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Site Environments and Stand Structure of the Mangrove Forests on Pohnpei Island, Micronesia

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Abstract
In order to obtain fundamental data for the prediction of stand productivity and sustainable management, two permanent plots, 1 ha each, were established in two types of mangrove habitats, i.e. estuary and coral reef types, on pohnpei Island, Micronesia. This paper analyzes the stand structure and the site environments and their relationships. The number of trees in the estuary type was less than half of that in the coral reef type and tree size in the former was larger than in the latter. These differences were attributed to the difference in the age between the forests which was estimated from the thickness of the mangrove peat layers. Distribution of Rhizophora apiculata and *Xylocarpus granatum* trees may possibly be related to the submergence frequency which affects the soil water content and soil water EC. *Large Sonneratia alba* trees were widely scattered in both plots. These trees were assumed to have survived by vegetative reproduction in spite of the changes in site environments that have occurred since the mangrove forests were developed at their present site. There were few *Bruguiera gymnorrhiza* and *X. granatum* trees with a diameter between 10 and 25 cm in the estuary type. This fact suggests that some environmental changes which disturbed the establishment of *B. gymnorrhiza* and *X granatum* trees, such as a relative rise in sea level, occurred during a certain period of time.

Discipline: Forestry and forest products
Additional key words: coral reef type, estuary type, soil water EC, tidal condition, topography

Introduction

Pohnpei Island is located in the East Caroline Islands (lat. 6°45′ to 7°04′ N., long. 158°05′ to 23′E.). The island, which consists of Tertiary volcanic rocks, is surrounded by barrier reefs except for a part of the southeastern side, where a fringing reef was formed. Mangrove forests surround the island, most of which developed on the reef flats fringing the island and some of them are situated in estuaries (Fig. 1). The former is referred to as coral reef type and the latter as estuary type. There are few data on the stand structure and site environments of these types of mangrove forests in comparison with the delta type found in continental areas and large islands.

The USDA Forest Service estimated the timber volumes in the mangrove forests of Pohnpei Island[5] and drew vegetation maps[3]. However, detailed investigations have not yet been conducted on the structure and site environments.

The purpose of this study is to set up permanent plots and to analyze the stand structure and site environments of each type. Furthermore, the relationship between the stand structure and the site environments and the differences between the coral reef type and the estuary type will be discussed. Periodical census for the plots may enable to analyze the stand dynamics. These results may contribute

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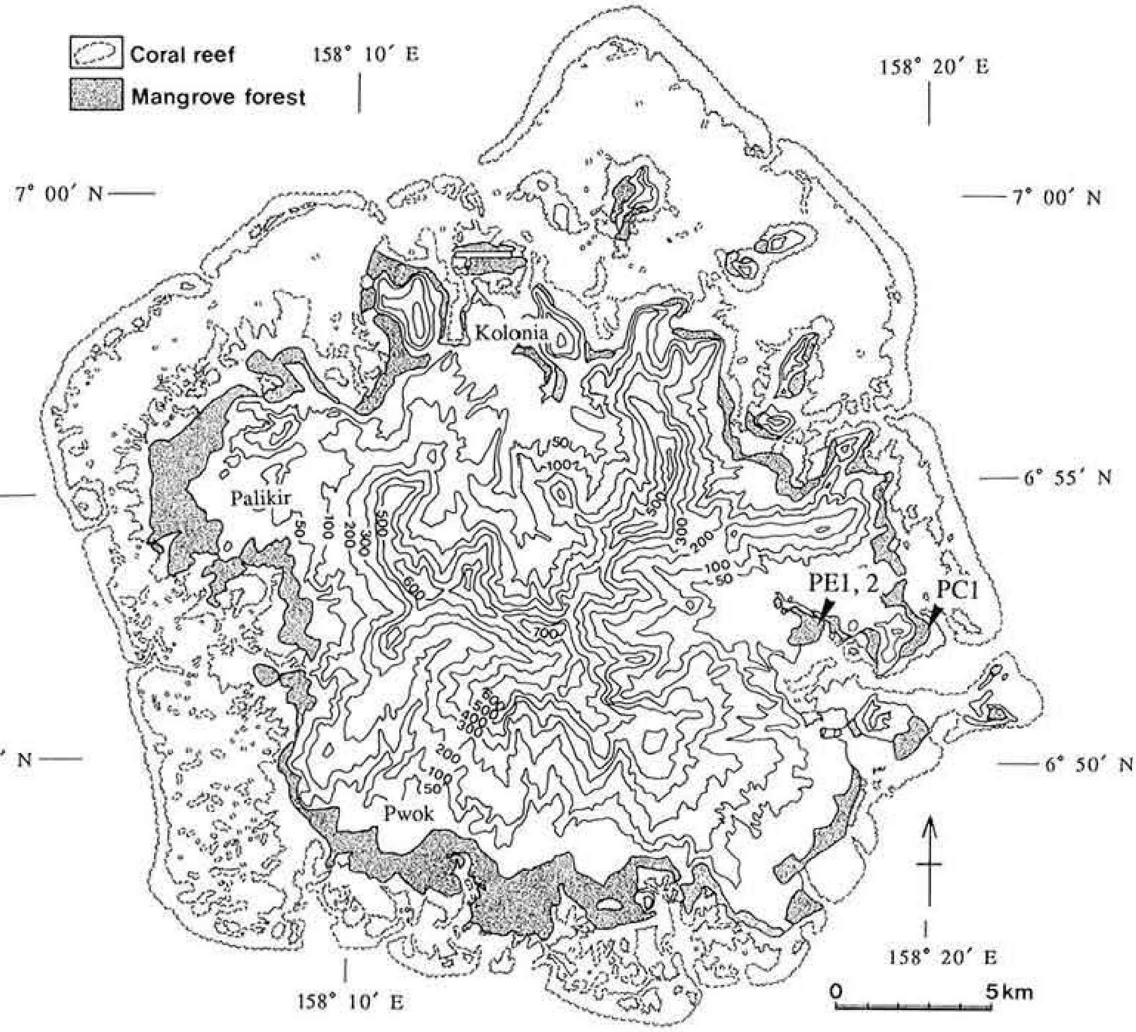

