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# 墾丁國家公園海域軟珊瑚類的研究

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內政部營建署墾丁國家公園管理處

中華民國七十七年十月

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# 中文摘要

本研究針對墾丁國家公園海域獨特的軟珊瑚類資源進行其系統分類、生殖週期、生態功能及成長速率的調查。

軟珊瑚的系統分類依據其群體形態、珊瑚虫的構造及骨針的特徵等三項重要特徵，鑑定出 32種，分屬於冠形軟珊瑚（*Alcyonium*）3種、指形軟珊瑚(*Sinularia*）16種、葉形軟珊瑚（*Lobophytum*）6種、肉質軟珊瑚（*Sarcophyton*）6種及穗珊瑚（*Nephthea*）1種，本省沿海的軟珊瑚生物相屬於印度、西太平洋系統之一部，其種歧異度與琉球群島及海南島者相似。

軟珊瑚類生殖週期的研究經標識追蹤三種軟珊瑚：花環肉質軟珊瑚（*Sarcophyton trocheliphorum*）、肥厚肉質軟珊瑚（*Sarcophyton crassocaule*）和肉質葉形軟珊瑚（*Lobophytum sarcophytoides*）生殖腺發育的情形發現其生殖排卵期，可能在八～九月間或四～六月間。

軟珊瑚移植實驗的結果顯示，軟珊瑚分佈的差異，可能與海流能量的強弱有關；南灣東側沿岸的軟珊瑚分佈甚少，可能係由於該區弱的海流無法滿足其生理需求所致。

競爭能力的分析顯示，軟珊瑚在空間的競爭上屬於弱勢者，軟珊瑚造礁功能之調查發現，指形軟珊瑚（*Sinularia spp.*）基部的骨針通常有膠結形成岩石的現象，其他之軟珊瑚則未發現有直接造礁的情形。

## ABSTRACT

This report presents a preliminary study on the systematics, reproductive cycles, growth rates, and ecological roles of alcyonacean soft corals in the Kentin National Park area. It is concluded that colony morphology, polyps, and sclerites are the most important characters in alcyonacean systematics. Thirty-two species, including 3 species of Alcyonium, 16 species of Sinularia, 6 species of Lobophytum, 6 species of Sarcophyton, and 1 species of Nephthea, have been identified according to the morphological characters. The alcyonacean fauna of the study area is a part of the Indo-West Pacific province. Studies on the reproductive cycles of three of the most abundant alcyonacean corals, Sarcophyton trocheliophorum, S. crassocaule, and Lobophytum sarcophytoides, have revealed that the possible spawning seasons of these three species are August-September or/and April-June. Transplantation studies on the distribution of alcyonacean corals showed that the impoverished alcyonacean fauna on the east side of Nanwan Bay is possible due to low water energy of the environment and the physiological restrictions of alcyonacean corals. Studies on the competitive abilities of alcyonacean corals indicate that alcyonacean corals are subordinate and they often suffer tissue damage by scleractinian corals. Investigation on the reef-building function of alcyonacean corals has revealed that species of Sinularia often build rock on their colony base while species of other genera do not have this function.

# 前　言

軟珊瑚類是墾丁國家公園海域生態系中最重要的自然資源之一。它們具有優美的形態、鮮艷的色彩和亮麗的外觀，是海洋中最引人注目的焦點；尤其它們柔軟的群體，會隨海流而擺動，爲平靜的海底增添許多的生動和撫媚；無疑地，它們是國家公園海域中非常重要的景觀和生態資源。此外，大部份的軟珊瑚都含有豐富的化學物質，由軟珊瑚群體所分離出來的化學物質，已被證實能抑制癌細胞的增長，具有做爲天然藥物的潛力，其經濟價值，正在由科學家評估中，因此，軟珊瑚可說是具有多重價值的海洋生物。

軟珊瑚在分類上屬於刺絲胞（或腔腸）動物門；珊瑚蟲綱、八放珊瑚亞綱的海雞頭目（或稱軟珊瑚目）。它們在墾丁國家公園內分佈相當廣泛，但是由於它們的分類非常困難，因此，有關其生態習性，族群特徵和生活吏等資料，也鮮爲人知。根據張等（1985,1986），戴（1986）的研究，共記錄了39 種的軟珊瑚，然而由於該研究的重點在石珊瑚類，對於數量也很多的軟珊瑚類，因工作時間的限制，並未做深入的研究，因此，國家公園海城實際所有的軟珊瑚種類，可能遠超過此，亟須進一步的研究，予以發掘。同時軟珊瑚資源保育所需的資料，如：族群特徵、生殖週期、生活史等也都缺乏，亟須專門的研究，以充實海域生態保育的資料。此外軟珊瑚在國家公園海域內的分佈並不平均，它們主要分佈在後壁湖至貓鼻頭、白沙附近和鵝鑾鼻附近的沿岸海域，其餘地區如：萬里桐、潭子灣、香蕉灣等海域則相當稀少，造成這種分佈差異的原因，也是值得深入研究的課題。

本計畫即根據軟珊瑚類資源保育、解說和開發利用的需要，對軟珊瑚的分類、生態、生理和生活史進行全盤的研究，其結果將能充實國家公園海域內軟珊瑚的分類資料，增進對軟珊瑚生態習性及經濟價值的瞭解，以做爲資源保育與復育的基礎，並可做爲開發利用軟珊瑚資源的參考。

# 研究項目及方法

## 一、軟珊瑚的分類：

採用野外實地觀測記錄和實驗室的分析分別進行。在野外，以潛水方式測量軟珊瑚群體及珊瑚蟲的形態特徵，拍攝生態照片，並採取標本，以 10％ 福馬林溶液固定之，攜回實驗室後，先在解剖顯微鏡下觀察外形，再取群體組織的一小塊，置於 20％ KOH 溶液中，在加熱的狀態下，溶去其組織析出骨針，在投影式解剖顯微鏡下觀察繪圖，必要時以掃描式電子顯微鏡拍攝骨針照片做爲分類的依據。

## 二、軟珊瑚類生殖週期的研究：

生殖週期是任何一種生物保育和復育的必須資料，而其研究工作也最繁雜，本研究選擇三種軟珊瑚類：花環肉質軟珊瑚、肥厚肉質軟珊瑚和肉質葉形軟珊瑚，每種固定標示 10 顆大型群體，每月採集其群體的一部份，同時每月也逢機採取其他種類的軟珊瑚群體的部份，以 10％ 福馬林溶液固定後，攜回實驗室做進一步研究，在採取軟珊瑚標本之時，也量取群體的大小，以探討其性成熟的群體大小和年齡。在實驗室中，以解剖顯微鏡觀察及測量軟珊瑚之卵巢和精巢的大小，以估計其孕卵數和生殖季節，並以染色切片的方法，觀察生殖腺發育的情形。經福馬林及酒精處理後之生殖腺，一般已無法用顏色來判別其雌雄。Benayahu and Loya ( 1986 ) 研究藍綠肉質軟珊瑚 ( *Sarcophyton glaucum* ) 指出，卵細胞每年都可發生，但需兩年的時間才成熟，排出體外受精，因此由於生長時間之不同，會形成兩種大小之卵細胞群，而精巢則雖也每年發生，但一年即可成熟排出體外，不會形成大小兩群之精巢，所以據此現象以判斷其爲精巢或卵巢。

## 三、軟珊瑚類分佈情形的探討：

生物的分佈，往往是反映環境條件的表徵。軟珊瑚類在國家公園內，以後壁湖、貓鼻頭、白沙和鵝鑾鼻附近較多，是優勢種類，在其他地區則甚少，造成此種分佈差

異的原因頗值探討。移植是探討軟珊瑚分佈的直接方法，本研究把原來生長在軟珊瑚區的群體，移植到石珊瑚區，觀察其生長和生活情形，以探討影響其分佈的原因。本項實驗，於 76 年二月間，移植原來生長在軟珊瑚區的花環肉質軟珊瑚（*Sarcophyton trocheliophorum*）、肉質葉形軟珊瑚（*Lobophytum sarcophytoides*）及肥原肉質軟珊瑚（*Sarcophyton crassocaule*）各 10 顆，和指形軟珊瑚（*Sinularia* spp.）等共 44 顆軟珊瑚群體，栽植於石珊瑚區水深 12m 處。選擇頭冠部面積在 90～180$cm^2$ 的軟珊瑚群體，以鐵鎚及鑿子敲開其基部，並留下一小塊岩石供其附著及固定，分離之群體立即置於裝滿海水之大水桶內，運至石珊瑚區（眺石附近），栽植在塑膠花盆中，花盆並固定於鋼架上，每月測量，觀察及記錄群體大小變化的情形。測量頭冠部兩個互相垂直的直徑，據此以計算其面積。

## 四、軟珊瑚生態功能的探討：

軟珊瑚類廣泛分佈於熱帶印度、太平洋的珊瑚礁區，但是其生態功能和其在珊瑚礁生態系中的角色，至今仍鮮爲人知。它們對珊瑚礁成長的貢獻，大致可分爲兩方面，一方面是軟珊瑚類碳酸鈣質的骨針可能是構成珊瑚礁沉積物的重要成份，另一方面，軟珊瑚類可能對珊瑚礁的膠結、鞏固和成長有直接的貢獻。欲探討這個問題也可以從兩方面著手，其一是分析珊瑚礁沉積物中軟珊瑚類骨針的含量，另一則是測量大型軟珊瑚群體基部石灰質骨骼增加的速率。本項研究分別在雷打石、眺石及石頭坡附近海底，和核三廠出水口、南灣、船帆石及砂島沙灘等地區各採取五個 740立方公分的標本。採回之標本在 100℃下，烘乾 48 小時。烘乾的標本，使用 4mm, 2mm, 1mm, 0.5mm, 0.25mm 及 0.125mm 等 6 個網目，依次篩取，並測量每一標本各網目篩得的沉積物重量及重量百分比。再以解剖顯微鏡放大 12 倍觀察，記錄每一標本各網目所篩得之沉積物的骨針數及總骨針數。此外，研究期間亦廣泛調查軟珊瑚類造礁的情形，調查方法爲用直徑 4 公分的不銹鋼管，在軟珊瑚群體的中央垂直採取岩心，觀察該種軟珊瑚是否有建造礁岩的特性。

## 五、軟珊瑚的成長速率的研究：

成長速率是生物體和生物族群的一項重要特徵，也是擬定保育計畫時的必需資料

。本研究針對國家公園海域中數量最多，分佈最廣的三種軟珊瑚——花環肉質軟珊瑚、肥厚肉質軟珊瑚和肉質葉形軟珊瑚，以 Alizarin-Red-S 染色和標識追蹤群體面積增加的方法，研究其成長速率。

# 結果與討論

## 一、軟珊瑚的分類：

1. 檢索表：

由分析135個軟珊瑚標本的骨針及外部形態，共得 31 種軟珊瑚，其分類檢索如下：

1a. 珊瑚虫（或稱水螅體）具兩種形態…… 2

1b. 珊瑚虫只具一種形態…… 3

2a. 群體蕈狀，具明顯的柱部和頭冠部，頭冠部邊緣往往具褶起；群體內部共肉的骨針紡錘形，外側表皮的骨針小棍棒狀……*Sarcophyton* 肉質軟珊瑚…… 6

2b. 群體通常呈扁平或厚的表覆形，可能具有短的柱部，但分界不明顯；共肉內部骨針紡錘形，其表面的疣突常排列成環，……*Lobophytum* 葉形軟珊瑚…… 11

3a. 群體厚、團塊形，群體表面扇形或葉形…… 4

3b. 群體直立、葉形，但非團塊形；骨針爲多棘的紡錘形和啞鈴形……*Alcyonium* 冠形軟珊瑚…… 5

4a. 骨針主要爲粗大、多棘的雙星形；群體表面的突起短、呈圓形……*Cladiella* 瘤形軟珊瑚

4b. 骨針主要是大的紡錘形，表皮層的骨針則爲小棍棒形；群體表面具複雜的球形或指狀突起，突起可能具次生的分枝……*Sinularia* 指形軟珊瑚…… 15

5a. 骨針呈平滑的紡錘形，表面具有少數顆粒狀突起，部份的骨針較短，呈棍棒狀……*A. Simplex* 簡易冠形軟珊瑚

5b. 骨針多數爲寬圓的姆指形或圓柱形，具有少數的突起；頭冠部分枝的骨針爲紡錘形，表面具有尖細的棘……*A. molle* 柔軟冠形軟珊瑚

5c. 骨針多數爲寬，廣的柱形或橢圓形，兩端稍膨大且鈍，表面密佈圓丘形或棘刺形的突起，部份橢圓形骨針的中央具有凹入的環，形似啞鈴……*A. rotundum* 圓實冠形軟珊瑚

6a. 共肉的骨針短，在 0.40mm以內 …… 7

6b. 共肉的骨針長可達 0.50mm以上 …… 9

7a. 共肉的骨針，形態不規則，往往呈四角形，骨針上的疣突，在兩端排列成環 …… *S. stellatum* 星形肉質軟珊瑚

7b. 柱部內側骨針，主要爲粗短的桶形，疣突成二環排列 …… 8

8a. 共肉的骨針長在 0.25mm以內，小棍棒形，頭部不明顯，群體肥厚盤狀 …… *S. crassocaule* 肥厚肉質軟珊瑚

8b. 共肉的骨針長約 0.28～0.35mm，小棍棒形，頭部明顯，群體蕈狀 …… *S. trocheliophorum* 花環肉質軟珊瑚

9a. 共肉的骨針長約 1.30～2.30mm，群體蕈狀，邊緣多褶 …… *S. glaucum* 藍綠肉質軟珊瑚

9b. 共肉的骨針短於 1.30mm …… 10

10a. 群體杯形或漏斗形，邊緣薄，頭冠部內側骨針具鹿角狀突起，共肉骨針紡錘形 …… *S. ehrenbergi* 杯形肉質軟珊瑚

10b. 群體低矮，頭冠部薄，邊緣具許多褶，管狀體小，共肉骨針通常不超過 0.50mm …… *S. tortuosum* 卷曲肉質軟珊瑚

11a. 柱部內層骨針絞車形，長 0.15～0.20mm …… 12

11b. 柱部內層骨針絞車形和延長形，長約 0.20～0.30mm …… 14

11c. 柱部內層骨針皆爲紡錘形，長在 0.3mm 以上，群體碟形，邊緣較高，表層骨針 0.07～0.15mm …… *L. sarcophytoides* 肉質葉形軟珊瑚

12a. 柱部內層可能具紡錘形骨針，長度在 0.30mm 以內 …… 13

12b. 柱部內層可能具紡錘形骨針，長度約 0.32～0.35mm，群體的頭冠部具雞冠形的脊，脊薄（約 3mm厚），常層疊如覆瓦狀 …… *L. mirabile* 聚集葉形軟珊瑚

13a. 頭冠部具厚、指形的突起，分佈稀疏，高可達 3mm，柱部內層絞車形骨針，具有腰環 …… *L. solidum* 實葉形軟珊瑚

13b. 頭冠部具密集分佈的突起，高約 15mm，柱部內層絞車形骨針，具有短的腰環 …… *L. strictum* 小葉形軟珊瑚

14a. 柱部內層具紡錘形骨針，長度在 0.3mm 以上，葉形突起厚約 6～9mm，直立、

不重疊，略成輻射狀…… *L. altum*

14b. 柱部內層不具長度在 0.3mm 以上的紡錘形骨針，群體具有許多指狀的突起，表層骨針主要爲紡錘形…… *L. pauciflorum* 簡單葉形軟珊瑚

15a. 指形突起的表層，幾乎不具棍棒形骨針…… 16

15b. 指形突起的表層，具許多棍棒形骨針…… 17

16a. 柱部表層的骨針長約 0.14～0.19mm ，突起內層的骨針少或無，柱部內層骨針紡錘形，長可達 6.25mm ；群體具有短、指狀的突起…… *S. mollis* 肉質指形軟珊瑚

16b. 柱部表層骨針 0.07～0.13mm ，三角形或卵圓形，柱部內層骨針，長可達 3.40mm …… *S. flexibilis* 柔軟指形軟珊瑚

17a. 棍棒形骨針的頭部具有許多葉形突起…… 18

17b. 棍棒形骨針的中央，具有一環的突起…… 21

17c. 棍棒形骨針的形態與上述不符…… 26

18a. 群體碟形，邊緣向上彎曲，表面的突起少，分佈疏、不規則…… *S. facile* 簡易指形軟珊瑚

18b. 群體非碟形，具有許多突起…… 19

19a. 群體具有雞冠形或扇形的突起，柱部的棍棒形骨針多疣突，棍棒的基部，具許多圓形的結節……*S. muralis* 緣葉指形軟珊瑚

19b. 群體具有許多結節狀的突起…… 20

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20b. 棍棒形骨針 0.08～0.10mm 長，突起上的骨針，尚有桿形和紡錘形，長 0.14～0.22mm …… *S. exilis* 分離指形軟珊瑚

21a. 棍棒形骨針，長約 0.08～0.10mm ，極少較長的骨針…… 22

21b. 棍棒形骨針，長在 0.10mm 以上，極少短的骨針…… 23

22a. 群體表面的突起粗大，高可達 12cm ，基部厚 3cm……*S. grandilobata* 巨大指形軟珊瑚

22b. 群體表面的突起小而多，高可達 4cm ，厚 1.5cm ，棍棒形骨針長約 0.08～

0.15mm …… *S. gibberosa* 脈結指形軟珊瑚

23a.共體的骨針往往具分枝或分叉，群體具明顯的柱部或表覆形，突起指形、分枝形，分佈密集……*S. polydactyla* 衆多指形軟珊瑚

23b.共體的骨針極少分枝或分叉形…… 24

24a.群體表面的突起高，可達 5cm…… 25

24b 突起較短，圓形或扁平形，內層骨針具有密集的疣突……*S. numerosa* 聚集指形軟珊瑚

25a.突起不規則，表面粗糙，棍棒形骨針 0.10～0.20mm 長，柱部內層骨針，長度達 5mm…… *S. scabra* 鱗指形軟珊瑚

25b.突起扁平、平滑，棍棒形骨針長約 0.09～0.14mm 突起內層的骨針爲細長、彎曲的紡錘形…… *S. halversono* 哈氏指形軟珊瑚

26a.棍棒形骨針的長度約 0.06～0.12mm …… 27

26b.棍棒形骨針的長度在 0.12mm 以上，群體具直立、長和分枝的指狀突起，共肉的骨針具分叉，形態不規則……*S. inexplicita* 混淆指形軟珊瑚

27a.突起短，扁平或呈結節狀，具有小、顆粒狀的疣突，群體具高度不等的柱部……*S. granosa* 顆粒指形軟珊瑚

27b.突起較長，指形，具有分枝…… 28

28a.突起的分枝短，指形或結節狀，分佈密集，共體的骨針具有不規則的疣突…… *S. pavida* 冠指形軟珊瑚

28b.分枝細長、不規則，寬約 2mm 棍棒形骨針多數約 0.08～0.10mm 長，頭部具鈍棘，共體骨針長在 5mm 以上…… *S. lochmodes* 叢指形軟珊瑚

Annotated List of Species

Order ALCYONACEA Lamouroux, 1812

Family ALCYONIIDAE Lamouroux, 1812

Genus Alcyonium Linnaeus, 1758

Alcyonium is easily distinguished from Sirularia by the absence of very large stem spindles and the dense outer layer of clubs found in Sinularia (Figure 10). Living Alcyonium is softer and more slippery to the touch than Sinularia.

