https://doi.org/10.1038/s41559-023-02008-w

Better incentives are needed to reward academic software development

Software innovation is critical for integrating, synthesizing and modelling big data in ecology and evolution[1,2], and increasingly underlies analyses in high-profile research. However, underappreciation of the support needed to create and maintain the software that underpins scientific advances could cause stagnation, lead to insufficient maintenance and stifle innovation.

Software development in ecology and evolution, and perhaps across other fields as well, is at an important junction. Open software underpins most research today, increasing accessibility for scientists to perform state-of-the-art analyses. Positions that require programming skills have correspondingly doubled over the past decade[3]. The accuracy and reproducibility of scientific results is increasingly dependent on updating and maintaining software. However, the incentive structure in academia for software development — and especially maintenance — is insufficient. It is time that appropriate incentives are embraced to reflect their importance.

When releasing new software, developers often follow the standard academic credit model and publish a 'software note'. But after publishing, the work of the developers has only just begun. Maintenance often necessitates more effort than the original development[4], requiring bug fixes, user feedback, security upgrades, and maintaining system standards and compatibility with changing dependencies. Although this work is essential to the ongoing life of the software, it lacks a formal academic credit model. Software notes that describe upgrades are often not considered publishable by journals, which means that developers are expected to provide free maintenance without professional incentive.

How can we best reward academic software development and maintenance? Without the novelty required for higher-profile journals, most publication opportunities are limited to lower-profile journals with more restricted audiences. Similarly, larger grants are available to support new software rather than maintenance. Citations and grants for software are tangible credits for first versions of software, but may not be sufficient incentive for continuing maintenance.

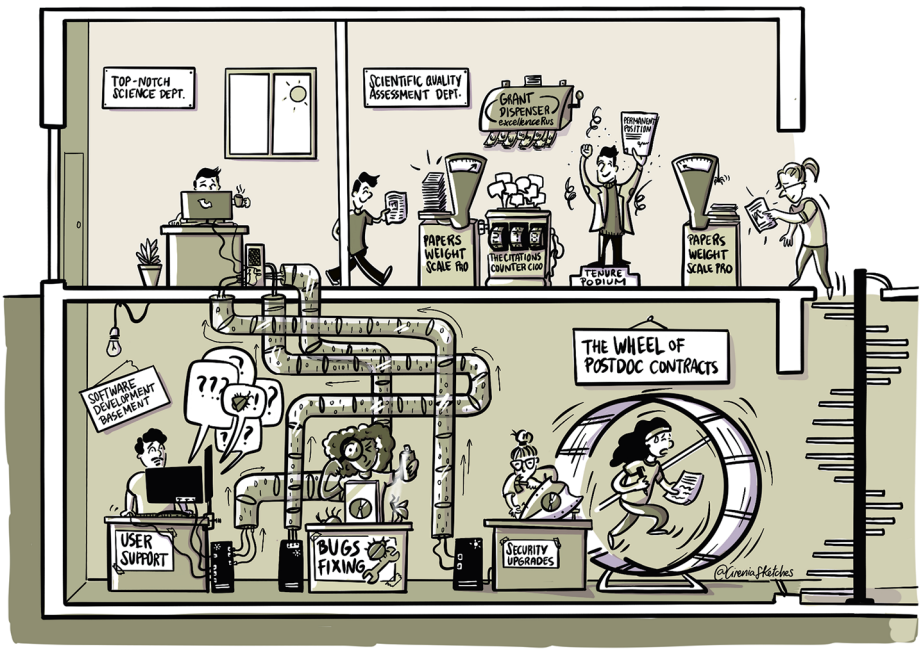

Fig. 1 | Current incentive structures do not reward academic software maintenance. Academic software developers do very time-consuming work that is not fully recognized (in the 'software development basement') — particularly regarding the maintenance of existing software — with few incentives to help in their career progress ('the wheel of postdoc contracts'). Software developers provide valuable tools (represented by the code-filled pipes) that other researchers use for state-of-the-art analyses in their own publications (paper weight scale). After a typical initial publication presenting version 1.0 of the software, there are no career-advancing incentives to reward the considerable time and expertise that are needed to maintain and further develop the software. Ironically, this can make the CVs of software developers less competitive than those of users who depend on their work, unless we advance a new credit model that rewards software maintenance.

This lack of credit poses a tough decision, especially for early-career scientists. Hiring, promotion and tenure opportunities are based on standard academic credit such as publications[5]. Investing time in updating and maintaining software may limit the career opportunities of developers relative to non-developers, as these activities do not add to a CV — although, ironically, nondeveloper scientists rely on maintained software (Fig. 1). Despite calls to expand the professional evaluation criteria beyond traditional CV items[6], adoption of these changes is slow and diffuse. We must implement new policies to align academic career goals with scientific goals.

Academia may lose its most brilliant developers without credit models to advance their careers. Alternative, well-paid careers in industry are compelling for developers who become disillusioned in academia[7]. Concurrently, a resignation wave is hitting academia[8] and the recruitment of graduate students, postdocs and pre-tenure-track personnel has become increasingly difficult[9], so academic positions with transferable, in-demand skills are at risk.

Existing approaches in response to these credit issues are unsustainable or undesirable. Some projects outsource programming to consultants, which is problematic because:

CREDIT: CIRENIA ARIAS BALDRICH

(1) development often requires domain knowledge to make user-friendly code; (2) financial costs are prohibitive for most laboratories; and (3) retaining developers for maintenance is difficult because higher-paying jobs await elsewhere. This leaves us constantly training nonbiologists at a high expense. Other projects hire a professional developer who is willing to work at below market value through the luck of a personal connection to the research or researchers, which is unfair for the undervalued workers. A final option — common in industry — is for software developers to keep their code proprietary, requiring payment (financial or collaboration on papers) to share their work.