Fig. 1. Map showing the topography of Pohnpei Island, distribution of mangrove forests and location of research plots

to the improvement of the predictions of stand productivity and to the development of a sustainable management system for mangrove forests throughout the Pacific region.

Methods

Two rectangular permanent plots, 1 ha (50 m × 200 m) each, were set up in the southeastern part of the island (Fig. 1), i.e. a coral reef type (PC1) and estuary type (PE1). Additionally, a small plot (30 m × 60 m) also was set up at a slightly higher elevation in the estuary type (PE2). Each plot was subdivided into subplots (10 m × 10 m each). Ground level was surveyed at all the grids and some additional points using a pocket compass with a level in order to analyze the microtopographical conditions. The sea level when the topographical survey was performed was used as a base level and the survey data were later adjusted to the elevation using the tide table at Pohnpei Harbor.

Sedimentary structure in the mangrove habitats was examined by boring using a peat sampler in order to estimate the formative processes and age. Soil water samples were collected from several depths and their pH and EC (electric conductivity) values were measured as key environmental factors in the rhizosphere of mangrove trees. In order to observe the submergence frequency by tide fluctuation, two dataloggers were set up in PE1 and PC1, respectively. One of them was set in the seawardmost part of the plots and the other in the landwardmost part of the plots.

All trees taller than 1.3 m were numbered and tagged for repeated measurement. Species, root height and stem diameter were recorded. In the case of *Rhizophora* spp., stem diameter at 30 cm above root collar was measured, while DBH (diameter at breast height: 1.3 m) was measured for non-*Rhizophora* spp. Tree height was determined using a subsampling method. The positions of all the trees measured were mapped to provide further information for horizontal stand structure analysis.

Results

1) Topography of the permanent plots

Fig. 2 shows the topography of the permanent plots. PE1 and PE2 were set up at almost right angles to the river channel. PE1 has a tidal creek between line 13 and line 16. The elevation around the tidal creek is relatively low. The ground level of PE2 except for the immediate riverside area is higher than that of PE1. PC1 was set up at right angles to the coastline. The ground level rises gradually from seaward to landward and is higher than that of PE1. The ground level around a large *Sonneratia alba* tree is usually higher than that of the peripheral area, especially in PE1.

2) Sedimentary structure

Fig. 3 shows the sedimentary structures in and around the permanent plots. Mangrove peat layer overlies a marine clay layer in PE1, but overlies a

