tweeters, in 197 countries.

3.3. In the News

The 53,000 publications from the last 10 years were ranked by News mentions. The publications in the top 20 list were dominated by various malaria themes, relating to surveillance, drug resistance and targets including antimalarials. However, of note was the interest in the decline of bumblebees (two reports) and cryptosporidiosis outbreaks in the USA. The publication with the highest mentions in the news was a 2018 case report describing conjunctival infestation with *Thelazia gulosa* (Bradbury et al., 2018).

Table 1
Ten major contributors to Twitter mentions on Parasitology (from Altmetric Explorer)

Twitter Handle	Mentions (total)	Mentions (2019)	Followers (2019)	Description
@par_papers	2,400	660	1,414	Twitter bot of Parasitology papers in PubMed, bioRxiv, and PeerJ PrePrints. https://twitter.com/FilipHusnik
@bloodSparasites	1,598	2,638	1,405	https://twitter.com/bloodsparasites
@worm_papers	982	301	528	Twitter bot for academics interested in parasitic worms, gut parasites and anthelminthics https://twitter.com/worm_papers
@BehavEcolPapers	807	479	3,008	https://twitter.com/behavecolpapers
@MalariaPapers	704	129	244	Twitter bot of papers about malaria as they appear on PubMed and preprints on BioRxiv https://twitter.com/MalariaPapers
@Nematode_papers	605	343	332	https://twitter.com/nematode_papers
@oceanologia	552			Marine Sciences Publications Feed https://twitter.com/oceanologia
@IBIS_journal	505	154	16,438	British Ornithologist's Union https://twitter.com/IBIS_journal
@protistologists	460	337	3,568	International Society of Protistologists https://twitter.com/protistologists
@nematologists	427	280	717	International Federation of Nematology Societies https://twitter.com/nematologists

3.4. Altmetrics of peer reviewed journal articles

Over 2,300 journals and collections were mentioned in the above-mentioned search using Altmetric Explorer, including many publishing primary research on parasitology. However, no parasitology journal makes the top 10 for total mentions; this section is dominated by *Nature*,

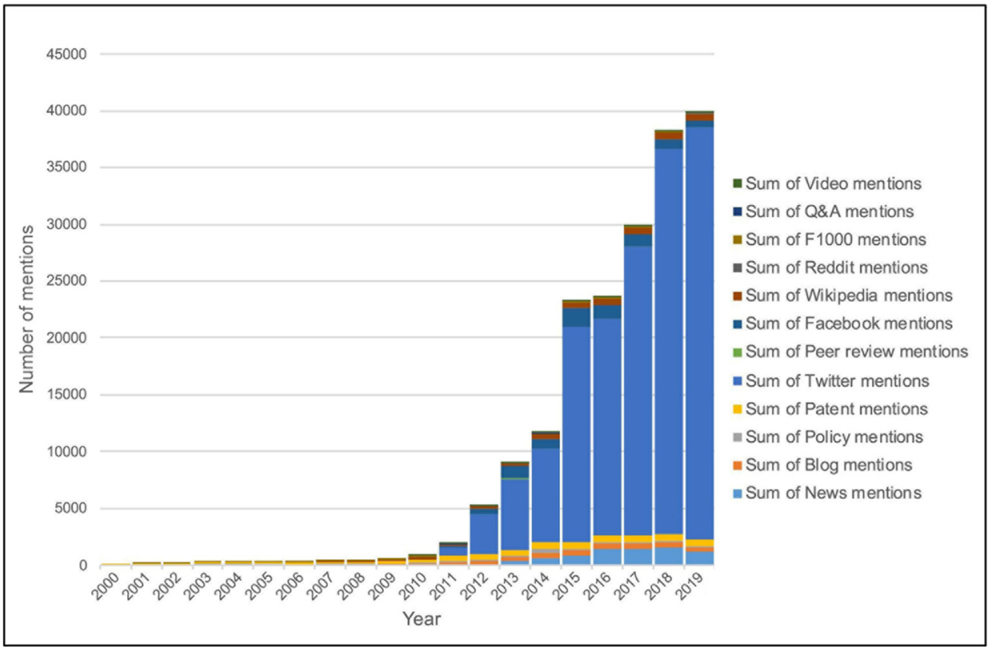

Fig. 1 Graph showing the accumulation in time of altmetrics data (sourced from Altmetric Explorer) relating to the discipline of parasitology

Science, *PNAS* and *Nature Communications*. Journals in the top 10 that more commonly publish parasitology related articles were *PLoS One*, *PLoS Pathogens*, *Proceedings of the Royal Society B: Biological Sciences* and *Scientific Reports*.

A search of the Dimensions database using the keyword "parasite" in the title and abstract AND year (e.g. 2019) was performed. The search was restricted to "articles", and altmetrics data for each year of publication during 2012–2019 were produced in Altmetric Explorer (leading to a total of 44,377 publications for 2012–2019). The descriptive statistics for these data are shown in Table 2. On a per article basis, the mentions identified are relatively low, but the range of mentions for each outlet varied significantly. The range of tweets received by an article varied from 0 to a maximum of 2,364, whereas mentions for an article on Wikipedia ranged from 0 to 26. Ninety percent of articles received no News, Blog, Policy, Patent or Wikipedia mentions. For these data, the mean, median and mode values for each type of social media are close to or equal to 0. The high kurtosis and skewness values indicate heavy tailed distributions of the data (containing outliers), which are positively skewed. For citations, the mean number/paper was ~15 but the range was very large (0–1,475).

Exploratory analyses of structure within the altmetrics dataset showed that the Bartlett's test was statistically significant, indicating that the observed correlation matrix was not an identity matrix (chi-square value: 662208, P-value < 0.0001). The KMO value was 0.51, indicating only a marginal value in pursuing factor analysis for the investigation of structure in the dataset. A scree plot showed that two factors generate an eigenvalue greater than 1, which explains more variance in the observed data than any single variable alone. Factor 1 was strongly correlated with AAS and news, while moderately correlated with Blog and Twitter mentions; Factor 2 was strongly correlated with the number of Mendeley readers and citations (not shown).

Exploratory PCA analyses of the altmetrics data from the 44,377 publications during 2012–2019 showed that five main components with eigenvalues of 3.29, 1.52, 0.91, 0.58, and 0.45 explained 96.5% of the variance within the data. The first two components alone explained ~69% of the variance. Component 1 was moderately associated with AAS, News, Blog and Twitter mentions, whilst component 2 was strongly associated with Mendeley readers and citations (Fig. 2). In conclusion, both factor and PCA analyses indicate the presence of two main trends in the altmetrics data. The first is the relationship amongst AAS, news, blog and Twitter mentions; since AAS is calculated from the other metrics then this relationship is to be expected. The second trend points to a relationship between Mendeley readers and citations.