Alcyonium simplex Thomson and Dean, 1931 (Figure 1)

Reference: Thomson and Dean (1931) p. 43, pl. 8 fig. 2, pl. 13 fig. 3.

Colony much branched with short, blunt lobes and short stalk. Sclerites spindle-shaped with few or no prominences.

Distribution: Indonesia, Southern Taiwan.

Alcyonium molle Thomson and Dean, 1931 (Figure 2)

Reference: Thomson and Dean (1931) p. 43, pl. 8 fig. 3, pl. 24 fig. 4.

The colony is softer in texture and the zooids are less crowded than S. simplex. Sclerites are biscutlike or oval shaped with more prominences.

Distribution: Indonesia, Southern Taiwan.

Alcyonium rotundum Thomson and Dean, 1931 (Figure 3)

Reference: Thomson and Dean (1931) p. 43, pl. 12 fig. 1, pl. 24 fig. 8.

The colony is stiffer with numerous fingerlike secondary lobes. Sclerites are mostly short, broad, blunt-ended or rotund.

Distribution: Indonesia, Southern Taiwan.

Genus Sinularia May, 1898

Sinularia is readily distinguishable by its monomorphic zooids and by the fact that its capitulum is not delimited from its sterile stalk. The inner sclerites are very large warted spindles up to 1 cm long. The typical sclerites of this genus are shown in Figure 10. Living colonies of Sinularia are usually stiffer in texture than Alcyonium.

Sinularia densa (Whitelegge, 1897)

Reference: Verseveldt and Alderslade (1982) p. 625, fig. 3 pl. 5A.

The colony of this species is low with numerous short blunt-ended lobes. Sclerites from surface of lobes are mostly clubs and those from coenenchyme are pointed spindles.

Distribution: Widely distributed in the West Pacific.

Sinularia exilis Tixier-Durivault, 1970

Reference: Verseveldt (1980) p. 51, fig. 20, pl. 14 fig. 2.

The colony is encrusting with widely spaced, blunt, low lobes or processes Sclerites from surface layer are leaf-clubs.

Distribution: Bay of Nah Trang, Vietnam; Southern Taiwan.

Sinularia facile Tixier-Durivault, 1970

Reference: Verseveldt (1980) p. 53, fig. 21, pl. 13 fig. 3.

The colony is encrusting with higher stalk and larger, ridgelike lobes.

Distribution: Bay of Nah Trang, Vietnam; Southern Taiwan.

Sinularia flexibilis (Quoy & Gaimard, 1833)

Reference: Verseveldt (1980) p. 54, fig. 23.

This species is easily distinguishable by the long, slender tube-like lobes.

Distribution: Widely distributed in the Indo-Pacific Ocean.

Sinularia gibberosa Tixier-Durivault, 1970

Reference: Verseveldt (1980) p. 61, fig. 27, pl. 27, 28.

The colony is high with elongated stalk. The cpaitulum consists of lobes in groups which often form hillock-shaped rosettes.

Distribution: Bay of Nah Trang (Vietnam), Seychelles, Southern Taiwan.

Sinularia grandilobata Verseveldt, 1980

Reference: Verseveldt (1980) p. 63-65, fig. 28, pl. 19.

The colony is high and bushlike with a thick stalk and numerous large, long, stiff lobes on the capitulum.

Distribution: Mindoro (Philippines), Southern Taiwan.

Sinularia granosa Tixier-Durivault, 1970 (Figure 10)

Reference: Verseveldt (1980) p. 73, fig. 35, pls. 24, 29.

The colony consists of several large elongated lobes with a number of digitiform lobules or protuberances and a stalk of 3-5 cm high.

Distribution: Bay of Nah Trang (Vietnam), Great Barrier Reef, Southern Taiwan.

Sinularia lochmodes Kolonko, 1926

Reference: Verseveldt (1980) p. 80, figs. 39, 40.

The colony consists of lobes with small, elongated lobules and a stalk of 2-3 cm high.

*Distribution: Widely distributed in the West Pacific.*

Sinularia mollis Kolonko, 1926

Reference: Verseveldt (1980) p. 92, fig. 47, pl. 24.

The colony consists of a long stalk and a capitulum with numerous long, slender lobes. Surface layer of lobes without sclerites.

Distributuon: West Pacific from the Philippines to Okinawa.

Sinularia muralis May, 1899

Reference: Verseveldt (1980) p. 94, fig. 48, pl. 30.

The colony consists of a thick basal plate with wide, sinuous crests and a low, broad stalk.

Distribution: Sri Lanka, Southern Taiwan.

Sinularia numerosa Tixier-Durivault, 1970

Reference: Verseveldt (1980) p. 96, figs. 49, 50.

The capitulum is densely covered with blunt finger like lobules. Sclerites from coenenchyme are up to 3.5 mm long and about 0.5 mm wide.

Distribution: New Caledonia, West Madagascar, Southern Taiwan.

Sinularia polydactyla (Ehrenberg, 1834)

Reference: Verseveldt (1980) p. 108, fig. 57.

The colony is densely lobed with varying lengths of fingerlike lappets and in all spiculation shows the very long pointed spindles.

Distribution: Widely distributed in the Indian and the Pacific Ocean.

Sinularia scabra Tixier-durivault, 1970

Reference: Verseveldt (1980) p. 118, fig. 63, pl. 36.

The colony is small with densely lobed capitulum and an indistinct stalk. Sclerites from coenenchyme are often in irregular shapes.

Distribution: Bay of Nah Trang (Vietnam), Southern Taiwan.

Genus Lobophytum Von Marenzeller, 1886

The colony may be either low, encrusting, or dish-shaped with a distinct stalk. Polyps are dimorphic; both siphonozooids and autozooids exist on the capitulum. It differs with Sarcophyton by its capitulum with crests or fingerlike, lobes and by its low colony. Figures 7-9 shows its typical sclerites.

Lobophytum batarum Moser, 1919

Reference; Verseveldt (1983) p. 16, figs. 2, 3, pl. 7 fig. 1.

The living colony is low and encrusting with densely folded capitula. The autozooids and siphonozooids are small with a distance about 1 mm between them.

Distribution: Philippines, Okinawa, Madagascar, Vietnam, Southern Taiwan.

Lobophytum crassum Von Marenzeller, 1886

Reference: Verseveldt (1983) p. 25-32, figs. 8, 9. pls. 4-6.

The colony is flat with a broad capitulum and a low stalk. The capitulum is irregularly folded with cockscomblike crests.

Distribution: Widely distributed in the Indo-West Pacific tropical areas.

Lobophytum miraabile Tixier-Durivault, 1956 (Figure 7)

Reference: Verseveldt (1983) p. 70-72, fig. 34, pl. 19.

The capitulum is dnesely lobed with sinuous crests. Sclerites from surface layer are clubs of 0.10 to 0.25 mm long and those from coenenchyme are spindles of 0.2 to 0.3 mm long.

Distribution: Pacific Ocean, Madagascar.

Lobophytum pauciflorum (Ehrinberg, 1834) (Figure 8)

Reference: Verseveldt (1983) p. 74-79, figs. 36, 37.

The colony is low and encrusting. The capitulum is flat with erect, digitiform lobes. Sclerites from surface layer of lobes are mostly fusiform. Distribution: Widely distributed in the Indo-West Pacific seas.

Lobophytum sarcophytoides Moser, 1919 (Figure 9)

Reference: Verseveldt (1983) p. 86-89, fig. 43, pls. 26, 27.

The colony is flat with open folds and digitiform of crestlike lobes. Sclerites from surface layer are small clubs and those from interior part are slender spindles.

Distribution: West Pacific and Madagascar.

Lobophytum solidum Tixier-Durivault, 1970

reference; Verseveldt (1983) p. 91, fig. 45, pl. 18.

The colony is erect and usually small. The cpaitulum is folded with slender, fingerlike lobes.

Distribution: New Caledonia, Southern Taiwan.

Genus Sarcophyton Lesson,

The colony is usually mushroom-shaped. The capitulum is smooth and only folded on the margin. Polyps are dimorphic.

Sclerites from the surface layer are cluds and those from the coenenchyme are spindles or rods. Figures 5-6 shows its typical sclerites.

Sarcophyton crassocaule Moser, 1919 (Figure 5)

Reference: Verseveldt (1982) p. 27-34, figs. 9-11, pls. 5-8.

The colony is thick with flat, basin-like capitulum. The capitulum has distinct, thick folds on the margin. The colony may reach up to 2 m in diameter.

Distribution: Widely distributed in the West Pacific.

Sarcophyton ehrenbergi Von Marenzeller, 1886

Reference: Verseveldt (1982) p. 40-48, figs. 14-17, pls. 10, 12.

The species' is distinguished by its cup-shaped capitulum. The capitulum is thin and folded in the margin.

## 二、軟珊瑚生殖週的期研究：

本項研究在 76 年 2 月間即先行在雷打石附近，標定 30 顆軟珊瑚群體，分別屬於肉質軟珊瑚（ *Sarcophyton* ）。葉形軟珊瑚（ *Lobophytum* ）及指形軟珊瑚（ *Sinularia* ）各 10 顆；自二月起按月採取標本，進行其生殖腺的測量及追蹤其生殖腺的發育情形。但是，由於受到九月間兩個強烈颱風：傑魯得和琳恩，強風巨浪侵襲的影響，所標示的群體，幾乎全部遺失。因此，另於 10 月間重新標識 55 顆群體，並於 11 月起採取標本，繼續進行本項研究。

觀察結果發現軟珊瑚的生殖腺皆位於珊瑚蟲體腔內的隔膜絲（ mesentery ）上。生殖腺的數目和體腔的長短有關；體腔愈長，則隔膜絲也愈長，提供生殖腺發育的空間也愈大，因此生殖腺的數目也愈多。生殖腺極可能由隔膜絲的細胞分化而來，在顯微鏡下，經常可發現隔膜絲上，聚集有顏色較深的小點，顯示生殖腺的發育從痕跡狀至形成胞膜狀的過程。

生殖腺經酒精及福馬林浸泡處理之後多呈黃色或微透明黃色，少部份呈黃綠色或深綠色。較大的生殖腺其細胞膜較厚，細胞質較濃，較小的生殖腺其細胞膜較薄，質也較稀，甚至呈半透明狀。

卵囊（ oocytes ）通常有大小兩群，混合在一起生長，通常大的卵囊色澤較深和小的卵囊差別明顯。

各種軟珊瑚生殖腺在各月中的平均直徑及機差如表一、表二、及表三所示，其中沒有數據者表示該月份各標本皆沒有發現生殖腺。圖十一、十二、及十三爲三種軟珊瑚生殖腺月別變化的圖示，雌性和雄性珊瑚體皆個別做統計。由結果知，肥厚肉質軟珊瑚（ *Sarcophyton crassocaule* ）生殖腺的最大直徑在四月份，六月份又沒發現精囊，精囊在 11 月至翌年四月間，也呈逐漸增長，因此本種軟珊瑚成熟排卵日期可能在四至六月或八至十月之間。花環肉質軟珊瑚（ *S. trocheliophorum* ）卵囊的最大直徑出現在八月份，精囊亦同，因此其生殖期可能在八月～九月之間。肉質葉形軟珊瑚（ *L. sarcophytoides* ）的最大卵囊直徑出現在四月份，最大精囊直徑也出現在四月份，因此預測其排卵期可能在四至六月或八至十月之間。

## 三、軟珊瑚類分佈情形的探討：

本項研究移植原來生長在軟珊瑚區雷打石附近的軟珊瑚 44 顆至石珊瑚區～南灣至潭子間，同時於軟珊瑚區移植 44 顆軟珊瑚以做爲對照組。實驗組與對照組的軟珊瑚皆種植於固定在鋼架上的花盆中，追蹤其生長情形。

圖 14 表示實驗組和對照組軟珊瑚群體頭冠部面積變動的情形，實驗組的軟珊瑚群體在三月至四月及七月至八月間呈現明顯的減小，由現場的觀察發現，三月至四月的減小可能與松藻（ *Codium* ）的大量蔓延有關，松藻可能分泌化學物質抑制軟珊瑚的生長，或對軟珊瑚的生存不利。七至八月間的變化，則可能與沉積物在軟珊瑚群體上的堆積有關。由於七至九月是恆春半島的雨季，雨水沖刷所產生的陸源沉積物，在海流較緩的海域容易聚積在珊瑚群體的表面，同時由於軟珊瑚群體爲大型的活組織，其營養物的循環和代謝廢物的排出，均須仰賴水流的交換以達成，因此，緩慢的水流和沉積物的堆積，都足以影響軟珊瑚群體的生理，造成不利於它們生存的環境。對照組的珊瑚群體，則呈現持續的生長，由於該地區海流較強勁，所以並無松藻的繁衍，也無沉積物的堆積，環境條件利於軟珊瑚的生長。因此，軟珊瑚在國家公園海域的分佈，可能與海流的強弱有關，它們主要分佈在海流較強的海域，如：貓鼻頭至後壁湖漁港間，鵝鑾鼻半島兩側及白沙附近海域。

## 四、珊瑚類的種間競爭：

本項研究以野外觀察記錄之資料爲基礎以分析珊瑚種間競爭能力的強弱。珊瑚的種間競爭現象，分爲三項記錄：⑴直接作用，兩珊瑚群體間有一明顯的分界帶（圖 15 ）；⑵覆蓋生長（ overgrowth ），一種珊瑚群體生長蓋過另一珊瑚群體，群體之間並無明顯的分界帶（ 圖 16 ）⑶對峙（ stand-off ），兩種珊瑚之群體在接觸區停止生長（ 圖 17 ）。本研究共記錄了 1168 次珊瑚競爭的情形，其中 533 次（ 45.6 %）爲直接作用， 433 次（ 37.9 %）爲覆蓋生長， 184 次（ 15.8 % ）爲對峙，其他 8 次則可能爲化學物質所引起者。爲了比較珊瑚競爭能力的強弱，每一種珊瑚都分別計算其競爭能力係數（ RCA ），此係數的計算式爲：

$$RCA = \frac{\text{No. of wins - No. of losses}}{\text{Total No. of interactions}}$$

所有的珊瑚種類，依據其競爭能力係數的大小，區分爲五組，其結果如表4所示。

競爭能力最強的種類，如：片繩紋珊瑚（*Merulina ampliata*）斜花珊瑚（*Mycedium*）及粗糙棘葉珊瑚（*Echinophyllia asper*）等在海域的珊瑚群聚中，也是數量較多的種類（張和戴，1987）。

軟珊瑚類，一般而言，屬於競爭能力較弱的種類，它們在和石珊瑚類接觸時，通常都會受到石珊瑚的攻擊，野外觀察的證據顯示，石珊瑚類能藉其攻擊行爲，分解或被壞軟珊瑚的組織（圖18）。

## 五、軟珊瑚類的生態功能：

軟珊瑚的直接造礁功能，經廣泛採取大型軟珊瑚群體的岩心分析知，造礁能力以指形軟珊瑚（*Sinularia* spp.）最明顯，此類軟珊瑚通常有大型紡錘形的骨針；骨針在群體內的分佈，以群體的基部最密集且最大型，這些骨針在基部膠結形成岩石（圖19），群體組織與膠結的岩石間有一明顯的分界，促成軟珊瑚骨針膠結的機制，目前仍不明瞭。肉質軟珊瑚（*Sarcophyton* spp.）、葉形軟珊瑚（*Lobophytum*）和冠形軟珊瑚（*Alcyonium*）則未發現有明顯的造礁情形。

沉積物的分析結果（表5）顯示，在軟珊瑚區，軟珊瑚的骨針較多，非軟珊瑚區（如：船帆石、砂島和跳石），則骨針在沉積物中含量甚少，顯示軟珊瑚對珊瑚礁鈣質沉積物的貢獻頗大，其重要性不容忽視。

## 六、軟珊瑚類成長速率的研究：

本項研究於76年八月間在核三廠出水口至牽打石間標示30顆軟珊瑚群體，另於核三出水口東側至後壁湖間標示20顆軟珊瑚群體，分別屬於花環肉質軟珊瑚，肥厚肉質軟珊瑚及肉質葉形軟珊瑚三種。經用染色劑（Alizarin-Red-S）染色，效果並不佳，因此同時以隔月照相的方法，追蹤其表面積的變化情形。所標示的50顆群體，因受兩次強烈颱風的影響，至十一月時，僅餘27顆。調查結果顯示軟珊瑚的表面積受其生長環境的影響很大。76年9月及10月間的傑魯得和琳恩颱風，破

壞了部份的軟珊瑚群體，殘存的軟珊瑚群體都受到輕重不一的損傷，表面積顯著減小，但是這些群體卻能快速的再生和復原，由於天然災害的影響，測量值間具很大的變異，因此不適合用以估計其成長速率。

## 七、核三廠出水口右側至貓鼻頭海域珊瑚白化之調查

自從民國 76 年 7 月 10 日首次發現出水口右側小灣內有許多珊瑚白化現象以來，本實驗室即利用每個月出差南灣期間，前往該區從事白化珊瑚與其共生動物的觀察與記錄；今年七月又再度發生珊瑚白化現象，茲將一年多來所觀察到的現象與結果，分別做比較並簡單敍述如下：

