Diversity of soft corals (Alcyonacea: Alcyoniina) in Thai waters

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ชื่อวิทยานิพนธ์ ความหลากหลายของปะการังอ่อนในน่านน้ำไทย

ผู้เขียน นายทนงศักดิ์ จันทร์เมธากุล

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บทคัดย่อ

ศึกษาความหลากหลายของปะการังอ่อนในน่านน้ำไทย โดยเน้นศึกษาการแพร่กระจาย ความชุกชุมของสกุล ลักษณะทางนิเวศวิทยาบางประการของแต่ละสกุล และศึกษาอนุกรมวิธาน ของปะการังอ่อนสกุล *Sarcophyton* ในน่านน้ำไทย ระหว่างเดือนมิถุนายน 2545 – พฤษภาคม 2551 แบ่งพื้นที่ศึกษาออกเป็นบริเวณฝั่งทะเลอันดามัน 117 สถานีย่อย จาก 17 หมู่เกาะ และ บริเวณฝั่งอ่าวไทยทั้งหมด 85 สถานีย่อยจาก 12 หมู่เกาะ บันทึกข้อมูลการสำรวจโดยใช้การ ประเมินด้วยสายตา รวมถึงการถ่ายรูป และบันทึกลักษณะสภาพแวดล้อม เช่น ลักษณะของพื้นที่ ยึดเกาะ มุมเอียงของพื้นวัสดุที่ยึดเกาะ ความโปร่งแสงของน้ำทะเล สำหรับการศึกษาอนุกรมวิธาน ของปะการังอ่อนในสกุล *Sarcophyton* ศึกษาโดยเก็บตัวอย่างของปะการังอ่อนจากภาคสนามและ ศึกษาตัวอย่างที่เก็บรักษาไว้ในพิพิธภัณฑ์สัตว์และพืชทะเล สถาบันวิจัยทรัพยากรทางทะเลและ ชายฝั่ง จังหวัดภูเก็ต

ผลการศึกษาพบปะการังอ่อนในน่านน้ำไทยทั้งหมด 4 ครอบครัว 19 สกุล ได้แก่ ครอบครัว Alcyoniidae สกุล *Sinularia, Dampia, Cladiella, Klyxum, Sarcophyton, Lobophytum* และ *Eleutherobia* ครอบครัว Nephtheidae สกุล *Nephthea, Stereonepthya, Scleronephthya, Dendronephthya* และ *Umbellulifera* ครอบครัว Nidaliidae สกุล *Nidalia*, *Siphonogorgia*, *Chironephthya* และ *Nepthyigorgia* ครอบครัว Xeniidae สกุล

Xenia, *Heteroxenia* และ *Sansibia* จากรายชื่อสกุลดังกล่าวพบว่าเป็นรายงานใหม่ของปะการังอ่อนในน่านน้ำไทยจำนวน 9 สกุลได้แก่สกุล *Eleutherobia*, *Nepthyigorgia*, *Nidalia*, *Heteroxenia*, *Chironephthya, Siphonogorgia*, *Stereonepthya, Dampia* และ *Sansibia*

ผลการศึกษาการแพร่กระจายของปะการังอ่อนพบว่าครอบครัว Alcyoniidae เป็นครอบครัวเด่นในอ่าวไทย ในขณะที่ครอบครัว Nephtheidae และ Alcyoniidae เป็นครอบครัวเด่นฝั่งทะเลอันดามัน ผลจากการคำนวณค่าความถี่ของการปรากฏจากทั้งหมดทุกสถานีสำรวจพบว่าปะการังอ่อนสกุลที่มีความถี่ของการปรากฏสูงสุดได้แก่ สกุล *Sinularia, Dendronephthya* และ *Sarcophyton* ตามลำดับ ในขณะที่ปะการังอ่อนที่มีความถี่ของการปรากฏต่ำได้แก่ สกุล *Nidalia*, *Nephthyigorgia* และ *Heteroxenia* ซึ่งกลุ่มสกุลดังกล่าวเป็นสกุลที่หายากในการศึกษาครั้งนี้

จำนวนสกุลของปะการังอ่อนที่พบในน่านน้ำไทยมีความสัมพันธ์กับระยะห่างจากชายฝั่ง โดยพบว่าบริเวณหมู่เกาะห่างฝั่งพบปะการังอ่อนจำนวนมากกว่า 10 สกุล ได้แก่บริเวณ เกาะโลซิน หมู่เกาะสิมิลันและหมู่เกาะอาดัง-ราวี ผลจากการศึกษาครั้งนี้พบว่าบริเวณที่มีสำคัญด้านความหลากหลายของปะการังอ่อนฝั่งทะเลอันดามันได้แก่ บริเวณหมู่เกาะสิมิลัน พบปะการังอ่อนจำนวน 13 สกุล ในขณะที่ฝั่งอ่าวไทยได้แก่ เกาะโลซิน พบปะการังอ่อนจำนวน 10 สกุล

กล่าวได้ว่าปะการังอ่อนมีลักษณะถิ่นที่อยู่อาศัยแบบจำเพาะแตกต่างกันไปในแต่ละครอบครัว โดยปะการังอ่อนครอบครัว Nephtheidae มีการแพร่กระจายและมีความชุกชุมดีบนพื้นหินมากกว่าแนวปะการังแท้ ในขณะที่ปะการังอ่อนครอบครัว Alcyoniidae แพร่กระจายและมีความชุกชุมดีบนพื้นแนวปะการังแท้มากกว่าพื้นหิน นอกจากนั้นพบว่าโซนที่ปะการังอ่อนเจริญเติบโตได้ดีได้แก่ โซนลาดชัน และพื้นทรายด้านนอกแนวปะการัง สำหรับมุมลาดเอียงของพื้นวัสดุพบว่าปะการังอ่อนครอบครัว Alcyoniidae สามารถยึดเกาะได้ตั้งแต่แนวระนาบถึงลาดเอียงประมาณ 90 องศา สำหรับปะการังอ่อนสกุล Neptheidae ซึ่งเป็นกลุ่มที่ไม่มีสาหร่ายเซลล์

เดียวในเนื้อเยื่อสามารถยึดเกาะได้ทุกมุมลาดเอียง ความชุกชุมและจำนวนชนิดของปะการังอ่อนมีความสัมพันธ์กับความโปร่งใสของน้ำทะเล โดยพบว่าความชุกชุมและจำนวนชนิดของปะการังอ่อนเพิ่มขึ้นตามความโปร่งใสของน้ำทะเล

ผลการศึกษาอนุกรมวิธานของปะการังอ่อนสกุล *Sarcophyton* ในการศึกษาครั้งนี้พบว่ามีจำนวน 10 ชนิด ได้แก่ *S. ehrenbergi*, *S. elegans*, *S. stellatum*, *S. trocheliophorum* และ *S. glaucum* นอกจากนี้พบว่าเป็นชนิดใหม่จำนวน 5 ชนิด ซึ่งต้องมีการศึกษาเพิ่มเติมต่อไปในอนาคต

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ABSTRACT

The aim of this study is on biodiversity survey of soft corals (Alcyoniina group) in Thai waters, focusing on genera richness, distribution, abundance and some ecological aspect. The study locations in Thai waters were divided into two geographic regions, Andaman Sea coast of Thailand and Gulf of Thailand. In the Andaman Sea coast of Thailand, it consisted of 17 locations, which were divided into 71 substations of the true reef and 46 substations of the rocky substrate. The Gulf of Thailand consisted of 12 locations; which were divided into 60 substations of true reefs and 25 substations of rocky substrate. All of study sites were surveyed in June 2002 – May 2008. The surveys and data collection were conducted by SCUBA. The record of distribution and abundance data by visual estimates was done by counting 40 minutes of diving time (200 m approximately) along each survey site. Moreover, record of the environment parameters; substrate type, depth of sampling site including depth range where the particular genus distributed, water transparency by measuring sechi depth, angle of substrate (horizontal, ~15^{o}, ~ 45^{o}, ~90^{o} or overhang 180^{o}) were recorded. Soft corals were identified on site to generic level. The taxonomy of *Sarcophyton* in Thai waters was also examined. The specimens were collected by SCUBA diving, including type specimens which are stored in the PMBC Reference Collection.

The soft corals of 4 families comprising of 19 genera were found in this study. They are: Alcyoniidae; *Sinularia, Dampia, Cladiella, Klyxum, Sarcophyton, Lobophytum* and *Eleutherobia*, Nephtheidae; *Nephthea, Stereonepthya,*

Scleronephthya, Dendronephthya and *Umbellulifera*, Nidaliidae; *Nidalia*, *Siphonogorgia*, *Chironephthya* and *Nepthyigorgia*, Xeniidae; *Xenia*, *Heteroxenia* and *Sansibia*, of which 9 genera are new records. These are *Eleutherobia*, *Nepthyigorgia*, *Nidalia*, *Heteroxenia*, *Chironephthya, Siphonogorgia*, *Stereonepthya Dampia* and *Sansibia*.

The Alcyoniidae is the dominant family in the Gulf of Thailand, whereas in the Andaman Sea coast of Thailand, Nephtheidae is the dominant family. In calculating as percentage of occurrence frequency, 3 major genera had the highest percentage occurrences: *Sinularia, Dendronephthya* and *Sarcophyton* respectively. In contrast, lowest occurrences were *Nidalia*, *Nephthyigorgia* and *Heteroxenia*. They are rare genera in this study.

In spatial term, genera richness correlated to distance from mainland. High richness (≥ 10 genera) was found on offshore islands, at GT12 (Losin Island), AN06 (Similan Islands) and AN16 (Adang-Rawi Islands). At these locations, reefs develop to over 20 m depth. The "hot spot" of soft coral diversity in the Gulf of Thailand locates at GT12 (Losin Island), where 10 genera were found. It is an offshore reef with the distance of 80 km from mainland. While the "hot spot" in the Andaman Sea coast of Thailand locates at AN06 (Similan Islands) which are offshore reefs with the distance of 70 km from mainland and 13 genera were recorded.

This study suggests that different genera of soft corals show habitat preference. It has been found that the Nephtheidae family widely distributes on rocky shore or submerged rocks than on true reefs whereas the Alcyoniidae family are more abundant on true reefs than rocky habitats. The finding shows that soft coral growth are strongly related to site specific such as zonation on reef. They are often found on the slope area and sand floor. The angle of substrate has an influence on distribution and abundance of soft corals. The Alcyoniidae were found on substrates with varying angles ranging from horizontal to ~ 90°. In this study, azooxanthellate genera of Neptheidae and Nidaliidae were found attached to substrates at all angles. In term of effect of environmental parameters, it is concluded that soft corals abundance and richness increases with increasing water transparency.

From result of the first part 42 colonies of *Sarcophyton* from this filed survey and some specimen from PMBC Reference collection. Ten species were found of

which five species are new species to be described in the future. The others are *S. ehrenbergi*, *S. elegans*, *S. stellatum*, *S. trocheliophorum* and *S. glaucum*.

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Thanongsak Chanmethakul

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CHAPTER 1
INTRODUCTION

1. Background and importance

Soft corals (Cnidaria: Octocorallia: Alcyonacea: Alcyoniina) are distributed worldwide and are an important component of coral reefs ecosystem, especially in the Indo-Pacific region. There are 35 genera of soft corals distributed over 15 percent of the area (Dai 1990, Fabricius 1997; Fabricius and De'ath 2001, Fabricius and Alderslade 2001).

In the last decade, knowledge of taxonomy and ecology of soft corals especially from the shallow tropical reefs in the Indo-Pacific region has increased. Taxonomic studies were carried out in some selected areas i.e., South Vietnam (Malyutin 1990), Red sea (Reinicke 1997; Perkol-Finkel and Benayahu 2004), Southern Red Sea (Benayahu et al. 2002), in the east and the south of Africa (William 2000; William 2003; Benayahu et al. 2003), Seychelles (Ofwegen 2001; Malyutin 1992), American Samao (Cornish and DiDonato 2004), South-West of Australia (Alderslade 2003), South of Taiwan (Benayahu et al. 2004), South China Sea, and Indo-Pacific sea (Li et al. 2000; Ofwegen 2005), and Indonesia (Ofwegen 1999; Manuputty and Ofwegen 2007). However, only a few studies on effect of environmental parameters, such as sedimentation and turbidity, were conducted (Dai 1991a; Riegl and Bloomer 1995; Riegl and Branch 1995; Fabricius and De'ath 2001; Schleyer and Celliers 2003), depth (Fabricius and Klump 1995), current and flow (Fabricius et al. 1995a). Biological factors such as predation (Wylie and Paul 1989) and competition (Sammarco et al. 1983) have been deemed unlikely to influence abundance and richness of soft corals.

Knowledge on soft coral diversity and abundance in Thai waters is limited. Most of the available information on reef organisms is for hard corals, for example: taxonomic studies (Ditlev 1976, 1978; Phongsuwan 1986; Kongjandtre 2004; Chankong 2006); community distribution (Brown et al. 1986; Sakai et al. 1986; Jiravat 1985; Chou et al. 1991; Phongsuwan and Chansang 1992); coral recruitment

(Yeemin 1998); distribution of coral reefs, reef condition and general morphology of reefs (Chansang et al. 1999a, b) and reef management (Yemin et al. 2001, 2006).

The first study of soft corals in Thai waters was carried out by Verseveldt, (1982a), who described a new species of soft coral, *Cladiella steineri* from Sri-Chang Island. In 1987, there was a workshop on the taxonomy of soft corals and sea fans at the Phuket Marine Biological Center (UNESCO-COMAR training course), which resulted in recording 15 genera in 5 families from Phuket and vicinity Islands. In addition, a study on soft coral taxonomy at the inshore islands along the coasts of Prachuabkhirikhan, Chumphon and Suratthani Provinces was conducted by Satapoomin in 1989. Ten genera in 4 families were reported. After that, Benayahu (1998) study lobe variation of *Sinularia nanolobata* at Patong Bay, Phuket Island. A survey of coral reefs in the Thai waters by Chansang et al. (1999a, b); revealed that soft corals were present at all survey sites, with especially high abundance on offshore islands. No specific study on soft coral distribution has been done. Worachananan (2000) reported finding 12 genera in 4 families in distribution and diversity of soft corals in Thai waters. However, these reports are limited in both scale and important ecological aspects of soft corals, such as depth, substrate preference, and abundance. The geographic setting of Thai waters, situating between the Andaman Sea and Gulf of Thailand is an ideal location for a comparative study of Indo-Pacific reef organisms between the 2 seas.

Previous studies demonstrate that soft corals in Thai waters are highly diverse (Satapoomin 1989; Chansang et al. 1999a, b; Worachananan 2000). Thailand does not have a scientist that is sufficiently knowledgeable and qualified to study this subject. This study aims to build up research capability in the taxonomic study of soft corals in this country, and the genus *Sarcophyton* is the first genus to be studied. The genus *Sarcophyton* is a large taxon with 39 valid species, which are widely distributed throughout the Indo-pacific region (see: Verseveldt and Benayahu 1978; Verseveldt 1982b; Li 1984; Alderslade and Shirwaiker 1991 and Benayahu and Perkol-Finkel 2004). In addition, this genus is one of several genera that had a new revision within the last two decades: *Sinularia* (Verseveldt 1980); *Sarcophyton* (Verseveldt 1982b); *Lobophytum* (Verseveldt 1983); *Bellonella*, *Eleutherobia*, *Nidalia* and *Nidaliopsis*

(Verseveldt and Bayer 1988); *Minabea* (Williams 1992; Williams and Alderslade 1999).

Recently, the population of soft corals has decreased dramatically due to a number of anthropogenic and pollution factors such as American Samoa reefs (Cornish and DiDonato 2004) including bleaching phenomenon (Fabricius 1999) and tourism (Walters and Samways 2001). These combined and accumulated threats have had a direct impact onpopulations of soft corals and their habitats. Continuing reductions in abundance and distribution caused by increases in the magnitude and frequency of detrimental factors indicate that the future impacts on coral reef community structure will be severe. An investigation into the distribution, abundance and some ecological factors affecting soft corals is essential in order to implement successful resource management. This is not possible without a solid base of scientific knowledge and understanding. It must be supplemented with data collected on a large scale from a number of sites.

2. Objectives

3.1 To study the distribution and abundance of soft corals at genus level and the importance of some ecological parameters such as habitat preferences, substrate and angle of substrate types which might influence their distribution and abundance in Thai waters.

3.2 To conduct a taxonomic study of *Sarcophyton* in Thai waters.

3. Duration of the study

Data and collections were obtained between June 2002 – May 2008.

CHAPTER 2
LITERATURE REVIEW

1. Classification of the soft corals

The classification of soft corals used here follows that of Bayer (1981) and can be summarized as follows:

Class Anthozoa

Subclass Octocorallia

Order Alcyonacea

Group Alcyoniina (Soft corals) (See Bayer 1981 Key page 943)

Family Paralcyoniidae

Alcyoniidae

Nephtheidae

Nidaliidae

Xeniidae

2. General characteristics of the soft corals

Soft corals like other cnidarians, consists of three layers: an exterior layer of protective epithelial tissue called an epidermis, an interior layer of a digestive epithelial tissue called a gastrodermis, and the mesogloea layer that lies between these two tissues (Fabricius and Alderslade 2001).

The Octocorallia, soft corals, of the family (Alcyoniidae) mostly have one type of polyp which is called an autozooid which is responsible for the capture of prey and also the production of gametes. Colonies that have one type of polyp are termed monomorphic. Some taxa within this family have another type of polyp called a siphonozooid, which is small with no tentacles. Colonies that have two types of

polyps are called dimorphic. Siphonozooids have small-sized mesenteries and cilia that help to transport the seawater into the colony, which takes small suspended food to the body (Bayer 1973; Fabricius and Alderslade 2001).

The autozooid polyp has a cylindrical or tubular shape. The upper portion is called the anthocodia and carries the mouth and tentacles and is usually the visible portion. Autozooid polyps have eight tentacles which generally have pinnules of varying numbers: some are small and may not be easily visible. In most groups autozooids polyps can be retracted into the general coenenchymal mass or into the stiffened lower part of the anthocodia, called the calyx (Bayer 1956, 1973; Fabricius and Alderslade 2001).

From the mouth down to the gastrovascular cavity is the short pharynx. The pharynx is the compressed tube which on its narrower side is formed into a longitudinal tract called the siphonoglyph (or sulcus). Here there are flagella which continually pump up water into the gastrovascular cavity. The gastrovascular cavity has eight thin mesenteries above connecting to the wall of pharynx while their lower part is free making the gastrovascular cavity divided by the mesenteries. There are 8 mesenteries in all soft corals (Fig. 1) (Bayer 1973; Fabricius and Alderslade 2001).

In the terms of contraction, the polyp anthocodiae become shortened and the tentacles folded over the oral disc, or into the mouth. In retraction, a retractile polyp is withdrawn into the upper part of the gastrovascular cavity (Fabricius and Alderslade 2001).

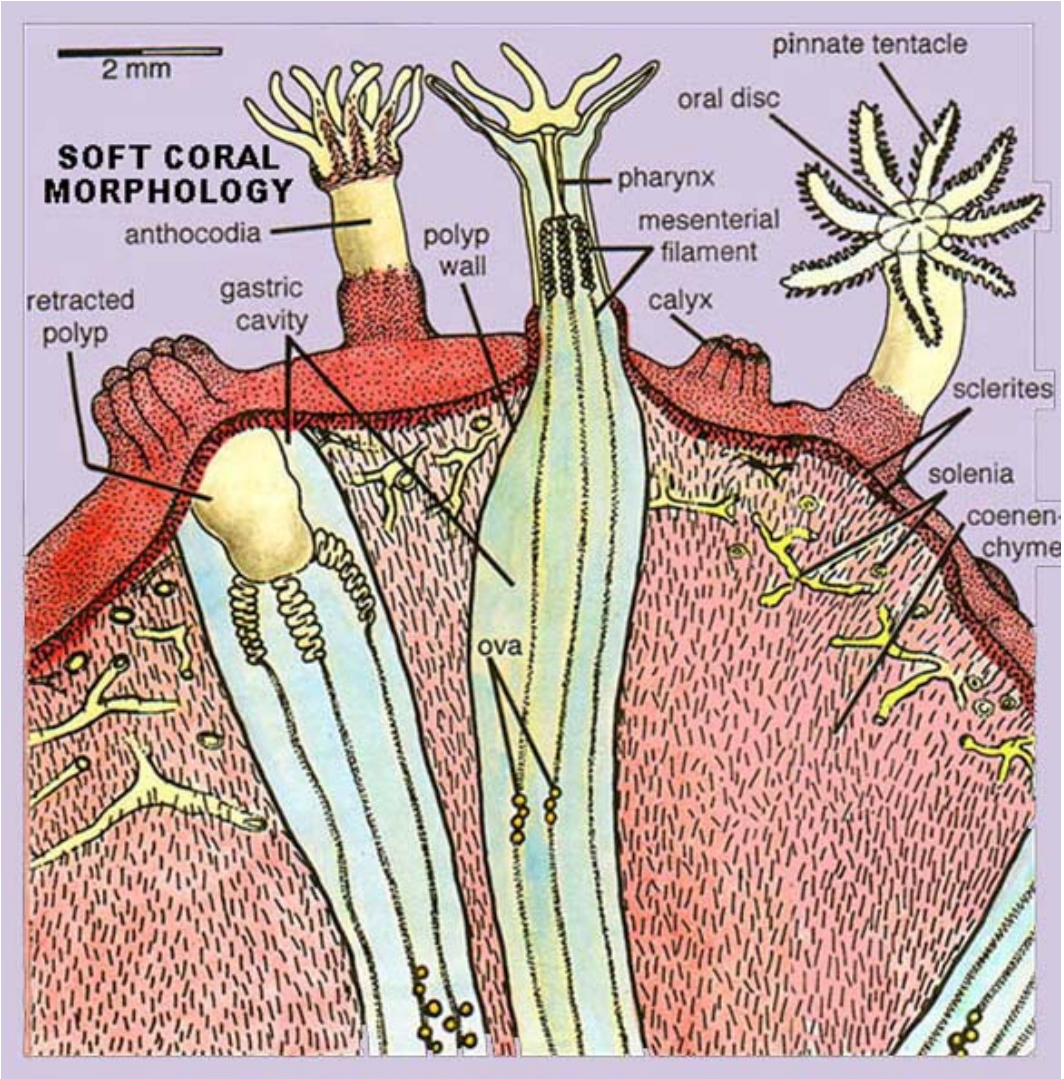


Fig. 1. Polyp structure of soft corals.
(http://research.calacademy.org/research/izg/softcoralmorphology.htm)

Soft corals have two main layers with the outer layer called the ectodermis and the inner layers the endodermis or gastrodermis. Between these two is a less prominent middle layer called the mesogloea. In the mesogloea there are scleroblast cells that produce the calcareous sclerites.

There are various types of sclerites differing in shape, size and color (Fabricius and Alderslade 2001). They may occur as spindles, clubs, radiate, needles, rods, plates etc. (see Bayer et al. 1983). The sclerites are most important for taxonomic identification of the different soft coral taxa. In some soft corals such as *Sinularia*, the larger sclerites are in the form of spindles are in the basal part of the

colony. In the family Neptheidae there are typically large-sized sclerites in the polyps called supporting bundle along with collaret and points. Some species of soft corals have points without the collaret (Fabricius and Alderslade 2001).

Colonies of soft corals may consist of different parts such as stalk, stem, branch, lobe, disc and capitulum. The majority of soft coral corals have no solid skeleton to help in supporting the body. There is just the seawater which enters the mouth of the polyp and distributes throughout the body causeing pressure within the skeleton (hydrostatic pressure) and is thus termed a hydroskeleton. The pressure of the fluid and action in the body are used in changing the soft coral's shape. They can shrink quickly when they are disturbed or in stressful conditions.

Soft corals can be divided into two groups by the absence or presence of symbiotic algae (zooxanthellae) that live within the gastrodermal cells. Most tropical soft corals have zooxanthellae. They are mainly distributed on shallow coral reefs; they are members for example of the families of Alcyoniidae, Xeniidae and some of the Nephtheidae. These soft corals get supplemental nutrition from zooxanthellae which have no a direct role for calcification, unlike scleractinian coral (Bayer 1973). Azooxanthellate soft coral are another group which lives without symbiotic photosynthesising algae. Members of this group are for example some of the Nephtheidae, Nidaliidae and Paralcyoniidae. These families commonly feed on passing zooplankton (Fabricius et al. 1995ab; Fabricius and Alderslade 2001).

Soft corals have a variety of colours and this may depend on the zooxanthellae. Dark green or brown soft corals that commonly met on shallow reefs, especially members of the Alcyoniidae. Coloured sclerites such as pink, red, and yellow are often found for example in azooxanthellate species of the family Nephtheidae.

The distribution and abundance of soft corals are determined by many factors such as light, water movement, sedimentation etc. Previous research has found that two important factors for corals are the depth and the distance from the mainland. Xeniid, nephtheid and alcyoniid soft corals are generally found in the clear sea water while *Xenia* and *Paralemnalia* species are found in shallow water located on windward side of an island (Benayahu and Loya 1981; Tursch and Tursch 1982; Dinesen 1983; Fabricius and Alderslade 2001). Zooxanthellae soft corals were rarely

found in inshore areas where there was heavy sediment. Under heavy sedimentation species of the genera *Sinularia*, *Sarcophyton* and *Klyxum* can be found (Frabricius and Alderslade 2001). Most soft corals are well spread in the areas where the prevailing current helps to bring plankton and wash away the wastes from colonies. The influence of waves and wind was found to be a limiting factor for the distribution of soft corals. Most of them also grow well in the leeward regions where there are quite waves, and other genera survive well at the windward sites. Most of soft corals well spread in the area where the water flows as this area helps to bring plankton and blow out the waste from colony. The optimal flow fir particle capture in octocoral ranges between 8 – 15 cm s^{-1} (Dai and Lin 1993; Fabricius et al. 1995a).

Most of soft corals exist well in the areas where the water flows as this helps to bring plankton and remove the waste from colony. The optimal flow for particle capture in octocorals ranges between 8 – 15 cm s^{-1} (Dai and Lin 1993; Fabricius et al. 1995a).

Light is important for photosynthesis which is necessary for zooxanthellate genera (Fabricius and Alderslade 2001). Moreover, light is also support the calcification of a soft coral (Tentori and Allemand 2006). Light intensity and quality are a function of depth. Even though shallow areas have more light they may also have higher wave action that can effect growth and shape of soft corals. Most of them reach peak cover and abundance between 15-25 m (Fabricius 1996).

Reproduction is clearly important to support and control the structure of a population of soft corals. Both sexual and asexual reproduction has been documented in soft corals. Soft coral possess a number of asexual reproductive strategies: colony fission (Benayahu and Loya 1985; Lasker 1988), rapid autonomy of small fragments with root-like processes (Dahan and Benayahu 1997), partial mortality with division into two separate entities (Farrant 1985) or survival and reattachment of colony fragments (Lasker 1984, Walker and Bull 1983). Those were found to be important for the dynamics of the soft coral taxa in a given area. Sexual reproduction is divided to three distinctive categories: 1) Gonochoric broadcasting such as *Heteroxenia fuscescens* 2) External surface brooding and 3) Internal brooding (Dahan and Benayahu 1997).

The spawning pattern is different for each mode of reproduction. In the gonochoric group, *Heteroxenia fuscescens* displays year-round gametogenesis and planulation processes (Benayahu 1991). Some of the broadcast spawners reproduce year-round (Dahan and Benayahu 1997). In both modes of reproduction there may be external cues such as seawater temperature rise. In addition, the spawning behavior may coincide with lunar cycles, with gamete release occurring at or following full moons (Alino and Coll 1989; Babcock 1990; Brazeau and Lasker 1989, 1990; Kruger et al. 1998), and even preceding the moon's last quarter (Benayahu and Loya 1983), and may be also affected by tidal cycle (Alino and Coll 1989).

The settlement of soft coral planulae occurs rather quickly and thus they have a short planktonic phase. Benayahu and Loya (1987) proposed that short-range dispersal of planulae is a common trait among coral reef alcyonaceans. Soft corals such as *Xenia macrospiculata* and *Parerythropodium fulvum* can develop embryos to mature planula in a few days, and these mostly settle near the parent colony (Benayahu and Loya 1984).

Recruitment is an important aspect of the population dynamics of sessile organisms (Hughes and Tanner 2000). Recruitment of corals can differ with area and time (Wallace 1985; Connell et al. 1997; Dunstan and Johnson 1998). This alteration depends on many factors such as the ability to produce offspring of adult colonies in each area (Hughes et al. 2000), the rate of juvenile surviving (Harrison and Wallace 1990), and the competitive ability with other living sessile organism (Birkeland 1977; Miller et al. 2000).

Several studies indicated that soft corals may spread and occupy space rather rapidly by asexual reproduction. For example, *Dendronepthya hemprichii* produces small fragment with root-like processes, and when the colony reaches a height of more than 20 centimeters it can produce hundred of pieces. These small fragments fall down around parent colony or disperse to adjacent areas by current. After falling down the fragments will be attached quickly within 5-10 hours. This reproductive strategy can produce dominant groups in an area (Dahan and Benayahu 1997).

2. General characteristics of *Sarcophyton* Lesson, 1834

2.1 Systematic review of *Sarcophyton*

At present there are 39 species within the genus *Sarcophyton* (see: Verseveldt and Benayahu 1978; Verseveldt 1982b; Li 1984; Alderslade and Shirwaiker 1991 and Benayahu and Perkol-Finkel 2004):

Genus *Sarcophyton* Lesson, 1834

Sarcophyton acutangulum Von Marenzeller, 1886

Sarcophyton acutum Tixier-Durivault, 1970

Sarcophyton auritum Verseveldt & Benayahu, 1978

Sarcophyton birkelandi Verseveldt, 1978

Sarcophyton boettgeri Schenk, 1896

Sarcophyton boletiforme Tixier-Durivault, 1958

Sarcophyton buitendijki Verseveldt, 1982

Sarcophyton cherbonnieri Tixier-Durivault, 1958

Sarcophyton cinereum Tixier-Durivault, 1946

Sarcophyton cornispiculatum Verseveldt, 1971

Sarcophyton crassocaule Moser, 1919

Sarcophyton crassum Tixier-Durivault, 1946

Sarcophyton digitatum Moser, 1919

Sarcophyton ehrenbergi Von Marenzeller, 1886

Sarcophyton elegans Moser, 1919

Sarcophyton flexuosum Tixier-Durivault, 1966

Sarcophyton furcatum Li, 1984

Sarcophyton gemmatum Verseveldt & Benayahu, 1978

Sarcophyton glaucum (Quoy & Gaimard, 1833)

Sarcophyton infundibuliforme Tixier-Durivault, 1958

Sarcophyton latum (Dana, 1846)

Sarcophyton mililatensis Verseveldt & Tursch, 1979

Sarcophyton nanwanensis Benayahu & Perkol-Finkel, 2004

Sarcophyton pauciplicatum Verseveldt & Benayahu, 1978

Sarcophyton portentosum Tixier-Durivault, 1970

Sarcophyton pulchellum (Tixier-Durivault, 1957)

Sarcophyton regulare Tixier-Durivault, 1946
Sarcophyton roseum Pratt, 1903
Sarcophyton serenei Tixier-Durivault, 1958
Sarcophyton solidum Tixier-Durivault, 1958
Sarcophyton spinospiculatum Alderslade & Shirwaiker, 1991
Sarcophyton spongiosum Thomson & Dean, 1931
Sarcophyton stellatum Kükenthal, 1910
Sarcophyton stolidotum Verseveldt, 1971
Sarcophyton subviride Tixier-Durivault, 1958
Sarcophyton tenuispiculatum Thomson & Dean, 1931
Sarcophyton tortuosum Tixier-Durivault, 1946
Sarcophyton trocheliophorum v. Marenzeller, 1886
Sarcophyton turschi Verseveldt, 1976

2.2 Characteristics of the *Sarcophyton*

Colony shape: *Sarcophyton* has a mushroom shaped colony, often large. The disc on the upper part of colony is called the capitulum or polypary. The capitulum is rounded, rather than flat, lobed or folded strongly at the margin. The capitulum surface bears dimorphic and fully retractile polyps (Verseveldt 1982b).

The capitulum is connected to the stalk which may bury into a sand bottom or be attached on the dead coral substrate (Fig. 2). The colony size is variable and some time species specific. Colonies of *Sarcophyton* may change their shape due to water loses when being disturbed. In some species the capitulum can be fold or has cup or funnel shape.

Polyps: Colonies of *Sarcophyton* are dimorphic with two types of polyps; autozooids and siphonozooids. In some species polyps are fully retractile when being disturbed whiles in others they are semi-contractile. The distance between two autozooids are vary in different species and is a feature which is considered as useful for species identification. Polyps at the edge of the capitulum are closer to each other compared to those found in the middle part of the capitulum.

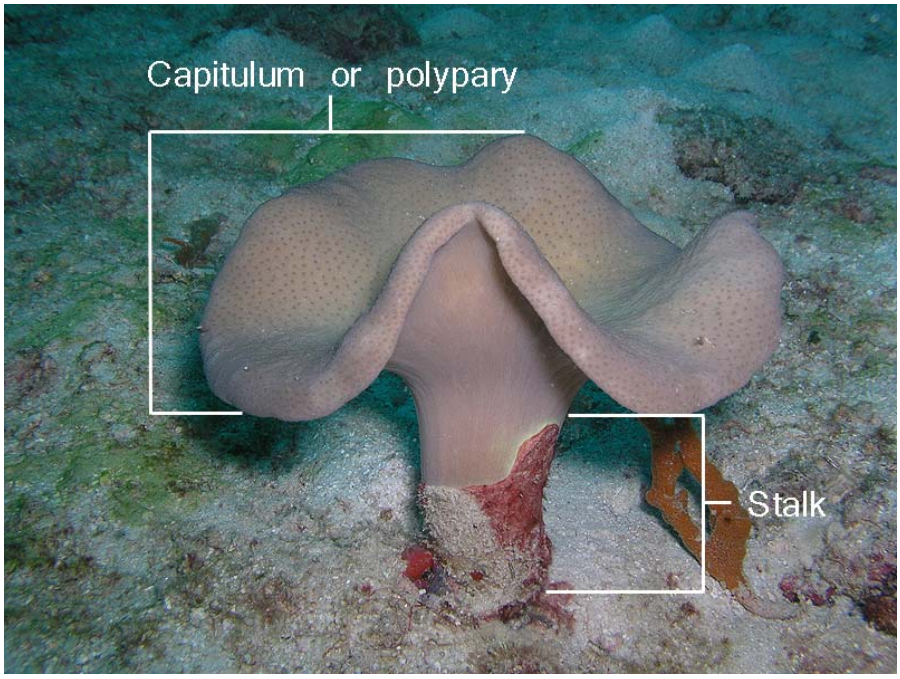


Fig. 2. The morphology of a *Sarcophyton* colony.

Sclerite: Sclerites are much more important for taxonomical value; shape and size are different in each species and vary with position within the colony. The surface layer of the capitulum and the stalk contain clubs. The characters of the clubs will be different in each species, some clubs have a larger head while some are small and narrow. In the interior of the capitulum and the stalk most sclerites are spindles, rods or needles. Various sizes of warts can be present: simple spines, spiny warts, truncated or smooth.

