NEWS FEATURE

Can predators have a big impact on carbon emissions calculations?

Models suggest that predators and even biodiversity in general play a potentially significant role in carbon sequestration. But whether such results buttress conservation arguments remains a matter of debate.

Leslie Willoughby, *Science Writer*

Gray wolves lie at the heart of vigorous debate about the costs and benefits of conservation. But they also might inform another ongoing debate: the pace and projections for atmospheric CO_2 accumulation in a warming world.

Ecologists are venturing into a new field of inquiry as they attempt to estimate how populations of predators affect atmospheric carbon levels. It turns out that losing wildlife could mean losing an important mechanism of carbon sequestration.

Wolves and other predators generally affect carbon sequestration indirectly, by controlling the abundance of plants. For instance, when a wolf kills a moose, the moose no longer consumes woody plants, thus indirectly increasing woody plant abundance (1). Carbon accumulated in a plant remains sequestered throughout the plant's lifetime and perhaps longer if it ultimately turns into coal or oil (2). In another well studied example, sea otters, by controlling the sea urchin population, indirectly allow for more carbon-storing kelp, a food source for the urchins (3).

Wolf kills may indirectly affect woody-plant abundance by having an impact on the number of plant-eating prey. Here, a wolf at Jasper National Park in Alberta, Canada, stands over an elk carcass. Image courtesy of Mark Bradley (Boreal Nature Photos).

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And predation is not the only way that animals mediate carbon storage. Ecologists recently found that the amount of diversity in an ecosystem is itself linked to increased amounts of carbon storage (4).

The result of such dynamics, say those conducting these studies: an estimated tens of millions of metric tons of carbon stored. These carbon-storage calculations, though, represent extrapolations of baseline densities observed in modern times and applied throughout the animals' range. The relevance and importance of these calculations remain a matter of debate; the baseline densities are in areas of species recovery, such as national parks and parts of the Amazon devoid of large-scale habitat degradation. Even so, some researchers contend that the estimates have introduced intriguing new variables in CO_2 emissions calculations.

Sea otters, such as this one photographed off Calvert Island in British Columbia, Canada, help control the sea urchin population and, hence, indirectly allow for more carbon-storing kelp, an urchin food source. Image courtesy of Erin Rechsteiner (Hakai Institute, Heriot Bay, BC, Canada).

Pricing Predators

Only in recent years have ecologists begun to apply decades of field observations to consider how mammals affect the carbon cycle. Starting with direct observations of a specific type of mammal within a particular region and timeframe, researchers typically calculate a local effect on carbon. They then extrapolate that effect throughout a mammal's larger range (1, 3, 5).

The carbon footprint of wolves depends on what these carnivores kill. And their main prey depends on whether they inhabit grasslands or boreal forests—the spruce, hemlock, pine, and fir forests of northern latitudes. Wildlife ecologist Christopher Wilmers of the University of California, Santa Cruz and ecologist Oswald Schmitz of Yale University set out to determine whether wolves and their ripple effects throughout the ecosystem affect carbon at a level of magnitude that warrants attention—or whether the wolves' effects were so small that they could be ignored.

To find out, Wilmers and Schmitz estimated the potential for gray wolves to have cascading effects on carbon cycling within two ecosystems: elk-inhabited grasslands and moose-inhabited boreal forests. These effects are the "trophic cascades" that propagate down through food webs (6, 7). Such cascades can be triggered when predators eat prey.

Although wolves inhabit both ecosystems, elk generally do not live in the boreal forest of North America and moose do not generally live in high-altitude grasslands. In boreal forests such as those of Isle Royale National Park in Michigan, wolves primarily eat moose, moose eat woody vegetation, and woody vegetation stores carbon. However, in grasslands such as those of Yellowstone National Park in Wyoming, Montana, and Idaho, wolves primarily eat elk, elk eat grasses and other nonwoody plants, and those plants store carbon. For each ecosystem, Wilmers and Schmitz wanted to determine how the presence of wolves indirectly affects carbon storage.