(1)珊瑚白化的範圍與深度：

去年七月珊瑚白化範圍主要集中在出水口右側小灣凹處，水深 6 公尺以淺，其中以 3 公尺以淺幾乎所有珊瑚均有白化現象。

今年到八月底爲止發現珊瑚白化範圍已從小灣擴展至貓鼻頭東側，繞過貓鼻頭西南側則無珊瑚白化現象，白化深度在出水口右側小灣凹處較深約 5 公尺以淺，其中仍以 3 公尺以淺較嚴重，然而珊瑚白化種類較去年少了幾種，而且白化情形不如去年灣內的嚴重，但至貓鼻頭一帶水深 3 公尺以淺均有珊瑚白化情形。

(2)珊瑚的成長與白化現象

溫度是影響珊瑚生長的重要因子，一般而言，造礁珊瑚在水溫 23 ～ 28 ℃之間生長最佳， 18 ℃ 以下的低溫和 30 ℃ 以上的高溫，都不利於珊瑚的生存。然而珊瑚的顏色主要來自寄居在它們細胞內的共生藻，這些共生藻具有豐富的色素，能隨環境的狀況而呈現不同的顏色，因此也使得珊瑚具有許多種鮮艷的色彩，同時共生藻更對珊瑚的新陳代謝和骨骼的堆積有非常重要的貢獻，不過當造礁珊瑚在環境不適宜的時候，也會失去它們的共生藻，形成「白化」現象。

(3)水文記錄

根據資料得知墾丁海域月本均水溫在 21 ～ 30 ℃之間，適合珊瑚生長，以往墾丁海域從未發生過有珊瑚白化現象，直到民國七十六年七月十日才經由潛水人員發現出水口右側灣內有大量珊瑚白化現象，三公尺以淺的珊瑚幾乎全部白化，據知前三天氣候晴朗炎熱，風浪均小，加上該區緊鄰核三廠熱廢水排水出口之右側，在天候及凹處

地形等諸多因素影響下，造成高水溫靜滯灣內，而使該地亞潮帶珊瑚暴露在高水溫之中。

今年發生白化現象的時間亦與去年相似，開始有白化現象也是相同地點，只不過白化區域逐漸擴展，到八月下旬則延伸至貓鼻頭。今年 7 月 23 日本實驗室曾以潛水方式攜帶溫度計測量發現出水口右側灣內表面水溫高達 33 ℃ ，5 公尺深則得 28 ℃ ，10 公尺深則爲 25 ℃當天在入水口 D 站測面表面水溫爲 28 ℃ ， 10 公尺深則爲 25 ℃ 。8 月 22 日灣內水溫 32 ℃ ，貓鼻頭附近 31 ℃ ，顯然出水口右側海水溫度均比其他海域高，從地形觀之在出水口右側灣內及靠近貓鼻頭方向的凹處，珊瑚白化的情形都較爲嚴重，然而繞過貓鼻頭西南側則無珊瑚白化現象，另外出水口左側及南灣其他海域亦無珊瑚白化現象，因此可以說明自然的天候因素並非影響珊瑚白化之主要因子，而是以出水口熱水排放影響爲主要因素，其次風向若爲東南風及夏季黑潮水流，日光照射等均可視爲影響之次要因素。另外值得一提的事，有關去年白化現象發生後，核三廠只剩一部機在運轉，而今年則持續有二部機運轉，此乃影響排放高水溫與水量的因素。

(4)生物記錄

去年白化珊瑚種類，約有三分之一死亡，其中又以枝狀珊瑚居多數，尤其是尖枝列孔珊瑚（ *Seriatopora hystrix* ）死亡的數量最多，受影響的深度也較深，可說是對高水溫較爲敏感的珊瑚種類。根據所採白化珊瑚標本中，可發現有互利共生的甲殼類，對宿主珊瑚有相互依存的密切關係；在白化珊瑚中，互利共生動物大部份都逃逸，例如十脚類槍蝦科的 *Alpheus lottini*，扇蟹科（ Xanthidae ）的 *Trapezia guttata*, *T. cymodoce*, *T. areolata* 在白化珊瑚中均無發現。

根據八月下旬觀察記錄得知白化的尖枝列孔珊瑚仍發現上述共生蝦蟹類，其珊瑚虫體亦伸展開來，因此若是今年水溫不再持續高溫，也許今年白化珊瑚活存的比率將可提高。

有關今年白化珊瑚，珊瑚虫存活情形及去年白化珊瑚死亡，被藻類覆蓋情形，以及去年白化未死亡，而今年再遭受白化的情形，可參閱所附照片（圖 20 ， 21 ）。

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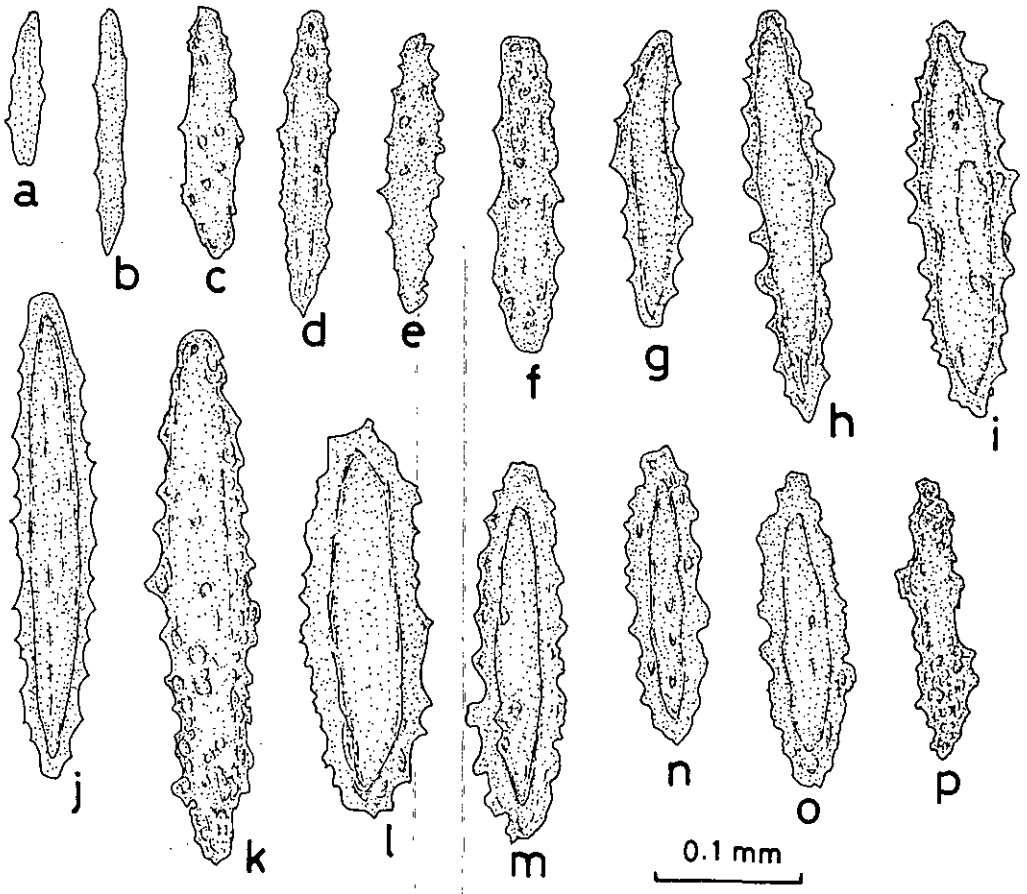



Fig. 1. Alcyonium simplex Thomson and Dean, a-j, sclerites from lobes and branches; k-p, sclerites from the stalk. (TA-48)

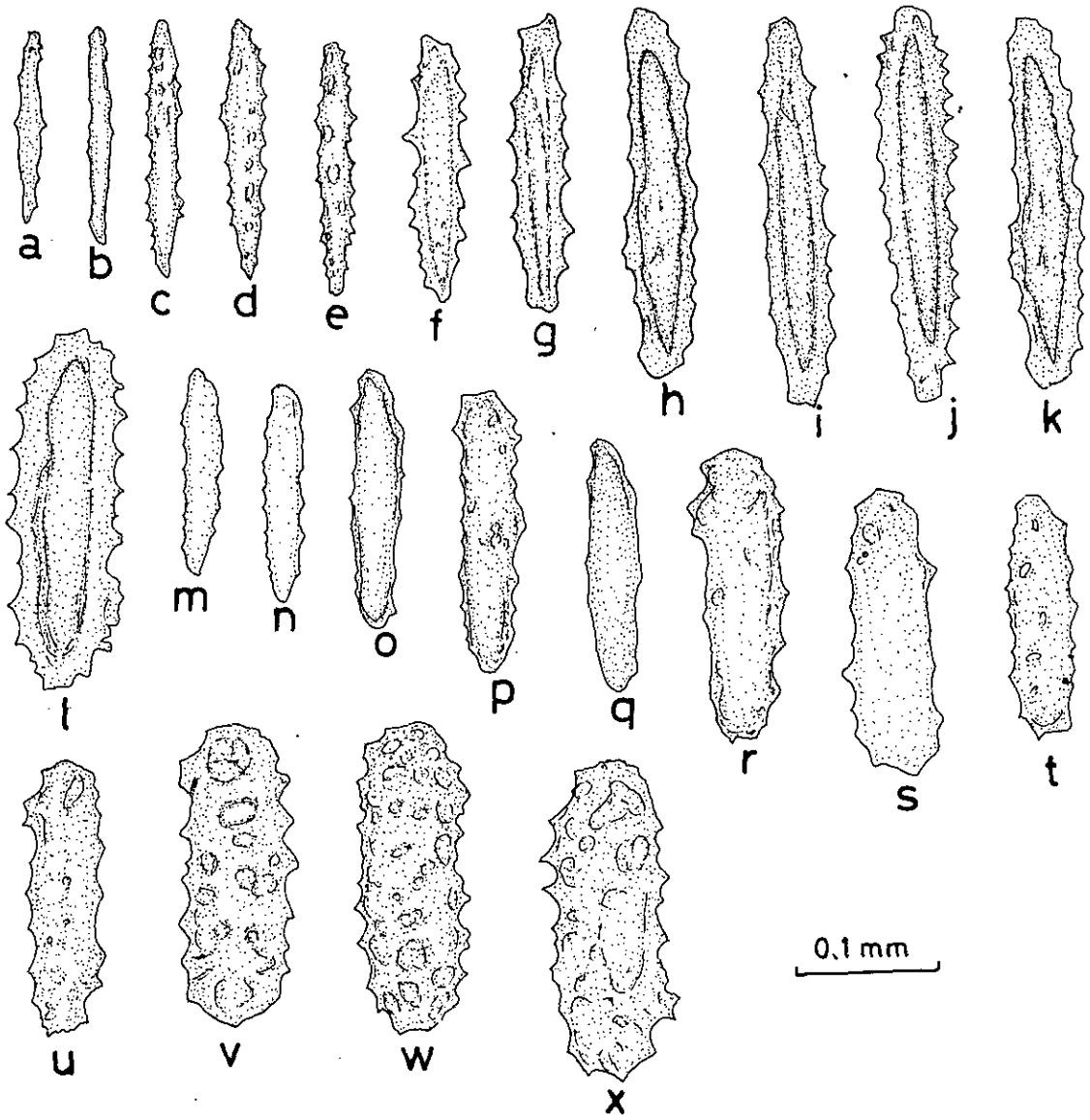



Fig. 2. Alcyonium molle Thomson and Dean, a-l, sclerites from lobes and branches; m-x, sclerites from the stalk. (D-7)

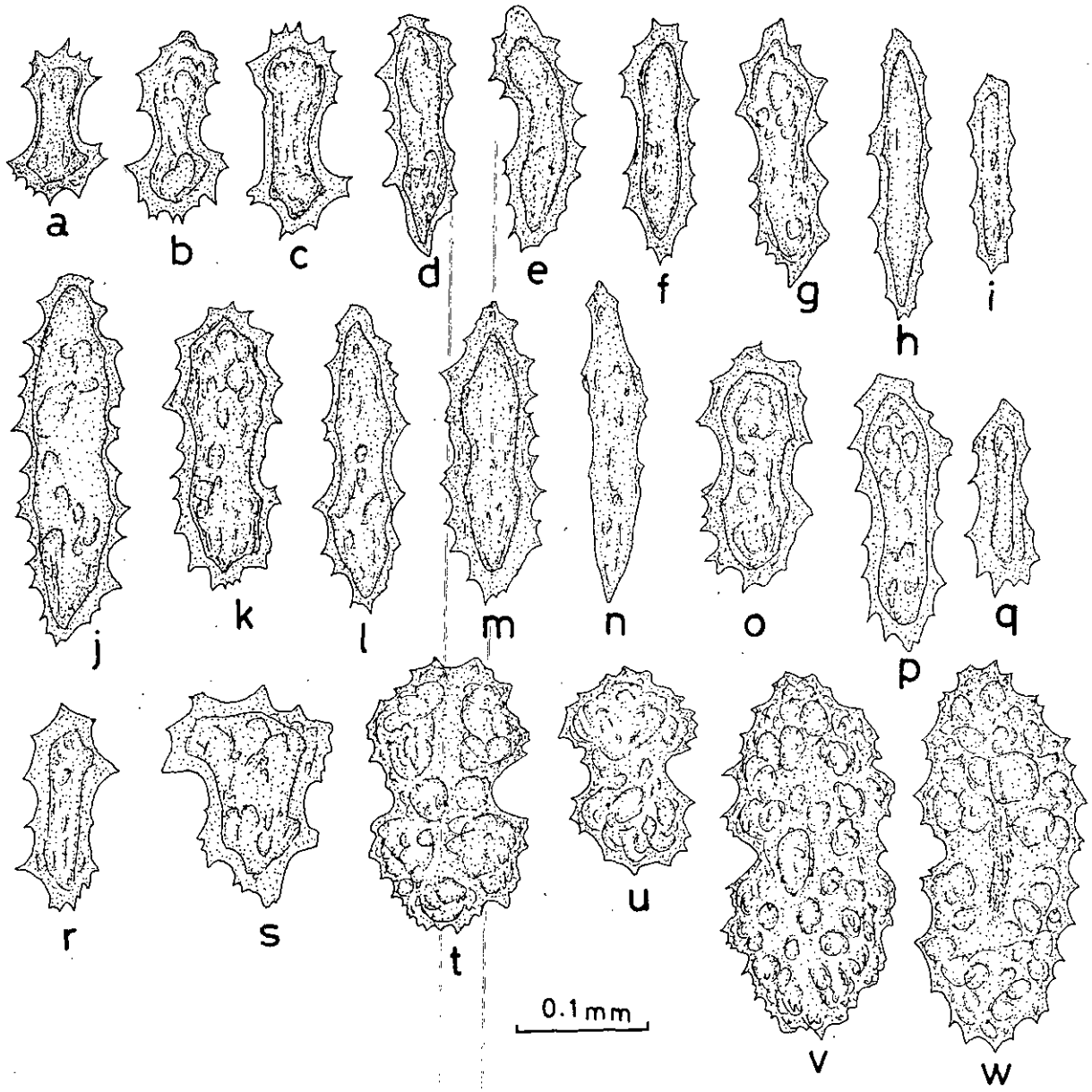



Fig. 3. Alcyonium rotundum Thomson and Dean. a-i, sclerites from surface layer of a lobe; j-n, sclerites from interior of a lobe; o-s, sclerites from surface layer of the stalk; t-w, sclerites from interior of the stalk. (B-3)

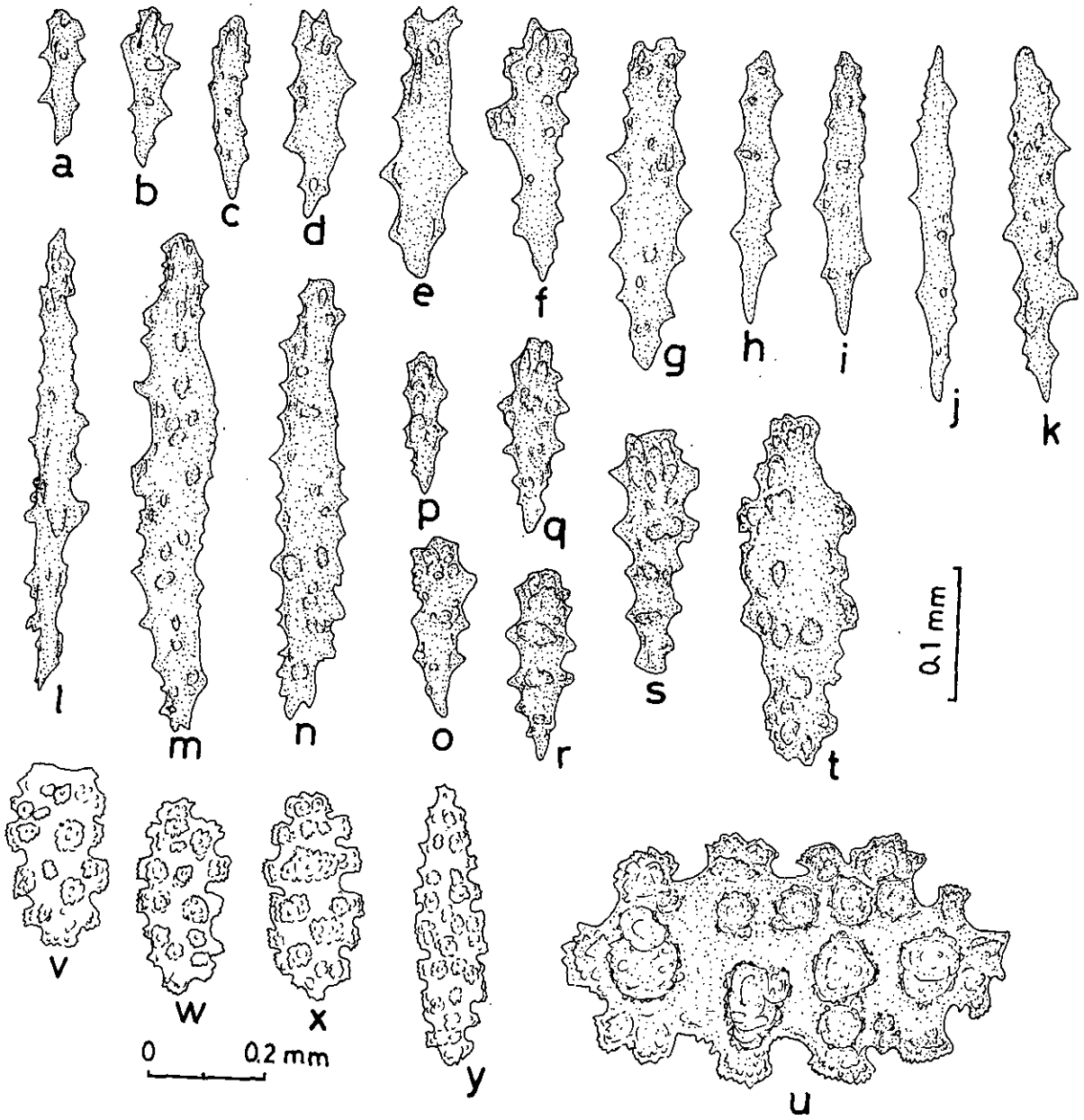



Fig. 4. Sarcophtor trocheliophorum Von Marenzeller. a-g, sclerites from surface layer of the disc; i-n, sclerites from interior of the disc; o-t, sclerites from surface of the stalk; u-y, sclerites from interior of the stalk; a-u, at upper scale by 0.1mm; v-y, at lower scale by 0.2mm. (B-8, TA-17)