CHAPTER 3
MATERIALS AND METHODS

1. Distribution and abundance of soft corals

1.1 Study sites

Study locations were surveyed during March 2004 – March 2005. The study locations in Thai waters were in two geographic regions, the Gulf of Thailand and the Andaman Sea coast of Thailand, as shown in Fig. 3.

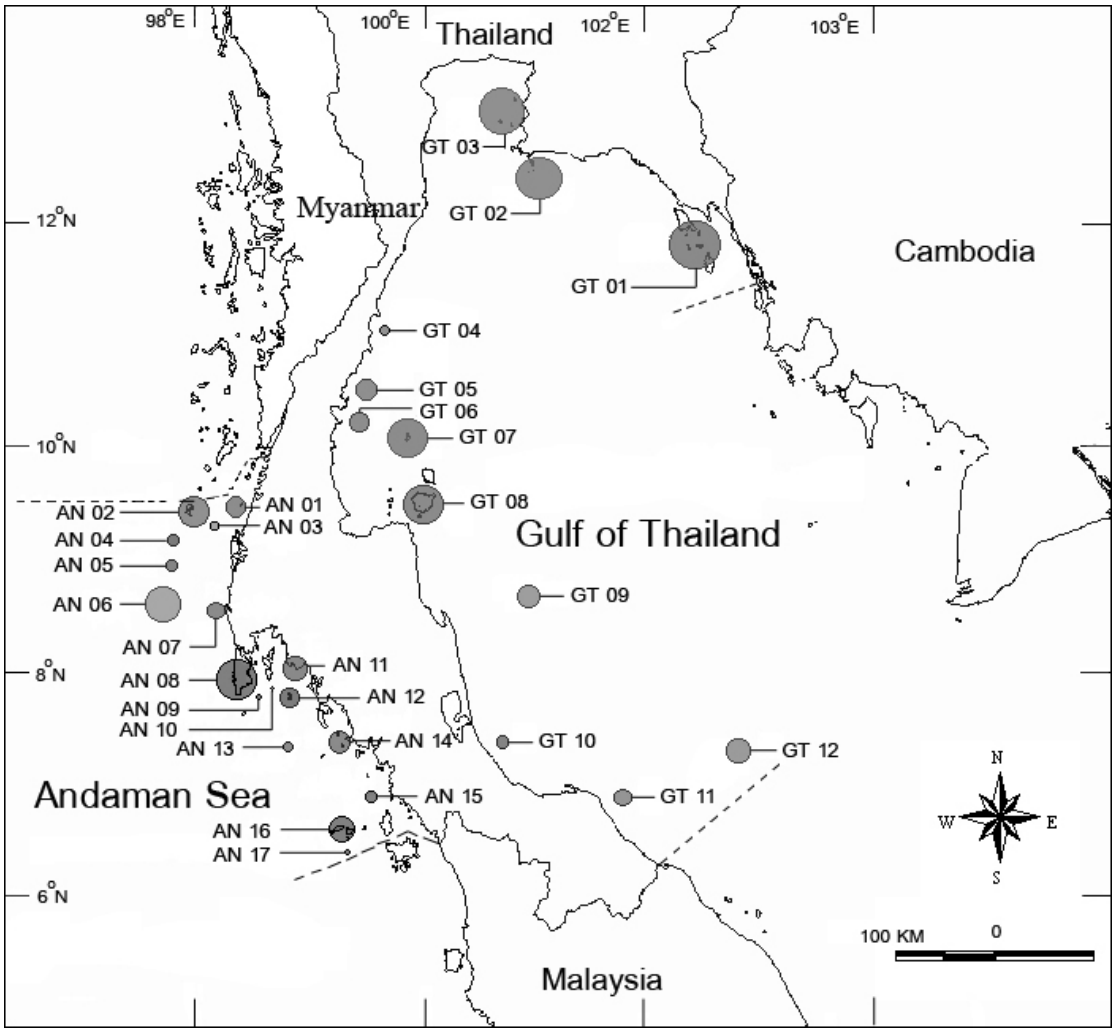


Fig. 3. Map of Thai waters indicating the location of all survey sites, including true reefs, rocky shores and submerged rocks.

(a) The Andaman Sea (AN) locates at the eastern part of the Indian Ocean bordering by 5 countries, i.e. Myanmar, Thailand, Malaysia, Indonesia and India (Andaman and Nicobar Islands). The coastline of Thailand extends from Ranong Province in the north to Satun Province in the south covering the distance of about 865 km with over 130 islands along the coast. The coastline of the mainland and the islands consists of various ecosystems such coral reefs, mangroves, seagrass beds and rocky shore etc. Coral reefs are fringing reefs with and approximate total reef area of 79 km^2 (Chansang et al. 1999b). There are distinct differences in coral reef habitats between inshore and offshore islands. The South-west monsoon exerts a powerful influence on the development of coral reefs throughout the AN. On the east of islands facing mainland, protecting from powerful monsoon storms, coral reefs develop extensively whereas west coast of the islands are mainly rocky shores with some reef development in pockets of small bays. The mainland reefs and inshore reefs extend from 3-10 m in depth, but in offshore islands, the water clarity enables reefs to develop to the depth of 20-40 m. The reef topography in the AN can be divided into three zones: reef flat, reef edge and reef slope. Besides under South-west monsoon influence, reefs are also affected by other physical environment parameters. In the AN the tide is semi-diurnal and reefs in protected bay develop extensive intertidal reef flats which exposed to air for 2-4 hours during spring tide. The water temperature range from 25.9-30.4 C^o and the salinity levels of 29-33 ppt (Limpsaichol et al. 1991).

(b) The Gulf of Thailand (GT) is a semi-enclosed sea bordered by the coastline of Vietnam, Cambodia, Thailand and Malaysia with connection to the South China Sea in the south. In Thailand coastline of the GT is separated into the east coast (Chonburi to Trat Province) and the west coast (Phetchaburi to Narathiwat Province) with the Inner Gulf in between. The lengths of the coastline are approximately 544 km. for the east coast and 1,296 km. for the west coast. There are about 250 surrounding islands all along the coast. The physical parameters of the coastal waters are as the followings: diurnal tide and mixed tide, sea surface temperature ranging from 31-32 C^o on the east coast and 29-31 C^o on the west coast, and salinity of 30-33 part per thousand (Pollution Control Department 2001).

The total coral reef area in the Gulf of Thailand is about 75 km^2. Coral reef development is under monsoonal influence as in the Andaman Sea. The coral reefs of

islands on the east coast of the GT develop on the east of the islands, i.e. leeward side of Southwest Monsoon wind, whereas reefs of islands on the west coast of the GT develop on the west of island which is the leeward side of the Northeast Monsoon. Coral reefs are fringing reefs and they can be found both in inshore and offshore islands. Reef growth can extend to about 5 – 15 m in depth for the inshore islands and 15-20 m in depth for the offshore islands. The mainland coastline is mainly open coast and protected bays, of which environments are not suitable for reef development (Chansang et al. 1999a).

1.2 Methods

This study is the most extensive survey of soft coral distribution within Thai waters of the AN and the GT. Due to numerous study sites, the grouping of study sites were as follow:

Each island group was considered as a station. Altogether there were 17 stations in GT (Fig. 3). Theses stations were divided into 2 groups according to bathymetric charts no 045 of Royal Thai Navy's Hydrographic Department as 1) inshore islands which locate nearshore not exceeding 20 m depth and 2) offshore islands which locate in deep water over 20 m depth. For each station, it was divided according to habitats as true reef and rocky substrate. These were considered as substations (Fig. 4). The rocky substrate included rocky shores which had less than 25 percentage of coral cover to submerged rocks of which majority of them located in offshore areas.

At each substation, sampling/survey was carried out according to reef zonation for true reef habitat and depth range for submerged rock habitat. These were listed as sites: reef flat, reef slope and fore reef for true reef; and upper zone, lower zone and fore reef for submerged rock habitat (Fig. 5).

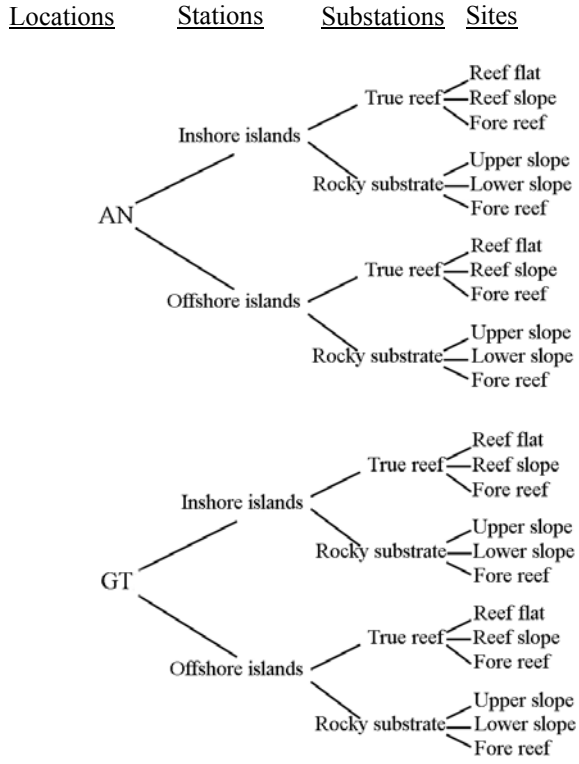


Fig. 4. Sampling designed for measuring spatial distribution and abundance of the soft corals at the Andaman coast of Thailand (AN) and the Gulf of Thailand (GT).

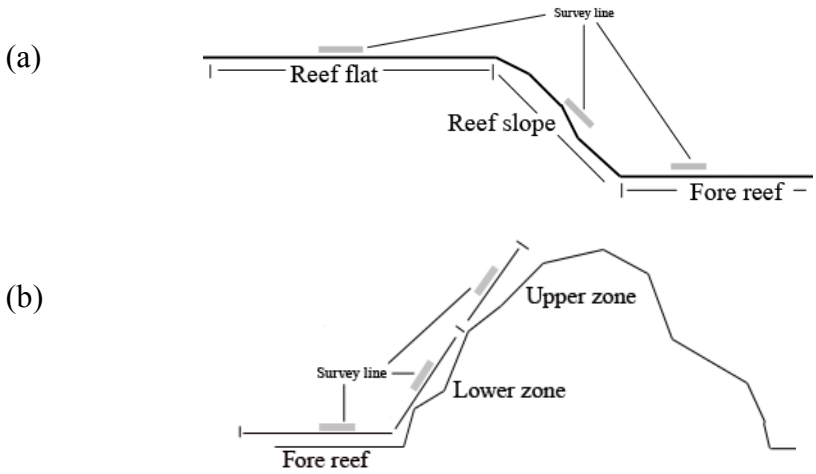


Fig. 5. Survey sites on soft corals habitats (a) true reef (b) submerge rock or rocky habitat.

The surveys and data collection were conducted by SCUBA. In the AN, it consisted of 17 locations, which were divided into 71 substations of the true reef and 46 substations of the rocky substrate (Table 1a). The GT consisted of 12 locations;

which were divided into 60 substations of true reefs and 25 substations of rocky substrate (Table 1b).

Table 1. Study sites regions, names and habitat types in the Andaman Sea coast of Thailand (a) and the Gulf of Thailand (b).

(a)

Location	Name of islands Or Rocky habitats	Number of survey sites		Location description
		True reef	Rocky substrate	
AN 01	Kam Islands	9	8	Inshore islands
AN 02	Surin Islands	8	4	Offshore islands
AN 03	Richelew Rock	-	1	Submerged rock
AN 04	Tachai Rock	-	1	Submerged rock
AN 05	Bon Island	-	1	Offshore islands
AN 06	Similan Islands	10	6	Offshore islands
AN 07	Kao Na Yak	1	-	Mainland reef
AN 08	Phuket Island and vicinity islands	18	-	Inshore islands
AN 09	Dokmai Island	-	2	Offshore islands
AN 10	Musang Rock	-	1	Submerged rock
AN 11	Coastal islands in Krabi Province	9	-	Inshore islands
AN 12	Phi Phi Islands	10	7	Inshore islands
AN 13	Deang Rock	-	1	Submerged rock
AN 14	Coastal islands in Trang Province	1	7	Inshore islands
AN 15	Coastal islands in Satun Province	1	3	Inshore islands
AN 16	Adang-Rawi Islands	4	3	Offshore islands
AN 17	Eight Mile Rock	-	1	Submerged rock
Total		71	46	

(b)

Location	Name of islands Or Rocky habitats	Number of survey sites		Location description
		True reef	Rocky substrate	
GT 01	Chang Islands	16	6	Inshore islands
GT 02	Samaesarn Islands	6	3	Inshore islands
GT 03	Lan Islands and few islets to the north	5	2	Inshore islands
GT 04	Talu Islands	2	1	Inshore islands
GT 05	Ngam Islands	1	3	Inshore islands
GT 06	Coastal Islands in Chumporn Province	5	1	Inshore islands
GT 07	Tao Islands	5	9	Offshore islands
GT 08	Samui Island	6	-	Inshore islands
GT 09	Kra Islands	6	-	Offshore islands
GT 10	Kham Island	2	-	Inshore islands
GT 11	Laopi Island	2	-	Inshore islands
GT 12	Losin Island	4	-	Offshore islands
Total		60	25	

Assessment and survey in both locations (AN and GT) were made by a semi-quantitative method which has proven to be superior to the traditional quantitative methods (line transects, quadrates etc.), and it is considered an advantage in terms of area surveys (DeVantier et al. 1998; Fabricius and De'th 2001).

The record of distribution and abundance data by visual estimates was done by counting 40 minutes of diving time (200 m approximately) along each survey site (reef flat, reef slope and fore reef). For rocky substrate, surveys were accomplished by swimming around the rocks not repeating the same route for 40 minutes. Abundance grades were given to all of the soft corals at each site and separated to 5 levels applied from Dinesen (1983) and Benayahu et al. (2004), by using $\log_{10}$ (0 = absent, 1 = rare, 2 = sporadic, 3 = abundant, 4 = dominant) (Table 2). Moreover, photographs were taken by using Olympus C5050 camera and record of the environment parameters; substrate type, depth of sampling site including depth range where the particular genus distributed, water transparency by measuring sechi depth, angle of substrate (horizontal, ~15^{o}, ~ 45^{o}, ~90^{o} or overhang 180^{o}) were recorded. Soft corals were identified on site to generic level.

Table 2. Abundance scales from semi-quantitative survey of soft corals, applied from Dinesen (1983) and Benayahu et al. (2004).

Abundance scales	Level	No. colonies
4	Dominant	101 - 1000
3	Abundant	11 – 100
2	Common	2 – 10
1	Rare	1
0	Absent	0

1.3 Data Analysis

Spatial distribution pattern

To understand spatial distribution the frequency of occurrence data were used. Data of occurrences were transformed to percentage by calculation of (number of site which soft coral occurring in each parameter x 100) / all sites of each parameter. The parameter in this formula means inshore islands and offshore islands, true reef and rocky habitat, including reef flat/upper zone and reef slope/lower zone and fore reef.

Comparison of the frequency of occurrence of each genus at all sites between the AN with GT was analyzed by using SPSS V.11 Program for Chi-square test.

Habitat preference of soft corals

Habitat preference for each genus of soft corals was investigated in details at all levels, i.e., reef zone, and angle of substrates. Data analysis was carried out by using Primer V.5 Program based on presence-absence data and abundance rank scale from semi-quantitative survey data. The analysis used Euclidean Distance as the clustering algorithm and complete linkage.

Environmental parameters

The correlation between soft corals abundance and water transparency was tested by rank abundance, using Spearman Rank Correlation method. The relationship between genera richness and water transparency was tested by Simple Regression Analysis, using the data which were derived from the survey stations in both the Andaman Sea coast and the Gulf of Thailand. The water transparency was considered as independent variable and number of genus as dependent variable. Both analyses SPSS V.11 Program were used for both analyses.

2. *Sarcophyton* from Thai waters

Sarcophyton specimens were collected by SCUBA diving. Underwater photographs of live specimens were taken. Data on physical parameters, such as sites, substrate whereby the specimen was found and depth were recorded. Samples of *Sarcophyton* were preserved in 70% alcohol.

Specimen preparation for sclerites identification was carried out. Samples were prepared by cutting small pieces of specimens from relevant parts of colonies and placed on the microscopic slides. Approximately 2-3 drops of sodium hyperchlorite (Clorox) were added to digest the tissues, and then undigested sclerites on the slides were carefully cleaned 3-5 times with fresh water. The shape and forms of sclerites were measured under the stereo microscope (Nikon SMZ645) or compound microscope (Nikon E600). Photographs were taken by using a digital camera.

Most of specimens in this study were gathered during several field trips in Part I, including type specimens which have been stored in the PMBC Reference Collection. The list of specimens are as follow: PMBC24802, PMBC24803, PMBC24804, PMBC24805, PMBC24806, PMBC24807, PMBC24808, PMBC24809, PMBC24810, PMBC24811, PMBC24812, PMBC24813, PMBC24814, PMBC24815, PMBC24818, PMBC24819, PMBC24820, PMBC24821, PMBC24823, PMBC24824, PMBC24825, PMBC24826, PMBC24827, PMBC13314, PMBC13315, PMBC13318, PMBC13319 and PMBC13320. All together 42 colonies were examined.

This taxonomic study follows the references by Verseveldt & Benayahu (1978), Verseveldt (1982b), Li (1984), Alderslade & Shirwaiker (1991) and Benayahu & Perkol-Finkel (2004).

CHAPTER 4
RESULTS AND DISCUSSIONS

Part I: Richness and distribution of soft corals in Thai waters

1. Results

1.1 Richness patterns

The surveys were conducted during 2004 – 2005. In the AN, it consisted of 71 stations of true reefs, and 46 stations of rocky shores and submerge rocks, and in the GT, there were 25 stations of true reefs and 60 stations of rocky shores and submerged rocks. Soft corals of 4 families comprising of 19 genera were found in this study. They are

Alcyoniidae: *Sinularia, Dampia, Cladiella, Klyxum, Sarcophyton, Lobophytum,* and *Eleutherobia*

Nephtheidae: *Nephthea, Stereonepthya, Scleronephthya, Dendronephthya* and *Umbellulifera*

Nidaliidae: *Nidalia*, *Siphonogorgia*, *Chironephthya* and *Nepthyigorgia*

Xeniidae: *Xenia, Heteroxenia* and *Sansibia*

Table 2 shows the results from the survey. At the AN, the total genera found in this study were 19 genera: *Sinularia*, *Dampia*, *Cladiella*, *Klyxum*, *Sarcophyton*, *Lobophytum*, *Eleutherobia*, *Nephthea*, *Stereonepthya*, *Scleronephthya*, *Dendronephthya*, *Umbellulifera*, *Nidalia*, *Siphonogorgia*, *Chironephthya*, *Nepthyigorgia*, *Xenia*, *Heteroxenia* and *Sansibia*. The AN06 (Similan islands) was the station which contained highest generic richness (13 genera) in the AN. The area is in deep water with visibility over 30 m and it contains diverse habitats include true reefs, rocky shores and submerged rocks (Table 1). The reefs are fringing reefs extend to over 30 m and reef flat are 3-5 m depth. Soft corals can grow in all zones (reef flat, slope and fore reef zone). The Alcyoniidae can be found on reef flat and reef slope, and the Nephtheidae, azooxanthellae group, can be found on reef slope to fore reef in over 40 m depth.

At the GT, the total genera reported were 12 genera: *Sinularia*, *Dampia*, *Cladiella*, *Klyxum*, *Sarcophyton*, *Lobophytum*, *Eleutherobia*, *Scleronephthya*, *Dendronephthya*, *Siphonogorgia Chironephthya* and *Nepthyigorgia*. The GT12 (Losin Island) was the location which contained highest generic richness (10 genera) in the Gulf of Thailand. The area of GT12 is a small islet in deep water near Malaysian border in the south of the GT. The coral reef in this island lies at 5-40 m depth with good visibility over 30 m. Coral reef was in good condition with live coral cover over 70%. The dominant soft corals in this area were *Dendronephthya* and *Scleronephthya*. Moreover, *Sarcophyton* were commonly found on the fore reef at 40 m depth.

Table 3. Showing survey locations in Thai waters and taxa present in each location, including true reefs, rocky shores and submerge rocks. (The legend; /, present; - , absent; *, new record; *Sin = Sinularia*, *Dam = Dampia*, *Cla = Cladiella*, *Kly = Klyxum*, *Sar = Sarcophyton*, *Lob = Lobophytum*, *Ele = Eleutherobia*; *Nep = Nephthea*, *Ste = Stereonephthya*, *Scl = Scleronephthya*, *Den = Dendronephthya*, *Umb = Umbellulifera*, *Nid = Nidalia*, *Sip = Siphonogorgia*, *Chi = Chironephthya*, *Neph = Nephthyigorgia*, *Xen = Xenia*, *Het = Heteroxenia*, *San = Sansibia*)

	Alcyoniidae							Nephtheidae					Nidaliidae				Xeniidae			No. of genus at each station
	Sin	*Dam**	*Cla*	*Kly*	*Sar*	*Lob*	*Ele**	*Nep*	*Ste**	*Scl*	*Den*	*Umb*	*Nid**	*Sip**	*Chi**	*Neph**	*Xen*	*Het**	*San**	
AN01	/	/	/	-	/	/	-	-	-	-	/	-	-	-	-	-	/	-	/	7
AN02	/	-	/	-	/	/	-	/	-	/	/	-	-	/	/	-	-	-	-	9
AN03	-	-	-	-	-	/	/	-	-	/	/	-	-	/	-	-	-	-	-	5
AN04	-	-	-	-	/	/	-	/	-	/	/	-	/	/	/	-	-	-	-	8
AN05	/	-	-	-	-	/	-	-	-	/	/	-	-	-	-	-	-	-	-	4
AN06	/	-	-	/	/	/	/	/	/	/	/	-	/	/	/	-	-	/	-	13
AN07	/	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
AN08	/	-	-	-	/	/	-	/	-	/	/	/	-	-	/	-	-	-	-	8
AN09	/	-	-	-	-	-	-	-	-	/	-	-	-	/	/	-	/	-	-	5
AN10	-	-	-	-	-	-	-	/	-	-	/	-	-	-	-	-	-	-	-	2
AN11	/	-	-	-	/	/	-	/	-	-	/	-	-	-	-	-	-	-	-	5
AN12	/	-	-	-	/	-	-	/	-	/	/	-	-	/	-	-	-	-	-	6
AN13	-	-	-	-	-	-	-	-	-	/	/	-	-	/	-	-	-	-	-	3
AN14	/	-	-	-	/	-	-	-	-	-	/	-	-	-	/	-	-	-	/	5
AN15	-	-	-	-	-	/	-	-	-	/	/	-	-	-	/	/	/	-	-	6
AN16	/	-	-	-	/	/	-	/	/	/	/	/	-	/	/	-	/	/	-	12
AN17	/	-	-	-	-	-	-	-	-	/	/	-	-	-	/	-	-	-	-	4
GT01	/	-	/	/	/	/	-	-	-	-	-	-	-	/	/	-	-	-	-	7
GT02	/	/	/	/	/	/	-	-	-	-	/	-	-	-	/	-	-	-	-	8
GT03	-	-	/	/	/	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3
GT04	/	-	/	/	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3
GT05	/	-	/	/	/	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4
GT06	/	-	-	/	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2
GT07	/	/	/	/	/	/	-	-	-	-	/	-	-	-	-	-	-	-	-	7
GT08	-	-	/	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
GT09	/	-	/	/	/	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4
GT10	-	-	/	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
GT11	-	-	-	-	-	-	-	-	-	-	-	-	-	-	/	-	-	-	-	1
GT12	/	/	/	-	/	-	/	-	-	/	/	-	-	/	/	/	-	-	-	10

In spatial term, genera richness correlated to distance from mainland. High richness (≥ 10 genera) was found on offshore islands, at GT12, AN06 and AN16 (Adang-Rawi Islands). At these locations, reefs develop to over 20 m depth.

Low richness was generally found at the inshore sites: AN07 (Kho Na Yak), GT08 (Samui Island), GT10 (Kham Island) and GT11 (Lao-pi Island). These locations are affected by nearshore turbidity and freshwater run off from mainland. AN07 is a mainland reef in shallow water of 5 m depth. The reef flat is exposed at low tide and the site was badly affected by freshwater run off and sedimentation. The dominant coral species were tabulate form of *Acropora* spp., with live coral cover less than 40 percent. Only few colonies of *Sinularia* were found. GT08, GT10 and GT11, were inshore islands located in southwest of the GT (Fig. 3). The genera features of these reefs are fringing reefs extend to of 3-5 m depth. In GT08 and GT10, reef flats are exposed at low tide, and reefs are dominated by massive coral of *Porites*. Only *Cladiella* was found in the area. At GT11, only few colonies *Chironephthya* were found.

The dominant genera obtained from this study were *Sinularia* (20 locations), *Dendronephthya* (18 locations) and *Sarcophyton* (16 locations). In calculating as percentage of occurrence frequency, 3 major genera had the highest percentage occurrences: *Sinularia* (30.20%), *Dendronephthya* (22.11%) and *Sarcophyton* (19.97%) respectively. In contrast, lowest occurrences (0.33%) were *Nidalia*, *Nephthyigorgia* and *Heteroxenia*. They are rare genera in this study (Fig. 6).

It can be said that family Alcyoniidae is the dominant family and family Xeniidae is the rare family base on number of genera presented and percentage occurrence of each genera (Table 3 and Fig. 6). This study records 19 genera in Thai waters, of which 9 genera are new records. These are *Eleutherobia*, *Nepthyigorgia*, *Nidalia*, *Heteroxenia*, *Chironephthya, Siphonogorgia*, *Stereonepthya Dampia* and *Sansibia*. Ranking in term of percent occurrence, they can be placed in this order: *Sinularia* > *Dendronephthya* > *Sarcophyton* > *Cladiella* > *Lobophytum* > *Klyxum* > *Scleronaphthya* > *Chironephthya* > *Siphonogorgia* > *Nephthea* > *Xenia* > *Sansibia* > *Eleutherobia* > *Stereonephthya* > *Dampia* > *Umbellulifera* > *Nephthyigorgia, Nidalia* and *Heteroxenia*.

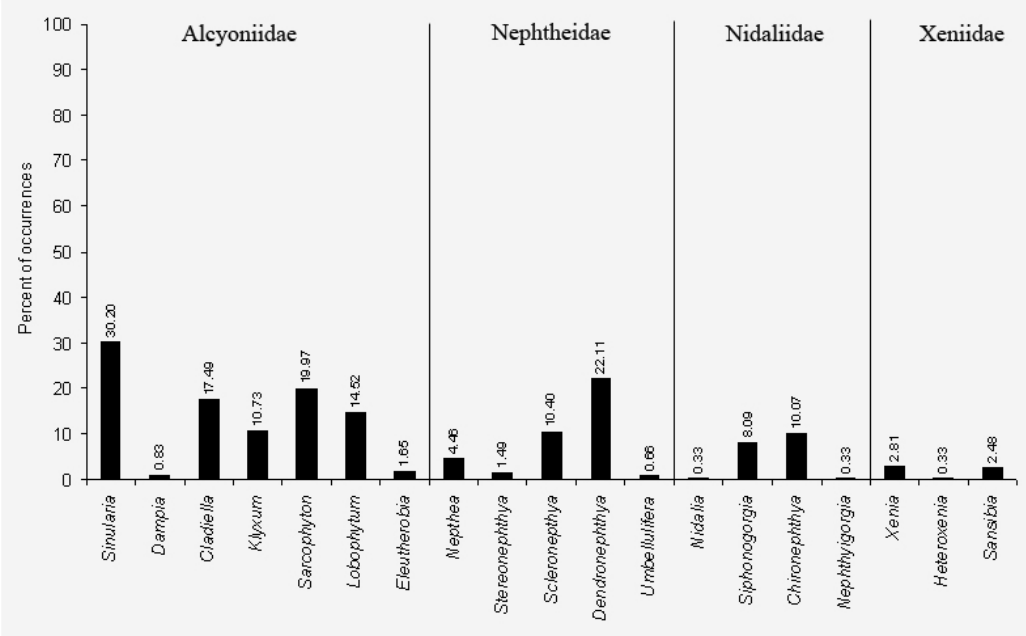


Fig. 6. The occurrences of all soft coral genera calculating as percentage of occurrence from 606 sites in Thai waters.

1.2 Distribution patterns

It can be said that each genus of soft corals had different geographical distribution pattern (Fig. 7). The highest occurrences in the GT were *Cladiella*, *Sinularia* and *Klyxum*, with 56.06, 47.06 and 42.35 percent occurrence respectively. In the AN, *Sinularia* (45.87%) was the highest occurrences, following by *Dendronephthya* (43.97%) and *Lobophytum* (32.76 %).

By comparing frequency of occurrence between the AN and the GT, it was found that for *Sinularia*, *Dampia*, *Sarcophyton*, *Eleutherobia* and *Nephthyigorgia*, there were not significantly different (Chi-square test – $p>0.05$). For *Cladiella*, *Klyxum*, *Lobophytum*, *Scleronephthya*, *Dendronephthya*, *Siphonogorgia* and *Chironephthya*, it was significant (Chi-square test - $p<0.05$) however. Seven genera were found only in the AN: *Nephthea*, *Stereonephthya*, *Umbellulifera*, *Nidalia*, *Xenia*, *Heteroxenia* and *Sansibia*.

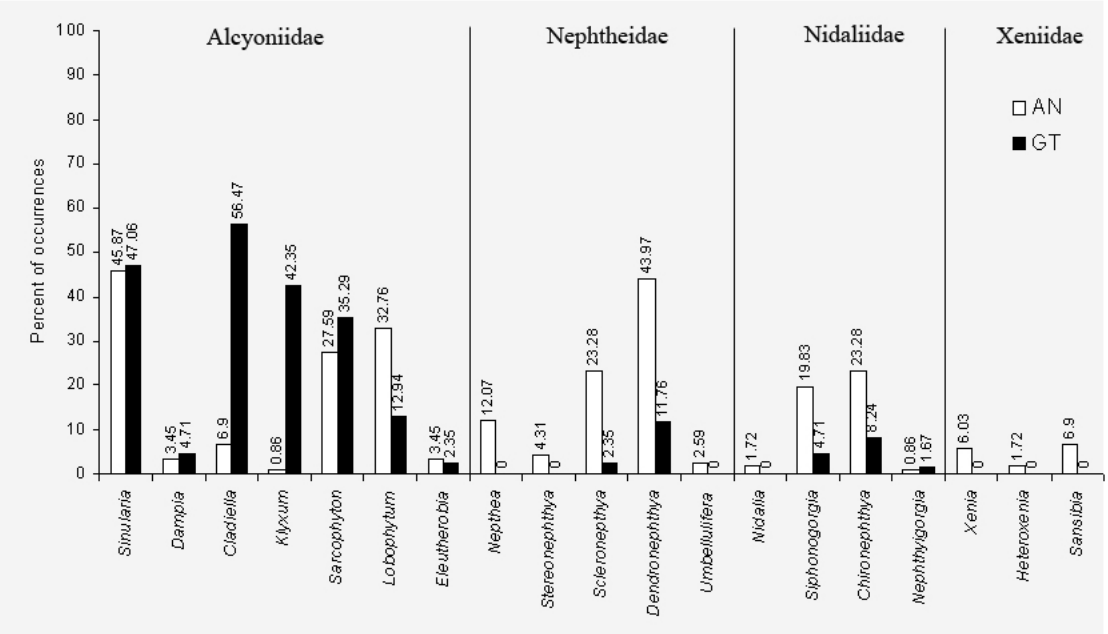


Fig. 7. The total percent of occurrences at the AN and the GT, in various genera which occurring in Thai waters.

At habitat level, soft corals were found both on true reefs and on rocky habitat. The richness and abundances in the AN were found on coral reef on eastern side of island and on submerged rocks in relatively strong currents. In the eastern part of the GT the pattern of abundance and distribution was also the same as in the AN, whereas high diversity and abundance of soft corals in the western part of the GT was on western side of islands.

The windward side of islands were generally rocky shores, limestone cliff or steep walls. On the upper zone of these areas, which were affected by strong waves, a few dominant genera such as *Lobophytum* and *Sinularia* were found encrusted on rocky substrate. A few *Dendronephthya* colonies were found in the lower zone.

Figure 8 presents the information on occurrence of each genus at different zonation of habitats for both inshore and offshore islands in Thai waters. The dominant genera of Alcyoniidae such as *Sinularia* and *Sarcophyton* were found at all sites (reef flat/upper zone, reef slope/lower zone and fore reef) of both inshore and offshore islands whereas certain dominant genera (*Cladiella* and *Klyxum*) were found dominant only in the GT. For genera of Nephtheidae, Nidaliidae and Xeniidae, they

were present or dominant only in the AN. They were more abundant in offshore sites than inshore sites.

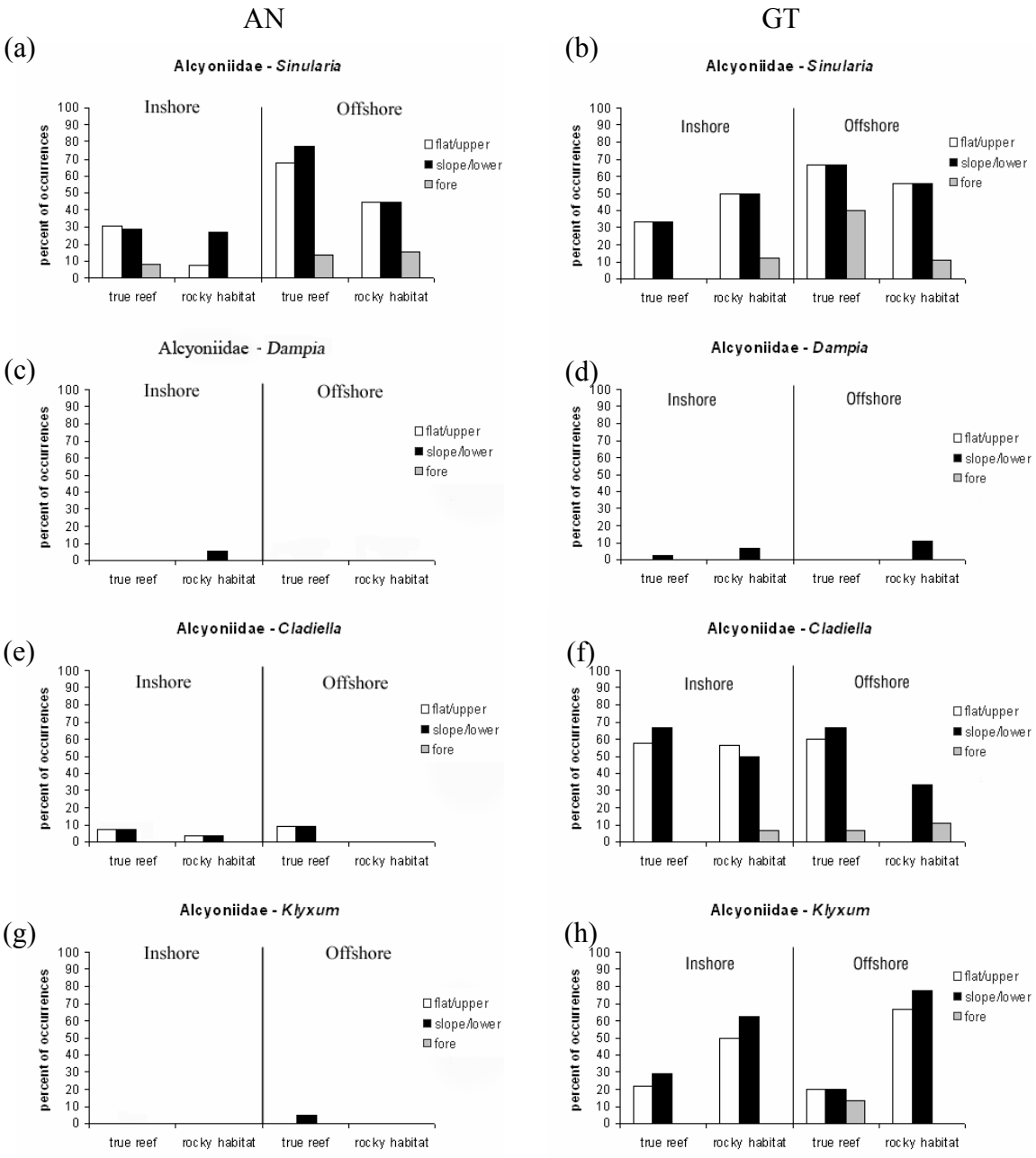


Fig. 8. Percent occurrences of soft corals by genus at various types of sites ranging from different zones of true reef and rocky habitat (reef flat/upper zone, reef slope/lower zone and fore reef) of both inshore and offshore islands in the Andaman Sea coast of Thailand and the Gulf of Thailand.

