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PLANT DISTRIBUTION IN RELATION TO SOIL CONDITIONS IN HANGZHOU BAY COASTAL WETLANDS, CHINA

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Abstract

Plant group classification relation to soil environmental characteristics was monitored in Hangzhou Bay coastal wetland, China. 18 taxa, belonging to 17 genus and 7 family were recorded, and classified into five groups by TWINSPAN *viz* A, *Scirpus mariqueter* group, B, *Spartina alterniflora* group, C, *Phragmites communis* group, D, *Tamarix chinensis - P. communis* group, and E, *Salix matsudana - Imperata cylindrica* group, respectively. Soil salinity and moisture in group A, B and C were significantly higher than group D, E, while higher pH values was found in group E, A and B. From the intra-set correlations of the soil factors with the first 2 axes of DCCA, it can be noted that DCCA axis 1, was positively correlated with altitude and negatively with soil salinity and moisture, represented soil salinity and moisture gradient. Axis 2 of the DCCA was clearly negatively correlated to soil pH, and called as soil pH gradient.

Introduction

Coastal wetlands, occupying zones of transition between terrestrial and marine ecosystems, are the interface of the coastal landscape (Lee *et al.*, 2006). Coastal wetlands are suggested to offer many important ecosystem services, such as high productivity and diversity (Bird, 1984; Woodward & Wui, 2001), providing habitats for flora and fauna (Ishikawa *et al.*, 2003), and helping to moderate water quality (Faulkner, 2004). Hangzhou Bay coastal wetlands is the intersection of north and south costal wetlands in China, and is suggested to be of high value for scientific research (Nakata *et al.*, 2005), maintaining ecological balance and acting as a safeguard to prevent from erosion, attenuate waves and encourage sediment deposition.

Soil conditions, like soil salinity, soil pH, are major physical factors to affect plant distribution in coastal wetlands (Silvestri *et al.*, 2005; Li *et al.*, 2008), and understanding plant segregation along soil environmental gradients is not simply a major gap in our knowledge of tidal wetlands; it is also crucial for both the conservation and restoration of coastal marsh systems. Hence the objectives of present study were (1) to clarify the classification of vegetation and find out the soil environment characteristics in each plant group; and (2) to study the soil conditions driver of plant distribution in Hangzhou Bay wetlands. These can provide new proof for the debate on environmental driver of plant distribution, and scientific basis for vegetation restoration in degraded ecosystems (Prach *et al.*, 2001; Rehounkova & Prach, 2006).

Materials and Methods

Site description: Hangzhou Bay is an inlet of the East China Sea, bordered by the province of Zhejiang and the municipality of Shanghai. Hangzhou Bay Wetlands Ecosystem Research Station, the site of this study, is located on southern bank of Hangzhou Bay, in Cixi City, Zhejiang province, East of China (121°08'43″N, 30°18'40″E). The climate is subtropical monsoon with a long-term mean rainfall of 1 344.7 mm. Average maximum temperature in July is 28.2 ℃ and average minimum temperature in January is 3.8 ℃. The total annual sunshine hours are 2 038.8 h, and frostless period is around 244 d. The soil type belongs to coastal solonchak belt, developed by sediment accumulation chronosequence from Yangtze River and some other rivers in Zhejiang and submarine of East China Sea.

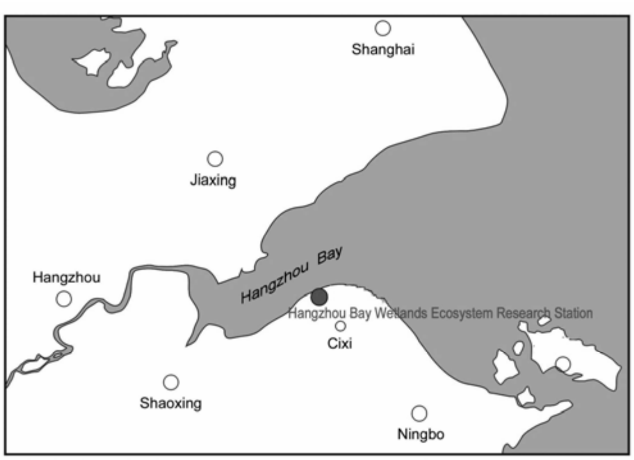

Fig. 1. Location of the study area.

