allows the local benzenoid distortions to be more of the twist form, cost less energy, and have less in common with the reactive geometry. Indeed, incredible twist geometries have been obtained in open systems, and the products are still relatively stable in air (*8*). Clar's sextet rule would predict the new nanohoop to actually be a [6]cycloparaphenylene, conformationally restricted by bridging carbon-carbon double bonds (*9*). Golder and are attempting a metathesis-based strategy that parallels this structural leitmotif (*10*).

The crowning jewel of the work is that the authors obtained a crystal structure, which will no doubt inspire others to continue the pursuit of practical syntheses of this material and other variants. In the crystal structure of the nanohoop, the molecular geometry nearly perfectly follows the Clar's rules prediction. The six benzenoid rings that define the equatorial belt display benzene-like carbon-carbon bond lengths (~1.40 Å) and have a slight twist conformation. The remaining rings have carbon-carbon bond lengths of 1.35 Å and 1.45 Å—closer to C_{sp2}-C_{sp2} double- (1.33 Å) and single-bond lengths (1.50 Å), respectively. This result bodes well for the alternative metathesis strategy.

The age of designer allotropes of carbon has been with us for a while, and the achievement of Povie *et al.* shows that there is still room for more examples. Ultimately, the interest in practical applications will drive the search for efficient large-scale synthesis routes, similar to those found for the kilogram-scale synthesis of corannulene (*11*). Having a crystal structure of a nanohoop provides a lead structure to motivate further detailed theoretical studies and generally infuses energy into the field of designer allotopes. Contributions to the efficient large-scale synthesis of new carbon-rich quasi-allotropes, such as nanohoops, by young investigators would mark a welcome evolution to this promising field of nonplanar "curved" aromatic molecule research. The directed synthesis of a nanohoop with length greater than its diameter remains an important target. ■

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CONSERVATION

Eating ecosystems

Wildlife harvest and depletion compromise socioecological stability

By **Justin S. Brashares** *and* **Kaitlyn M. Gaynor**

The hunting and trade of tropical wildlife is a multibillion dollar enterprise that provides food and livelihoods to millions but is also the single greatest threat to the persistence of our planet's larger mammals and birds (*1*). Hunting not only directly affects harvested wildlife but also reshapes entire ecosystems and, in some cases, human societies (*1*–*3*). It can change food web interactions, enable disease transmission to humans, and even fund militias (*3*). Yet, the impacts of wildlife harvest have been difficult to measure because of the largely unregulated and remote nature of hunting and its co-occurrence with other anthropogenic disturbances. On page 180 of this issue, Benítez-López *et al.* (*4*) present a broadscale, synthetic effort to quantify the effects of hunting on birds and mammals throughout the tropics.

Hunting by humans has profoundly altered the composition of Earth's ecosystems for tens of thousands of years. During the Pleistocene, hunting contributed to the extinction of more than 100 genera of large-bodied mammals across the Americas, including giant bison, mammoths, tapirs, and ground sloths (*5*). Yet by most accounts, this past reshaping of ecosystems pales in comparison with the process by which today's humans consume ecosystems. Historically unprecedented demand, access, and technology have fostered a deep human reliance on wildlife throughout the tropics, and this reliance has promoted widespread overexploitation (*1, 6, 7*).

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A child carries a basket containing a Gambian rat and a monkey in Lomela, Democratic Republic of the Congo. The harvest, consumption, and trade of wild meat is central to people's livelihoods in many countries, yet is also responsible for widespread animal population declines.

Scientists' appreciation of the vast scope and impact of modern hunting is relatively young. In the 1990s, Redford's (*8*) alarm over apparently pristine forests empty of wildlife pushed biologists to recognize the limits of habitat preservation for protecting Neotropical mammals from the gun and the snare. Similar revelations from throughout the tropics ignited a field of enquiry that has examined local and regional causes and consequences of hunting at hundreds of sites (*1*, *6*, *7*, *9*). These efforts have painted a detailed picture of hunting's direct and indirect impacts on local biodiversity. But it has been difficult to define universal measures of sustainability (*10*) and to separate the effects of hunting from associated forms of human disturbance, such as habitat alteration, noise, pollution, and introduction of domestic and exotic species.

