# A Study of Modern Pollen Representation in an Evergreen Broad-leaved Forest on Okinawa Island, Southwestern Japan

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**Abstract** Pollen spectra from forest floor samples obtained in the evergreen broad-leaved forest zone on Okinawa provide information about pollen representation on the scale of regional and local pollen deposition. Dominant trees in different forest stands primarily control the pollen assemblages of their forest floor on a regional scale. On a local scale within the *Castanopsis* forest, spatial distributions of pollen and their sources along a valley-ridge gradient show a good relationship for major trees such as *Castanopsis*, *Distylium* and *Schima*, but not for *Cyclobalanopsis*. The distributions are also comparable for *Camellia*, *Ilex* and *Myrsine* among minor trees and shrubs.

**Key words:** pollen analysis, modern pollen, valley-ridge gradient, evergreen broad-leaved forest, Okinawa.

The palynological data from closed-canopy sites reveal a number of features that are not apparent in conventional regional diagrams (Cruickshank and Cruickshank, 1981; Bradshaw, 1988). Since these forest floor sites have small pollen source area (e.g. Andersen, 1967, 1970; Bradshaw, 1981; Heide and Bradshaw, 1982), they provide high spatial resolution. However, almost all work to date which has shown local differences within closed-canopy forests has been done in cool temperate and boreal forest zones. Therefore, a palynological study was attempted at a closed-canopy plot in the evergreen broadleaved forest zone on Okinawa, where the vegetation structure has been well investigated (Hara et al., 1996).

This paper focuses on how maternal plants affect the pollen assemblages of their forest floor on scales of both regional and local pollen deposition (*sensu* Janssen, 1981; *vid*. Yonebayashi, 1996) in the evergreen broadleaved forest zone. In other words, are forest types distinguishable on the forest stand scale, and can plant distribution in a stand be reconstructed from pollen data for closedcanopy sites in the warm temperate zone?

## Site and Methods

This study was carried out mainly in a 50  $\times$  15 m plot (26° 45′ N, 128° 05′ E, c. 250 m a.s.l.) and three additional sites on northern Okinawa Island, southwestern Japan. The plot lies on a rather steep slope which exceeds 40 degrees at maximum. Dominant canopy species among 54 woody species in the plot are *Castanopsis sieboldii* (Makino) Hatusima ex Yamazaki et Mashiba ssp. *lutchuensis* (Koidz.) H. Ohba, *Quercus miyagii* Koidz., *Distylium racemosum* Sieb. et Zucc. and *Schima wallichii* (DC.) Korthals. Detailed descriptions on the relationships between landform and forest structure of the plot have been made by Hara *et al.* (1996).

In order to study local differences among pollen assemblages in a forest stand, intensive collection of 26 surface samples for pollen analysis was carried out in the plot. The samples were collected at an interval of 5 m along two lines 5 m apart (designated Lines 2 and 3), and four additional samples from between Lines 2 and 3 at 5, 15, 25 and 45 m distant from the baseline in the valley (Fig. 1). Three other samples from an artificial *Alnus japonica* (Thunb.) Steud.-*Styrax* 



**Fig. 1.** Site plan of the study, indicating sampling points as solid circles. For detailed topography, see Hara *et al.* (1996).

*japonica* Sieb. et Zucc. stand and two *Pinus luchuensis* Mayr. stands were obtained to clarify non-local properties. The *Alnus-Styrax* stand (St. 26: ca. 300 m a.s.l.) was located about 800 m north of the *Castanopsis* plot. Of the two *Pinus* stands, one (St. 25:

ca. 290 m a.s.l.) lay near the *Alnus-Styrax* stand and the other (St. 24: ca. 70 m a.s.l.) was located about 3.8 km northwest of the *Castanopsis* plot.

The samples contained litter and humus without undecomposed leaves and twigs. These were prepared for pollen analysis using 10% KOH solution to remove humic colloids, and deflocculant. After sieving to remove coarse particles, gravity separation in a saturated solution of ZnCl<sub>2</sub> was carried out. The samples were then acetolyzed to remove cellulose and finally mounted in glycerine jelly.

All pollen and spore grains were counted until the total count of arboreal pollen grains exceeded 500 at a magnification of  $\times$ 400, or ×1000 (633-2277 pollen and spore grains in total). Percentages of arboreal pollen types from different stands (Fig. 2) were expressed as part of their pollen sum in order to allow for comparison of regional forest composition among the stands. Percentages from the Castanopsis plot were expressed as part of the total pollen and spore sum, consisting of all identified and unidentified pollen and fern spore types. The values were averaged every 5 m from the baseline to reduce the lateral variability in surface samples pointed out by Adam and Mehringer (1975), and are shown in Fig. 3. Usage of "-type" and "/" in presenting pollen data follows Birks and Birks (1980), and the terms to indicate identification status such as comp. for *comparatus* and sim. for similis are those of Maloney (1991), which were modified from those of Benninghoff and Kapp (1962). Although Castanopsistype comp. pollen consists of Castanopsis, Castanea and/or Lithocarpus pollen, the latter two are absent on Okinawa.

