Harfoot Life

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Over the past two years, we at Microsoft Research and at the United Nations Environment Programme World Conservation Monitoring Centre, both in Cambridge, UK, have built a prototype GEM for terrestrial and marine ecosystems. Called the Madingley model, it uses real data on carbon flows as a starting point. We have hit all sorts of computational and technical hurdles, and are expecting more as we develop the model. Yet the project demonstrates that building GEMs is possible. From the relationship between the mass of individual organisms and how long they live, or the effects of human perturbations such as hunting, to the distribution of biomass across Earth (see 'Model life'), the model's outputs are broadly consistent with current understanding of ecosystems. Metabolic rates, for instance, have been measured in hundreds of animals in the lab, and researchers in the field have documented lifespans, growth rates and reproductive success for thousands (in some cases, millions) of birds, mammals, plants and bacteria. Ecologists have also mathematically determined numerous 'rules of existence' for some organisms, such as that an animal's metabolic rate is proportional to its mass raised to a power of around 0.70 (ref. 5). A new programme of data gathering is easy to envisage. Using automated cameras and image recognition, it should be possible to sample thousands of animals and determine their approximate size and what broad group they belong to: reptile or mammal, flying or non-flying. Motion-activated cameras used by conservationists and wildlife enthusiasts already produce tens of thousands of images of fish, birds and mammals every day. And stored away in numerous research institutions are vast samples of insects collected in traps that suck them out of the air, and data from continuous plankton recorders towed beneath ships for millions of kilometres. To reduce costs and to harness the power of citizen science, data collection could even be crowd-sourced. Rapidly growing websites such as iNaturalist and eBird (on which users can share their observations of wildlife) currently focus on traditional species identification. Such sites could potentially collate an extraordinary amount of information on functional groups of organisms and traits such as body size. The Harfoots lived in the highlands and hillsides along the foothills of the Misty Mountains and lived in holes they called smials.They were often Traders and Craftsmen and at friendly terms with the Dwarves who travelled through the High Pass and along the the Great Road.They themselves were however loathe to wanderings or adventures and preferred a settled and simple life. "And she's had to from a really young age care for her siblings, and her family, and the community, in a way that she's probably had to grow up a bit too quickly. And so I thought that it just made sense to ground that in wanting to subvert Harfoot tradition, to improve the quality of life and that that's where the curiosity into the unknown comes from as well." **Megan, food is very important for Hobbits of the Shire, way in the future. You're technically all Harfoots here, but that tendency's got to be in the DNA somewhere, so how does food factor into Harfoot life? What does their diet look like? What do they like to eat? Do they like to eat yet? How does that look?** Anthropogenic activities are causing widespread degradation of ecosystems worldwide, threatening the ecosystem services upon which all human life depends. Improved understanding of this degradation is urgently needed to improve avoidance and mitigation measures. One tool to assist these efforts is predictive models of ecosystem structure and function that are mechanistic: based on fundamental ecological principles. Here we present the first mechanistic General Ecosystem Model (GEM) of ecosystem structure and function that is both global and applies in all terrestrial and marine environments. Functional forms and parameter values were derived from the theoretical and empirical literature where possible. Simulations of the fate of all organisms with body masses between 10 µg and 150,000 kg (a range of 14 orders of magnitude) across the globe led to emergent properties at individual (e.g., growth rate), community (e.g., biomass turnover rates), ecosystem (e.g., trophic pyramids), and macroecological scales (e.g., global patterns of trophic structure) that are in general agreement with current data and theory. These properties emerged from our encoding of the biology of, and interactions among, individual organisms without any direct constraints on the properties themselves. Our results indicate that ecologists have gathered sufficient information to begin to build realistic, global, and mechanistic models of ecosystems, capable of predicting a diverse range of ecosystem properties and their response to human pressures. Empirical (black) and emergent model (grey) relationships between body mass and (A) growth rate, (B) maturity, (C) individual mortality rates, and (D) lifetime reproductive success. These life history metrics are not part of the model definition. Rather, they emerge from underlying ecological processes such as metabolism and feeding (see main text). Life history metrics were sampled from 100-y model runs for the four focal grid cells (Table 4). Individual mortality rates are estimated as the inverse of lifespan, and because the minimum simulated lifespan is one model time step (1 mo), estimated individual mortality rates were bounded at 12. Many aspects of the life history of individuals emerge from the underlying ecological processes and interactions with other organisms. For example, growth rates are determined by a combination of food assimilation rates and metabolic losses, which themselves depend on the abundance and properties of the other individuals at the location, and are also constrained by the maximum possible rate of assimilation and environmentally determined metabolic rate. Modelled growth rates varied widely among cohorts, between the maximum and minimum theoretically possible rates (Figure S3), but showed good correspondence with observed values (Figure 3A). Predicted mortality rates were much higher than empirically observed rates, especially for larger organisms (Figure 3C). This may reflect a mismatch with the data, as discussed below; in this case, empirical mortality rates were observed in laboratory conditions in the absence of predation mortality. Comparing the empirical data and model predictions at a higher level of resolution, for example within functional groups or biomes, might help us to better diagnose discrepancies in the future. In a related finding, a separate study that also drew on CITES data, this time in the United States, found that countries that were the biggest source of legal wildlife products also accounted for the most illegal products confiscated by U.S. authorities. Bager Olsen, M., Geldmann, J., Harfoot, M., Tittensor, D., Price, B., Sinovas, P., . . . Burgess, N. (2019.). Thirty-six years of legal and illegal wildlife trade entering the USA. Oryx, 1-10. doi:10.1017/S0030605319000541 A keen explorer and curious student of nature, Mike enjoys walking, mountaineering, climbing, surfing, sailing, kayaking, beekeeping and growing his own food. The biggest joy of his life comes from his two kids who he spends most of his free time with. Plus, the Stranger and Nori bond quickly and set off on a journey to the eastern lands together in the finale for season 1. If this wizard is Gandalf, the fact that he was saved by and fought alongside a harfoot when he first arrived in Middle-earth could explain why Gandalf is so fond of hobbits, descendants of the harfoots, and often travels to the Shire to visit them. The creation of the Harfoots' costumes isn't the only unconventional route that the Rings of Power crew took to bring the Second Age to life. Avery recounted the journey to create the show's iconic rings, explaining that, in a bog in Ireland, he found a shield that inspired him. "It had these interesting shapes that interlocked and had these three swirls so that if you pour the materials into here... each separates out into its own area," he explained, recalling that he ultimately used that shape to forge the rings. Perhaps much of the success surrounding "The Rings of Power" can be traced back to its own version of halflings: those hearty harfoots. Elanor "Nori" Brandyfoot (Markella Kavenagh), Poppy Proudfellow (Megan Richards), Largo Brandyfoot (Dylan Smith), Marigold Brandyfoot (Sara Zwangobani), and Sadoc Burrows (Lenny Henry) all provided much of the heart and soul throughout the first season of the new series. This came to a head in their last scene together in the recent finale, which featured the tough family of harfoots saying their final goodbyes as Nori parted ways with her clan to seek out adventures together with the Stranger (Daniel Weyman). The bittersweet sequence didn't leave many dry eyes among viewers, but we can now count at least one "The Rings of Power" writer among those of us who wore their hearts on their sleeves while crafting this moment.

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