Sample: There were a series of plant communities on beech from shoreline to inland (developed in different years). In July-August, 2008, line transects were introduced using random sampling methods (Buckland *et al.*, 2007) to investigate near-to-natural vegetation in different communities.

Plant sampling: 5 transects, each 1 000 m in length and 200 m in interval, were established in herbs communities near the shore. Along each transect, 1 m×1 m survey plots were placed with 200 m apart. And 6 transects, each 1 000 m in length and 200 m in interval, were established in two shrub communities inland, and along each transect, 5 m×5 m survey plots were placed at 200 m intervals for shrub survey, and 3 1 m×1 m sub-plots were placed randomly in each plot for herbs survey. A total of 66 plots were examined. Plant species presence/absence, coverage, density, abundance and height were estimated in each plot and sub-plot.

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Soil sampling: Soil samples were collected from 0-30 cm from each plot. Electrical conductivity (EC) was analyzed in a 4:1 water:soil suspension using a conductivity meter, and soil reaction (pH) was evaluated in a 1:1 water:soil suspension using PHS-3BW pH meter. Soil moisture was determined by comparing the wet- and dry-weights. Altitude was recorded by GPS.

Data analysis: A total of 18 species were recorded in 66 plots. The species importance value (IV) for each sample was calculated by the following formula:

$$IV = (\text{Relative density} + \text{Relative frequency} + \text{Relative coverage}) / 3$$

Two-way Indicator Species Analysis (TWINSPAN) was applied on a data matrix (66 plots and 18 species) using their Ivs for plant group classification (Flinn *et al.*, 2008), and detrended canonical correspondence analysis (DCCA) was introduced to analyze the relationship between plant distribution and soil conditions (ter Braak, 1990).

Results

Classification of vegetation data: 18 taxa, belonging to 17 genus and 7 families, were recorded in the study site. One species was found to be endemic in China (*Scirpus mariqueter*) and two were exotic species (*Spartina alterniflora* and *Solidago Canadensis*). TWINSPAN technique helped to distinguish five vegetation groups (A-E) at the third level of hierarchical classification (Fig. 2), which were named after their characteristic species as follows: A, *Scirpus mariqueter* group, appeared on the beach, near the shoreline, with dominant species of herb *S. mariqueter* and companion species of *Carex scabrifolia* and *Suaeda australis*. B, *Spartina alterniflora* group, overlapped between *S. mariqueter* group and *Phragmites communis* group, exotic species *S. alterniflora* was a dominant species, with companion species *S. mariqueter*, *Suaeda salsa* and *Suaeda australis*. C, *P. communis* group, was found on the beach, close to *S. alterniflora* group, *P. communis* was the dominant species in this group, with companion species *C. scabrifolia*, *Tripolium vulgare*, *S. salsa* and *S. australis*. D, *Tamarix chinensis - P. communis* group, occupied inland site, with upper layer including *T. chinensis* and few *S. matsudana*, and rich herbaceous layer including *C. scabrifolia*, *S. australis*, *T. vulgare*, *P. communis*, *Aster sublatus*, *Imperata cylindrica*, *Conyza bonariensis*, *Artermisia lavandulaefolia*, *Fimbristylis sericea*, *Sonchus brachyotus* and *Rumex japonicus*. E, *S. matsudana - I. cylindrica* group, occupied inland site next to *T. chinensis - P. communis* group, with upper layer of *S. matsudana* and *T. chinensis*, and herbaceous layer, such as *C. scabrifolia*, *I. cylindrica*, *Pterocypsela laciniata*, *C. bonariensis*, *Typhace angustifolia*, *F. sericea*, *P. communis*, *A.lavandulaefolia*, *S. brachyotus*, *R. japonicus* and invasive species *Solidago canadensis*.

