

The Floristic Relationship Among the Islands of Taiwan, Taipingtao and Tungshatao⁽¹⁾

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ABSTRACT: The floristic relationship among the Islands of Taiwan proper, Taipingtao (Aba Itu Island) and Tungshatao (Pratas Island) is presented. The floristic relationship is expressed by the similarity index of the two latter floras. The relationship between Taipingtao and Tungshatao is calculated by the index of similarity (Is) of Sorenson (1948) as 59%. Thus, these two islands are not very closely related floristically. When two floras are not comparable in size *i.e.*, the size of the large island is more 100 times bigger than that of the small island, the index of common plants (Ic) to express the floristic relationship of the small flora to the large one is proposed. The calculation is based on the common species of two floras divided by the total number of plants of the small island. Thus, the index (Ic) of floras of Taipingtao and Tungshatao to Taiwan proper is 88% and 93% respectively. The index (Ic) of floras of Taipingtao and Tungshatao to a small coastal area of Kenting National Park in Taiwan proper is 84% and 85%, respectively. The close floristic affinity among these islands is mainly due to their high composition of coastal elements in common.

KEYWORDS: Floras, Similarity indices, Taipingtao, Tungshatao, Taiwan.

INTRODUCTION

The floristic survey of Taipingtao and Tungshatao brought us a rough impression of a close similarity among these islands. Especially one can understand these floras easily even one only knows the floristic composition of the Kenting National Park well. This thought has been keeping in my mind after my return from our first botanical inventory of Taipingtao and Tungshatao in 1994. For this aim, this paper intends to present the mathematic values of their floristic relationships among the islands of Taiwan, Taipingtao and Tungshatao. The floristic compositions are then, calculated by the similarity index and the common plant index.

First a brief introduction of the geographical location (Fig. 1), and climatic conditions of Taiwan proper, Kenting National Park, Taipingtao and Tungshatao (Table 1) are summarized as below.

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Location

Taiwan proper is located off the east coast of mainland China, separated from the province of Fukien by the shallow Taiwan Strait which is about 150 km wide at the narrowest part. The length of the island is about 385 km long and the maximum breadth 144 km. The total area is about 35,800 sq.km. The highest peak, Mt. Morrison has an elevation of 3950 m.

Kenting National Park is located on Hengchun Peninsula, the coastal area of southernmost part of Taiwan. It lies between 120°40' 30" – 120°49'30" east longitude and 21°50'30" – 22°08'30" north latitude. It is about 444 km distant from Tungshatao and about 1574 km distant from Taipingtao. The total land area is about 177.31 sq.km. The highest peak, Mt. Wanliteshan has an elevation of 526 m.

Taipingtao (Aba Itu Island), belonging to Kaohsiung City, Taiwan, politically, is situated on Tizard Bank and Reefs of the South China Sea at latitude 10°22'50" N and longitude 114°20'30" E about 1600 km distant from Kaohsiung Harbour, Taiwan. This island is oblong in shape extending from southwest to northeast with the longest length about 1,300 m and widest width about 400 m, and an area of 0.48 km². The island is an atoll consisting of a tropical reef covered with sandy coral and shell. It is rather flat and low with an elevation of only 4 m. The name of Taipingtao is derived from the Japanese spelling of her warship Taihei which was passed to China at the end of the second world war near this island (Huang, Huang and Yang, 1994).

Tungshatao (Pratas Island) is located at longitude 116°43' E and latitude 20°42' N, about 1185 km distant from Taipingtao. The island, oblong in shape, extends from the southeast to the northwest with two long arms extending toward the northwest, and forming a lagoon. It consists of 1.74 km² in area with its longest length about 2,800 m and widest width about 865 m. The island is a coral reef covered with sandy coral and shell. It is flat and low with elevation of no more than 50 m (Huang, Huang and Hsieh, 1994).

Climate.

