

Invasion of an alien palm (*Trachycarpus fortunei*) into a large forest

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Abstract Range expansion of an alien palm (*Trachycarpus fortunei*) was studied in a continuous forest in Kanagawa Prefecture, Japan. Life history was studied in a mature population close to a residential area. A 1km x 1km plot in continuous forest was divided into 100m x 100m subplots and the presence or absence of adults and juveniles was recorded in each subplot.

The palm formed an erect trunk after reaching 120cm in leaf length and started to produce flowers after the trunk length reached 2m. Maximum height was 6m. Adult plants were found in subplots close to residential and agricultural areas. Juveniles were found around the subplot with adults, and their distribution was spreading into the forest. In the forest the rate of range expansion from the estimated colonisation kernel was slower than in the fragmented suburban landscape. A smaller probability of flowering under the forest canopy may be a reason for shorter colonisation distance. Despite strong shade tolerance in juveniles, the demand for light in the flowering stage, and the small maximum height suggest that the palm will not dominate inside the natural forests. However they may reproduce in abandoned coppice forest, disturbed forest (canopy dieback), forest edges and cliff side forests, and the juveniles can persist for many years under a closed canopy. The species composition of forests is likely to be changed by this alien palm.

Keywords: Miura peninsula; Kanagawa; Japan; *Trachycarpus fortunei*; colonisation kernel; seed dispersal; woody alien plant

INTRODUCTION

Woody alien plants are gradually increasing (Martin 1999, Fine 2002, Healey *et al.* 2002, Maesako *et al.* 2003) and they are likely to cause serious impacts because tall and shade tolerant plants are likely to gain dominance in communities and suppress other species (Keddy 1990, Koike 2001). On the subtropical Ogasawara Islands in Japan, an intentionally introduced tree (*Bischofia javanica*) invaded the climax forests, and became dominant, changing the climax forest ecosystems on this oceanic island.

In suburban, fragmented, forests of Kanagawa Prefecture, two woody alien species are spreading. They are *Trachycarpus fortunei* (Hook.) H. Wendl. (Palmae) and *Ligustrum lucidum* Ait. (Oleaceae). Both species were introduced for ornamental use. The palm (*T. fortunei*) is native in China (Murata 1994), and was often planted in gardens because of its strong cold tolerance (Fig. 1). This palm is now very common in fragmented forests (Komuro and Koike 2005). But naturalisation in large, continuous, forest has not hitherto been reported.

In the research reported here, the range expansion of the palm was studied in a large forest in Kanagawa Prefecture, and the rate of range expansion was compared with that in the urban landscape.

METHODS

Study site

Research was conducted in a forest in upper Morito River in Miura Peninsula (latitude 35°17'N, longitude 139°36'E, Fig. 2). Annual mean temperature is 16.1°C, and annual precipitation is 1634 mm. The area is hilly with an altitude between 20m and 200m. Slopes are very steep with many small cliffs. The area is covered with plantations of an evergreen conifer (*Cryptomeria japonica* (L.fil.) D.Don), and abandoned coppice forests of the deciduous tree *Quercus serrata* Thumb. ex. Murray. The forest floor of the abandoned coppice forests were often covered by a dwarf



Figure 1 The alien palm *Trachycarpus fortunei*. Adult plant in an abandoned coppice forest (left) and trunk-less juveniles on the forest floor (right).

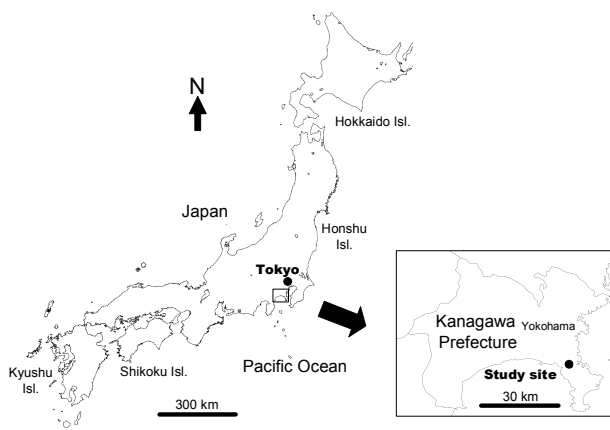


Figure 2 Study area.

bamboo (*Pleioblastus chino* (Franch. et Savat.) Makino). The conifer plantations are dying back for unknown reasons. Fallen logs were frequently found and the canopy was not closed in many parts of the conifer forest.

Life history

All field surveys were made in the summer of 2003. The longest leaf length, trunk length, and presence of inflorescence were recorded for *T. fortunei* palms in a site close to the residential area with an existing mature population (Fig. 3). This study site included forests, forest edges and agricultural lands. The palm does not produce a trunk when it is small. It does not produce sprouts from the base of the trunk and never regenerates vegetatively. It regenerates only by seeds, which are dispersed by birds (Wild Bird Society of Japan, Kanagawa Branch. 1992). Usually the palm is dioecious, but it sometimes bears both male and female flowers on one plant (Nakanishi 1997); gender of plants was therefore not recorded in this research. Leaf size in relation to trunk length and minimum size at first reproduction were analysed. Change in the probability of flowering with stem length was evaluated by logistic regression with an additional parameter of maximum probability of flowering. Maximum likelihood estimation of parameters was made using Microsoft Excel, *Solver*, and the threshold plant size required for flowering was determined.

