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# Soft Coral (Cnidaria: Alcyonacea) Distribution Patterns in Thai Waters

Thanongsak Chanmethakul*, Hansa Chansang, and Supareok Watanasit

*Department of Biology, Faculty of Science, Prince of Songkla University, Songkla 90210, Thailand*

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**Thanongsak Chanmethakul, Hansa Chansang, and Supareok Watanasit (2010)** Soft coral (Cnidaria: Alcyonacea) distribution patterns in Thai waters. *Zoological Studies* **49**(1): 72-84. The aim of this study was to conduct a biodiversity survey of soft corals in Thai waters by focusing on genera richness, distribution, and ecological aspects. The locations of the study were in 2 geographic regions: the Andaman Sea coast of Thailand and the Gulf of Thailand. All of the study sites were surveyed in June 2004 - May 2006. Soft corals of 4 families comprising 19 genera were found: Alcyoniidae: *Sinularia*, *Dampia*, *Cladiella*, *Klyxum*, *Sarcophyton*, *Lobophytum*, and *Eleutherobia*; Nephtheidae: *Nephthea*, *Stereonepthya*, *Scleronephthya*, *Dendronephthya*, and *Umbellulifera*; Nidaliidae: *Nidalia*, *Siphonogorgia*, *Chironephthya*, and *Nepthyigorgia*; and Xeniidae: *Xenia*, *Heteroxenia*, and *Sansibia*. The Alcyoniidae was the dominant family in the Gulf of Thailand, whereas the Nephtheidae was the dominant family along the Andaman Sea coast of Thailand. The 3 dominant genera were *Sinularia*, *Dendronephthya*, and *Sarcophyton*, while *Nidalia*, *Nephthyigorgia* and *Heteroxenia* were rare genera in this study. This study suggests that different genera of soft corals show different habitat preferences. Members of the Nephtheidae are widely distributed on rocky habitats rather than on true reefs, whereas members of the Alcyoniidae have a higher distribution on true reefs rather than on rocky habitats. Soft corals are strongly site specific and are often found on reef slopes and lower zones. The angle of the substrate has an influence on the distribution of soft corals as well, with the Alcyoniidae found on substrates with varying angles ranging from horizontal to ~90°. In this study, azooxanthellate genera of the Neptheidae and Nidaliidae were found attached to substrates oriented at all angles. http://zoolstud.sinica.edu.tw/Journals/49.1/72.pdf

**Key words:** Alcyonacea, Biodiversity, Soft coral, Thai waters.

Soft corals (Cnidaria: Octocorallia: Alcyonacea: Alcyoniina) are distributed worldwide and are important components of coral reef ecosystems, especially in the Indo-Pacific region. There are 35 genera of soft corals distributed over 15% of the region (Dai 1990, Fabricius 1997, Fabricius and Déath 2001, Fabricius and Alderslade 2001).

In the last decade, knowledge of the taxonomy and ecology of soft corals, especially from shallow tropical reefs in the Indo-Pacific region, has increased. Taxonomic studies were carried out in some selected areas such as southern Vietnam (Malyutin 1990), the Red Sea (Reinicke 1997, Perkol-Finkel and Benayahu 2004), the southern Red Sea (Benayahu et al. 2002), eastern and southern Africa (Williams 2000 2003, Benayahu et al. 2003), the Seychelles (Malyutin 1992, Van Ofwegen 2001), American Samao (Cornish and DiDonato 2004), southwestern Australia (Alderslade 2003), southern Taiwan (Benayahu et al. 2004), the South China Sea, the Indo-Pacific Ocean (Li et al. 2000, Van Ofwegen 2005), and Indonesia (Van Ofwegen 1999, Manuputty and Van Ofwegen 2007). However, only a few studies were conducted on the effects of environmental parameters, such as sedimentation and turbidity (Dai 1991a, Riegl and Bloomer 1995, Riegl and Branch 1995, Fabricius and Déath 2001, Schleyer and Celliers 2003), depth (Fabricius and Klump 1995), current, and flow (Fabricius et al. 1995b). Biological factors such as predation (Wylie and

*To whom correspondence and reprint requests should be addressed. E-mail:chanmethakul@gmail.com

Paul 1989) and competition (Sammarco et al. 1983) are deemed unlikely to influence the abundance and richness of soft corals.