Table 2
Descriptive statistics for altmetrics data (sourced from Altmetric Explorer) for 44,377 publications identified in the Dimensions database using the keyword "parasite" in the title and abstract AND year (2012–2019). The search was restricted to "articles"

Statistic	AAS[a]	News	Blog	Twitter	Facebook	Wikipedia	F1000	Mendeley	Citations
Mean	9.16	0.50	0.15	7.58	0.39	0.07	0.02	40.26	15.53
Standard error	0.20	0.02	0.00	0.15	0.02	0.00	0.00	0.32	0.16
Median	2	0	0	2	0	0	0	25	7
Mode	1	0	0	1	0	0	0	0	0
Standard deviation	41.20	4.06	0.79	32.01	3.48	0.42	0.19	66.42	32.80
Sample variance	1,697.13	16.51	0.63	1,024.81	12.10	0.17	0.04	4,411.00	1,075.34
Kurtosis	444.29	1,052.42	441.05	1,291.42	9,874.82	819.16	377.36	518.64	355.82
Skewness	17.15	25.39	15.00	28.03	82.81	19.19	13.50	15.20	13.63
Range	0–1,965	0–257	0–45	0–2,364	0–488	0–26	0–11	0–3,599	0–1,475
Sum[b]	406,340	22,038	6,830	336,372	17,510	2,974	1,063	1,786,437	689,162

[a] Altmetric attention score.
[b] Total number of mentions for each metric.

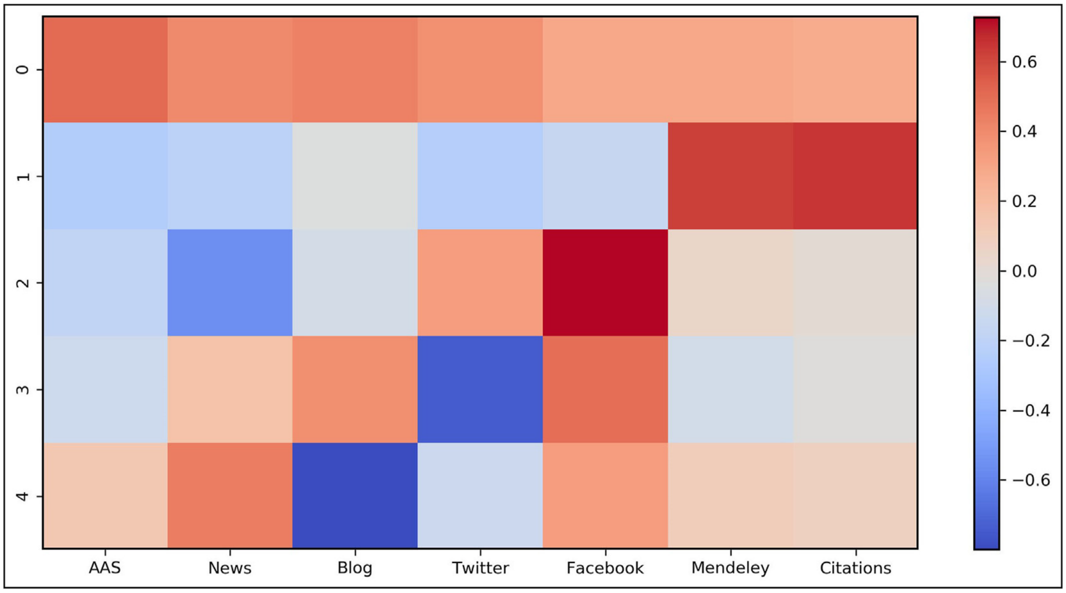

Fig. 2 Heatmap showing the covariation of altmetrics data from 44,377 publications from 2012 to 2019 with the five principal components, indexed from 0. Heatmap is based upon the PCA loadings data, which are derived from the eigenvalues and eigenvectors (providing magnitude and direction)

3.5. Altmetrics and citations

As the altmetrics data (sourced from Altmetric Explorer) are strongly negatively skewed with 0 mentions for many of the papers analysed, correlations amongst them were investigated using the Spearman's rank correlation coefficient. A heat map summarising the Spearman's correlations is shown in Fig. 3. A strong correlation was identified amongst Altmetric Attention Score and Twitter mentions; a low level of correlation also occurs between AAS and News, Blog or Facebook mentions. A relatively strong correlation was also identified between citations and Mendeley readers. The scatterplot resulting from a comparison of citations and Mendeley readers is shown in Fig. 4. Outlier analyses showed that 7.26% (for Mendeley readers) and 8.82% (for citations) of the papers fell above the upper boundary for these metrics (99.5 and 38

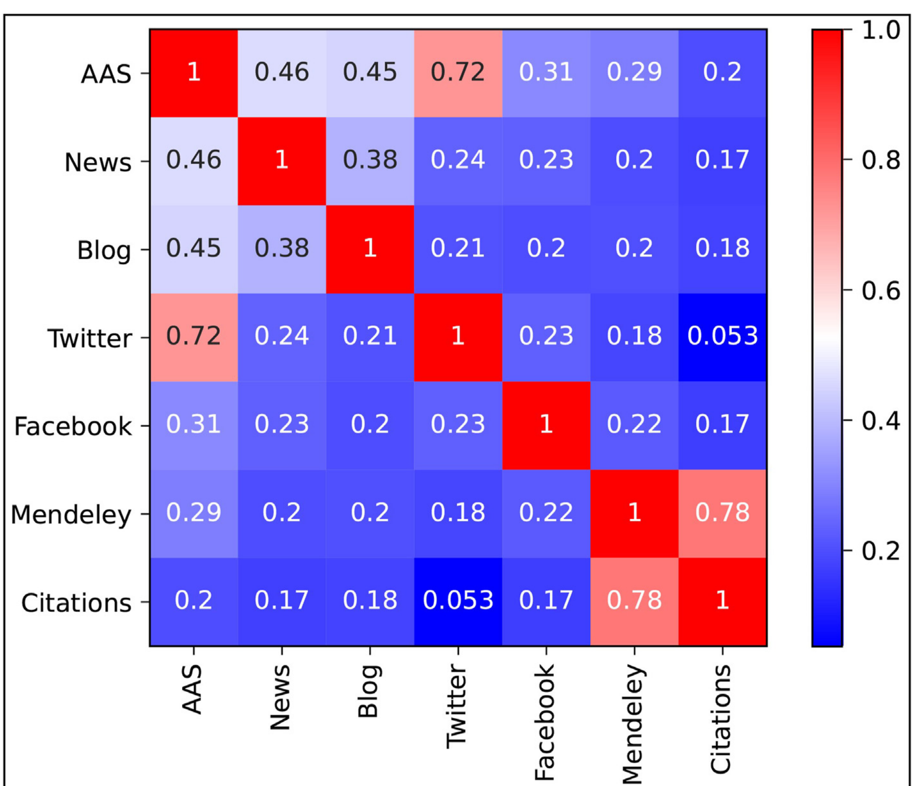

Fig. 3 Heatmap showing Spearman's correlations amongst the social media types. Altmetric attention score (AAS) was included for convenience. The heatmap is annotated with the Spearman's correlation coefficient