Colonisation kernel

A 1km x 1km plot was situated in the forest (Fig. 3), and was divided into a 100m x 100m subplot. An observer walked at least 100m in each subplot, and the presence or absence of adult and juvenile palms was recorded for each subplot. Adults and juveniles were distinguished, based on the threshold stem

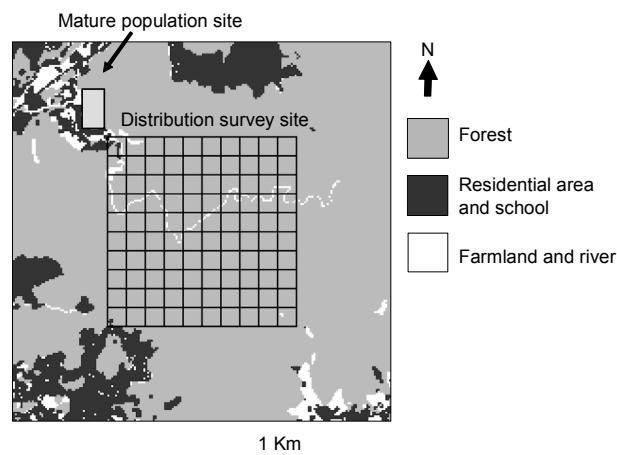


Figure 3 Land use map and research plots. The large school and sports grounds in the north of the distribution research site, and the residential area in the south-west were developed recently. Villages in north-west and south-east have a long history. Land use data was mapped using Minna de GIS (Koike 2004) based on Geographical Survey Institute (1997).

length for flowering.

Using these data, distance dependent colonisation to empty subplots was analysed. A subplot with adult palms was considered as a seed source (source subplot). Centre-to-centre distance from the nearest source subplot was obtained for all subplots. When a subplot had both adult and juvenile plants, the distance from the nearest source was assumed to be zero. The colonisation kernel was determined using the method described by Komuro and Koike (2005). Presence (value=1) or absence (value=0) was assigned as a dependent variable, and the distance from the nearest seed source subplot was assumed as an independent variable. If the distance to the outer edge of the whole research plot was smaller than the distance to a plot with adults, those data were not used, because there might be source plants outside the research area. Logistic regression was used to determine the colonisation kernel.

$$z(r) = \frac{1}{1 + e^{ar+b}} \quad (1)$$

Where $z(r)$ represents the probability that a subplot located r m distant from the nearest seed source has at least one juvenile in 1 ha, and a and b are regression coefficients. The slope a is usually positive, and a large value of a represents a steep decrease of colonisation probability along with the distance from the source subplot. The significance of coefficients was evaluated by boot strap re-sampling, and the semi inter-quartile range (SIQR, the range between the 75 and 25 percentile in the frequency distribution, corresponding to "standard deviation" in a parametric description) was obtained.

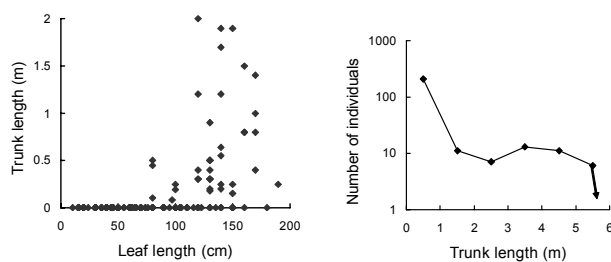


Figure 4 Trunk production by juveniles (trunk length <2m) against leaf size growth (left); and frequency distribution of trunk length in the whole population (right). No plant having a trunk longer than 6m was found. Data was from a survey in the mature site (Fig. 3).

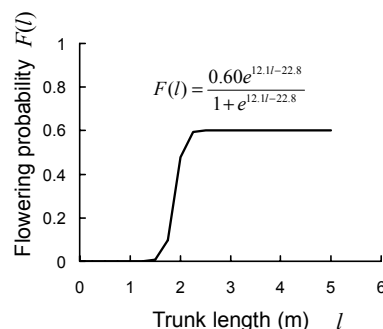


Figure 5 Flowering probability against trunk length. Logistic regression was used to fit the curve. Data was based on the survey in the mature population site (Fig. 3).

RESULTS

Life history of the palm

The palm usually forms a trunk after the leaf length attained 120cm (Fig. 4). Juveniles without trunks made up 72% of the population. No plants taller than 6m were found in the studied area, but many dead trunks of less than 6m height were observed. We therefore estimated the maximum height of the species to be 6m. Palm plants with a stem length larger than 2m bore flowers (Fig. 5). In the year of study about 60% of adult plants flowered. Palms larger than 2m in stem length were considered adult; smaller plants were considered juveniles.

