Most species are rare, but not very rare, finds biodiversity monitoring study

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The Sri Lanka Hanging-Parrot (Loriculus beryllinus) lives only in Sri Lanka. It is globally a very rare species, meaning there are few individuals. Credit: Corey Callaghan

More than 100 years of observations in nature have revealed a universal pattern of species abundances: Most species are rare but not very rare, and only a few species are very common. These so-called global species abundance distributions have become fully unveiled for some well-monitored species groups, such as birds. For other species groups, such as insects, however, the veil remains partially unlifted.

These are the findings of an international team of researchers led by the German Center for Integrative Biodiversity Research (iDiv), the Martin Luther University Halle-Wittenberg (MLU) and the University of Florida (UF), published in the journal *Nature Ecology and Evolution*. The study demonstrates how important biodiversity monitoring is for detecting species abundances on planet Earth and for understanding how they change.

"Who can explain why one species ranges widely and is very numerous, and why another allied species has a narrow range and is rare?" This question was asked by Charles Darwin in his ground-breaking book "The Origin of Species," published over 150 years ago. A related challenge has been to understand how many species are common (numerous) and how many are rare, the so-called global species abundance distribution (gSAD).

Two main gSAD models have been proposed in the last century: R. A. Fisher, a statistician and biologist, proposed that most species are very rare and that the number of species declines for more common species (so-called log-series model). On the other hand, F. W. Preston, an engineer and ecologist, argued that only few species are actually very rare and that most species have some intermediate level of commonness (so-called log-normal model). However, until now and despite decades of research, scientists did not know which model describes the planet's true gSAD.

Solving this problem calls for vast amounts of data. The study authors used data from the Global Biodiversity Information Facility (GBIF) and downloaded data representing over 1 billion species observations in nature from 1900 to 2019.

The leopard (Panthera pardus) is a rare to intermediate species. Credit: Corey Callaghan

"The GBIF database is an amazing resource for all sorts of biodiversity related research, particularly because it brings together both data collected from professional and citizen scientists all over the world," says first author Dr. Corey Callaghan. He began the study while working at

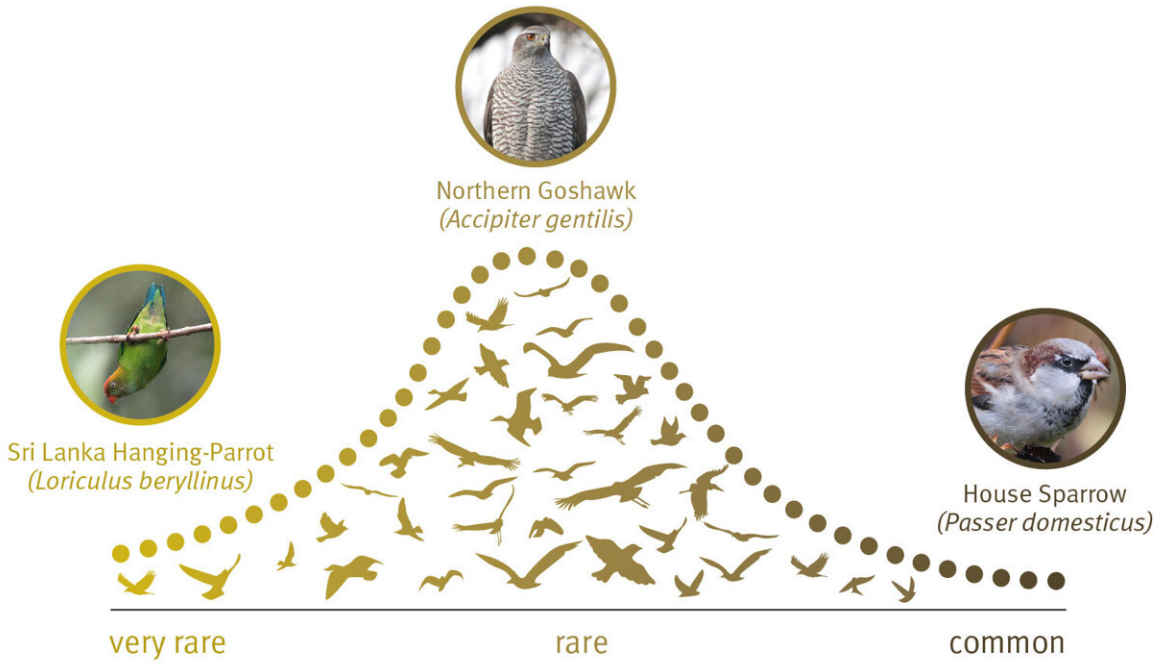
iDiv and MLU and is now working at the UF.

Callaghan and his fellow researchers divided the downloaded data into 39 species groups, for instance, birds, insects, or mammals. For each, they compiled the respective global species abundance distribution (gSAD).

The researchers detected a potentially universal pattern, which emerges once the species abundance distribution is fully unveiled: Most species are rare but not very rare, and only a few species are very common, as predicted in the log-normal model. However, the researchers also found that the veil has been fully lifted only for a few species groups like cycads and birds. For all other species groups, the data are yet insufficient.

"If you don't have enough data, it looks as though most species are very rare," says senior author Prof Henrique Pereira, research group head at iDiv and the MLU.

"But by adding more and more observations, the picture changes. You start seeing that there are, in fact, more rare species than very rare species. You can see this shift for cycads and birds when comparing the species observations from back in 1900, when less data was available, with the more comprehensive species observations we have today. It is fascinating: we can clearly see the phenomenon of unveiling the full species abundance distribution, as predicted by Preston several decades ago, but only now demonstrated at the scale of the entire planet."



The global species abundance distribution (gSAD) has been fully unveiled for birds and shows a potentially universal pattern: There are a few very rare species like the Sri Lanka Hanging-Parrot, many rare species like the Northern Goshawk, and few common species like the House Sparrow. This pattern was first proposed by F. W. Preston in 1948. Credit: Gabriele Rada (illustration), Corey Callaghan (photos)

"Even though we have been recording observations for decades, we have only lifted the veil for a few species groups," says Callaghan. "We still have a long way to go. But GBIF and the sharing of data really represents the future of biodiversity research and monitoring, to me."

The new study's findings enable scientists to assess how far the gSADs have been unveiled for different species groups. This allows for answering another long-standing research question: How many species are out there? This study finds that while for some groups like birds,

nearly all species have been identified, this is not the case for other taxa such as insects and cephalopods.

The researchers believe that their findings may help in answering Darwin's question of why some species are rare, and others are common. The universal pattern they found may point to general ecological or evolutionary mechanisms that govern the commonness and rarity of species.

While more research is being done, humans continue to alter the planet's surface and the abundance of species, for instance, by making common species less common. This complicates the researchers' task: They need not only to understand how species abundances evolve naturally but also how human impacts are altering these patterns simultaneously. There may still be a long way to go before Darwin's question is finally answered.

More information: Unveiling the global species abundance distributions of Eukaryotes, *Nature Ecology & Evolution* (2023). DOI: 10.1038/s41559-023-02173-y

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