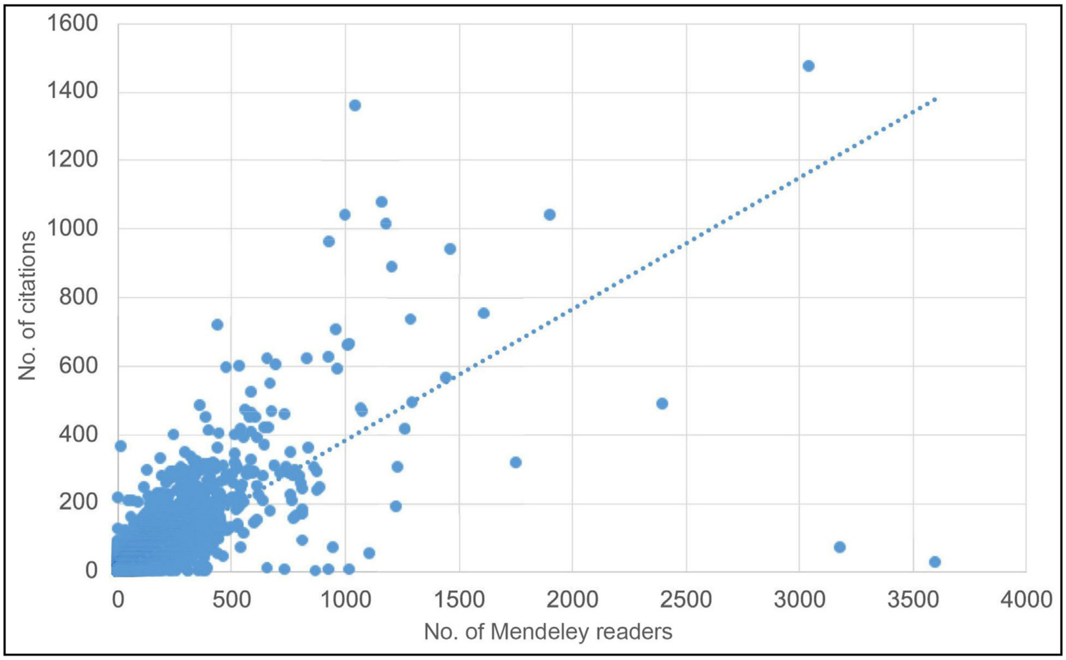

Fig. 4 Scatterplot showing the relationship between publication citations and the number of Mendeley readers (sourced from Altmetric Explorer) for the years 2012–2019. The vast majority of the papers are within the range 0–500 (Mendeley readers) and 0–400 (Citations). The trend line shown fits the equation $Y = 0.3834X + 0.0955$ and the Spearman's correlation coefficient is 0.78 with a P-value < 0.0001

respectively, calculated from the interquartile range and quartiles 1 and 3). Removing these outliers resulted in a mean number of Mendeley readers of ~29 and a mean number of citations of ~9 (down from ~40 to ~15, Table 2).

It is feasible that highly cited papers were receiving more attention through social media and so the total numbers of publications were analysed according to their citation percentile. A total of 4,411 publications received no citations, whereas the top one percentile was made up of 448 publications that received at least 123 citations/paper. For these percentile distributions (Table 3), AAS was strongly correlated with citations, Mendeley readers, and Twitter mentions (Table 4). Citations were strongly correlated with Mendeley readers and Twitter mentions.

3.6. A Twitter Index of journals publishing parasitology research

We investigated the identity of those journals active in social media. Eight journals met the initial criteria that they published 100 papers in 2019 that were identified by the keyword search; these were the *Malaria Journal*, *Parasites & Vectors*, *PLoS Neglected Tropical Diseases*, *Scientific Reports*, *Parasitology*, *Acta Tropica*, *PLoS One* and *Parasitology Research*. For the eight journals studied, the Twitter citation rate ranged from 3.5 to 8.7 tweets/publication; the percent of articles receiving at least one tweet ranged from 69 to 95%. Of the eight journals only four met the criteria of 80% or more articles had received a tweet; the Twitter Index of journals publishing parasitology research in 2019 was potentially limited to *Scientific Reports*, the *Malaria Journal*, *Parasites & Vectors* and *PLoS Neglected*

Table 3
Percentile distribution of altmetric data sourced from Altmetric Explorer

Percentile	Citation[a]	Mendeley[b]	Twitter[c]	Blog[d]	News[e]	AAS	N
0.01	0	0	0	0	0	0	
0.05	0	2	0	0	0	0	
0.1	1	5	0	0	0	1	36,527
0.2	2	10	1	0	0	1	33,492
0.3	3	15	1	0	0	1	30,765
0.4	5	20	2	0	0	1	26,032
0.5	7	25	2	0	0	2	22,152
0.6	10	32	3	0	0	3	17,602
0.7	15	41	5	0	0	4	13,314
0.8	21	55	7	0	0	7	8,714
0.9	35	83	15	0	0	14	4,317
0.99	123	261	85	3	11	135	448

Notes: To facilitate understanding, the 50th percentile (0.5) of citations have 7 or less citations, 25 or less Mendeley readers, 2 or less tweets, no mentions in blogs or news and an Altmetric Attention Score of 2. There are 22,152 publications in the top 50% percentile above this. The top one percentile contains 448 papers with citations greater than 123/paper.
Abbreviations: AAS, Altmetric Attention Score; N, number of publications above that percentile.
[a] Number of citations from Dimensions.
[b] Number of Mendeley readers.
[c] Twitter mentions.
[d] Blog mentions.
[e] News mentions.

Table 4
Spearman's correlation coefficient (above the diagonal) and associated *P*-value (below the diagonal) for the data shown in Table 3

	Percentile	Citations	Mendeley	Twitter	Blog	News	AAS
Percentile	–	1	1	0.99	0.48	0.48	0.98
Citations	1.29E-13	–	0.99	0.99	0.48	0.48	0.98
Mendeley	0	1.29E-13	–	0.99	0.48	0.48	0.98
Twitter	1.01E-09	4.12E-10	1.01E-09	–	0.48	0.48	0.96
Blog	0.114	0.011	0.114	0.11	–	1	0.48
News	0.114	0.011	0.114	0.11	0	–	0.49
AAS	2.11E-08	1.33E-08	2.11E-08	7.18E-07	0.11	0.11	–

Abbreviations: AAS, Altmetric Attention Score.