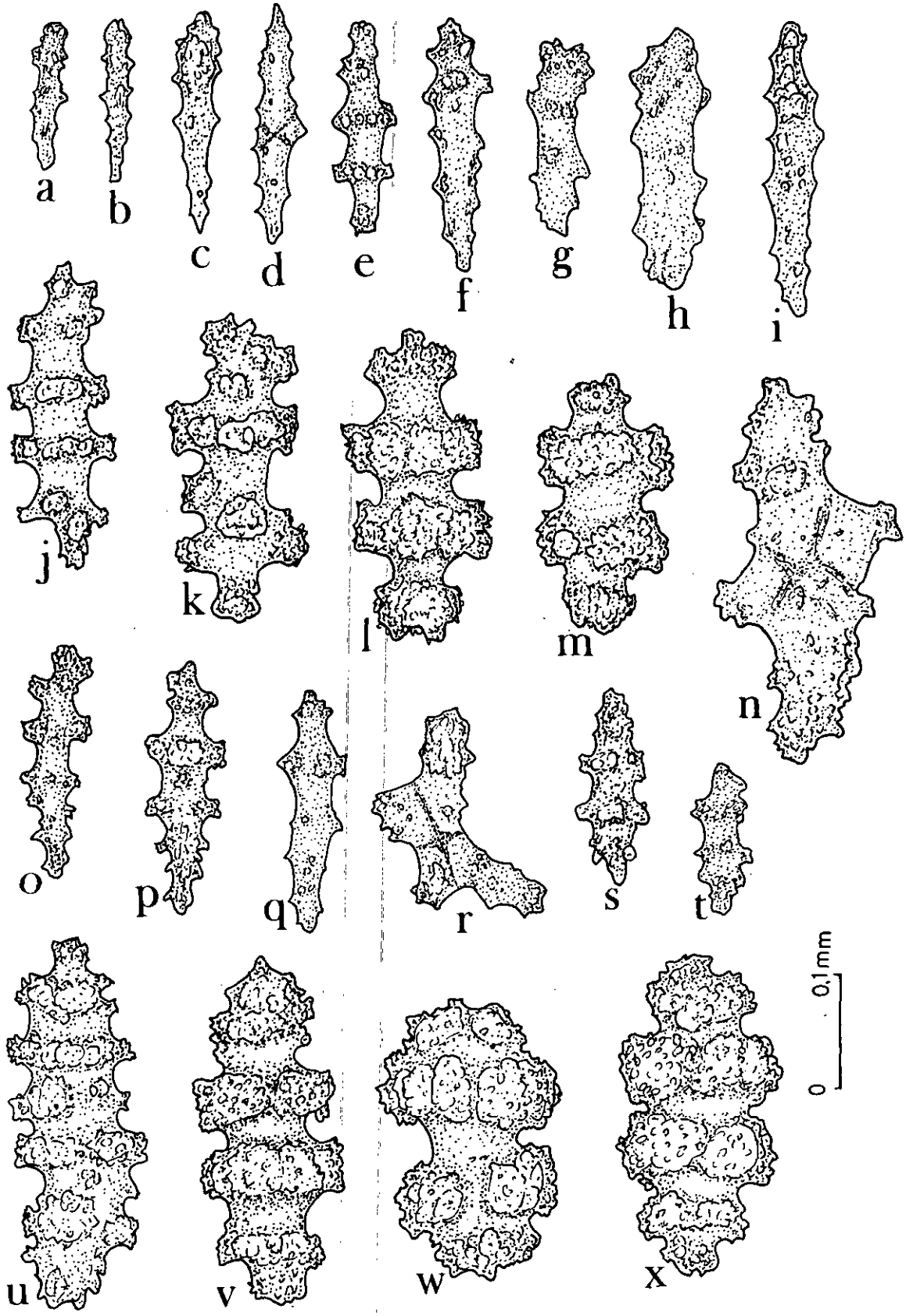



Fig. 5. Sarcophyton crassocaule Moser. (A-13, A-15). a-i, from disc surface; j-n, from disc interior; o-t, from stalk surface; u-x, from stalk interior; All with same scale.

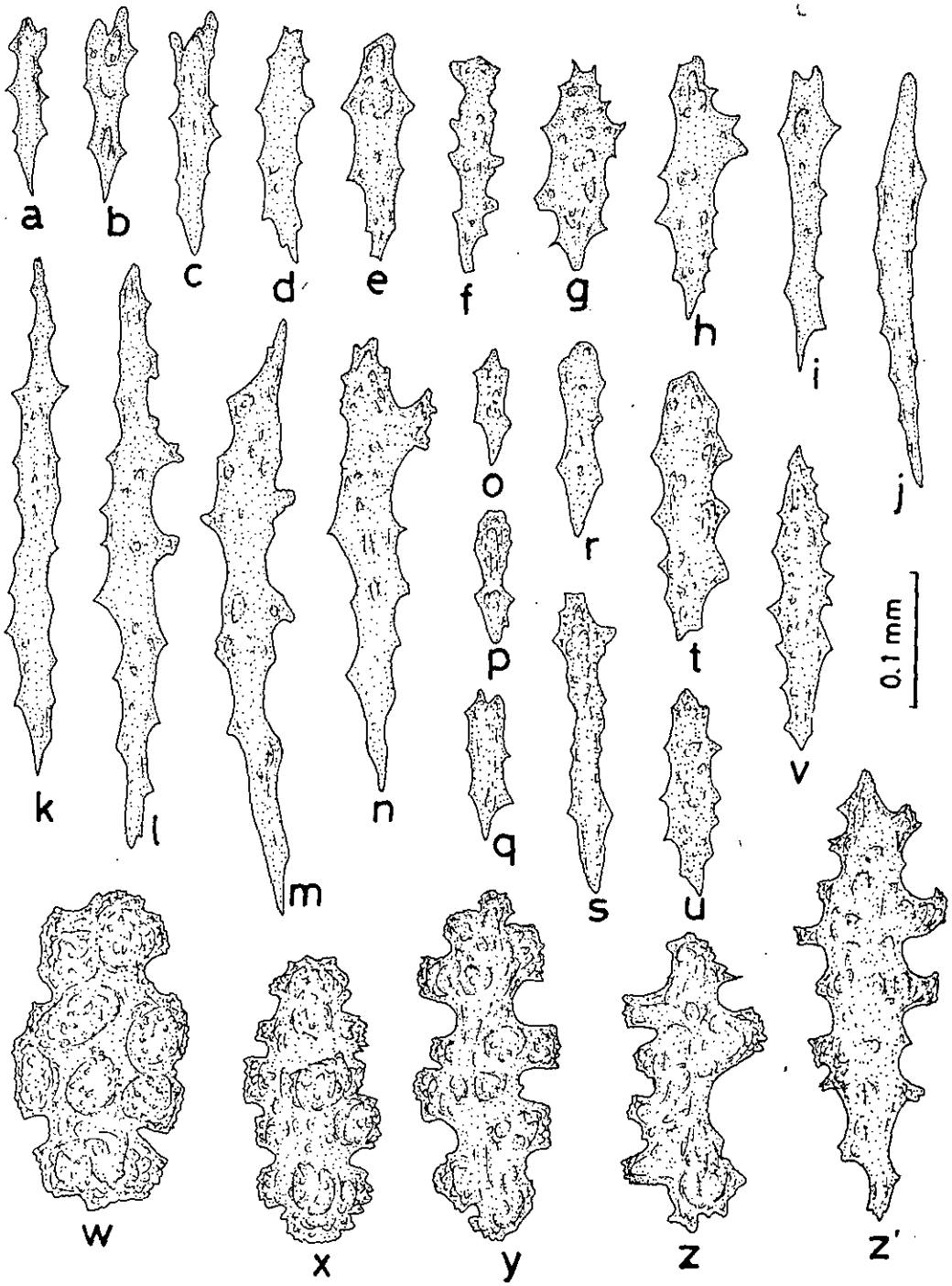



Fig. 6. Sarcophyton stellatum Kukenthal. a-i, sclerites from surface layer of the disc; j-n, sclerites from interior of the disc; o-u, sclerites from surface layer of the stalk; w-z, sclerites from interior of the stalk. (B-1)

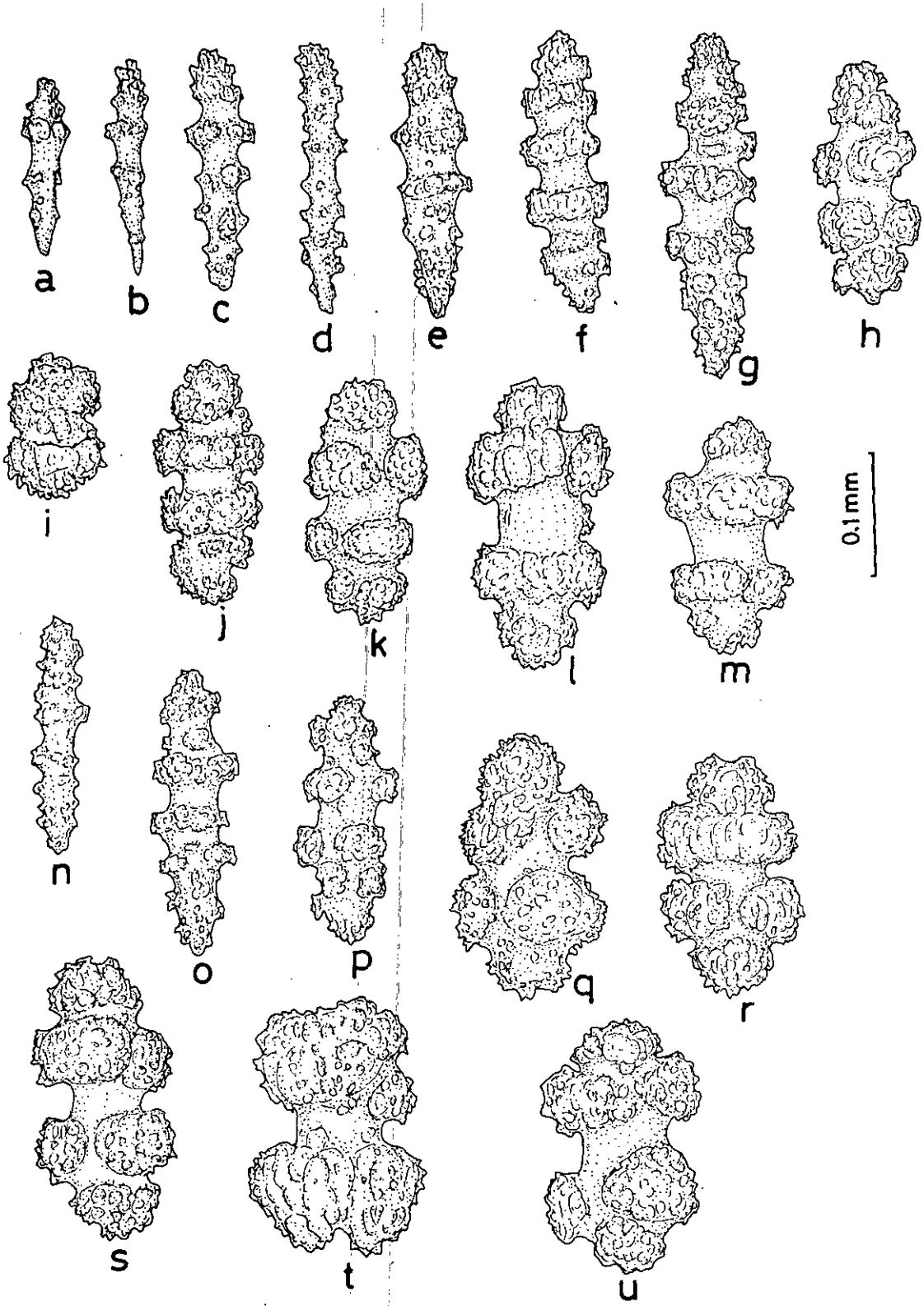



Fig. 7. Lobophytum mirabile Tixier-Durivault. a-g, sclerites from surface of the disc; h-m, from interior of the disc; n-r, sclerites from surface of the stalk; s-u, from interior fo the stalk. (TA-40).

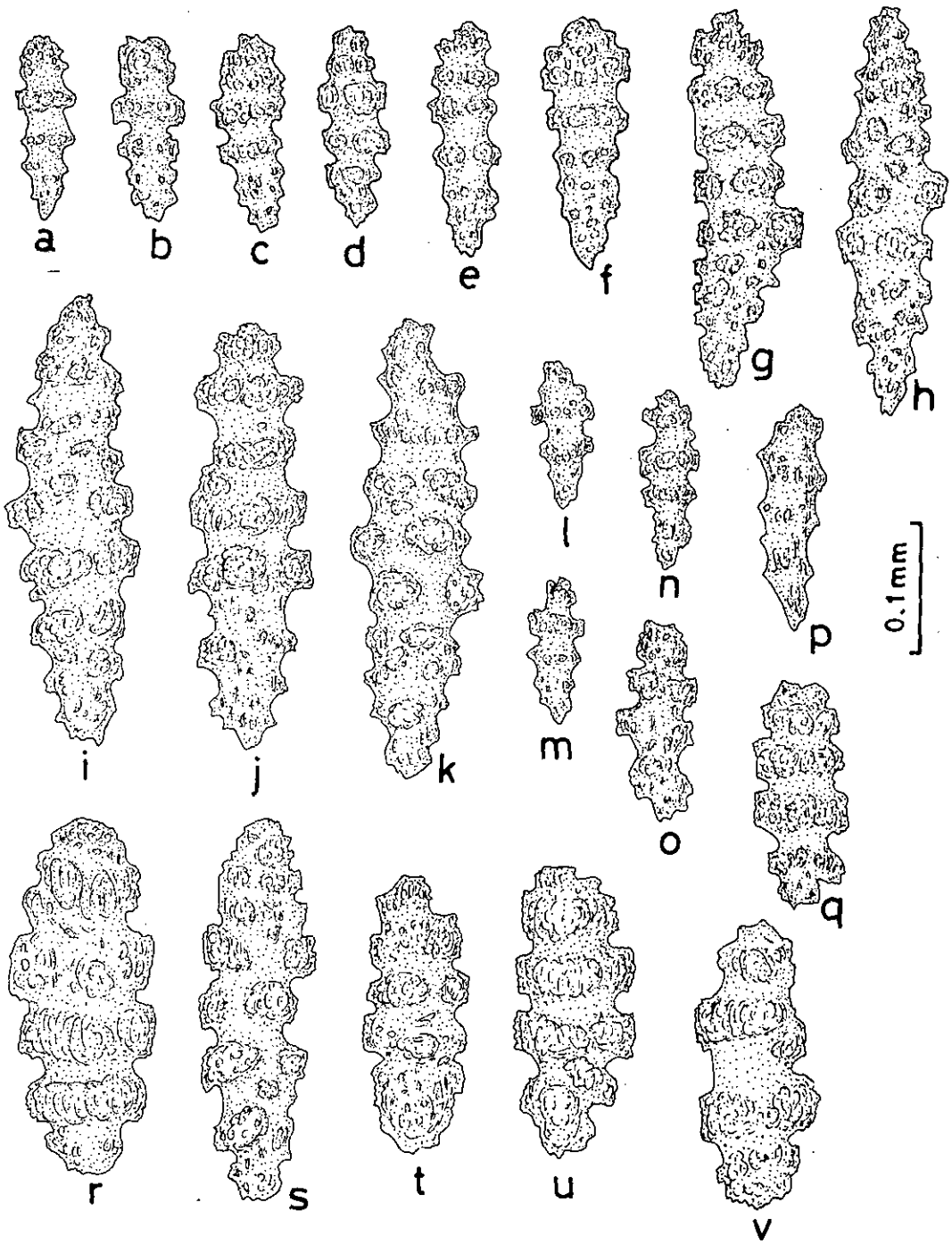



Fig. 8. Lobophytum pauciflorum (Ehrenberg). a-f, sclerites from surface layer of the disc; g-k, sclerites from interior of the disc; l-g, sclerites from surface of the stalk; r-v, sclerites from interior of the stalk. (TA-47)

