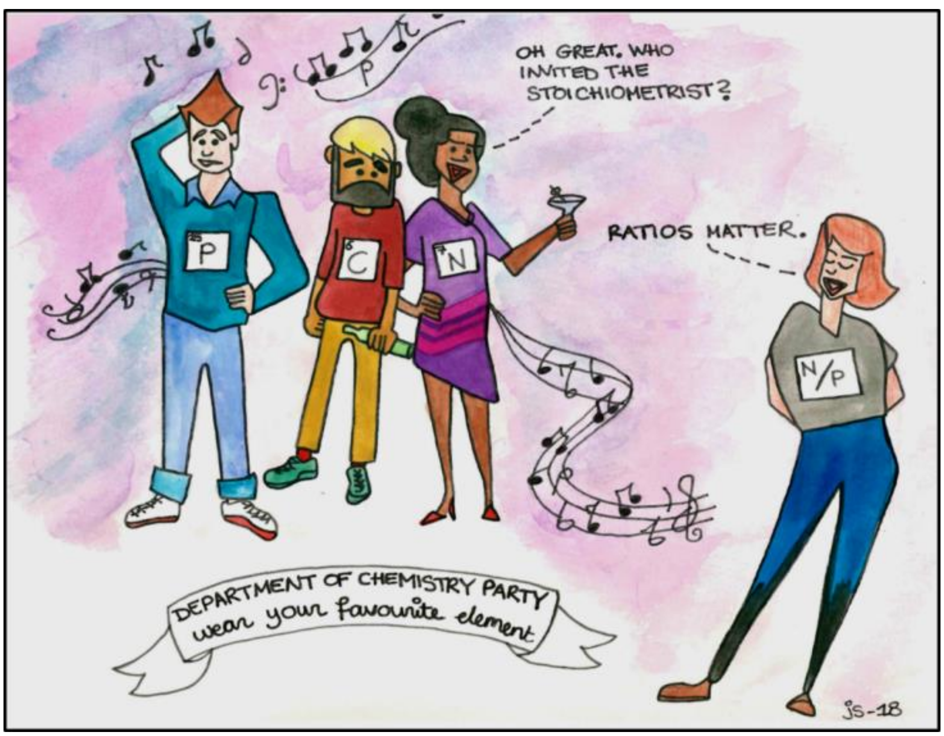
Ratios Matter

VOLUME 2 ISSUE 1 **JANUARY 2018**

Welcome to Year 2 of *Ratios Matter*!

Ratios Matter is entering its second year with our first issue being published about one year ago. We would like to thank everyone who has supported *Ratios Matter* over the past year. Our goal for the upcoming year is to continue being a source of ecological stoichiometry news both by highlighting new work and by providing insightful commentary on this research area. As the most interesting and important news comes from you, the stoichiometrists on the ground, we hope to hear more from you in the coming year! We are always looking for new material, whether its a summary of a new paper, an announcement of some stoichiometrically themed event, or maybe even some juicy ES gossip. If you have something to share, please send us an email (ratiosmatter@gmail.com) with a short description of your contribution. We look forward to hearing from you soon and to continuing to make *Ratios Matter* your go-to publication for stoichiometry news.

Stoich-Comic by Judith Sitters



In this issue:

Editorial Board

Special Features in Aquatic Sciences

Do you have an interesting perspective or comment on something about ecological stoichiometry? If so, consider submitting a short perspective paper to the journal, *Aquatic Sciences*, as a special feature. Contact the Special Features editor of *Aquatic Sciences*, Paul Frost (paulfrost@trentu.ca), to discuss your idea and to learn more about this and other publishing opportunities in *Aquatic Sciences*.