Tropical Diseases. The four journals which did not meet the 80% Twitter cut-off, despite publishing over 100 papers in 2019, were *Parasitology*, *Acta Tropica*, *PLoS One* and *Parasitology Research*.

The approach of using a key-word search is highly likely to miss many published journal articles not identified by the search. Consequently, we investigated 28 journals compiled from the Scimago Journal category for the parasitology discipline. We also included three additional journals identified in our analyses described above, but that did not appear in the Scimago listing (*Scientific Reports*, *PLoS One*, *PLoS Neglected Tropical Diseases*). We identified the total number of articles published by each of the 31 journals in 2019 as well as the number of articles in each journal receiving a tweet. These data are shown in Table 5. In this approach, 13 journals met the criteria of publishing greater than 100 papers in the year as well as receiving Twitter activity for at least 80% of them. These journals were *Ticks and Tick-borne Diseases*, *Cell Host & Microbe*, *Malaria Journal*, *PLoS Pathogens*, *Trends in Parasitology*, *Parasites & Vectors*, *Journal of Medical Entomology*, *Gut Pathogens*, *Medical and Veterinary Entomology*, *PLoS Neglected Tropical Diseases, International Journal for Parasitology, Epidemics* and *Journal of Parasitology*. This approach excludes the multi-disciplinary journals *Scientific Reports* and *PLoS One* from our Twitter index because of the large number of papers they publish, many of which do not receive Twitter mentions.

For the data from the 31 Journals and using a *P*-value cut-off of 0.05, there was no significant correlation between Twitter mentions and Journal quality metrics such as SJR, CiteScore, H-index or JIF. The Spearman's coefficient between SJR and percent of papers tweeted was 0.34 with a *P*-value of 0.062, suggestive of some influence of Twitter on SJR.

3.7. Analyses of terms in journal article titles

The titles of 5,628 peer-reviewed publications from 2019 (see Supplementary Table S1) that received at least one tweet were examined for the main topics associated with them (such as diseases, species and other noun phrases) using GATE and TermRaider. The vocabulary of the titles contained 11,346 words of which 6,845 represented hapaxes (i.e. appeared only once). The most common species mentioned in the titles were *Plasmodium falciparum*, *Plasmodium vivax*, *Toxoplasma gondii*, *Trypanosoma cruzi*, *Trypanosoma brucei*, and *Leishmania infantum* (Table 6). The main diseases mentioned were malaria, visceral leishmaniasis and Chagas disease, while the first mention of a control programme was drug. From a parasite biology perspective, the main terms were associated with parasite, infection, response and host. A word cloud summarising the top 50 noun phrases is shown in Fig. 5, which reinforces the nature of malaria research through terms such as malaria transmission and malaria elimination. Of further interest is that terms such as "new insight", "first report" and "new species" suggests that currency in dissemination is a significant component of Twitter activity.

4. Discussion

Altmetrics, the alternative metrics, includes mentions on social media, such as news and blogs, policy and patents and a range of other sources. There are a variety of sources that collect these data (Meschede & Siebenlist, 2018; Ortega, 2018; Bar-Ilan et al., 2019) and they seemingly differ in the way they collect and count data. In this study, we used Altmetric.com as a source of altmetrics, mainly because the tool Altmetric Explorer is relatively easy to use and it is feasible to easily import data directly from the Dimensions database. In addition, the Altmetric Attention Score has gained considerable popularity for assessing research impact. Altmetric.com no longer includes Pinterest, Google+, Weibo and LinkedIn data in their calculation of AAS, as these data are not publicly available.

Generally speaking, altmetrics data in parasitology are sparse, in that a large number of parasitology publications do not receive any social media attention. However, over the last 10 years, altmetrics data relating to parasitology have increased in their accumulation, primarily through Twitter which began in 2006 and has since become a very popular social microblogging site (Tang & Hew, 2017). Mentions on other social media are by comparison quite low. The scanty supply of data is not unique to parasitology; bibliometric specialists have made similar comments in the past for much greater datasets that include metrics with 0 scores (Thelwall et al., 2013; Haustein et al., 2014; Zahedi et al., 2014).

Twitter activity on parasitology has increased enormously since 2012 and is the primary mode of parasitology communication through social media. For comparison, in 2013 less than 10% of articles appeared on Twitter (Haustein et al., 2014). This is also true for parasitology research where the change observed goes from 0 to over 55,000 tweets/year in recent times. Tweets cover a wide range of topics in parasitology; often a tweet may be for journal or author promotion reasons, such as the release of a new publication, or for providing comment on a publication or idea. For whatever reason for their use, Twitter serves as a vehicle to quickly and efficiently disseminate information to a large majority of people. The investigation here revealed that Twitter bots feature significantly as the source of mentions of knowledge about parasitology research. Twitter bots, which are seemingly not linked to specific journals or publishers, are well known to be an automated vehicle for disseminating knowledge about scientific papers and so increasing Twitter counts (Haustein et al., 2016). Despite the negative press about Twitter bots, in parasitology they appear to be providing a valuable service for disseminating information about recently published papers.

Twitter activity within the mainstream has been called "simple, impulsive and uncivil" (Ott, 2017); we offer at this stage few viewpoints on the suitability of content of Twitter activity in parasitology. We note that circulation of details about published papers is occurring, as well as conference related activities and job opportunities. We investigated the terms in the titles of the papers that received Twitter activity, and demonstrated, using term extraction methodologies, that the neglected tropical diseases (malaria, visceral leishmaniasis and Chagas disease) were the main beneficiary of Twitter activity. Indeed, malaria does generally dominate Twitter in parasitology. Such Twitter activity is clearly beneficial to the broader community in many ways, including science dissemination. However, it would be interesting to investigate parasitology Twitter activity further through Sentiment, Linguistic Inquiry and Word Count and other forms of analyses (Tausczik & Pennebaker, 2010; Walter et al., 2019), as this may provide further insights into the psyche, motivation and drive behind the Twitter activity.

