Explanations for nitrogen decline

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Aquatic species risk becoming entangled in fishing nets that have been lost or abandoned.

PHOTO: MARCUS DAVIS ANDRADE BRAGA, MAR DO CEARÁ

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New treaty must address ghost fishing gear

In his News story "World's nations start to hammer out first global treaty on plastic pollution" (23 February, https://scim.ag/unplastictreaty), E. Stokstad discusses the issues that may be addressed by a new plastic treaty (*1*), including pollution resulting from fishing activities. Because fishing gear is often made from long-lasting synthetic polymers, such as nylon (*2*), lost and abandoned gear is a long-term problem. This type of pollution, known as ghost gear, is a serious and pervasive threat to the integrity of ecosystems (*2*). The first plastic treaty must address ghost gear in marine (*3*) and freshwater environments.

Ghost gear affects aquatic ecosystems on every continent. Abandoned or lost nets, for example, trap and often kill large fish (e.g., elasmobranchs), crustaceans (decapods), turtles, mammals (including cetaceans), and other organisms (*4*–*7*). Although reports are more frequent from marine ecosystems, damage has occurred in inland water ecosystems as well (*2*, *7*). Other animals, such as birds, are attracted to potential prey trapped in the ghost gear and can become entangled themselves (*5*, *8*), generating a negative cascade effect (*5*). As Stokstad notes, the problem is exacerbated by the lack of reliable data on the frequency and degree of impact of ghost gear in aquatic ecosystems around the world.

Given the increasing demand for resources to feed the world's growing population, fishing will intensify in coming years (*3*, *9*), and the amount of ghost gear in aquatic ecosystems will almost certainly increase as a result. To address this problem, the plastic treaty should aim to reduce the risk fishing gear poses to the environment. Possible strategies include replacing synthetic fishing gear with biodegradable alternatives, which are already available (*10*); limiting the sales of nylon nets; providing educational opportunities; and removing lost and abandoned fishing gear from ecosystems (*2*). In addition to drafting the plastic treaty, all countries must take urgent and comprehensive action to combat the harm caused by fishing activities.

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In their Review "Evidence, causes, and consequences of declining nitrogen availability in terrestrial ecosystems" (15 April, eabh3767), R. E. Mason *et al.* argue that nitrogen has decreased in availability worldwide over the past century and that the decline is best explained by human-driven elevated temperatures and CO_2. This conclusion conflicts with previous studies showing strong increases in nitrogen availability compared to preindustrial levels (*1*, *2*). Mason *et al.* present two main types of observational trends as evidence that nitrogen has declined: a decline in Europe and the United States since 1990 in various nitrogen availability indices, and a worldwide decline of nitrogen isotope ratios ($\delta^{15}N$) in plant leaves, tree rings, and lake sediments since 1920. We disagree that rising temperatures and CO_2 levels are the best explanation for these trends.

The decline in nitrogen since 1990 can be easily explained by reduced nitrogen emissions from fossil fuels and agriculture since 1990 in Europe and the United States (*3*). However, because nitrogen emissions remain far above preindustrial levels, high levels of nitrogen inputs in ecosystems continue to cause nitrogen eutrophication and biodiversity loss (*4*). The second trend can be explained by the human-driven shift since 1920 toward a much larger role of gaseous sources of reactive nitrogen in the global nitrogen cycle relative to direct uptake from soils and recycled residues (*1*, *4*). Increasing numbers of livestock, the urine and feces of which contain nitrogen that forms ammonia (NH_3), have led to increased release of this reactive nitrogen-containing gas into the atmosphere (a process known as volatilization). Artificial nitrogenous fertilizers, which are widely produced from nonreactive nitrogen gas (N_2), have also increased volatilization of nitrogen as ammonia (*5*). Compared with nitrogen released through organic matter decomposition in soils, these gaseous origins of reactive nitrogen are typically more depleted in the stable isotope ^{15}N (*1*, *6*, *7*).

The marked ^{15}N depletion in plants in natural ecosystems over the past century likely reflects these much-increased anthropogenic nitrogen emissions and gases (*6*, *8*, *9*) rather than lower nitrogen availability as Mason *et al.* suggest. Therefore, we caution against Mason *et al.*'s recommendation to fertilize seminatural ecosystems with nitrogen to improve carbon sequestration. To prevent the negative effects of excess nitrogen (such as biodiversity loss), implementing this intervention should wait until more compelling evidence is available.

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Response

Olff *et al.* select only a subset of the evidence for declining nitrogen availability and assign unlikely mechanisms to reach the conclusion that nitrogen availability is not declining over large areas of Earth. We disagree that the evidence can be grouped into the categories that Olff *et al.* describe; the complete set of observations is wider in scope and cannot be explained by the mechanisms that the authors propose.

Olff *et al.* claim that declines in nitrogen emissions since 1990 can explain declining nitrogen availability. Our Review acknowledges reduced emissions, and the resulting reduction in atmospheric deposition of nitrogen onto ecosystems, as a likely contributing factor. However, we also present long-term records of declining nitrogen availability, including declining nitrogen concentrations in plant leaves since around 1930 (*1*, *2*) and in plant pollen since the early 1900s (*3*), as well as declines in a broad suite of soil nitrogen availability indicators and stream water NO_3^- at Hubbard Brook in New Hampshire, United States, that date back to the 1960s and 1970s (*4*, *5*). These observations predate reductions in nitrogen deposition. Moreover, as we explain in the Review, declines in nitrogen availability indicators have occurred in places that have never experienced substantially elevated nitrogen deposition (*1*) and alongside declines in concentrations of other elements in plants (*6*–*8*).

Olff *et al.* then propose that large-scale declines in natural abundance nitrogen isotope ratio ($\delta^{15}N$) values in sediment and plants can be explained by a change over time in the isotopic signature of anthropogenic nitrogen emissions toward isotopically lighter, reduced forms of nitrogen. However, the evidence they cite of possible effects of this shift on plant $\delta^{15}N$ refers only to a handful of case studies in atypical environments (*9*–*11*). The isotopic ratio of deposited nitrogen is elevated by processes in soil that discriminate against ^{15}N; the effects of such processes increase with increasing nitrogen supply (*2*, *12*). Models show that the isotopic signature of deposited nitrogen would have to be implausibly low to cause plant $\delta^{15}N$ to decline at the observed rate (*2*).

There is little doubt that massive and poorly managed anthropogenic nitrogen inputs have led to eutrophication and biodiversity loss in many locations. However, rising atmospheric CO_2, warming, and several other global changes are concurrently driving a reduction in nitrogen availability (i.e., nitrogen supply relative to nitrogen demand). The well-documented increases in anthropogenic nitrogen supply noted by Olff *et al.* have not affected global ecosystems uniformly and are unlikely to be the overriding driver of changes in nitrogen availability across all terrestrial ecosystems.

As we state in our Review, the fundamental response to declining nitrogen availability must be to reduce CO_2 emissions. We point out that, although fertilization may be one option for increasing nitrogen availability to plants, microbes, and herbivores, numerous factors must be taken into account when designing interventions that can achieve well-defined goals without unacceptable negative consequences. Further work is necessary to more fully demonstrate the extent of declines in nitrogen availability, to clarify the underlying mechanisms, and to delineate appropriate responses. But before this can happen, the scientific evidence for declining nitrogen availability must be acknowledged.

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