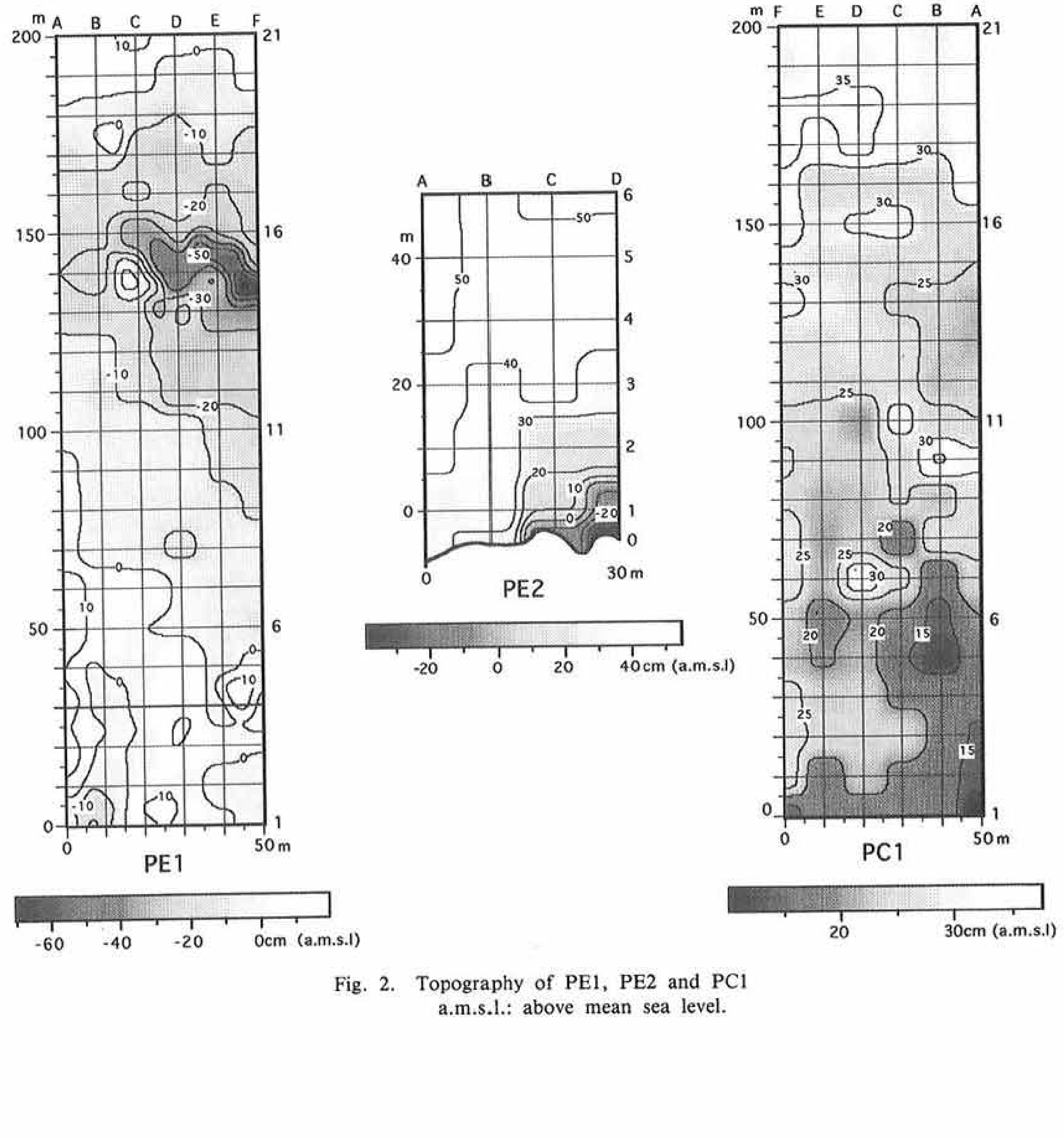

Fig. 2. Topography of PE1, PE2 and PC1
a.m.s.l.: above mean sea level.

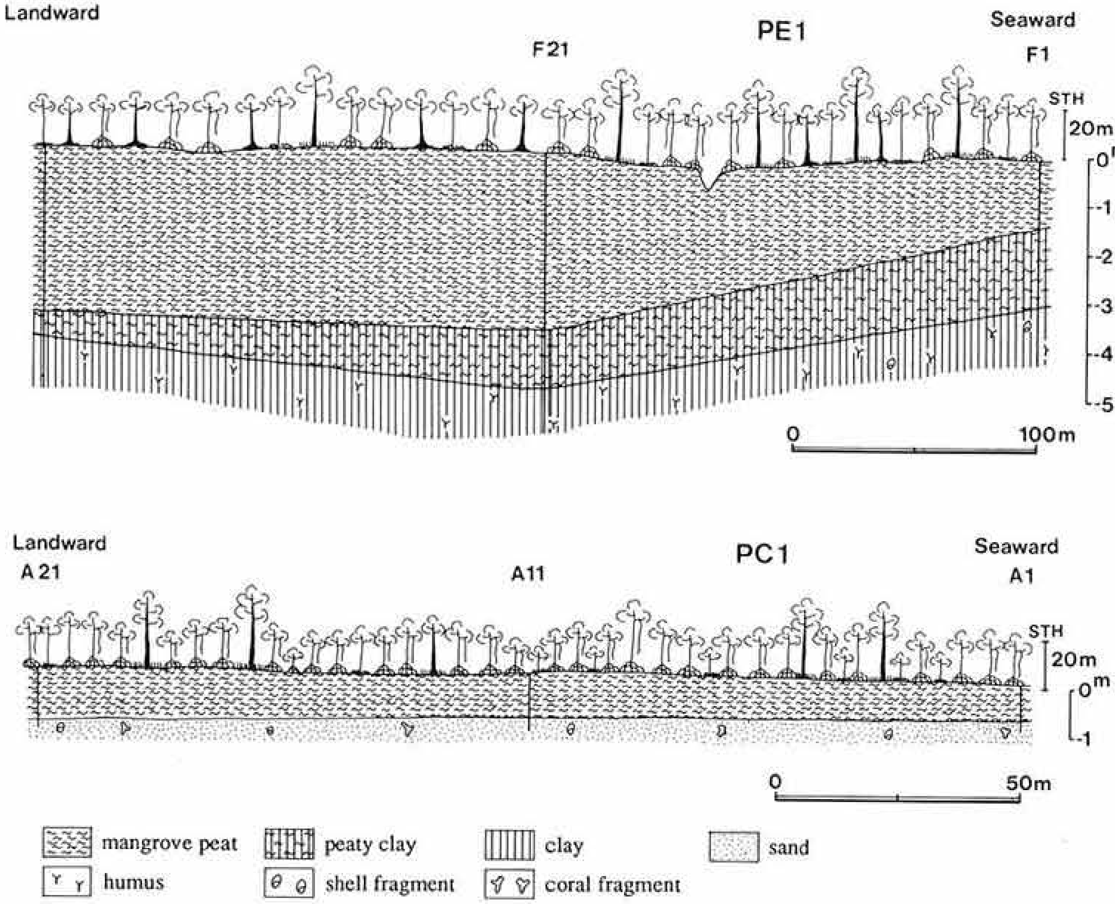

Fig. 3. Sedimentary structure around PE1 and in PC1
STH: Scale for tree height.

marine sand layer in PC1. As the depth of mangrove peat ranged from 3.0 to 4.8 m in PE1 and 0.7 to 1.2 m in PC1, it is suggested that the formative age of the mangrove forest around PC1 was younger than that around PE1. The formative age was estimated to be younger than 1,000 yrs BP for PC1 and about 2,000 yrs BP for PE1 on the basis of the radiocarbon data obtained from mangrove peat layers in previous studies[2,4] and the developmental processes of mangrove habitats on Pohnpei Island[1,2].