Distribution and range expansion

Adult plants were found in two distinct places in the studied plot (Fig. 6). Both were close to residential or agricultural areas (Fig. 3). Adult palms were found in valleys as well as on ridges, and no habitat preference was found. Juveniles were often found in a subplot

close to adults. The colonisation kernel obtained was as follows (Fig. 7);

$$z(r) = \frac{1}{1 + e^{0.017r - 2.426}} \quad (2)$$

The slope of the colonisation kernel was 0.017 ± 0.003 (median $\pm$ SIQR) in boot strap sampling.

DISCUSSION

Distribution of adults and juveniles suggests that the palm is spreading into the forest from adjacent residential and agricultural areas (Fig. 6). Shade tolerance and maximum height are important traits for plant survival in natural forests (Koike 2001). Juveniles without trunks are likely to have strong shade tolerance, given that growing juveniles are often observed on the forest floor. However, the flowering probability for adult plants in the forest (60%, Fig. 5) is likely to be lower than that for plants in gardens and at the forest edges, where almost all tall palms have flowers (Koike personal observation). This suggests that the palm in its flowering stage requires

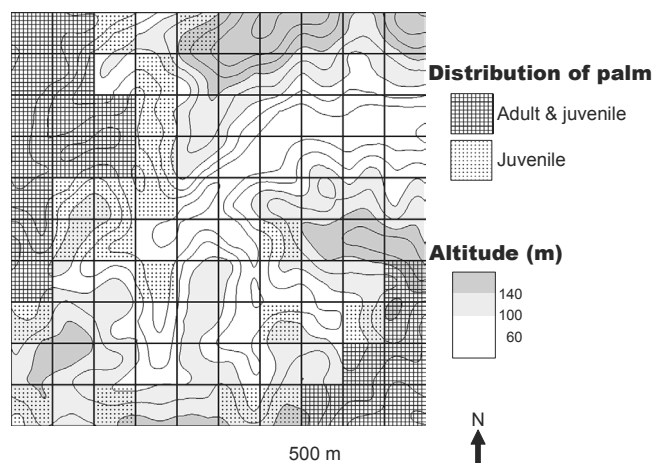


Figure 6 Distribution of juvenile and adult palm (*Trachycarpus fortunei*) in 1 km x 1 km area of continuous forest in Kanagawa Prefecture, Japan.

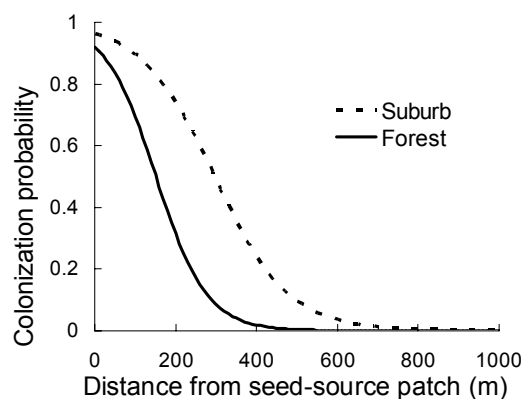


Figure 7 Colonisation kernel of the alien palm (*Trachycarpus fortunei*) in continuous forest and in the suburban landscape. Data for the suburb from Komuro and Koike (2005) for a study in Yokohama, Japan.

light. The estimated maximum height of 6m is lower than that for the most pronounced dwarf sub-canopy species of *Eurya japonica* Thumb. (Koike and Hotta 1996). This suggests that the palm will not become the dominant species in natural forests. They can reproduce on sites that are at least slightly open, such as in disturbed forests, under deciduous canopies, along riversides, forests close to cliffs, and at the forest edge. Juveniles dispersed from such habitats will persist for many years due to their strong shade tolerance. In this study area range expansion of the palm was enhanced due to the steep topography and die back of planted conifers.

The slope of the colonisation kernel for the same species in the suburban landscape of Yokohama was 0.011 ± 0.003 (median +SIQR, Komuro and Koike 2005), and smaller than in the continuous forest studied in this research. Thus the colonisation distance in continuous forest was smaller than that in the fragmented suburban landscape, and the palm spread slower in continuous forest than suburb. The reason for such phenomena is probably the smaller seed production in forests, due to the demand for light at the flowering stage. As shown in Komuro and Koike (2005), the number of seeds greatly affects the colonisation distance even if the dispersal distance for each single seed is the same.

Although the palm will not dominate inside the natural forests, the species composition of the forests will be changed by this alien species. The dominance of native species could be reduced to some extent. In the long term, accumulation of such shade tolerant sub-canopy alien species could possibly cause a

serious reduction in native plants, through neutral replacement (Hubble 2001). Removing adult palms can easily be done by cutting the trunk, because adult plants never sprout. However, when juvenile plants are cut they produce new leaves, and removing juveniles is hence labour intensive. It is recommended to stop selling the palm, and to develop suitable methods for control of the palm population.

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