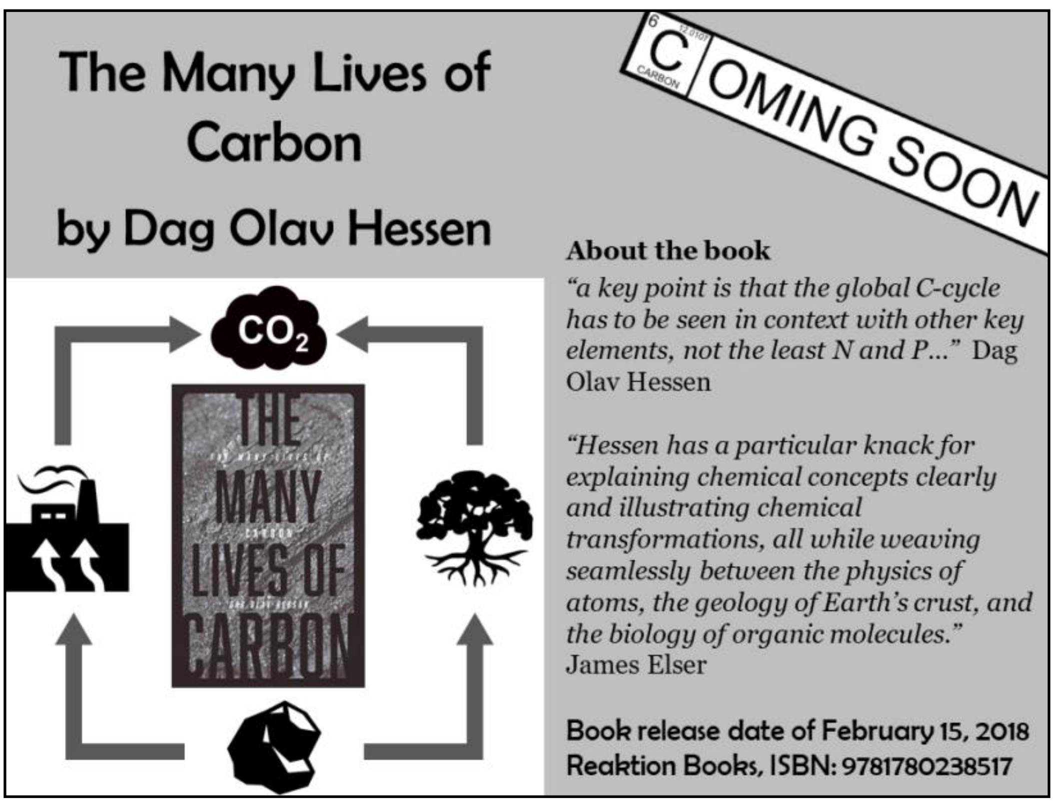
Conference on Biological Stoichiometry 2?

The first Conference on Biological Stoichiometry was held in 2015. Would you like to see a COBS2? For a 2019 version of this meeting, planning would need to start soon. For this to happen, COBS 2 needs a Chief Organizer and a new venue. Are you are interested in organizing and/or know of a possible venue? If so, send a brief message of interest or a quick overview of the venue to cobs2015@gmail.com.

Ratios Matter Reads

Do you like reading books? Maybe books on biology, chemistry and the environment? *Ratios Matter* will occasionally feature books of possible interest to stoichiometrists in this new section: **Ratios Matter Reads**.

In this issue, we are pleased to announce the publication of *The Many Lives of Carbon* by Dag O. Hessen. For more information on Dag's interesting new book, click here: The Many Lives of Carbon



Nutrient co-limitation of oceanic phytoplankton

Questions remain about which nutrient (N, Fe, or other nutrients) limits primary production in the oceans. Browning et al. (2017) examined the growth responses of marine phytoplankton in the South Atlantic gyre when exposed to higher concentrations of one or more of these nutrients. They collected water at different stations throughout the region and conducted 48 hr bioassay experiments with additions of different combinations of N, Fe, and cobalt (Co) or vitamin B12, a Co-containing vitamin, to determine if algae were limited by a single nutrient, serial limited, or co-limited. They classified serial limitation as the addition of two elements causing a larger response in growth compared to the addition of just one of these elements, whereas co-limitation was defined as a response in growth that only occured when both elements were added. Their results indicate that, in nearshore areas and sites between the latitudes of -10° and 10°, phytoplankton communities were limited primarily by N (with some sites displaying serial limitation or approaching co-limitation). However, offshore sites located below -10° latitude displayed either co-limitation of N-Fe or serial limitation with Co, indicating the phytoplankton community biomass is limited by both N and Fe, and almost by Co.

