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Original research article

Species composition, diversity and stratification in subtropical evergreen broadleaf forests along a latitudinal thermal gradient in the Ryukyu Archipelago, Japan

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ABSTRACT

A well-developed evergreen broadleaf forest exists in the northern part of Okinawa and in the central part of the Ishigaki Islands in the Ryukyu Archipelago, Japan. All woody plants were identified to species level and their heights and diameters were measured in a 750 m^2 plot in Okinawa and a 400 m^2 plot in the Ishigaki Islands. Species overlap, dominance, diversity, multi-strata structure, and spatial distribution were calculated. The floristic composition in Okinawa was found to be different from that in Ishigaki. The species overlap between strata was higher in Okinawa than in Ishigaki. Species diversity and evenness tended to increase from the top down in Okinawa and the reverse in Ishigaki. Mean tree weight of each stratum decreased and tree density increased from top down in both forests. This trend resembled the mean weight–density trajectory of self-thinning plant populations. The degree of stand stratification, species richness and species diversity for trees with DBH $\geqslant$ 4.5 cm increased along the latitudinal thermal gradient in the Ryukyu Archipelago. Thus, trees in the lower strata of Okinawa and upper strata of Ishigaki are important for sustainable maintenance of higher woody species diversity in the Ryukyu Archipelago.

1. Introduction

The coastal areas of the Western Pacific, from subarctic eastern Siberia to equatorial Southeast Asia, have forest climates, which develop a sequence of five forest formations: subarctic evergreen conifer forests, cool-temperate deciduous broadleaf forests, warm-temperate lucidophyll forests, subtropical forests and tropical rainforests (Kira, 1991). Within the Western Pacific sequence of thermal vegetation zones, the subtropical zone is mostly dry, with only a small part, including a chain of islands from Okinawa to Taiwan, and South China, sufficiently moist to allow the development of subtropical forests. The subtropical forests in the Ryukyu Archipelago are therefore valuable from a phytogeographical point of view. A well-developed evergreen broadleaf forest exists in the northern part of Okinawa Island and the central part of Ishigaki Island in the Ryukyu Archipelago, Japan. It is ecologically important to know how the multi-layered structure, floristic composition, woody species diversity and spatial distribution of trees change along the latitudinal thermal gradient in this Archipelago.

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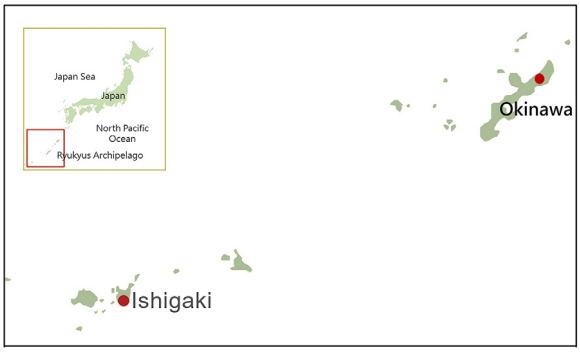

Fig. 1. Study area map. The red dots are the locations of the study sites on Okinawa and Ishigaki Islands of the Ryukyu Archipelago, Japan. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

The diversity of tree species is fundamental to total forest biodiversity, because trees provide resources and habitat for almost all other forest species (Hall and Swaine, 1976; Huston, 1994; Whitmore, 1998; Huang et al., 2003). Measures of species diversity play a central role in ecology and conservation biology. The most commonly employed measures of species diversity are the Shannon function, species richness (absolute number of species), and evenness (the distribution of abundance among the species, also known as equitability). In addition, the spatial distribution of trees has been a major source of interest for plant ecologists because of its potential role in explaining the coexistence of tree species in species-rich forests (Bunyavejchewin et al., 2003).

The degree of canopy stratification and the woody species diversity increase along the latitudinal thermal gradient from higher latitudes to the tropics (Hozumi, 1975; Yamakura, 1987; Kira, 1991; Ohsawa, 1995; Kimmins, 2004). The canopy multi-layering structure, i.e. architectural stratification, is an important factor in maintaining higher woody species diversity (Roberts and Gilliam, 1995; Lindgren and Sullivan, 2001). However, there is a dearth of studies reporting the effect of the architectural stratification on floristic composition and woody species diversity in subtropical evergreen broadleaf forests. Therefore, the aims of this study were to explore the status of architectural stratification, and to quantify floristic composition and woody species diversity on the basis of stratification in subtropical evergreen broadleaf forests along a latitudinal thermal gradient in the Ryukyu Archipelago, Japan.

2. Methods

2.1. The study area

Two study sites – on Okinawa Island and Ishigaki Island of the Ryukyu Archipelago, Japan (Fig. 1) – were selected for primary data collection. The Okinawa site is located in a subtropical evergreen broadleaf forest at Mt. Yonaha (26°45′N and 128°10′E), the northern part of Okinawa Island. The bedrock is composed of silicate and the soil pH is 4.35 (Alhamd et al., 2004; Feroz et al., 2006). The Ishigaki site is located in a subtropical evergreen broadleaf forest at Mt. Omoto (24°25′03″N and 124°11′17″E), the central part of Ishigaki Island. The bedrock is composed of silicate and the soil pH is 4.55 (Feroz et al., 2009).

Climatic data for the year of 2003–2007 were collected from the Nago Meteorological Station for the northern part of Okinawa Island and the Maezato Meteorological Observatory for the central part of Ishigaki Island. Mean annual temperature is 22.9 ± 0.3 °C (ranging from 16.2 ± 0.5 in January to 29.1 ± 0.2 in July) in Okinawa Island (Feroz et al., 2006) and 23.9±0.3 °C (ranging from 18.2 ± 0.4 in January to 29.2 ± 0.3 in July) in Ishigaki Island (Feroz et al., 2009). The warmth index is 214.2±0.5 °C month in Okinawa Island and 227.2±1.3 °C month in Ishigaki Island, within the range of 180–240 °C month of the subtropical region reported by Kira (1977). Mean monthly rainfall for both the islands is over 100 mm throughout the year, except for 84 ± 22 mm in February for Okinawa Island (Feroz et al., 2006) and 93 ± 19 mm in December for Ishigaki Island (Feroz et al., 2009). Mean annual rainfall is 2050 ± 182 mm in Okinawa Island (Feroz et al., 2006) and 1942 ± 159 mm in Ishigaki Island (Feroz et al., 2009). Typhoons with strong winds and rains frequently strike both the islands between July and October. Clear-cutting and complete removal of the undergrowth of forests in the northern part of the Okinawa Island has been carried out (Azuma et al., 1997; Itô, 1997; Itô and Aoki, 1997; Itô et al., 2000). These operations may have been done in the Ishigaki Islands as well, but the information is not available. Thus both sites have long histories of human impacts on their forests.

2.2. Sampling design and data collection

A vegetation survey in the Yaeyama Islands used a sampling area <400 m^2 (Niiro et al., 1974; Niiro, 1981; Miyawaki, 1989) and 400 m^2 was used in Iriomote Island for a forest stratification study (Hozumi, 1975). Therefore, in the Okinawa site, a sample plot of 750 m^2 (25 × 30 m) was established and divided into 120 quadrats of equal size (2.5 × 2.5 m). In the Ishigaki