Abstract: Article-level metrics (ALMs) provide a wide range of metrics about the uptake of an individual journal article by the scientific community after publication. They include citations, usage statistics, discussions in online comments and social media, social bookmarking, and recommendations. In this essay, we describe why article-level metrics are an important extension of traditional citation-based journal metrics and provide a number of example from ALM data collected for PLOS Biology.

The scientific impact of a particular piece of research is reflected in how this work is taken up by the scientific community. The first systematic approach that was used to assess impact, based on the technology available at the time, was to track citations and aggregate them by journal. This strategy is not only no longer necessary—since now we can easily track citations for individual articles—but also, and more importantly, journal-based metrics are now considered a poor performance measure for individual articles [1,2]. One major problem with journal-based metrics is the variation in citations per article, which means that a small percentage of articles can skew, and are responsible for, the majority of the journal-based citation impact factor, as shown by Campbell [1] for the 2004 Nature Journal Impact Factor. Figure 1 further illustrates this point, showing the wide distribution of citation counts between PLOS Biology research articles published in 2010. PLOS Biology research articles published in 2010 have been cited a median 19 times to date in Scopus, but 10% of them have been cited 50 or more times, and two articles [3,4] more than 300 times. PLOS Biology metrics are used as examples throughout this essay, and the dataset is available in the supporting information (Data S1). Similar data are available for an increasing number of other publications and organizations.

Scientific impact is a multi-dimensional construct that can not be adequately measured by any single indicator [2,5,6]. To this end, PLOS has collected and displayed a variety of metrics for all its articles since 2005. The array of different categorised article-level metrics (ALMs) used and provided by PLOS as of August 2013 are shown in Figure 2. In addition to citations and usage statistics, i.e., how often an article has been viewed and downloaded, PLOS also collects metrics about: how often an article has been saved in online reference managers, such as Mendeley; how often an article has been discussed in its comments section online, and also in science blogs or in social media; and how often an article has been recommended by other scientists. These additional metrics provide valuable information that we would miss if we only consider citations. Two important shortcomings of citation-based metrics are that (1) they take years to accumulate and (2) citation analysis is not always the best indicator of impact in more practical fields, such as clinical medicine [7]. Usage statistics often better reflect the impact of work in more practical fields, and they also sometimes better highlight articles of general interest (for example, the 2006 PLOS Biology article on the citation advantage of Open Access articles [8], one of the 10 most-viewed articles published in PLOS Biology).

A bubble chart showing all 2010 PLOS Biology articles (Figure 3) gives a good overview of the year’s views and citations, plus it shows the influence that the article type (as indicated by dot color) has on an article’s performance as measured by these metrics. The weekly PLOS Biology publication schedule is reflected in this figure, with articles published on the same day present in a vertical line. Figure 3 also shows that the two most highly cited 2010 PLOS Biology research articles are also among the most viewed (indicated by the red arrows), but overall there isn’t a strong correlation between citations and views. The most-viewed article published in 2010 in PLOS Biology is an essay on Darwinian selection in robots [9]. Detailed usage statistics also allow speculation about the different ways that readers access and make use of published literature; some articles are browsed or read online due to general interest while others that are downloaded (and perhaps also printed) may reflect the reader’s intention to look at the data and results in detail and to return to the article more than once.

When readers first see an interesting article, their response is often to view or download it. By contrast, a citation may be one of the last outcomes of their interest, occurring only about 1 in 300 times a PLOS paper is viewed online. A lot of things happen in between these potential responses, ranging from discussions in comments, social media, and blogs, to bookmarking, to linking from websites. These activities are usually subsumed under the term “altmetrics,” and their variety can be overwhelming. Therefore, it helps to group them together into categories, and several organizations, including PLOS, are using the category labels of Viewed, Cited, Saved, Discussed, and Recommended (Figures 2 and 4, see also [10]).

Essays articulate a specific perspective on a topic of broad interest to scientists.
All PLOS Biology articles are viewed and downloaded, and almost all of them (all research articles and nearly all front matter) will be cited sooner or later. Almost all of them will also be bookmarked in online reference managers, such as Mendeley, but the percentage of articles that are discussed online is much smaller. Some of these percentages are time dependent; the use of social media discussion platforms, such as Twitter and Facebook for example, has increased in recent years (93% of PLOS Biology research articles published since June 2012 have been discussed on Twitter, and 63% mentioned on Facebook). These are the locations where most of the online discussion around published articles currently seems to take place; the percentage of papers with comments on the PLOS website or that have science blog posts written about them is much smaller. Not all of this online discussion is about research articles, and perhaps, not surprisingly, the most-tweeted PLOS article overall (with more than 1,100 tweets) is a PLOS Biology perspective on the use of social media for scientists [11].

Some metrics are not so much indicators of a broad online discussion, but rather focus on highlighting articles of particular interest. For example, science blogs allow a more detailed discussion of an article as compared to comments or tweets, and journals themselves sometimes choose to highlight a paper on their own blogs, allowing for a more digestible explanation of the science for the non-expert reader [12]. Coverage by other bloggers also serves the same purpose; a good example of this is one recent post on the OpenHelix Blog [13] that contains video footage of the second author of a 2010 PLOS Biology article [14] discussing the turkey genome.

F1000Prime, a commercial service of recommendations by expert scientists, was added to the PLOS Article-Level Metrics in August 2013. We now highlight on the PLOS website when any articles have received at least one recommendation within F1000Prime. We also monitor when an article has been cited within the widely used modern-day online encyclopedia, Wikipedia. A good example of the latter is the Tasmanian devil Wikipedia page [15] that links to a PLOS Biology research article published in 2010 [16]. While a F1000Prime recommendation is a strong endorsement from peer(s) in the scientific community, being included in a Wikipedia page is akin to making it into a textbook about the subject area and being read by a much wider audience that goes beyond the scientific community.