The weather conditions for Taiwan proper obtained from 21 weather stations around Taiwan proper from lowest Kaohsiung station at the elevation of 2.1 m high and highest mountain station at elevation of 3884.8 m high, and Hengchun station of the Kenting National Park at elevation of 22.3 m high are as follow (Anonymous. 1981-1990):

Taiwan proper: The daily average temperature is 21.3 °C . The highest average temperature was 24.9°C while the lowest average temperature recorded between 1981-1990 was 18.5°C . The average wind speed is 3.5 m/s. The strong winter northeast monsoon, prevailing for about five months from late October to late March, brings a rainy season to the northern part of Taiwan. The southwest monsoon, beginning in early May and ceasing in late September, always brings heavy rains to the windward mountain slopes of the southern part . The average annual humidity is about 81.4 %. It rains in summer and winter. The typhoon normally blows from south to southeast from May to October. The average annual precipitation is about 2,555 mm, but the range of variation in precipitation was large in the past ten years, from 1403 mm at Wuchi station of elevation 7.2 m high to 5205.5 mm at Anpu station of elevation 825.8 m high.

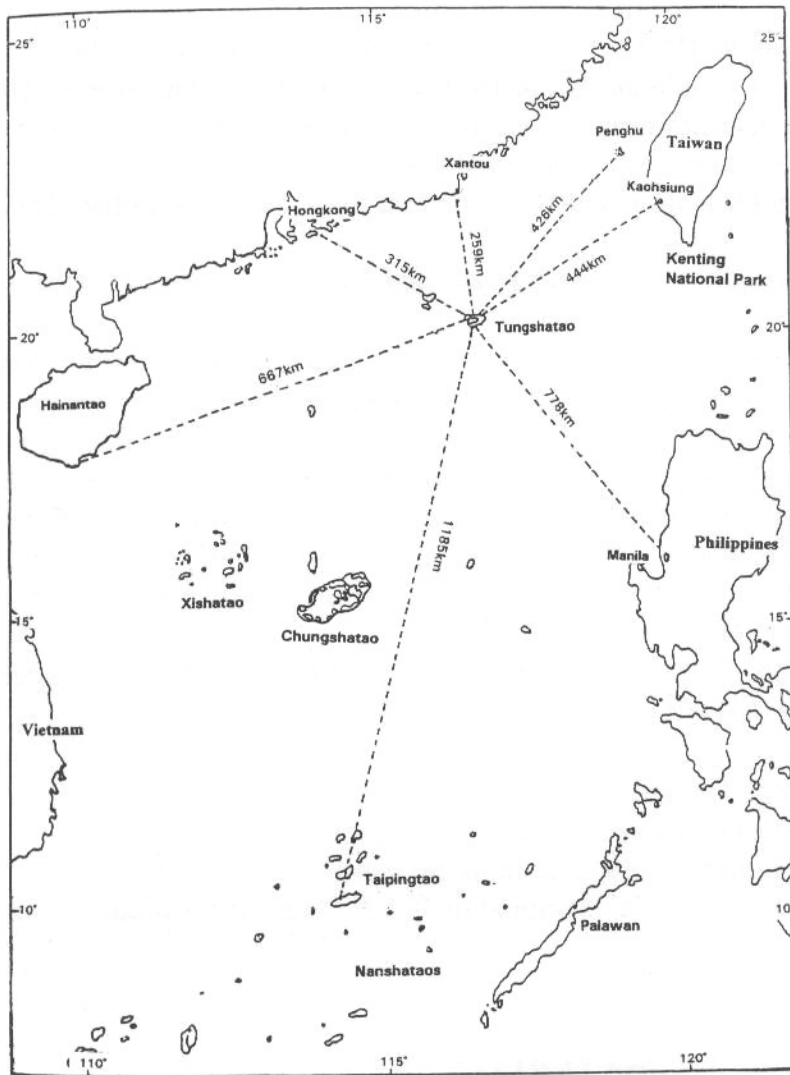


Fig. 1. Geographical location of Taiwan, Taipingtao and Tungshatao (Anonymous, 1990, revised)

Table 1. The climatic conditions among Tungshatao, Taipingtao and Taiwan proper including Kengting National Park.

	Taipingtao	Tungshatao	Kengting National Park	Taiwan proper
Daily average temperature (°C)	28.5	25.6	24.9	21.3
Daily highest temperature (°C)	37.0	34.9	28.5	24.9
Daily lowest temperature (°C)	20.2	11.0	22.1	18.5
Wind speed (m/s)	3.0	4.9	3.3	3.5
Average annual humidity (%)	83.0	84.0	76.5	81.4
Average annual precipitation (mm)	1500.0	1357.0	2045.0	2555.0

Kenting National Park: The daily average temperature is 24.9 °C . The highest temperature is 28.5°C while the lowest temperature is 22.1°C . The average wind speed is 3.3 m/s. The strong winter northeast monsoon, prevails for about five months from late October to late March. The average annual humidity is about 76.5 %. It rains in summer. The typhoons normally blow from south to southeast from May to October. The average annual precipitation is about 2,045 mm.