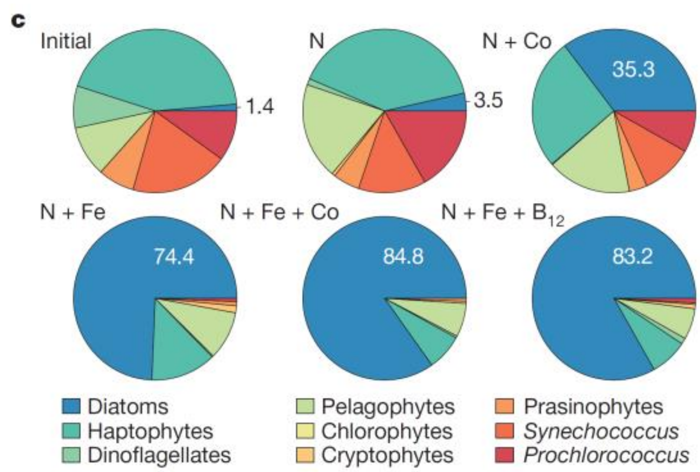


Figure 2c from Browning et al. (2017) showing change in phytoplankton communities produced with different types of nutrient enrichment. Reprinted with permission of Springer Nature.

In addition to changes in growth, Browning et al. (2017) also examined phytoplankton community structure before and after nutrient amendments. In sites classified as N+Fe co-limited, the initial communities had high biodiversity containing both prokaryotes and eukaryotes. This is likely because of increased niche dimensionality caused by the diversity in phytoplankton nutrient acquisition strategies. After adding nutrients to these co-limited sites, phytoplankton biodiversity decreased, which likely reflected altered competitive interactions and increased the advantage to diatoms under these conditions.

From the paper: "With nutrient inputs and stratification patterns expected to change under climate change, scenarios recognizing multi-nutrient serial- or co-limitation and better representation of the underlying processes within ocean models will lead to more realistic projections of feedbacks regulating climate and marine food webs."

Contributed by Nicole Wagner

Browning, T.J., E.P. Achterberg, I. Rapp, A. Engel, A. Tagliabue, and C.M. Moore. 2017. Nutrient co-limitation at the boundary of an oceanic gyre. Nature 551:242-246 DOI:10.1038/nature24063

Ecological Stoichiometry Meets Ecological Engineering

Even ecologists who don't read *Ratios Matter* could tell you that the Redfield ratio has a C:N:P of 106:16:1, but did you know that this ratio matters for the future of sustainable energy systems? The Redfield ratio has been used to show that replacing U.S. diesel transportation fuels with algae-based biofuels would demand 200% more nitrogen and 100% more phosphorus fertilizers than we currently use to grow our food! Clearly the benefits of algal biofuels for the C cycle could be far outweighed by negative impacts on N and P eutrophication.

An obvious solution to this problem is to grow algae with low N and P content, but since quickly growing species tend to have both a high N and P content, this leads to a conflict with productivity. A recent collaboration between ecologists and chemical engineers showed how polycultures of algae could be designed to overcome the conflict between high fuel productivity and efficient use of N and P. After the C-rich portion of the algae is extracted to make fuel, up to 85% of the N and P in algae can be directly recycled to grow more algae. While recycling dramatically increased the effective C:P and N:P (~700:90:1) for the process, the most productive species still exhibited a tradeoff between being efficient with N versus P (Figure 1). However, certain polycultures were able to escape this tradeoff and use both N and P efficiently. This work illustrates how ecological stoichiometry and ecological engineering can be harnessed to minimize the nutrient footprint of renewable fuel production without sacrificing output.