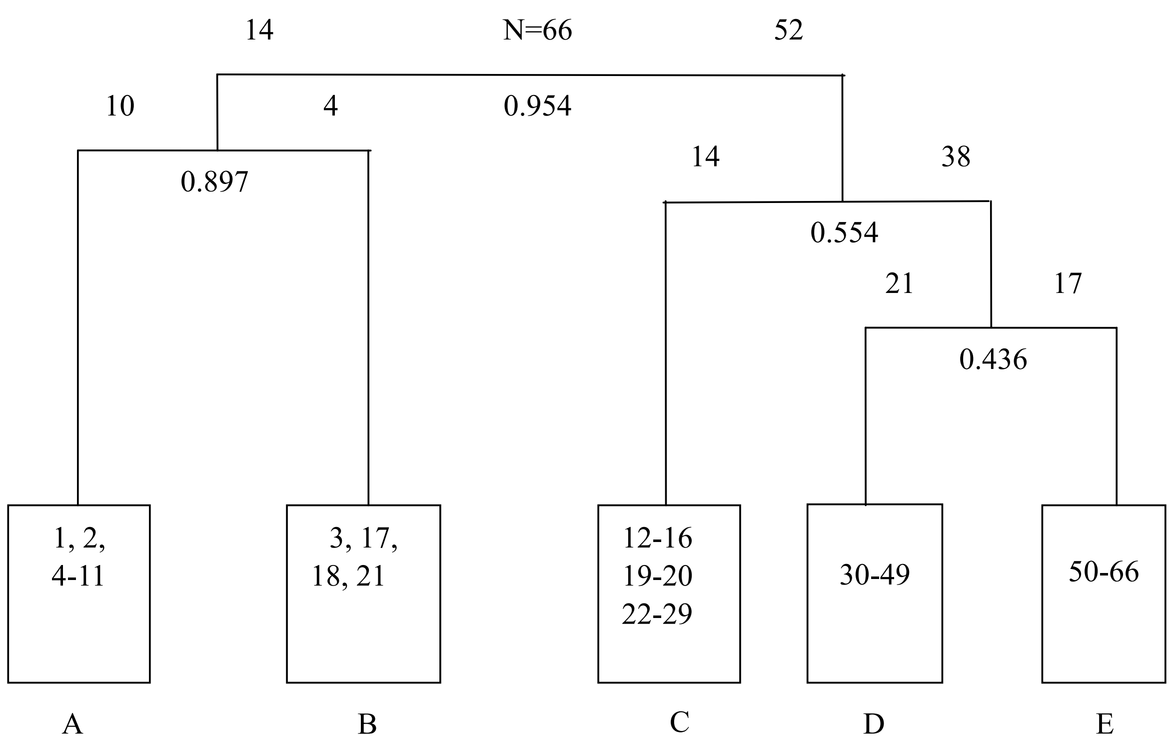

Fig. 2. TWINSPAN classification of the 66 plots.
A-E are the five vegetation groups, A, *S. mariqueter* group, B, *S. alterniflora* group, C, *P. communis* group, D, *T. chinensis - P. communis* group, and E, *S. matsudana - I. cylindrical* group.

Soil environment: Soil characteristics of each cluster groups by TWINSPAN are summarized in Table 1. Soil salinity in group A, B and C were significantly higher than group D, E, and obvious differences were also found between group D and E. Soil moisture showed same law to soil salinity, and notable differences were found between group A and group C, D, E, group B, C, D and group E. However, higher pH values were found in group E, A and B. Meanwhile, obvious differences were found between group E, A and group C, D.

Table 1. Soil characteristics of each group.