Another of the main conclusions from this study is that the altmetrics data associated with the peer-reviewed parasitology literature support a

Table 5
Determination of the Twitter Index of Parasitology journals. The journals are listed according to the total number of Twitter mentions received for papers published in 2019. Thirteen journals published more than 100 papers in 2019 and > 80% of these were subsequently mentioned in a tweet

Journal	No. of publications (2019)	Total no. of mentions	No. of Twitter mentions	Maximum no. of Twitter mentions/ paper	% papers receiving tweets	Scimago journal Rank	H-index	No. of self-citations	Total no. of citations	% (self/ total)	Publisher
Scientific Reports	20,424	242,011	14,156	7,429	69.3	1.3	179	12,558	283,384	4.4	Nature Publishing Group
PLoS One	16,227	154,906	10,172	9,677	62.7	1.0	300	7,034	193,380	3.6	Public Library of Science
PLoS Neglected Tropical Diseases	793	9,501	697	488	87.9	2.2	121	1,049	10,775	9.7	Public Library of Science
Parasites &Vectors	614	5,057	566	140	92.2	1.4	73	777	6,063	12.8	BioMed Central Ltd
PLoS Pathogens	557	11,155	524	688	94.1	3.6	191	457	11,840	3.9	Public Library of Science
Malaria Journal	449	4,046	429	80	95.5	1.8	96	1,025	4,264	24.0	BioMed Central Ltd
American Journal of Tropical Medicine and Hygiene	556	3,162	422	112	75.9	1.2	144	219	3,714	5.9	American Society of Tropical Medicine and Hygiene
Acta Tropica	378	3,695	285	2,151	75.4	1.0	95	217	2,753	7.9	Elsevier
Parasitology Research	383	927	255	25	66.6	0.7	89	200	2,624	7.6	Springer Verlag
Infection and Immunity	327	1,785	254	119	77.7	1.6	212	160	2,855	5.6	American Society for Microbiology
Journal of Medical Entomology	266	2,264	245	331	92.1	0.9	94	117	1,207	9.7	Oxford University Press
Cell Host & Microbe	204	13,589	198	521	97.1	7.2	163	102	6,736	1.5	Cell Press
Ticks and Tick-borne Diseases	189	1,566	189	98	100	1.2	39	313	1,623	19.3	Elsevier GmbH
Emerging Microbes & Infections	177	1,113	129	69	72.9	2.2	38	50	2,064	2.4	Nature Publishing Group
Veterinary Parasitology	171	475	124	35	72.5	1.1	117	252	2,273	11.1	Elsevier
Trends in Parasitology	130	2853	121	86	93.1	2.6	136	68	1,771	3.8	Elsevier
Tropical Medicine and International Health	151	814	117	85	77.5	1.3	109	25	1,204	2.1	Wiley-Blackwell Publishing Ltd
Journal of Parasitology	131	590	109	72	83.2	0.5	89	14	340	4.1	American Society of Parasitologists
Parasitology	185	859	107	109	57.8	1.1	109	85	1,506	5.6	Cambridge University Press
EFSA Journal	413	1,170	104	249	25.2	0.8	88	388	1,301	29.8	Wiley-Blackwell Publishing Ltd
Transactions of the Royal Society of Tropical Medicine and Hygiene	135	910	98	78	72.6	0.8	101	15	499	3.0	Oxford University Press
International Journal for Parastiology	102	908	89	53	87.3	1.7	139	38	1,108	3.4	Elsevier
Medical and Veterinary Entomology	65	584	60	47	92.3	0.9	78	27	346	7.8	Wiley-Blackwell Publishing Ltd
Gut Pathogens	59	274	54	28	91.5	1.1	36	13	643	2.0	BioMed Central Ltd
Epidemics	58	910	49	252	84.5	1.5	33	19	378	5.0	Elsevier
Virulence	75	201	46	18	61.3	1.8	57	23	1,626	1.4	Landes Bioscience
International Journal for Parastiology: Drugs and Drug Resistance	48	351	36	48	75.0	1.3	31	36	485	7.4	Elsevier BV
Molecular and Biochemical Parasitology	45	122	33	21	73.3	0.8	110	20	340	5.9	Elsevier
Parasite Immunology	53	70	33	6	62.3	1.1	72	25	595	4.2	Wiley-Blackwell Publishing Ltd
Pathogens and Global Health	46	133	26	23	56.5	1.0	67	9	343	2.6	Maney Publishing
Advances in Parasitology	36	25	8	7	22.2	2.6	84	8	653	1.2	Academic Press Inc.

Table 6
Top 25 dominant terms (nouns or noun phrases by frequency) identified in the titles of 5,628 publications from 2019 receiving at least one tweet (data sourced from Altmetric Explorer). Analyses performed in GATE using ANNIE and the TermRaider plugin

Single terms		Two terms commonly found together		
Term	Frequency	Term 1	Term 2	Frequency
parasite	688	*Plasmodium*	*falciparum*	281
infection	424	*Toxoplasma*	*gondii*	185
host	359	host	parasite	135
malaria	349	*Trypanosoma*	*cruzi*	132
falciparum	293	malaria	*Plasmodium*	129
Leishmania	266	malaria	parasite	114
response	244	infection	parasite	86
analysis	227	parasite	*Plasmodium*	85
gondii	196	*falciparum*	malaria	81
disease	183	*Plasmodium*	protein	66
protein	181	*Plasmodium*	*vivax*	63
study	176	gene	expression	59
species	173	*Leishmania*	*infantum*	58
cell	170	infection	*Plasmodium*	57
effect	163	visceral	leishmaniasis	52
transmission	144	Chagas	disease	52
nematode	139	infection	*Toxoplasma*	52
cruzi	138	*Trypanosoma*	*brucei*	51
characterization	137	infection	response	50
development	137	host	infection	49
drug	136	*falciparum*	parasite	48

link between Mendeley readers and citations. Correlation, factor and PCA analyses all point convincingly to this relationship. Further, this conclusion is convincing, given the fact that the same analyses also generate known correlations between AAS, News, Blog and Twitter mentions (since AAS is calculated from these metrics). Mendeley is a social reference manager, which allows users to bookmark, download, save and share research papers with other individuals. It is known that PhD (along with other postgraduate students) and postdoctoral scientists are the two main categories of Mendeley users (representing a particularly biased group), although there are many others (Mohammadi et al., 2015). The free online reference manager (Mendeley, CiteULike) reader/citation relationship has been described, and was previously identified in other studies (Li et al., 2012; Thelwall, 2020a, 2020b). This relationship is potentially relatively straightforward to interpret, in that authors are using the reference manager to bookmark, download and read publications, before authoring and citing their own papers.

Recent studies on altmetrics have attempted to determine whether they are related in some way to measures traditionally presumed to signify research quality, such as citations. Several studies have concluded that the numbers of Twitter mentions are not correlated with citations, and so their use as a measure of research quality is discouraged (Haunschild & Bornmann, 2018; Thelwall, 2020a, 2020b). Others (Eysenback, 2011) and (in a randomised trial) more recently suggested that Twitter promotion (particularly very early on after publication) does indeed predict subsequent citation rates (Ladeiras-Lopes et al., 2020; Sathianathen et al., 2020). However, the suggestion that altmetrics measure a different kind of impact is still under consideration (Baek et al., 2020).