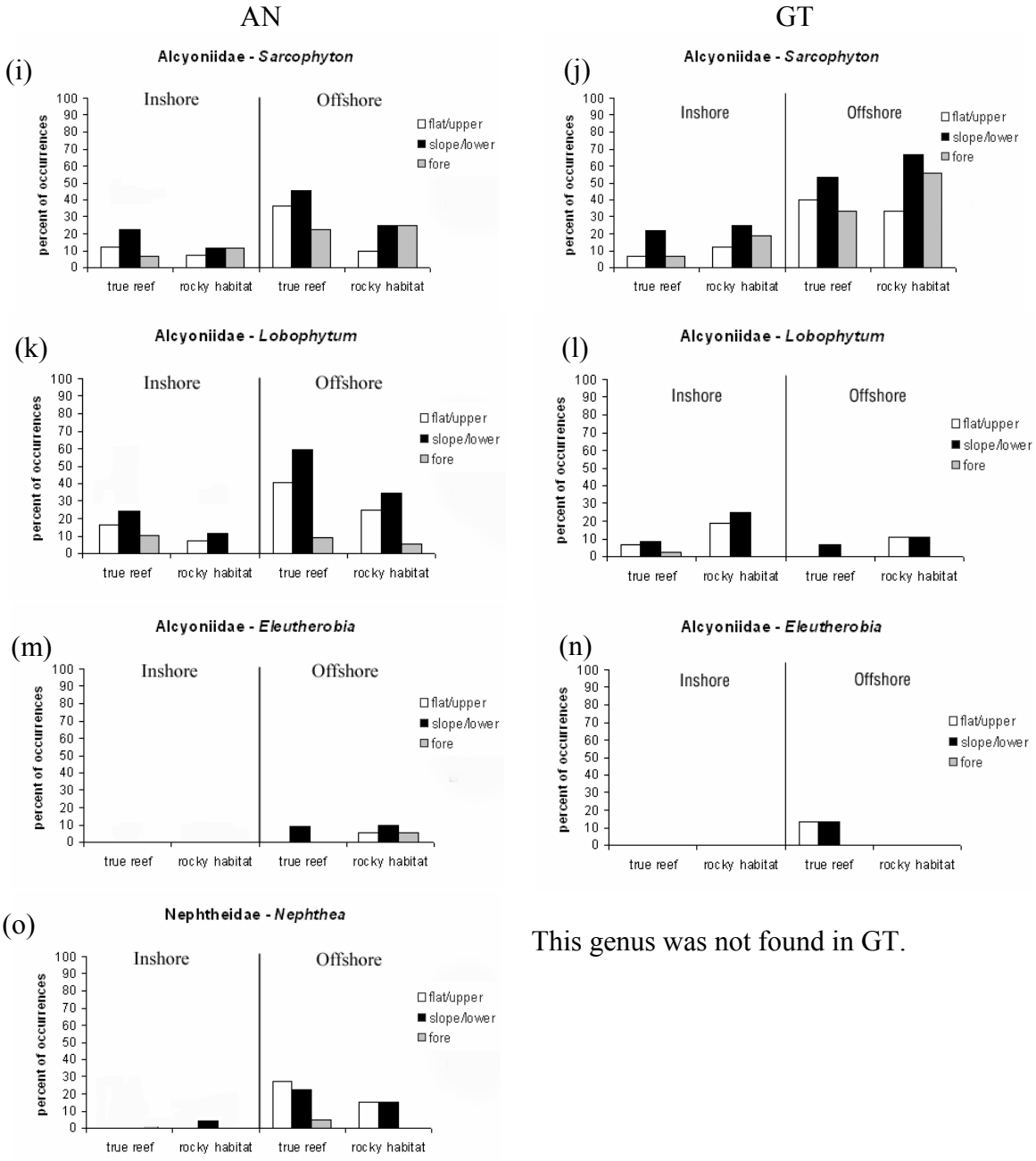
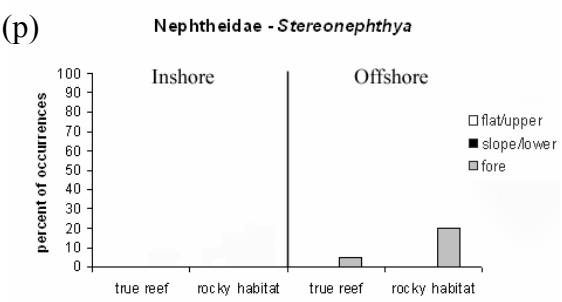


Fig. 8. (continue) Percent occurrences of soft corals by genus at various types of sites ranging from different zones of true reef and rocky habitat (reef flat/upper zone, reef slope/lower zone and fore reef) of both inshore and offshore islands in the Andaman Sea coast of Thailand and the Gulf of Thailand.

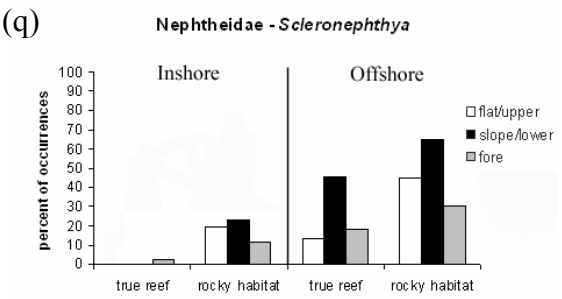
AN GT

(p)

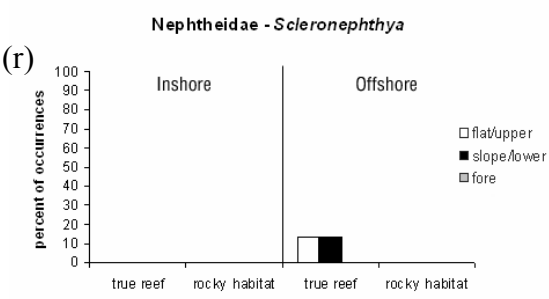


This genus was not found in GT.

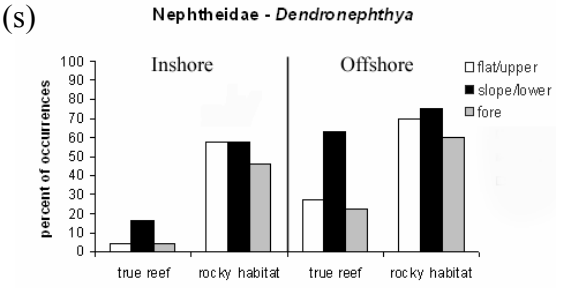
(q)



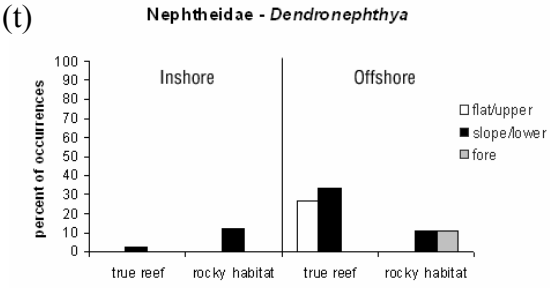
(r)



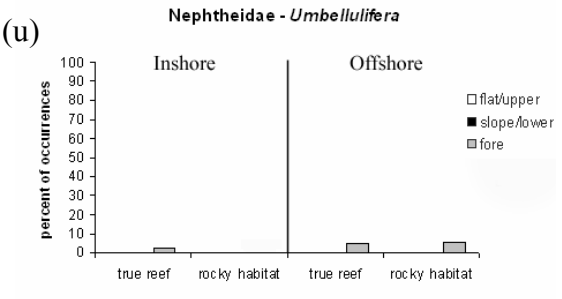
(s)



(t)



(u)



This genus was not found in GT.

Fig. 8. (continue) Percent occurrences of soft corals by genus at various types of sites ranging from different zones of true reef and rocky habitat (reef flat/upper zone, reef slope/lower zone and fore reef) of both inshore and offshore islands in the Andaman Sea coast of Thailand and the Gulf of Thailand.

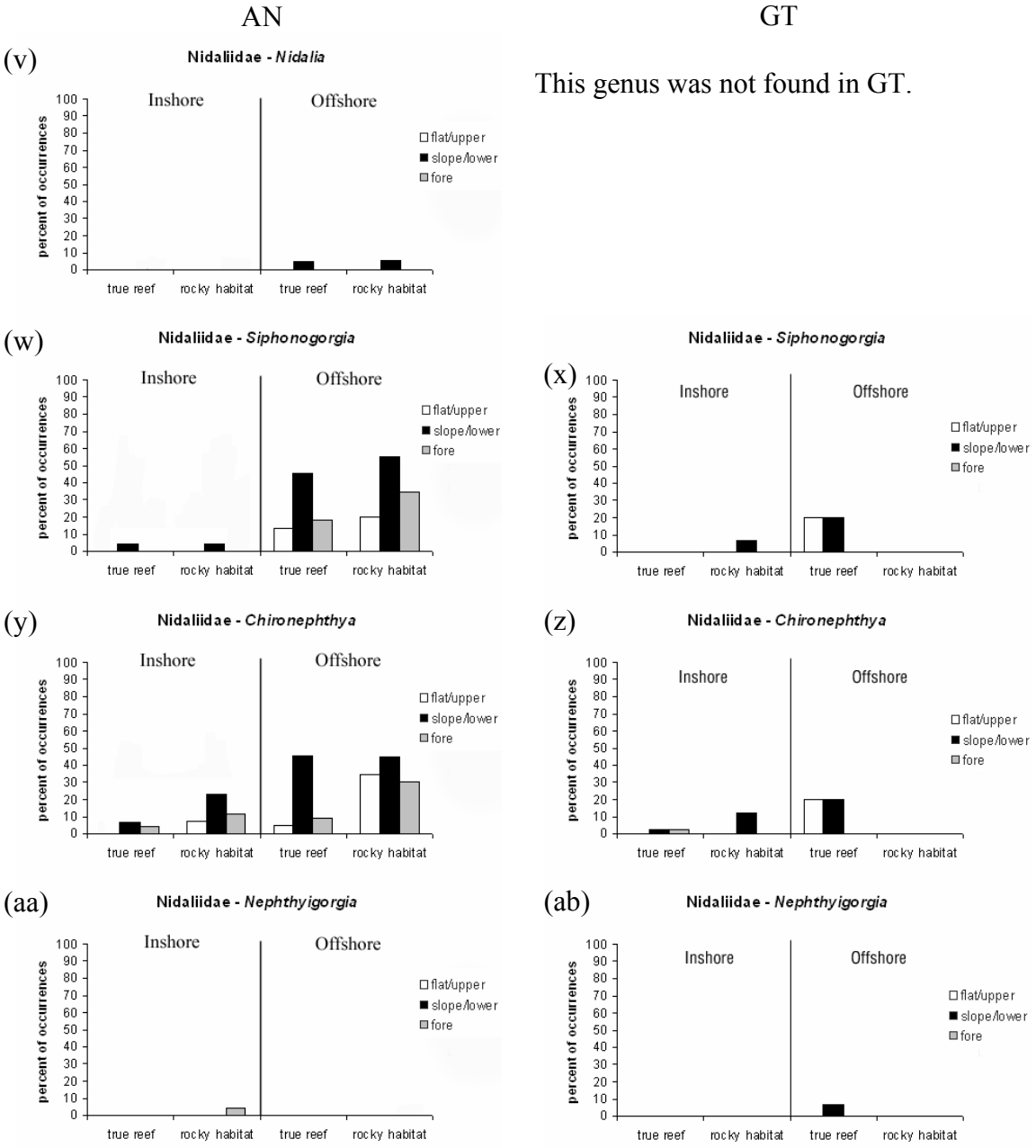


Fig. 8. (continue) Percent occurrences of soft corals by genus at various types of sites ranging from different zones of true reef and rocky habitat (reef flat/upper zone, reef slope/lower zone and fore reef) of both inshore and offshore islands in the Andaman Sea coast of Thailand and the Gulf of Thailand.

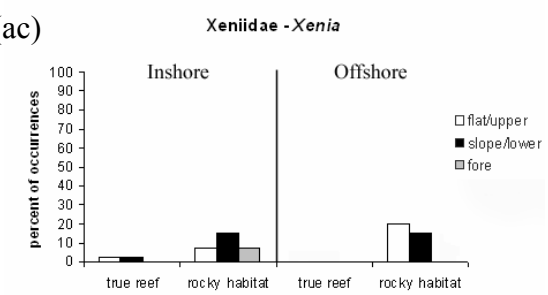
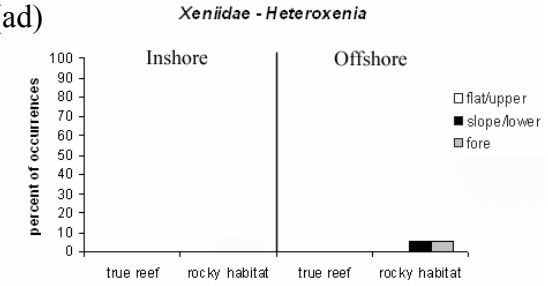
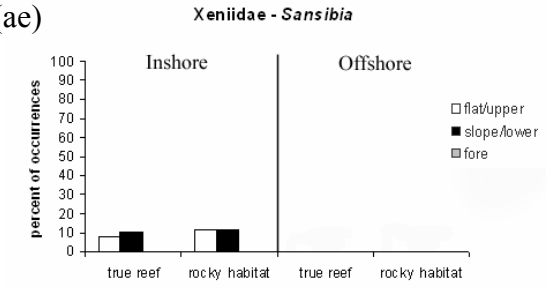
	AN	GT
(ac)		This genus was not found in GT.
(ad)		This genus was not found in GT.
(ae)		This genus was not found in GT.

Fig. 8. (continue) Percent occurrences of soft corals by genus at various types of sites, ranging from different zones of true reef and rocky habitat (reef flat/upper zone, reef slope/lower zone and fore reef) of both inshore and offshore islands in the Andaman Sea coast of Thailand and the Gulf of Thailand.

Distribution by genus in details is as follow.

Alcyoniidae: *Sinularia*

It is a genus which was found at both the AN and the GT in nearly all stations with higher percentages of occurrence frequencies at offshore islands than inshore islands. They were found at all zones (reef flat/upper zone, reef slope/lower zone and fore reef) of both habitats (true reef and rocky substrate). At the AN, most were found on reef flat/upper zone and reef slope/lower zones. At the GT, they were equally distributed on reef flat/upper zone and reef slope/lower zone for both inshore islands

and offshore islands. On offshore true reef significant population was found on fore reef (Fig. 8a-b).

Alcyoniidae: *Dampia*

The percentages of the occurrence frequency was low at both the AN and the GT. It was rarely found in the AN. It was found only at the area of AN01 (Kam Islands) in inshore area, and the percentage of occurrence frequency was 3.85 %. At GT, it was found at both offshore islands and inshore islands, and it was found only at reef slope/lower zone of true reef and rocky substrate (Fig. 8c-d).

Alcyoniidae: *Cladiella*

In the AN, it was found only at a few stations in the area of AN01 (Kam Islands) and AN02 (Surin Islands). The genus was found on reef flat and reef slope of true reef and upper and lower zone of rocky substrate (Fig. 8e). By comparison the percentage of occurrences in the GT was higher than in the AN and it was found on all three zones of both true reef and rocky substrate (Fig. 8f).

Alcyoniidae: *Klyxum*

In the AN it was found only on reef slope of true reef AN06 (Similan Islands) (Fig. 8g). On the contrary, it was quite common in the GT with a high percentage of occurrences on rocky substrate than on true reef habitat of both inshore and offshore islands. On inshore islands they were found on both upper and lower zone. On offshore islands they were found on all three zones of true reef and occurred on the upper and lower zone of rocky substrate (Fig. 8h).

Alcyoniidae: *Sarcophyton*

Both in the AN and the GT, the percentages of occurrence in all surveyed stations were higher in offshore islands than in inshore islands. It was found on all three zones of both true reef and rocky substrate (Fig. 8i-j).

Alcyoniidae: *Lobophytum*

This genus was found with higher percentages of occurrences in the AN than in the GT. In the AN, the percentage of occurrence was higher for offshore islands than inshore islands and it was found more frequent on true reef than on rocky substrate. It was also found all three zones of true reef and rocky substrate (Fig. 8k).

The percentage of occurrence in GT was slightly different between inshore and offshore islands. The genus was found more frequent on rocky substrate than true

reef. It was found on all three zones of true reef of inshore islands, on reef slope of offshore islands, and on upper and lower zone of rocky habitat (Fig. 8l).

Alcyoniidae: *Eleutherobia*

This genus was found in low frequency in offshore islands of both seas. In the AN, it was found on reef slope of true reef and all three zones of rocky substrate (Fig. 8m). In the GT, this genus was found only on reef flat and reef slope of true reef of GT12 (Losin Island) (Fig. 8n).

Nephtheidae: *Nephthea*

This genus was found only in the AN. It was found on both inshore and offshore islands with higher percentage on offshore islands. On inshore islands, it was found at lower zone of rocky habitat, whereas on offshore islands, it occurred on all zones of true reef. The percentage of occurrence on reef flat was higher than reef slope and fore reef. On rocky habitat, it was equally distributed on upper and lower zone (Fig. 8o).

Nephtheidae: *Stereonephthya*

This genus was found with low percentage of occurrence only on fore reef of true reef and rocky substrate of offshore islands in the AN (Fig. 8p).

Nephtheidae: *Scleronephthya*

The genus was in higher percentage of occurrence in the AN than the GT. In the AN this genus was found more frequent on offshore islands than inshore islands in all three zones with highest frequency on reef slope/lower zone (Fig. 8q).

In the GT, the genus was found with low frequency only on reef flat and reef slope of true reef of offshore islands, GT12 (Losin Island) (Fig. 8r).

Nephtheidae: *Dendronephthya*

This genus was more abundant in the AN than in the GT. In the AN, it was found with higher frequency on offshore islands than inshore islands. It was found at all zones of both true reef and rocky substrate. On true reef it was dominant on reef slope. On offshore islands this genus was found on all zones of reef slope/lower zone and the abundance was high on rocky habitat (Fig. 8s).

The occurrence in the GT was less than in the AN and it was more abundant offshore than inshore. On offshore islands, it was found more frequent on true reef habitat than on rocky habitat. The abundance on true reef was on reef flat and reef slope, and on rocky habitat was on lower zone and fore reef (Fig. 8t).

Nephtheidae: *Umbellulifera*

It was found only in the AN on both inshore islands and offshore islands at AN08 (Phuket Island and vicinity islands) and AN16 (Adang-Rawi Islands). The frequency of occurrence between inshore and offshore islands was slightly equal. On offshore islands, it was found on both true reef and rocky habitat. On inshore islands, it was found only on fore reef zone of true reef (Fig. 8u).

Nidaliidae: *Nidalia*

This genus was found only in the AN with restricted distribution range only on offshore islands of AN04 (Tachai rock) and AN06 (Similan Islands). It was found both on reef slope of true reef and lower zone of rocky shore with low frequency of occurrence (Fig. 8v).

Nidaliidae: *Siphonogorgia*

This genus was more abundant in the AN than in the GT. In the AN, the percentage of occurrence were high on offshore islands. It was far less abundant on reef slope/lower zone in inshore islands. On offshore islands it was found at all zones with the highest occurrence on reef slope/lower zone (Fig. 8w).

In the GT, it was found in low percentages of occurrence, distributing both in inshore and offshore. On offshore islands it was found on reef flat and reef slope of true reef, whereas it was found only in a specific lower zone of rocky habitat of inshore islands (Fig. 8x).

Nidaliidae: *Chironephthya*

This genus was found in both the AN and the GT. In the AN it was found on all zones of true reef and rocky habitat of inshore and offshore islands. It was more abundant on offshore islands than inshore islands (Fig. 8y).

In the GT, the higher frequency of occurrence was found offshore than inshore. They were found on true reef and rocky habitat of inshore islands. On rocky substrate, it was found on lower zone only. It was found on reef flat and reef slope of true reef of offshore islands (Fig. 8z).

Nidaliidae: *Nephthyigorgia*

The genus was found in both the AN and the GT. This is a rare genus with very low percentages of occurrences. In the AN, it was found only at AN15 (Coastal Island in Satun Province), on fore reef of rocky habitat (Fig. 8aa). In the GT, it was found only at GT12 (Losin Island) on true reef substrate (Fig. 8ab).

Xeniidae: *Xenia*

It was found only in the AN with slightly equal occurrence between offshore and inshore islands. On inshore islands, it was found on reef flat and reef slope of true reef and on all zones of rocky habitat, whereas on offshore islands it was found only on upper and lower zone of rocky substrate (Fig. 8ac).

Xeniidae: *Heteroxenia*

It was found only at AN06 (Similan Islands) and AN16 (Adang-Rawi Islands) which were offshore islands in the AN with low percentage of occurrence on lower and fore reef zone of rocky habitat (Fig. 8ad).

Xeniidae: *Sansibia*

It was found only at AN01 (Kam Island) and AN14 (Coastal islands in Trang Province), inshore islands of the AN. It was found on reef flat, reef slope of true reef and upper and lower zone of rocky habitat (Fig. 8ae).

1.3 Habitat preference of soft corals

1.3.1 Genera grouping within inshore and offshore islands

Illustrated below is the result of analyzing soft coral distribution pattern, in relation to inshore and offshore islands of Thai waters (Fig. 9).

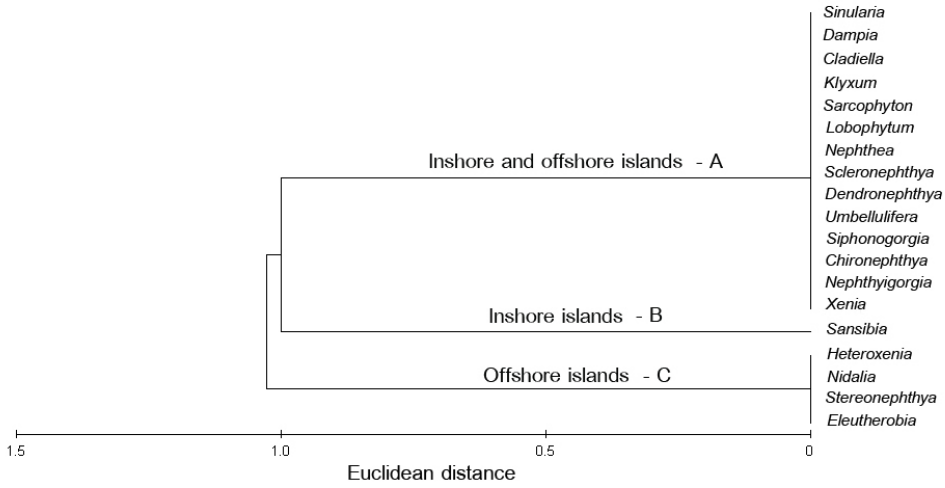


Fig. 9. Hierarchical cluster analysis of distribution of soft corals in Thai waters. The characteristic of the 3 types, showing genera grouping within inshore and offshore islands. The analysis was conducted using Euclidean Distance and Group Average, based on binary data from all study sites.

The results of the cluster analysis of habitat preference of different genus both in AN and GT can be grouping into 3 groups.

(A) It is the largest group with 14 genera of soft corals which were found in both inshore islands and offshore islands. These are *Sinularia*, *Dampia*, *Cladiella*, *Klyxum*, *Sarcophyton*, *Lobophytum*, *Nephthea*, *Scleronaphthya*, *Dendronephthya*, *Umbellulifera*, *Siphonogorgia*, *Chironephthya*, *Nephthyigorgia* and *Xenia*. Most of them were Alcyoniidae and Nephtheidae. The soft corals of this group were found on various habitats: true reef, rocky shore and submerged rocks. Moreover, they were found from

shallow water with low visibility to deep water over 40 m depth with clear visibility.

(B) The genus *Sansibia* was the only genus found only on inshore islands, at AN01 (Kam Islands) and AN14 (Coastal Islands in Trang Province). These sites were shallow reef with low visibility extended to 7 m depth with intertidal reef flat. The genus *Sansibia* was found on reef slope and fore reef.

(C) This group is clearly separated from the other groups and was found on offshore islands of the AN. They are *Heteroxenia*, *Eleutherobia*, *Nidalia* and *Stereonephthya*. All of them are rare or endemic genera. Most of them were found on rocky shores especially submerged rocks, with visibility over 30 m.

1.3.2 Soft coral abundance and genera richness in various habitat types in Thai waters

Localities at both seas, the AN and the GT, were clustered according to the similarity coefficient using Euclidean Distance and Group Average. Dendrogram obtained on ranking data and genera richness data together is giving in Fig. 10:

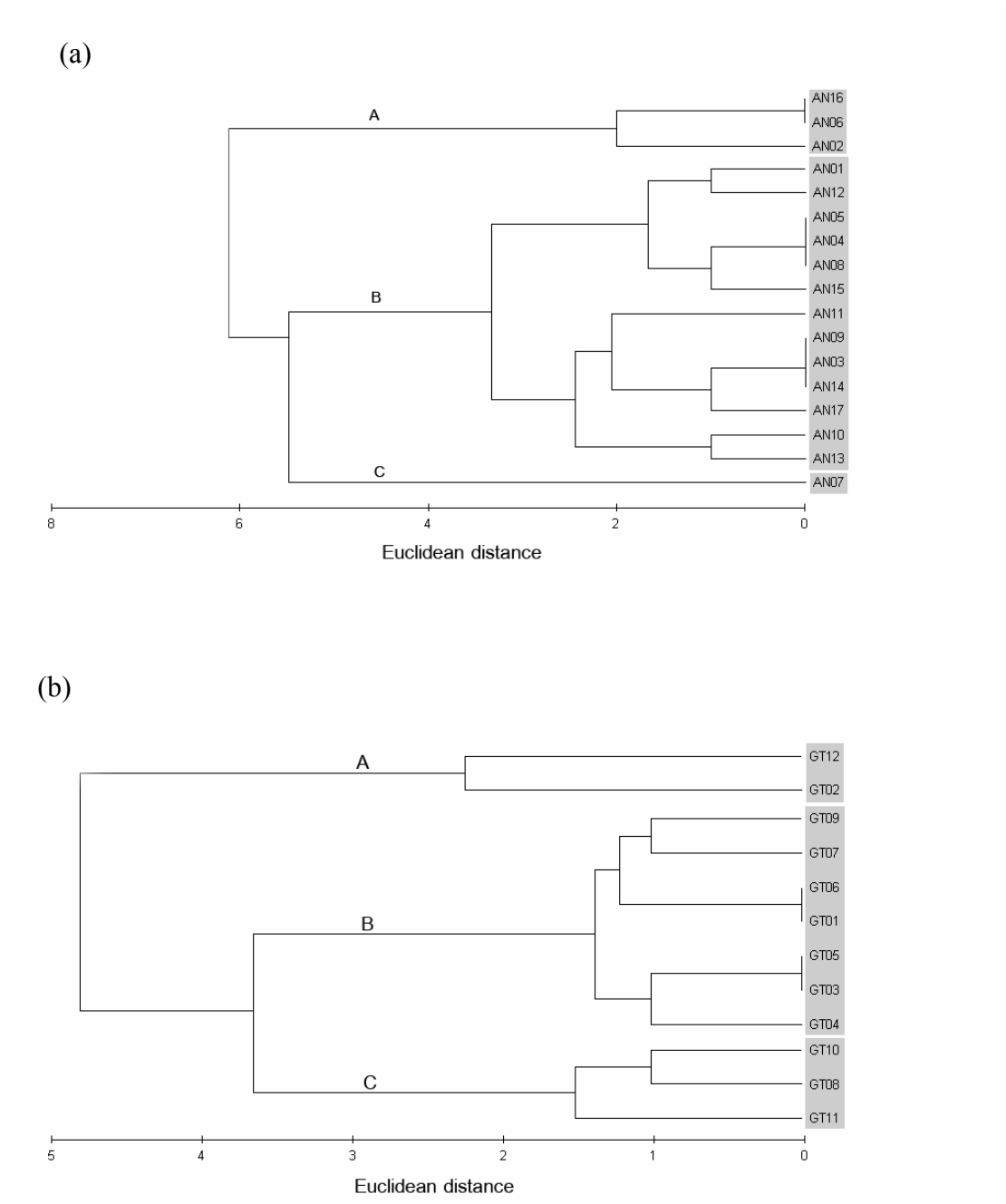


Fig. 10. Hierarchical cluster analysis of 17 locations in the AN (a) and 12 locations in the GT (b) showing similarity of location. The analysis was conducted using Euclidean Distance and Group Average base on ranking data and genera richness data together.

Andaman Sea

Base on the result of hierarchical cluster analysis 17 stations in the AN were grouped into 3 groups of high, moderate and low in abundance and richness.

(A) The abundance and richness was high in this group. The abundance scale was 4 and the genera richness ranged from 10 to 13 genera. The group composes of 3 large offshore islands: AN16 (Adang-Rawi Islands), AN06 (Similan Islands) and AN02 (Surin Islands). The *Dendronephthya* and *Scleronephthya*, were dominant genera in the areas. The AN16 and AN06 contained highest genera richness (13 genera) in the AN, whereas AN02 contained only 9 genera. Genera of Alcyoniidae were dominant in this group. The habitats in this group were diverse including all types (true reef, rocky substrate and submerged rock). The soft corals were found in all reef zones (reef flat, slope and fore reef zone). The water transparency could be up to 30 m visibility range. Genera of Alcyoniidae were commonly found on reef flat/upper zone and or reef slope/lower zone (Fig. 11), whereas genera of Nephtheidae were commonly found up on reef slope to fore reef in over 40 m depth (Fig. 12).

Fig. 11. *Lobophytum* were commonly found on reef flat of offshore islands.

Fig. 12. Nephtheidae were commonly found up on fore reef in over 40 m depth. Photograph: Nat Sumontemee

(B) This group was moderate in abundance and genera richness. The abundance rank was 2 – 4 and the genera richness ranged from 2 – 10. They were diverse group covering inshore islands and submerged rocks on inshore and offshore islands. The first subgroup was AN01 (Kam Islands) and AN12 (Phi Phi Islands). These two stations were similar in community pattern (shallow water reef with intertidal reef flat). The soft corals were mostly found on reef slope and fore reef. Both locations were equal in term of genera richness (6 - 7) and the abundance (3). The Alcyoniidae was dominant family in these locations.

The closest subgroup composed of AN04 (Tachai Rock), AN05 (Bon Island) and AN08 (Phuket Island and vicinity Islands). This subgroup composed of such diverse habitat types and different physical features. They had common features of containing high abundance (abundance scale 4) and relating moderate richness (7 – 10), however. AN04 (Tachai Rock) and AN05 (Bon Island) were offshore submerged rocks and rocky substrate whereas AN08 (Phuket Island and vicinity Islands) was inshore reef and rocky substrate. The quality of water offshore islands was good and soft corals were found even at more than 40 m depth. The Neptheidae was the dominant family

in these locations. Most of them were *Scleronephthya* and *Dendronepthya*. They grew on steep wall and spread over 30 m in depth (Fig. 13). AN08 (Phuket Island and vicinity Islands) covered diverse habitats of inshore islands, true reef, rocky substrate and submerged rocks. Some sites were affected by several physical factors especially sedimentation. Visibility was significantly lower than at AN04 (Tachai Rock) and AN05 (Bon Island). The reef features and community structures were diverse. In most sites, reef structures were massive form of scleractinian corals with *Porites* as dominant genera. In some area with less wave intensity, *Acropora* branching form was dominant species. Soft corals of Alcyoniidae were dominant. *Sinularia* and *Sarcophyton* were commonly found on coral reef whereas *Lobophytum* was dominant on rocky shore, western side of the island facing SW monsoon (Fig. 14).

Fig. 13. *Dendronepthya*, on submerged rocks at 30 m depth of AN04 (Tachai Rock).

Fig. 14. On rocky shore facing South-west monsoon, a few dominant genera such as *Lobophytum* and *Sinularia* were found encrusting on rocky substrate.

The subgroup of AN03 (Richelew Rock), AN09 (Dokmai Island) and AN14 (Coastal Islands in Trang Province) was distinctly separated as a subgroup with equal abundance (4) and genera richness (5). The soft coral communities of these locations were similar and *Dendronephthya* was dominant. These locations were diverse in term of physical features. AN03 (Richelew Rock) was submerged granit rocks in clear water with soft corals growth to over 40 m depth. The *Dendronephthya* was dominant and covered over 80 percentage of the substrate. AN09 (Dokmai Island) and AN14 (Coastal Islands in Trang Province) were limestone islands with steep wall extend to 30 m depth at AN09 and 10 m depth at AN14. Soft corals were abundant at depth of 15 - 20 m depth (Fig. 15).

Fig. 15. *Dendronephthya* was dominant on steep wall of limestone island at AN14 (Coastal Islands in Trang Province).

AN11 (Coastal Island in Krabi Province) comprised of 9 stations of true reef habitats of inshore islands within depth range not exceeding 15 m depth. The abundance scale was 2 and the genera richness was 5. On the reefs, the genera of Alcyoniidae, *Sinularia* and *Sarcophyton*, were found scattering among hard coral communities.

At AN09 (Dokmai Island), *Scleronephthya* was dominant covering over 60 percent of areas while at AN14 (Coastal Islands in Trang Province), *Dendronephthya* was dominant, percentage covering over 80 percent. This subgroup was closely related to AN17 (Eight mile Rock) which was separated into solitary location due to slightly lower in richness (4) but with same level of abundance scale (4). AN17 was a group of submerged rocks locating 60 km offshore. Soft corals were dominant from 8 m to 60 m depth. *Dendronephthya* genus was the dominant genus in this area, and clusters of *Scleronephthya* were found in the lower zone.

Another closely related subgroup comprised of AN10 (Musang Rock) and AN13 (Deang Rock), both were submerged rocks. Soft corals were more abundant than hard corals. They cover 60% of these areas and could be found

to over 30 m depth. Soft corals of family Nephtheidae were abundant with *Dendronephthya* as dominant genus (Fig. 16).