#### Results

A total of 51 pollen and spore types were detected in the *C. sieboldii* ssp. *lutchuensis* plot; 33 arboreal pollen types, 14 nonarboreal pollen types and 4 fern spore types. Nineteen out of the 33 arboreal pollen types were found in both the relevé and pollen assemblages; the rest (14 arboreal pollen types) were detected by pollen analysis, but the plants were absent. The latter group of taxa whose pollen grains were transported

#### Modern pollen representation in an evergreen broad-leaved forest



**Fig. 2.** Arboreal pollen spectra expressed as part of arboreal pollen sum from different forest stands on Okinawa Island. The 20 and 5 m in the *Castanopsis* plot represent distances where the percentages of the *Castanopsis*-type comp. pollen were highest and lowest, respectively. See text for explanation of Sts. 24, 25 and 26.

from outside the plot accounted for only 2.4-10.9% of all arboreal pollen (2.2-6.3% of total pollen and spore sum). Percentages of tree pollen types of this group such as *Pinus*, *Myrica* comp. and *Alnus* were low at the middle slope and tended to increase toward the valley and ridge. The percentage of *Castanopsis*-type comp. pollen was 53.1-87.9% of arboreal pollen types in the *Castanopsis* plot and 13.6-32.3% in other stands. In the *Alnus-Styrax* stand, *Alnus* pollen accounted for 40.7% of arboreal pollen types, while the *Pinus* stands yielded *Pinus* pollen at 56.8% and 59.0% (Fig. 2).

The percentages of basal area were 28.8%, 18.5%, 11.5% and 6.0% for *C. sieboldii* ssp. *lutchuensis*, *D. racemosum*, *S. wallichii* and *Quercus* (*Cyclobalanopsis*) *miyagii*, respectively (Hara *et al.*, 1996), whereas their pollen percentages accounted for 53.1-87.9%, 0.2–21.9%, 0.5–3.1% and 1.4-10.0% of the arboreal pollen types in the plot. Hence *Castanopsis*-type comp. pollen was over-

represented and *Distylium* comp., *Schima* comp. and *Cyclobalanopsis* comp. pollen types tended to be under-represented.

Pollen assemblages along the valley-ridge gradient in the *Castanopsis* plot are presented in Fig. 3. The proportion of arboreal pollen types was high (82.5–95.4%) above 10 m from the baseline in the valley, whereas that of fern spores was high (27.9–33.4%) at lower sites.

For the dominant trees, spatial distributions of pollen and their sources along valleyridge gradient were well comparable for *Castanopsis*, *Distylium* and *Schima*, but not for *Cyclobalanopsis*. The *Castanopsis*-type comp. pollen dominated other pollen types above 10 m from the baseline (58.8–81.1% of total pollen and spore sum). This corresponded to the actual distribution of *C. sieboldii* ssp. *lutchuensis*, i.e. the trees larger than 40 cm DBH (diameter at breast height) grew above 15 m. A large tree (>40 cm DBH) of *D. racemosum* whose pollen formed a peak at 5 m



**Fig. 3.** Distribution of selected modern pollen and spore percentages in an evergreen broadleaved forest at Yona, Okinawa Island. Percentages are expressed as part of the total sum. Clear bars represent values exaggerated  $\times 10$ . Plus signs represent values of less than 0.1%. \*: *sensu* Huang (1981)

grew at ca. 12 m. Schima comp. pollen type formed small peaks at 10–15 and 40 m, around where large trees (>40 cm DBH) of S. wallichii grew. The Cyclobalanopsis comp. pollen type occupied 1.3–7.2% and the value tended to increase downwards. Although Q. (Cyclobalanopsis) miyagii happened to occur on the middle slope in this plot, this tree tends to grow on lower slopes. Some species distributions in the plot including those of C. sieboldii ssp. lutchuensis and D. racemosum, are indicated in Hara et al. (1996).

Other trees and shrubs for which both plants and pollen were found in the plot were less significant in terms of pollen quantity. Spatial distributions of pollen and their sources seemed to correlate for *Camellia*, *Ilex* and *Myrsine*, but not for *Cleyera/Eurya*, Araliaceae, Ericaceae and *Symplocos*. The *Camellia* comp. pollen type formed a peak at the top of the plot, and *C. sasanqua* Thunb. grew around 45 m. The *Ilex* pollen type increased in quantity above 30 m and had another peak at 5 m. *I. integra* Thunb., *I. goshiensis*  Hayata and *I. liukiuensis* Loes. grew on the crest to the upper slope, and there was a large *I. warburgii* Loes. at ca. 6 m. The *Myrsine* comp. pollen type, whose source, *M. seguinii* Lév., grows on the crest to upper slope, occurred at a relatively high percentage in the upper part.