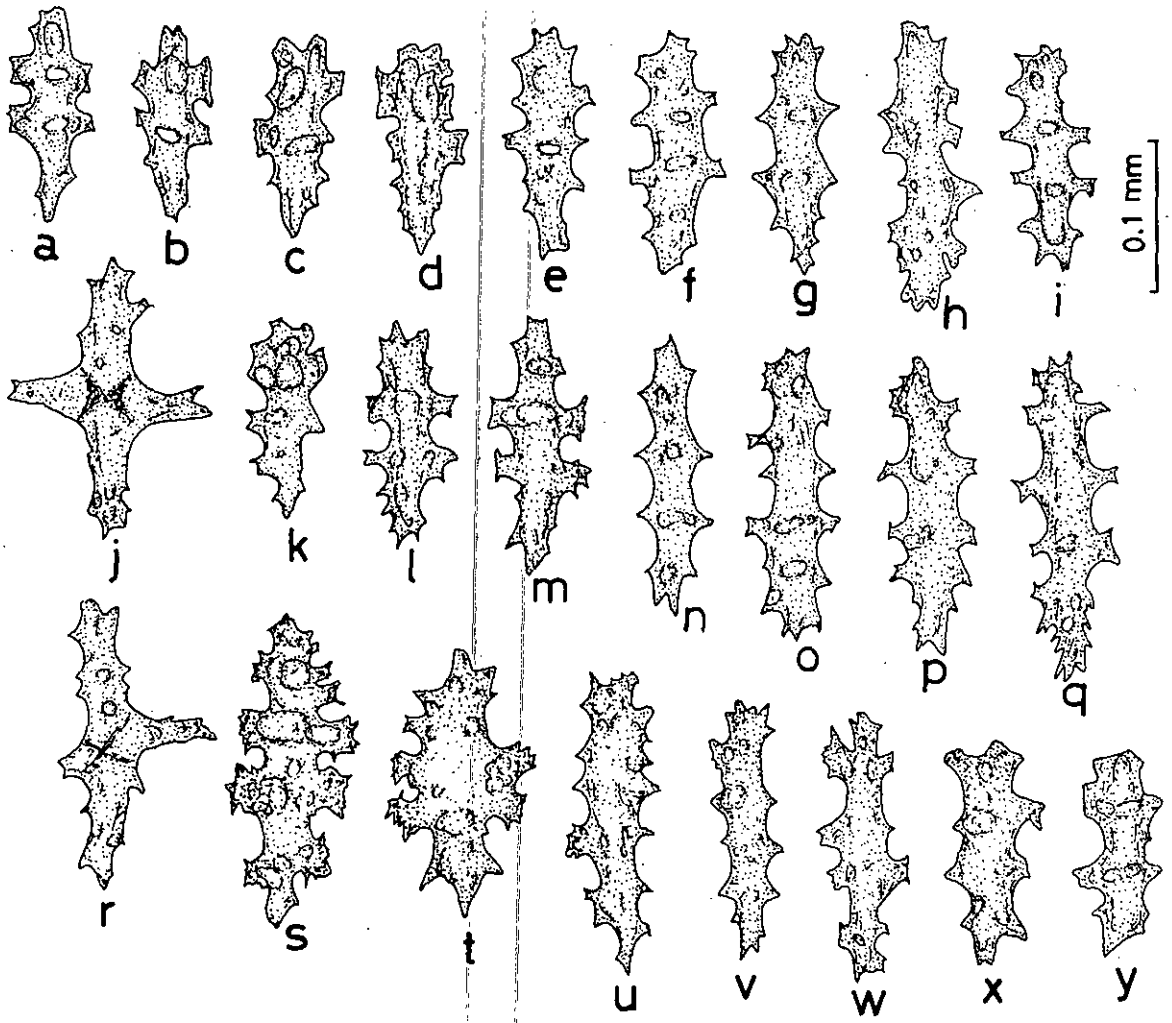



Fig. 9. Lobophytum sarcophytoides Moser. a-j, sclerites from surface layer of the disc; k-r, sclerites from interior of the disc; s-y, slcerites from interior of the stalk. Magnification of all of the sclerites as indicated by 0.1mm at i. (D-8)

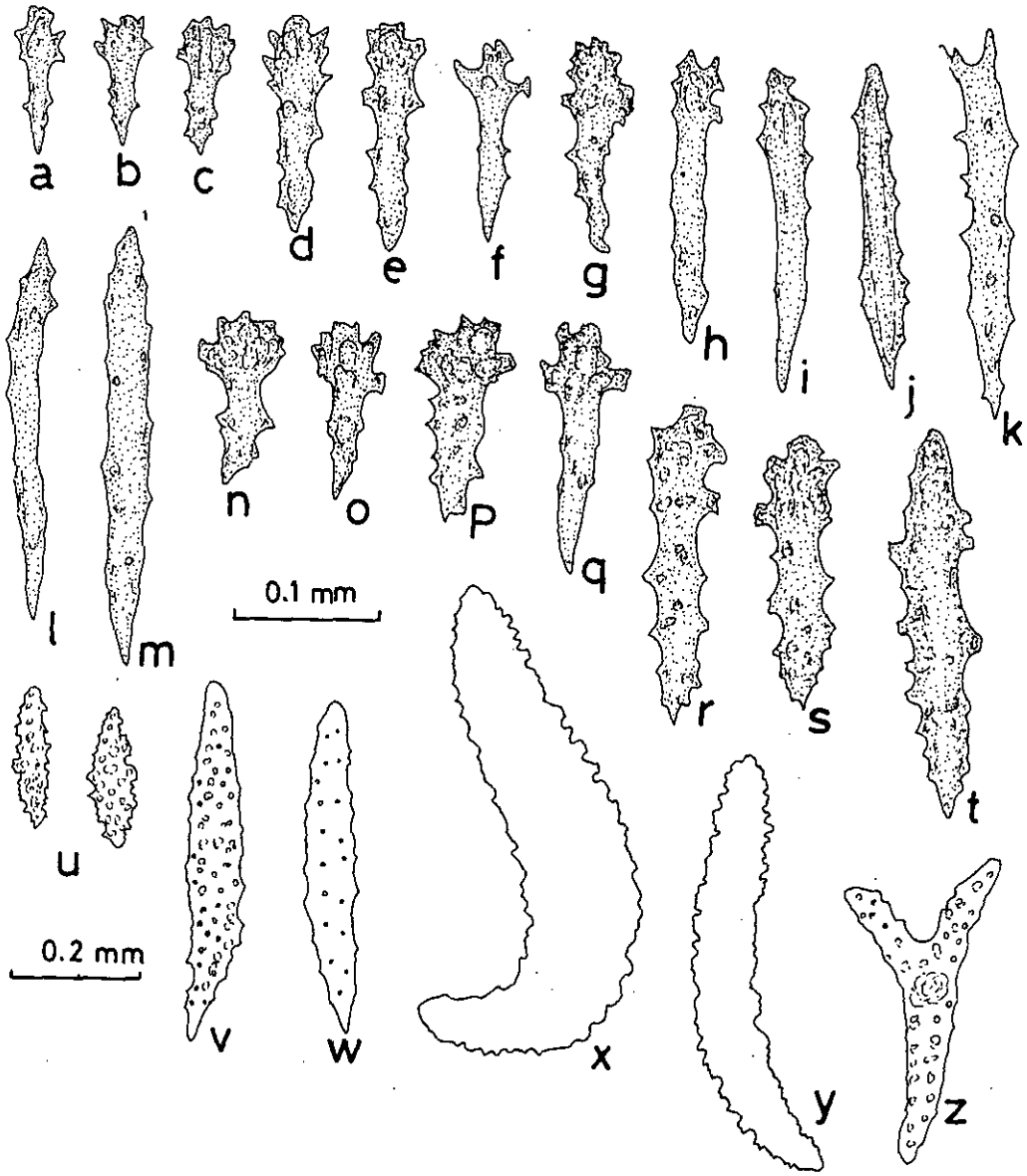



Fig. 10. Sinularia granosa Tixier-Durivauit. a-g, sclerites from surface layer of a lobe; h-m, sclerites from interior of a lobe; n-t, sclerites from surface layer of the stalk; u-z, sclerites from interior of the stalk; a-t, by upper scale; u-z, by lower scale. (D-6)

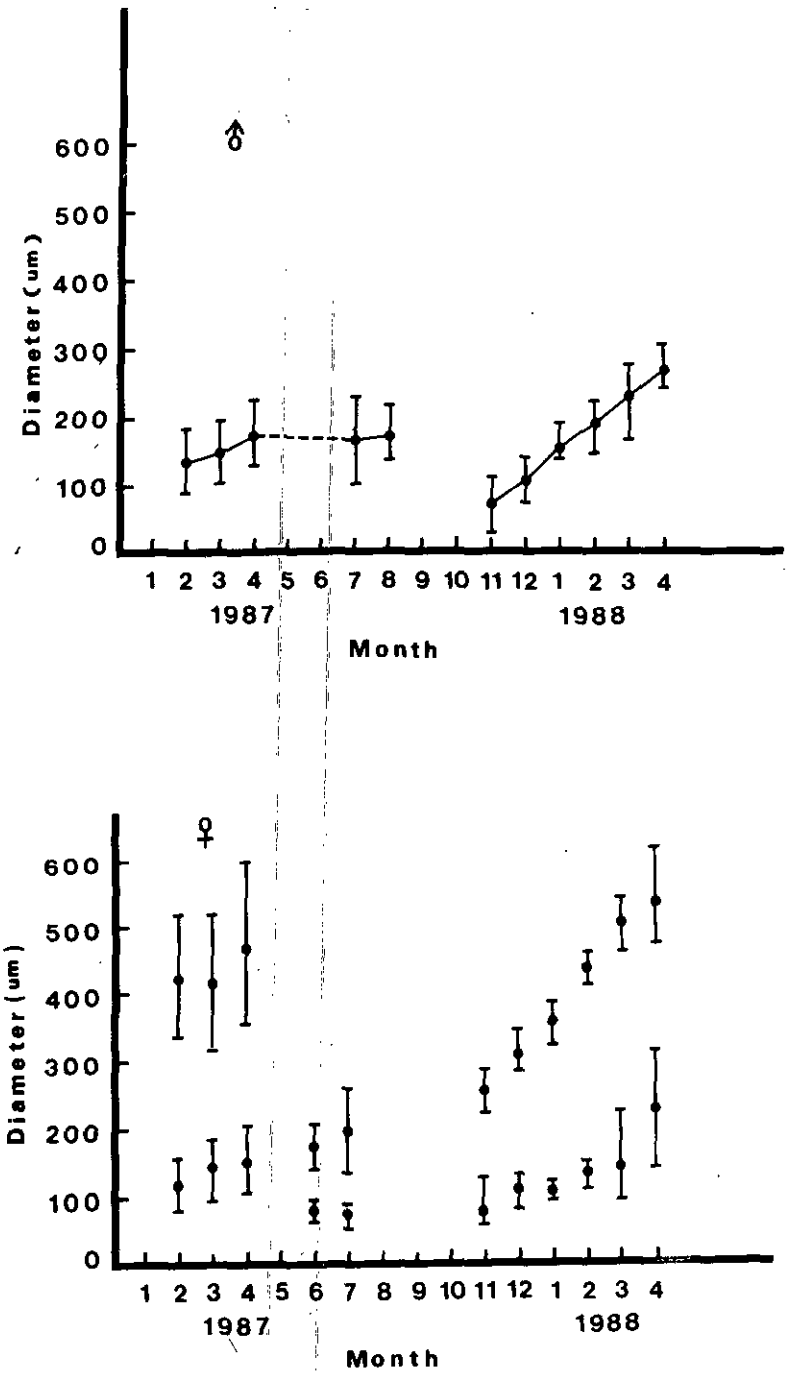



Fig. 11. Monthly variation of gonad diameters of Sarcophyton crassocaule. Bars indicate the ranges.

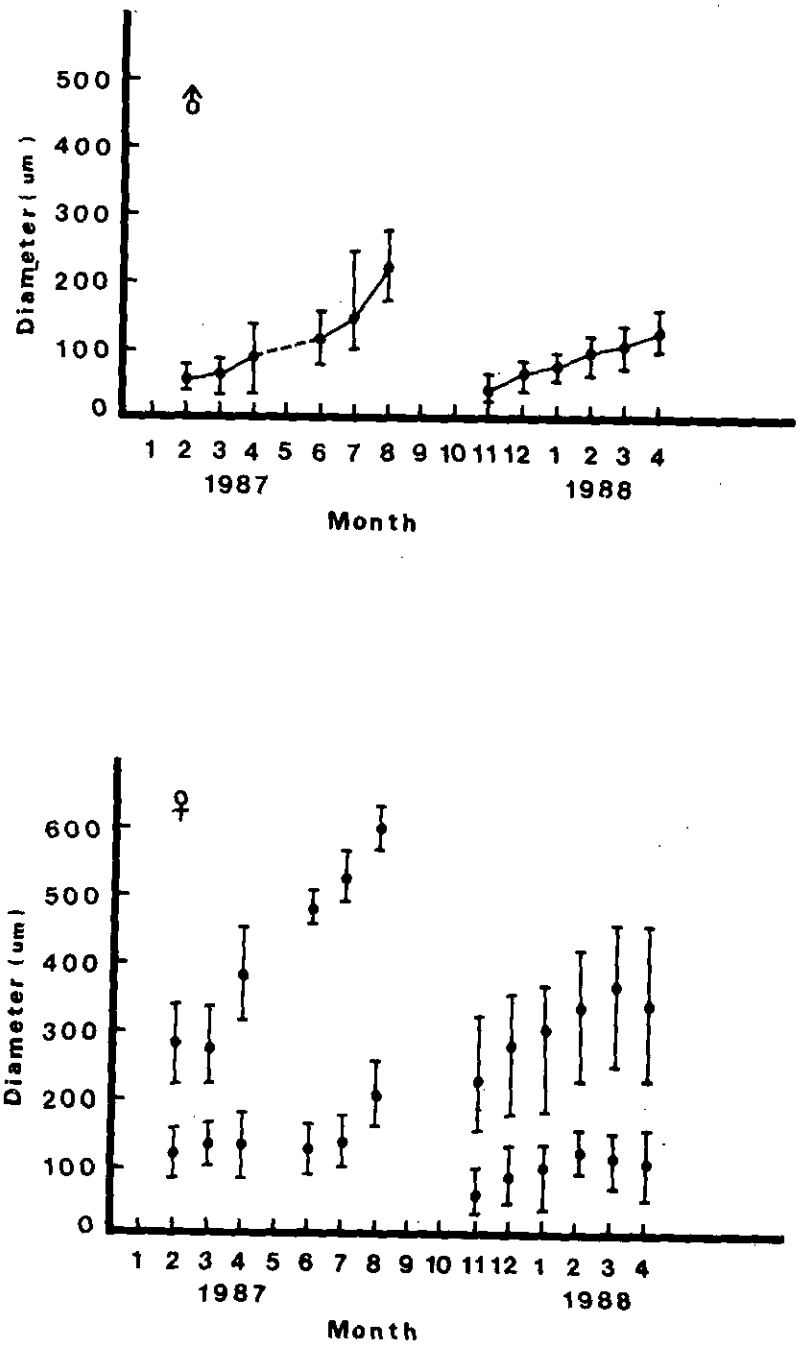



Fig. 12. Monthy variation of gonad diameters of Lobophytum sarcophytoides. Bars indicate the ranges.

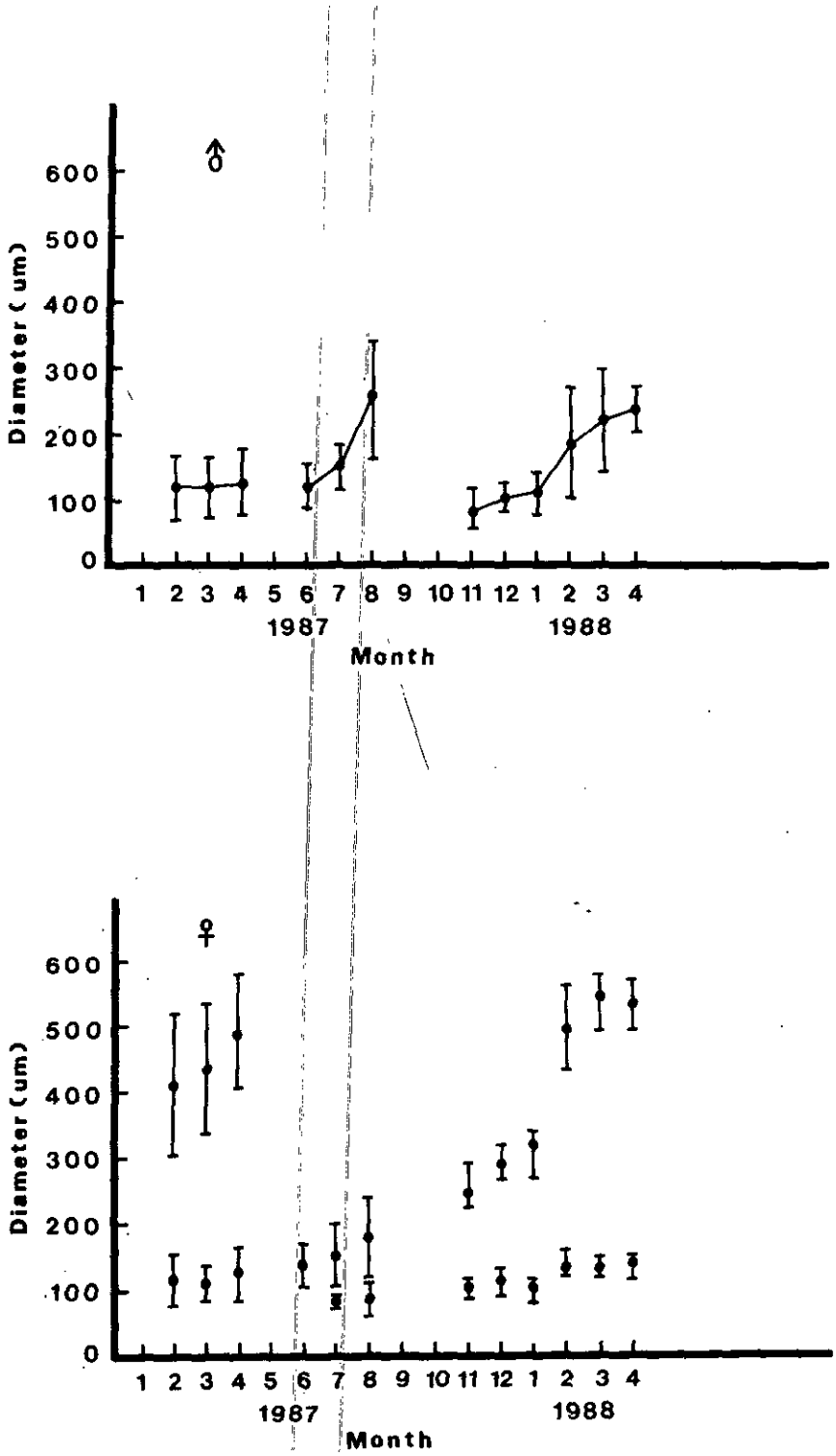



Fig. 13. Monthly variation of gonad diameters of Lobophytum sarcophytoides. Bars indicate the ranges.

