Lopped Off

Removal of top predators trickles through the food web

By Nadia Drake

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Sharks are stripped from the seas for their fins (hammerhead fin shown), which are a delicacy in East Asia.Jeffrey L. Rotman/Getty Images

In July, the Ecuadorean navy helped apprehend a fishing vessel within the waters of the Galápagos National Park. On board lay the carcasses of 379 sharks — including threshers, hammerheads, Galápagos, blues and a mako. Nearly severed fins hung from the mutilated, slippery bodies. The fins were presumably destined for trade in Asian markets, where shark-fin soup can sell for more than $100 a bowl.

The incident is no aberration; these illegally slaughtered sharks are just the bloodied face of a global problem. Not even marine sanctuaries are immune.

But sharks aren't the only predators under siege. A host of carnivores perched atop food webs are being eliminated by humans, the real killing machines. Although marine species such as sharks are primarily caught for food, large terrestrial hunters (think lions, wolves and grizzlies) are often targeted for removal because they threaten humans moving into previously wild spaces.

"We're eliminating large predators very quickly around the world," says wildlife biologist Michael Soulé of the Wildlands Network, who works out of Paonia, Colo. "It's estimated that 90 percent are already gone."

These end-of-the-line carnivores, known as "apex consumers," can influence the lower rungs of their ecological ladders. By keeping the critters they dine on in check, the apex species affect the next rungs down, and so on. The system remains balanced as populations fluctuate in sync.

So when predators are plundered, the ripples spread farther than a person sipping shark-fin soup might ever imagine. Recently, scientists have been able to follow these ripples by comparing habitats with and without their apex consumers. The findings suggest that the effects can cross boundaries between land and sea, alter entire landscapes and even touch the smallest microorganisms and the Earth's chemical cycles.

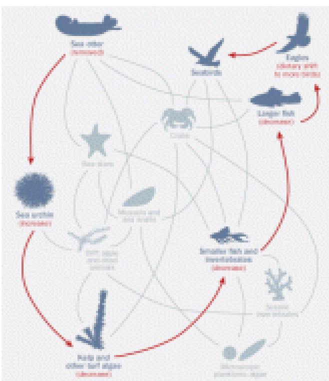
Beyond documenting such effects, scientists are working with conservation groups to reverse the changes brought by ecosystem decapitation. All agree that progress will be difficult as long as habitats continue shrinking and people continue yanking animals from the wild.

A wild laboratory

Though scientists have long known that apex consumers play important ecosystem roles, studying those roles is tricky. Nature isn't the easiest laboratory to work in: It doesn't provide rigorous experimental controls, and landscapes may take years, even decades, to reveal their bruises.

"Imagine looking out at an ecosystem that had wolves in it — just seeing a place with wolves — you wouldn't have any sense of the importance of wolves unless you took them out," says wildlife ecologist James Estes of the University of California, Santa Cruz, who outlined some of the consequences of losing predators in the July 15 *Science*.

Though researchers don't generally conduct such experiments, one removal study has been inadvertently set up in Yellowstone National Park.



RIPPLY REMOVALWhen otters are removed from their food web (portion shown here), the effects spread to many other organisms (as shown by red arrows). Studies have found that removing otters leads to an upswing in sea urchins, a drop in kelp populations and thus fewer fish. With fewer fish in their diets, eagles dine more heavily on seabirds.sea otter: tru/istockphoto; sea star, crab, sea urchin: Helen Cingisiz/shutterstock; eagle: abrakadabra/shutterstock; sea bird: Bambuh/shutterstock; larger fish, smaller fish: Potapov Alexander/shutterstock; drift algae, kelp: Pavlovic A/shutterstock; sessile invertebrates: jr trice/shutterstock; mussels, planktonic algae: T. Dubé

By the early 1900s, western gray wolves had disappeared from most of their range in North America, hunted for bounty or eliminated as threats to livestock.

"In 1997, I learned that the aspen trees in Yellowstone were disappearing, and no one really knew why," says ecologist William Ripple of Oregon State University in Corvallis. So he headed to the park and studied the growth records preserved in the aspens' trunks. It turns out that most shoots stopped growing into large trees in the early 1900s, around the same time that wolves vanished. Ripple hypothesized that disappearing wolves and disappearing aspen were linked via an intermediate species.

When wolves weren't around, Yellowstone became stuffed with elk, a wolf's favorite meal. The big-antlered ungulates were damaging the park's vegetation as they leisurely chewed on young aspen trees, limiting the growth of woodland plants. And there was more. In winter, when food was scarce, the elk would starve and die; the population had exceeded its carrying capacity.