In their meta-analysis, Benítez-López *et al.* bring together 176 studies of 351 species of birds and mammals from across the tropics to quantify and summarize the effects of hunting. The authors compare wildlife abundance in areas with and without hunting and report 58% smaller bird populations and 83% smaller mammal populations as a result of harvest. Benítez-López *et al.* explore several drivers of hunting, including distance to human infrastructure and major towns, and link these factors to outcomes for wildlife populations (*4*). Their findings echo results of studies at smaller spatial scales (*1*, *6*, *7*, *9*, *11*) and support more qualitative assertions that wildlife harvest presents a major threat to animal persistence throughout the tropics.

Hunting is part of a complex network of human and ecological dynamics, and the drivers of wildlife harvest and consumption are multifaceted and interacting. Food insecurity and limited access to alternative protein sources are among several key drivers of wild meat consumption (*11*, *12*). Wild-meat demand and hunting incentives are also tightly linked to economic factors, including poverty and wealth, livelihood opportunities, and market dynamics at local to global scales. Sociopolitical circumstances, including governance and social or armed conflict, further drive large-scale patterns of wildlife harvest (*3*). Not to be overlooked are the cultural importance of hunting and preferences for wild meat, which can endure as strong influences on hunting practices despite economic, nutritional, and sociopolitical security.

The effects of hunting do not stop at the loss of animal populations that Benítez-López *et al.* highlight. The "empty forests" that are created by harvest-induced defaunation are compromised ecosystems, with weakened food webs and impaired ecosystem functioning. The removal of bird and mammal species ripples throughout the food web to alter populations of plants, competitors, prey, and predators (*2*). Hunting also has important nonlethal effects on target and nontarget species. Fear of humans drives changes in behavior, such as altered habitat use and shifts toward nocturnal activity patterns, which can alter survival, reproduction, population dynamics, and community interactions. As with other top predators, the fear instilled by hunters in their prey may wreak greater havoc on ecosystems than the removal of individual animals itself.

These drivers and consequences of hunting do not begin or end in isolation but are part of a coupled human–natural system (*1*, *3*, *9*, *11*). Unsustainable levels of harvest further compromise food security in vulnerable human populations and increase the time and effort required to hunt for wild meat. The ecosystem impacts of hunting may also create long-term changes in water quality and zoonotic disease dynamics, which can be detrimental to human health (*2*). Further, hunting-induced changes in hydrology, soils, fire, nutrient cycling, pest and pollination dynamics, and even carbon flux can compromise the sustainability of agriculture and other alternative livelihoods to hunting and increase vulnerability to environmental shocks (*2*, *13*).

Developing interdisciplinary approaches to illuminate and quantify the coupled socio-ecological systems that regulate wildlife demand, harvest, and consumption represents the next frontier in the study of wildlife exploitation and persistence. Such knowledge will help to forecast the future of hunting on a planet characterized by new realities of resource scarcity, environmental variability, and economic globalization. ■

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STEM CELLS

Embryogenesis in a dish

We are at an early stage of developing embryos from stem cells in culture

By **Martin Pera**

Stem cells, grown under the right conditions in vitro, have a remarkable ability to undergo differentiation and self-assembly into complex, three-dimensional organoids, similar in anatomical and functional organization to the developing brain, kidney, gut and other tissues (*1*). On page 153 of this issue, Harrison *et al.* (*2*) show that when mouse embryonic stem cells are cultured together with trophoblast stem cells (which give rise to part of the placenta), the resulting constructs develop into structures that bear a striking resemblance to the mouse embryo after it has implanted into the womb. The finding raises the possibility that by using advanced cell culture techniques, including coculture of multiple cell types, and engineering the appropriate culture microenvironment, it might be possible to model human embryogenesis in a petri dish.

"…it might be possible to model human embryogenesis in a petri dish."

Human embryo culture and embryonic stem cell culture have opened up a previously inaccessible phase of the human life cycle to experimental study. Until recently, in vitro growth of mouse or human embryos has mainly been limited to cultures that reach the blastocyst stage, or the equivalent of about 5 or 6 days of embryonic development. Many of the most important events in embryogenesis, including those involved in developmental disorders, occur in a critical interval shortly after this stage. In 2016, the culture of human embryos was extended out to 13 days of development, a point at which many of the key structures that will support the growth of the embryo have formed. At this stage, the embryo is preparing to

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Eating ecosystems
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Editor's Summary