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Where did broadleaved evergreen trees survive during the last glacial period in Japan? - New evidence for conservation of genetic diversity -

Highlights

- ✓ We modeled the phylogeographic relationships and demographic changes of *Castanopsis sieboldii*, which is a dominant tree of the broadleaved evergreen forests of Japan, dating back to about 100,000 years ago.
- ✓ The model strongly suggested that *C. sieboldii* survived in at least 4 areas through the last glacial maximum (LGM).
- ✓ The results present new evidence concerning conservation of genetic diversity of *C. sieboldii*.

Researchers in Forestry and Forest Products Research Institute (herein after referred to as FFPRI), in cooperation with Osaka University, Gifu Academy of Forest Science and Culture, University of Tsukuba, Kyoto University, and Tokyo Metropolitan University, investigated whether a dominant tree of warm temperate broadleaved forests in Japan, *Castanopsis sieboldii*, underwent northward migration over hundreds of kilometres from Last Glacial Maximum (LGM) (about 21,000 years ago) refugia in the Ryukyu archipelago and southern Kyushu, where fossil pollen indicates the LGM survival of broadleaved evergreen forests or was in fact able to survive closer to its present range in colder areas such as the coast of the Japan Sea and the Pacific Ocean side of eastern Honshu during the LGM. Using a combined genetic analysis and modelling approach it was found that the East Japan populations, where few pollen fossil records exist, survived *in situ* during the LGM on both the Japan Sea and Pacific coasts and were not established via expansion after the LGM from southern areas.

Our data indicates that the genetic diversity of extant broadleaved evergreen forests of Japan is a legacy of past LGM survival in multiple regions of Japan. This result is useful for the preservation of genetic resources of *Castanopsis sieboldii* and for forming guidelines to ensure the preservation of the species genetic diversity and structure.

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For the last 10,000 years or so the climate of Japan has been temperate but the climate has changed drastically over the last 2 million years with fluctuations between repeated around every 100,000 years. The climate of the earth about 21,000 to 18,000 years ago was particularly cold and is called the LGM with average temperatures 5 to 7 °C lower than now. For example, the climate of Tokyo (annual average temperature of 15.4 °C) becomes like that of Sapporo (annual average temperature of 8.9 °C). From the excavation of fossil pollen and plant bodies, it is believed that broadleaved evergreen forests were driven to warmer areas in the Ryukyu archipelago and southern Kyushu at LGM. After the LGM, they expanded the distribution northward to the Japan Sea and the Pacific coast. There has been a debate whether the broadleaved evergreen forests, which is presently occupy the wide areas in the warm temperate region of Japan, had expanded from a limited area in the southern part of Kyushu, or survived at a small forest in various areas in Japan. Using a species distribution modelling approach to model the species LGM distribution, suitable climate is predicted in the southern part of the Pacific coast (Fig. 1) which is also supported by genetic evidence.

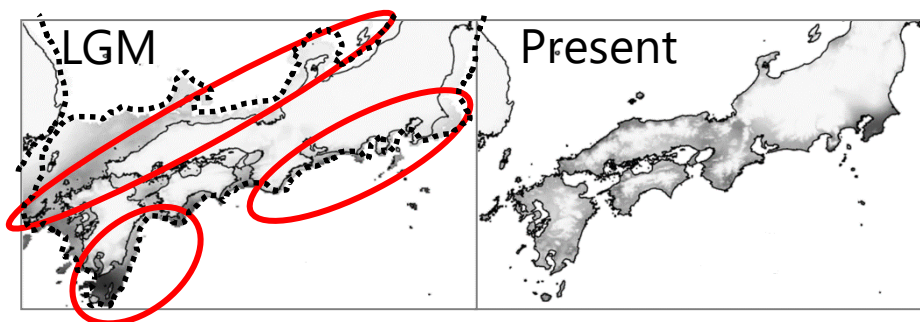


Fig. 1 Species distribution modeling of *C. sieboldii*. Area with darker color indicates higher probability of suitable habitat. In the Last Glacial Maximum (LGM), the sea level decreased by about 120 m compared to the present, and the land was expanded. The dashed line shows the estimated coastline at the LGM. The areas surrounded by a red line are estimated areas (West Japan, Japan Sea, and East Japan), where *C. sieboldii* is likely to have survived during LGM based on genetic and modelling based evidence (the Ryukyu archipelago is not shown in the figure).