Ripple noticed a similar effect during studies in Utah's Zion Canyon. Some areas of the park are frequently visited by humans — and thus avoided by cougars — while others are relatively undisturbed. In areas where the big cats were scarce, deer flourished and limited the growth of cottonwoods. Where pumas were present, Ripple says, "we found more wildflowers, we found more butterflies, we found more lizards, we found more frogs and fish."

Ripple got the chance to test how the wolf, elk and aspen pieces fit together when wolves were reintroduced to Yellowstone in 1995.

"If our hypothesis is correct, we should start to see the trees growing again," he says. "And guess what? They are, but only in places." Ripple and Oregon colleague Robert Beschta have started noticing burgeoning plant communities in some areas of the park's northern reaches, where trees are just beginning to grow tall enough to escape munching elk.

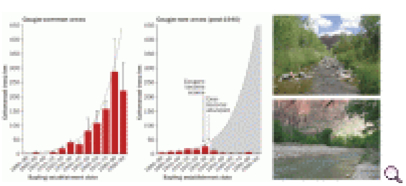
In 2010 in *Restoration Ecology*, the team reported the re-emergence of cottonwood and willow; in an upcoming *Ecology*, they describe ongoing monitoring of 98 aspen stands and ascribe tree regrowth to the return of wolves.

How widespread the recovery will be and how long it will take is not yet clear. Ripple estimates that it may be several decades before Yellowstone's vegetation returns to its former state. "The experiment in time continues," he says.

Tracing takeaway effects

Though sea otters may not have the snarl of a wolf or cougar, these furry marine mammals are also apex consumers. Normally pictured playing in kelp, otters are actually quite fierce. "Imagine a hundred-pound weasel, but cute," Estes says. "Looks are very deceiving."

In *Ecology* in 2008, Estes and colleagues attributed a curious observation to the decline of the otters: Bald eagles soaring over windswept southwestern Alaska were preferentially eating seabirds, rather than their usual, more fishy feasts.



COUGAR-COTTONWOOD CONNECTORView larger image | In some areas of Utah where people tread, cougars have become scarce. Compared with lands where the cats roam, the cougarless spots have fewer cottonwoods (graphs), a shift linked to an increase in grazing deer. Riverbanks without cougars thus have less vegetation and more erosion (bottom photo, compared with top).graphs: W.J. Ripple and R.L. Beschta/Biological Conservation 2006; photos: W.J. Ripple

Like Ripple's wolf investigations, Estes' work has looked at comparable Alaskan ecosystems both with and without sea otters. When otter populations began to recover in the early 1900s following their collapse due to the fur trade, they recolonized only some remote Alaskan islands. Differences in otter presence among the islands gave researchers an opportunity to look at how the marine mammals affect nearshore environments.

Then, in the 1990s, otter populations unexpectedly plunged because killer whales began preying on them. The drop allowed Estes to define the otter's role in the rugged Alaskan ecosystem in much more detail.

When otters are present, they limit sea urchin numbers, keeping kelp forests intact. Without otters, sea urchins flourish, munching at the base of stories-tall kelp fronds and deforesting the underwater coastal world. Less kelp means fewer fish, and fewer fish, Estes and his colleagues found in a series of follow-up investigations, means hungry eagles. So the eagles turn to seabirds for sustenance.

Because kelp are primary photosynthesizers, less kelp also means the oceans absorb less atmospheric carbon, unpublished work has revealed. "Otters have a significant effect of drawing down carbon dioxide," Estes says. "It's a very deeply interconnected system."

Estes could trace these far-flung impacts because he'd been on the trail since the 1970s. Darcy Ogada is documenting a similar interconnectedness over a shorter timescale. She studies African landscapes in the presence and absence of vultures.

Though mostly known for being nature's trash collectors, vultures' position as apex consumers might mean that they have a crucial part to play in limiting the spread of disease among wild populations, says Ogada, a conservation biologist based outside Nairobi, Kenya, and the Peregrine Fund's assistant director for Africa programs. The hypothesis is supported by reports from India, where roughly 97 percent of the country's vultures have disappeared since the 1990s. In their absence, rotting carcasses became putrid banquets for feral dogs, which carry and spread rabies.

In Kenya, vultures are declining in part because they're being poisoned, an unintended consequence of farmers aiming to remove the threat to livestock from another apex species, lions. Animal carcasses laced with "lion killers" — agricultural pesticides meant to poison marauding felines — are also eaten by vultures, which flock to the toxic carcasses and feast in large groups.

"If people are poisoning lions, then vultures are being hit a hundred times more," Ogada says. "Nothing really competes with them in terms of scavenging. They can cover more land area and arrive faster."

In Kenya's Laikipia district, Ogada says, vulture populations have dropped by 60 to 70 percent in the last decade or so. In 2010, Ogada published a study in the *Journal of Raptor Research* describing a 48 percent decline in just one year. "The situation is not good," she says.