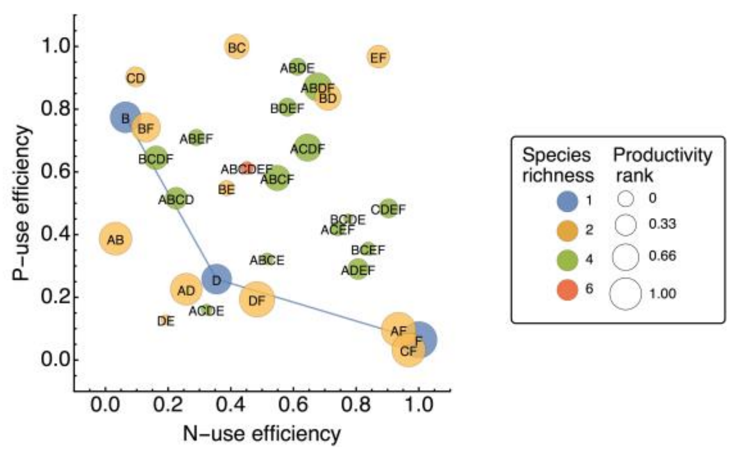
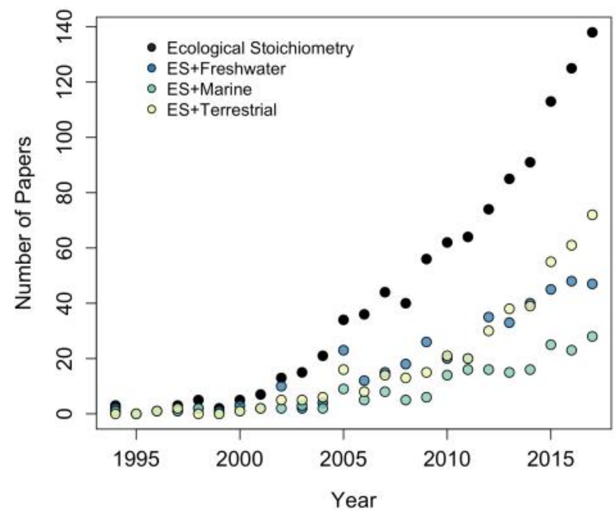


Figure 1. Relative performance of algae in terms of nitrogen use efficiency, phosphorus use efficiency, and biofuel productivity. Each function is ranked so that the worst performer is 0 and the best performer is 1. Letters denote algal species.

Contributed by Casey Godwin

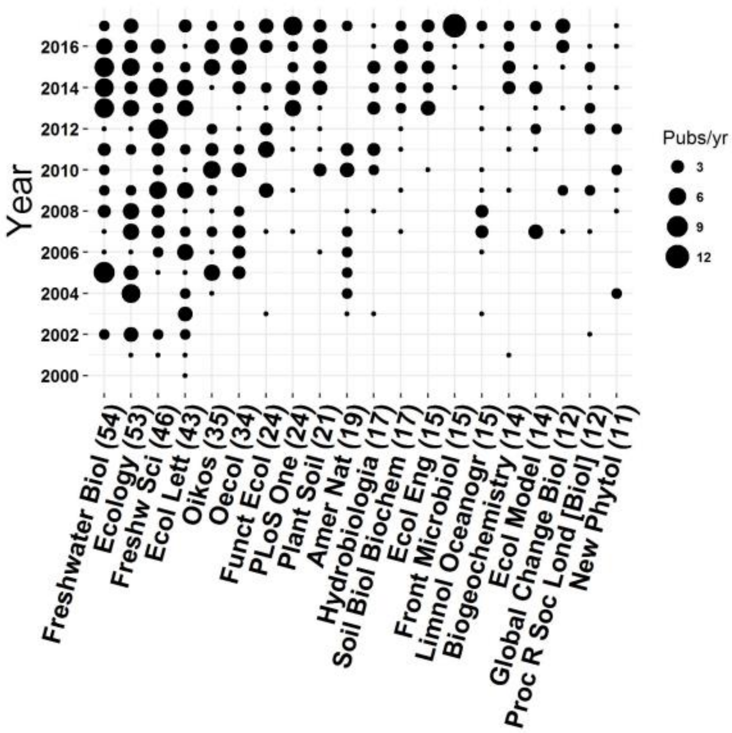
Godwin, C.M., D. Hietala, A. Lashaway, A. Narwani, P.E. Savage, and B.J. Cardinale. 2017. Ecological stoichiometry meets ecological engineering: using polycultures to enhance the multifunctionality of algal biocrude systems. Environmental Science and Technology 51:11450-11458.