Knowledge of soft-coral diversity in Thai waters is limited, as most of the available information on reef organisms is of hard corals. The 1st study of soft corals in Thai waters was carried out by Verseveldt (1982), who described a new species of soft coral, *Cladiella steineri*, from Sri-Chang I. 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 15 genera in 5 families being recorded from Phuket and surrounding islands. In addition, a study on soft coral taxonomy of inshore islands along the coasts of Prachuabkhirikhan, Chumphon, and Suratthani Provinces was conducted by Satapoomin in 1989, with 10 genera in 4 families reported. After that, Benayahu (1998) studied lobe variations of *Sinularia nanolobata* at Patong Bay, Phuket I. A survey of coral reefs in Thai waters by Chansang et al. (1999a b) revealed that soft corals were present at all survey sites, with especially high abundances on offshore islands. Nevertheless, no specific study on soft coral distribution was done. Worachananan (2000) reported finding 12 genera in 4 families of soft corals in Thai waters and provided information on their distribution and diversity. However, those reports were limited in both scale and important ecological aspects of soft corals, such as depth and substrate preferences. Even though no specific study on soft-coral distribution has been done, the geographic setting of Thai waters, situated between the Andaman Sea and the Gulf of Thailand, is an ideal location for comparative studies of Indo-Pacific reef organisms between the 2 water bodies.

Recently, populations of soft corals have dramatically decreased due to a number of anthropogenic and pollution factors as seen in American Samoa reefs (Cornish and DiDonato 2004); other factors include bleaching (Fabricius 1999) and the impacts of tourism (Walters and Samways 2001). These combined and accumulating threats have had direct impacts on populations 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 future impacts on coral reef community structures may be severe. An investigation, with data collected on a large scale from a number of sites, of the distribution of soft corals and ecological factors affecting them is essential in order to implement successful resource management programs. This report examined the distributions of soft corals at the genus level and the importance of ecological parameters such as habitat preference, substrate, and angle of substrate types which might influence their distribution in Thai waters.

## MATERIALS AND METHODS

### Study sites

Surveys were conducted in June 2004 to May 2006. Most locations were surveyed in 2004 and 2005, with a few locations surveyed in 2006. Study locations were in 2 geographic regions: the Gulf of Thailand (GT) and the Andaman Sea (AN) coast of Thailand, as shown in figure 1.

The AN is located in the eastern part of the Indian Ocean and is bordered by the 5 countries of Myanmar, Thailand, Malaysia, Indonesia, and India (including the Andaman and Nicobar Is.). Coastlines of the mainland and islands consist of various ecosystems such coral reefs, mangroves, seagrass beds, and rocky shores. Coral reefs are here fringing reefs with an approximate total reef area of 79 $km^2$ (Chansang et al. 1999b), and there are distinct differences in reef habitats between inshore and offshore islands. The southwesterly monsoon exerts a powerful influence on the development of coral reefs throughout the AN. On the east coasts of islands facing the mainland, which are protected from powerful monsoon storms, coral reefs have extensively developed, whereas the west coasts of these islands are mainly rocky shores with some reef development in pockets of small bays. Mainland reefs and inshore reefs extend from 3 to 10 m in depth, but on offshore islands, the water clarity enables reefs to develop to depths of up to 40 m. The reef topography in the AN can be divided into 3 zones: reef flats, reef edges, and reef slopes. Besides being under the influence of the southwesterly monsoon, reefs are also affected by other physical environmental parameters. In the AN, the tide is semidiurnal, and reefs in protected bays develop extensive intertidal reef flats which are exposed to air for 2-4 h a day during spring tides. Water temperatures range 25.9-30.4°C, and salinities range 29-33 ppt (Limpsaichol et al. 1991).

The GT is a semi-enclosed sea bordered by the coastlines of Vietnam, Cambodia, Thailand, and Malaysia with a connection to the South

China Sea in the south. The total area covered by coral reefs in the Gulf of Thailand is about 75 km$^2$. Coral reef development is under monsoonal influence as in the AN. Coral reefs of islands on the east coast of the GT develop on the east sides of the islands, i.e., the leeward side of the southwesterly monsoon winds, whereas reefs of islands on the west coast of the GT develop on the west sides of the island, i.e., the leeward side of the northeasterly monsoon. Coral reefs here are fringing reefs which are found around both inshore and offshore islands. Reef growth can be up to 15 m in depth at inshore islands and 20 m in depth at offshore islands. The mainland coastline is mostly open coast and protected bays, which are environments not suitable for reef development (Chansang et al. 1999a). The physical parameters of coastal waters are as follows: diurnal tide and mixed tide, sea surface temperature ranging 31-32°C on the east coast and 29-31°C on the west coast, and salinities of 30-33 ppt (Pollution Control Department 2001).