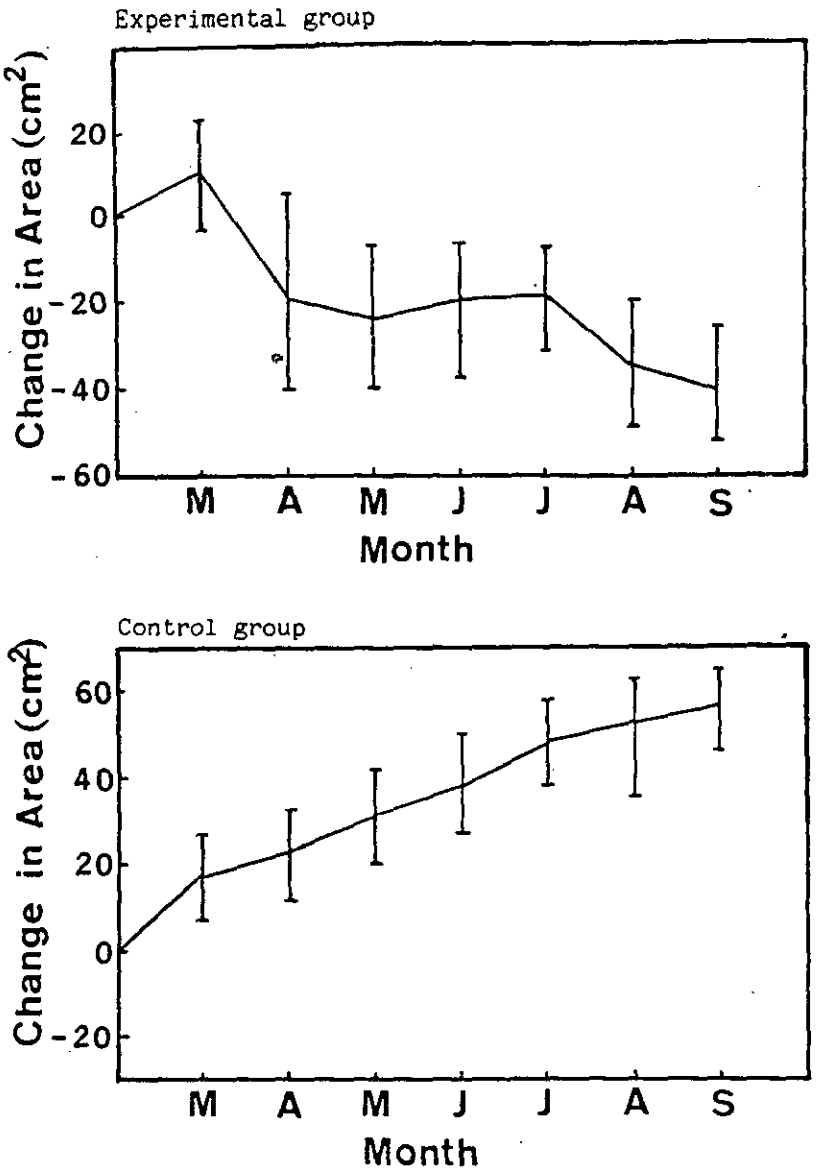



Fig. 14. Changes in projected capitula area of alcyonacean corals for the experimental (near site E) and the control (between sites C and D) groups of the transplantation study. The original capitula areas (in February, 1987) were from 98 to 176 $cm^2$ for the experimental group and from 95 to 167 $cm^2$ for the control group. Bars indicate ranges.



圖15　珊瑚間的直接競爭，競爭優勢者（*Acanthastrea echinata*，圖左）對競爭弱勢者（*Porites lutea*，圖右）造成組織的破壞。

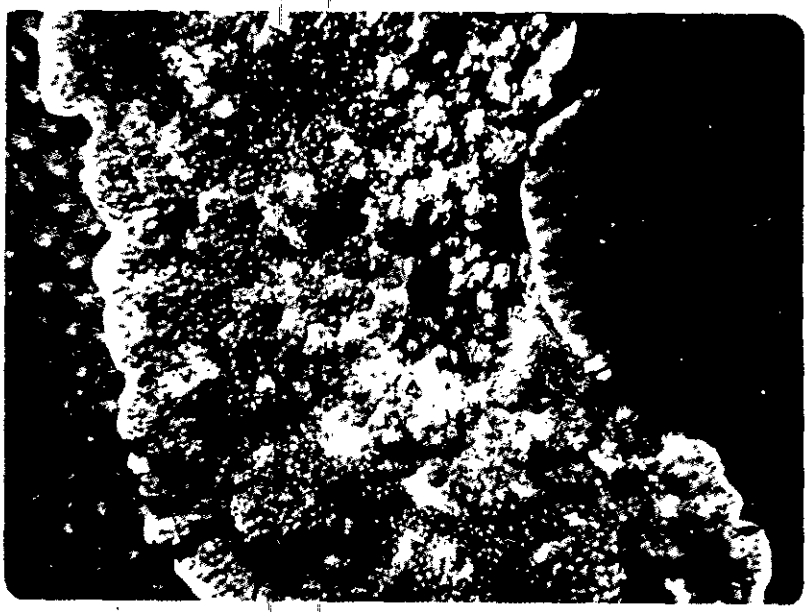


圖16　珊瑚間的覆蓋生長，縐紋珊瑚（*Merulina ampliata*，圖右）⇄葉形表孔珊瑚（*Montipora foliosa*，圖中）→同形雙星珊瑚（*Diploastrea heliopora*）。

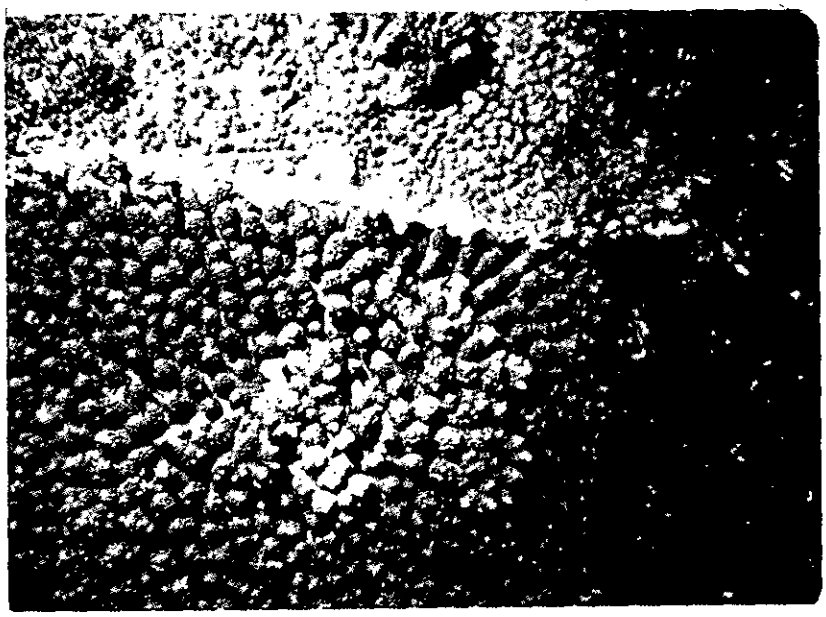


圖17　珊瑚種間競爭的對峙（*Stand-off*）現象，方格軸孔珊瑚（*Acropora clathrata*；圖上）及桌形軸孔珊瑚（*Acropora hyacinthus*；圖下）。

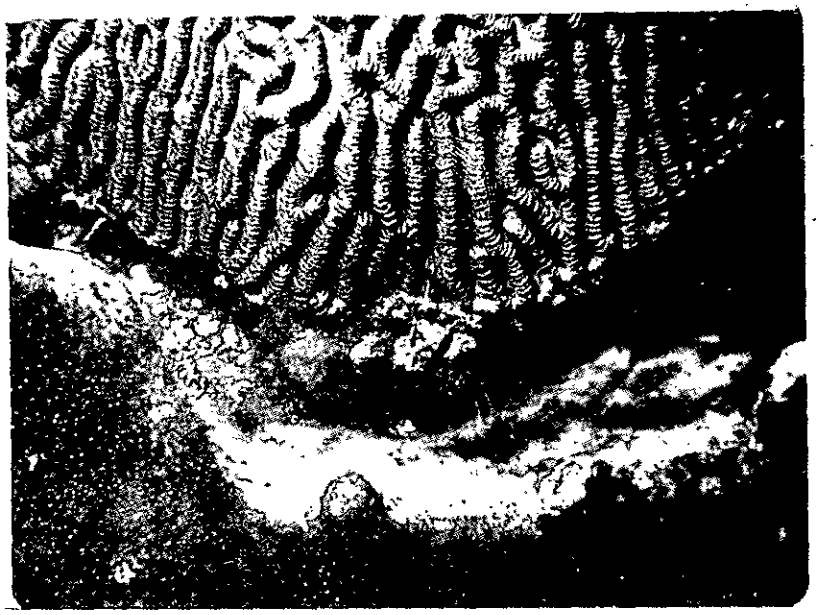


圖18　腦紋珊瑚（*Platygyra lamellina*，圖上）對葉形軟珊瑚（*Lobophytum sarcophytoides*，圖下）造成組織的傷害。

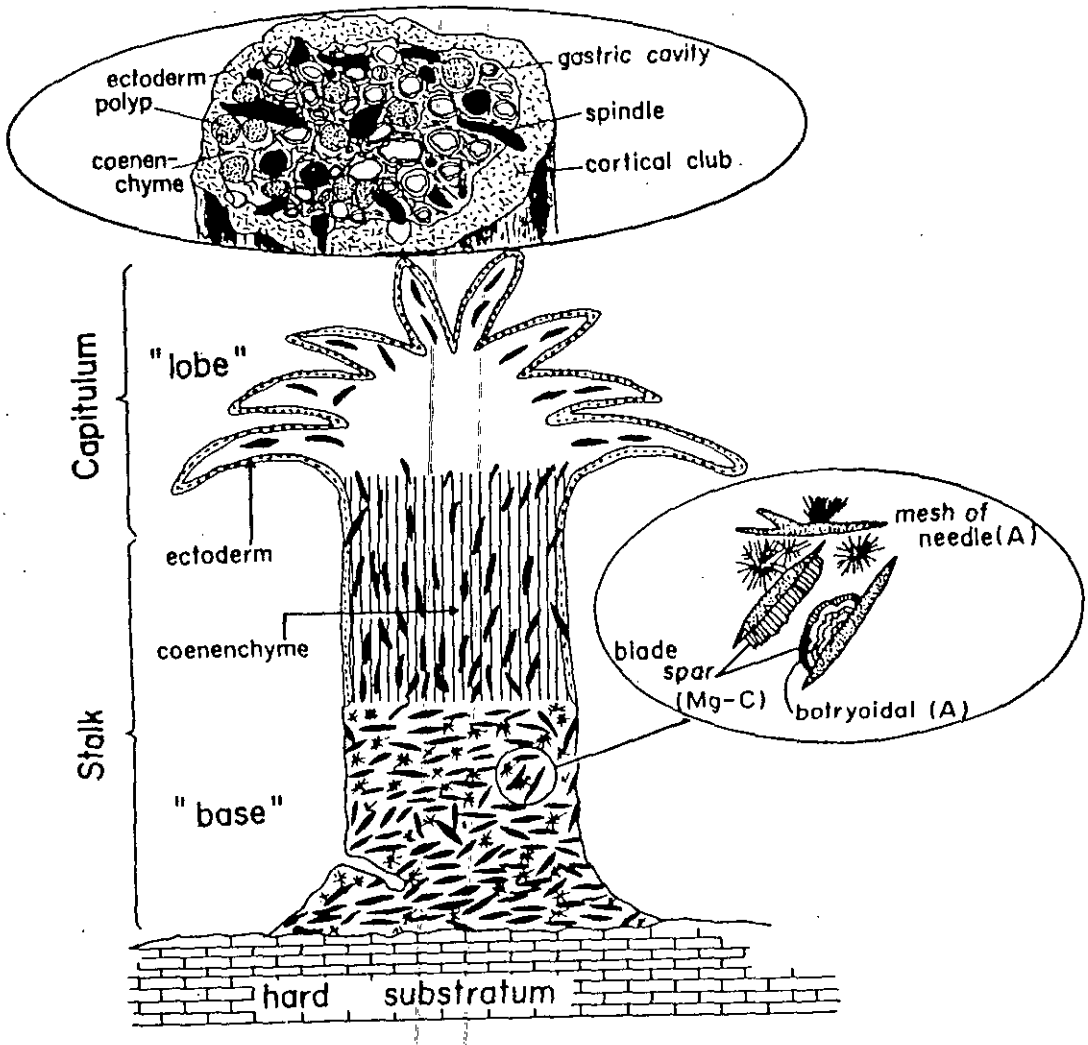



圖19　軟珊瑚骨針堆積及其岩化作用的圖示。

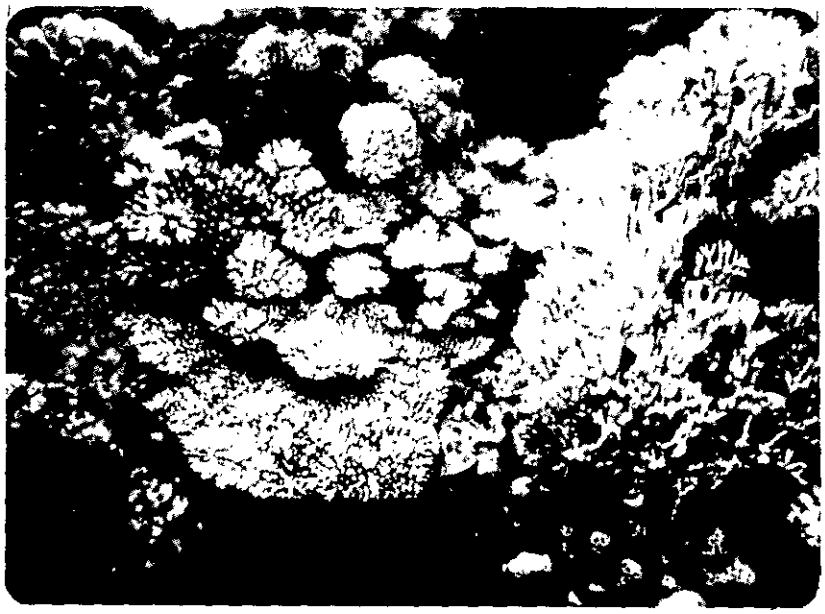


圖20　核能電廠出水口附近，熱排水造成珊瑚白化的現象，圖示有千孔珊瑚（右），軸孔珊瑚（中）及鹿角珊瑚（左上）



圖21　核能電廠熱排水造成軟珊瑚（*Sarcophyton trocheliophorum*，中）白化的現象。

Table 1. Monthly average and standard error of gonad diameters of Sarcophyton trocheliophorum.

| Month | | 2 | 3 | 4 | 6 | 7 | 8 | 11 | 12 | 1 | 2 | 3 | 4 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Testes diameter (μm) | $\bar{X}$ | 59 | 65 | 96 | 120 | 150 | 222 | 48 | 73 | 82 | 102 | 110 | 130 |
| | S | 21 | 20 | 53 | 46 | 47 | 50 | 15 | 22 | 19 | 33 | 45 | 31 |
| Oocyte diameter (μm) I | $\bar{X}$ | 279 | 276 | 382 | 481 | 526 | 605 | 230 | 281 | 304 | 338 | 370 | 346 |
| | S | 58 | 56 | 68 | 23 | 36 | 29 | 68 | 70 | 74 | 88 | 85 | 96 |
| Oocyte diameter (II) | $\bar{X}$ | 120 | 135 | 135 | 128 | 142 | 209 | 63 | 90 | 105 | 128 | 120 | 118 |
| | S | 37 | 32 | 51 | 36 | 37 | 42 | 18 | 26 | 23 | 18 | 20 | 22 |

Table 2. Monthly average and standard error of gonad diameters of Sarcophyton Crassocaule.

| Month | | 2 | 3 | 4 | 6 | 7 | 8 | 11 | 12 | 1 | 2 | 3 | 4 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Testes diameter ($\mu$m) | $\bar{X}$ | 139 | 150 | 176 | - | 165 | - | 76 | 108 | 159 | 194 | 228 | 274 |
| | S | 44 | 49 | 45 | - | 65 | - | 21 | 37 | 46 | 76 | 82 | 85 |
| Oocyte diameter ($\mu$m) I | $\bar{X}$ | 422 | 414 | 468 | 173 | 196 | 177 | 258 | 308 | 354 | 425 | 501 | 528 |
| | S | 90 | 100 | 110 | 34 | 64 | 34 | 43 | 75 | 108 | 97 | 115 | 156 |
| Oocyte diameter ($\mu$M) (II) | $\bar{X}$ | 120 | 141 | 154 | 85 | 72 | - | 78 | 103 | 110 | 128 | 150 | 220 |
| | S | 36 | 42 | 49 | 13 | 18 | - | 19 | 41 | 13 | 32 | 46 | 87 |

Table 3. Monthly average and standard error fo gonad diameters of Lobophytum Sarcophytoides.

| Month | | 2 | 3 | 4 | 6 | 7 | 8 | 11 | 12 | 1 | 2 | 3 | 4 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Testes diameter ($\mu$m) | $\bar{X}$ | 118 | 124 | 127 | 120 | 152 | 260 | 81 | 104 | 110 | 183 | 222 | 238 |
| | S | 50 | 52 | 53 | 32 | 35 | 87 | 30 | 18 | 35 | 76 | 72 | 38 |
| Oocyte diameter ($\mu$m) I | $\bar{X}$ | 409 | 431 | 488 | 135 | 148 | 177 | 245 | 288 | 313 | 492 | 531 | 532 |
| | S | 108 | 103 | 84 | 31 | 45 | 59 | 32 | 28 | 40 | 82 | 58 | 41 |
| Oocyte diameter ($\mu$M) II | $\bar{X}$ | 116 | 108 | 125 | - | 83 | 86 | 103 | 110 | 100 | 142 | 133 | 131 |
| | S | 34 | 28 | 35 | - | 12 | 30 | 25 | 18 | 22 | 26 | 20 | 32 |

Table 4. Coral species occupy the five categories of relative competitive ability.

