LETTERS

Edited by **Jennifer Sills**

Fauna in decline: Meek shall inherit

ALTHOUGH LARGE ANIMALS capture our attention and directly or indirectly play essential ecological and ecosystem functions (*1*), it is the sheer diversity and abundance of invertebrates that make them "run the world" (*2*). A recent Review presented evidence of human-induced pervasive defaunation in terrestrial ecosystems ("Defaunation in the Anthropocene," R. Dirzo *et al.*, special section on Vanishing Fauna, 25 July, p. 401). Given that larger animals are more likely to go extinct [Dirzo *et al.* and (*3*)], invertebrates may soon play even more important roles in the dynamics of ecosystems than they already do (*1, 4*).

Many of the vertebrate species that have been locally extirpated or are in decline are herbivores, seed dispersers, or granivores

[Dirzo *et al.* and (*1, 3*)]. Therefore, as the Anthropocene progresses, invertebrates—and notably ants—will be the prospective heirs of these plant-animal interactions.

Although human disturbances affect ants, the effect is frequently much less pronounced than on vertebrates or on other insects such as Lepidoptera and bees (*3, 5*). Ants are remarkably abundant across most terrestrial ecosystems, interacting with many other species of insects, plants, and vertebrates. There is increasing evidence that ants benefit fleshy-fruited plants adapted for vertebrate seed-dispersal; indeed, they can be quantitatively as important as birds as seed removers (*6*). The dominant herbivore in the Neotropics—leaf-cutter ants (*Atta spp.*)—actually increases in abundance after ecosystem disturbance, which could profoundly alter plant regeneration and ecosystem processes (*7*). As invasive ant species continue to change the composition of local biota across the globe, there could be further cascading effects on plant and animal communities (*8*). With continued Anthropocene extinctions, it will become increasingly critical to elucidate the myriad ways through which this dominant group of invertebrates influences ecosystem functions across continents and biomes.

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REFERENCES

1. J. A. Estes *et al.*, *Science* **333**, 301 (2011).
2. E. O. Wilson, *Conserv. Biol.* **1**, 344 (1987).
3. IUCN, The IUCN Red List of Threatened Species (2014); www.iucnredlist.org.
4. F. Keesing, T. P. Young, *Bioscience* **64**, 487 (2014).
5. S. G. Potts *et al.*, *Trends Ecol. Evol.* **25**, 345 (2010).
6. A. V. Christianini, P. S. Oliveira, *J. Ecol.* **98**, 573 (2010).
7. I. R. Leal, R. Wirth, M. Tabarelli, *Biotropica* 10.1111/btp.12126 (2014).
8. C. E. Christian, *Nature* **413**, 65 (2000).

Fauna in decline: Extinct pigeon's tale

E. STOKSTAD'S NEWS article about the ecological consequences of elimination of megafauna resulting from overhunting ("The empty forest," special section on Vanishing Fauna, 25 July, p. 397) is especially poignant, given that 2014 marks 100 years since the extinction of the passenger pigeon (*Ectopistes migratorius*), once the most abundant bird of eastern North American forests. In the 19th century, new railroads across the eastern United States expanded the market for wild meat, just as new roads through the tropical forests are affecting hunting in Borneo and elsewhere in the developing world today. The passenger pigeon was unable to withstand the onslaught of unregulated commercial hunting, and the story is being repeated in the forests of Borneo and elsewhere.

The passenger pigeon population crashed from billions in the mid–19th century, to extinction of the wild population in less than half a century, to extinction with the loss of the last captive bird in 1914. Stokstad describes alarmingly similar trajectories for hunted mammals and birds of Borneo, even in an area that is nominally protected as a national park.

There were a number of ecological consequences of the extinction of the passenger pigeon. The pigeons damaged forest canopies and deposited nutrient-rich excrement, which may have been important for the maintenance of now-rare canebrakes in the southeastern United States (*1*). Because of their dietary preferences, their extinction changed the balance

between white oaks and red oaks (*2*). The extinction of the passenger pigeon may even have led to an increase in the incidence of Lyme disease (*3*, *4*). The pigeons were effective seed predators. In years with a bumper crop of acorns and beechnuts, the pigeons ate so much that competitors for the food, such as white-footed mice (*Peromyscus*), could not eat enough to increase in number. Now, in the pigeons' absence, the mice increase during these years (*5*). Because mice are the reservoir for the tick-transmitted Lyme disease bacterium (*Borrelia*), when they increase in number, the *Borrelia* do as well, and increased cases of Lyme disease result (*6*). These impacts are still being felt a century after the last passenger pigeon died.