Fig. 16. Soft corals of family Nephtheidae especially *Dendronephthya* were abundant at AN10 (Musang Rock).

(C) It was the grouped of lowest in abundance (1) and genera richness (1) and comprised of one location, AN07 (Kao Na Yak) which was the only mainland reef in this study. The area was in shallow water in front of an estuary in the AN. The reef was in degraded condition with less than 40 percent live coral cover. Only few colonies of *Sinularia* were found (Fig. 17).

Fig. 17. Degraded reef community of AN07 (Kao Na Yak) with low live coral cover and high sedimentation rate.

Gulf of Thailand

Base on the result of hierarchical cluster analysis, 12 locations in the GT were also grouped into 3 groups of high, moderate and low in abundance and richness (Fig. 10b).

(A) The abundance and richness was high. In this group the abundance was 3 – 4 and the genera richness was 7 – 9. Only 2 locations were in this group, GT02 (Samaesarn Islands) and GT12 (Losin Island). Eight genera was found at GT02 (Samaesarn Islands) and ten genera at GT12 (Losin Island). GT02 (Samaesarn Islands) was the location of high richness (8) in the east of GT, whereas GT12 (Losin Island) was the area of the high richness (10) in the west of GT. The communities patterns were quite different by comparison. GT02 (Samaesarn Islands) was an inshore islands comprising of large and small islands including submerged rocks. Reef development extends to about 10 - 15 m depth. *Porites* was dominant coral species. The soft corals were more abundant on true reef than on rocky substrate, *Sinularia*, *Cladiella* and *Klyxum* were dominant genera (Fig. 18). In addition within nearby location at Suthathip shipwreck, which situated near Chan Island the genus *Dendronephthya* was found at 25 - 30 m depth. GT12 (Losin Island), locating

in the southern part of GT, was a small rocky island offshore in clear water of visibility over 30 m depth and coral communities was found down to 40 m depth. The coral reef was good condition with live corals cover over 70 %. The dominant soft corals in this area were *Dendronephthya* and *Scleronephthya*. Moreover, the *Sarcophyton* was widely distributed with high abundance on the fore reef of 40 m depth (Fig. 19).

Fig. 18. *Sinularia* was dominant on rocky substrate at GT02 (Samaesarn Islands).

Fig. 19. At GT12 (Losin Island) *Sarcophyton* was found distributed widely and with high abundance on the fore reef at 40 m depth.

(B) It was a group of moderate level of richness and abundances. The abundance scale was 4 and the genera richness was 3 – 5. The difference of this group from the previous group could be due to the number of genera, not the level of abundance that affected the Euclidean distance. The same result applied here as in the AN. The moderate abundance and richness group was the mix group of various habitat types: inshore islands, offshore islands, true reef, rocky shore and submerged rocks. The offshore islands subgroup located in the western part of the GT, GT09 (Kra Island) and GT07 (Tao Island). The abundance and genera richness in this subgroup were 3 - 4 and 4 - 5 respectively. They were true reef habitat extended to 15 - 25 m depth, with clear visibility of 10 - 20 meters. Alcyoniidae was dominant in both areas. The *Sinularia* and *Cladiella* were dominant on true reef and *Klyxum* on rocky substrate.

The next closely subgroup comprised of GT06 (Coastal Islands in Chumporn Province) and GT01 (Chang Islands). The abundance and genera richness were 3 and 5, respectively. The features of habitats were inshore islands developed in 5 - 10 m depth and some reefs were reef with intertidal reef flat. The distribution of soft corals was good on reef slope or lower zone of both areas. The soft corals were high in abundance and richness at a group of small islands (Mark island) of GT01 (Chang Islands). On the contrary, Chang island which is the largest island was generally low in abundances and richness of soft corals. The island was in shallow turbid water of 2 – 4 m depth with extensive mudflat on the eastern side. GT06 was the location comprised of reefs of small islands in 5 m depth with low visibility of 3 – 5 m. The reefs were mainly *Porites* dominant communities. The Alcyoniidae (*Sinularia* and *Klyxum*) were dominant in both GT01 (Chang Islands) and GT06 (Coastal Islands in Chumporn Province) (Fig. 20).

Fig. 20. The general feature of rocky shore at location GT01 (Chang Islands), *Sinularia* was the dominant genus in this habitat.

Another subgroup of GT05 (Ngam Island) and GT03 (Lan Islands and few islets to the north), was similar in abundance and genera richness. The abundance and genera richness were 3 and 4, respectively. They are inshore islands in the northern part of the GT. The dominant genera in this area were *Sinularia*, *Klyxum*, *Sarcophyton* and *Cladiella*. The habitats of both areas were quite different. In GT05 (Ngam Island), it was encrusting scleractian corals on the limestone wall at 10 – 15 m. The gorgonian *Junceella* sp. was abundant on true reef. The soft corals were found in all zones. GT03 (Lan Islands and few islets to the north) are true reef extend to 5 - 10 m depth. The dominant scleractinian corals were as *Porites* spp.. *Cladiella* was dominant on reef flat and reef slope, but not on fore reef. In addition, *Dendronephthya* was also found at 20 – 30 m depth at Khram shipwreck sites within the area.

GT04 (Talu Islands) was a distinguished group which was similar to the previous subgroup above with equal in richness but less in abundance (abundance scale 3). *Sinularia* and *Cladiella* were dominant in area with similar communities pattern to GT05 (Ngam Islands). Both islands locate in some vicinity and with similar physical features.

(C) It was the group with low richness and abundances comprised of GT08 (Samui Island), GT10 (Kham Island) and GT 11 (Laopi Island). These were reefs of inshore islands in shallow water depth of 3-5 m located of the west of GT. At GT08 (Samui Island) and GT10 (Kham Island), only *Cladiella* was present on intertidal reef flat, whereas at GT11 (Laopi Island), the reef flat was submerged and only few colonies of *Chironephthya* was found.

1.3.3 Zonation preference patterns

In evaluating specific sites preference of soft corals at each habitat, it was found that soft corals tend to be associated with particular zonation such as reef flat/upper zone, reef slope/lower zone and fore reef. Cluster analysis produces 4 different groups (Fig. 21) as follow:

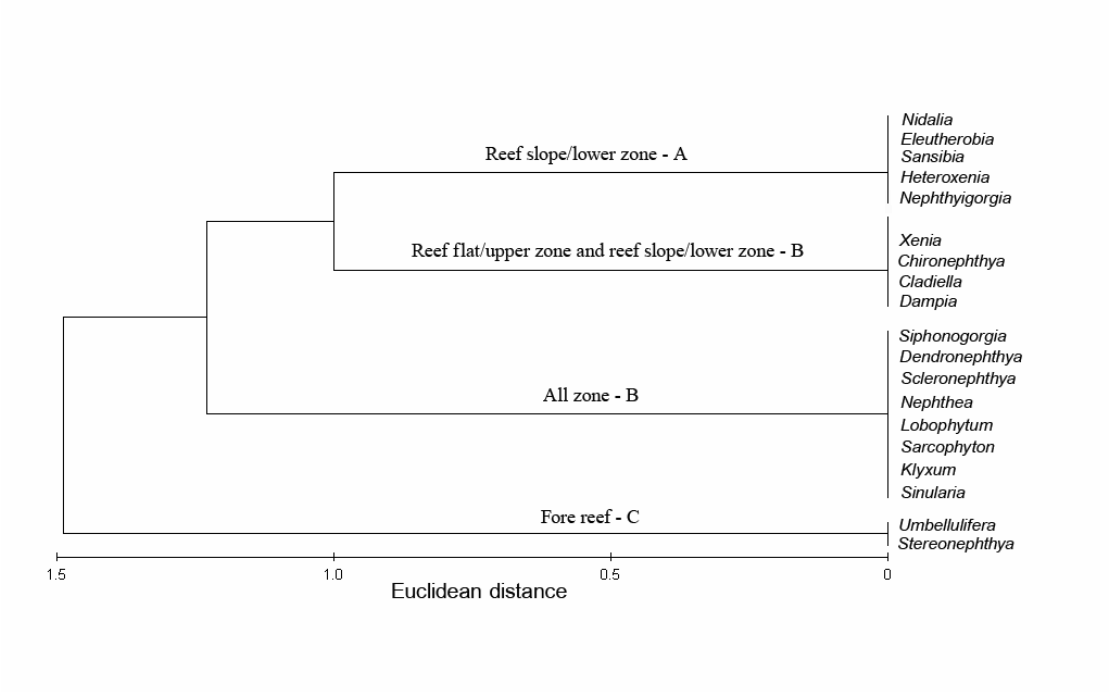


Fig. 21. Hierarchical cluster analysis of zonation of the soft corals. It shows grouping of zonation preference of all genera of soft corals. The analysis was conducted using Euclidean Distance and Group Average based on binary data from all study sites.

(A) Soft corals in this group were found on reef slope or lower zone of rocky habitat. These were *Nidalia*, *Eleutherobia*, *Sansibia*, *Heteroxenia* and

Nephthyigorgia. The soft corals in this group were found only in the AN, except *Nephthyigorgia*. The reef slope/lower zone of in the AN varied between 2-40 m depth. Most of these soft corals are azooxanthellae groups except *Sansibia*. Most of them occurred at 10 - 30 m depth, whereas *Sansibia* was found on the shallow reef slope at 2 - 5 m depth.

(B) Soft coral genera of this group were found on reef flat/upper zone and reef slope/lower zone. These were *Xenia*, *Chironephthya*, *Cladiella* and *Dampia*. However, there were significant depth variation of reef flat/upper zone and reef slope/ lower zone in the AN and the GT. The *Xenia* were found on the reef flat/upper zone to reef slope/lower zone, where they were commonly found with extensive cover at a depth range of 2 - 10 m. The *Chironephthya*, an azooxanthellate, was found in shallow reef or rocky habitat with low light intensity. The *Cladiella*, a zooxanthellate group, was dominant in the GT. It was found in a few numbers on reef slope over 40 m depth in the AN. *Dampia* was found in shallow water of 2 - 5 m depth.

(C) This is the largest group distributing in all zones of habitats. They were *Siphonogorgia*, *Dendronephthya*, *Scleronephthya*, *Nephthea*, *Lobophytum*, *Sarcophyton*, *Klyxum* and *Sinularia*. All were the dominant soft corals in Thai waters. They occurred from depth range of 0 - 40 meters.

(D) This is the azooxanthellate group which was only found in fore reef at 15 - 40 m depth. The *Umbellulifera* was found on sandy bottom, and the *Stereonephthya* attached to rubbles or dead coral fragments.

1.3.4 Habitat preference base on angle of substrate

As part of location preference of soft corals base on substrate position, the cluster analysis on angles of substrate position is shown in Fig. 22.

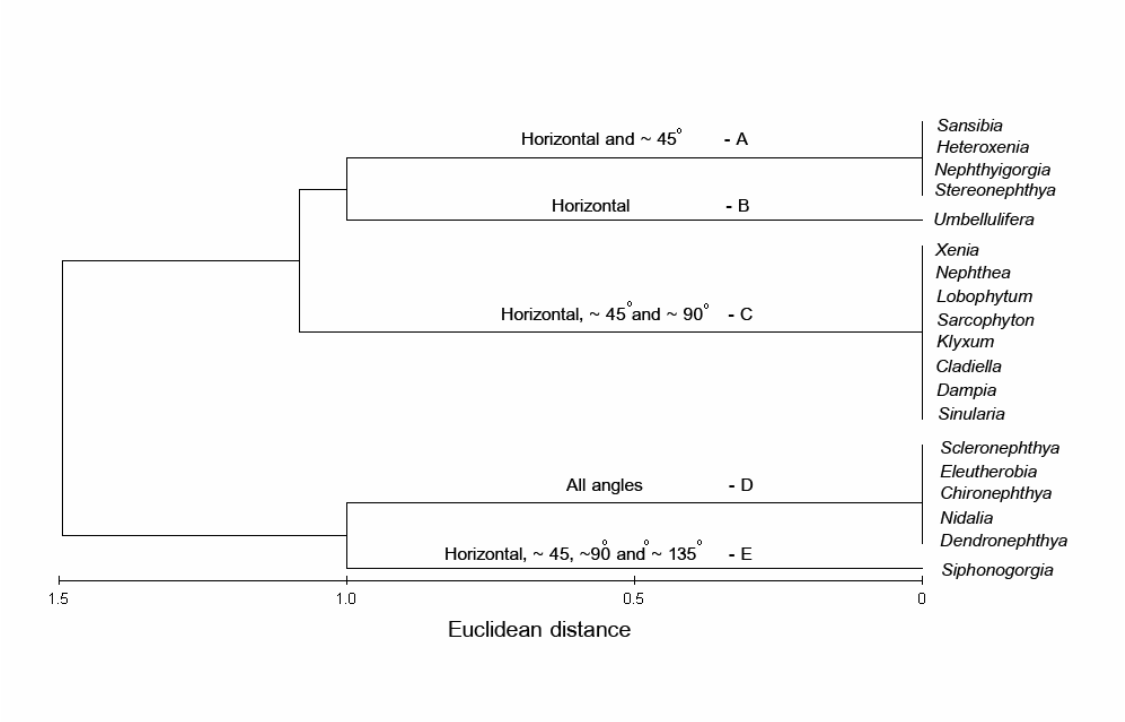


Fig. 22. Hierarchical cluster analysis describing the habitat preference base on angles of substrate.

(A) The *Sansibia*, *Heteroxenia*, *Nephthyigorgia*, and *Stereonephthya* were found occurring on horizontal substrate and ~ 45^{o} angled substrates.

(B) The *Umbellulifera* was the only group occurring on horizontal substrate exclusively found on fore reef/sand floor.

(C) This group is characterized by three features: horizontal, ~ 45^{o} and 90^{o} angled substrates. Most of soft corals were within this group. They were *Xenia*, *Nephthea*, *Lobophytum*, *Sarcophyton*, *Klyxum*, *Cladiella*, *Dampia*, and *Sinularia*.

(D) This group includes soft corals which grow on substrates of all degree of angles from horizontal to overhang. They were *Scleronephthya*,

Eleutherobia, *Chironephthya*, *Nidalia* and *Dendronephthya*. All of them are well distributed on rocky shores especially submerged rock and crevices.

(E) Soft corals of this group were found attached on substrates at all angles, except overhanging substrate. Only *Siphonogorgia* was found.

1.4 Effect of water transparency on soft coral distribution and abundance

Figure 23 shows the effect of water transparency on genera richness by using regression analysis. It was found that genera richness was significantly related to water transparency ($r^2 = 0.19$, $p<0.0001$, $n = 152$, $Y=0.1173X+1.8766$).

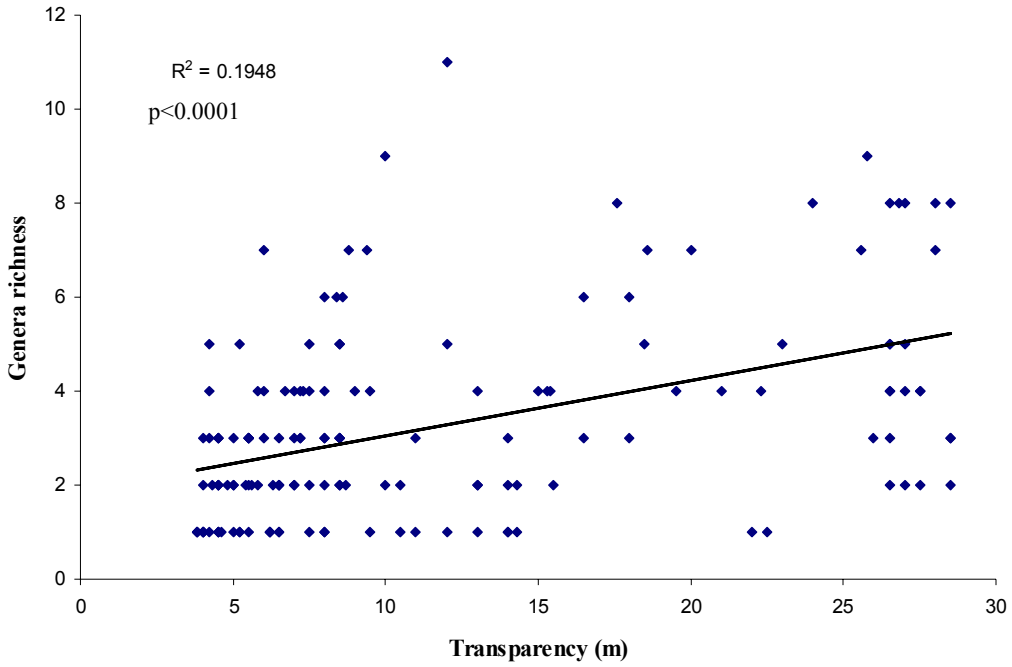


Fig. 23. Regression analyses effects of water transparency base on genera richness of soft corals.

In analysis the effect of water transparency on soft coral abundance, Spearman Rank Correlation was used for analysis correlation between water transparency at each site and abundance data obtain from semi-quantitative survey. The result shows that the abundance was significantly related to water transparency ($r_s = 0.35$, 95% C.I. = 0.22 – 0.47, $p<0.0001$, $n = 197$). Thus, it is concluded that soft corals distribution and abundance increases with increasing water transparency.

2. Discussion

This study is the most extensive study on soft coral distribution in Thai waters and it is the first revision of soft coral taxa knowledge in Thai waters. The total genera of soft corals in Thai waters reported under this study are 19 genera (Table 2). They are 9 newly recorded: *Eleutherobia*, *Nepthyigorgia*, *Nidalia*, *Heteroxenia*, *Chironephthya, Siphonogorgia*, *Stereonepthya*, *Dampia* and *Sansibia*. Some past studies had problems of misidentification. Worachananan (2000) reported 12 genera in Thai waters, but some genera were misidentified i.e. *Stereonephthya* = *Scleronephthya*, *Chironephthya* = *Scleronephthya* and *Siphonogorgia* = *Dendronephthya*, and 1 synonymous genus; *Alcyonium* = *Klyxum*. The genus *Lemnalia* which was reported in Worachananan (2000) was not found under this study. In addition, Satapoomin (1989) also misidentified 1 genus (*Stereonephthya* = *Scleronephthya*) which was later corrected (Satapoomin personal communication).

Many genera are distributed widely throughout, the GT and the AN: *Sinularia*, *Dampia*, *Cladiella*, *Klyxum*, *Sarcophyton*, *Lobophytum*, *Eleutherobia*, *Scleronephthya*, *Dendronephthya*, *Siphonogorgia*, *Chironephthya* and *Nephthyigorgia*. Some genera occur in small number in restrict locations. The rare genera found in the GT are *Dendronephthya, Scleronephthya, Nephthyigorgia* and *Eleutherobia*. All of them were found at GT12. In contrast, only 3 genera are rare in the AN: *Nidalia* at AN04 and AN06; *Heteroxenia* in AN06; and AN16, and *Nephthyigorgia* in AN15.

The “hot spot” of soft coral diversity in the GT locates at GT12, where 10 genera were found. It is an offshore reef with the distance of 80 km from mainland. While the “hot spot” in the AN locates at AN06 which are offshore reefs with the distance of 70 km from mainland and 13 genera were recorded.

The dominant genera of soft corals in Thai waters are many genera of the Family Alcyoniidae (*Sinularia*, *Sarcophyton* and *Cladiella*) and Nephtheidae (*Dendronepthya* and *Scleronepthya*) (Fig. 6). The Alcyoniidae is the dominant family in the GT, whereas in the AN, Nephtheidae is the dominant family.

The Alcyoniidae is a dominant family of soft corals in Indo-Pacific as reported in several locations: Great Barrier Reef (Dinesen 1983; Fabricius and De'ath 2001), South Africa (Schleyer and Celliers 2003), Southern Taiwan (Benayahu et al. 2004; Dai 1991b) etc. In Thai waters the Alcyoniidae was found distributed widely in all habitat types ranging from reef flat to fore reef over 40 meters in depth as well as covering true reefs and rocky substrates both inshore and offshore islands. Furthermore, they often form patches and cover large areas in mono-specific carpets. In the GT, most of the inshore islands are affected by sedimentation and soft corals genera of Alcyoniidae are dominant genera i.e. *Cladiella*, *Sinularia*, *Klyxum* and *Sarcophyton*. They are able to survive under heavy sediment loads (Schleyer and Celliers 2003) and are able to produce toxic secondary metabolites (Tursch and Tursch 1982, Sammarco et. al. 1983, Wylie and Paul 1989; Van Alstyne et. al. 1992). They are able to compete with scleractinian corals for space which is important defense mechanism for surviving on reef habitats (Griffith 1997). Therefore soft corals of Alcyoniidae family have higher chance than other families in occupying diverse habitats especially in turbid environment of Thai waters.

The Nephtheidae such as *Dendronephthya* and *Scleronephthya* is the second family with a wide range of distribution especially in the AN (Fig. 7). The distinctive feature which supports wide range of distribution of this family is vigorous asexual propagators (Dahan and Benayahu 1997). They can grow to become large mono-specific stands especially in rocky shores or submerged rocks, especially *Dendronephthya* which is overgrowth rapidly and spreads over the substrates by vigorous asexual propagators (Fabricius et al. 1995a; Dahan and Benayahu 1997). The ability to settle at all angles of substrates including crevices is also an advantage for the Nephtheidae. The crevices and overhangs are suitable microhabitats for the Nephtheidae which is azooxanthellate group. They can grow under limited light which is an advantage by comparison to other families of soft corals. Nephtheidae such as *Dendronepthya* and *Scleronepthya* occurred more frequently on rocky habitats than on true reef habitats. Moreover, the submerged rocks which generally locate in area facing strong current and turbulence, is also suitable environment for the growth of soft corals in the family Nephtheidae (Dai 1993). Most rocky habitats including submerged rock in the survey region are exposed to relatively strong current or water

turbulence. Soft corals of Nephtheidae are suspension feeders feeding on phytoplankton (Fabricius, et al. 1995b) and planktons are more available in these areas than on true reef habitats. In addition, the water movement can blow out the deposit sediment from their colonies (Riegl 1995). Interestingly, in a few sites within location AN16, an azooxanthellate member of Nephtheidae such as *Dendronephthya* was found on the shallow reef at about 1 m depth. The majority of reports indicate that this genus is confined to the deep zone (Fabricius and Alderslade 2001; Mahadi et al. 2004).

This study suggests that different genera of soft corals show habitat preference. It has been found that the Nephtheidae family widely distributes on rocky shore or submerged rocks than on true reefs whereas the Alcyoniidae family are more abundant on true reefs than rocky habitats. The finding shows that soft coral growth are strongly related to site specific such as zonation on reef. They are often found on the slope area and sand floor. The occurrences of soft corals were greater on reef slope/lower zone than on reef flat/upper zone and sand floor in the AN. The depth of reef slope/lower zone varies between 3 – 10 m of inshore reefs, and > 10 – 40 m of the offshore reefs. However in the GT, majority of them occur on slope/lower zone, between 3 – 30 m depth. On reef flat or upper zone, they would encounter highly variable environments. The strong wave action is a limiting factor for colonization and distribution of soft coral especially on shallow or unprotected reefs (Tursch and Tursch 1982; Dinesen 1983). Desiccation is also a limiting factor for soft corals. In the AN sessile organisms have to tolerate high stress environment of intertidal reef flat or upper zone of rocky shore during spring tide, few genera of Alcyoniidae such as *Sinularia*, *Cladiella* and *Lobophytum* can be found in that zone. The colony shapes of these genera in these areas are predominantly short lobe, encrusting or massive form.

The angle of substrate has an influence on distribution and abundance of soft corals. The zooxanthellate group which is a light-dependent group requires long exposure to photosynthetically active radiation (PAR), especially in turbid water or at greater depths. The Alcyoniidae are found on substrates with varying angles ranging from horizontal to ~ 90°. In this study, azooxanthellate genera of Neptheidae and Nidaliidae were found attached to substrates at all angles. They are suspension feeders

and they do not require light. Thus they can colonize on shady undersides of overhangs and in crevices, making them more successful space colonizer than light-dependent group.

The distribution of soft corals in Thai waters is restricted by some physical parameters. This study shows that the difference in richness and abundance of soft corals between the inshore and offshore islands is related to difference of physical parameters (Fig. 8). The major physical parameters that affect distribution of soft corals especially in the zooxanthellate group are water turbidity and sedimentation (Dinesen 1983; Fabricius and De'ath 2001; Schleyer and Celliers 2003). High sediment is reported to cause serious tissue damage (Riegl and Bloomer 1995). Although, this study has focused on only few parameters, the results show that offshore islands which locate in clear water contain high abundance and richness of soft corals and inshore islands or mainland reefs which are affected by high sedimentation contain low richness and abundance of soft corals. Most of soft coral habitats in the GT are in higher turbid environment than those in the AN. Thus this may be a factor that the generic richness is higher in the AN (13 genera) than in GT (10 genera).

The generic difference of both the AN and the GT may due to other causes besides the difference of habitat environment. The past history of marine organisms colonization in both seas is cited as a possible cause. Both the GT and the eastern part of the AN are part of the relatively shallow Sunda Shelf connecting the Pacific and Indian Oceans. There are few comparisons on diversity of marine fauna between the AN and the GT. Satapoomin (2000, 2002) shows that besides higher diversity of reef fish communities in the AN, the taxonomic composition of the communities is also different. This study also shows that soft coral genera in the AN are more diverse than the GT and it is different in term of some dominant genera. The sea level change due to glaciations during the Pleistocene period is considered as an important cause of this difference. During glaciations period, some parts of the Sunda Shelf, especially part of the Andaman Sea and the Gulf of Thailand were exposed (Haq et al. 1987; Voris 2000). A map of the region during the Pleistocene period in Voris (2000) shows the sea level at 120 m below present sea level and indicates that the eastern part of the Indian Ocean (Andaman Sea) had a narrower shelf, while the GT was largely

exposed. All habitats under this study were fully exposed and the success of marine organism colonization in post glacial period depended upon the pattern of sea level rise as well as the dispersal of organism from point sources. The width of the continental shelf and the environment of newly flooded area would have affected dispersal and colonization of benthic sessile fauna.

At present the Gulf of Thailand environment is characterized by low salinity, high turbidity and mud bottom, in comparison with the conditions in the Andaman Sea which is more oceanic and reefs are more extensively developed. Base on oceanic circulation model (see Fig.3 Carpenter and Springer 2005), the source of present-day soft corals in the GT must have been dispersed from the South China Sea/Pacific Ocean. That assumable may give clear explanation of boundary the soft coral distribution. The GT12 which situated in the more oceanic environment of southern part of the GT has the highest genera richness in the GT. At that position it may be the sink area for planular or larvae from the other sources in the South China Sea and served as a "stepping stone" for the dispersal of soft corals within the Gulf of Thailand. In the AN source of soft corals must have been dispersal from the western part of the Andaman Sea/Indian Ocean. Unfortunately, no information on soft coral distribution at genera level within South China Sea or eastern Indian Ocean is available to support this concept.

In conclusion, this study shows that the soft corals are more diverse in the Andaman Sea than in the Gulf of Thailand. The family Alcyoniidae has most percentage occurrences in Thai waters and genera *Sinularia, Dendronephthya*, *Sarcophyton* and *Cladiella* are dominant genera respectively. This study suggests that different genera of soft corals show habitat preference in term of location (inshore vs. offshore islands), habitat types (coral reef, rocky shore and submerged rocks), zones on habitat (reef flat/upper zone, reef slope/lower zone and fore reef) and angles of substratum. It is recommended that the areas with high diversity and rare genera such as Similan islands in the Andaman Sea and the Losin Island in the Gulf of Thailand are priority sites for designation as marine protected areas.

Part II: *Sarcophyton* from Thai waters

1. Result

Description of *Sarcophyton* from Thai waters

From result of the first part we gathered 42 colonies of *Sarcophyton* from the field and some specimen from PMBC Reference collection. There were 5 species found and there are 5 new species as the following:

Sarcophyton ehrenbergi Von Marenzeller, 1886

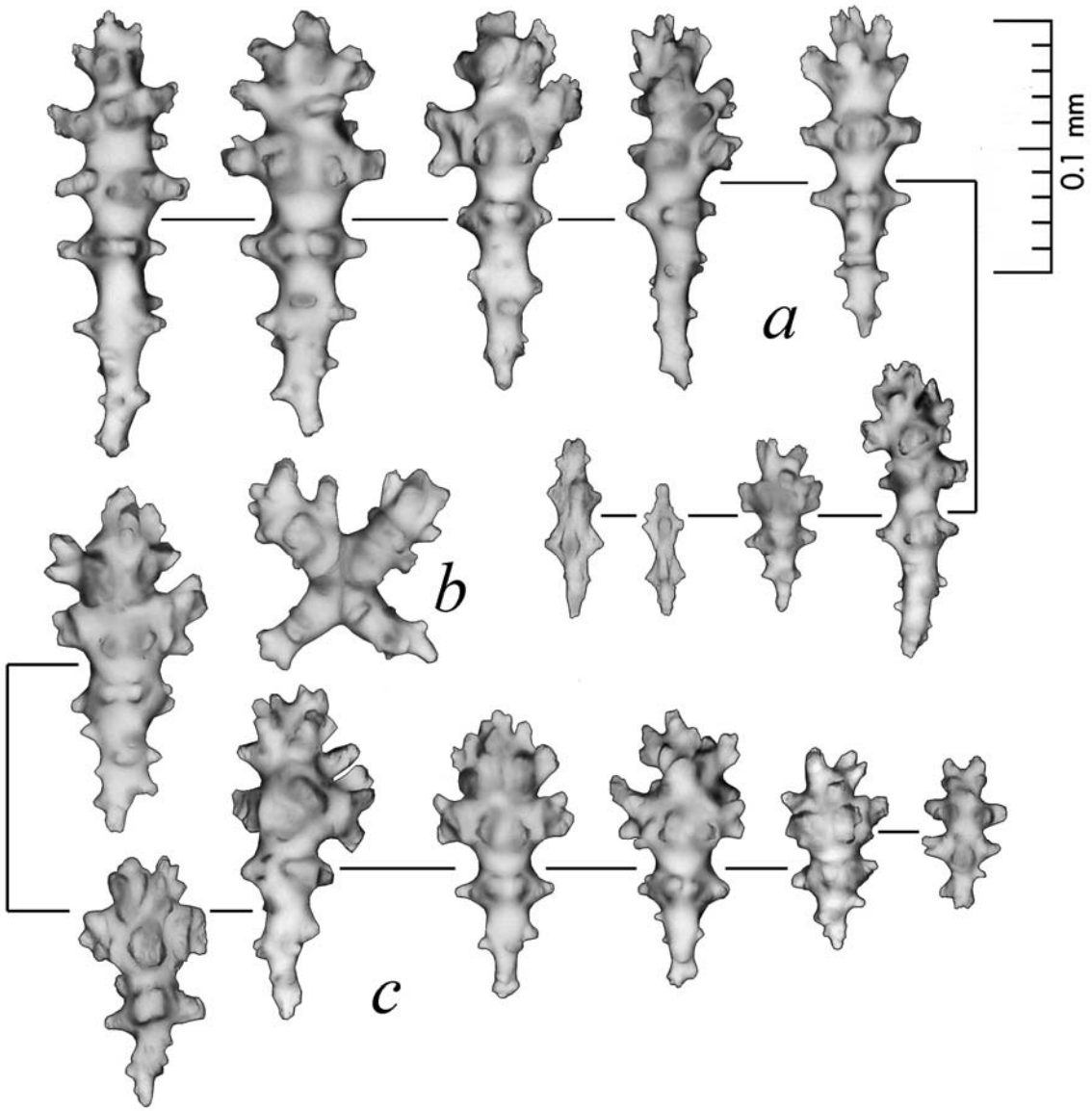


Fig. 24. *Sarcophyton ehrenbergi*, sclerites from specimen PMBC24809: a, b, from the surface of the capitulum; c, from the surface of the stalk. Enlargement of a – j indicated by 0.1 mm scale at a.

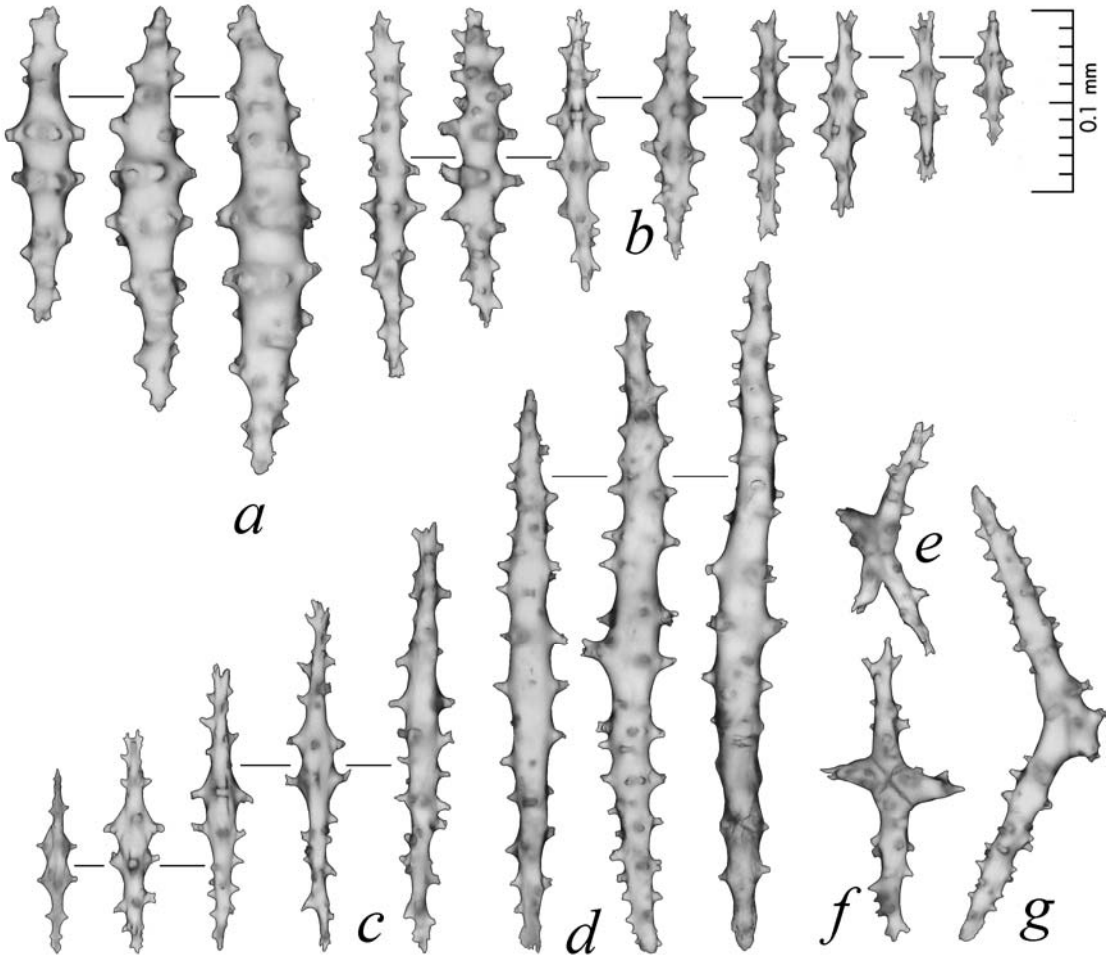


Fig. 25. *Sarcophyton ehrenbergi*, sclerites from specimen PMBC24809: a – b, from the interior of the capitulum; c – g, from the interior the stalk. Enlargement of a – f indicated by 0.1 mm scale at a.