The weather conditions for Taipingtao and Tungshatao are as follows (Anonymous, 1989-1993).

Taipingtao: The daily average temperature is 28.5°C . The highest temperature is 37.0°C while the lowest temperature is 20.2°C . The average wind speed is 3 m/s. It blows lightly from the southwest from June to September, but sometimes, influenced by typhoons outside current, the wind is strong, up to 14 m/s. It blows from the northeast from October to April, and is rarely struck by typhoons when the wind speed may be up to 12 m/s. The average annual humidity is about 83 %. It rains in summer and winter. The average annual precipitation is about 1,500 mm, but the range of variation in precipitation was large in the past five years, from 669 mm to 2,144 mm.

Tungshatao: The daily average temperature is 25.6°C . The highest temperature is 34.9°C while the lowest temperature is 11.0°C . The average wind speed is 4.9 m/s, It often blows from the south or southwest during July and September with the wind speed no more than 10 m/s, but rarely upto 30 m/s for during typhoons from the eastsoutheast. The wind blows from the northeast or eastnortheast from October to April with the wind speed up to 20 m/s. The average annual humidity is 84%. It rains the year round but most heavily from April to September. The average annual precipitation is 1,357 mm with variation from 1,093 to 2,011 mm

MATERIALS AND METHODS

Materials

The information used for this study was obtained from floras of Taiwan island proper (Li *et al.*, 1975-1979; Huang *et al.*, 1993-1996) including Kenting National Park, Taipingtao (Huang, Huang and Yang, 1994), Tungshatao (Huang, Huang and Hsieh, 1994), Hsishachuntao (Chen *et al.* 1983), Okinawa (Walker, 1976), Philippine Flowering Plants (Merrill, 1923-1926), Malay Peninsula (Ridley, 1923-1925), and Java (Bakker and Bakhuizen van den Brink, 1963-1968).

Methods

The floristic relationship among the islands of Taiwan, Taipingtao and Tungshatao are calculated by the similarity index and the common plant index as follow:

Similarity index:

The similarity coefficient of Sorenson (1948) was used as an index of similarity of floras. It is based on the presence or absence relationship between the number of species of two floras and the total number of species listed in these two floras. Therefore, the coefficient expresses the ratio of the common species to all species found in two floras. Thus,

$$I_s = \frac{2 \times \text{common species}}{\text{total species in floras A and B}} \times 100 = \frac{2c}{a+b} \times 100$$

where I_s = index of common species to floras of A and B
 c = common species to floras of A and B
 a = total number of species in flora A
 b = total number of species in flora B

Common Plant Index:

When the two floras are not comparable in size *i.e.*, the size of a large island is more than 100 times bigger than that of a small island, the index of common plants is used to express the floristic relationship of small floras to the large one. The calculation is based on the plants common to the two floras divided by the total number of plants of the small island. Thus,

$$I_c = \frac{\text{species common to both areas}}{\text{total species in a small flora A only}} \times 100 = \frac{c}{a} \times 100$$

where I_c = index of common species in the small island of A
 c = total number of species common to floras A and B
 a = total number of species in small island A

This index is similar to its formula to the index proposed for faunistic studies by Simpson (1943) when their sizes are markedly disparate, except the objects of the concerned sizes are different, the former concerns the size of territory, while the latter considers the sizes of fauna .

$$I_c = \frac{\text{common species}}{\text{total species of smaller fauna}} \times 100 = \frac{c}{a} \times 100$$

RESULTS

Similarity index:

The total number of native vascular plants (Checklist) found in Taipingtao and Tungshatao is 123 species. Their total number of common species is 52. Thirty-six out of 88 species are only recorded in Taipingtao ("A" preceding to the name in checklist), and 35 out of 87 species are only recorded in Tungshatao ("P" preceding to the name in checklist). Therefore their floristic relationship expressed by the similarity index of these two floras is calculated by the index of similarity (I_s) of Sorenson (1948) as follow:

$$I_s = \frac{2c}{a+b} \times 100 = \frac{2 \times 52}{88 + 87} \times 100 = \frac{104}{175} \times 100 = 59.42\%$$

The I_s of both islands is 59%. Thus these islands are floristically not very closely related.