So the researchers calculated the difference between carbon taken into plants through photosynthesis and the carbon plants give off, arriving at a figure for net primary productivity. They then subtracted carbon released by animals and microbes to get an estimate of the net carbon stored in the ecosystem. Thus, they arrived at a carbon budget to compare the absence of wolves with the presence of wolves at densities observed in wilderness during modern times.

The researchers applied these estimates to the entire area of boreal forest of North America, in regions where wolves and moose—wolves' primary prey in that habitat—live together, to achieve an approximation of the impact of wolves on carbon storage there. The result: an estimated increase in carbon storage between 46 million and 99 million metric tons may be attributed to the presence of wolves in boreal forest, compared with a complete absence of the predators.

There are important caveats. An increase in forest could exacerbate warming under some circumstances. At high latitudes in springtime, for example, dark boreal forests absorb sunlight, compared with highly reflective, snow-covered land nearby (8) This warming may exceed any cooling effect of extra carbon removed from the atmosphere. When herbivores such as moose thin the forest canopy, they may help with cooling. But too much of this herbivory may lead to soil warming, explains Schmitz, resulting in an increase in soil microbial activity and release of CO_2 from soil storage. Such release is of particular concern at high latitudes (9). "Wolves help strike a balance between these opposing factors by controlling moose herbivory," Schmitz says.

Complicating matters, the carbon-storage calculations themselves are far from straightforward. Wolves that live in grasslands, where they primarily eat elk, may decrease stored carbon. Elk stimulate grassland by enhancing the cycling of nutrients. This cycling occurs when elk excrete the grasses they eat and trample their feces into the soil. In this scenario, an increase in the number of wolves may decrease the

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abundance of elk and thereby significantly suppress carbon storage. If gray wolves and elk coinhabited the entire area of North American high-altitude grasslands, the researchers estimated a loss of carbon storage between 8.8 million and 30 million metric tons of carbon.

To arrive at the combined effect of gray wolves across the *two* ecosystems, the researchers subtracted the loss of carbon storage attributable to gray wolves throughout wolf/elk grasslands from the increase of carbon storage attributable to wolves throughout the much larger wolf/moose boreal forest. That potential net effect is on the same order of magnitude, say the researchers, as the removal of fossil fuel emissions from between 6 million and 20 million passenger cars per year.

"We don't view this as a global home run solution," says Schmitz, referring to local conservation efforts that may be bolstered by estimates of wildlife's role in carbon sequestration. "We feel that by creating a portfolio of these regional options we might actually get more traction—because you don't need global agreement about this one strategy."

Urchin Suppressor

Although they're among the smallest of marine mammals, sea otters, like wolves, function near the top of trophic cascades that may affect the storage and flow of atmospheric carbon. The otters eat sea urchins, and sea urchins eat kelp, which stores carbon. These keystone predators of the nearshore environment remain listed as threatened under the US Endangered Species Act (10, 11).

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>
> —Monica Turner

Wilmers and colleagues examined 40 years of data collected by James Estes and colleagues to estimate the effects of these ocean predators on ecosystem carbon production and storage (3). They applied that estimate across the sea otter range within the study area, from southern Vancouver Island out through the western tips of the Aleutians.

By gauging the extent to which sea otters change the productivity of kelp beds, the researchers hoped to calculate the effect on carbon. First they analyzed the biomass of living kelp for carbon density at sites populated by sea otters and compared that amount to carbon density within sites where sea otters had ceased to exist. They then estimated the balance of carbon gained in kelp through photosynthesis versus the carbon released from kelp through respiration, decomposition, and ultimately sinking into the deep sea. Finally, the researchers estimated the difference that otters make in kelp carbon in grams of carbon per square meter. They applied this "predator effect" across the total potential habitat area for sea otters.

The increase: between 44 million and 87 million metric tons. With otters present, the amount of carbon that kelp stores would stay roughly the same over time. That means the presence of otters translates to a decrease of carbon between 5.6 and 11% in the volume of atmosphere that exists over the sea otter range within the relatively small study area. "If you imagine that different species of animals are having different kinds of effects throughout the globe, then they could all add up to be quite significant," Wilmers says.