Material examined:

- PMBC24809 one adult colony, Hin Ki-Nok, depth 7 m, collected on 25 December 2002.

- PMBC24810, three adult colonies, Koh Kam, depth 5 m, collected on 03 March 2004**.**

- PMBC24811, one adult colony, Koh Kra-Lek, depth 8 m, collected on 10 June 2005**.**

- PMBC24812, one adult colony, Koh Losin, depth 20 m, collected on 11 September 2004.

- PMBC24813, two adult colonies, Koh Chang, depth 4 m, collected on 9 May 2004.

- PMBC24814, one adult colony, Koh Kra, depth 7 m, collected on 7 June 2005.

- PMBC13314, two adult colonies, Koh Rok-Tai, collected on 25 February 1979.

- PMBC13318, one adult colony, Koh Rok, collected on December 1987.

Most of specimens collected by T. Chanmethakul, except PMBC13314 and PMBC13318 unknown collectors.

Geographical distribution: Widely distributed in the tropical Indo-West-Pacific, Red Sea (Verseveldt 1982b: 48), East Africa (Benayahu et al. 2003: 55).

Ecological notes: This species is distributed along the Andaman Sea coast of Thailand, and Gulf of Thailand. It is a common species in Thai waters and widely spread over the reef flat to the fore reef, from 2 to over 40 m depth, attached to dead coral substrate or rocky substrate. Specimens were often encountered in clear water.

Colony shape: Small colonies; the capitulum is flattened and the margins of the capitulum slightly folded. The capitulum is cup-shaped in adult colonies, the margins are strongly folded, and project far out of the sterile stalk. In the bigger colonies the folds extend up to the center of the capitulum.

In the preserved specimen PMBC24809, the capitulum shrank to 11.7 cm diameter. The sterile stalk is about 7 cm high and about 4 cm in diameter. Some colonies are flat and encrusting when in zones of strong wave action. Color is brown.

Polyps: A large number of the autozooids are not completely retracted. The siphonozooids are visible. The number of siphonozooids between two autozooids in the middle is 3 - 4 and at the margin 2 – 3.

Sclerites: The surface layer of the capitulum contains clubs. They have wide warty heads and thick handles, often zoned with blunt spines, and are 0.05 – 0.18 mm long

(Fig. 24a). The surface layer of the sterile stalk also contains clubs. They are broader and very warty, 0.08 – 0.17 mm long (Fig. 24b).

The interior of the capitulum contains sclerites of two shapes. First, spindles covered with blunt or cone-shape prominences, up to 0.26 mm long (Fig. 25a). Second, spindles with branched or bifurcated prominences: a few with antler-like processes. Spindles are 0.07 – 0.21 mm long (Fig. 25b). In the interior of sterile stalk there are also spindles, up to 0.24 mm, with branched processes (Fig. 25c) and rods, 0.31 - 0.37 mm long (Fig. 25d)

Moreover, a few fantastic shapes occurred in the surface of capitulum (Fig. 24b) and in the interior of stalk (Fig. 25e – g).

Remarks: The specimens show characteristics that agree with those described by Verseveldt (1982: 40-48), in which the sclerites in the surface of capitulum are club-shaped with wide, warty heads and thick handles. In the interior, spindles with antler-like processes are common (Fig. 25b).

Macroscopic characters differed between two specimens from Hin Ki-Nok (PMBC24809) and Koh Kam (PMBC24810). The siphonozooids of specimen from Hin Ki-Nok are clearly visible, while in the specimen from Koh Kam (PMBC24810), they are scarcely visible. However, microscopic characters agree in the two specimens.

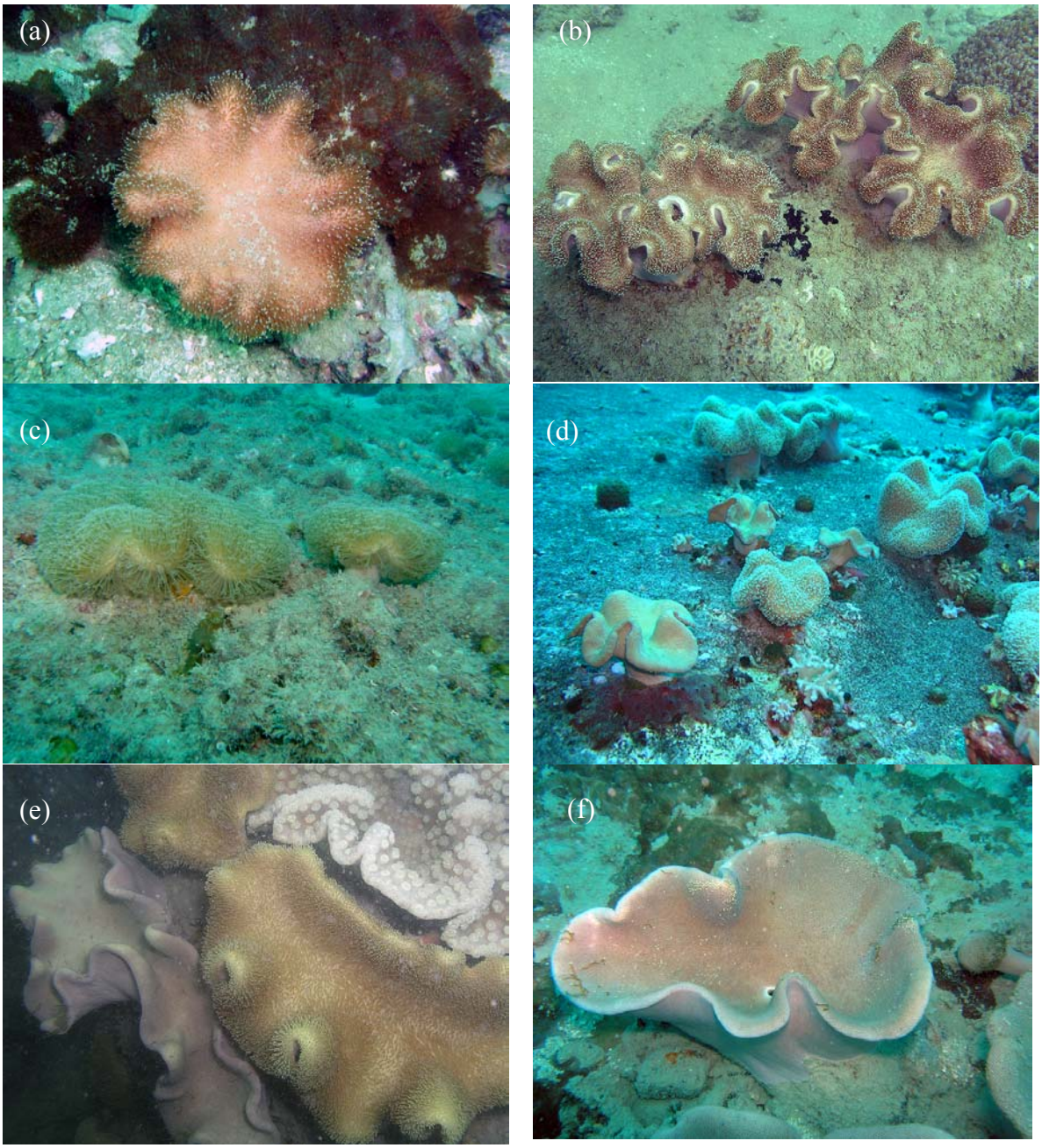


Fig. 26. Live specimens of *Sarcophyton ehrenbergi* from each station: a, Hin Ki-Nok (PMBC24809) attached to rocky substrate, depth 5 m; b, Koh Kam (PMBC24810); c, Koh Kam (PMBC24811); d, Koh Losin (PMBC24812); e, Koh Chang (PMBC24813); f, PMBC24814.

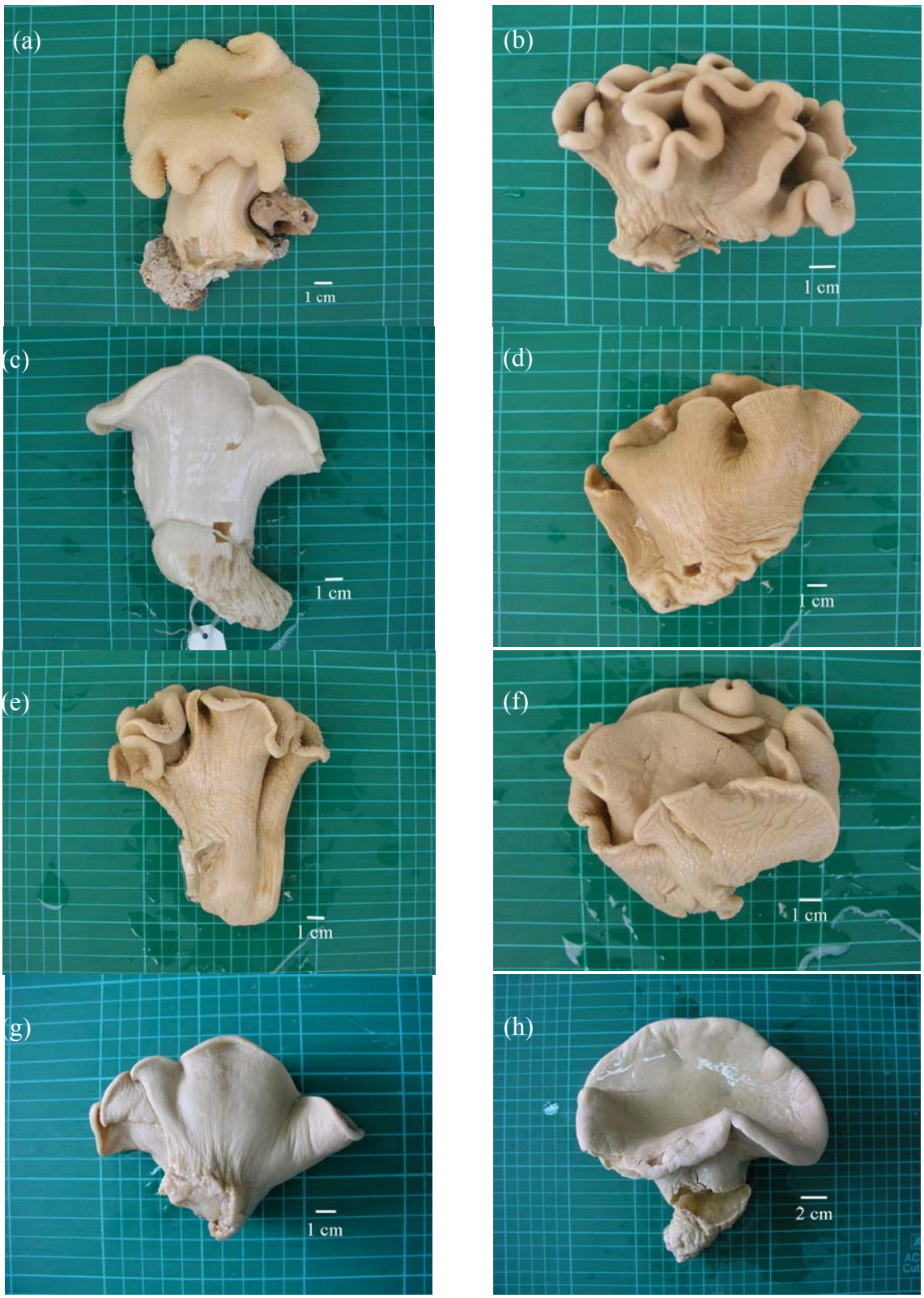


Fig. 27. Preserved specimens of *Sarcophyton ehrenbergi*: a, PMBC24809; b, PMBC24810; c, PMBC24811; d, PMBC24812; e, PMBC13314; f, PMBC13318; g, PMBC24813; h, PMBC24814.

Sarcophyton elegans Moser, 1919

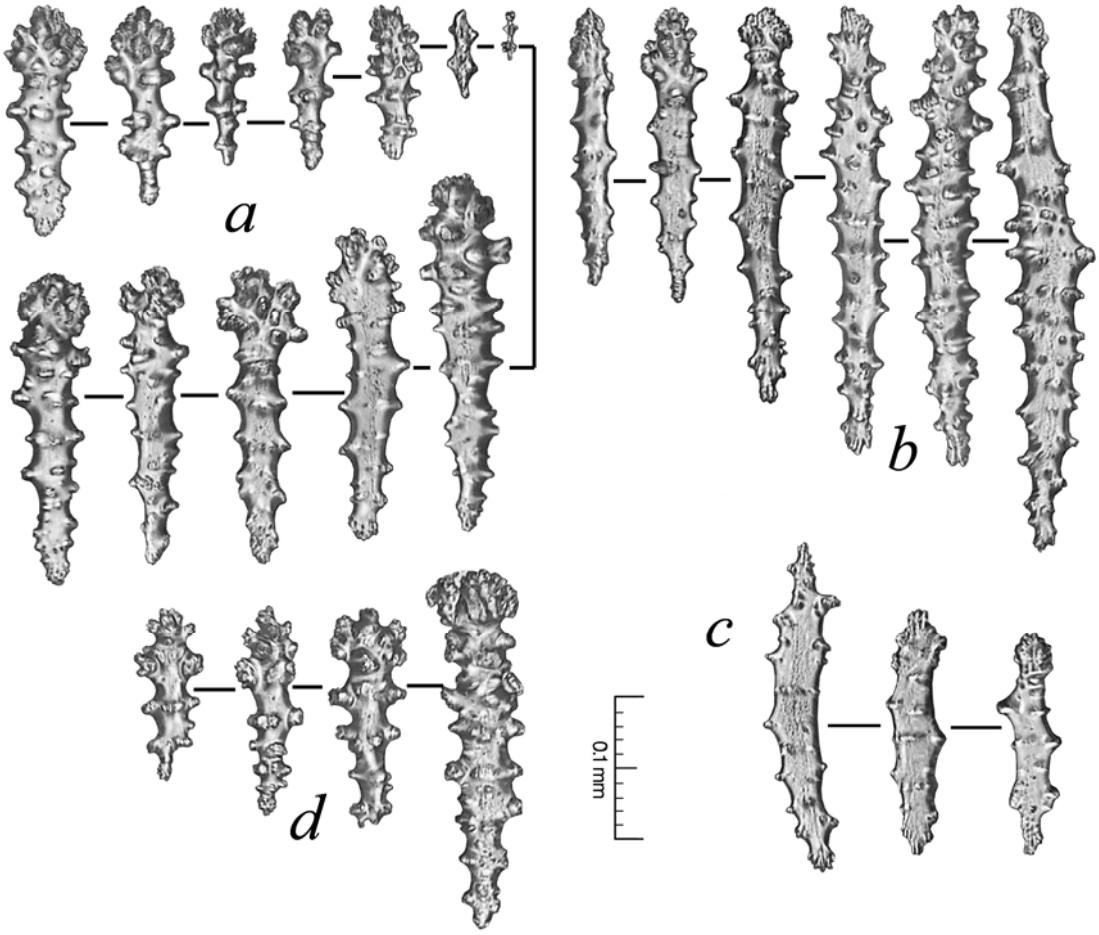


Fig. 28. *Sarcophyton elegans*, sclerites from specimen PMBC24815: a – c, from the surface of the capitulum; d, from the surface of the stalk. Enlargement of all, indicated by 0.1 mm scale at c.

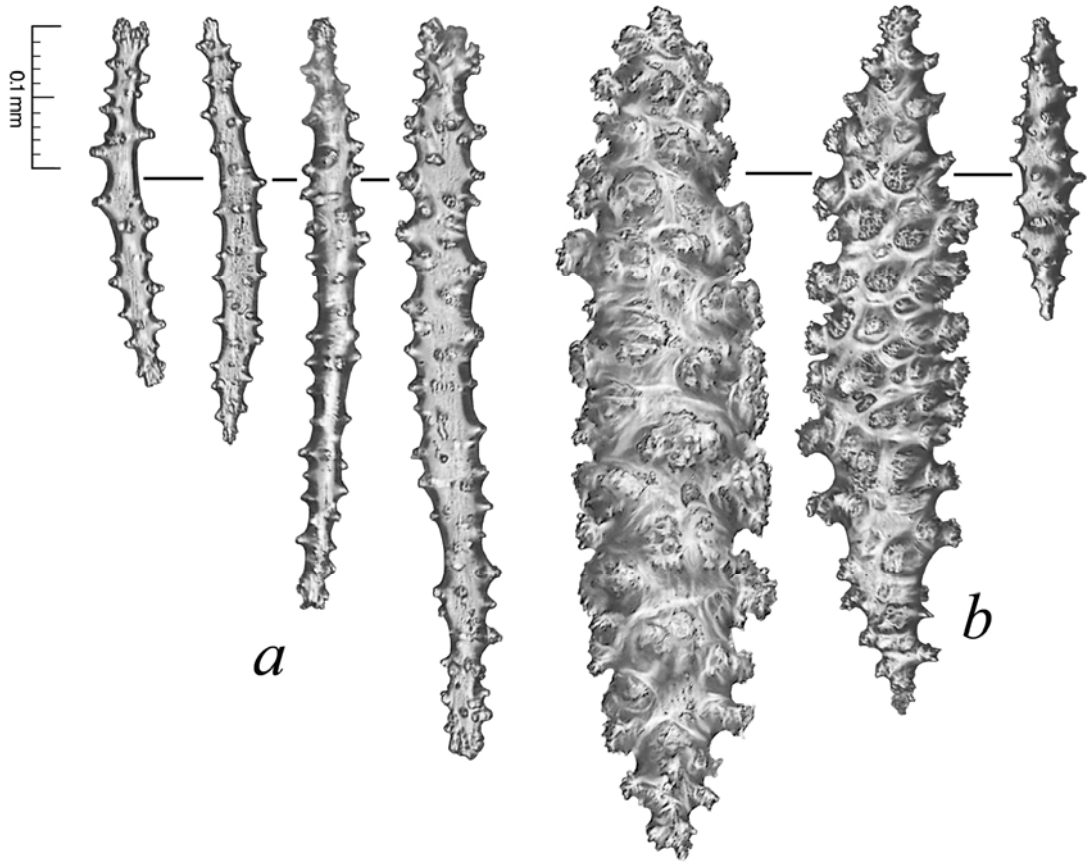


Fig. 29. *Sarcophyton elegans*, sclerites from specimen PMBC24815; a, from the interior of the capitulum; b, from the interior of the stalk. Enlargement of all, indicated by 0.1 mm scale at a.

Material examined:

- PMBC24815 one adult colony, Koh Miang (Similan Islands), depth 3 m, collected on 3 April 2003 by T. Chanmethakul.

Geographical distribution: Seychelles (Malyutin 1992: 2); Laing Island (Papua New Guinea) (Tursch and Tursch 1982: 325); Philippines, Great Barrier Reef, Madagascar, Japan, Vietnam, New Caledonia (Verseveldt 1982b: 51).

Ecological notes: This species is distributed along the Andaman Sea coast of Thailand attached to coral rubble, depth 3 m. They occur in shallow waters entirely in the reef zones although they can grow up to 40 m depth attached to dead coral substrate or on rock. They are also distributed on both sheltered and exposed reef.

However, they may also occur in the Gulf of Thailand, especially at Koh Tao. The photos (Fig. 20) show the macroscopic characters typical of this species.

Colony shape: The colony on the reef has a very folded margin, which extends far beyond the stalk. The capitulum is about 30 cm diameter and the total height of the colony is about 20 cm. The preserved specimen is pale brown.

Polyps: In the fresh specimen the autozooids are extended. The preserved specimen polyps are completely retracted. The siphonozooids between two autozooids are single at the margin of the capitulum. In the center of the capitulum there are three to four.

Sclerites: The surface layer of the capitulum contains several different club-shaped forms. 1) The head has a number of warts, the handles bear simple warts, and, in the middle part of the club, they are often arranged in girdles. The length varies from 0.03 – 0.25 mm but those with a length of 0.16 – 0.20 mm are the most common (Fig. 28a). 2) Spindles or sticks, 0.19 – 0.37 mm long (Fig. 28b), with an accumulation of tubercles at one end are also common; their heads are underdeveloped and the handles are covered with cone-shaped prominences. 3) There are also a few club-like sclerites that are flattened, 0.15 - 0.23 mm long (Fig. 28c), and they have heads dotted with simple warts.

In the surface layer of the sterile stalk lie clubs 0.13 to 0.25 mm long (Fig. 28d); the head consists of warts. The handles bear cones and truncated spines, often arranged in girdles.

The interior of the capitulum has straight or curved rods, with low blunt prominences, up to 0.52 mm long (Fig. 29a). The sclerites in the stalk interior have spindles, seldom up to 0.60 long. Most of these sclerites are rather densely covered with spiny warts (Fig. 29b).

Remarks: The characteristics of the sclerites matched the specimen from Laing Island (Papua-New Guinea: RMNH Coel. no.13974), as described in Verseveldt (1982b: 48-51). However, there are some notable differences in the club-shaped sclerites from the surface of the capitulum. In the specimen described here, the spindles or sticks and the few flattened club-like forms (Fig. 28b – c), are not quite the same as in Verseveldt's Fig. 18. But, in my opinion, most of the main spiculation

conforms, thus suggesting this specimen should remain as *S. elegans*. Further, numbers of samples from various localities need to be studied in order to clarify the stability of the characters.

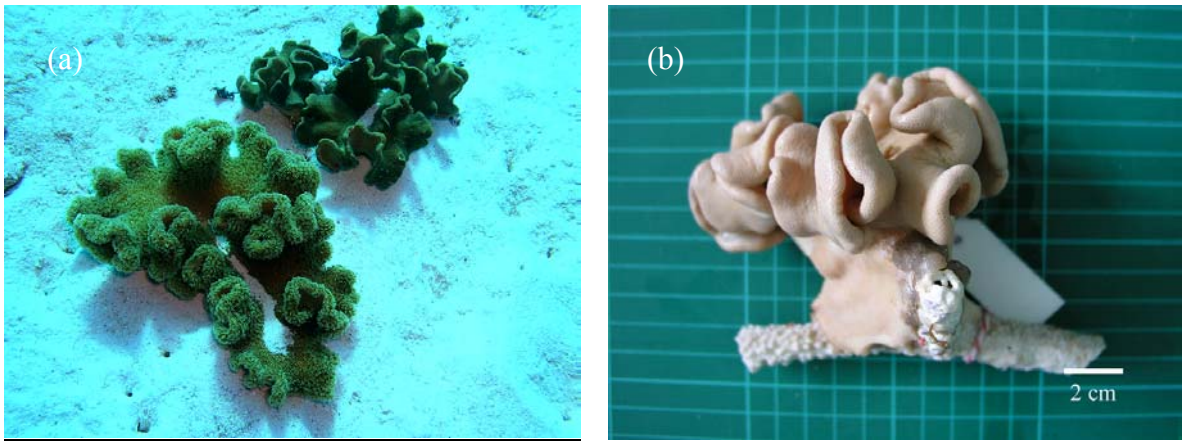


Fig. 30. *Sarcophyton elegans,* specimen PMBC24815 from Koh Miang: a, live; b, preserved.

Sarcophyton stellatum Kükenthal, 1910

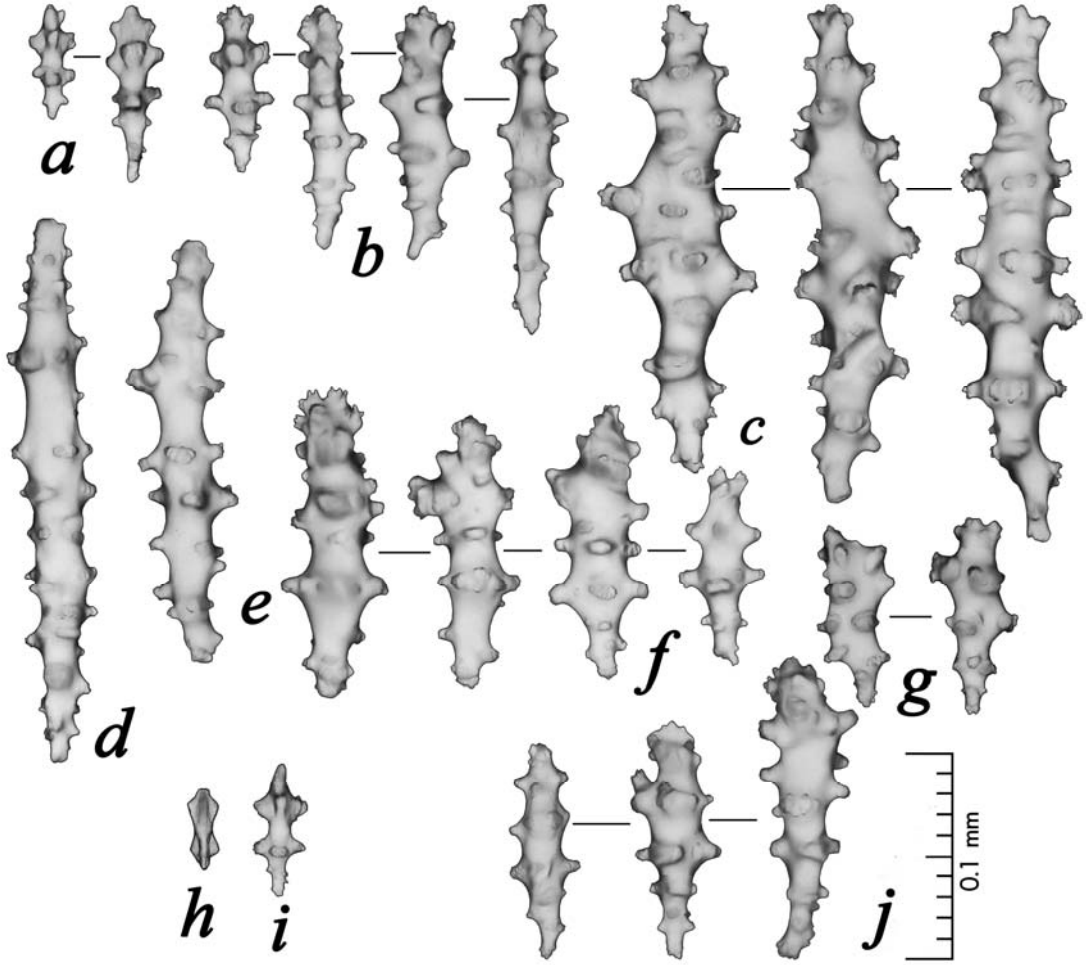


Fig. 31. *Sarcophyton stellatum*, sclerites from PMBC24821; a – d, from the surface of the capitulum; e – j, from the surface of the stalk. Enlargement of a – j, indicated by 0.1 mm scale at j.

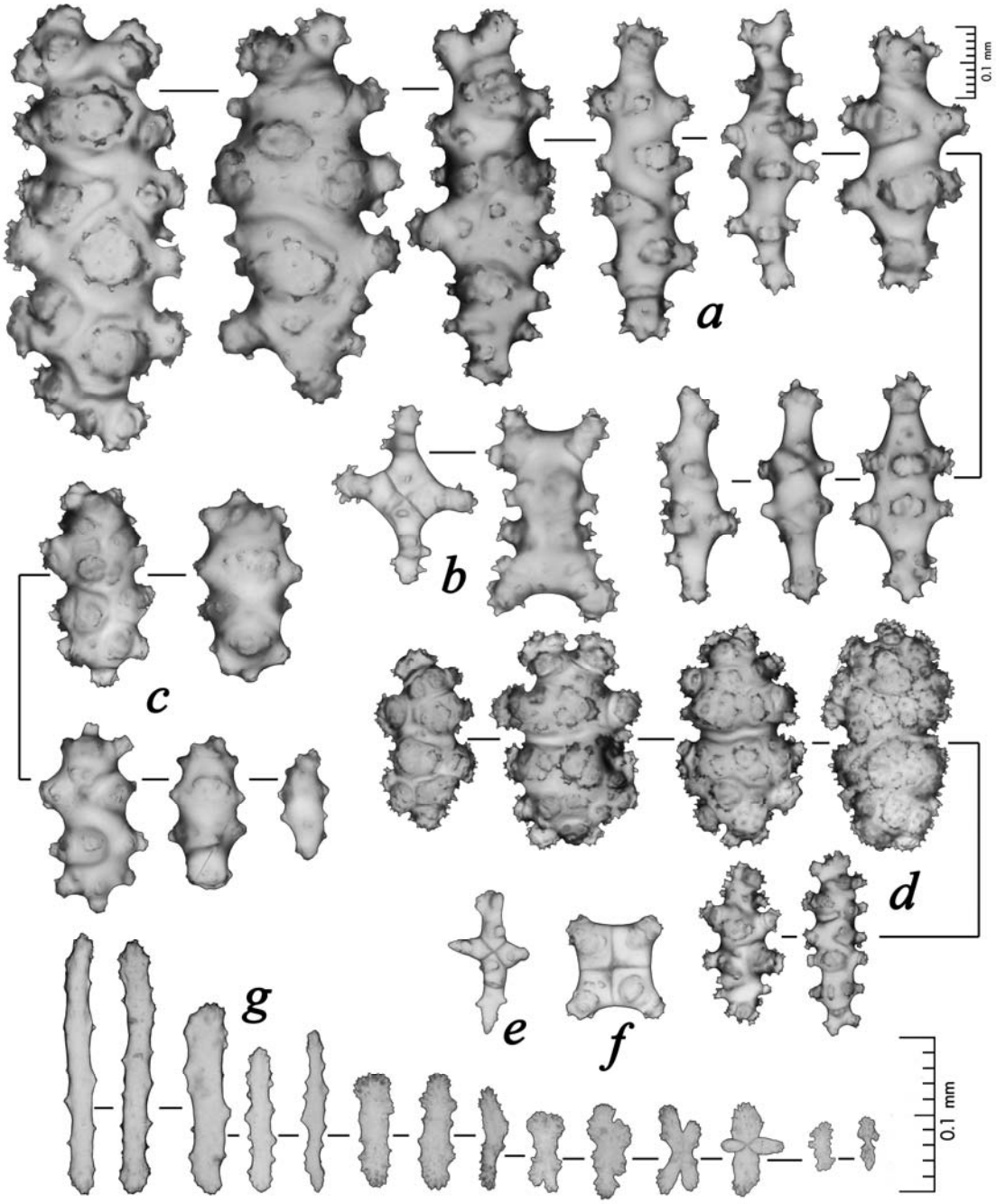


Fig. 32. *Sarcophyton stellatum*, sclerites from PMBC24821; a - b, from the interior of the capitulum; c – f, from the interior of the stalk; f, anthocodial and tentacular sclerites. Enlargement of a – f, indicated by 0.1 mm scale at a; that of g indicated by 0.1 mm scale at g.

Material examined:

- PMBC24821; two adult colonies, Hin-Wong (Koh Tao Group), on dead coral and rock, depth 10 m, collected on 26 April 2004 by T. Chanmethakul.

Geographic distribution: Southern Taiwan (Dai 1991b: 23), Aru Island (Verseveldt 1982b: 77).

Ecological notes: This species is found only in the Gulf of Thailand. It is abundant and widely distributed at Koh Tao. Specimens grow attached to the rocky substrate and cover large areas in clumps. They are distributed from 5 to 15 m depth.

Colony shape: The capitulum of live adult colonies are 30 - 50 cm in diameter. It is convex, the margin is folded, and the stalk is about 8 cm high. Some colonies in areas of strong wave action are laterally flat. The color is brown. The capitulum of one of the preserved specimens has shrunk to 7.2 cm in diameter and the stalk is 5.50 cm high.

Polyps: Polyps are contractile. The siphonozooids are scarcely visible.

Sclerites: The surface layer of the capitulum contains clubs. Many are small, 0.05 – 0.08 mm in length (Fig. 31a). Others are longer with weakly developed heads and sparsely distributed warts (Fig. 31b). There arte also irregularly-shaped spindles with blunt prominences (Fig. 31c) and a few rod-like forms (Fig. 31d).

There are a few rods, up to 0.28 mm long (Fig. 31e), in the surface layer of the sterile stalk; they have girdles are made up of rounded spines, The majority of the sclerites are clubs, 0.10 - 0.15 mm long, which have a head of small warts, and wide (Fig. 31f) or narrow handles (Fig. 31j). In addition, there are flattened clubs (Fig. 31g) and small forms with volcano shaped prominances in girdles (Fig. 31h - i).

In the interior of the capitulum, ovals and spindles predominate; the spiny warts are usually arranged into three to five girdles, and the ends of the sclerites are also covered with spiny warts. The majority of them are 0.17 – 0.21 mm long (Fig. 32a).

In the interior of the stalk lie oval-shaped sclerites, some of which are nearly smooth surfaced (Fig. 32c), and about 0.21 – 0.29 mm long. Larger forms, from 0.22

– 0.31 mm long, have two girdles of spiny warts separated by a median constriction and two terminal compound warts (Fig. 32d).

The anthocodia have flattened rods arranged *en chevron* below the tentacle bases, and small scales in the tentacles (Fig. 32g): sclerite length 0.03 – 0.18 mm.

Finally there are irregular shaped sclerites in the interior of capitulum (Fig. 32b) and in the interior of the stalk (Fig. 32e - f).

Remarks: The specimens show characteristics that conform to those described by Verseveldt (1982b: 76-77). Most of the coenenchymal sclerites are short, irregularly shaped, with warts sometimes forming two terminal girdles. However, the capitulum in both the fresh and preserved specimen is folded. It differs from Kükenthal's syntypes (ZMB no 6444), which are described in Verseveldt (1982b). This variability is probably a function the variation in the colony shape.

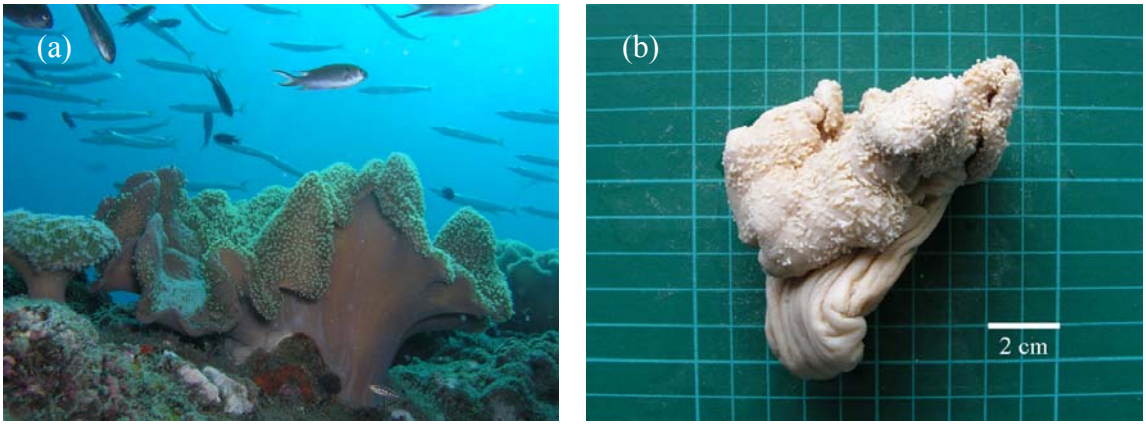


Fig. 33. *Sarcophyton stellatum,* specimen PMBC24821: a, live; b, preserved.