Common Plant Index:

When one compares the floras of these two islands with Taiwan proper and Kenting National Park, the similarity coefficient (I_s) can not be used effectively to express their relationship. Since the altitude, age, proximity of source areas and state of exploration (van Balgooy, 1971) are so different, especially the size relations among Taiwan proper and these two islands (Table 2) are very different in magnitude. Therefore, the relationship of these areas is expressed by using the common species recorded on the small island.

Table 2. The area km² and elevation (m) among Taipingtao, Tungshatao, Taiwan proper and Kenting National Park

	Taipingtao	Tungshatao	Kenting National Park	Taiwan proper
Area (km ²)	0.48	1.74	177.31	35,800
Highest altitude (m)	4	50	526	3950

Eleven out of 88 native species, *i.e.* *Pisonia grandis*, *Triumfetta procumbens*, *Ochrosia oppositifolia*, *Acalypha boehmerioides*, *Caesalpinia major*, *Pipturus argenteus*, *Cayratia trifolia*, *Digitaria setigera* var. *calliblepharata*, *Stenotaphrum micranthum*, and *Pandanus tectorius*, do not occur on Taiwan proper and its adjacent islands, but all occur in Malasia. The index of common plants can be calculated as:

$$I_c = \frac{c}{a} \times 100 = \frac{77}{88} \times 100 = 87.50\%$$

Tungshatao and Taiwan proper:

Six out of 87 species, *i.e.*, *Pisonia grandis*, *Triumfetta procumbens*, *Cordia subcordata*, *Suriana maritima*, *Tribulus cistoides*, *Syringodium isoetifolium* are not recorded from Taiwan proper, but all occur in Xisha Island (Chen, 1983). The index of common plants can be calculated as:

$$I_c = \frac{c}{a} \times 100 = \frac{81}{87} \times 100 = 93.10\%$$

Taipingtao and the Kenting National Park :

Thirteen out of 88 species, *i.e.*, *Pisonia grandis*, *Triumfetta procumbens*, *Ochrosia oppositifolia*, *Acalypha boehmerioides*, *Caesalpinia major*, *Pipturus argenteus*, *Cayratia trifolia*, *Digitaria setigera*, *Digitaria setigera* var. *calliblepharata*, *Stenotaphrum micranthum*, *Pandanus tectorius*, *Heliotropium ovalifolium* var. *depressum*, *Canavalia cathartica*, and *Ipomoea triloba* do not occur on Taiwan proper and its adjacent islands. The index of common plants can be calculated as:

$$Ic = \frac{c}{a} \times 100 = \frac{74}{88} \times 100 = 84.09\%$$

Tungshatao to the Kenting National Park :

Thirteen out of 87 species, *i.e.*, *Pisonia grandis*, *Triumfetta procumbens*, *Cordia subcordata*, *Suriana maritima*, *Tribulus cistoides*, *Syringodium isoetifolium*, *Heliotropium ovalifolium* var. *depressum*, *Bidens pilosa* var. *minor*, *Portulaca quadrifida*, *Lepturus repens*, *Paspalum vaginatum*, *Sporobolus virginicus*, and *Halophila ovalis*, are not recorded from Taiwan proper. The index of common plants is calculated as:

$$Ic = \frac{c}{a} \times 100 = \frac{74}{87} \times 100 = 85.06\%$$

The indicis of common plants of Taipingtao and Tungshatao to Taiwan proper and the Kenting National Park are high.