We identified 13 journals that are relatively prolific in using social media, notably Twitter. A journals profile is subject to the many policies and processes adopted by the publishers and the editorial boards that manage the day-to-day activities of a journal. There is of course the potential here for significant levels of gaming to occur (Thelwall, 2020a, 2020b), through management of the various strategies for disseminating

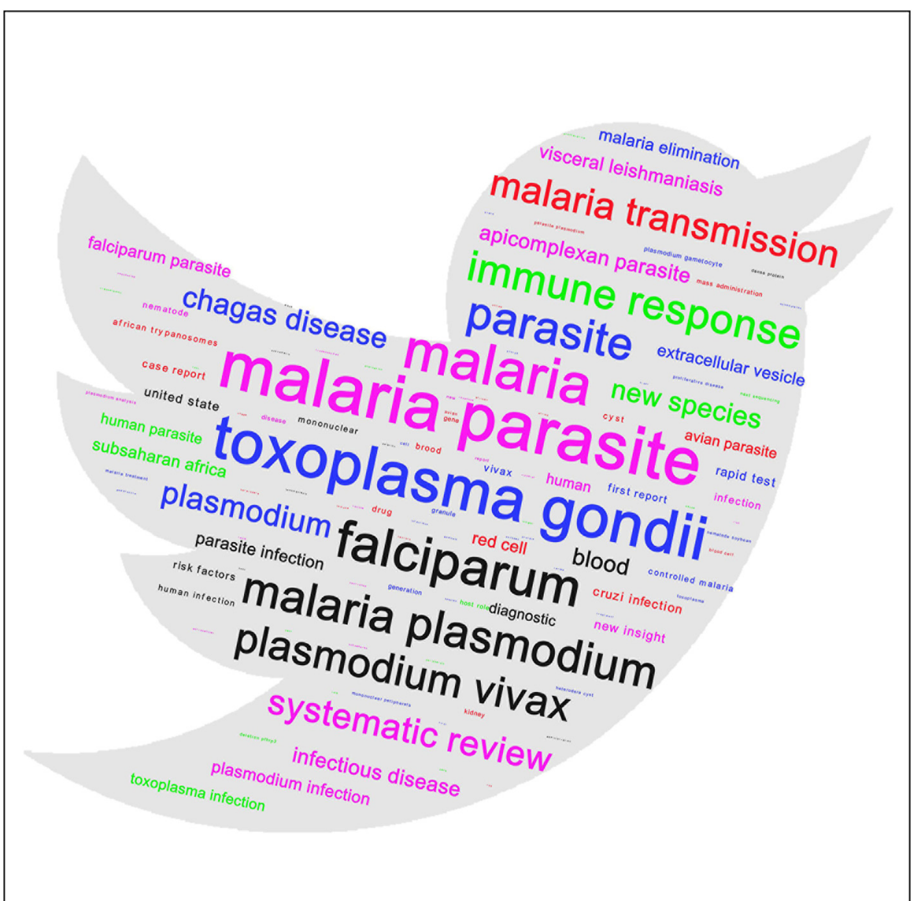

Fig. 5 Word cloud of the top 50 nouns and noun phrases identified using GATE and TermRaider from 5,628 peer-reviewed publications receiving Twitter activity

news about a journal's publications and the associated social media that goes with it. In our analyses, we included journals simply by the volume of parasitology papers published, as others have pointed out that it is inappropriate to rank journals (e.g. in the anaesthesia discipline) according to altmetrics data as they bear little relationship to traditional quality measures (Fassoulaki et al., 2018). Most publishers have a social media strategy that includes Twitter, Facebook and Blogs that are aimed to be informative to the wider community as well as promotional; for example, BugBitten is a blog for the parasites and vectors community that contains valuable informative content (http://blogs.biomedcentral.com/bugbitten/).

Recently, concern has been raised over the level of self-citation occurring in some journals; a practice that seemingly is also used extensively by some authors (see Van Noorden & Singh Chawla, 2019). Whilst there may be some logical reasons for self-citation, such as authors being simply highly productive and advancing knowledge boundaries (Mishra et al., 2018), self-citation varies considerably amongst authors (Ioannidis et al., 2019) and is now being viewed negatively because of the potential for citation manipulation and misrepresentation of research performance (Szomszor et al., 2020). Similarly, journal self-citation rates may influence metrics such as journal impact factor; and in some disciplines including parasitology this may account to 5–20% of citations received by a Journal in a time-dependent fashion (Heneberg, 2016). Of the 31 journals examined in the study presented here, the mean level of journal self-citations was ~7%; a relatively low level that appears compatible with those reported elsewhere for parasitology (Heneberg, 2016). Four journals (*EFSA Journal*, *Ticks and Tick-borne Diseases*, *Malaria Journal* and *Parasites & Vectors*), in contrast however, show relatively higher levels of self-citation. We presume there are rational and valid reasons for this. Three of these journals are Open Access (OA) whilst the fourth relates to a restricted research area (ticks). OA publishers tend to blog and microblog their articles, as open access publishing aims conscientiously to reach a broader than usual readership. Articles are accessible to a wide range of readers, including those in professional practice, lay-people, and also allows News agencies to access material directly from an OA journal. Authors expect journals to help them with their outreach now not just with press releases (which their institutes can often do) but with promoting through Twitter and blog posts about the article. Hence OA journals potentially give rise to a loyal authorship pool, which may be the basis of any putative relationship between Twitter activity and journal self-citation ratios for these journals. Other reasons for this observation, may include that OA journals do simply attract a larger volume of papers as well as many top cited papers for their field and as a result accumulate citations. Nevertheless, an important conclusion is that a journal's research profile along with its associated social media strategy are increasingly important to authors in their consideration of where to publish, which is reflected in the high standing of the *Malaria Journal* and *Parasites & Vectors* within the community for example.

Clearly, altmetrics can play an important role in science dissemination. On the one hand, they can bridge the temporal gap between publication and subsequent citation (the accepted measure of publication success), which can traditionally be a couple of years. This can potentially be of particular value for early-career researchers. They are also an undeniable product of our time, that has developed in the past decade. On the other hand, social media publicity must also be part of the science dissemination strategy of traditional publishers where OA authors arguably are now paying for publishers to put their science out there to be noticed. While the true relationship between altmetric measure and traditional metrics are yet to be fully explored, grant funding bodies (and institutional research quality assessment exercises) also increasingly value the societal impact of research, and social media presence and publicity may be just one other way to demonstrate that quickly.