Publication Trends in Ecological Stoichiometry



We can learn a lot about the impact and trajectory of a field by examining trends in publications over time. Using publication data from Web of Science, we examined the growth of ES research over the past two decades. First, we tabulated the number of publications found for the search term for “ecological stoichiometry” each year and compared those data to the number of publications that resulted from a search of “ecological stoichiometry” and a set of system-specific keywords for freshwater (“freshwater” or “stream” or “river” or “lake” or “wetland” or “pond” or “lentic” or “lotic”), marine (“marine” or “coastal” or “estuary” or “ocean” or “sea” or “gulf”), or terrestrial (“terrestrial” or “forest” or “rainforest” or “grassland” or “soil” or “tundra” or “desert”) ecosystems. These searches returned 1037 results for ecological stoichiometry and 410, 201, and 424 respectively for the freshwater, marine and terrestrial keywords. The annual number of ES publications has increased dramatically over the past few years with much of this very recent increase due to the growth of terrestrial stoichiometry.

We used these data to uncover which journals have published the most ES articles since 2000. In our search results, 50% of the total papers were published by about 20 journals. The top five of these journals, *Freshwater Biology*, *Ecology*, *Freshwater Science*, *Ecology Letters*, and *Oikos*, appear to rank highly because they were the most frequent publishers of stoichiometric articles in the pre-2010 era while a wider range of journals have published stoichiometry papers over the past 10 years. Stoichiometry articles are now appearing in journals such as *Plant and Soil*, *Frontiers in Microbiology*, and *Soil Biology and Biochemistry*, which partly reflects the trend of more research being conducted on plants and microbes.



The bottom line is that we are seeing more ecological stoichiometry papers published in more places as the field continues to expand. Where will we see stoichiometric research head next?

Contributed by Sarah Collins and Charlotte Narr

Frog recycling affects rice nutrition: Sometimes it's easier being green

Ever wonder about 'practical' applications of nutrient cycling? Over half of the global human population is likely affected by some form of nutrient limitation in their diet. This has stimulated a number of studies examining elemental concentrations in staple crops such as rice and grain. A recent study by Sha et al. (2017) monitored the effects of frog-driven nutrient cycling on rice production in China. The researchers compared fertilization intensive conventional farming practices with organic techniques that involved paddies colonized by frogs. The potential value of frogs in rice paddies is from their control of rice pests, stimulation of microbial biomass, and resuspension of soil-bound elements. Sha et al. (2017) found rice production and protein content in frogged paddies was comparable to conventional practices, while frog activity was also associated with increased content of P, Fe, Zn, Mo and Se in rice. On the other hand, lower Ca concentrations and higher Cd levels were also found in rice from the frog intensive paddies. While more research on the potential nutritional and toxic effects of these changes is warranted, this study concluded that, "Organic rice farming is an ecologically friendly strategy to avoid excessive use of chemical fertilizers, herbicides and pesticides without decreasing yields and to improve the nutritional status of rice by increasing the micronutrient contents."

Contributed by Clay Prater

Sha, Z., Q. Chu, Z. Zhao, Y. Yue, L. Lu, J. Yuan and L. Cao (2017). Variations in nutrient and trace element composition of rice in an organic rice-frog coculture system. *Scientific Reports 7*: 15706.

Enjoy ecological stoichiometry and Canada at the ASLO 2018 Summer Meeting (June 10-15, 2018). Submit your abstract to one of several stoichiometry special sessions before the deadline of February 23, 2018.

SS29: *Putting ecological stoichiometry to the test: When and where do ratios matter in aquatic ecosystems?* Organizers: C.M. Godwin (Univ. Michigan) S.K. Thompson (Univ. Minnesota)

SS30: *Make stoichiometry great again! [sic] Coupled biogeochemical cycles through the freshwater pipe.* Organizers: R. Maranger (Univ. Montreal) S.E. Jones (Notre Dame) J.B. Cotner (Univ. Minnesota)

SS43: *Nature's barometer? Microbes and their role as "Stoichiometers"*. Organizers: T. Scott (Baylor) J.B. Cotner (Univ. Minnesota)

Check out the **ASLO 2018** website for more information by clicking here: ASLO 2018