3) *Soil water pH and EC*

Soil water pH in PE1, at 6.5–7.1, was lower than that in PC1 which was 7.1 to 7.4 (Fig. 4). However, no difference in soil water pH within a plot was recognized. On the other hand, soil water EC decreased from seaward to landward in a plot, though around the tidal creek in PE1 the value was slightly higher than at seaward sites (Fig. 5).

4) *Tidal conditions*

The mean tidal range at Pohnpei Harbor is 70 cm, and mean spring tidal range reaches 104 cm.

Tidal fluctuations were observed using dataloggers between January 24 and February 28 in 1994 at the seaward site of PE1, between February 7 and February 28 at the landward site of PE1, between January 20 and February 28 at the seaward site of

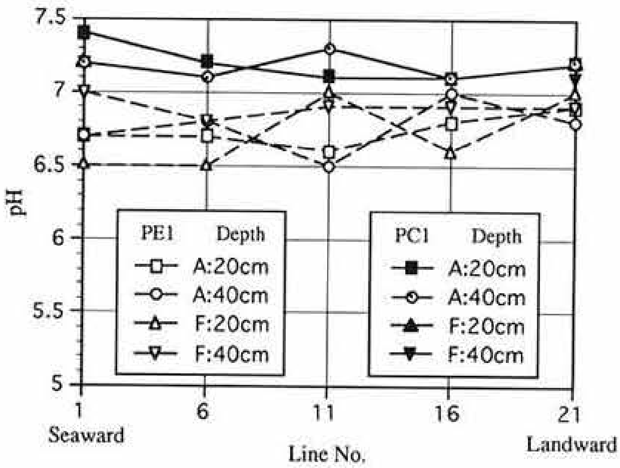

Fig. 4. Soil water pH in PE1 and PC1

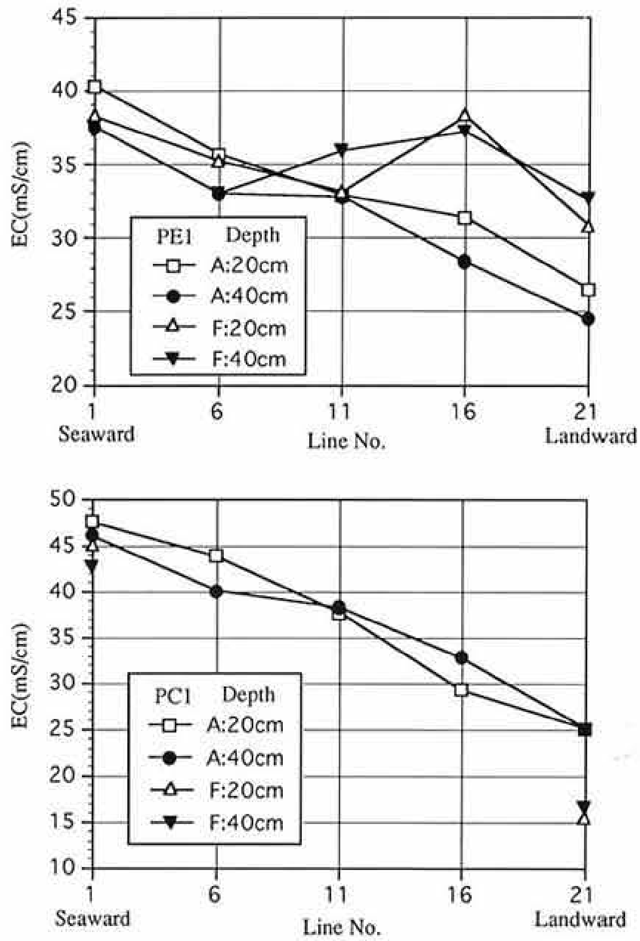

Fig. 5. Soil water EC in PE1 and PC1

PC1, and between January 21 and February 7 at the landward site of PC1. Every high tide level at the landward site was lower than that at the seaward site in both plots. The average decrease in the tide level during the observation of tide was 16 cm in PE1 and 12 cm in PC1. The decrease in the values was divided between all the points surveyed of the ground level in proportion to the distance from line 1 where the seaward dataloggers were set, and the minimum high tide level for submergence at every point was estimated using the decreased value. The submergence frequency at every point was obtained by counting the frequency of high tide events over the minimum level using the tide table of 1994 and was expressed in Figs. 6, 7 and 8 as the ratio to the total high tide frequency in 1994.

In most of the area in PE1, the submergence frequency exceeded 90% except for the landwardmost part and the area around some large *Sonneratia alba* trees (Fig. 6). On the other hand, for most of the area in PE2 the frequency was below 50% except for the seawardmost part (Fig. 7). In PC1, it decreased gradually from over 70% in the seaward area to below 40% in the landward area (Fig. 8).

5) Stand structure

Total numbers of trees measured at PE1, PE2 and PC1 were 651, 151 and 1,554, respectively. Fig. 9 shows the frequency distribution of the diameter of the respective species in PE1 and PC1.

In PE1, *Rhizophora apiculata*, *Bruguiera gymnorrhiza*, *Xylocarpus granatum* and *Sonneratia alba* were observed. Numbers of these species were 369, 184, 64 and 34, respectively. Few of the *R. apiculata* had a diameter below 10 cm. On the other hand, many *B. gymnorrhiza* with a DBH below 10 cm were observed though in few trees the DBH ranged between 10 and 25 cm. There were relatively few *X. granatum* trees with a DBH below 10 cm and between 15 and 25 cm. The DBH of *S. alba* was generally large though the number of trees was small, and none showed a DBH below 20 cm. The DBH of the largest tree in this plot, *S. alba*, was 204 cm. *R. apiculata* was distributed throughout the plot. However, trees with a diameter between 10 and 30 cm were concentrated in the area where the submergence frequency exceeded 90% (Fig. 6). *B. gymnorrhiza* and *S. alba* were equally distributed in the plot. *X. granatum* was not found around the tidal creek where the submergence frequency was high.