Groups		Soil salinity %	Soil moisture %	pH
A	Range	0.40 - 0.55	32 - 39	8.10 - 9.07
	Average	0.50 ± 0.05 a	36 ± 3 a	8.34 ± 0.32 b
B	Range	0.44 - 0.61	29 - 34	8.20 - 8.29
	Average	0.50 ± 0.06 a	32 ± 2 ab	8.25 ± 0.04 bc
C	Range	0.30 - 0.82	26 - 41	7.75 - 8.42
	Average	0.48 ± 0.14 a	29 ± 3 b	8.12 ± 0.20 c
D	Range	0.02 - 0.40	16 - 31	7.74 - 8.80
	Average	0.11 ± 0.07 b	28 ±3 b	8.14 ± 0.27 c
E	Range	0.01 - 0.08	16 - 25	8.21 - 8.79
	Average	0.05 ± 0.01 c	21 ± 4 c	8.53 ± 0.16 a

Means within row with different letters for each parameter are significant at 0.05 level by LSD test.

Ordination analysis of vegetation data: Fig. 3 showed a DCCA ordination diagram of the floristic and soil environmental data set. The length and the direction of an arrow representing a given environmental variable provided an indication, of the importance and direction of the gradient of environmental change for that variable, within the set of samples measured. The Monte Carlo permutation test showed that both the overall effect of the environmental variables on species and the first three canonical axis were significant (p = 0.001). The 66 plots scores were plotted along the axe 1 and 2, and clustered into the five groups that obtained from TWINSPAN. The first three eigenvalues are 0.65, 0.12 and 0.019, and explained 19.7%, 3.6% and 0.6% of the species variation, respectively, and 58.1%, 15.9%, 0.0% of the species and environment variation.

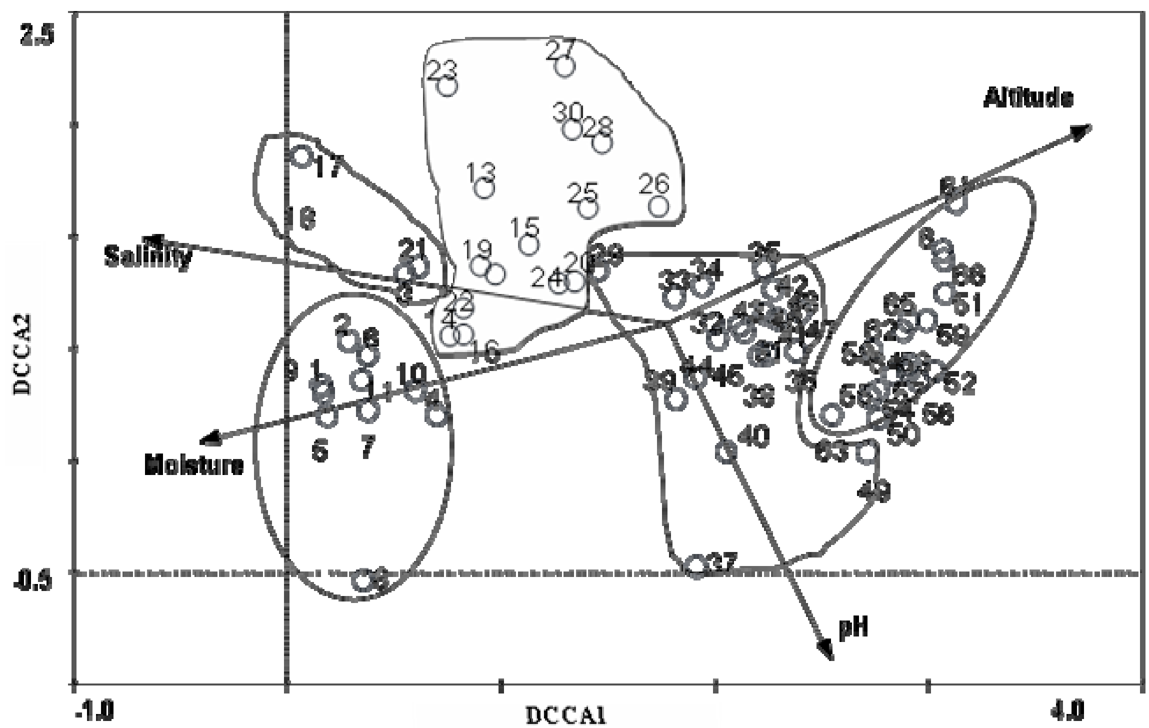

Fig. 3. DCCA analysis of 66 plots in Hangzhou Bay wetlands.

