Human Depopulation Does Not Yield Automatic Biodiversity Gains in Semi-natural Ecosystems

Kei Uchida * [1] [2], Peter Matanle * [3], Yang Li [3], Taku Fujita [4], and Masayoshi K. Hiraiwa *[5]

1, Faculty of Environmental Studies, Tokyo City University, Yokohama, Japan.
2, Institute for Sustainable Agro-ecosystem Services, The University of Tokyo, Tokyo, Japan.
3, School of East Asian Studies, University of Sheffield, UK.
4, The Nature Conservation Society of Japan, Tokyo, Japan.
5, Faculty of Agriculture, Kindai University, Nara, Japan.

* Corresponding Authors: k.uchida023@gmail.com, p.matanle@sheffield.ac.uk

Abstract

In recent decades, earth's ecosystems have been facing collapse. Global studies consistently demonstrate a direct relationship between human population growth and economic expansion, and the resulting habitat destruction and species loss. Meanwhile, developed countries are experiencing below-replacement fertility rates and beginning to depopulate. Many scientists and citizens believe that depopulation will automatically lead to environmentally restorative outcomes. But is this true for biodiversity restoration?

To answer this, we must examine the relationship between human depopulation and biodiversity restoration. Using UN data, we identified Japan as the Depopulation Vanguard Country for Northeast Asia, and we analyzed biodiversity change in Japan's semi-natural areas, considering factors such as population dynamics, land use, and surface temperature.

Our findings reveal that, regardless of whether human populations increase or decrease, habitat and biodiversity losses continue, with some species declining more sharply under depopulation. This trend is primarily driven by changes in agricultural land use, whether through urbanization, disuse and abandonment, or intensification. Only in areas where human populations remain more stable does biodiversity appear to be more sustainable. We conclude by urging depopulating countries to adopt land-use policies that consider the potential impacts of depopulation within active biodiversity conservation and restoration strategies.

Extended Abstract

Theoretical focus

Since 1970, 69 percent of global wildlife has been lost, while the human population has grown to over 8 billion (WWF, 2022). Meanwhile, an increasing number of countries are experiencing below-replacement fertility, aging populations, and the onset of depopulation. Many view this as good news, suggesting it might lead to environmentally restorative outcomes. But is this true?

East Asia's modern expansion has been a significant driver of the Great Acceleration (McNeill & Engelke, 2016). With Japan at the forefront, many neighboring countries have followed similar accelerated demographic and economic development paths. The resulting ecosystem damage, including habitat loss and species extinctions, has been extensive.

Japan is one of the few countries where research into the relationship between human depopulation and environmental change can be conducted on a large scale and with sufficient rigor to have implications beyond its borders. Sixty-three percent of the country's territorial area—23 of its 47 prefectures—has been depopulating since before 1995, with many remote areas experiencing continuous population losses since the 1950s, if not earlier. Japan is also one of 36 global biodiversity hotspots, home to some of the most diverse and threatened ecosystems on Earth.

Unlike most biodiversity hotspots, where human population growth is encroaching on habitats, Japan's population has been decreasing, particularly in semi-natural areas. This trend foreshadows similar depopulation patterns expected in Northeast Asia and globally later this century. Therefore, it is crucial to examine the relationship between human depopulation and biodiversity restoration, identifying Japan as the Depopulation Vanguard Country for Northeast Asia.

Methods and Data

We analyzed biodiversity changes at 158 sites in semi-natural and peri-urban areas across the Japanese archipelago, considering local spatial and temporal variations in human population, land use, and average annual surface temperature. Our biodiversity dataset includes a comprehensive list of taxa within the ecological trophic pyramid of semi-natural ecosystems, with over 1.5 million individual detections covering 467 taxonomic species of birds, butterflies, fireflies, and frog egg masses, as well as 2,922 native and non-native plant species.

To address temporal and spatial inconsistencies between demographic and biodiversity data, we employed explanatory variables and combined local area mesh statistics with the National Census data from 1995 to 2020. Mesh statistics divide a region into grids (or "meshes") based on latitude and longitude, organizing statistical data for each grid. By integrating these datasets, we were able to accurately observe demographic and biodiversity changes on relatively small geographic scales.

Findings

We found that regardless of whether human populations are increasing or decreasing, habitat and biodiversity losses persist, with some species declining more sharply in depopulated areas. This is primarily due to changes in agricultural land use—whether through urbanization, disuse and abandonment, or intensification. Biodiversity appears more sustainable only in areas where human populations remain relatively stable. We conclude by urging depopulating countries to adopt land-use policies that anticipate potential depopulation outcomes as part of active biodiversity conservation and restoration strategies.

Overall, our research shows that biodiversity, in terms of species abundance and richness, is declining in areas where human populations are decreasing, with some species experiencing sharp declines. In areas where local human populations are increasing, biodiversity continues to decline for most taxonomic groups, with certain species also showing steep declines. However, a few groups—primarily butterflies and native and non-native plants—are increasing in abundance and richness. Across various taxonomic groups, the reduction in species richness and abundance is significantly more pronounced in regions with either increasing or decreasing human populations compared to areas with stable populations.

While human population growth is correlated with biodiversity decline in some regions, we find no evidence that population decline is correlated with biodiversity recovery. Instead, the crucial factor is not the total number of people inhabiting an area, but rather what those people do with the land they inhabit.

As East Asia's Depopulation Vanguard Country, Japan's experience is instructive for neighboring countries and regions, including South Korea and Northeast China. Globally, many countries are now on a depopulation pathway, even if at the national level their populations are still growing. In future, we should identify Depopulation Vanguard Countries for other regions and research more deeply how human populations are changing, how human activity is evolving in response to population decline, and what the outcomes are, in order to achieve a depopulation dividend.