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

Each island group was considered a single location. Altogether there were 17 locations in

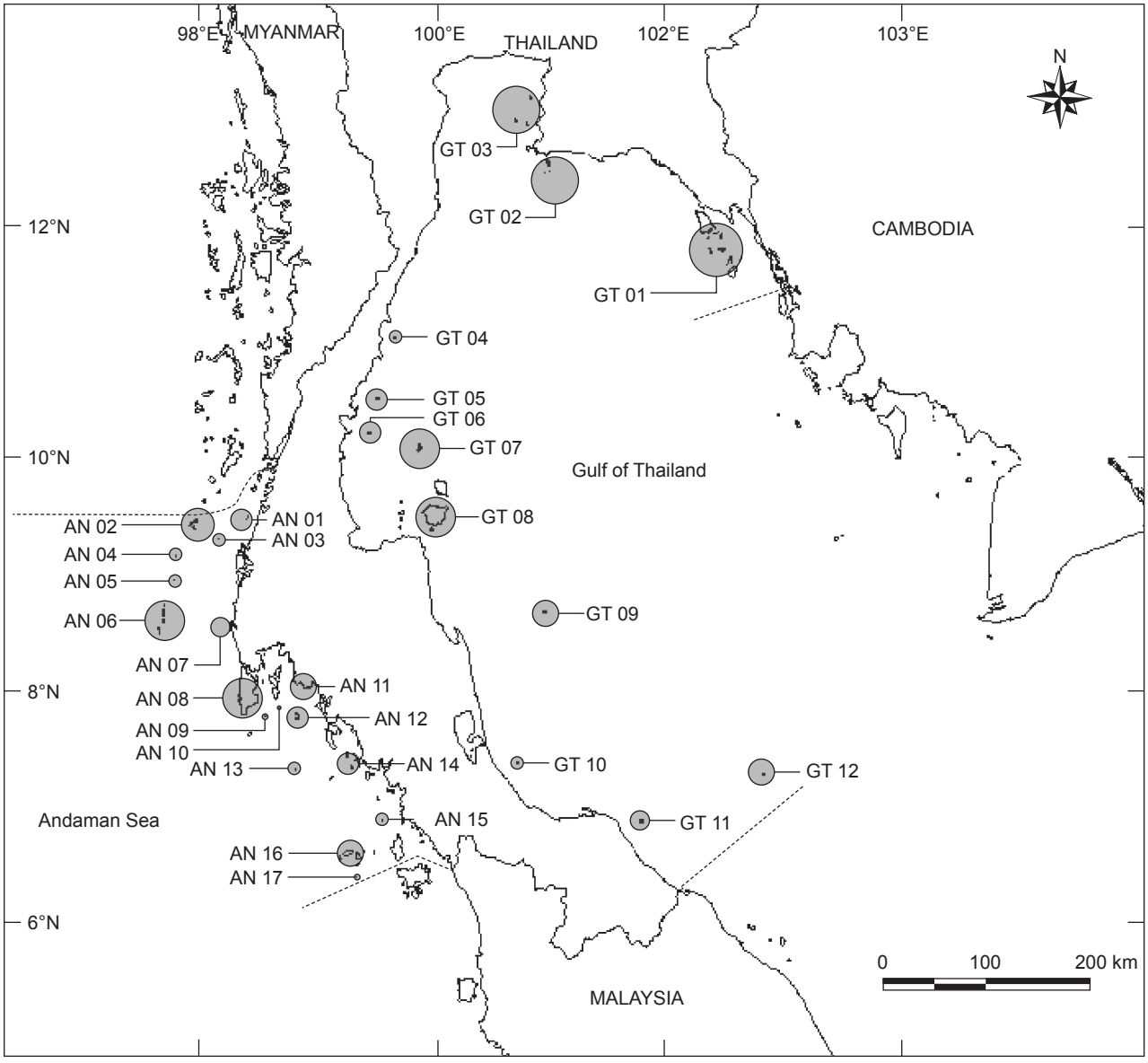


**Fig. 1.** Map of Thai waters indicating the locations of all survey sites, including true reefs, rocky shores, and submerged rocks.

the AN and 12 locations in the GT (Fig. 1), these locations were divided into 2 groups according to bathymetric charts (no. 045 of Royal Thai Navy's Hydrographic Department) as: 1) inshore islands located nearshore not exceeding 20 m in depth and 2) offshore islands located in deep waters of over 20 m in depth.