From the intra-set correlations of the soil factors with the first 2 axes of DCCA, it can be noted that DCCA axis 1 was positively correlated with altitude and negatively correlated with soil salinity and moisture. We interpret DCCA axis 1 as soil salinity and moisture gradient. This fact became more clearly in the ordination biplot (Figure 3). Axis 2 of the DCCA analysis was clearly negatively correlated to soil pH. We interpret DCCA axis 2 as soil pH gradient.

Discussion and conclusions

Plant communities had been investigated widely in coastal wetland around the world (Crain *et al.*, 2004; Cornwell and Ackerly, 2009). Although low in plant diversity and poor in species, the vegetation composition was distinguished to five groups from TWINSPAN classification in Hangzhou Bay wetlands, which was similar to groups in Huanghe Delta (Xi *et al.*, 2003), Yangtze estuarine (Yan *et al.*, 2007) in East China. *S. mariqueter* was the endemic saline species in Yangtze delta and Hangzhou Bay coastal wetlands, and *C. australis*, *S. australis* and *P. communis* were the ubiquitous species, indicting their wide range of ecological amplitude.

DCCA was a multivariate statistical technique widely used by ecologists to find the main environmental factors to the distribution of plant community, which axes were forced by multiple linear regression to correlate optimally with a linear combination of environmental variables (Bayley & Mewhor, 2004). Environmental factors played a key role in driving plant distribution patterns and plant succession in wetlands (Crain *et al.*, 2004). Soil salinity, together with other soil physical and chemical properties, influenced plant composition, productivity, and distribution in coastal marsh ecosystems because of the different tolerances of plant species to salinity (Pennings *et al.*, 2005; Wang *et al.*, 2007). In this paper, soil salinity, moisture, pH and altitude were the most important environmental variable related with the plant group distribution in Hangzhou Bay coastal wetlands. Soil salinity and moisture (tidal restrictions) had been reported to be the main factors that influence plant distribution and species assemblages in coastal wetlands (Otto *et al.*, 2006), however, few halophytic species, for instance *S. mariqueter*, *S. alterniflora* and *P. communis*, etc, had higher salt tolerance and flooding tolerance. Elevation of tidal marshes (altitude uplift) was accelerated because of saline plants preventing wave, encouraging silt accumulation, decreasing inundation frequency and duration of tides, and soil desalination improved due to the influence of aerodynamic resistance and bulk surface resistance on electron transfer from saline plants (Wang *et al.*, 2007), certain little salt tolerance wood species, like *T. chinensis* and *S. matsudana*, and herb species, like *I. cylindrical*, appeared and occupied. This was suggested that soil salinity, moisture and altitude (DCCA1) played an important role in the community structure and function of salt marsh ecosystem, this was in conformity with the results reported by many ecologists in coastal regions (Min *et al.*, 1999; Silvestri *et al.*, 2005; Li *et al.*, 2008).

Although most studies were concentrated to study the influence of soil salinity, moisture on plant community distribution and structure, soil pH should not be neglected for responsible for variations in the pattern of vegetation in coastal wetlands (Li *et al.*, 2008). Soil pH influenced the plant growth and distribution through markedly altering the macronutrient (N, P) and micronutrient (Mn, Cu, Zn) availability and distribution in soil (Sims, 1986). Soil pH had no uniform rise or fall with the increasing distance from the tidal coast in Hangzhou Bay, which was similar to swamps of Sundarbans in India (Joshi and Ghose, 2003). Group A showed lower salinity than group B, one of the main reasons for the salinity increase above the mean high water (MHW) level was the decreased duration of the tidal inundation, which allows evapotranspiration to concentrate porewater salinity and salt to accumulate (Mondal *et al*., 2001; Silvestri *et al.*, 2005).

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