Monolete and trilete-type fern spores were responsible for the higher percentages of non-arboreal pollen and spore types at lower sites. This coincided with the increase in herbaceous plants towards the valley, and the dominance of ferns such as *Bolbitis subcordata* (Copel.) Ching, *Diplazium donianum* (Mett.) Tard., *D. subsinatum* (Wall. ex Hook. et Grev.) Tagawa and *Cyathea podophylla* (Hook.) Copel. in the valley (Oono *et al.*, 1997).

## Discussion

The small proportions of non-local elements (whose pollen grains were transported from a distance) suggest that pollen assemblages from the floor of this plot were primarily attributable to local vegetation. In fact, dominant anemophilous trees in several forest stands seem to control the pollen assemblages of their forest floor. The pollen percentages of dominant trees were higher in *Castanopsis* forest and lower in *Alnus-Styrax* and *Pinus* forests, respectively, in comparison with those from *C. tribuloides* (Sm.) A.DC., *A. nepalensis* D.Don and *P. roxburghii* Sarg. forests in eastern Nepal (Yonebayashi *et al.*, 1993). This suggests that *Castanopsis*-type comp. pollen contributes more intensively to regional (background) pollen incidence in Okinawa than in Nepal.

Castanopsis-type comp. pollen was overrepresented. whereas Distylium comp., Schima comp. and Cyclobalanopsis comp. pollen types tended to be under-represented in the plot. Pollen assemblages obtained from open sites on Amami-ohshima Island of the same archipelago (Ryukyu Islands) seem to support these tendencies, although the percentages of component species around the sites are unavailable (Nakamura, 1957). Other available data also show that the Castanopsis/Lithocarpus pollen type has tended to be over-represented and the Quercus (s. lat.) pollen type under-represented, with the exception of three cases at higher altitude where anemophilous trees are scarce, whereas Schima has been over-represented in a Castanopsis tribuloides-S. wallichii forest in eastern Nepal (Yonebayashi et al., 1993).

Pollen deposited on closed forest is derived largely from rather small areas. The empirical data showed that trees within 20-30 m of the sampling site were responsible for the pollen representation (Andersen, 1967; Bradshaw, 1981; Heide and Bradshaw, 1982). Pollen percentages and both crown and basal area along two ca. 200m-long transects in Draved Forest, Denmark, suggested a good (positive) relationship between them for tree species occurring in the forest (Alnus, Betula, Fagus, Fraxinus, Quercus and Tilia) (Andersen, 1967, 1970). On the other hand, a simulation experiment by Sugita (1994) using patchy vegetation landscapes predicted that the 'relevant' source area for pollen in lakes was within 50-100 m from the lake edge for small forest hollows (radius of hollow = 2 m). This was also demonstrated by empirical data for Upper Michigan and north-west Wisconsin, USA; the source areas were about 50 m and 70–80 m according to variation in vegetation patch sizes (Calcote, 1995). However, it must be remembered that the model of Sugita (1994) assumes small but open lakes, where pollen transported above a canopy is more important than that on the closed forest floor.

Although soil movement would be expected in plots located on rather steep slopes, this study suggests that these good relationships between pollen assemblages and vegetation on a local scale in the deciduous broadleaved forest zone is applicable to samples from the warm temperate evergreen broadleaved forest zone. High spatial resolution is also shown by the data in the transitional zone between cool temperate and warm temperate zones (Miura et al., 1994; Yamanaka et al., 1996). The local differences within closed-canopy forests in the tropical mountain area will be distinguishable, because a close relationship on a regional scale has already been shown and pollen types of high, medium and low relative export are all present in this area (e.g. Flenley, 1973).

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#### References

- Adam, D. P. and P. J. Mehringer, Jr. 1975. Modern pollen surface samples — An analysis of subsamples. J. Res. U.S. Geol. Surv. 3(6): 733-736.
- Andersen, S. T. 1967. Tree-pollen rain in a mixed deciduous forest in south Jutland (Denmark). Rev. Palaeobot. Palynol. 3: 267–275.
- Andersen, S. T. 1970. The relative pollen productivity and pollen representation of north European trees, and correction factors for tree pollen spectra. Dan. Geol. Unders., II Raekke (96): 1–99.
- Benninghoff, W. S. and R. O. Kapp. 1962. Suggested notations to indicate identification status of fossil pollen. Pollen et Spores 4: 332.
- Birks, H. J. B. and H. H. Birks. 1980. Quaternary Palaeoecology. 289 pp. Edward Arnold, London.
- Bradshaw, R. H. W. 1981. Modern pollen-represen-

tation factors for woods in south-east England. J. Ecol. 69: 45–70.