How can the academic credit problem for software maintenance be addressed? We propose the creation of a new class of article for software updates to provide an outlet for developers to receive academic credit for these updates. The logic is simple — major software updates that are impactful for scientific conclusions and reproducibility are as important as the original version release. Publications describing updates also acknowledge and incentivize new contributors, thus advancing collaboration. Journals should publish noteworthy update articles for the software that they originally featured in software notes to ensure that the impact scales with the original publication. A precedent already exists for brief updates — journals regularly publish corrigenda to existing articles to correct errors. Extending this concept to feature updates (and omitting the error connotation) would result in new citable and indexed articles that reward developers using the existing academic credit model. Importantly for journals, such updates could only increase their impact factor (like reviews or editorials that only contribute to the numerator of this index). Software developers can include these articles in their CV to increase recognition during professional evaluation.

An alternative, more-challenging solution would be to establish a specialized software journal (or subsection of an existing journal) that includes update articles. Similar to 'data' articles, such a journal would define standards on metadata, quality control and sufficiency of updates. In addition to incentivizing maintenance, software update articles could optionally be used to advance training by mirroring the format of current package vignettes, while also benefiting vignettes by encouraging peer review. The details of a dedicated software journal would need to be further developed with extensive community input.

We must urgently come together to remove career-based constraints on our science-based software needs. We must support academics with both domain training and expertise in software development. These individuals are the key to maintaining open science infrastructure. They are also central hubs in facilitating collaborations that link scientists with traditional skill sets to cutting-edge data analysis that truly leverages the power of big data.

Cory Merow[1] ✉, Brad Boyle[2], Brian J. Enquist[2], Xiao Feng[3], Jamie M. Kass[4], Brian S. Maitner[5], Brian McGill[6,7], Hannah Owens[8,9], Daniel S. Park[10,11], Andrea Paz[12], Gonzalo E. Pinilla-Buitrago[13,14], Mark C. Urban[15,16], Sara Varela[17] & Adam M. Wilson[5]

[1]Department of Ecology and Evolutionary Biology and Eversource Energy Center, University of Connecticut, Storrs, CT, USA. [2]Department of Ecology and Evolutionary Biology, University of Arizona, Tucson, AZ, USA. [3]Department of Geography, Florida State University, Tallahassee, FL, USA. [4]Biodiversity and Biocomplexity Unit, Okinawa Institute of Science and Technology Graduate University, Onna, Japan. [5]Department of Geography, University at Buffalo, Buffalo, NY, USA. [6]School of Biology and Ecology, University of Maine, Orono, ME, USA. [7]Mitchell Center for Sustainability Solutions, University of Maine, Orono, ME, USA. [8]Center for Macroecology, Evolution and Climate, Globe Institute, University of Copenhagen, Copenhagen, Denmark. [9]Florida Museum of Natural History, University of Florida, Gainesville, FL, USA. [10]Department of Biological Sciences, Purdue University, West Lafayette, IN, USA. [11]Purdue Center for Plant Biology, Purdue University, West Lafayette, IN, USA. [12]Department of Environmental Systems Science, Institute of Integrative Biology, ETH Zürich, Zurich, Switzerland. [13]Department of Biology, City College of the City University of New York, New York, NY, USA. [14]PhD Program in Biology, Graduate Center of the City University of New York, New York, NY, USA. [15]Department of Ecology and Evolutionary Biology, University of Connecticut, Storrs, CT, USA. [16]Center of Biological Risk, University of Connecticut, Storrs, CT, USA. [17]Departamento de Ecoloxía e Bioloxía Animal, Universidade de Vigo, Vigo, Spain.

✉e-mail: cory.merow@gmail.com

Published online: 27 February 2023

References

1. Farley, S. S., Dawson, A., Goring, S. J. & Williams, J. W. *Bioscience* **68**, 563–576 (2018).
2. Feng, X. et al. *Glob. Ecol. Biogeogr.* **31**, 1242–1260 (2022).
3. Feng, X., Qiao, H. & Enquist, B. J. *Front. Ecol. Environ.* **18**, 123–124 (2020).
4. Schach, S. *Software Engineering (Sie) 7E* (McGraw-Hill Education, 2012).
5. Wilson, L. & Altbach, P. G. *The Academic Man: A Study in the Sociology of a Profession* (Routledge, 2017).
6. Esposito, L. A. et al. *Bull. Soc. System. Biol.* **1**, https://doi.org/10.18061/bssb.v1i1.8332 (2022).
7. Woolston, C. *Nature* **599**, 519–521 (2021).
8. Gewin, V. *Nature* **606**, 211–213 (2022).
9. Langin, K. *Science* **376**, 1369–1370 (2022).

Acknowledgements

C.M. and G.E.P.-B. acknowledge funding support from NSF DBI 1661510 and NASA 80NSSC18K0406. J.M.K. was supported by the Japan Society for the Promotion of Science Postdoctoral Fellowships for Foreign Researchers Program. A.M.W. and B.S.M. are supported by NASA no. 80NSSC21K1183 and no. 80NSSC21K0086. B.J.E., C.M., B.B., B.S.M. and B.M. were supported by NSF HDR-1934790. B.J.E., C.M. and B.B. were supported by NSF HDR-1934790, NSF ABI-1565118 and BoCP - 2225076. B.J.E. was also supported by the US Department of Energy, Office of Science, Office of Biological and Environmental Research, Earth and Environmental Systems Sciences Division and Data Management Program, under award number DEAC02-05CH11231, as part of the Watershed Function Scientific Focus Area and the ExaShed project.

Competing interests

The authors declare no competing interests.