Each location was comprised of many stations, depending on the size of the island, with 117 stations in the AN and 85 stations in the GT. These stations included true reefs and rocky substrates.

At each station, sampling/surveying was carried out according to reef zonation for true reef habitat and the depth range for submerged rock habitat. These were described as reef flat, reef slope, and fore reef for true reefs and upper zone, lower zone, and fore reef for submerged rock habitats.

**Field methods**

Distribution data were recorded by visual estimates during surveying for 40 min (200 m approximately) along each site (reef flat, reef slope, and fore reef). For rocky substrate, surveys were carried out by swimming around the rocks for 40 min without covering the same route. Moreover, photographs were taken with an Olympus C5050 camera (Tokyo, Japan), and the following environmental parameters were recorded: substrate type, depth of the sampling site including the depth range where the particular genus was distributed, water transparency as measured by a Secchi disk, and the angle of the substrate (horizontal, ~15°, ~ 45°, ~90° or overhang 180°). Soft corals were identified on site to the generic level.

**Data analysis**

To understand the spatial distribution, frequency of occurrence data were used. Occurrence data were transformed to percentages by the following calculation: [(number of stations at which a soft coral occurred in each genus) / (all stations surveyed)] × 100.

Comparisons of the frequency of occurrence of each genus at all stations between the AN with GT were analyzed by Chi-square test using the SPSS vers.11 program (IBM, Illinois, United State).

Habitat preference for each genus of soft corals was investigated in detail at all levels, i.e., location, reef zone, and angle of the substrate. Data were analyzed by Primer vers. 5 (PRIMER-E, Plymouth, United Kingdom) using presence-absence data. Similarity was calculated using Euclidean distances as the clustering algorithm with complete linkage. A 2-dimensional multi-dimensional scaling (MDS) was generated using the similarity matrix.

The relationship between genera richness and water transparency was examined by a simple regression analysis, using data derived from survey stations in both the AN and GT. The water transparency was considered an independent variable, and the number of genera was a dependent variable. The analysis was done using SPSS vers.11.

## RESULTS

The results from the survey are shown in table 1. In the AN, 19 genera were found: *Sinularia*, *Dampia*, *Cladiella*, *Klyxum*, *Sarcophyton*, *Lobophytum*, *Eleutherobia*, *Nephthea*, *Stereonepthya*, *Scleronephthya*, *Dendronephthya*, *Umbellulifera*, *Nidalia*, *Siphonogorgia*, *Chironephthya*, *Nepthyigorgia*, *Xenia*, *Heteroxenia*, and *Sansibia*. AN06 (Similan Is.) was the station which contained the highest generic richness (13 genera) in the AN, at depths up to 60 m, with visibility over 30 m, and diverse habitats including true reefs, rocky shores, and submerged rocks. There are fringing reefs here up to 30 m in depth, while reef flats are 3-5 m in depth. Soft corals were found in all zones (reef flat, slope, and fore-reef zone). The Alcyoniidae was found on the reef flat and reef slope, and the Nephtheidae (the azooxanthellae group) was found from the reef slope to the fore reef to depths of over 40 m.

In the GT (Table 2), 12 genera were found: *Sinularia*, *Dampia*, *Cladiella*, *Klyxum*, *Sarcophyton*, *Lobophytum*, *Eleutherobia*, *Scleronephthya*, *Dendronephthya*, *Siphonogorgia Chironephthya*, and *Nepthyigorgia*. GT12 (Losin I.) contained the highest generic richness (10 genera) in the GT. The area at GT12 is a small islet near the Malaysian border in the south of GT. The coral reef around this island lies at 5-40 m in depth with good visibility to over 30 m. The reef was in good condition with over 70% live coral cover. The dominant soft corals in this area were *Dendronephthya* and *Scleronephthya*. Moreover, *Sarcophyton* was commonly found on the fore reef at a depth of 40 m.

In spatial terms, generic richness was

correlated with distance from the mainland. High richness (≥ 10 genera) was found on offshore islands, at GT12, AN06, and AN16 (Adang-Rawi Is.). At these locations, reefs were developed to depths of over 20 m.