To learn how these scavengers fit into the Kenyan savanna ecosystem, Ogada compared carcasses with and without vultures and found that decomposition took three times as long when the feathered feasters weren't around, turning the savanna into the equivalent of a stinky city street when the garbage collectors are on strike.

She noticed that mammalian scavengers such as hyenas and jackals visited more frequently and stuck around longer when the vultures were gone. "There was a threefold increase in the number of contacts between these animals," Ogada says. "So the problem, potentially, is that these carcasses could become focal centers for disease transmission."

Take some rotting, microbe-slathered meat, up the number of animals feeding from it and spice the situation with rabies or canine distemper, and you have a recipe for yuck.

"It's actually really gross when vultures aren't around," says ecologist Felicia Keesing of Bard College in Annandale-on-Hudson, N.Y. Keesing and Ogada now plan to study disease transmission rates around vultureless carcasses.

Bringing big ones back

Like the vultureless savanna, a sharkless ocean may also have the potential to mess with microbial activity.

Marine ecologist Stuart Sandin studies sharks and large fish living around neighboring coral reef ecosystems in the Pacific Ocean, some of which are heavily fished by humans. The Line Islands include both protected, unfished areas, such as Kingman Reef and the Palmyra atoll, and inhabited islands such as Kiritimati (also known as Christmas). In these reefs, Sandin monitors species abundance, the amount of junk in the water and coral health.

In 2008, he and his colleagues reported that microbial populations in waters surrounding inhabited islands were 10 times higher than those in undisturbed waters. Since then, Sandin has linked the microbe-mottled waters, which also host an increased number of pathogenic organisms, to the loss of large reef inhabitants, including sharks.

Diving near the untouched reefs is shocking, Sandin says, since the vast majority of science has been done in seas where big animals are already gone. In fished areas, he says, "it's actually really special when you're diving or snorkeling and you see an animal that's bigger than a meter long."

In *PLoS ONE* in June, Sandin's team described the effects of predator scarcity on prey populations swimming in Kiritimati waters: Most prey species studied grew bigger and lived longer, while remaining big predators were smaller than on untouched Palmyra. The team also noticed that islands with big fish and big predators intact had healthier corals and less algae — a crucial player in the cultivation of microbe-laden waters.

Sandin hypothesizes that removing large reef residents such as sharks, parrot fish and surgeonfish can clear the way for smaller herbivores to proliferate, because of decreased predation and competition. In studies comparing Kingman Reef with Kiritimati, Sandin saw a 60-fold increase in the number of damselfish tending to algal gardens in the absence of bigger fish. The gardens, familiarly known as seaweed, can compete with corals and suppress their growth.

Eventually, Sandin says, the seaweed's unchecked growth dumps extra sugars into the surrounding water. Bacteria like sugar, and their populations compete. Over time that competition can select for hardy pathogens.

"You can end up with a nasty microbial consortium," Sandin says — bad news for corals, algae and fish.

Sandin estimates that 75 percent of Pacific reefs have been affected by humans, but says that maybe only 10 percent are beyond help. The others could be restored to their former numbers by limiting the fishing of predators or large herbivores. Leaving the reefs alone will let such species, which have longer life cycles, survive.

This approach works in the water where humans don't live, but conservation on land requires a different take. Because people often figuratively butt heads with wild animals, re-establishing species that are missing from their ancestral habitats — a process known as "rewilding" — is controversial. Still, returning areas to their original state has some precedent; it has been done successfully, most notably in Yellowstone with the return of the gray wolves.

But simply boosting animal numbers isn't enough. They need space, and they need cooperation from nearby humans.

National parks, while a good start, aren't sufficient, says Peter Kareiva, who is chief scientist for the Nature Conservancy and works out of Seattle. "Protected areas might be good for capturing plants, but you can't get enough land locked up in nature reserves for mountain lions, wolves or grizzlies," he says. Predators aren't going to stay within park or sanctuary boundaries, meaning their survival depends on cultivating tolerance and respect among people living nearby.

"There's something really beautiful about hearing wolves at night," Kareiva says. "The sense of wild that a grizzly conveys, it's humbling. I think wildlife and humans can coexist, but certainly it's not an automatic process."

Establishing predator-friendly ranchlands in the areas around national parks, for example, might help predators struggling to find space by expanding protected areas and offering corridors of connectivity between those habitats.

If predators are able to do what predators do (taking care of their ecosystems by eating stuff), the end result will be a healthier environment — even if it means that people living in areas currently drenched with deer have to get used to living with cougars again.

Says Kareiva: “If you could restore the balance of ecosystems — look at how many deer there are in the Northeast, and what a big problem they create for homeowners and everybody — would it be so bad if cougars came back?”