Sarcophyton trocheliophorum Von Marenzeller, 1886

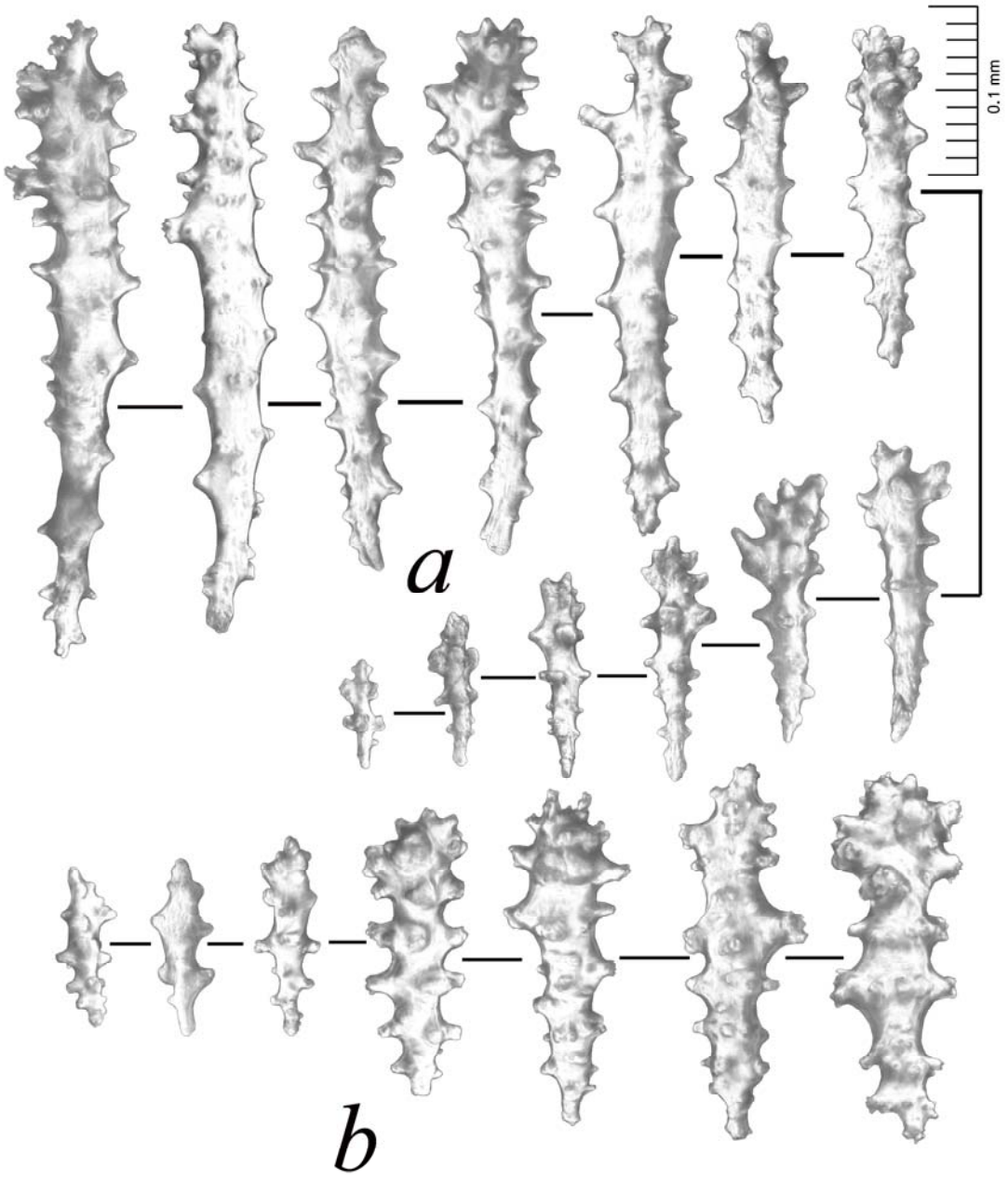


Fig. 34. *Sarcophyton trocheliophorum*, sclerites from specimen PMBC24823: a, from the surface of the capitulum; b, from the surface of the stalk. Enlargement of all, indicated by 0.1 mm scale at a.

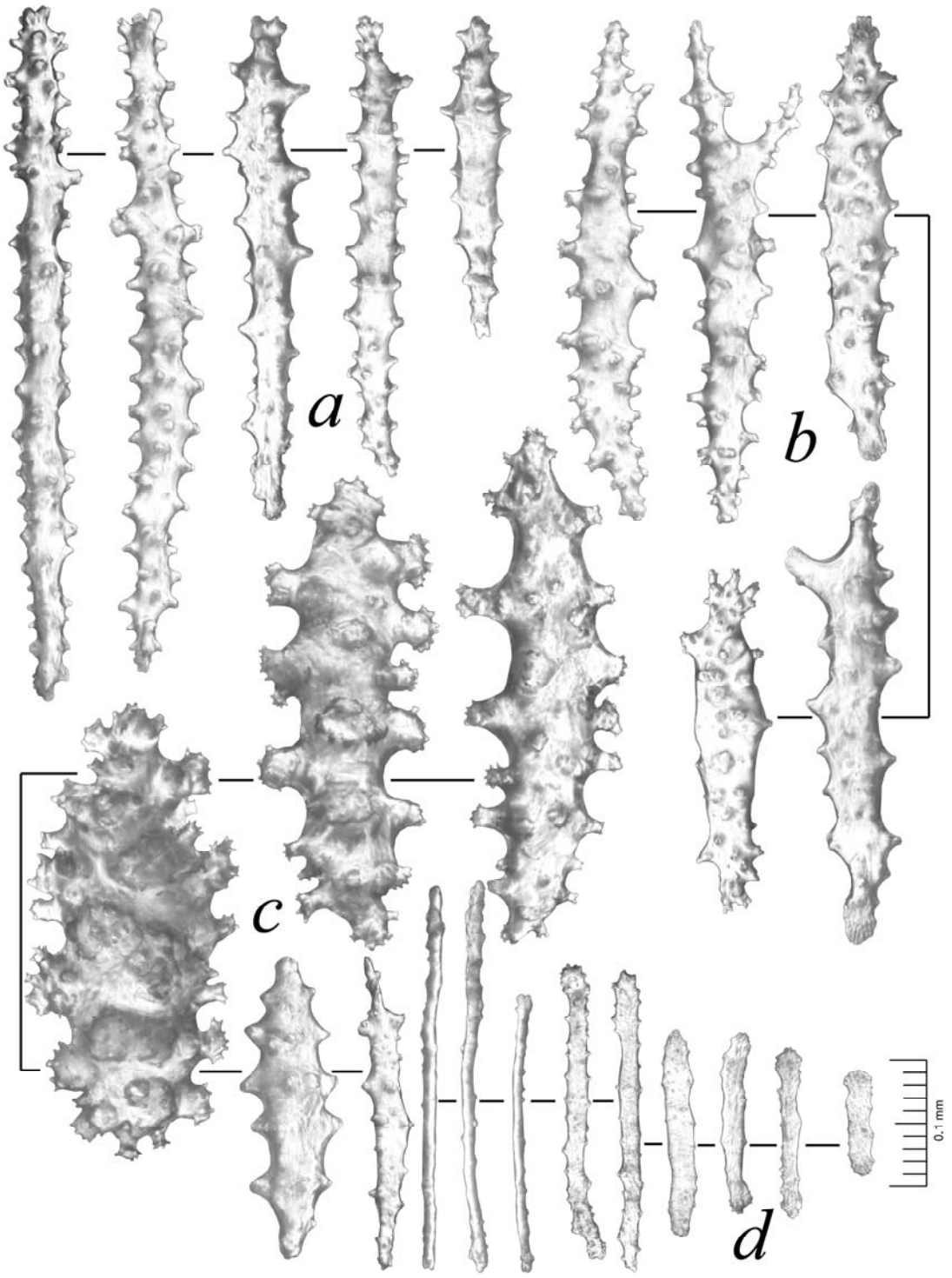


Fig. 35. *Sarcophyton trocheliophorum*, sclerites from specimen PMBC24823: a-b, from the interior of the capitulum; c, from the interior of the stalk; d, anthocodial and tentacle sclerites. Enlargement of all, indicated by 0.1 mm scale at d.

Material examined:

- PMBC24823, one adult colony, Koh Kra-Yai, on rocky substrate, depth 3 m, collected on 7 June 2005.

- PMBC24824, one juvenile colony, Koh Chan, depth 2 m, collected on 9 October 2004.

- PMBC24825, one small fragment, Koh Era, depth 4 m, collected on 10 October 2004.

All specimens collected by T. Chenmethakul.

Geographic distribution: Southern Taiwan (Dai 1991a: 242; Benayahu et al. 2004: 550), Dong-Sha Atoll (Li et al. 2000: 5), East Africa (Benayahu et al. 2003: 55), Indian Ocean and the West Pacific area (Verseveldt 1982b: 88), Laing Island (Papua New Guinea) (Tursch and Tursch 1982: 325).

Ecological notes: This species is common on the eastern and western parts of the Gulf of Thailand. Most colonies are distributed on rocky substrate. Specimens are often found in large aggregations and occur on the upper to lower slopes from 2 – 6 m depth.

Colony shape: The adult colony is large, the capitulum 40 cm in diameter, with a short stalk about 10 cm long. The capitulum has strong folds and extends beyond the sterile stalk. The color was pale-brown and stayed the same preserved in alcohol. Between two autozooids there are 2 - 3 siphonozooids at the rim of the capitulum. In the centre they are separated by 4 – 6 siphonozooids.

Polyps: In live specimens the autozooids were fully extended. In the preserved specimen the polyps are nearly completely retracted, but protrude above the surface of the capitulum.

Sclerites: The surface layer of the capitulum contains two types of clubs. First, small clubs, usually 0.07 – 0.18 mm long, with a few, somewhat leaf-like prominences and handles with warts and cone-shaped processes. Second, long clubs sometimes up to 0.37 mm length or irregular forms with heads consisting of small warts and cones (Fig. 34a). The clubs, 0.1 – 0.23 mm long, from the surface of the sterile stalk have high warts, more irregular in shape, and placed in zones, (Fig. 34b).

The interior of the capitulum has straight or curved sticks or rods, 0.25 - 0.74 mm long, with conical prominences (Fig. 35a), and broader spindle-like forms, occasionally branched, 0.26 – 0.40 mm long (Fig. 35b). The sclerites in the interior stalk are mostly oval up to 0.43 long. Many are densely covered with large, spiny, complex warts (Fig. 35c). Smooth spindles are also present.

The anthocodiae and tentacles contain needles, rods and flat sclales, approximately 0.08 to 0.32 mm long (Fig. 35d).

Remarks: Verseveldt (1982b: 83) described the sclerite characters of this species from several specimens. The sclerites on the surface of the capitulum are clubs with heads consisting of upward pointing prominences, sometimes leaf-like, and handles usually with one or more girdles of tubercles. The clubs in the surface of the sterile stalk have a similar basic shape. Other common characters are the interior oval-shaped sclerites with high spiny warts. PMBC24823 and PMBC24825 show these typical characters, however, the lengths of sclerites are different; those from PMBC24823 being slightly longer. The sclerites of PMBC24824 and PMBC24825, are longer in all parts to those described from the lectotype (Verseveldt 1982b: Fig.37; NHMW no. C2327) and, except for the oval-shaped ones, are equal with those from the paralectotype (Verseveldt 1982b: Fig. 38; ZMH no. C2442). The clubs on the surface of the capitulum are longer than those described from the Paris Museum specimen (Verseveldt 1982b: Fig.39; MNHN). However, Verseveldt (1982b: 84-88) correctly indicated the variability in the size of sclerites in several specimens of *S. trocheliophorum*.

It should therefore be noted that there is variability between the Thai specimens of this species. For example, there may be differences in the width and length of the sclerites of the interior of the capitulum. The sclerites in the interior of the capitula of PMBC24824 and PMBC24825 have narrow spindles. They bear cone-shaped or wart-like prominences; but sometimes these are antler-like. However, the spindles of PMBC24823 are shorter and the cone-shaped structures are lower than those of PMBC24824 and PMBC24825.

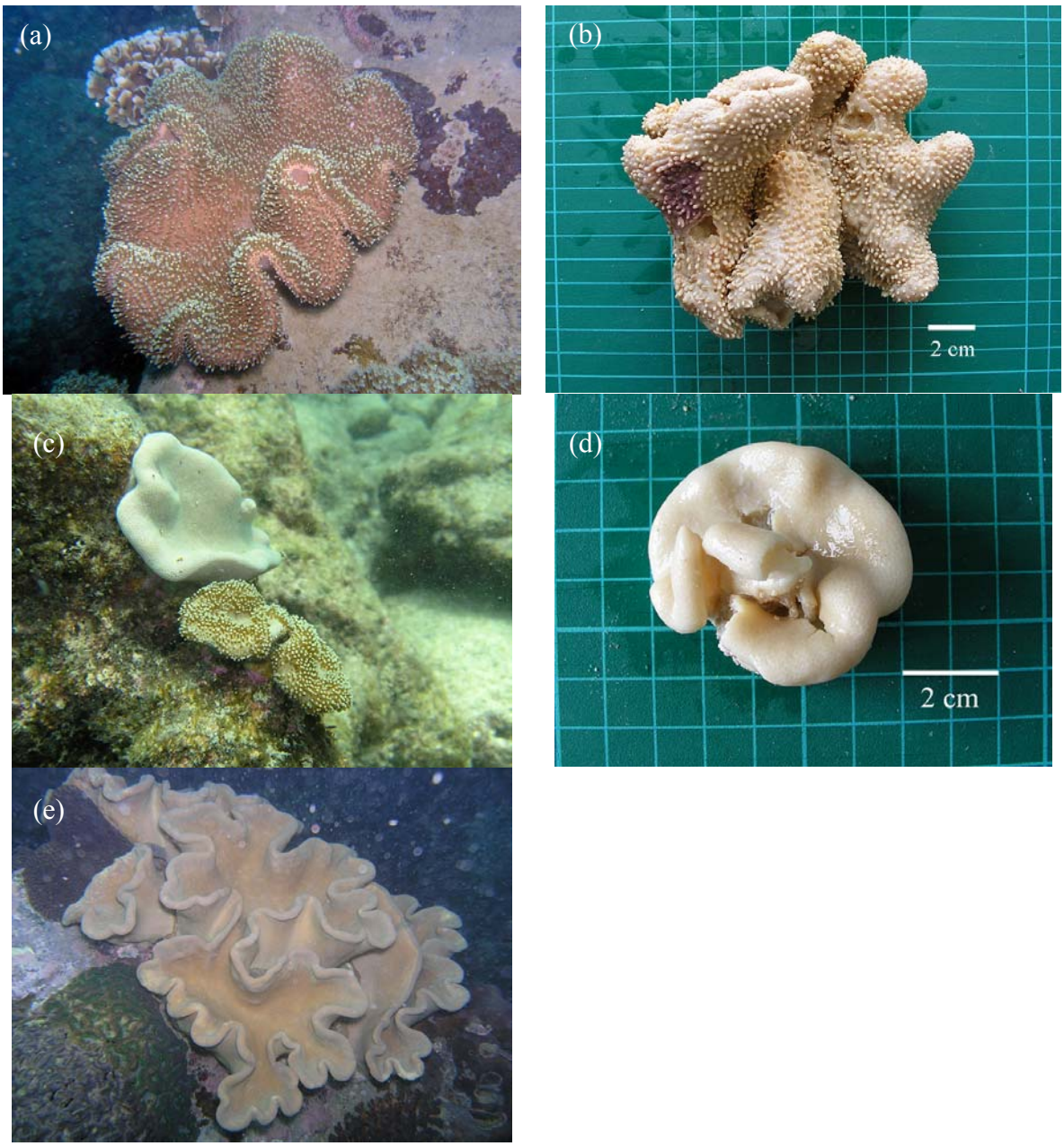


Fig. 36. *Sarcophyton trocheliophorum,* live and preserved specimens: a, PMBC24823 live; b, PMBC24823 preserved (upper side); c, the live juvenile colonies of PMBC24824 attach to dead coral substrate; d, PMBC24824 preserved; e, a large live colony of PMBC24825.

Sarcophyton glaucum (Quoy & Gaimard, 1833)

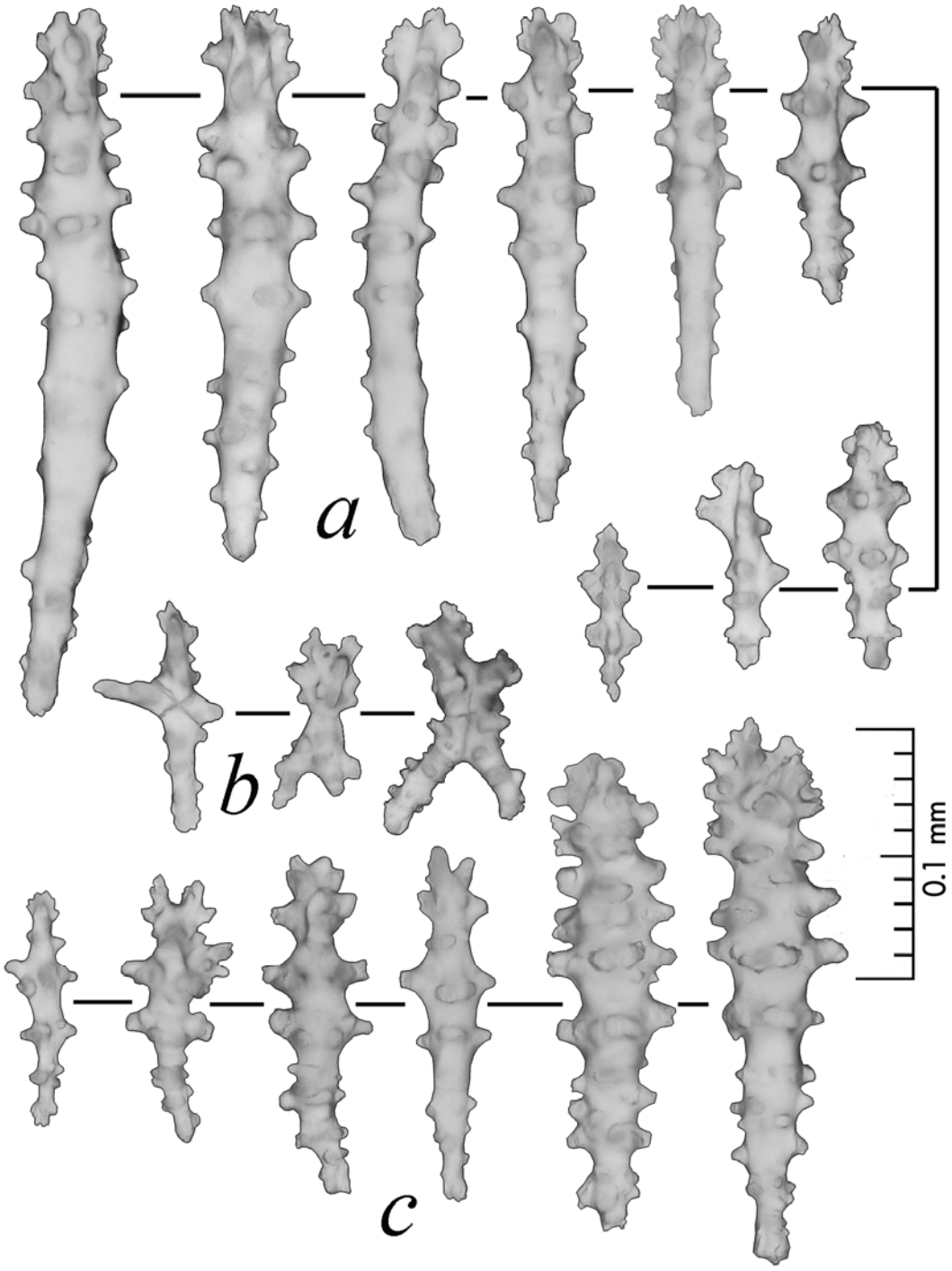


Fig. 37. *Sarcophyton glaucum*, sclerites from specimen PMBC24827; a – b, from the surface of the capitulum; c, from the surface of the stalk. Enlargement of a – c, indicated by 0.1 mm scale at c.

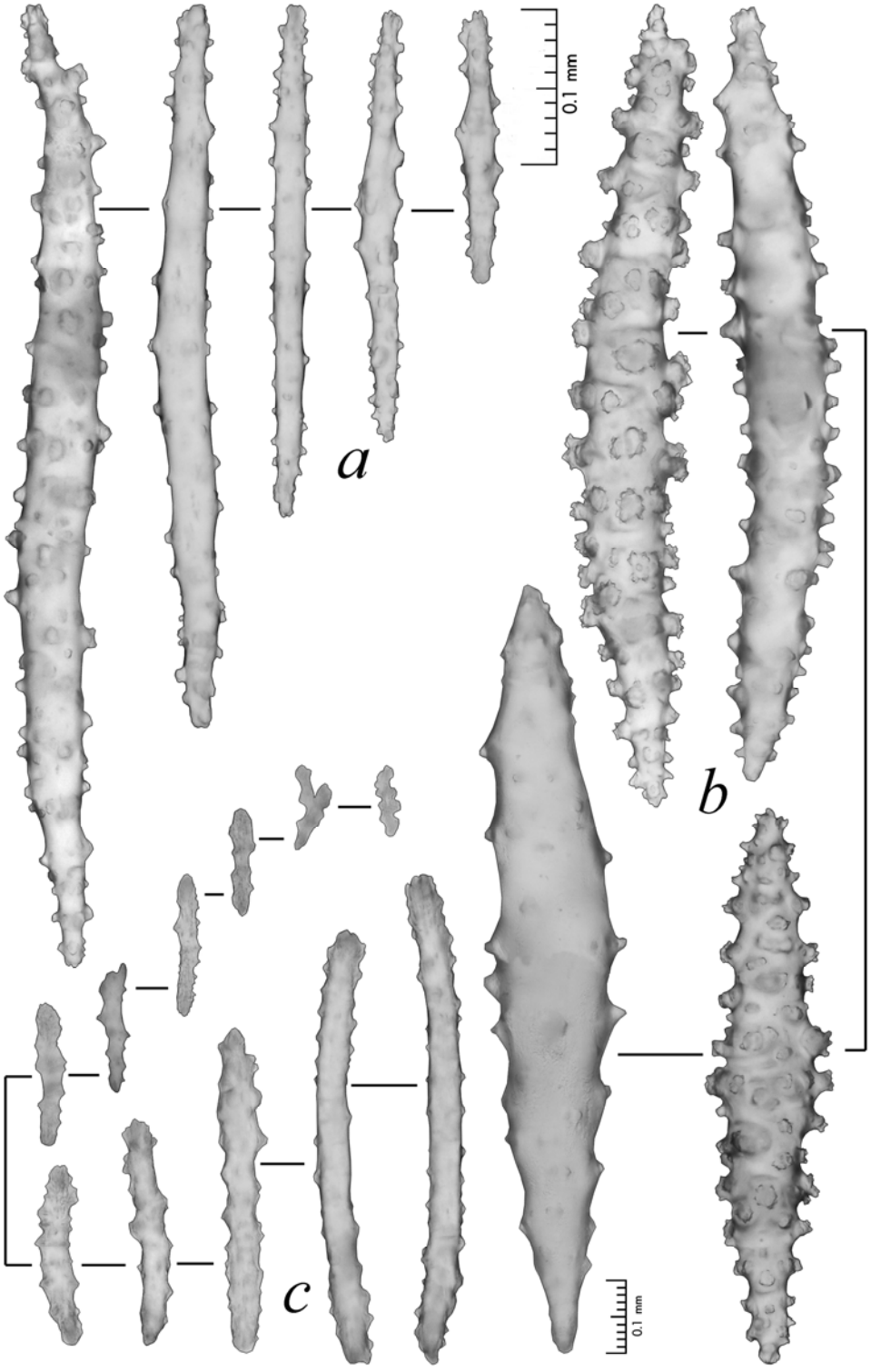


Fig. 38. *Sarcophyton glaucum*, sclerites from specimen PMBC24827: a, from the interior of the capitulum; b, from the interior of the stalk; c, from tentacles and anthocodiae. Enlargement of a and c, indicated by 0.1 mm scale at a; that of b by 0.1 mm scale at b.

Material examined:

- PMBC24827, one adult colony, Koh Miang (Similan Islands), on dead coral substrate, depth 25 m, collected on 10 April 2002 by T. Chanmethakul.

Geographic distribution: Laing Island (Papua New Guinea) (Tursch and Tursch 1982: 325), Yalong Bay (Vietnam) (Li 1982: 166), Red Sea (Perkol-Finkel and Benayahu 2004: 199), Indian Ocean (Verseveldt 1982b: 57), East Africa (Benayahu et al. 2003: 55).

Ecological notes: This species is common on the offshore islands, especially in the northern coast of the Andaman Sea of Thailand. They were often found in large aggregations. Most were distributed on the true reef and widely spread across the reef flat to the fore reef from 3 to over 30 m depth.

Colony shape: The capitulum of the adult colony in alcohol is 13 cm in diameter. The margin of the capitulum is strongly folded and protrudes beyond the sterile stalk, which is curved, cylindrical shaped and about 9 cm high.

On the coral reef the diameters of the capitula vary from small to 1 m and have more fully expanded polyps in the daytime. The young colonies are mushroom-shaped.

Polyps: The autozooids protrude from above the surface of the capitulum and are usually only partly retracted. On the folds the distance between two autozooids is 2 mm, in the central part of the capitulum they are spaced from 2 - 4 mm. The anthocodiae of the extended autozooids reach a length of 0.40 cm. The siphonozooids are clearly visible. The number of siphonozooids between two autozooids is 2 – 5 at the periphery and 2 – 8 in the center.

Sclerites: The surface layer of the capitulum contains clubs. The small sclerites have constriction between the head and handles. In the longer clubs, the head consists of small warts and sometimes the prominences are leaf-like. The handles are blunt prominences, up to 0.29 mm long (Fig. 37a). A few fantastic shapes occur in the surface of capitulum (Fig. 37b). The surface layer of the sterile stalk also contains clubs. The processes are higher, wart-like, and often arranged in zones; the sclerite length is 0.10 – 0.22 mm (Fig. 37c).

The interior of the capitulum has longer rods, up to 0.64 mm long (Fig. 38a), the prominences of which are truncated spines, although some of them are covered with low blunt structures and are nearly smooth. The internal sclerites of the stalk are spindles up to 1.04 mm long, most with high spiny warts (Fig. 38b). A few spindles are smooth surfaced and covered with low truncated spines.

The anthocodiae and tentacles contain needles, rods and scales, and vary from 0.05 to 0.32 mm long (Fig. 38c).

Remarks: It is difficult to identify this specimen because there are many nominal species that have similar characteristics. These were referred to as "*Sarcophyton glaucum*: a cryptic species complex?" by McFadden et al (2006: 299), and the authors included a number the numerous species. However, they are some characteristic that correspond with *S. glaucum* as described by Verseveldt (1982). The clubs in the surface of the capitulum and stalk are similar in shape with the type from Laing Island (Verseveldt 1982: Figs. 20-21; RMHN Coel. No 13975), and the details of the sclerites in the interior of the capitulum and on surface of the stalk are also close to *S. glaucum*. More specimens would help to further confirm the identity of my material.

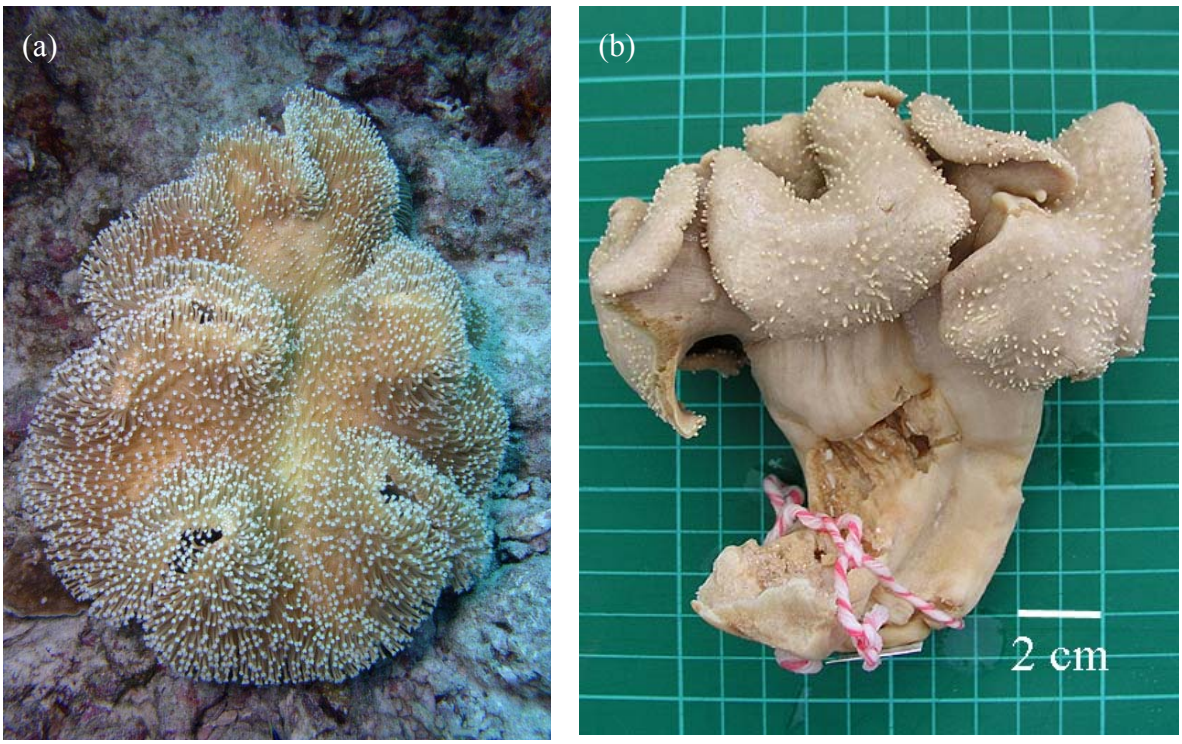


Fig. 39. *Sarcophyton glaucum* specimen PMBC24827: a, alive; b, preserved.

***Sarcophyton* sp. nov. A**

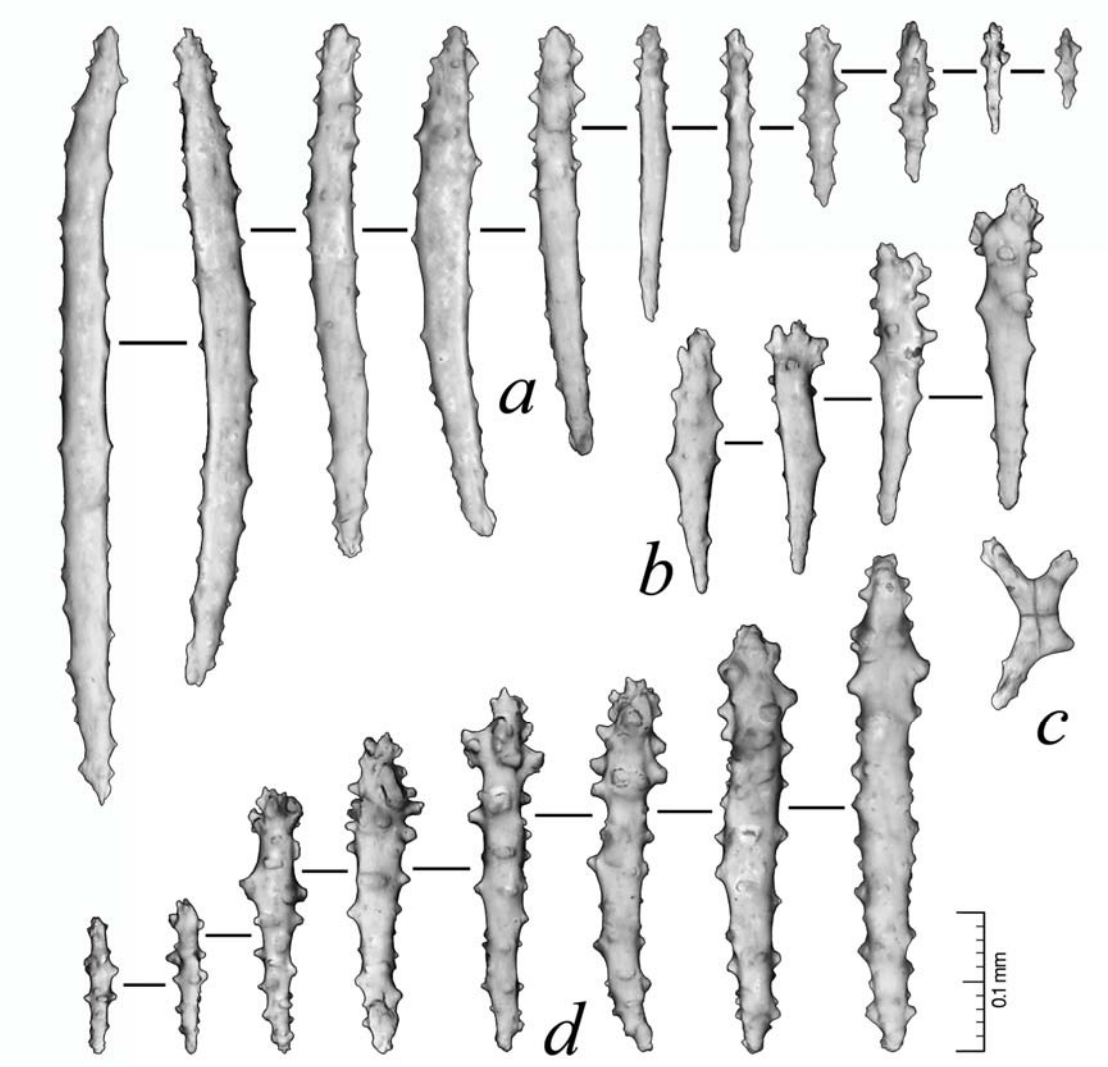


Fig. 40. *Sarcophyton* sp. nov. A, sclerites from specimen PMBC24802: a – c, from the surface of the capitulum; d, from the surface of the stalk. Enlargement of all, indicated by 0.1 mm scale at d.