Low richness was generally found at inshore sites: AN07 (Kho Na Yak), GT08 (Samui I.), GT10 (Kham I.), and GT11 (Lao-pi I.). These locations are affected by nearshore turbidity and freshwater runoff from the mainland. AN07 is a mainland reef in shallow water 5 m deep. The reef flat is exposed at low tide, and the site is severely impacted by freshwater runoff and sedimentation. The dominant coral species were tabulate forms of *Acropora* spp., with live coral cover at < 40%. Only a few colonies of *Sinularia* were found. GT08, GT10, and GT11 are inshore islands located in the southwestern GT (Fig. 1) which have fringing reefs at 3-5 m in depth. At GT08 and GT10, reef flats are exposed at low tide, and reefs are dominated by massive *Porites*. Only *Cladiella* was found in these areas. At GT11, only a few colonies of *Chironephthya* were found.

The dominant genera from this study were *Sinularia* (20 locations), *Dendronephthya* (18 locations), and *Sarcophyton* (16 locations). In calculating the percent occurrence, 3 major genera had the highest values: *Sinularia* (30.20%), *Dendronephthya* (22.11%), and *Sarcophyton* (19.97%). In contrast, the lowest occurrences (0.33%) were found for *Nidalia*, *Nephthyigorgia*, and *Heteroxenia* which were the rarest genera in this study (Fig. 2).

The Alcyoniidae was the dominant family, while the Xeniidae was the rarest family based on the number of genera present and percent occurrence of each genera (Table 1, Fig. 2). Of the 19 genera in this study, 9 are newly recorded in Thai waters, including *Eleutherobia*, *Nepthyigorgia*, *Nidalia*, *Heteroxenia*, *Chironephthya*, *Siphonogorgia*, *Stereonepthya Dampia*, and *Sansibia*. In terms of percent occurrence, the genera 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*.

## Distribution patterns

The results indicate that each genus of soft coral has a different geographical distribution pattern (Fig. 3). The highest occurrences in the GT were for *Cladiella*, *Sinularia*, and *Klyxum*,

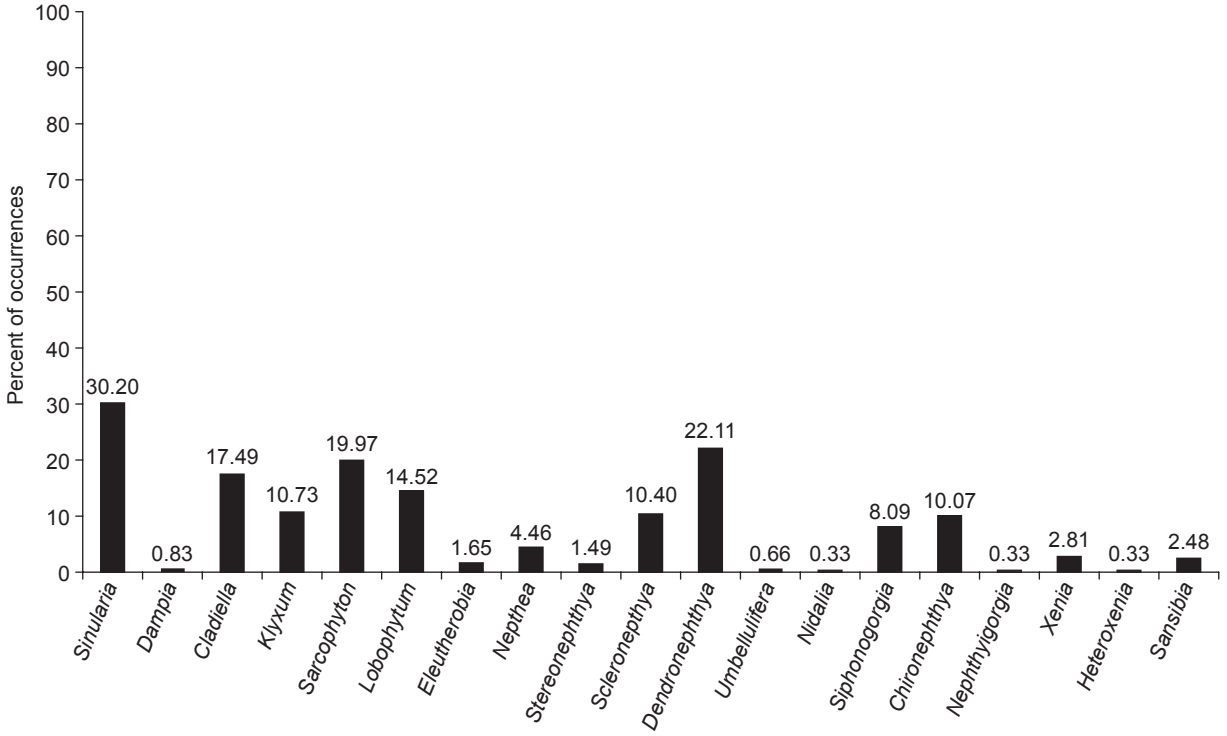


**Fig. 2.** Occurrences of all soft coral genera calculated as a percent of occurrence from all stations in Thai waters.

with 56.06%, 47.06%, and 42.35% occurrences, respectively. In the AN, *Sinularia* (45.87%) had the highest occurrence, followed by *Dendronephthya* (43.97%) and *Lobophytum* (32.76 %).