In conclusion, we show that the use of social media has changed significantly over the last ten years in the way it is used for disseminating "news and views" about parasitology. Twitter activity is now prolific in the discipline, and 13 peer-reviewed journals are very active in using Twitter for a variety of means. In the subject area of parasitology, citations was shown to correlate with the number of Mendeley readers; our study also provides considerable support for the dominance of Twitter as a social media based, science communication strategy for encouraging readership. Whilst we have yet to explore completely the main drivers behind Twitter activity, we encourage the responsible use of social media by the parasitology community, as we engage and disseminate accurate and sometimes nuanced knowledge about and around the discipline.

Declaration of competing interests

None declared.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.crpvbd.2021.100013. With permission from Altmetric.

References

Baek, S., Yoon, D.Y., Lim, K.J., Hong, J.H., Moon, J.Y., Seo, Y.L., Yun, E.J., 2020. Top-cited articles versus top altmetric articles in nuclear medicine: A comparative bibliometric analysis. Acta Radiol. 0(0): 0284185120902391 https://journals.sagepub.com/doi/abs/10.1177/0284185120902391.

Bar-Ilan, J., 2012. Jasist 2001–2010. Bull. Am. Soc. Inform. Sci. Tech. 38 (6), 24–28. https://asistdl.onlinelibrary.wiley.com/doi/abs/10.1002/bult.2012.1720380607.

Bar-Ilan, J., Halevi, G., Milojević, S., 2019. Differences between altmetric data sources – a case study. J. Altmetr. 2, 1. https://doi.org/10.29024/joa.4.

Bornmann, L., 2015. Alternative metrics in scientometrics: A meta-analysis of research into three altmetrics. Scientometrics 103, 1123–1144.

Bornmann, L., Haunschild, R., 2016. How to normalize twitter counts? A first attempt based on journals in the twitter index. Scientometrics 107, 1405–1422. https://www.ncbi.nlm.nih.gov/pubmed/27239079.

Bornmann, L., Haunschild, R., Adams, J., 2019. Do altmetrics assess societal impact in a comparable way to case studies? An empirical test of the convergent validity of altmetrics based on data from the UK research excellence framework. J. Informetr. 13 (1), 325–340. http://www.sciencedirect.com/science/article/pii/S1751157718302700.

Bradbury, R.S., Breen, K.V., Bonura, E.M., Hoyt, J.W., Bishop, H.S., 2018. Case report: Conjunctival infestation with *Thelazia gulosa*: A novel agent of human thelaziasis in the United States. Am. J. Trop. Med. Hyg. 98 (4), 1171–1174. https://www.ncbi.nlm.nih.gov/pubmed/29436343.

Costas, R., Zahedi, Z., Wouters, P., 2015. Do "altmetrics" correlate with citations? Extensive comparison of altmetric indicators with citations from a multidisciplinary perspective. J. Assoc. Info. Sci. Tech. 66 (10), 2003–2019. https://asistdl.onlinelibrary.wiley.com/doi/abs/10.1002/asi.23309.

Cruz Rivera, S., Kyte, D.G., Aiyegbusi, O.L., Keeley, T.J., Calvert, M.J., 2017. Assessing the impact of healthcare research: A systematic review of methodological frameworks. PLoS Med 14 (8), e1002370. https://doi.org/10.1371/journal.pmed.1002370.

Cunningham, H., Tablan, V., Roberts, A., Bontcheva, K., 2013. Getting more out of biomedical documents with GATE's full lifecycle open source text analytics. PLoS Comput. Biol. 9 (2), e1002854. https://www.ncbi.nlm.nih.gov/pubmed/23408875.

Erdt, M., Nagarajan, A., Sin, S.-C.J., Theng, Y.-L., 2016. Altmetrics: An analysis of the state-of-the-art in measuring research impact on social media. Scientometrics 109 (2), 1117–1166. https://doi.org/10.1007/s11192-016-2077-0.

Eysenback, G., 2011. Can tweets predict citations? Metrics of social impact based on Twitter and correlation with traditional metrics of scientific impact. Med. Internet. Res. 13 (4), e123. https://www.jmir.org/2011/4/e123/.

Fassoulaki, A., Vassi, A., Kardasis, A., Chantziara, V., 2018. Altmetrics should not be used for ranking of anaesthesia journals. Br. J. Anaesth. 121, 514–516.

Greenhalgh, T., Raftery, J., Hanney, S., Glover, M., 2016. Research impact: A narrative review. BMC Med. 14 (1), 78. https://doi.org/10.1186/s12916-016-0620-8.

Haunschild, R., Bornmann, L., 2018. Field- and time-normalization of data with many zeros: An empirical analysis using citation and twitter data. Scientometrics 116 (2), 997–1012. https://www.ncbi.nlm.nih.gov/pubmed/30147201.

Haustein, S., Bowman, T.D., Holmberg, K., Tsou, A., Sugimoto, C.R., Larivière, V., 2016. Tweets as impact indicators: Examining the implications of automated "bot" accounts on Twitter. J. Ass. Info. Sci.Tech. 67 (1), 232–238. https://doi.org/10.1002/asi.23456.

Haustein, S., Peters, I., Sugimoto, C.R., Thelwall, M., Larivière, V., 2014. Tweeting biomedicine: An analysis of tweets and citations in the biomedical literature. J. Ass. Info. Sci. Tech. 65 (4), 656–669. https://doi.org/10.1002/asi.23101.

Heneberg, P., 2016. From excessive journal self-cites to citation stacking: Analysis of journal self-citation kinetics in search for journals, which boost their scientometric indicators. PLoS One 11 (4), e0153730. https://doi.org/10.1371/journal.pone.0153730.

Holmberg, K., Vainio, L., 2018. Why do some research articles receive more online attention and higher altmetrics? Reasons for online success according to the authors. Scientometrics 116 (1), 435–447. https://doi.org/10.1007/s11192-018-2710-1.

Imwong, M., Hien, T.T., Thuy-Nhien, N.T., Dondorp, A.M., White, N.J., 2017. Spread of a single multidrug resistant malaria parasite lineage (pfpailin) to Vietnam. Lancet Infect. Dis. 17 (10), 1022–1023.

Ioannidis, J.P.A., Baas, J., Klavans, R., Boyack, K.W., 2019. A standardized citation metrics author database annotated for scientific field. PLoS Biology 17 (8), e3000384. https://doi.org/10.1371/journal.pbio.3000384.

Kamenetzky, A., Hinrichs-Krapels, S., 2020. How do organisations implement research impact assessment (RIA) principles and good practice? A narrative review and exploratory study of four international research funding and administrative organisations. Health Res. Policy Syst. 18 (1), 6-6. https://pubmed.ncbi.nlm.nih.gov/31959198.