| Family | aggressive | moderate aggressive | intermediate | moderate subordinate | subordinate |
|---|---|---|---|---|---|
| Acroporidae | Acropora aspera<br>A. palifera | A. humilis<br>A. nana<br>A. tenuis<br>Montipora foliosa<br>M. undata<br>M. verrucosa<br>M. spumosa | A. hyacinthus<br>A. monticulosa<br>A. gemmifera<br>M. grisea<br>M. tuberculosa<br>M. aequituberculosa | M. informis<br>M. foveolata<br>M. peltiformis<br>M. ehrenbergi | M. venosa<br>M. monasteriata<br>Astreopora listeri |
| Pocilloporidae | | Pocillopora verrucosa | Seriatopora hystrix<br>Stylophora pistillata | P. eydouxi | P. damicornis |
| Poritidae | | | Porites australiensis<br>P. (Synaraea) rus | P. lichen<br>P. cylindrica<br>P. nigrescens | P. lutea |
| Agaricidae | | Pavona varians | Pachyseris rugosa<br>P. speciosa<br>Coeloseris mayeri | | |
| Faviidae | Hydnophora exesa<br>Favia favus | Favia speciosa<br>F. pallida<br>Echinopora lamellosa<br>Goniastrea pectinata<br>Platygyra daedalea<br>P. lamellina<br>P. sinensis | Montastrea valenceinessi<br>Favites flexuosa | Leptastrea purpurea | Cyphastrea chalcidicum<br>Plesiastrea versipora |
| Merulinidae | Merulina ampliata | | | | |
| Pectiniidae | Echinophyllia asper<br>Mycedium leephantotus | | | | |
| Oculinidae | Galaxea fascicularis | | | | |
| Mussidae | | Symphyllia radians<br>S. recta<br>S. agaricia<br>Lobophyllia corymbosa<br>Acanthastrea echinata | | | |
| Dendrophyllidae | | | Turbinaria frondens<br>T. reniformis<br>T. immersa | | |
| Milleporidae | Millepora platyphylla | | | | |
| Helioporidae | | | | | Heliopora coerulea |
| Alcyoniidae | | | Sarcophyton trocheliophorum<br>L. pauciflorum<br>Sinularia polydactyla<br>Sinularia scabra | Lobophytum sarcophytoides<br>Sinularia compacta<br>Sinularia facile<br>Sinularia gibberosa | S. crassocaule<br>S. glaucum<br>Sinularia granosa<br>Sinularia exilis<br>sinularia numerosa |

表5　沉積物分析結果

| 採集地點 | 標本編號 | 總重量(g) | 骨針總數 | 4mm 網目 | | | 2mm 網目 | | | 1mm 網目 | | | 0.5mm 網目 | | | 0.25mm 網目 | | | 0.125mm 網目 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | 重量(g) | 重量% | 骨針數 | 重量(g) | 重量% | 骨針數 | 重量(g) | 重量% | 骨針數 | 重量(g) | 重量% | 骨針數 | 重量(g) | 重量% | 骨針數 | 重量(g) | 重量% | 骨針數 |
| 出水口 | 1 | 780.33 | 77913 | 0 | 0 | 0 | 16.50 | 2 | 0 | 96 | 12 | 61 | 283.81 | 36 | 1174 | 340.95 | 48 | 44711 | 15.61 | 2 | 31967 |
| | 2 | 768.97 | 98966 | 0 | 0 | 0 | 0 | 0 | 0 | 64.98 | 8 | 11 | 252.56 | 33 | 63 | 281.64 | 37 | 54351 | 169.79 | 22 | 44541 |
| | 3 | 643.2 | 137267 | 41.69 | 7 | 0 | 73.73 | 11 | 0 | 77 | 12 | 46 | 110.88 | 17 | 396 | 286.97 | 45 | 47204 | 53.34 | 8 | 89621 |
| | 4 | 778.44 | 126823 | 30.27 | 4 | 0 | 58.08 | 7 | 0 | 77.94 | 10 | 52 | 168.95 | 22 | 588 | 415.97 | 53 | 70305 | 27.23 | 4 | 55908 |
| | 5 | 790.68 | 30750 | 43.62 | 5 | 0 | 84.96 | 11 | 0 | 179.63 | 23 | 30 | 292.57 | 37 | 955 | 188.33 | 24 | 25438 | 1.57 | 0 | 4327 |
| 南灣 | 1 | 967.66 | 338146 | 0 | 0 | 0 | 0 | 0 | 0 | 11.33 | 1 | 0 | 25.95 | 3 | 77 | 482.39 | 50 | 65585 | 448.01 | 46 | 272484 |
| | 2 | 927.02 | 274676 | 0 | 0 | 0 | 0 | 0 | 0 | 7.59 | 1 | 0 | 11.39 | 1 | 58 | 484.8 | 52 | 39485 | 423.24 | 46 | 235133 |
| | 3 | 958.83 | 231344 | 0 | 0 | 0 | 2.92 | 0 | 0 | 8.42 | 1 | 0 | 25.57 | 3 | 150 | 496.64 | 52 | 56609 | 425.46 | 46 | 174585 |
| | 4 | 961.26 | 220696 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 8.53 | 1 | 60 | 455.77 | 47 | 67697 | 496.96 | 52 | 152539 |
| | 5 | 1029.5 | 257351 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 7.91 | 1 | 22 | 539.83 | 52 | 51091 | 481.8 | 47 | 206238 |
| 帆船石 | 1 | 910.25 | 16222 | 0 | 0 | 0 | 0 | 0 | 0 | 0.64 | 0 | 0 | 11.85 | 1 | 17 | 887.14 | 98 | 15070 | 10.62 | 1 | 1145 |
| | 2 | 1006.8 | 26162 | 0 | 0 | 0 | 0 | 0 | 0 | 3.2 | 0 | 0 | 30.63 | 3 | 52 | 933.54 | 93 | 18765 | 39.4 | 4 | 7343 |
| | 3 | 962.18 | 22669 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 13.19 | 2 | 49 | 906.94 | 94 | 17087 | 41.33 | 4 | 5533 |
| | 4 | 918.52 | 22250 | 0 | 0 | 0 | 0 | 0 | 0 | 1.49 | 0 | 0 | 46.87 | 5 | 87 | 857.91 | 93 | 17879 | 13.73 | 2 | 4284 |
| | 5 | 1073.5 | 39822 | 0 | 0 | 0 | 0 | 0 | 0 | 0.91 | 0 | 0 | 15.33 | 2 | 68 | 1011.9 | 94 | 32203 | 46.07 | 4 | 7491 |
| 砂島 | 1 | 1007.4 | 1945 | 0 | 0 | 0 | 7.85 | 1 | 0 | 259.87 | 26 | 64 | 707.02 | 70 | 530 | 33.42 | 3 | 1351 | 0 | 0 | 0 |
| | 2 | 1011.9 | 3656 | 0 | 0 | 0 | 2.30 | 0 | 0 | 121.06 | 12 | 32 | 753.38 | 35 | 433 | 135.24 | 13 | 3191 | 0 | 0 | 0 |
| | 3 | 926.21 | 2586 | 0 | 0 | 0 | 0 | 0 | 0 | 105.33 | 11 | 32 | 745.82 | 81 | 345 | 74.87 | 8 | 2187 | 0.91 | 0 | 22 |
| | 4 | 179.9 | 6002 | 0 | 0 | 0 | 0 | 0 | 0 | 180.83 | 15 | 47 | 864.56 | 73 | 1170 | 134.6 | 12 | 4785 | 0 | 0 | 0 |
| | 5 | 1027.7 | 2750 | 0 | 0 | 0 | 0 | 0 | 0 | 119.14 | 12 | 39 | 874.17 | 85 | 991 | 34.02 | 3 | 1720 | 0.32 | 0 | 0 |
| 雷打石 | 1 | 682.25 | 286189 | 0 | 0 | 0 | 1.16 | 0 | 8 | 9.39 | 1 | 35 | 77.56 | 11 | 310 | 496.83 | 73 | 107671 | 98.16 | 15 | 178065 |
| | 2 | 799.82 | 544665 | 0 | 0 | 0 | 7.18 | 1 | 45 | 16.54 | 2 | 71 | 65.11 | 8 | 420 | 513.74 | 64 | 116134 | 197.25 | 25 | 427995 |
| | 3 | 835.2 | 395241 | 0 | 0 | 0 | 0.7 | 0 | 0 | 12.45 | 2 | 58 | 88.72 | 11 | 490 | 623.71 | 74 | 182761 | 109.62 | 13 | 211932 |
| | 4 | 850.85 | 469550 | 0 | 0 | 0 | 6.15 | 0.7 | 42 | 6.59 | 0.8 | 38 | 59.45 | 7 | 378 | 619.91 | 73 | 140137 | 165.34 | 19 | 326958 |
| | 5 | 703.92 | 485082 | 0 | 0 | 0 | 8.46 | 1 | 68 | 33.53 | 5 | 127 | 111.06 | 16 | 655 | 365.82 | 52 | 75822 | 185.05 | 26 | 408411 |
| 桃石 | 1 | 989.37 | 40767 | 29.6 | 3 | 26 | 43 | 4 | 41 | 115.17 | 15 | 52 | 248.57 | 25 | 960 | 443.22 | 45 | 20069 | 73.81 | 8 | 19619 |
| | 2 | 1011.8 | 38027 | 44.46 | 4 | 34 | 2.84 | 5 | 32 | 133.75 | 13 | 40 | 248.42 | 25 | 667 | 469.47 | 47 | 20621 | 62.47 | 6 | 17233 |
| | 3 | 1013.9 | 51756 | 17.81 | 2 | 8 | 25.71 | 3 | 10 | 110.51 | 11 | 37 | 216.79 | 21 | 865 | 547.73 | 54 | 24068 | 95.33 | 9 | 26768 |
| | 4 | 1067.9 | 48225 | 31.38 | 3 | 12 | 37.19 | 3 | 18 | 130.77 | 12 | 45 | 253.33 | 24 | 943 | 543.67 | 51 | 26474 | 72.12 | 7 | 20733 |
| | 5 | 1018.2 | 32369 | 54.01 | 5 | 21 | 26.67 | 3 | 8 | 111.92 | 11 | 35 | 249.17 | 25 | 793 | 520.71 | 52 | 20234 | 55.64 | 5 | 11078 |
| 石頭坡 | 1 | | | | | | | | | | | | | | | | | | | | |
| | 2 | 685.72 | 515724 | 0 | 0 | 0 | 17.03 | 2 | 59 | 24.29 | 4 | 121 | 80.26 | 12 | 181 | 423.27 | 62 | 135918 | 140.87 | 20 | 378445 |
| | 3 | 482.11 | 312953 | 0 | 0 | 0 | 8.67 | 2 | 28 | 32.35 | 7 | 196 | 78.62 | 16 | 751 | 280.55 | 58 | 88800 | 81.81 | 17 | 223178 |
| | 4 | 741.78 | 383486 | 0 | 0 | 0 | 4.46 | 1 | 16 | 30.84 | 4 | 192 | 112.15 | 15 | 1683 | 512.55 | 69 | 175309 | 81.78 | 11 | 206286 |
| | 5 | 812.74 | 315550 | 50.84 | 6 | 26 | 29.4 | 4 | 54 | 58.17 | 7 | 928 | 138.66 | 17 | 2416 | 463.29 | 57 | 154430 | 72.83 | 9 | 157695 |

# 出席第六屆國際珊瑚研討會報告

## CORAL COMMUNITIES OF SOUTHERN TAIWAN


### ABSTRACT

Coral communities on the fringing reefs of southern Taiwan were studied by a line-transect sampling method. Six sites were selected for this sampling and a total of 161 lines, with 25 to 30 lines from each site, were surveyed. On average, corals (including scleractinians, alcyonaceans, and hydrozoans) cover from 33 to 50% of the reef surface. Comparison of faunal composition among study sites reveals two types of coral communities. The type I community, represented by two sites on the west coast and two sites on the east side of Nanwan Bay, is mainly composed of scleractinian corals; alcyonaceans contribute less than 6% to the total coral cover. The type II community, represented by two sites on the west side of Nanwan Bay, is comprised of more than 50% alcyonaceans and less than 50% scleractinians in total coral cover. At the within reef scale, four types of coral communities were recognized, i.e., (1) the reef margin and reef front, (2) the alcyonacean-dominated community, (3) the foliaceous coral community, and (4) the current track community. Among them, only the alcyonacean-dominated and the foliaceous coral communities have distinct faunal uniformity. The foliaceous coral community, existing at deeper protected areas (15-25 m), is dominated by foliaceous scleractinians. The alcyonacean-dominated community, existing at areas exposed to moderately strong water flow, is dominated by fleshy alcyonaceans.

## INTRODUCTION

Taiwan is located near the centers of species and generic diversity of Indo-Pacific corals which lies between the Philippines and Northeastern Australia (Wells, 1957, 1969; Stehli and Wells, 1971; Pichon, 1977; Potts, 1983). Among the reefs of the island and several adjacent islets, southern Taiwan (Lat. 21°55'-22°00' N, Long. 120°40'-120°52' E) has the best developed fringing reefs and the highest diversity of corals (Dai, 1986). Jones et al. (1972) first drew attention to the coral communities of southern Taiwan. During their short period of survey, they described the reef morphology and biological communities of southern Taiwan with emphasis on fishes and corals. Subsequent studies (Yang et al. 1976, 1977; Randall and Cheng, 1977, 1979; Yang, 1985) were focused on further descriptions of reef morphology and on the ecology of plankton and fishes. According to previous studies, two major characteristics of the coral reefs of southern Taiwan are (1) the discontinuity of the reef which is separated by sand channels of various width, and (2) the pronounced variation of coral fauna that exists among different localities of the study area. However, no quantitative studies on coral communities encompassing the reefs of southern Taiwan have been conducted before the present one.

The purposes of this study are : (1) to provide a quantitative comparison of coral communities at different localities; (2) to demonstrate the distribution pattern of corals along bathymetric gradients; and (3) to determine whether ther are detectable within-reef zonation patterns.

## METHODS

### Sampling

Six sites on the coast of Hengchun Peninsula, southern Taiwan, two on the east coast (A, B) and four in Nanwan Bay (C, D, E, F), were chosen for the study of coral communities (Fig. 1). The six study sites were chosen to represent the various types of coral communities of the study area. At each site, a traverse was established perpendicular to the coast and extending seaward to the edge of the reef (about 25 m in depth). A 10-m chain with links 1.5 cm in length was laid parallel to the depth contour at intervals and with its center sitting on the traverse line. A line-transect was sampled at approximately 15-m intervals with reference to depth contours for most part of the study sites except the submarine terrace of site D where the reef is flat and a 25-m interval was applied. A total of 25-30 line-transects were sampled at each sites. All benthic organisms under the line were recorded and the length of each organism that intercepted the line was measured to the nearest 0.25 cm and recorded. All scleractinian, alcyonacean and hydrozoan corals were identified to species. Whenever confronted with the identification of a certain coral colony, a color photograph was taken by Nikonos V camera and a small piece was chopped off and placed into a plastic bag carrying a number tag for further identification in the laboratory. No effort was made to identify the species of algae, sponges and other benthic organisms. These organisms were recorded easily recognizable classes or phyla. A coral colony was defined as any continuous tissue growing independently of its neighbors. In the cases where two or more colonies were overlapping, only the intersected length of the top colony was used for coverage calculations, while the length of the underlying colonies were also recorded for coral species diversity (Loya, 1972; Loya, 1978). The study was conducted in May to August, 1986, and February to April, 1987.

### Data Processing

Several indices were calculated for each linetransect. The basic descriptors are (1) number of species, S; (2) number of colonies, N; and (3) percent of coral coverage (COV %). Four information indices were also calculated.

(1) Shannon-Wiener's index (H')

$H' = -\sum pi \log epi$ where

$$pi = \frac{\text{Total length covered by species i}}{\text{Total length covered by all species}}$$

(2) Pielou's evenness index (J')

$J' = H'/Hmax$ where

$Hmax = \log_e S$, S = total number of species in a transect.

(3) Simpson's index (D)

$$D = \frac{\sum ni\ (ni-1)}{N\ (N - 1)}$$

(4) Size index (SI), where

$$SI = \frac{\text{Total coral coverage}}{\text{Total number of coral colonies}}$$

A single one-way analysis of variance was carried out on all the community descriptors (S, N, COV %, H', J', D, and size index) to compare the community structure of the study sites. The null hypothesis for this analysis is that there are no differences in the coral community structure among the study sites. Where ANOVA indicated significant differences, a multiple comparison of means for each of the community parameters was carried out by using Tukey's studentized range (HSD) test procedures (Ray, 1982a).

Hierarchical classification analysis was used to group the study sites and lines on a traverse to reval the faunal similarity among and within reefs. The characters used in the classification were coral coverage of each species and were log (X+1.0) transformed prior to the analysis. Species that occurred on only one line-transect were omitted in the analysis. Ward's agglomerate hierarchical method of SAS cluster procedures was used for this grouping.

All statistical analyses were conducted at the Yale Computer Center using the SAS package (Ray, 1982a, b).

## RESULTS

A total of 214 species representing 62 genera of corals were recorded during the sampling study of coral communities. Of this total, 170 species in 50 genera of scleractinians, 39 species in 11 genera of alcyonaceans, and 4 species of 1 genus (Millepora) of hydrocorals were recognized. These represent 76% of the species recorded in the study area. Among them, only 45 species were recorded on all traverses

and 135 species were recorded on 3 to 6 traverses.

## Among Reef Comparisons

Table 1 shows the average and standard deviation of various statistics measured for each line-transect at the six traverses. The results of one-way ANOVA indicated significant differences ($P < 0.05$) for all community descriptors (except Simpson's index) among the traverses. Further analysis of Tukey's multiple comparison test (Table 2) shows that site D had the lowest average number of species and the differences in remaining sites were not statistically discernible. The values of the species diversity index (H') and the evenness index (J') show similar trends to that of the average number of species. However, comparisons of living coverage show a reversw relationship. Site A had the lowest average coral coverage and no significant differences were discernible among the remaining sites. The trend in size index was similar to that of coral coverage. In conclusion, site D has the highest living coral coverage, the largest average colony size, the lowest species diversity, and the lowest evenness. On the other end, site A has the lowest coral coverage, the smallest colony size, the highest species diversity, and the highest evenness.