DISCUSSION AND CONCLUSION

1. The Islands of Tungshatao and Taipingtao are separated from each other by about 1185 km and this floristic affinity is not close as shown from the 59%, by similarity index (Is) of Sorenson.
2. Since Taiwan Island (or Kenting National Park), is more than 10,000 (or 100) times bigger than both Tungshatao and Taipingtao, the index of common plants (Ic) is used to express their floristic affinity.
3. The index of common species for Taipingtao to Taiwan proper is 88% and for Tungshatao to Taiwan proper is 93%. A close floristic relationship between Taiwan proper and these islands is indicated.
4. The Kenting National Park about 177.31 km² in area is located in the coastal area of southern Taiwan. It is 240 miles away from Tungshatao and about 850 miles away from Taipingtao. Although long distance separates them from Taiwan, Taipingtao and Tungshatao have indicated high indices of common plants to Kenting National Park, *i.e.*, 84% and 85% respectively. This implies that the close affinity among these islands are due to a high content of coastal elements in common. This is aslo true with Taiwan proper.
5. The similarity of Tungshatao and Taipingtao flora's with the Philippines and Malesia is not accountable at the moment, since the projects for Floras of the Philippines supported by the Philippine National Museum and the Botanical Research Institue of Texas, and for the Flora Malesiana project supported by the Rijksherbarium/Hortus Botanicus are still on going. I am sure that if the entire floras of the Phillipines and Malesia were properly known, the islands might even have a 100% index of common plants with the Flora of the Philippines (personal comment by P. Baas).

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Checklist of native vascular plants of Tungshatao and Taipingtao

(P) = plants occur in **Tungshatao only** and (A) = plants occur in **Taipingtao only**.

- (A) *Nephrolepis auriculata* (L.) Trimen
 (A) *Nephrolepis biserrata* (Sw.) Schott.
 (A) *Psilotum nudum* (L.) Beauv.
 (A) *Blechnum pyramidatum* (Lam.) Urban
Sesuvium portulacastrum (L.) L.
 (P) *Trianthema portulacastrum* L.
Achyranthes aspera L. var. *indica* L.
 (P) *Celosia argentea* L..
 (A) *Ochrosia oppositifolia* (Lam.) K.Schum.
 (A) *Ehretia resinosa* Hance
 (P) *Cordia subcordata* Lam.
Heliotropium ovalifolium Forssk. var. *depressum* (Cham) Merr.
Messerschmidia argentea (L.) Johnston
 (P) *Cleome gynandra* L.
Terminalia catappa L.
Bidens pilosa L.
 (P) *Bidens pilosa* L. var. *minor* (Bl.) Sherff
 (A) *Eclipta prostrata* L.
 (T) *Erigeron bonariensis* L.,
 (A) *Synedrella nodiflora* (L.) Gaert.
Tridax procumbens L.
Vernonia cinerea (L.) Less.
Wedelia biflora (L.) DC
 (A) *Ipomoea gracilis* R. Br.
 (P) *Ipomoea nil* (L.) Roth.
Ipomoea obscura (L.) Ker-Gawl.
Ipomoea pes-caprae (L.) Sweet subsp. *brasiliensis* (L.) Oostst.
 (A) *Ipomoea triloba* L.
Ipomoea tuba (Schlecht.) G. Don
 (A) *Acalypha boehmerioides* Miq.
 (P) *Acalypha indica* L.
Chamaesyce atoto (Forst. f.) Croizat
Chamaesyce hirta (L.) Millsp.
 (A) *Chamaesyce prostrata* (Ait.) Small
 (P) *Chamaesyce tashiroi* (Hayata) Hara
 (A) *Chamaesyce thymifolia* (L.) Millsp.
 (A) *Flueggea virosa* (Roxb. ex Willd.) Voigt
Phyllanthus urinaria L.
Scaevola tascada (Gaertner) Roxb.
Calophyllum inophyllum L.
 (A) *Hernandia sonora* L.
 (A) *Barringtonia asiatica* (L.) Kurz.

- Cassytha filiformis* L.
Alysicarpus vaginalis (L.) DC.
Caesalpinia bonduc (L.) Roxb..
(A) *Caesalpinia major* (Medik.) Dandy & Exell
(A) *Canavalia cathartica* Thou.
(P) *Canavalia rosea* (Sw.) DC.
(A) *Desmodium scorpiurus* (Sw.) Desv.
Erythrina variegata L.
Mimosa pudica L.
(P) *Senna occidentalis* (L.) Link
Senna tora (L.) Roxb.
Sesbania cannabina (Retz.) Poir.
Sophora tomentosa L.
(A) *Vigna adenantha* (G.F.Meyer) Marechal et al.
Vigna marina (Burm.) Merr.
(P) *Abutilon indicum* (L.) Sweet
Malvastrum coromandelianum (L.) Garcke
(P) *Sida acuta* Burm. f.
(A) *Sida veronicaefolia* Lam.
Ficus microcarpa L. f..
(P) *Ficus septica* Burm. f.
(P) *Morus australis* Poir.
Boerhavia diffusa L.
Pisonia grandis R.Br
(P) *Passiflora foetida* L. var. *hispida* (DC.) Killip
Portulaca oleracea L.
(P) *Portulaca quadrifida* L.
Colubrina asiatica (L.) Brongn.
(A) *Dentella repens* (L.) Forst.
Guettarda speciosa L.
Hedyotis corymbosa (L.) Lam.
(P) *Hedyotis paniculata* (L.) Lam.
Morinda citrifolia L.
Allophylus timorensis (DC.) Blume
(P) *Suriana maritima* L.
(P) *Datura metel* L.
Physalis angulata L.
Solanum nigrum L.
Corchorus aestuans L.
Triumfetta procumbens Forst. f.
(A) *Pipturus argenteus* (Forst. f.) Wedd.
(P) *Clerodendrum inerme* (L.) Gaertn.
(A) *Phyla nodiflora* (L.) Greene.
(A) *Premna obtusifolia* R. Brown
Stachytarpheta urticaefolia (Salisb.) Sims.