Even a microbe could have a sizeable effect. In one case, management of a virus may have flipped the Serengeti from a net carbon source to a sink. "It's not always the biggest animals that have the most impact," says Mark Ritchie, environmental scientist at Syracuse University in New York. Ritchie and colleagues studied how eradication of rinderpest virus affected ecosystem carbon (5).

In the presence of rinderpest, fewer wildebeests grazed the Serengeti, an ecosystem of approximately 25,000 square kilometers in Tanzania and Kenya. Grasses grew tall and provided fuel for fire, which returned carbon to the atmosphere. With these fires and a lack of trees, the ecosystem functioned as a net carbon source.

After eradication of the virus, the wildebeest population recovered. Their grazing resulted in shorter grasses, less fuel, and less fire. More trees grew, storing more carbon. Some of the carbon in plants that the wildebeests ate returned to the soil as dung.

Taking these factors into consideration, the researchers simulated grazing's effects on soil carbon based on about 50 years of data. They found that the Serengeti trees and soil now comprise a net carbon sink that annually removes between 40 and 70 metric tons of carbon per square kilometer, equivalent to 1 million metric tons of carbon stored throughout the ecosystem (5). "If you look collectively at all tropical grasslands, that occupy around 15% of the earth's surface, and try to control how much of the grass is eaten and how many trees are growing," Ritchie says, "then you would definitely have an impact on global processes."

Individual species aside, the diversity of mammals in a given ecosystem could itself have implications. Ecologist Mar Sobral and colleagues found that mammal diversity is linked to the amount of carbon stored in plants and the carbon concentration in soil, even after accounting for location, the physical environment, human disturbance, animal abundance, and the diversity of tree types (4). Working in the Amazon, Sobral, then at Stanford University, and her colleagues collected data with the help of 355 Makushi, Wapishana, and Wai-Wai peoples from Guyana, through more than 10,000 surveys over the course of 3 years in an area of 5 million hectares—an area about the size of Costa Rica.

The study did not focus on carbon stocks but rather on carbon cycling. "However, a very cautious estimation is that a tropical forest with higher mammal diversity should sequester an extra 10,000 kilograms per hectare in above-ground tree biomass alone," says Sobral, who's now based at the Centre

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d'Ecologie Fonctionnelle et Evolutive in Montpellier, France. Mammal diversity may affect the amount of carbon stored via changes in plant community composition. For example, mammals may help disperse large seeds by consuming and excreting them over a wide area.

Making an Impact?

Skeptics, though, question the scope of these results. "We should be cautious in extrapolating carbon effects to whole ecosystems or landscapes, when we look at only a subset of species," says Monica Turner, ecosystem and landscape ecologist of the University of Wisconsin–Madison. For instance, not only wolves but also mountain lions and grizzly bears prey on elk in Yellowstone National Park, Turner notes. Not only elk but also bison, deer, and antelope graze within the park. She suggests that additional studies consider "myriad factors that affect how an ecosystem stores carbon, such as climate, and the variation in grazing patterns, intensity, and timing."

And it's important to tread carefully when recommending carbon storage as a top management priority for ecosystems, says Christopher Field, director of the Stanford Woods Institute for the Environment. "When we think about a healthy ecosystem that's got a vibrant mix of species and robust food chains," he says, "it doesn't necessarily mean it's always going to be the one that has the most carbon in it."

Nonetheless, researchers making these calculations raise the possibility that mammal conservation in the coming decades will yield valuable dividends in the form of carbon sequestration (1, 3–5). Despite extensive global habitat destruction and fragmentation, there are large tracts of land and water, Wilmers and colleagues note, where food-web structure and dynamics could be restored or altered with appropriate conservation and management (3). And in future studies, more accurate data may be obtained through the use of remote sensing methods such as LiDAR, which can directly monitor changes in the abundance and location of carbon stocks, such as in tens of thousands of trees.

"Nature cannot save us from the problem," Field says. "But we should be taking advantage of all these solutions, particularly where we win both in terms of a healthier ecosystem and also a positive contribution to addressing climate change."

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