In PE2, *R. apiculata, B. gymnorrhiza, X. granatum, Lumnitzera littorea* and *Heritiera littoralis* were observed (Fig. 7). The respective numbers of trees were 61, 23, 57, 7 and 3. *S. alba* was not found in the plot. The frequency distributions of *R. apiculata* and *B. gymnorrhiza* were almost the same as those of PE1. However, there were many small *X. granatum* trees with a DBH below 10 cm and some large trees with a DBH between 75 and 135 cm.

In PC1, *R. apiculata, B. gymnorrhiza* and *S. alba* were observed, and the numbers of these trees were 1,168, 352 and 34, respectively. *X. granatum* was not detected. This plot was dominated by dense stands of *R. apiculata,* particularly in a landward quarter of the plot and the seaward part where the submergence frequency was high (Fig. 8). Few trees showed a diameter below 10 cm. On the other hand, many small *B. gymnorrhiza* with a DBH below 10 cm were distributed in this plot except for a landward quarter of the plot. Some large *S. alba* trees were scattered throughout the plot, though there were no small *S. alba* trees with a DBH below 20 cm. Tree size was smaller than that in PE1 (Fig. 9).

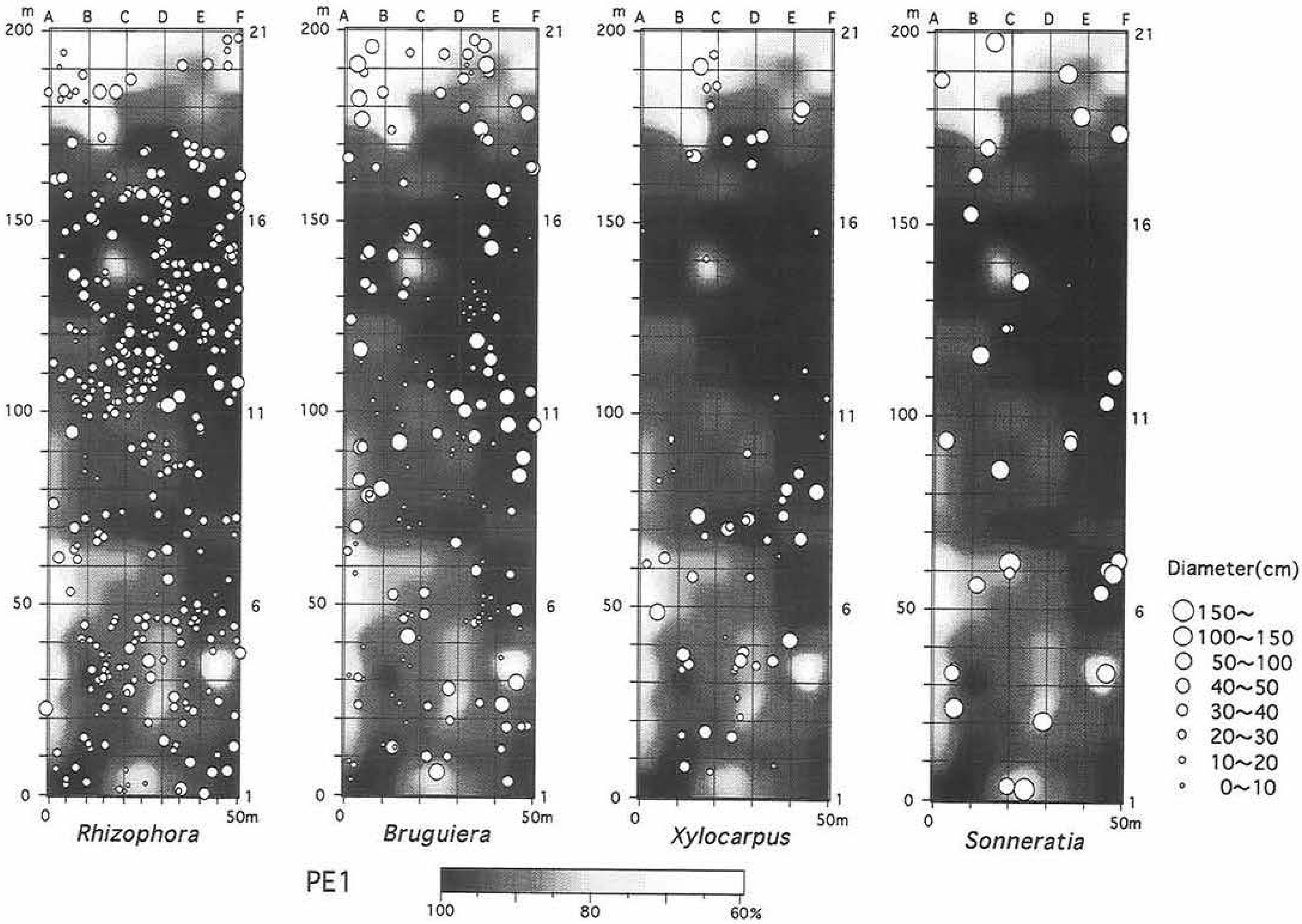

Fig. 6. Submergence frequency and distribution of each species in PE1

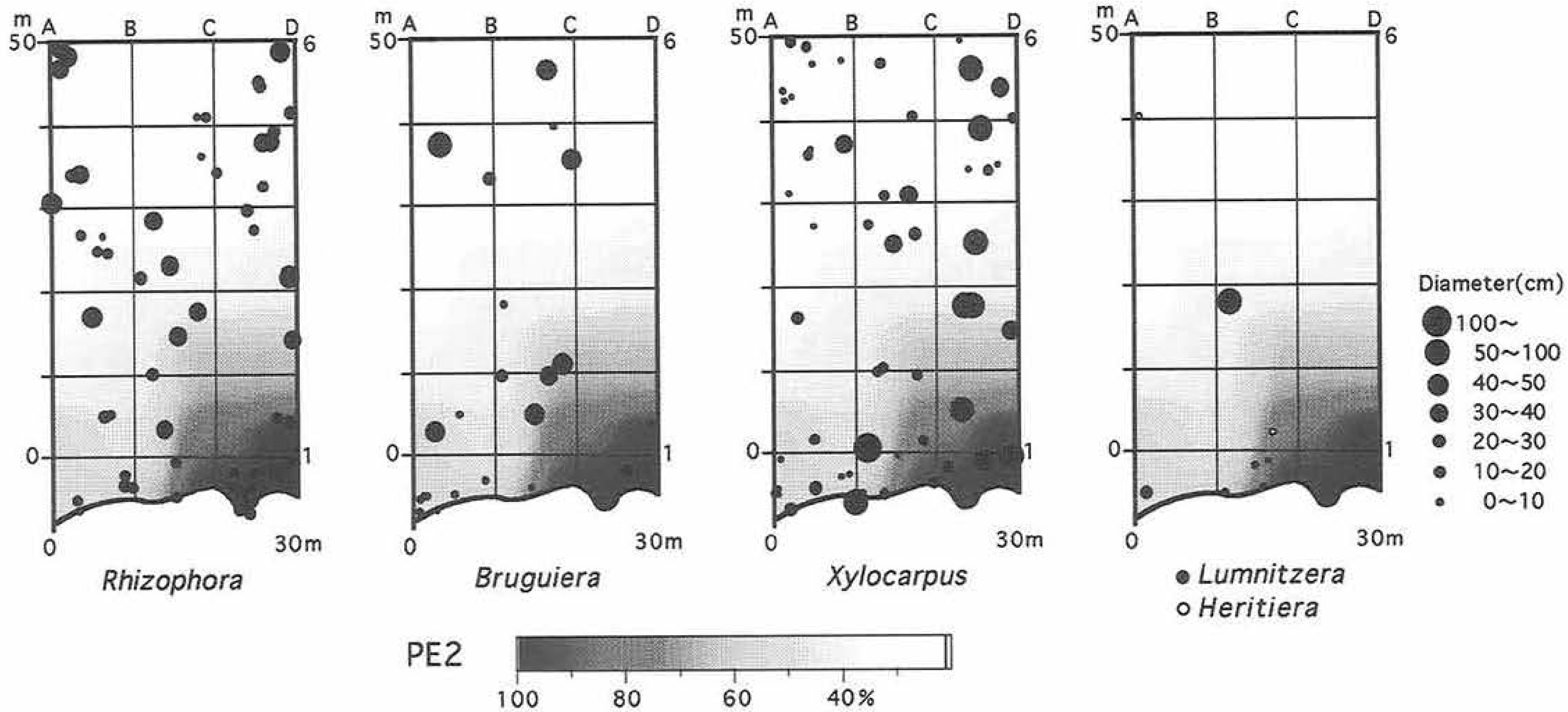

Fig. 7. Submergence frequency and distribution of each species in PE2

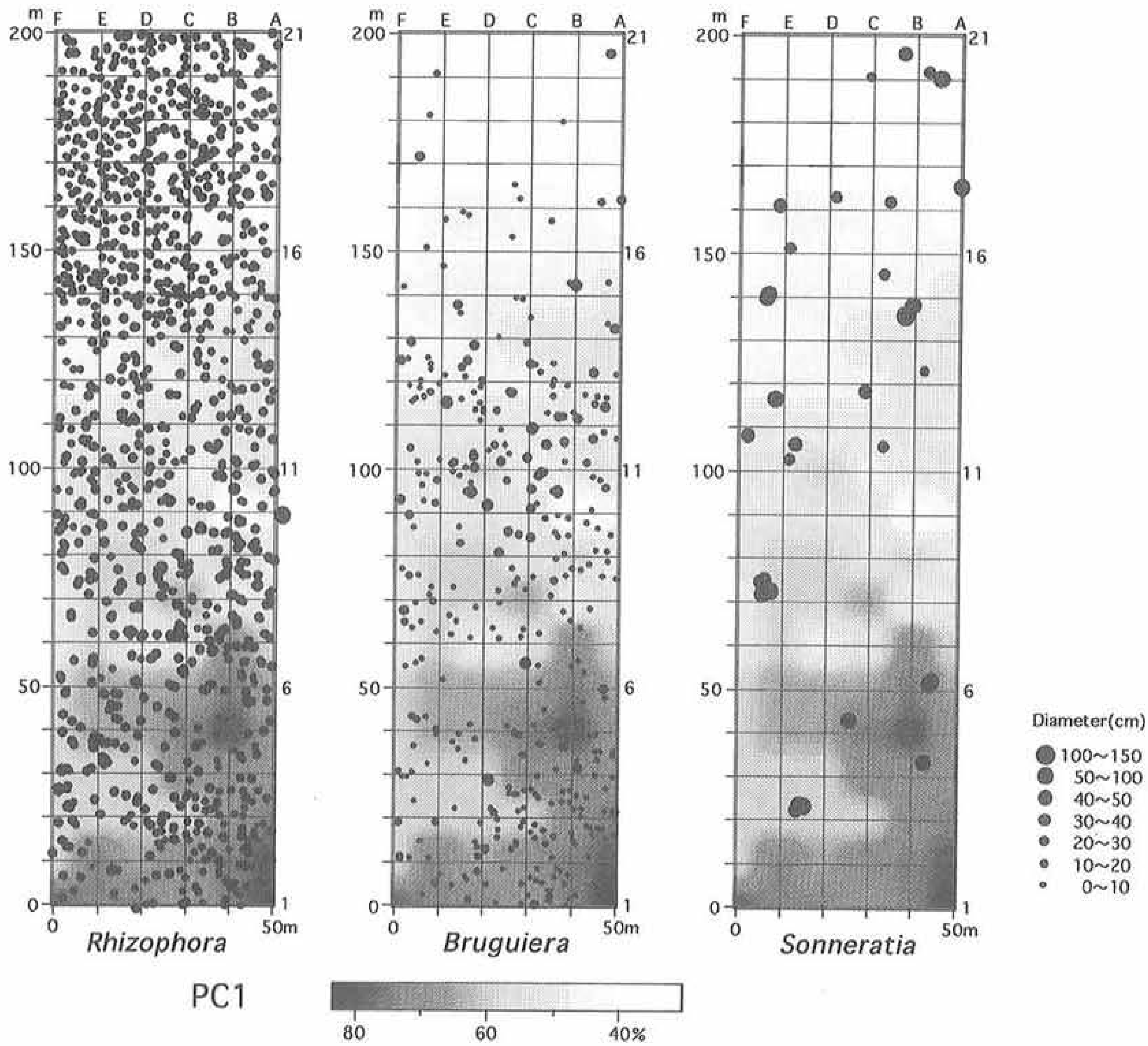

Fig. 8. Submergence frequency and distribution of each species in PC1

Discussion

1) Relationship between stand structure and site environments

(1) Differences between the estuary type and the coral reef type

The number of trees in PE1 was less than half of that in PC1, and the tree size in PE1 was larger than that in PC1. These differences were attributed to the difference in age between the forests. The formative ages of the forests around PC1 and PE1 were estimated to be younger than 1,000 yrs BP and about 2,000 yrs BP, respectively. The fact that *Xylocarpus granatum* was not detected in PC1 may also be caused by the difference in forest age.

(2) Distribution of each species and site environments in a plot

Relative frequency of appearance of *Rhizophora apiculata* was high in the area where the submergence frequency was also high in every plot except for the landward part of PC1. On the other hand, *Xylocarpus granatum* occurred where the submergence frequency was relatively low. Usually, the submergence frequency affects the water content and chemical conditions of the soil. A proportional relationship was recognized between the submergence frequency and soil water EC in PE1 and PC1 (Figs. 5, 6 and 8), though the soil water pH was not related to the submergence frequency (Fig. 4). Distributions of *R. apiculata* and *X. granatum* may possibly be related to the soil water content and soil water EC. In the