- Bradshaw, R. H. W. 1988. Spatially-precise studies of forest dynamics. *In* Huntley, B. and T. Webb III (eds.), Vegetation History, pp. 725-751. Kluwer Academic Publishers, Dordrecht.
- Calcote, R. 1995. Pollen source area and pollen productivity: evidence from forest hollows. J. Ecol. 83: 591–602.
- Cruickshank, J.G. and M. M. Cruickshank. 1981. The development of humus-iron podsol profiles, linked by radiocarbon dating and pollen analysis to vegetation history. Oikos 36: 238–253.
- Flenley, J. R. 1973. The use of modern pollen rain samples in the study of the vegetational history of tropical regions. *In* Birks, H. J. B. and R. G. West (eds.), Quaternary Plant Ecology, pp. 131– 141. Blackwell Scientific Publications, Oxford.
- Hara, M., K. Hirata and K. Oono. 1996. Relationship between micro-landform and vegetation structure in an evergreen broad-leaved forest on Okinawa Island, S-W. Japan. Nat. Hist. Res. 4(1): 27– 35.
- Heide, K. M. and R. H. W. Bradshaw. 1982. The pollen-tree relationship within forests of Wisconsin and Upper Michigan, U.S.A. Rev. Palaeobot. Palynol. 36: 1–23.
- Huang, T-C. 1981. Spore Flora of Taiwan. 111 pp. National Taiwan University, Taipei.
- Janssen, C. R. 1981. On the reconstruction of past vegetation by pollen analysis. K. Ned. Akad. Wet., Series C 84: 197-210.
- Maloney, B. K. 1991. Notes on pollen and pteridophyte spore types. *In* Higham, C. F. W. and R. Bannanurag (eds.), The Excavation of Khok Phanom Di: A Prehistoric Site in Central Thailand. Vol. II, The Biological Remains (Part I), pp. 113-134. The Society of Antiquaries, London.
- Miura, O., N. Miyake, M. Yamanaka and S. Ishikawa. 1994. Pollen analysis of forest soils from Mt. Kuishi and distribution pattern of pollen grains in soil profiles. Ecol. Rev. (Sendai) 23(1): 57-65.
- Nakamura, J. 1957. Pollen analyses from two swamps of the Amami Islands. Rep. Usa Marine Biol. Stat. 4(4): 1–12, with 2 plates.

- Oono, K., M. Hara, M. Fujihara and K. Hirata. 1997. Comparative studies on floristic composition of the lucidophyll forests in southern Kyushu, Ryukyu and Taiwan. Nat. Hist. Res., Special Issue No. 4: \*-\*.
- Sugita, S. 1994. Pollen representation of vegetation in Quaternary sediments: theory and method in patchy vegetation. J. Ecol. 82: 881-897.
- Yamanaka, M., Y. Yanagawa and S. Ishikawa. 1996. A preliminary pollen analysis of the forest soil from the temperate mixed forest of Mt. Kuishi, Kochi Prefecture, Shikoku, Japan. Mem. Fac. Sci. Kochi Univ. Ser. D (Biol.) 16/17: 45-56. (in Japanese with English summary)
- Yonebayashi, C. 1996. Reconstruction of the vegetation at A.D. 915 at Ohse-yachi Mire, northern Japan, from pollen, present-day vegetation and tephra data. Vegetatio 125: 111-122.
- Yonebayashi, C., H. Sugita, M. N. Subedi, M. Minaki and H. Takayama. 1993. Relationships between modern pollen assemblages and vegetation in the Arun Valley, eastern Nepal. Ecol. Rev. (Sendai) 22(4): 185–196.

## 沖縄の常緑広葉樹林における 表層花粉組成

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沖縄の常緑広葉樹林帯の土壌表層の花粉分析から, 林床の花粉組成が森林構成種と局地的および広域的に どのように関係しているのかを調べた. 優占種の異な る(オキナワジイ,ハンノキーエゴノキ,リュウキュウ マツ)林分の土壌表層では,各々の優占種の花粉が優 占した. オキナワジイ優占林の中の表層花粉と,その 散布源になる植物の空間分布を比較すると,優占種群 のうち,オキナワジイ,イスノキ,ヒメツバキではよ い対応がみられたが,オキナワウラジロガシでは両者 に明瞭な関係が認められなかった. その他の分類群で も,ツバキ属,モチノキ属,ツルマンリョウ属では, 両者の分布に比較的よい対応がみられた.