A Stoichiometric Opinion

by Paul Frost
Trent University

My lab recently received the news that one of our manuscripts was rejected from a mid-tier ecology journal. While this decision was partly based on conflicting viewpoints of two reviewers, it ultimately was an editorial decision that concluded the study wasn't novel and wouldn't be interesting to a broader ecological audience. As you can imagine, this decision was disappointing and a difficult pill to swallow. I was most disturbed by its conclusion that the paper lacked novelty and interest. We probably all think that our stoichiometric research is broadly important and hearing from a valued colleague that you aren't meeting this standard can be eye-opening. This is even more so when it appears that your manuscript is otherwise quite sound, methodologically and scientifically. While we have already submitted the paper to another publishing venue, I'm left with lingering questions about the meaning of this previous decision to the field of ecological stoichiometry. These questions are especially pertinent as ecological stoichiometry expands with studies of new organisms, topics, and different environments, and as the number of published papers continues to grow (See pg. 5 for an overview of this growth).

The first of my questions is: What does it take to make a stoichiometry study interesting to ecologists? I can see how taxa- or site-specific studies can be perceived to be of limited interest. Similarly, studies that refine our knowledge or understanding of previously developed concepts may also fall into this category. My lab has dealt with the issue of "interest" for the past few years as we hoped to publish our work on nutrition and physiology in ecological journals. This isn't an entirely new issue for stoichiometrists as I remember wondering years ago why ecologists should be interested in the RNA content of zooplankton. While some responsibility clearly lies with the authors to adequately frame their study and explain its significance, editors and reviewers should also be wary of over-weighting this criteria when making a decision. We should not reject papers based on perceptions of possible 'interest' given the subjective nature of this evaluation and the impossibility of knowing the future.

My other lingering question is: What should constitute novelty in ecological stoichiometry? I personally dislike the concept of novelty in science as it is often a subjective assessment of what has already been established. With increasing calls to replicate more science to solidify and deepen our knowledge, there appears to be a need for more confirmatory research and a reduced reliance on the novelty assessment. There may be a point that future work on ecological stoichiometry, itself, will no longer be novel in the sense that the guiding principles are already well established and have been tested. Future studies on these topics, except perhaps those involving exotic habitats and/or on charismatic fauna, will likely be cast as merely supporting, confirmatory and un-novel. On the other hand, contrarian studies (those challenging the stoichiometric dogma) would have a stronger case for novelty and would be better placed to be published in the literature. While new work and applications of ecological stoichiometry certainly deserve our attention, we shouldn't be so quick to dismiss work that doesn't meet this novelty criteria. *Continued on page 8.*

Stoichiometric Ecotoxicology Workshop Held

The United States' National Institute for Mathematical and Biological Synthesis held an Investigative Workshop, "Stoichiometric Ecotoxicology," on January 17-19, 2018 at NIMBioS on the campus of the University of Tennessee, Knoxville (USA).

During this workshop, experts from ecology, toxicology, and applied mathematics shared insights from across their fields and discussed incorporating multiple elements and contaminates in ecotoxicological models. The workshop included six keynote lectures (Bryan Brooks, Paul Frost, Hao Wang, Roger Nisbet, and Angela Peace) summarizing these fields and identifying challenges in linking ecological stoichiometry and ecotoxicology both empirically and mathematically. Three directions were identified and further discussed in smaller break-out groups: 1) developing a predator-prey model subject to concurrent toxicant and nutrient stressors, 2) incorporating size-structured dynamics subject to food quality, and 3) developing a stoichiometric-toxicological model under the Dynamic Energy Budget framework. The small groups plan to continue their efforts in these new research directions and proposed models. In addition, the larger group is planning a synthesis paper summarizing the results of this successful workshop.

Click here for more information on NIMBioS and this workshop.

A Stoichiometric Opinion (continued from page 7)

The most important criteria for judging our work in ecological stoichiometry should be the soundness of the study. Soundness could mean a lot of things but includes using appropriate methods, having a reasonably correct interpretation and application of stoichiometric theory, and reaching conclusions based on solid evidence. While we should expect no less, I don't think expecting more in the way of meeting unknown and undefined expectations of novelty and importance will be helpful to ecological stoichiometry over the long term.

Do you have a stoichiometric opinion to share with the readers of *Ratios Matter*? Email your submission to ratiosmatter@gmail.com and be featured in an upcoming issue.