- Cayratia trifolia* (L.) Domin
(P) *Tribulus cistoides* L.
(P) *Crinum asiaticum* L.
(P) *Epipremnum pinnatum* (L.) Engl.
Typhonium divaricatum (L.) Decne.
(P) *Halodule uninervis* (Forsk.) Aschers.
(P) *Syringodium isoetifolium* (Aschers.) Dandy
(A) *Cyperus compressus* L.
Cyperus rotundus L.
(A) *Fimbristylis cymosa* R. Br.0
(A) *Mariscus javanicus* (Houtt.) Merr. & Metcalfe
Brachiaria subquadripara (Trin.) Hitchc.
Cenchrus echinatus L.
(P) *Chloris barbata* Sw.
Cynodon dactylon (L.) Pers.
Dactyloctenium aegyptium (L.) Beauv.
(A) *Digitaria setigera* R. & S.
(A) *Digitaria setigera* R. & S. var. *calliblepharata* (Henr.) Veldk.
Eleusine indica (L.) Gaertn.
(P) *Eragrostis amabilis* (L.) Wight & Arn. ex Nees
(P) *Imperata cylindrica* (L.) Beauv. var. *major* (Nees) Hubb. ex Hubb & Vaughan
(P) *Lepturus repens* (G. Forst.) R. Br.
Panicum repens L.
(P) *Paspalum vaginatum* Sw.
Pennisetum setosum (Sw.) L. C. Rich.
(A) *Sorghum nitidum* (Vahl) Pers
(A) *Sporobolus diander* (Retz.) Beauv.
(P) *Sporobolus virginicus* (L.) Kunth
(A) *Stenotaphrum micranthum* (Desv.) C. E. Hubb.
Thuarea involuta (Forst.) R. Br. ex Roem. & Schult.
(P) *Zoysia tenuifolia* Willd. ex Trin.
(P) *Halophila ovalis* (R. Br.) Hook. f.
Thalassia hemprichii (Ehrenb.) Aschers.
(P) *Pandanus odoratissimus* L. f.
(A) *Pandanus tectorius* Sol.

台灣本島、太平島和東沙島之植物區系關係⁽¹⁾黃增泉^(2,3)

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摘 要

本文首次探討台灣本島及太平島和東沙島間之植物區系關係。植物區系乃表示兩地植物相的相似度，本文採用 Sorenson (1948) 計算法，由此所得太平島及東沙島之相似度 (Is) 為 59.43%，顯示此兩島的區系關係並不算密切。

當兩島(地)面積大小懸殊，難以比較時(大小相差百倍以上)，以兩島(地)之共有度 (Ic) 表示小島相對於大島的植物區系關係。計算法是根據兩地共有的種類，除以小島的總種數；依此法可求得太平島、東沙島相對於台灣本島的共有度值分別為 87.50% 及 93.10%。本文所提共有度 (Ic) 和動物學者 Simpson (1943) 所提之公式，頗有類同。

若以兩島和台灣海岸地區之墾丁國家公園比較，求得之共有度值太平島為 84.09%，東沙島為 85.06%。其植物區系關係具有高度類似性，由此推論，最主要原因係其植物相皆具有高度海岸植被因子所組成。

關鍵詞：植物相，區系關係，太平島，東沙島，台灣，墾丁國家公園。

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