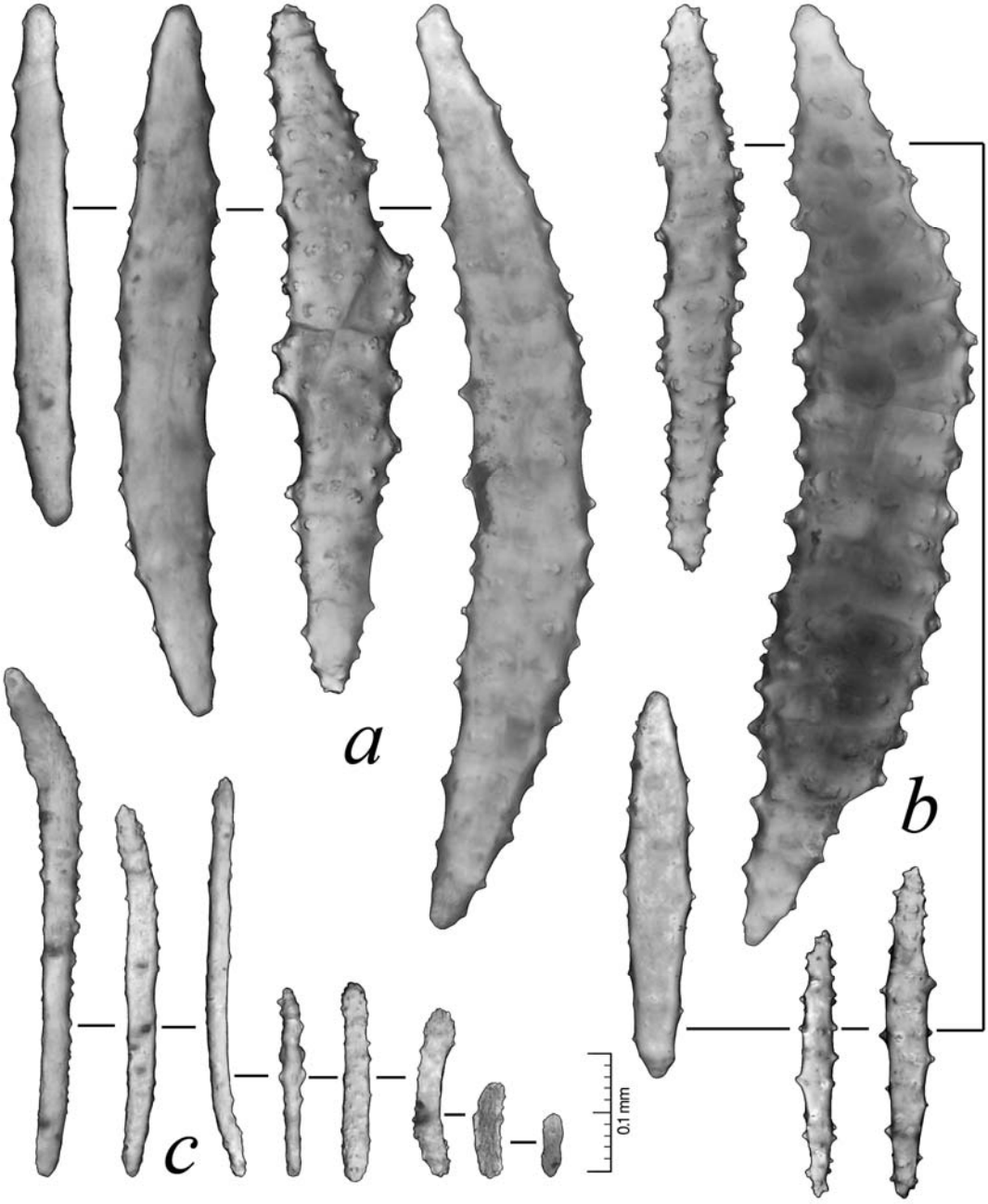


Fig. 41. *Sarcophyton* sp. nov. A, sclerites from specimen PMBC24802: a, from the interior of the capitulum; b, from the interior of the stalk; c, from the anthocodia and the tentaculas. Enlargement of all, indicated by 0.1 mm scale at c.

Material examined:

- PMBC24802, one adult colony, Koh Kra, on dead coral substrate, depth 10 m, collected on the 20th March 2004, by T. Chanmethakul.

Ecological notes: This species was found only at Koh Kra, on the offshore islands from the western part of the Gulf of Thailand. Only one colony was found, attached to dead coral substrate at 10 m depth on the reef slope.

Colony shape: The adult colony was small, 11 cm in capitulum diameter, with a total height of about 15 cm. The colony is slightly funnel-shape; the marginal folds of the capitulum are low and erect. The capitulum extends beyond the sterile stalk. The colour was pale-brown on the coral reef but the alcohol-preserved colony is dark brown.

Polyps: In the live specimen the autozooids were extended, and densely distributed along the margin. In the preserved specimen the polyps are semi-contracted and protruding above the surface. Near the edge of the capitulum there are three to four siphonozooids between two autozooids. Siphonozooids are scarcely visible in the center.

Sclerites: The surface layer of the capitulum contains slender clubs, pseudo-clubs, and long rods, 0.06 to 0.57 mm long (Fig. 40a). The most common clubs have small warts or truncated spines, and are usually 0.17 to 0.31 mm long. Pseudo-clubs are also common. Their heads are weakly developed and the handles are sculptured with widely spaced, low, cone-shaped prominences: those even less developed can be called rods. There are also a few clubs with the head composed of diverging simple warts; sclerite length 0.23 mm (Fig. 40b). Brackets may also be found in the surface of the capitulum (Fig. 40c).

In the surface layer of the sterile stalk lie clubs 0.11 to 0.42 mm long (Fig. 40e), the heads of which consists of small warts and cones. The handles are blunt-ended and bear cones and truncated spines.

The interior of the capitulum has straight or curved spindles, also with low blunt prominences or almost smooth surfaces, sometimes up to 0.74 mm long (Fig. 41a). The sclerites in the stalk interior are spindles, 0.21 to 0.76 long. Most are densely covered with low spines (Fig. 41b).

The anthocodiae and tentacles contain needles, rods arranged *en chevron*, and scales: sclerite lengths approximately 0.05 to 0.43 mm (Fig. 41c).

Remarks: The sclerites of the specimen are similar to those of the syntypes of *S. acutum* Tixier-Durivault, 1970, as illustrated by Verseveldt (1982b: Fig.1), in his revision of the genus *Sarcophyton*. In that paper, Verseveldt stated that the species has clubs in the surface layer of the capitulum, with some irregular-shaped, weakly developed heads, and others have long handles with stronger heads and sometimes wart-like processes. In my material, the clubs of the capitulum are longer than those of the syntypes. In addition, I found that the club heads are composed of stronger, foliate processes. Although, many of the characters of the sclerites tend to be similar to *S. acutum*, especially the clubs in the surface of the sterile stalk, the spindles in the interior of the capitulum and on the sterile stalk, there are distinct differences and it is hard to conclude that this specimen is *S. acutum*.

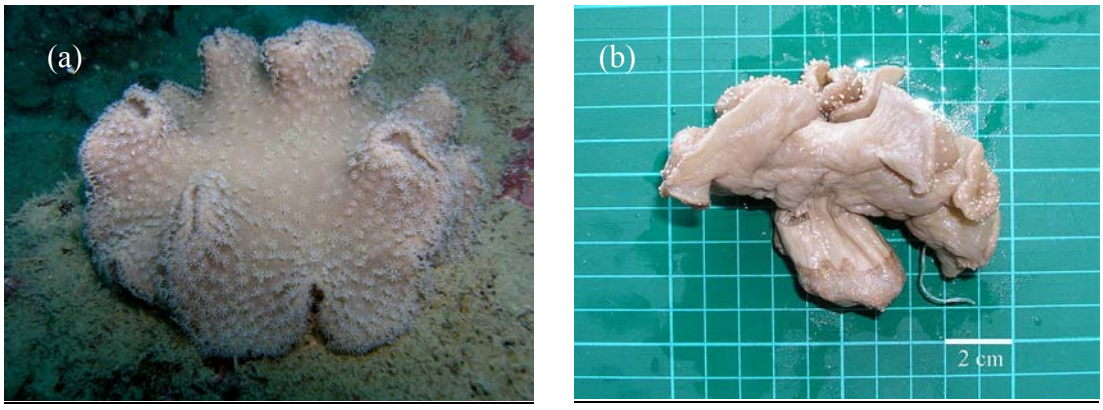


Fig. 42. *Sarcophyton* sp. nov. A, PMBC24802: a, the live specimen from the Koh Kra attached to dead coral substrate; B, the preserved specimen.

***Sarcophyton* sp. nov. B**

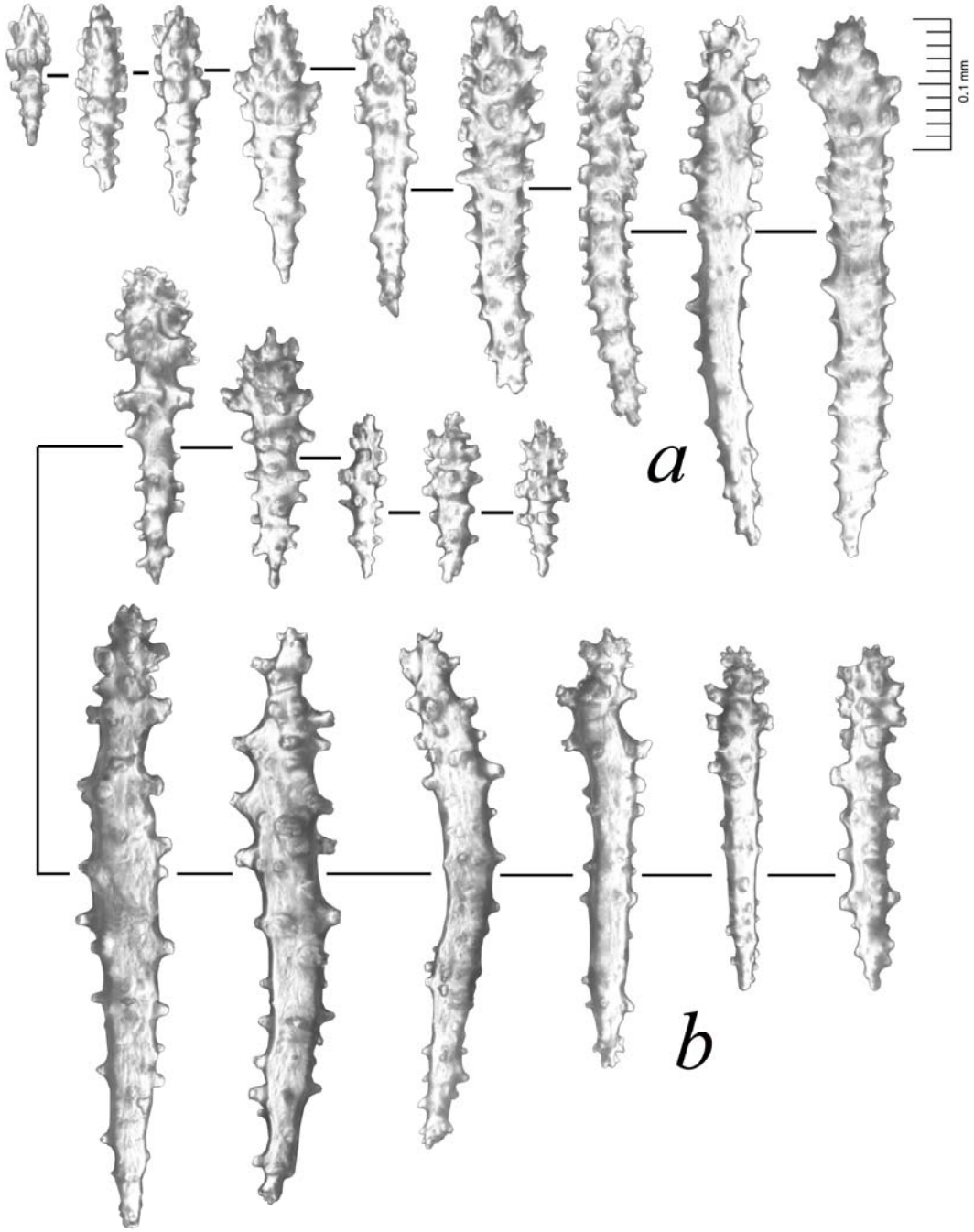


Fig. 43. *Sarcophyton* sp. nov. B, sclerites from specimen PMBC24803: a, from the surface of the capitulum; b, from the surface of the stalk. Enlargement of all, indicated by 0.1 mm scale at a.

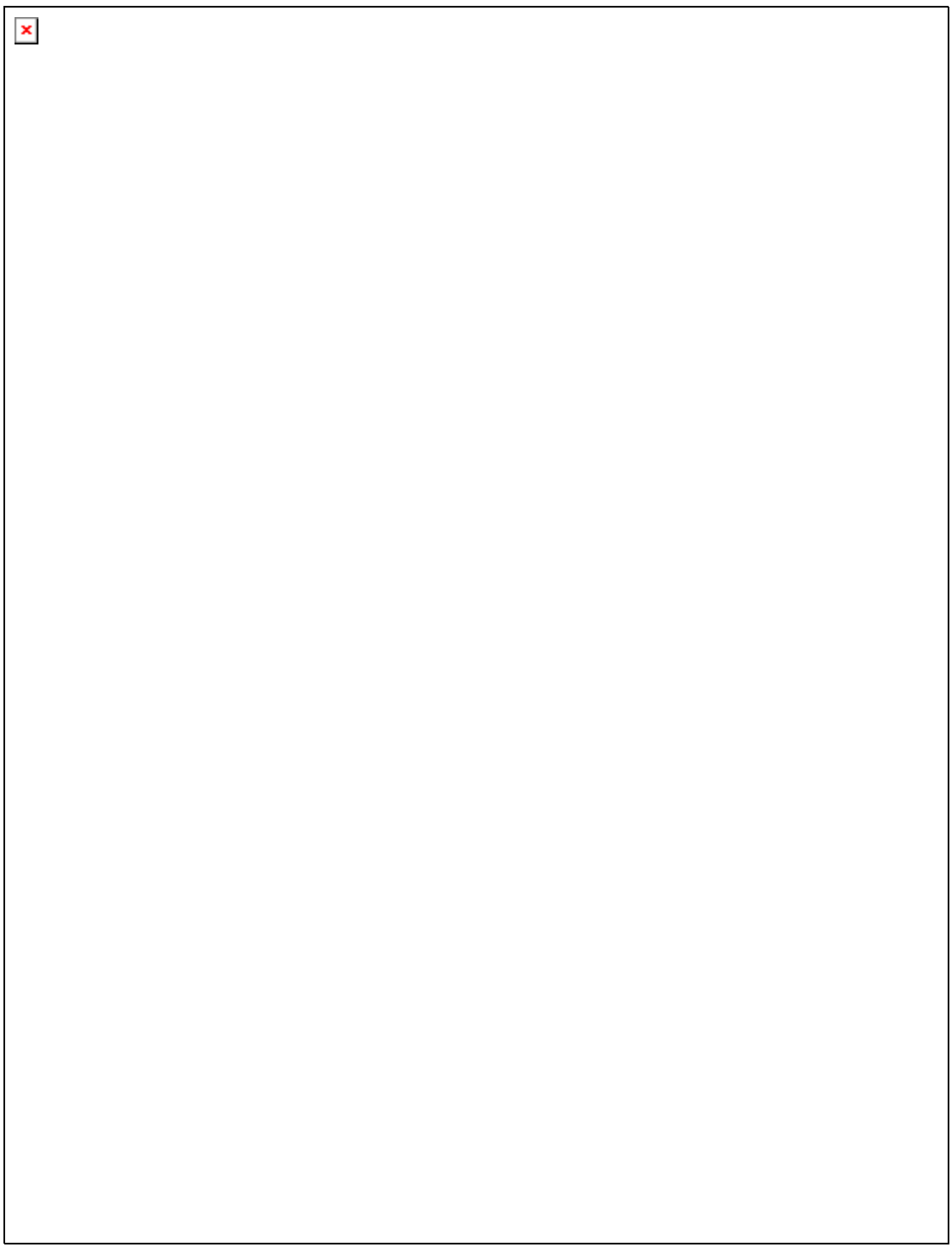


Fig. 44. *Sarcophyton* sp. nov. B, the sclerites from specimen PMBC24803: a-c, from the interior of the capitulum; d, from the interior of the stalk; e, from tentacles and anthocodiae. Enlargement of all, indicated by 0.1 mm scale at d.

Material examined:

- PMBC24803, PMBC24804, two adult colonies, Koh Kra-Klang, on rocky substrate, depth 15 m, collect on 8 June 2005, by T. Chanmethakul using SCUBA.

- PMBC24805, one adult colony, Koh Bon, depth 15 m, collected on 22 March 2006 by T. Chanmethakul.

- PMBC24806, small colony, Koh Similan, depth 20 m, collected on 20 April 2004 by T. Chanmethakul.

- PMBC24826, one adult colony, Koh Karta (Adang-Rawi Islands), on dead coral substrate, depth 5 m, collect on 20 March 2006, by T. Chanmethakul.

Ecological notes: This species is found near Koh Kra, which is situated in the western Gulf of Thailand. It is also wide spread along the Andaman Sea coast of Thailand. Colonies are distributed on rocky substrate and often occur in large aggregations on the slope at 10 – 20 m depth.

Colony shape: The capitulum of small colonies is rather flat, while large colonies are cup or funnel-shaped. The margin of the capitulum slightly folds and the edge is thin. The live adult colony was large, 20 cm in capitulum diameter. The stalk was bottle-shaped and about 10 cm long. The live colour was pale-brown and this has remained in alcohol.

Polyps: In the live specimen the autozooids were extend in some parts of the capitulum. In the preserved specimen PMBC24803 the polyps are completely retracted. There are 2 - 3 siphonozooids between two autozooids at the rim of capitulum, but they are hardly visible in the centre of the capitulum. In PMBC24804 the polyps are fully extended. At the centre of the capitulum there are 4 - 5 siphonozooids between two autozooids, but only 1 - 3 at the margin of the capitulum.

Sclerites: The surface layer of the capitulum contains robust clubs (Fig. 43a). Some of the heads of which consist of sharp leaf-like prominences pointing towards the summit of the head. Smaller clubs have pointed heads and wide handles covered with stumpy spines. Longer clubs have slender handles with blunt spines, and are 0.42 mm long (Fig. 43a). The small clubs in the surface layer of the stalk are the same shape and size, but in the longer clubs, the heads are often weak, and the handles are covered with blunt spines. They are up to 0.49 mm long (Fig. 43b).

The interior of the capitulum has spindles and rods which can be straight or curved. Rods are few and up to 0.73 mm long (Fig. 44a). Most of the sclerites are spindles, 0.96 mm long (Fig. 44b), covered in spiny warts, although some have truncated cones or stumpy spines. The sclerites in the interior of the stalk are also spindles. Many are covered in stumpy or conical spines and up to 1.26 mm long (Fig. 44c). There are also spindles, up to 1.40 mm long (Fig. 44d), covered in complex warts.

The tentacular sclerites are flat rods. The anthocodia is armed with many blunt, flat rods arranged *en chevron*, 0.05 – 0.10 mm long (Fig. 44e).

Remarks: The colony shapes of specimen PMBC24803 and PMBC24804 correspond with *S. boletiforme*, as shown in Verseveldt (1982b, see Pl.2 Fig.4). However, the sclerites in the interior of the capitulum are different. The sclerites in the holotype described by Verseveldt (1982b: 19) are slender and nearly smooth needles, and not like spiny spindles which were occurred in my material. Thus, it's difficult to confirm that this specimen is *S. boletiforme*.

In specimen PMBC24826 the sclerites in the surface layer of the capitulum and stalk seem to correspondend with the type specimen of *S. subviride* Tixier-Durivailt, 1958, as described in Verseveldt (1982b: 78 - 79). However, in the details there are quite a few differences: 1) Verseveldt stated that there are sclerites in the anthocodiae, which in this specimen are absent. 2) The spindles in the surface layer of the stalk and the rods in the interior of the capitulum of this specimen are longer than type specimen.

Fig. 45. *Sarcophyton* sp. nov. B: a – b, live colonies attached to rocky substrate; c, preserved specimen PMBC24803; d. preserved specimen PMBC24804.

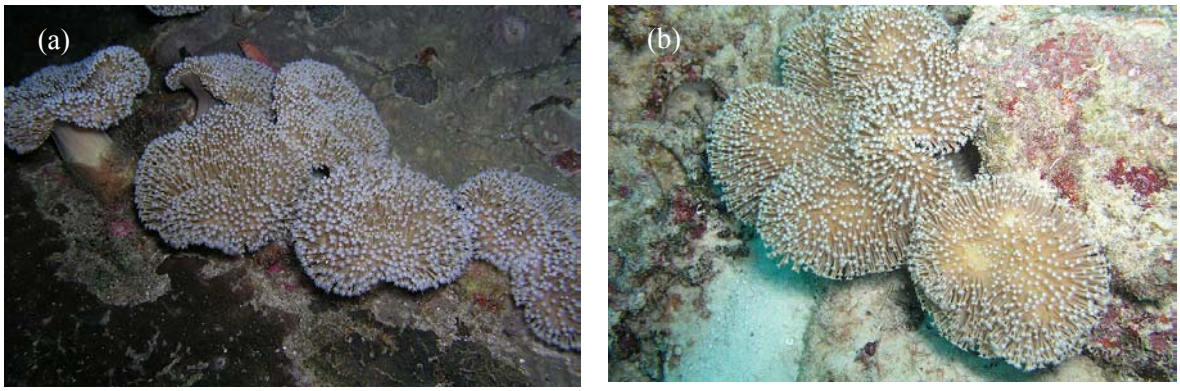


Fig. 46. *Sarcophyton* sp. nov. B, live colonies on rocky or dead coral substrate: a, PMBC24805; b, PMBC24806.

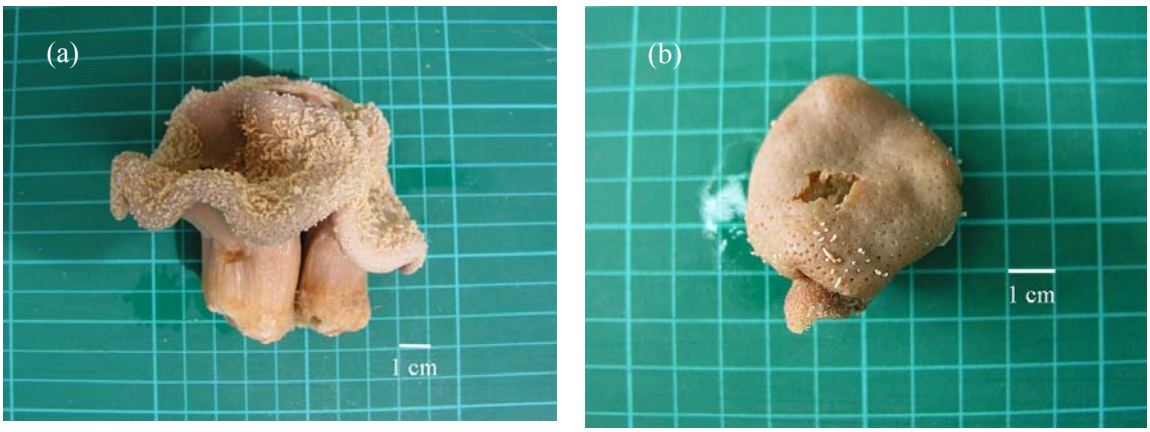


Fig. 47. *Sarcophyton* sp. nov. B, preserved specimens; a, PMBC24805; b, PMBC24806.

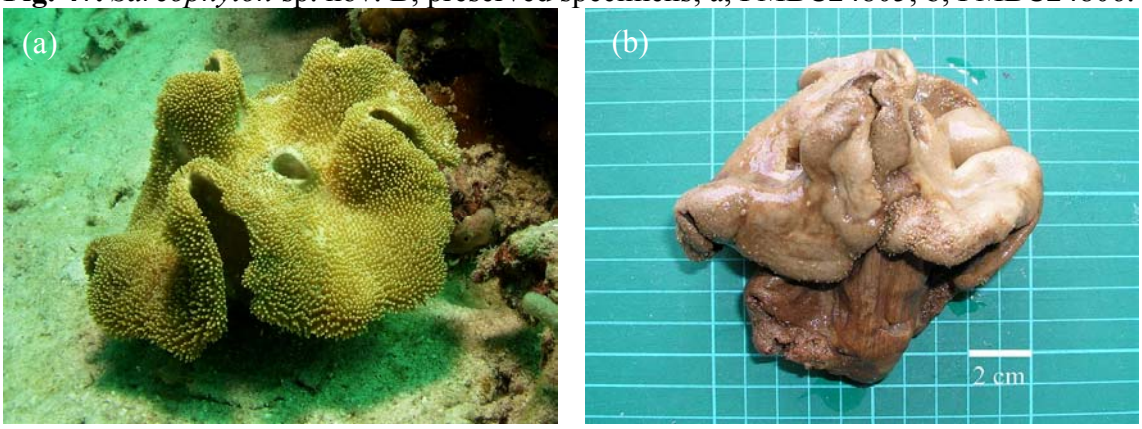


Fig. 48. *Sarcophyton* sp. nov. B, PMBC2486; a, live, depth 5 m; b, preserved.

***Sarcophyton* sp. nov. C**

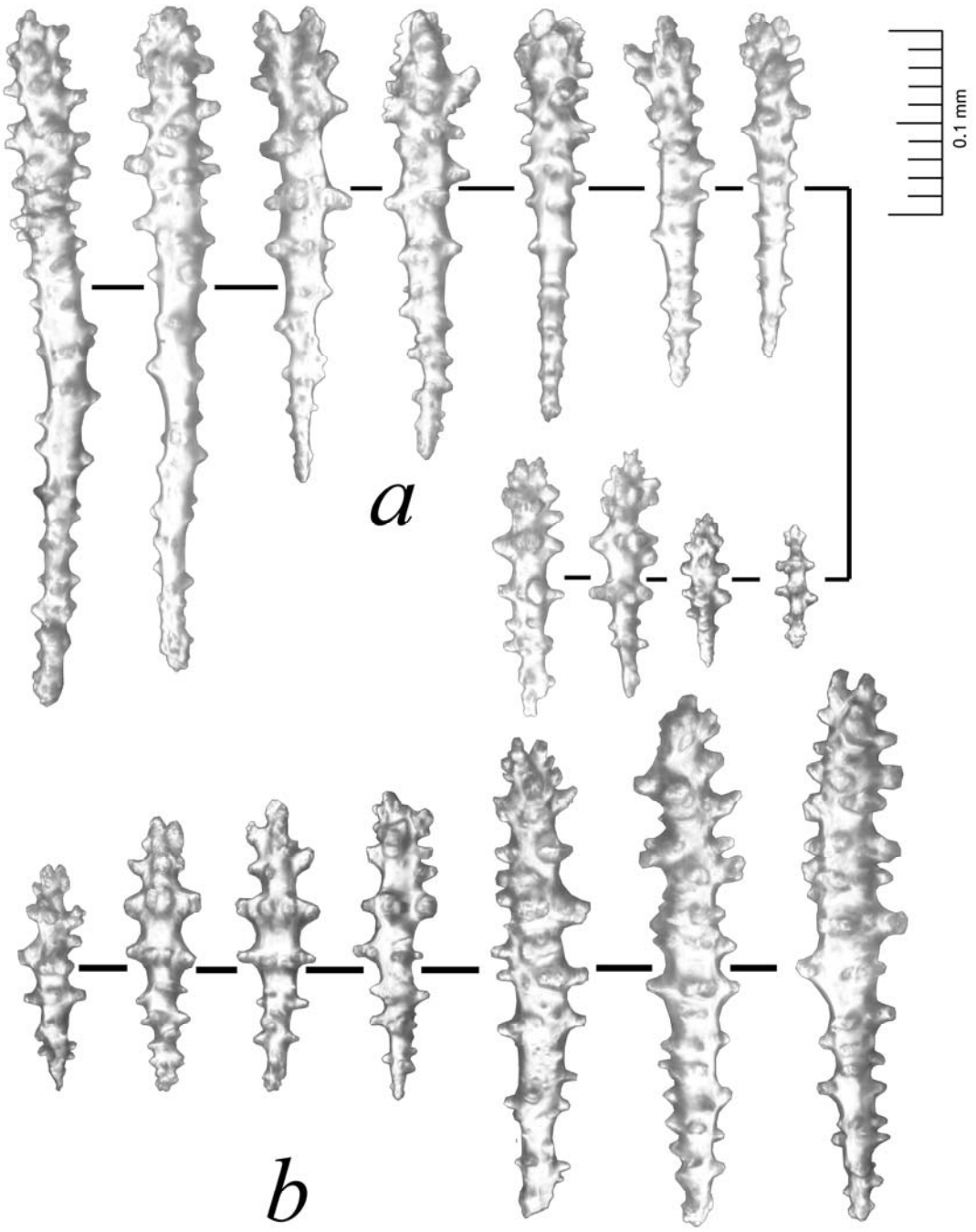


Fig. 49. *Sarcophyton* sp. nov. C, sclerites from specimen PMBC24807: a, from the surface of the capitulum; b, from the surface of the stalk. Enlargement of all, indicated by 0.1 mm scale at a.

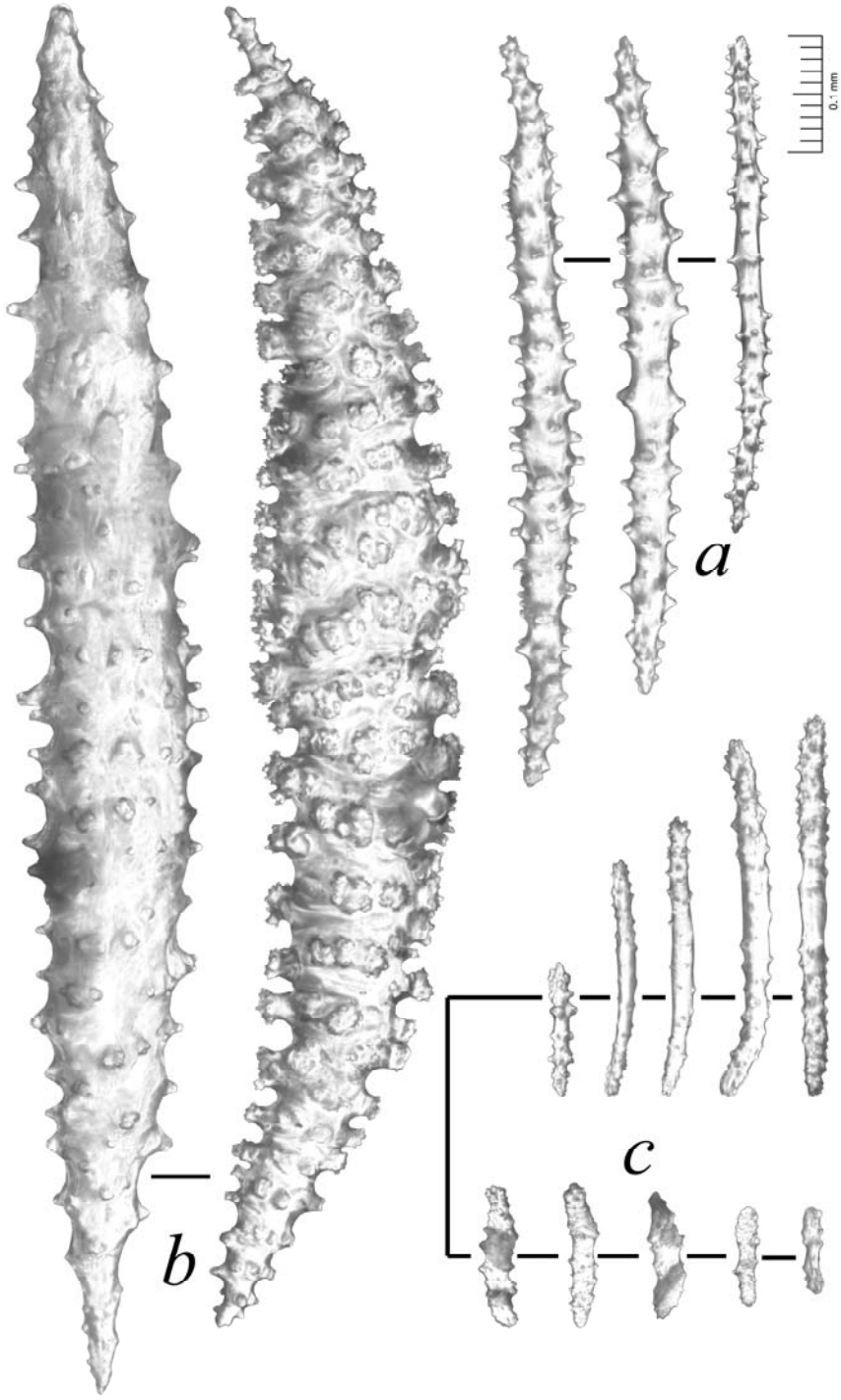


Fig. 50. *Sarcophyton* sp. nov. C, sclerites from specimen PMBC24807: a, from the interior of the capitulum; b, from the interior of the stalk; c, from tentacles and anthocodiae. Enlargement of all, indicated by 0.1 mm scale at a.

Material examined:

- PMBC24807, one adult colony, Koh Losin, on rocky substrate, depth 8 m, collected on 8 June 2005 by T. Chanmethakul.

- PMBC13315, Nai-Harn Reef, collected on 2 December 1987 by UNESCO.

- PMBC13319, Koh Phi-Phi Don, collected on 3 March 1979, unknown collector.

- PMBC13320, one juvenile and three adult colonies, Koh Racha-Noi, 15 – 20 m depth, collected on 4 December 1987 by UNESCO.

- PMBC24808; Jabang Rock, on rocky substrate, depth 10 m., collected on 30 March 2004, by T. Chanmethakul.

Ecological notes: This species is widely distributed from inshore to offshore islands along the Gulf of Thailand and the Andaman Sea coast of Thailand. Most of them occur on rocky substrate. They are distributed in the all depth zones from 3 – 30 m.

Colony shape: The colonies are flattened laterally. In large colonies the capitulum is funnel-shaped. The margin of the capitulum has many thick folds, which are also found on the edge beyond the stalk. The adult colony is large, with a capitulum about 30 cm in diameter. The stalk is low about, 5 cm long. The color is pale-brown but the alcohol-preserved colony is dark-brown.

Polyps: In the live specimens the autozooids were extended on the capitulum. In the preserved specimen PMBC24807 and the other specimens, the polyps are semi-contracted. The numbers of siphonozooids between two autozooids are 2 - 3 at the margin of the capitulum, and 4 – 5 in the centre.

Sclerites: Clubs occur in the surface layer of the capitulum. Most of the heads are weakly developed and bear some warts or cone-shaped processes. The handles are covered with low truncated spines. The length is 0.06 – 0.37 mm (Fig. 49a). The clubs in the surface layer of the stalk have the same shape, but on the longer clubs the handles are covered with high blunt spines. They up to 0.30 mm long (Fig. 49b).

The interior of the capitulum contains straight and curved rods; sometimes they look like slender spindles. They are covered with truncated cones or with stumpy spines, and are up to 0.64 mm long (Fig. 50a). The sclerites in the interior stalk are spindles with stumpy spines or shorter and more conical tubercles the length is up to

1.12 mm. A few of the spindles bear fewer and shorter prominences, and are up to 1.19 mm long (Fig. 50b). Rods also occur at the same length and size.

The tentacular sclerites are flat rods. The anthocodia are armed with a number of flat, blunt rods, arranged *en chevron*: the lengths are 0.07 – 0.32 mm (Fig. 50c).

Remarks: The colony shape and sclerites of specimens PMBC24807, PMBC13315, PMBC13319, PMBC13320 and PMBC24808 did not corresponded with any species reported in Verseveldt and Benayahu (1978), Verseveldt (1982b), Li (1984), Alderslade and Shirwaiker (1991) and Benayahu and Perkol-Finkel (2004).