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Selected Recent Stoichiometry Publications

Busch, V., V.H. Klaus, C. Penone and others. 2018. Nutrient stoichiometry and land use rather than species richness determine plant functional diversity. Ecol. Evol. 8: 601–616. doi:10.1002/ece3.3609

Carrillo, U., V. Díaz-Villanueva and B. Modenutti. 2018. Sustained effects of volcanic ash on biofilm stoichiometry, enzyme activity and community composition in North- Patagonia streams. Sci. Total Environ. 621: 235–244. doi:10.1016/j.scitotenv.2017.11.270

Dalton, C.M., R.W. El-Sabaawi, D.C. Honeyfield, S.K. Auer, D.N. Reznick and A.S. Flecker. 2017. The influence of dietary and whole-body nutrient content on the excretion of a vertebrate consumer. PLoS One 12: e0187931. doi:10.1371/journal.pone.0187931

Demi, L.M., J.P. Benstead, A.D. Rosemond and J.C. Maerz. 2018. Litter P content drives consumer production in detritus-based streams spanning an experimental N:P gradient. Ecology In Press: 1–13. doi:10.1002/ecy.2118

Godwin, C.M. and J.B. Cotner. 2018. What intrinsic and extrinsic factors explain the stoichiometric diversity of aquatic heterotrophic bacteria? ISME J. 12: 598–609. doi:10.1038/ismej.2017.195

Guiz, J., A. Ebeling, N. Eisenhauer and others. 2018. Interspecific competition alters leaf stoichiometry in 20 grassland species. Oikos In Press: 1–32. doi:10.1111/oik.02629

Hill, B.H., C.M. Elonen, A.T. Herlihy, T.M. Jicha and G. Serenbetz. 2018. Microbial ecoenzyme stoichiometry, nutrient limitation, and organic matter decomposition in wetlands of the conterminous United States. Wetl. Ecol. Manag. In Press: 1–13. doi:10.1007/s11273-017-9584-5

Krist, A.C., L. Bankers, K. Larkin, M.D. Larson, D.J. Greenwood, M.A. Dyck and M. Neiman. 2017. Phosphorus availability in the source population influences response to dietary phosphorus quantity in a New Zealand freshwater snail. Oecologia 185: 595–605. doi:10.1007/s00442-017-3983-4

Lacroix, C., E.W. Seabloom and E.T. Borer. 2017. Environmental nutrient supply directly alters plant traits but indirectly determines virus growth rate. Front. Microbiol. 8: 2116. doi:10.3389/fmicb.2017.02116

Leroux, S.J., E. Vander Wal, Y.F. Wiersma and others. 2017. Stoichiometric distribution models: ecological stoichiometry at the landscape extent. Ecol. Lett. 20: 1495–1506. doi:10.1111/ele.12859

Linzner, K.A., A.G. Kent and A.C. Martiny. 2018. Evolutionary pathway determines the stoichiometric response of *Escherichia coli* adapted to high temperature. Front. Ecol. Evol. 5: 173. doi:10.3389/fevo.2017.00173

Montiel-González, C., Y. Tapia-Torres, V. Souza and F. García-Oliva. 2017. The response of soil microbial communities to variation in annual precipitation depends on soil nutritional status in an oligotrophic desert. PeerJ 5: e4007. doi:10.7717/peerj.4007

Urabe, J., Y. Shimizu and T. Yamaguchi. 2018. Understanding the stoichiometric limitation of herbivore growth: the importance of feeding and assimilation flexibilities. Ecol. Lett. 21: 197–206. doi:10.1111/ele.12882

Veldhuis, M.P., M.I. Gommers, H. Olff and M.P. Berg. 2018. Spatial redistribution of nutrients by large herbivores and dung beetles in a savanna ecosystem. J. Ecol. 106: 422–433. doi:10.1111/1365-2745.12874

Wam, H.K., A.M. Felton, C. Stolter, L. Nybakken and O. Hjeljord. 2018. Moose selecting for specific nutritional composition of birch places limits on food acceptability. Ecol. Evol. 8: 1117–1130. doi:10.1002/ece3.3715 10.1371/journal.pone.0183236