Table 1. Average and standard deviation (in parenthesis) of various statistics measured on the six study sites. n: number of lines, S: number of species, N: number of colonies, COV: coral coverage (%).

| site | n | S | N | COV | H' | J' | D | SI |
|---|---|---|---|---|---|---|---|---|
| A | 26 | 22.54 | 31.58 | 34.29 | 2.788 | 0.899 | 0.917 | 10.92 |
| | | (3.77) | (6.42) | (7.65) | (0.205) | (0.038) | (0.029) | (1.36) |
| B | 26 | 21.50 | 36.86 | 44.61 | 2.623 | 0.858 | 0.890 | 12.41 |
| | | (3.81) | (7.40) | (7.27) | (0.288) | (0.070) | (0.049) | (2.52) |
| C | 25 | 21.96 | 34.40 | 49.06 | 2.662 | 0.865 | 0.864 | 14.21 |
| | | (3.95) | (6.12) | (14.78) | (0.289) | (0.059) | (0.183) | (3.46) |
| D | 30 | 17.63 | 29.43 | 50.41 | 2.322 | 0.814 | 0.857 | 18.07 |
| | | (4.40) | (8.81) | (18.21) | (0.364) | (0.073) | (0.061) | (7.70) |
| E | 28 | 21.21 | 34.57 | 46.49 | 2.618 | 0.864 | 0.893 | 13.70 |
| | | (5.14) | (7.34) | (14.72) | (0.306) | (0.049) | (0.035) | (4.87) |
| F | 26 | 20.42 | 31.96 | 48.11 | 2.607 | 0.869 | 0.898 | 15.10 |
| | | (3.98) | (6.64) | (12.92) | (0.263) | (0.50) | (0.006) | (3.29) |

Table 2. Tukey's studentized range (HSD) test for differences between site means for: No. of species, △ ; No. of colonies, ● ; coral coverage, ★; H', □ ; J, o; D, ■ ; size index, ▲ .

| site | A | B | C | D | E | F |
|---|---|---|---|---|---|---|
| A | — | | | | | |
| B | ●★ □o | — | | | | |
| C | ★ o■ | | — | | | |
| D | △ ★ o■▲ | △● □o▲ | △● □o▲ | — | | |
| E | ★□o | | | △● □o▲ | — | |
| F | ★□o | △ ▲ | | △ □o▲ | | — |

Table 3.

Shows the coral faunal composition of the six traverses by families. At site- A, B, E, and F, most of the coral covergae is composed of scleractinian corals and the most abundant families are Acroporidea and Faviidae. Alcyonacean soft corals, including families Alcyoniidae and Nephtheidae, constitute less than 6% of the total coverage. However, at sites C and D, soft corals comprise more than half of the total coverage and scleractinian corals comprise less than half of the coverage. It is obvious that two types of coral communities can be differentiated in terms of faunal composition. Cluster analysis on faunal similarity based on coral coverage (Fig. 2) confirms this fact. The type I community, represented by sites A, B, E, and F, is dominatd by scleractinian corals, and the type II community, represented by sites c and D, is dominated by alcyonacean corals.

Table 3. Percent coral cover in families of the six study sites.

| Family site | A | B | C | D | E | F |
|---|---|---|---|---|---|---|
| Alcyoniidae | 4.89 | 0.46 | 48.04 | 61.73 | 5.82 | 0.29 |
| Nephtheidae | 0.46 | 0.26 | 4.56 | 1.92 | - | - |
| Helioporidae | 0.73 | 10.16 | 0.03 | 0.35 | 0.30 | 2.49 |
| Acroporidae | 32.04 | 54.61 | 9.40 | 9.02 | 20.40 | 43.25 |
| Pocilloporidae | 6.04 | 5.70 | 1.48 | 2.90 | 2.77 | 1.03 |
| Poritidae | 4.32 | 2.06 | 6.83 | 8.13 | 11.87 | 9.32 |
| Faviidae | 26.54 | 12.29 | 19.94 | 12.54 | 23.43 | 25.30 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Pectiniidae | 5.78 | 6.44 | 1.04 | 0.16 | 14.76 | 1.94 |
| Merulinidae | 2.42 | 1.73 | 2.06 | 0.45 | 12.53 | 4.96 |
| Agariciidae | 2.73 | 1.62 | 3.01 | 0.23 | 0.42 | 6.66 |
| Others | 5.05 | 4.67 | 3.61 | 2.57 | 8.06 | 4.76 |

Table 4. A list of ten of the most abundant coral species and their relative abundance (percent of total coral cover) on the six study sites.

| A | | B | | C | | D | | E | | F | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| HECO | 9.73 | HECO | 10.16 | SATR | 9.30 | SATR | 10.43 | MEAM | 12.53 | MOIN | 8.85 |
| MOIN | 3.43 | MOIN | 8.93 | LOSA | 7.31 | LOSA | 8.35 | MYEL | 10.58 | MOFL | 5.82 |
| PLLA | 2.73 | MOEH | 8.05 | SACR | 7.22 | SACR | 7.55 | LOSA | 2.51 | MOSP | 5.67 |
| MOTU | 2.59 | MOSP | 4.73 | NEER | 4.60 | SIGR | 4.94 | MOFL | 2.45 | FASP | 5.18 |
| MEAM | 2.42 | ACFO | 3.23 | SAEH | 3.75 | SIEX | 4.19 | PORU | 2.18 | MEAM | 4.83 |
| ACHY | 2.33 | MYEL | 2.97 | SIFA | 3.25 | SIFA | 3.77 | POAU | 2.12 | MOVE | 3.87 |
| ECAS | 2.31 | MOVE | 2.82 | SIEX | 2.95 | SIPO | 3.59 | PLLA | 2.11 | PLLA | 3.34 |
| MYEL | 2.06 | MOHI | 2.47 | FASP | 2.44 | DIHE | 3.16 | FIAB | 1.98 | POLI | 2.89 |
| ACDI | 2.02 | SEHY | 2.35 | SINU | 2.27 | LOSO | 2.79 | PLSI | 1.84 | MOEH | 2.81 |
| ACTE | 2.00 | STPI | 2.17 | POAU | 2.21 | POLU | 2.65 | POLI | 1.83 | MOVR | 2.51 |

ACDI: Acropora divaricata
ACFO: Acropora fomosa
ACHY: Acropora hyacinthus
ACTE: Acropora tenuis
DIHE: Diploastroa heliopora
ECAS: Echinophyllia asper
FASP: Favia speciosa
FIAB: Favites abdita
HECO: Heliopora coerulea
LOSA: Lobophytum sarcophytoides
LOSO: Lobophytum solichum
MEAM: Merulina ampliata
MOEH: Montipora ehrenbergi
MOFL: Montipora foliosa
MOHI: Montipora hispida
MOIN: Montipora informis
MOSP: Montipora spumosa
MOTU: Montipora tuberculosa
MOVE: Montipora venosa
MOVR: Montipora verrucosa
MYEL: Mycedium elephantotus
NEER: Nephthea erecta
PLLA: Platygyra lamellina
PLSI: Platygyra sinensis
POAU: Porites australiensis
POLI: Porites lichen
POLU: Porites lutea
PORU: Porites (Symaraes) rus
SACR: Sarcophyton crassocaule
SAEH: Sarcophyton ehrenbergi
SATR: Sarcophyton trocheliophorum
SEHY: Seriatopora hystrix

| | | | |
|---|---|---|---|
| SIEX: | Sinularia exilis | SIFA: | Sinularia facile |
| SIGR: | Sinularia grandilobata | SINU: | Sinalaria numerosa |
| SIPO: | Sinularia polydactyla | STPI: | Stylophora pistillata |

Figure 2. Dendrogram showing classification of the six study sites based on tissue coverage of corals. Two main groups (I and II) are distinguished at the similarity level $R^2$=0.5.

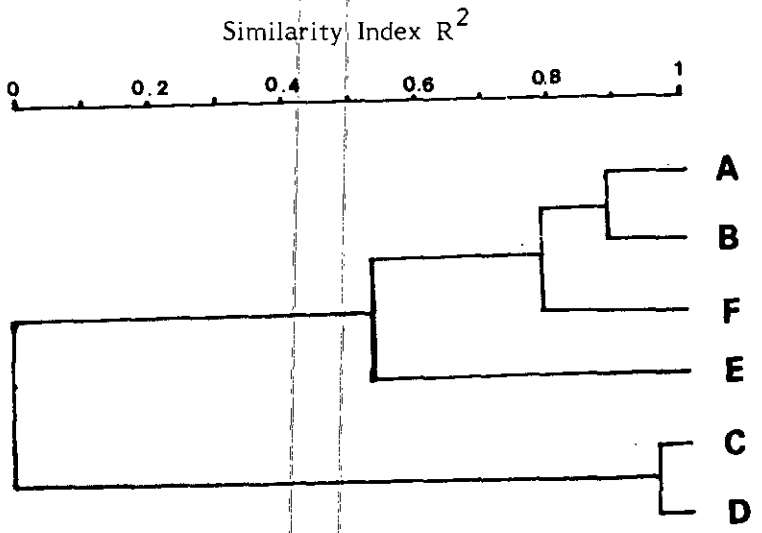



Table 4. lists ten of the most abundant coral species at each study site. At sites C anc D, eight in ten of the most abundant species are alcyonacean corals. among these, five species occur at both sites and the top three in rank are identical at both sites. Scleractinian corals which appear in the lists, such as Favia speciosa, Porites lutea, and Diploastrea heliopora, are species with massive forms. Species that are abundant at site A, B, E and F, are: Montipora informis, M. foliosa, M. venosa, Platygyra lamellina, Merulina ampliata, Mycedium elephantotus, Heliopora coerulea. The abundant coral species show differences in growth form at the four sites. At sites E and F, the common growth forms of these species are foliaceous, encrusting, and massive. Branching corals are less abundant at these two sites. However, they are relatively abundant at sites A and B, although different species are abundant at the two sites. At site A, abundant species are Acropora hyacinthus, A. divaricata, and A. tenuis; at site B, the abundant species are Acropora formosa, Seriatopora hystrix, and Stylophora pistillata.

**Within Reef comparisons**

Zonation of reefs in the study area was first described by Jones et al. (1972) based mainly on topographic characters. The topographical zones defined by them, such as reef margin, reef front, reef slope, submarine terrace, and block-and-fissure

zone, were followed in the current study. In addition, cluster analysis based on faunal composition was applied to reveal the biotic zones. The grouping by this numerical method shows considerable overlap of faunal compositions in the within-reef scale. Biotic zones are detectable only at some protected areas such as the reef slopes of sites B, E and F, and the submarine terrace of site D. By considering both the topographic features and faunal compositions, four types of coral communities were recognized.

(1) The reef margin and reef front community, represented by a mixture of massive, encrusting, and branching scleractinian corals, exists in highly exposed areas and extends from the shoreline to about 15 m in depth. Species common in this community include Montipora informis, M. spumosa, M. venosa, Porites lichen, P. australiensis, Platygyra lamellina, Favia speciosa, Stylophora pistillata, etc. The species diversity of this community is relatively high and the total coral coverage ranges from 25 to 45 percent of the surface area.

(2) The alcyonacean-dominated community, characterized by the dominance of alcyonacean corals intermingled with scattered massive and encrusting scleractinian corals, occurs on the submarine terrace and reef front of sites C and D, ranging from 4 to 15 m in depth. The major species of this community are Sarcophyton trocheliophorum, Sarcophyton crassocaule, Lobophytum sarcophytoides, Sinularia exilis, and Sinularia facile. The coral cover of this community is the highest, while the species diversity is relatively low due to the dominance of alcyonacean corals.

(3) The reef slope community, represented by foliaceous scleractinian corals, exists on the protected reef slopes and extends from 16 to 25 meters in depth. The major corals of this community are Merulina ampliata, Mycedium elephantotus, Echinophyllia asper, Pachyseris speciosa, and Montipora foliosa. These corals have a similar morphology of foliaceous or plate-like forms with a variety of modifications. In general, this community has high coral cover and low species diversity.

(4) The block-and-fissure community, represented by highly irregular reef topography and a mixture of small scleractinian and alcyonacean colonies, exists on some high-energy seaward slopes and ranges from 15 meters in depth to the edge of reefs. Scleractinian corals common in this community have massive, encrusting or stout and compact branching forms, including Diploastrea heliopora, Favia speciosa, Montipora foveolata, and Pocillopora verrucosa. Alcyonacean corals common at this area are small colonies of Sarcophyton trocheliophorum, S. ehrenbergi, and S. crassocaule. Both species diversity and coral coverage at this community are relatively low.

## DISCUSSION

Coral communities on the reefs of southern Taiwan display patterns of distribution at two spatial scales, i.e., a between-reef scale and a within reef scale. The patterns are distinctive despite the considerable overlaps in species composition of the within-reef zones and of the between-reef communities defined. The distribution patterns among these communities result from numerous biotic and abiotic mechanisms.

### Between-Reef Patterns

The most prominent pattern made known by this study is related to occurrence of two distinct faunal assemblages among the six sites. The formation and maintenance of this pattern is of primary interest. In particular, sites D and E, located in the same bay and with a distance of about 1 mile between them, have very different coral faunas. Since the current pattern shows a considerable mixing of the water mass in Nanwan Bay during successive tidal cycles (Liang et al. 1978), there would appear to be no barriers to larval dispersal. Indeed, young alcyonacean colonies were consistently found in areas dominated by scleractinian corals during the survey. However, very few large alcyonacean colonies (>10 cm in diameter) were recorded.

Differential survival of recruits seems to be the primary factor that leads to the between-reef distribution pattern of alcyonacean corals. Dinesen (1983) in her study of the distribution patterns of soft corals across the central Great Barrier Reef found that alcyonacean corals, especially members of the families Alcyoniidae and Nephtheidae, apparently favor growing on outer- and mid-shelf slopes where the water clarity is high and the water circulation is good. Benayahu and Loya (1977) and Tursch and Tursch (1982) reported that both high cover and high species diversity of alcyonacean corals occur at intermediate depths on the reefs of the Red Sea and Papua New Guinea. Since in alcyonacean corals the living tissues are spread throughout the bulk of the colony, as the colony grows larger, stronger water flow will be required to bring essential substances and carry away wastes (Tursch and Tursch, 1982). In addition, in calm waters sediment accumulation is heavier, a factor that is harmful to alcyonacean corals and restrict their distribution in areas where the water flow is relatively slow. On the other hand, since they do not have a solid skeleton, extreme water flow will dislodge them and cause mechanical damage to them. Fishelson (1970) suggested that the damaging effect of wave action is a major factor inhibiting the growth of soft corals. This view is substantiated by the depauperate faune of alcyonacean corals on very shallow reef flats (0-3 m) and the predominance of low, encrusting forms (e. g. Sinularia exilis, S. facile) on lower reef flats and the upper reef front (3-6m) in the study area.

Wherever they are present, local space monopolization by alcyonaceans corals

seems frequent. Both the studies by Benayahu and Loya (1977) and Tursch and Tursch (1982) indicated that the first five most abundant species contribute over 80% to the soft coral cover, and the first ten species comprise more than 95% of the cover. Although the soft coral fauna on the reefs of southern Taiwan does not show obvious space monopolization by few species, monospecific aggregations are frequently observed. Such a patch distribution pattern may result from asexual propagation by colony fission and/or gregarious behavior of planula larva (Benayahu and Loya, 1984b, Benayahu, 1985).

**Within-reef Patterns**

The observation and description of zonation patterns on reefs is longstanding (e. g. Marshall, 1931; Goreau, 1959; Wells, 1954; Stoddart, 1969; Barnes et al., 1971; Rosen, 1971;, Rosen, 1975; Pichon 1978; Dana, 1979; Done, 1983). Wells (1954) has defined a zone as "an area where local ecological differences are reflected in the species association and signalized by one or more dominant species". By referring to this dafinitien, only two biotic "zones" are distingulishable at the study area, i.e., the reef slope and the alcyonacean-dominated communities.

The reef slope community has been reported on most Indo-Pacific reefs (e.g. Wells, 1954; Stoddart, 1969; Dinesen, 1977; Sheppard, 1980, 1982; Done, 1983; Kühlmann, 1983). It has been named the Echinophyllia zone by Wells (1954), or the Agariciidae and Pectiniidae zone by Pichon (1978). The Agaricia zone reported by Goreau and Goreau (1973) and the 'lower fore reef slope' by Liddell and Ohlhorst (1987) are equivalents of this type of community in the Caribbean. The formation of the reef slope community has been related to light, sedimentation and trophic features of corals. Since the environment of the protected reef slope is stable, and the corals that dominate the community are good competitors (Sheppard, 1979; Dai, unpubl. data), it is likely that interspecific competition is an important factor in structuring the reef slope community.

The alcyonacean-dominated communities exist near the tips of Hengchun Peninsula The areas are exposed to relatively high water energy from constant current flow and occasional strong surge waves (Liang et al. 1978). The major environmental factor that influences the organisms in the alcyonacean dominated community seems to be water movement. Studies on the effect of water movement on scleractinian corals suggest that strong water movement excludes corals with fragile skeletal morphologies and leads to the zonation of species with high skeletal plasticity or compact growth forms (Guaus et al. 1977; Chappell, 1980). Scleractinian corals that exist in the alcyonacean-dominated community are mostly in massive or encrusting forms. Alcyonacean corals, however, adopt different strategies. Soft corals alter

their morphology and body volume significantly under the influence of mechanical stresses such as wave energy (Koehl. 1977, 1982). In the case of high mechanical stress, soft corals may contract significantly and lose more than half of their body volume. Therefore, they can resist wave surge by reducing the drag caused by water flow and hold the space efficiently. In terms of competitive ability, most of the alcyonaceans are subjected to mesenterial attacks by scleractinian corals. However, they are able to resist the aggressive behavior by developing a protective layer (Sammarco et al., 1985) and by modifying their growth directions to escape the attack or they may even overgrow scleractinians.

The distribution pattern of corals on the reefs of southern Taiwan displays two extreme types of communities which may be mainly structured by biological forces in the one case and by physical forces in the other case. The basic morphological explanation for this pattern is that the very attributes that contribute to competitive dominance (such as faster growth rate and concomitant greater morphological relief) may make them susceptible to wave damage (Wilson and Keddy, 1986). Conversely, the morphologies most resistant to wave damage (massive, compact colonies) may be weak competitors, since they grow slower and are more constant in form. On coral reefs, physical factors (e. g. wave energy, sediment) appear to determine which species can live in a certain environment, and then, biological processes (e. g. competition, predation) sturcture the community.

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