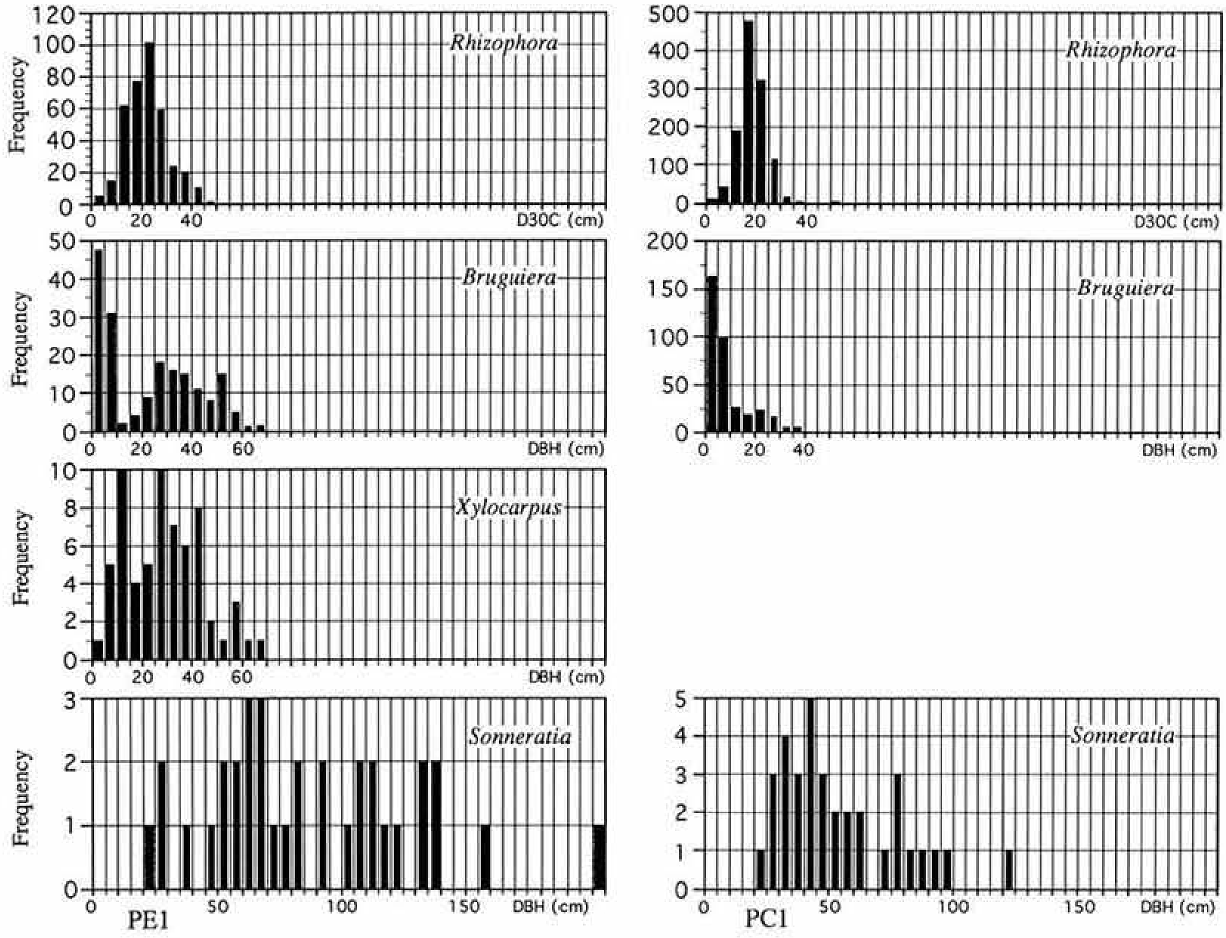

Fig. 9. Frequency distribution of diameter of respective species
DBH: Diameter at breast height,
D30C: Diameter at 30 cm above root collar.

landward part of PC1, *R. apiculata* with a diameter between 10 and 30 cm dominated despite the low submergence frequency and the low soil water EC. Usually, under such circumstances, if the forest is mature and has no *Xylocarpus* spp., the relative frequency of *Bruguiera gymnorrhiza* ought to be high. It is difficult to explain, based on purely natural factors, the reason why *R. apiculata* was a dominant species in such site environments. Therefore, human activities may have affected the formation of the stand structure.

2) *Factors related to the size structure of respective species*

It is worth noting that only large trees of *Sonneratia alba* were widely distributed in both PE1 and PC1. This phenomenon has been recognized in other mangrove forests on this Island[1]. Usually, *S. alba* can be established only at an open site such as in the front of a forest as a pioneer species. It is assumed that these trees were able to survive by vegetative reproduction in spite of the changes in site environments since the mangrove forest developed at its present site.

There were few *Rhizophora apiculata* trees with a diameter below 10 cm in all the plots; on the other hand, there was a large number of small *Bruguiera gymnorrhiza* trees in this diameter class. This trend has been generally recognized in mangrove forests. However, it is worth noting that there were few *B. gymnorrhiza* trees with a diameter between 10 and 25 cm in PE1. Size structure of *Xylocarpus granatum* in PE1 showed the same tendency, suggesting that some environmental changes which disturbed the establishment of *B. gymnorrhiza* and *X. granatum* had occurred during a certain period. The establishment of *B. gymnorrhiza* in PC1 after the occurrence of environmental changes may account for the fact that this tendency was not recognized in PC1 and the relative rise in the sea level could be one of

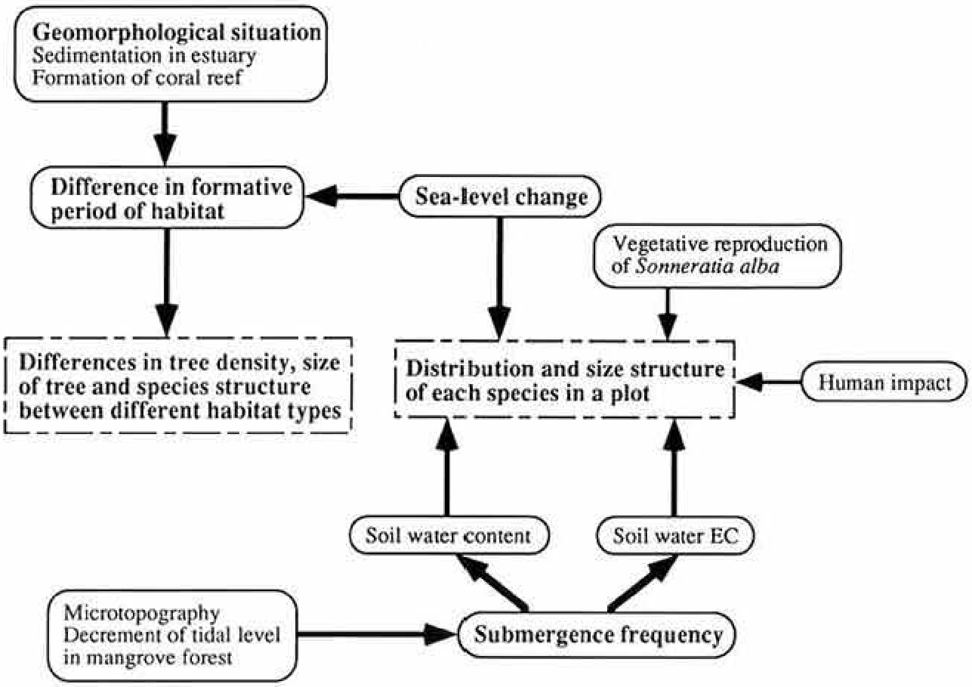

Fig. 10. Site environments controlling formation of stand structures of mangrove forests on Pohnpei Island

the causes.

Fig. 10 shows the site environments controlling the formation of stand structures of the mangrove forests on Pohnpei Island as a conclusion of this paper.

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