PLOS Biology is the PLOS journal with the highest percentage of articles recommended in F1000Prime and mentioned in Wikipedia, but there is only partial overlap between the two groups of articles because they focus on different audiences (Figure 5). These recommendations and mentions in
turn show correlations with other metrics, but not simple ones; you can’t assume, for example, that highly cited articles are more likely to be recommended by F1000Prime, so it will be interesting to monitor these trends now that we include this information.

With the increasing availability of ALM data, there comes a growing need to provide tools that will allow the community to interrogate them. A good first step for researchers, research administrators, and others interested in looking at the metrics of a larger set of PLOS articles is the recently launched ALM Reports tool [17]. There are also a growing number of service providers, including Altmetric.com [18], ImpactStory [19], and Plum Analytics [20] that provide similar services for articles from other publishers.

As article-level metrics become increasingly used by publishers, funders, universities, and researchers, one of the major challenges to overcome is ensuring that standards and best practices are widely adopted and understood. The National Information Standards Organization (NISO) was recently awarded a grant by the Alfred P. Sloan Foundation to work on this [21], and PLOS is actively involved in this project. We look forward to further developing our article-level metrics and to having them adopted by other publishers, which hopefully will pave the way to their wide incorporation into research and researcher assessments.

Supporting Information

Data S1  Dataset of ALM for PLOS Biology articles used in the text, and R scripts that were used to produce figures. The data were collected on May
Figure 5. PLOS Biology articles: sites of recommendation and discussion. Number of PLOS Biology research articles published up to May 20, 2013 that have been recommended by F1000Prime (red) or mentioned in Wikipedia (blue). doi:10.1371/journal.pbio.1001687.g005

References

1. Campbell P (2008) Escape from the impact factor. Ethics Sci Environ Polit 8: 5–7. doi:10.3354/esep00078.
2. Glaunzel W, Wouters P (2013) The dos and don’ts in individual level bibliometrics. Presented at the ISSI 2013 conference. Available: http://www.slideshare.net/paulwouters1/issi2013-wg-pw. Accessed 15 August 2013.
3. Narendra DP, Jin SM, Tanaka A, Suen D-F, Gautier CA, et al. (2010) PINK1 is selectively stabilized on impaired mitochondria to activate Parkin. PLoS Biol 8: e1000298. doi:10.1371/journal.pbio.1000298.
4. Dickson SP, Wang K, Kranz I, Hakonarson H, Goldstein DB (2009) Rare variants create synthetic genome-wide associations. PLoS ONE 4: e6022. doi:10.1371/journal.pone.0006022.
5. Schekman R, Patterson M (2013) Reforming research assessment. eLife 2: e00855-e00855. doi:10.7554/eLife.00855.
6. van Eck NJ, Waltman L, van Raan AFJ, Klautz RJM, Preis WC (2013) Citation analysis may severely underestimate the impact of clinical research as compared to basic research. PLoS ONE 8: e62395. doi:10.1371/journal.pone.0062395.
7. Eysenbach G (2006) Citation advantage of Open Access articles. PLoS Biol 4: e157. doi:10.1371/journal.pbio.0040157.
8. PLoS Biol 8: e1000292. doi:10.1371/journal.pbio.1000292.
9. Floreano D, Keller L (2010) Evolution of adaptive behaviour in robots by means of Darwinian selection. PLoS Biol 8: e1000292. doi:10.1371/journal.pbio.1000292.
10. Lin J, Feener M (2013) Altmetrics in evolution: defining & redefining the ontology of article-level metrics. Information Standards Quarterly 25(2): 20–26. doi:10.3789/isqv25mo2.2013.04.
11. Bik HM, Goldstein MC (2013) An introduction to social media for scientists. PLoS Biol 11: e1001535. doi:10.1371/journal.pbio.1001535.
12. Fausto S, Machado FA, Bene LJJ, Jamain, N, Tahas TR, et al. (2012) Research blogging: indexing and registering the change in science 2.0. PLoS ONE 7: e50109. doi:10.1371/journal.pone.0050109.
13. Video Tip of the Week: Turkeys and their genomes (2012) OpenHelix blog. Available: http://blog.openhelix.eu/?p=14308. Accessed 15 August 2013.
14. Dalloul RA, Long JA, Zimin AV, Aslam L, Beal K, et al. (2010) Multi-platform next-generation sequencing of the domestic turkey (Meleagris gallopavo): genome assembly and analysis. PLoS Biol 8. doi:10.1371/journal.pbio.1000475.
15. Tasmanian devil (2013) Wikipedia. Available: http://en.wikipedia.org/wiki/Tasmanian_devil.
16.Nilsson MA, Churakov G, Sommer M, Van Tran N, Zemann A, et al. (2010) Tracking marsupial evolution using archaic genomic retroposon insertions. PLoS Biol 8: e1000436. doi:10.1371/journal.pbio.1000436.
17. ALM Reports (2013) Available: http://almreports.plos.org. Accessed 15 August 2013.
18. Altmetric.com (2013) Available: http://www.altmetric.com. Accessed 15 August 2013.
19. Impactstory (2013) Available: http://impactstory.org. Accessed 15 August 2013.
20. Plum Analytics (2013) Available: http://www.plumanalytics.com. Accessed 15 August 2013.
21. NISO Alternative Assessment Metrics (Altmetrics) Project (2013) Available: http://www.niso.org/topics/altmetrics_initiative. Accessed 15 August 2013.