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REFERENCES

1. R. Noss, *Forgotten Grasslands of the South* (Island Press, Washington, DC, 2012).
2. A. W. Schorger, *The Passenger Pigeon: Its Natural History and Extinction* (Univ. of Wisconsin Press, Madison, WI, 1955).
3. D. E. Blockstein, *Science* **279**, 1831 (1998).
4. D. E. Blockstein, *Birding* **33**, 302 (2001).
5. R. Ostfeld, *Lyme Disease: The Ecology of a Complex System* (Oxford Univ. Press, New York, 2011).
6. J. Bunikis *et al.*, *J. Infect. Dis.* **189**, 1515 (2004).

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Corrected 8 September 2014; see full text.

Carbon: No silver bullet

ON BEHALF OF the European Academies Science Advisory Council (EASAC)—established by the national science academies in Europe to advise EU policy-makers on the science underpinning key decisions—we would like to respond to S. M. Benson's Editorial, "Negative-emissions insurance" (27 June, p. 1431). EASAC has recently completed two studies on carbon capture and storage (CCS) (*1*) and on biofuels in Europe (*2*). The studies broadly support Benson's view that bioenergy with CCS might make a useful contribution to climate change mitigation in Europe, but their overall conclusion is that it is likely to be modest.

As Benson recognizes, CCS is expensive. Costs are likely to be higher for biomass CCS than for CCS associated with large fossil-fuel–based plants, as the biomass CCS will be smaller scale and often remote from CO_2 transport and storage facilities. The EASAC study concluded that there is rather limited scope to bring costs down.

Confidence in the long-term integrity of CO_2 storage will build slowly, given the need to monitor geological processes over long periods of time. This will slow the rate of the rollout of CCS in Europe. Furthermore, only limited indigenous biomass resources in Europe can sustainably be harvested for energy uses without deleterious impacts on the environment and food production.

The research, development, and demonstration of relevant technologies to promote biomass-based CCS should be actively pursued, but it is no silver bullet.

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REFERENCES

1. Carbon capture and storage in Europe, EASAC Policy Report 20 (May 2013); www.easac.eu/fileadmin/Reports/Easac_13_CCS_Web_Complete.pdf.
2. The current status of biofuels in the European Union, their environmental impacts and future prospects, EASAC Policy Report 19 (December 2012); www.easac.eu/fileadmin/PDF_s/reports_statements/Easac_12_Biofuels_Complete.pdf.

TECHNICAL COMMENT ABSTRACTS

Comment on "Local impermeant anions establish the neuronal chloride concentration"

Juha Voipio, Walter F. Boron, Stephen W. Jones, Ulrich Hopfer, John A. Payne, Kai Kaila

■ Glykys *et al.* (Reports, 7 February 2014, p. 670) conclude that, rather than ion transporters, "local impermeant anions establish the neuronal chloride concentration" and thereby determine "the magnitude and direction of $GABA_AR$ currents at individual synapses." If this were possible, perpetual ion-motion machines could be constructed. The authors' conclusions conflict with basic thermodynamic principles.

Full text at http://dx.doi.org/10.1126/science.1252978

Comment on "Local impermeant anions establish the neuronal chloride concentration"

Heiko J. Luhmann, Sergei Kirischuk, Werner Kilb

■ Glykys *et al.* (Reports, 7 February 2014, p. 670) proposed that cytoplasmic impermeant anions and polyanionic extracellular matrix glycoproteins establish the local neuronal intracellular chloride concentration, $[Cl^-]_i$, and thereby the polarity of γ-aminobutyric acid type A ($GABA_A$) receptor signaling. The experimental procedures and results in this study are insufficient to support these conclusions. Contradictory results previously published by these authors and other laboratories are not referred to.

Full text at http://dx.doi.org/10.1126/science.1255337

Response to Comments on "Local impermeant anions establish the neuronal chloride concentration"

J. Glykys, V. Dzhala, K. Egawa, T. Balena, Y. Saponjian, K. V. Kuchibhotla, B. J. Bacskai, K. T. Kahle, T. Zeuthen, K. J. Staley

■ We appreciate the interest in our paper and the opportunity to clarify theoretical and technical aspects describing the influence of Donnan equilibria on neuronal chloride ion (Cl^-) distributions.

Full text at http://dx.doi.org/10.1126/science.1253146

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