In the current study, we investigated where *C. sieboldii*, a dominant tree species of broadleaved evergreen forests in Japan, inhabited during the glacial period by constructing multiple models based on the genetic diversity. The result indicated that the Ryukyu and the West Group existed from the oldest time, and that the East and the Japan Sea Group were formed from the West Group (Figure 2). Furthermore, estimated time of the diversification suggested that these four groups had already been established before LGM. The result suggested that *C. sieboldii* survived separately in Ryukyu, West, Japan Sea, East at LGM, and expanded the population as it became warmer during the past-glacial.

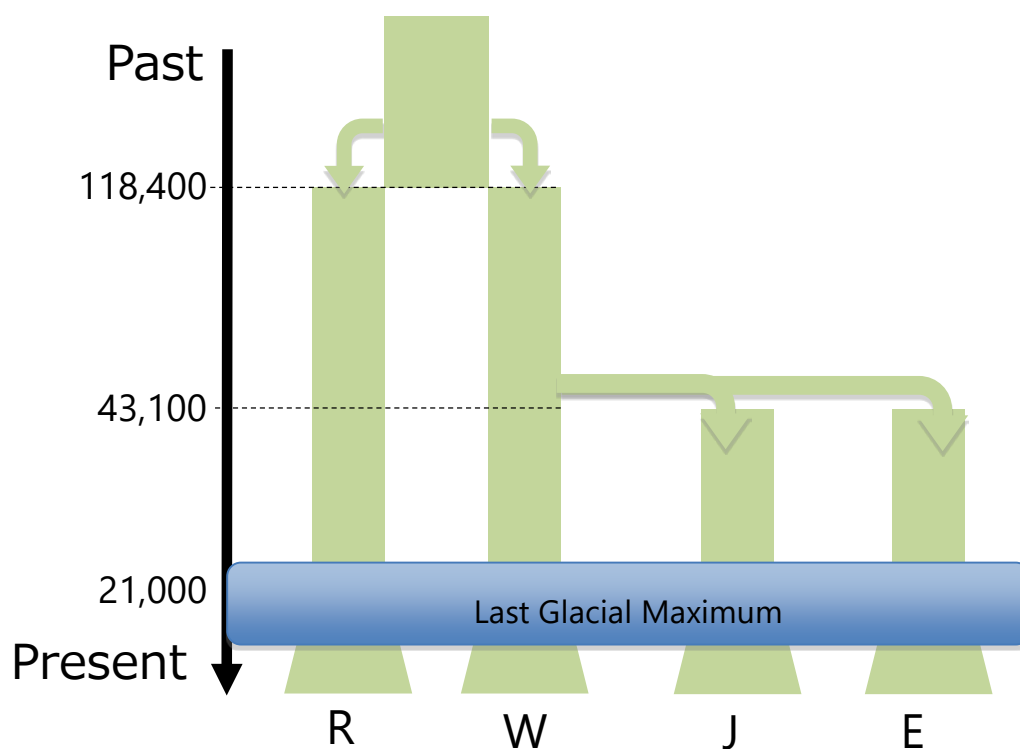


Fig. 2 The best historical demographic model of *C. sieboldii*. In this model, after the Ryukyu (R) and the West (W) Group diverged, the Japan Sea (J) and the East (E) Group diverged from the West (W) Group. West and East Group includes populations in western and eastern parts of the main islands along the Pacific Coast, respectively. The branch length is proportional to the number of generations, with the major splits in the species estimated to have occurred 118,400 and 43,100 years ago, assuming that one generation of *C. sieboldii* is 100 years.

Implication

This study identified major genetic lineages in the broadleaved evergreen tree species *C. sieboldii* in the Ryukyu archipelago, Western Japan, the Japan Sea, and Eastern Japan. The unique genetic composition of each region has formed as a result of a long history of genetic isolation associated with the glacial-interglacial cycles.

In recent years, the importance of preserving the local genetic diversity has been recognized. When planting broadleaved trees to assist natural regeneration or during afforestation, it is necessary not to disturb the local genetic diversity as much as possible. Our research highlights the importance of restrict the distribution of seedlings across the genetic boundaries identified between Ryukyu, Western Japan, Japan Sea, and Eastern Japan in order to retain genetic patterns which have formed over thousands of years.

Original Article

K. Aoki, I. Tamaki, K. Nakao, S. Ueno, T. Kamijo, H. Setoguchi, N. Murakami, M. Kato, and Y. Tsumura, Approximate Bayesian computation analysis of EST associated microsatellites indicates that the broadleaved evergreen tree *Castanopsis sieboldii* survived the Last Glacial Maximum in multiple refugia in Japan, Heredity, (in press), DOI: 10.1038/s41437-018-0123-9

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