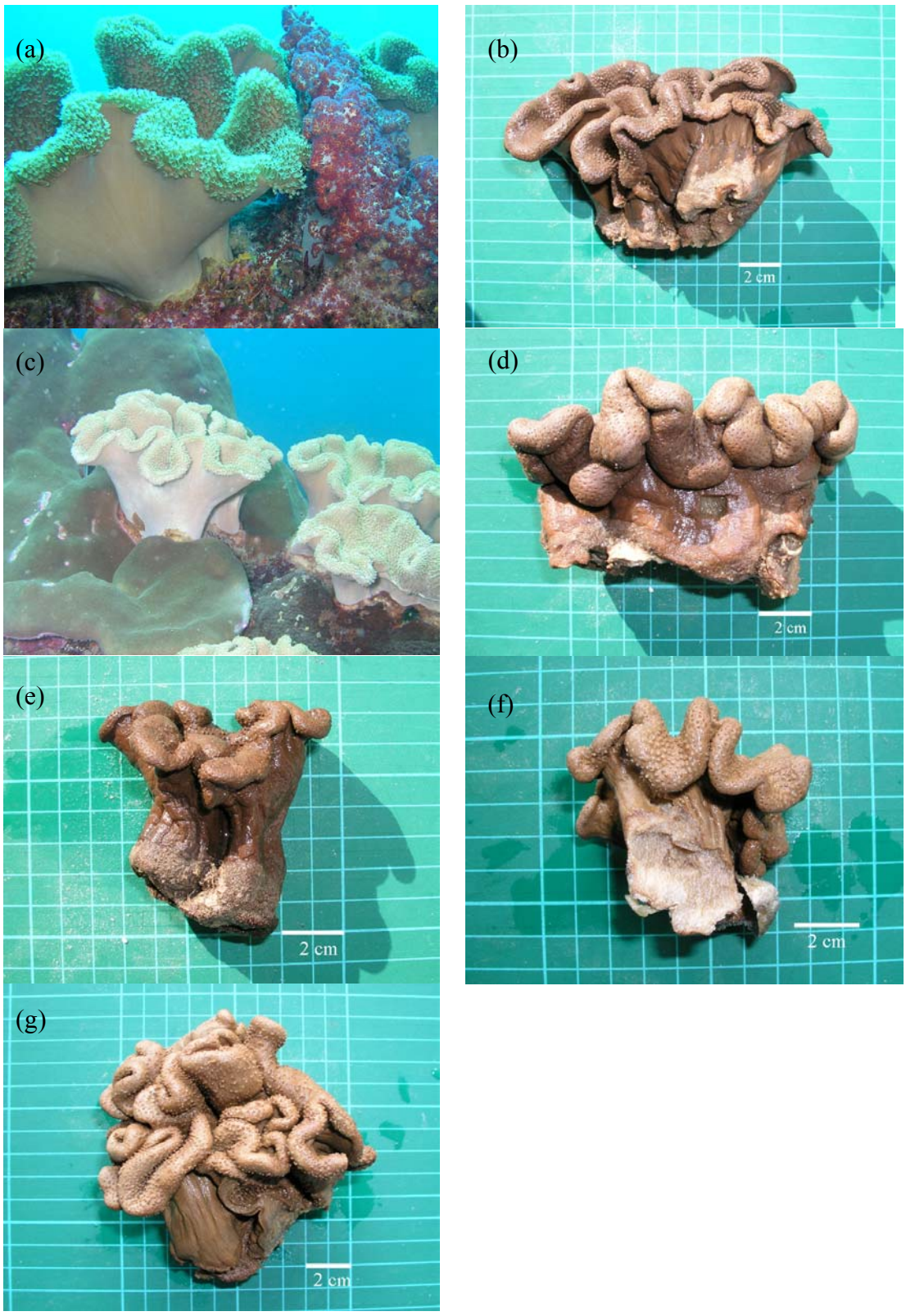


Fig. 51. *Sarcophton* sp. nov. C: a – b, live and preserved specimens of PMBC24807; c – d, live and preserved specimen of PMBC24808; e, preserved specimen of PMBC13315; f, PMBC13319; g, PMBC13320.

***Sarcophyton* sp. nov. D**

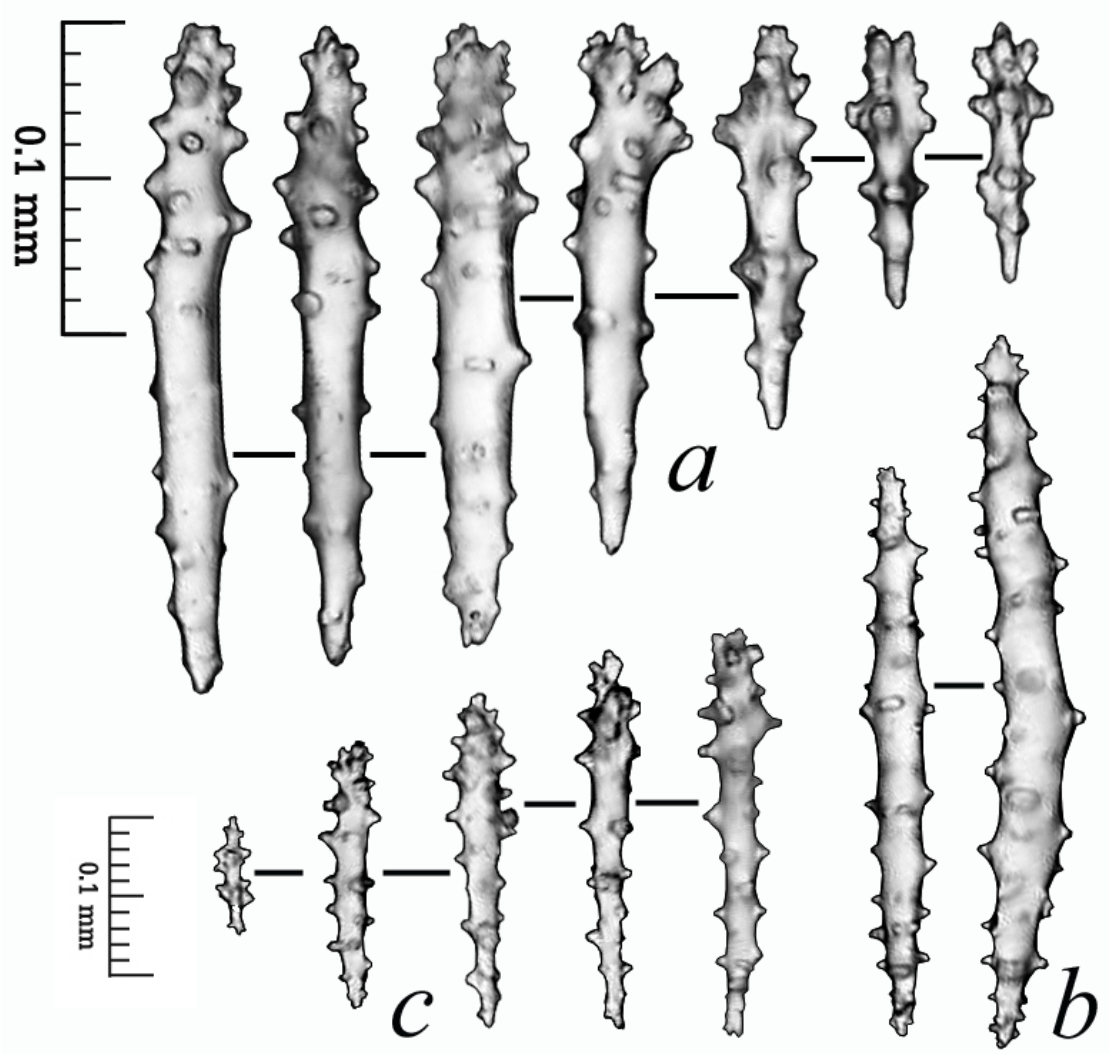


Fig. 52. *Sarcophyton* sp. nov. D, sclerites from PMBC24818: a, from the surface of the capitulum; b-c, from the surface of the stalk. Enlargement of a, indicated by 0.1 mm scale at a; that of b – c indicated by 0.1 mm scale at b.

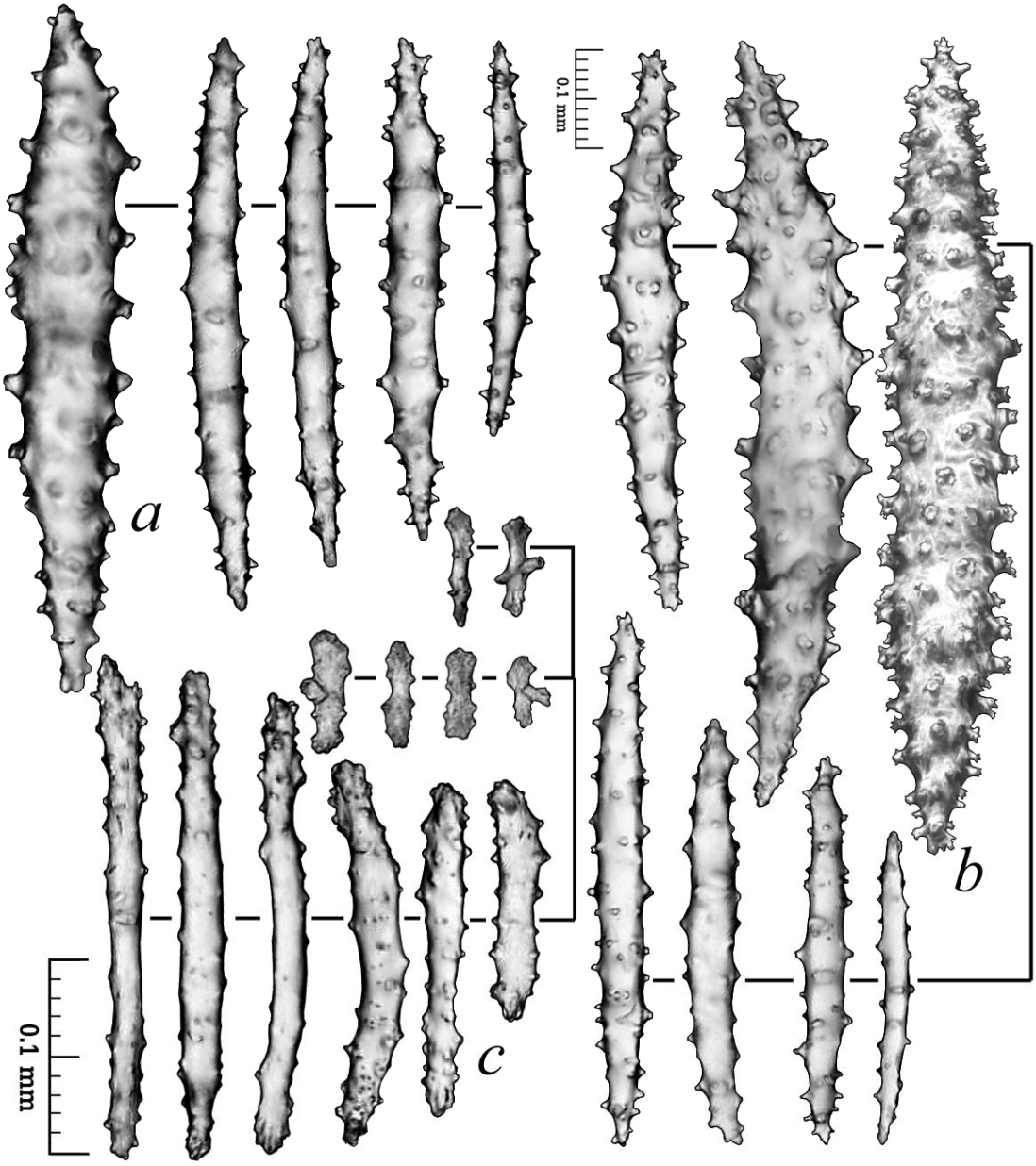


Fig. 53. *Sarcophyton* sp. nov. D, sclerites from PMBC24818: a, from the interior of the capitulum; b, from the interior of the stalk; c, anthocondial and tentacular sclerites. Enlargement of a - b, indicated by 0.1 mm scale at b; that of c indicated by 0.1 mm scale at c.

Material examined:

- PMBC24818, one adult colony, Koh Karta (Adang-Rawi Islands), on dead coral substrate, depth 15 m, collected on 20 March 2006 by T. Chanmethakul,.

- PMBC24819, Mai-yai Bay (Surin Islands), on sand floor attached to the rubble, depth 20 m, collected by T. Chanmethakul on 15 January 2003.

- PMBC24820, ten juvenile colonies, Koh Lek, collected on 26 January 1987, unknown collector.

Ecological notes: This species is distributed along the Andaman Sea coast of Thailand. The specimens from this study occur on the sand floor at the fore reef, attached to dead coral rubble, 15 – 20 m depth.

Colony shape: The adult colony is mushroom-shaped. The capitulum extends beyond the sterile stalk, with a strongly folded margin. The colony is low, and some parts of the stalk were immersed in the sand floor. The live specimen PMBC24818 was dark brown, while PMBC24819 was pale brown. The preserved colonies are dark brown and about 9 cm high and 9 cm in capitulum diameter. The texture of the tissue is soft and sponge-like.

Polyps: In the live specimens the autozooids were extended, densely on the margin. The anthocodiae were transparent, and the tentacles were white. In the preserved specimens the polyps are semi-contracted and they protrude above the surface. On the folds, the number of siphonozooids between two autozooids is 2 - 6 and 6 - 8 at the centre.

Sclerites: The surface layer of the capitulum contains slender clubs, 0.08 to 0.22 mm long (Fig. 52a). The clubs are somewhat poorly developed; the head being little wider than the handle, with low, rounded prominences, which are more numerous than on the handle. But, some clubs with a wide head also occur. The shorter clubs have more warts, sometimes leaf-like prominences, and the handle has one girdle of blunt spines. Some of sclerites are transitional to coenenchymal sclerites.

In the surface layer of the sterile stalk lie clubs and slender spindles. The spindles are transitional forms to coenenchymal sclerites, bearing low cones, and up to 0.44 mm long (Fig. 52b). The clubs have heads that consist of small warts and

cones, and sometimes the prominences seem to be leaf-like. The handles are rather blunt-ended. Clubs vary from 0.07 to 0.26 mm long (Fig. 52c).

The interior of the capitulum has both narrow and broad spindles that bear truncated spines, and vary from 0.40 to 0.58 in length (sometime up to 0.70 mm long) (Fig. 53a). The sclerites in the stalk interior are spindles that are rather densely covered with high truncated spines and with simple warts. The bigger spindles are up to 0.84 mm long (Fig. 53b).

The anthocodiae contain needles and rods, varying from 0.09 to 0.26 mm long, *arranged en* chevron. There are also scales ranging from 0.04 to 0.06 mm long (Fig. 53c).

Remarks: The sclerites of these specimens are very similar to *S. cinereum* Moser, 1919, as described in Verseveldt (1982: 24-27). Many of the disc surface sclerite characters are similar, but in my material the strikingly long clubs do not occur. Also the lectotype has spindles that are rather densely covered with simple warts, (Verseveldt 1982: Fig.8j, k, n). These characteristic are not found in my specimens. Moreover, the shape of colonies shows differences from figure of the lectotype (Verseveldt 1982: pl.2 Fig.3) which displays the colony in natural size. The lectotype is funnel-shaped and has few folds, but my specimens are less funnel-shaped and have numerous folds.

The other probability is *S. regulare* as mentioned by Verseveldt (1982b: 67 - 68). The characteristics of sclerites in each part of the colony bear similarities with this study. However, in *S. regulare* the spindles in the interior of the capitulum differ in the accumulation of prominences at one end or at both ends, and the specimens from this study are not found bifurcated.

Although some characters of my material are shared by *S. regulare* and *S. cinereum*, I can conclude that there are significant differences in sclerite shapes.

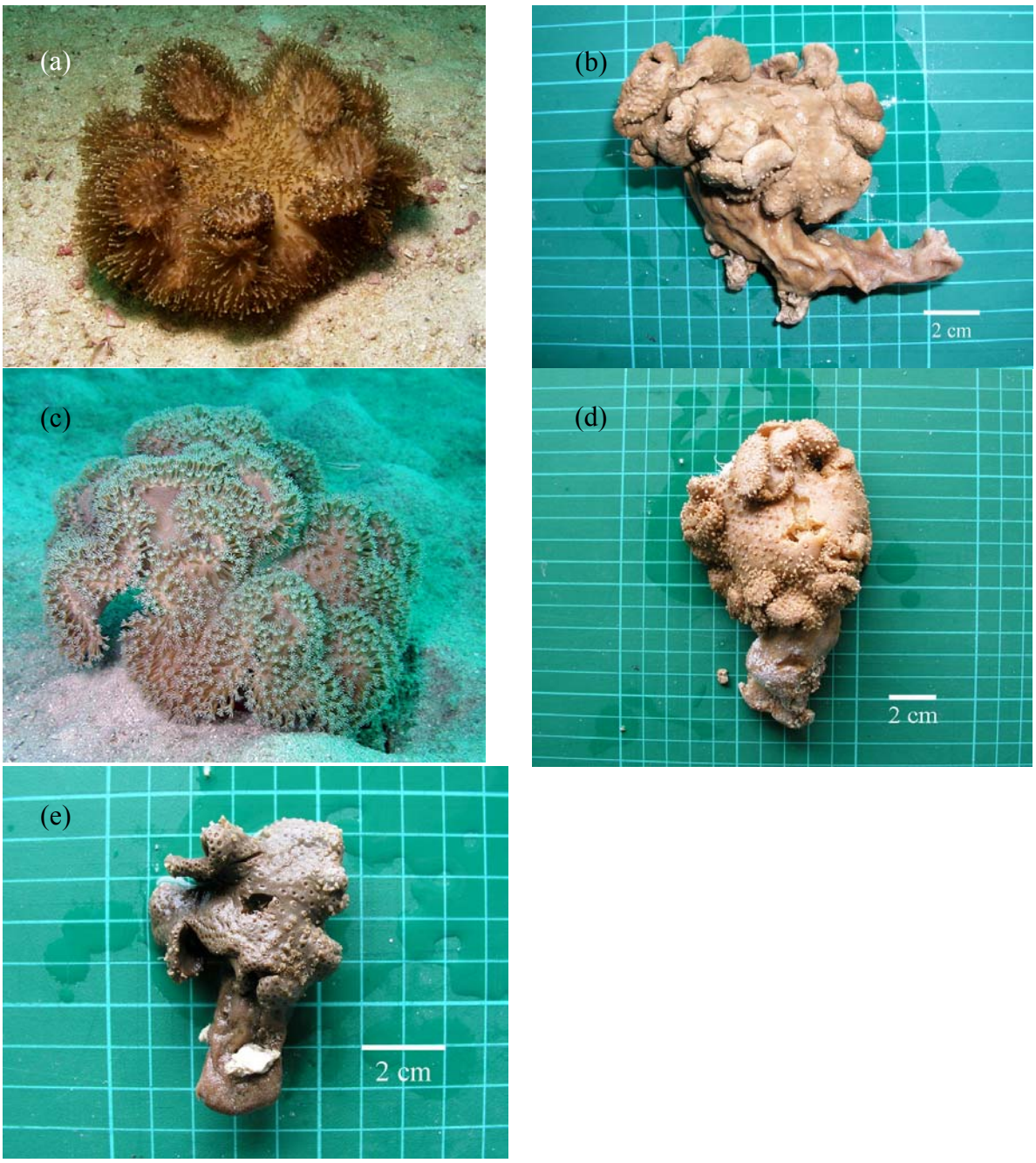


Fig. 54. *Sarcophyton* sp. nov. D: a – b, live and preserved specimen PMBC24818; c – d, live and preserved specimen PMBC24819; and e, preserved specimen of PMBC24820.

***Sarcophyton* sp. nov. E**

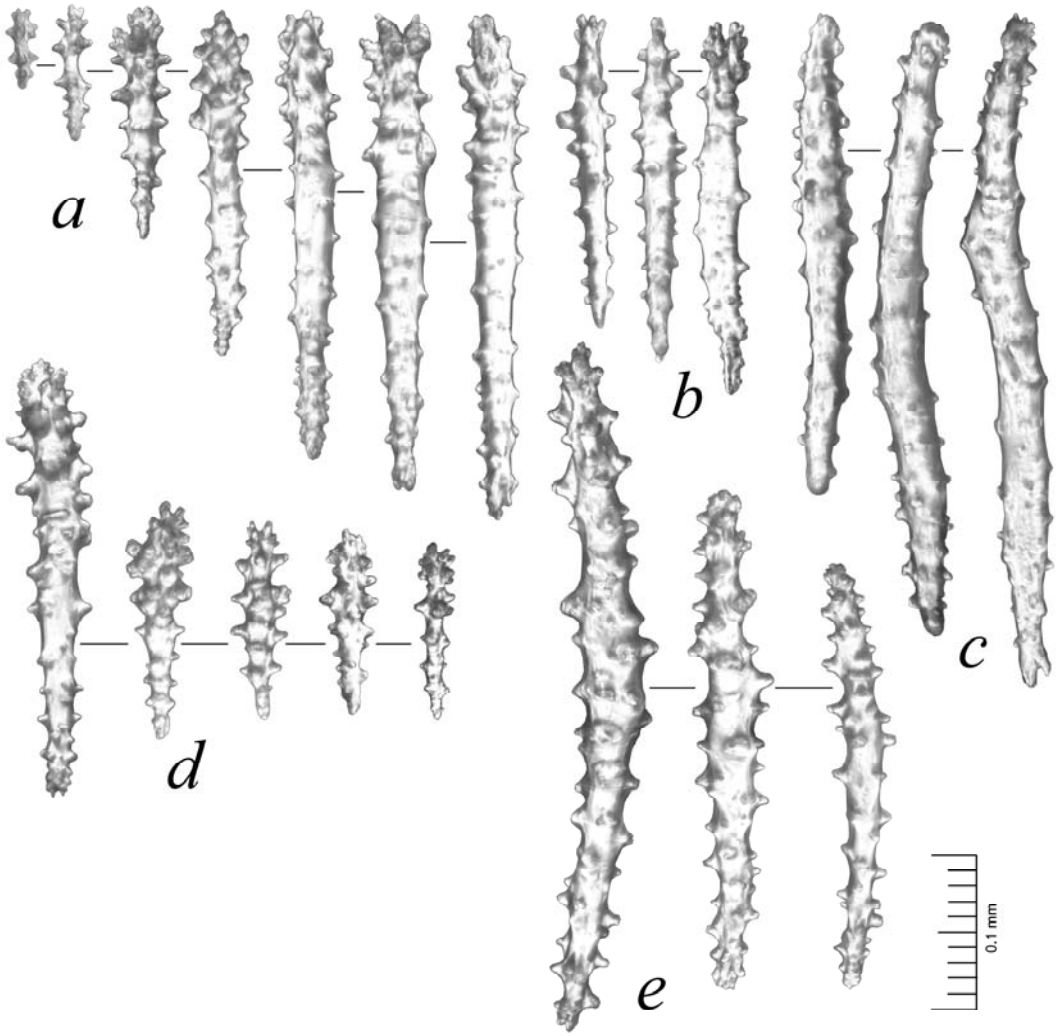


Fig. 55. *Sarcophyton* sp. nov. E, sclerites from specimen PMBC24822: a-c, from the surface of the capitulum; d-e, from the surface of the stalk. Enlargement of a - e, indicated by 0.1 mm scale at e.

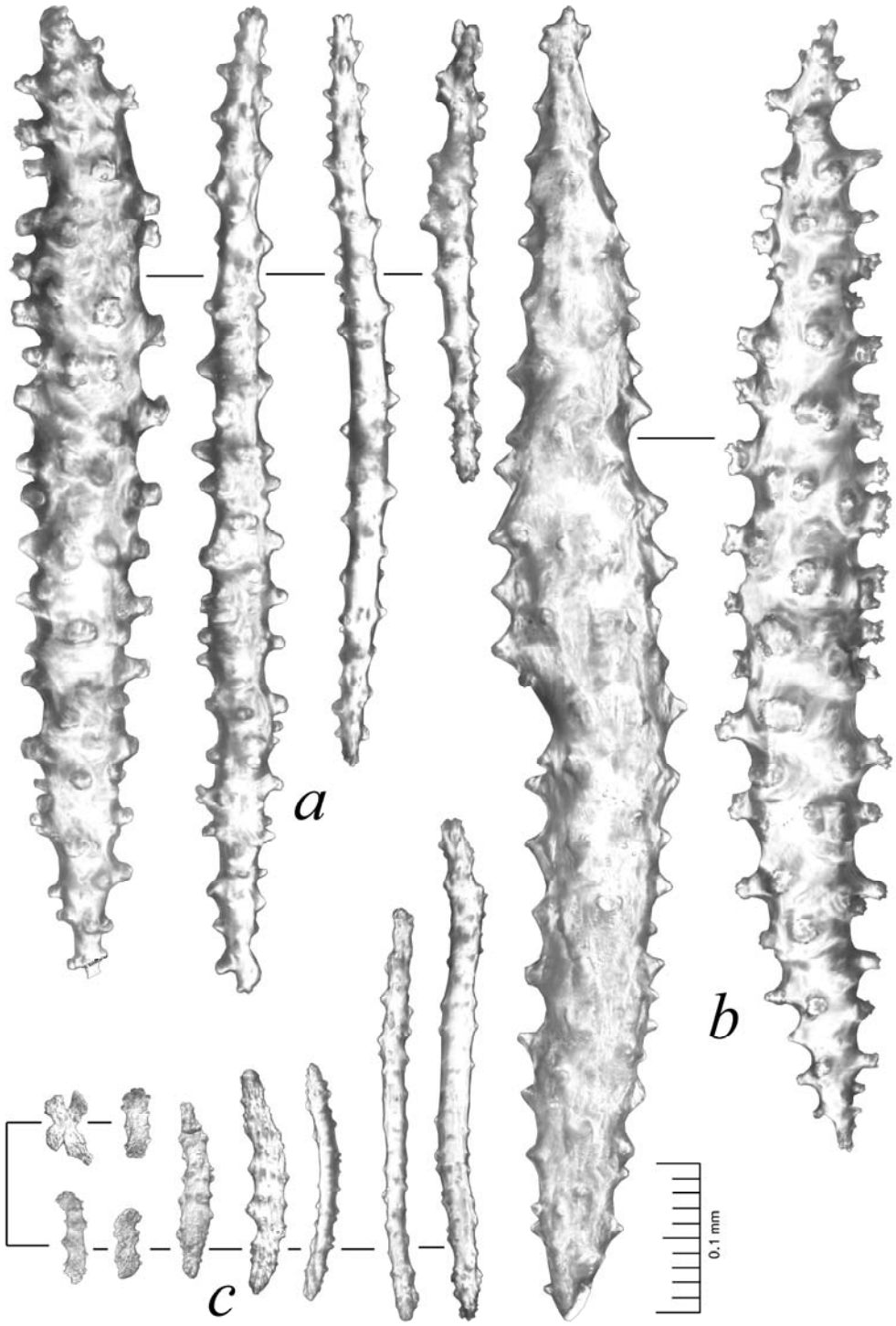


Fig. 56. *Sarcophyton* sp. nov. E, sclerites from specimen PMBC2482: a, from the interior of the capitulum; b, from the interior of the stalk; c, from anthocodial and tentacular sclerites. Enlargement of a - c, indicated by 0.1 mm scale at c.

Material examined:

- PMBC24822, one adult colony, Koh Karta (Adang-Rawi Islands), on dead coral substrate, depth 8 m, collected on 20 March 2006, by T. Chanmethekul.

Ecological notes: This species was found on the southern part of the Andaman Sea coast of Thailand. A few colonies were found on the reef slope and some on the sand floor at the fore reef, 3 – 10 m depth. They were attached to the dead coral or rocky substrates.

Colony shape: The colony is low and funnel-shaped. The capitulum has a strong folded margin, high and erect. The sterile stalk is short. The colour is pale brown. The preserved colony is dark brown and the colony is about 6 cm high and 8.5 cm in capitulum diameter.

Polyps: In the live specimens the autozooids were extended, densely on the margin and decreasing in the middle of the capitulum. The color of the tentacles was pale-brown. In the preserved specimen, the polyps are semi-contracted, protruding above the surface. The siphonozooids are small and invisible to the naked eye. On the fold there are between zero and two siphonozooids between two autozooids but in the central part there may be more, up to about four.

Sclerites: The surface layer of the capitulum contains numerous remarkable sclerites. Slender clubs are the most common and are 0.05 to 0.33 mm long (Fig. 55a). The clubs are somewhat indefinite; the head is a little wider than the handle, and consists of low, rounded prominences, which are more numerous than on the handle. The prominences on the handle show a tendency to being in zones. Narrow headed clubs with a length of up to 0.24 mm also occur (Fig. 55b). Moreover, the spindles with an accumulation of tubercles at one end also occur; the length is up to 0.43 mm (Fig. 55c).

In the surface layer of the sterile stalk lie clubs and pseudo-clubs. The majority of clubs have a length of 0.11 - 0.16 mm, quite a few are long handled, up to 0.29 mm (Fig. 55d). The pseudo-clubs have an accumulation of prominences at one end and numerous prominences, which may be high or low, on the handle: these sclerites up to 0.46 mm long (Fig. 55e).

The interior of the capitulum has rods and spiny spindles, up to 0.68 mm long (Fig. 56a). The spindles in the coenenchyme of the stalk may be smooth surfaced with low truncated spines, up to 0.89 mm long (Fig. 56b). Other spindles are covered with small warts, which are sometimes densely arranged, up to 0.76 mm long (Fig. 56b).

The anthocodiae contain needles and rods that are up to 0.34 mm long, and arranged *en chevron*. There are also scales varying from 0.05 to 0.15 mm in length (Fig. 56c).

Remarks: Specimen PMBC24822 shows some characters that resemble those of *S. tortuosum* (Verseveldt 1982b: 82). However, that species differs in having the spindles and the pseudo-club in the surface of the capitulum.

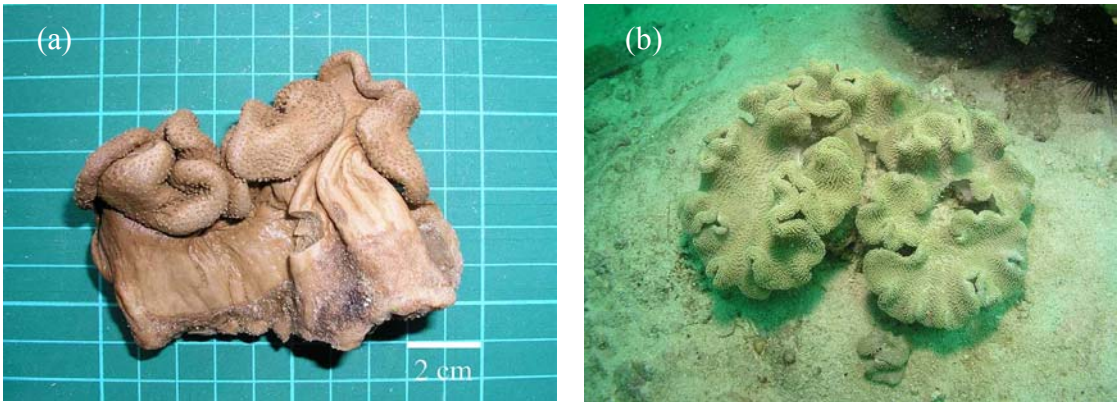


Fig. 57. *Sarcophton* sp. nov. E, PMBC24822: a, preserved; b, alive.

CHAPTER 5

CONCLUSIONS

Part I: Richness and distribution of soft corals in Thai waters

1. Richness patterns

The surveys were conducted during 2004 – 2005. In the AN, it consisted of 71 stations of true reefs, and 46 stations of rocky shores and submerge rocks, and in the Gulf of Thailand, there were 25 stations of true reefs and 60 stations of rocky shores and submerge rocks. The soft corals of 4 families comprising of 19 genera were found in this study. They are

Alcyoniidae: *Sinularia, Dampia, Cladiella, Klyxum, Sarcophyton, Lobophytum,* and *Eleutherobia*

Nephtheidae: *Nephthea, Stereonepthya, Scleronephthya, Dendronephthya* and *Umbellulifera*

Nidaliidae: *Nidalia*, *Siphonogorgia*, *Chironephthya* and *Nepthyigorgia*

Xeniidae: *Xenia, Heteroxenia* and *Sansibia*

This study records 19 genera in Thai waters, of which 9 genera are new records. These are *Eleutherobia*, *Nepthyigorgia*, *Nidalia*, *Heteroxenia*, *Chironephthya, Siphonogorgia*, *Stereonepthya Dampia* and *Sansibia*.

The “hot spot” of soft coral diversity in the Gulf of Thailand locates at GT12, where 10 genera were found are AN06 in the Andaman Sea where 13 genera were found. The locations are the offshore islands.

It can be said that family Alcyoniidae is the dominant family and family Xeniidae is the rare family base on number of genera presented and percentage occurrence of each genera.

The dominant genera obtained from this study are *Sinularia*, *Dendronephthya* and *Sarcophyton*. In calculating as percentage of occurrence frequency, 3 major genera had the highest percentage occurrences: *Sinularia, Dendronephthya* and *Sarcophyton* respectively. In contrast, lowest occurrences were *Nidalia*, *Nephthyigorgia* and *Heteroxenia*. They are rare genera in this study.

2. Distribution patterns

By comparing frequency of occurrence between the Andaman Sea and the Gulf of Thailand. It was found that for *Sinularia*, *Dampia*, *Sarcophyton*, *Eleutherobia* and *Nephthyigorgia*, there were not significantly different between location (Chi-square test – $p>0.05$). For *Cladiella*, *Klyxum*, *Lobophytum*, *Scleronephthya*, *Dendronephthya*, *Siphonogorgia* and *Chironephthya*, it was significant (Chi-square test - $p<0.05$), however. Seven genera were found only in the AN: *Nephthea*, *Stereonephthya*, *Umbellulifera*, *Nidalia*, *Xenia*, *Heteroxenia* and *Sansibia*.

The dominant genera of Alcyoniidae such as *Sinularia* and *Sarcophyton* were found at all sites (reef flat/ upper zone, reef slope/ lower zone and fore reef) of both inshore and offshore islands whereas certain dominant genera (*Cladiella* and *Klyxum*) were found dominant only in the Gulf of Thailand. For genera of Nephtheidae, Nidaliidae and Xeniidae, they were present or dominant only in the Andaman Sea. They were more abundant in offshore sites than inshore sites.

3. Habitat preference of soft corals

This study suggests that different genera of soft corals show habitat preference. It has been found that the Nephtheidae family widely distributes on rocky shore or submerged rocks than on true reefs whereas the Alcyoniidae family are more abundant on true reef than rocky substrates. The finding shows that soft coral growth are strongly related to site specific such as zonation on reef. They are often found on the slope and fore reef.

The angle of substrate has an influence on distribution and abundance of soft corals. The Alcyoniidae were found on substrates with varying angles ranging from horizontal to ~ 90°. In this study, azooxanthellate genera of Neptheidae and Nidaliidae were found attached to substrates at all angles.

In term of effect of environmental parameters, it is concluded that soft corals abundance and richness increases with increasing water transparency.

Part II: *Sarcophyton* from Thai waters

From result of the first part 42 colonies of *Sarcophyton* from this filed survey and some specimen from PMBC Reference collection. Ten species were found of which five species are new species to be described in the future. The others are *S. ehrenbergi*, *S. elegans*, *S. stellatum*, *S. trocheliophorum* and *S. glaucum*.

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