Ladeiras-Lopes, R., Clarke, S., Vidal-Perez, R., Alexander, M., Lüscher, T.F., On behalf of the ESC (European Society of Cardiology) Media Committee and European Heart Journal, 2020. Twitter promotion predicts citation rates of cardiovascular articles: A preliminary analysis from the ESC journals randomized study. Eur. Heart J. 41 (34), 3222–3225. https://doi.org/10.1093/eurheartj/ehaa211.

Li, X., Thelwall, M., Giustini, D., 2012. Validating online reference managers for scholarly impact measurement. Scientometrics 91 (2), 461–471. https://doi.org/10.1007/s11192-011-0580-x.

Maflahi, N., Thelwall, M., 2016. When are readership counts as useful as citation counts? Scopus *versus* Mendeley for LIS journals. J. Ass. Info. Sci. Tech. 67, 191–199. https://doi.org/10.1002/asi.23369.

Maynard, D., Li, Y., Peters, W., 2008. Nlp techniques for term extraction and ontology population. In: Buitelaar, P., Cimiano, P. (Eds.), Ontology learning and population: Bridging the gap between text and knowledge. IOS Press, Amsterdam, pp. 171–199.

Meschede, C., Siebenlist, T., 2018. Cross-metric compatability and inconsistencies of altmetrics. Scientometrics 115 (1), 283–297. https://doi.org/10.1007/s11192-018-2674-1.

Milat, A.J., Bauman, S.E., Redman, S., 2015. A narrative review of research impact assessment models and methods. Health Res. Policy Syst. 13, 18. https://doi.org/10.1186/s12961-015-0003-1.

Mishra, S., Fegley, B.D., Diesner, J., Torvik, V.I., 2018. Self-citation is the hallmark of productive authors, of any gender. PLoS One 13 (9), e0195773. https://www.ncbi.nlm.nih.gov/pubmed/30256792.

Mohammadi, E., Thelwall, M., Haustein, S., Larivière, V., 2015. Who reads research articles? An altmetrics analysis of Mendeley user categories. J. Ass. Info. Sci. Tech. 66 (9), 1832–1846. https://asistdl.onlinelibrary.wiley.com/doi/abs/10.1002/asi.23286.

Mohammadi, E., Thelwall, M., Kousha, K., 2016. Can Mendeley bookmarks reflect readership? A survey of user motivations. J. Ass. Info. Sci. Tech. 67 (5), 1198–1209. https://asistdl.onlinelibrary.wiley.com/doi/abs/10.1002/asi.23477.

Ortega, J.L., 2018. Reliability and accuracy of almetric providers: A comparison among Altmetric.com, PlumX and Crossref Event data. Scientometrics 116, 2123–2138.

Ott, B.L., 2017. The age of Twitter: Donald J. Trump and the politics of debasement. Crit. Stud. Med. Comm. 34 (1), 59–68. https://doi.org/10.1080/15295036.2016.1266686.

Priem, J., 2013. Beyond the paper. Nature 495 (7442), 437–440. https://doi.org/10.1038/495437a.

Priem, J., Piwowar, H.A., Hemminger, B.M., 2012. Altmetrics in the wild: Using social media to explore scholarly impact. arXiv:1203.4745. https://arxiv.org/abs/1203.4745.

Priem, J., Taraborelli, D., Groth, P., Neylon, C., 2010. Altmetrics: A manifesto. http://altmetrics.org/manifesto.

Sathianathen, N.J., Lane III, R., Murphy, D.G., Loeb, S., Bakker, C., Lamb, A.D., Weight, C.J., 2020. Social media coverage of scientific articles immediately after publication predicts subsequent citations - "#SoME_Impact Score. Observational analysis. J. Med. Internet Res. 22 (4), e12288 https://doi.org/10.2196/12288.

Swann, J.B., Holland, S.J., Petersen, M., Pietsch, T.W., Boehm, T., 2020. The immunogenetics of sexual parasitism. Science 369 (6511), 1608–1615. https://doi.org/10.1126/science.aaz9445.

Szomszor, M., Pendlebury, D.A., Adams, J., 2020. How much is too much? The difference between research influence and self-citation excess. Scientometrics 123 (2), 1119–1147. https://doi.org/10.1007/s11192-020-03417-5.

Tang, Y., Hew, K.F., 2017. Using Twitter for education: Beneficial or simply a waste of time? Comput. Ed. 106, 97–118. http://www.sciencedirect.com/science/article/pii/S0360131516302469.

Tausczik, Y.R., Pennebaker, J.W., 2010. The psychological meaning of words: LIWC and computerized text analysis methods. J. Lang. Soc. Psych. 29 (1), 24–54. https://journals.sagepub.com/doi/abs/10.1177/0261927X09351676.

Thelwall, M., 2018. Early Mendeley readers correlate with later citation counts. Scientometrics 115 (3), 1231–1240. https://doi.org/10.1007/s11192-018-2715-9.

Thelwall, M., 2020a. Mendeley reader counts for us computer science conference papers and journal articles. Quantitative Science Studies 1 (1), 347–359 https://www.mitpressjournals.org/doi/abs/10.1162/qss_a_00010 %X DOI 10.1162/qss_a_00010.

Thelwall, M., 2020b. The pros and cons of the use of altmetrics in research assessment. Sch. Assess. Rep. 2 (1), 2. https://www.scholarlyassessmentreports.org/articles/10.29024/sar.10/print/.

Thelwall, M., Haustein, S., Lariviere, V., Sugimoto, C.R., 2013. Do altmetrics work? Twitter and ten other social web services. PLoS One 8 (5), e64841. https://www.ncbi.nlm.nih.gov/pubmed/23724101.

Van Noorden, R., Singh Chawla, D., 2019. Policing self-citations. Nature 572, 578–579.

Walter, S., Lorcher, I., Bruggemann, M., 2019. Scientific networks on Twitter: Analyzing scientists' interactions in the climate change debate. Public Underst. Sci. 28 (6), 696–712. https://www.ncbi.nlm.nih.gov/pubmed/31027461.

Williams, A.E., 2017. Altmetrics: An overview and evaluation. Online Inf. Rev. 41 (3), 311–317. https://doi.org/10.1108/OIR-10-2016-0294.

Yahalomi, D., Atkinson, S.D., Neuhof, M., Chang, E.S., Philippe, H., Cartwright, P., Bartholomew, V., Huchon, D., 2020. A cnidarian parasite of salmon (Myxozoa: *Henneguya*) lacks a mitochondrial genome. Proc. Natl. Acad. Sci. USA 117 (10), 5358–5363. https://www.pnas.org/content/pnas/117/10/5358.full.pdf.

Zahedi, Z., Costas, R., Wouters, P., 2014. How well developed are altmetrics? A cross-disciplinary analysis of the presence of 'alternative metrics' in scientific publications. Scientometrics 101 (2), 1491–1513. https://doi.org/10.1007/s11192-014-1264-0.