By comparing the frequencies of occurrence between the AN and GT, it was found that there were no significant differences ($p > 0.05$) for *Sinularia*, *Dampia*, *Sarcophyton*, *Eleutherobia*, or *Nephthyigorgia*. However, there were significant differences ($p < 0.05$) for *Cladiella*, *Klyxum*, *Lobophytum*, *Scleronephthya*, *Dendronephthya*, *Siphonogorgia*, and *Chironephthya*. Seven genera were found only in the AN: *Nephthea*, *Stereonephthya*, *Umbellulifera*, *Nidalia*, *Xenia*, *Heteroxenia*, and *Sansibia*.

At the habitat level, soft corals were found on both true reefs and rocky habitat. The richest and most abundant sites in the AN were coral reefs on the eastern sides of islands and on submerged rocks in relatively strong currents. In the eastern part of the GT, the pattern of abundance and distribution were also the same as in the AN, whereas the highest diversity and greatest abundance of soft corals found in the western part of the GT were on the western sides of islands.

The windward sides of islands were generally composed of rocky shores, limestone cliffs, and steep walls. In 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.

**Habitat preference of soft corals**

The MDS plot shows a pattern of soft-coral distribution in relation to inshore and offshore islands in Thai waters (Fig. 4).

The MDS shows 3 groupings of habitat preference of different genera, in both the AN and GT.

(A) The largest group of 14 genera of soft corals was found at both inshore and offshore islands, and included *Sinularia*, *Dampia*, *Cladiella*, *Klyxum*, *Sarcophyton*, *Lobophytum*, *Nephthea*, *Scleronaphthya*, *Dendronephthya*, *Umbellulifera*, *Siphonogorgia*, *Chironephthya*, *Nephthyigorgia*, and *Xenia*. Most of these are of the Alcyoniidae and Nephtheidae. These soft corals were found

**Table 1.** Survey locations in the Andaman Sea and taxa present at each location, including true reefs, rocky shores, and submerged rocks (+, present; -, absent; *, new record; in, inshore island; of, offshore island)

| | Location | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Taxa | AN01 (in) | AN02 (of) | AN03 (of) | AN04 (of) | AN05 (of) | AN06 (of) | AN07 (in) | AN08 (in) | AN09 (of) | AN10 (in) | AN11 (in) | AN12 (in) | AN13 (of) | AN14 (in) | AN15 (in) | AN16 (of) | AN17 (of) |
| 1. *Sinalaria* | + | + | - | - | + | + | + | + | + | - | + | + | - | + | - | + | + |
| 2. *Dampia** | + | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 3. *Cladiella* | + | + | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 4. *Klyxum* | - | - | - | - | - | + | - | - | - | - | - | - | - | - | - | - | - |
| 5. *Sarcophyton* | + | + | - | + | - | + | - | + | - | - | + | + | - | + | - | + | - |
| 6. *Lobophytum* | + | + | + | + | + | + | - | + | - | - | + | - | - | - | + | + | - |
| 7. *Eleutherobia** | - | - | + | - | - | + | - | - | - | - | - | - | - | - | - | - | - |
| 8. *Nephthea* | - | + | - | + | - | + | - | + | - | + | + | + | - | - | - | + | - |
| 9. *Stereonephthya** | - | - | - | - | - | + | - | - | - | - | - | - | - | - | - | + | - |
| 10. *Scleronephthya* | - | + | + | + | + | + | - | + | + | - | - | + | + | - | + | + | + |
| 11. *Dendronephthya* | + | + | + | + | + | + | - | + | - | + | + | + | + | + | + | + | + |
| 12. *Umbellulifera* | - | - | - | - | - | - | - | + | - | - | - | - | - | - | - | + | - |
| 13. *Nidalia** | - | - | - | + | - | + | - | - | - | - | - | - | - | - | - | - | - |
| 14. *Siphonogorgia** | - | + | + | + | - | + | - | - | + | - | - | + | + | - | - | + | - |
| 15. *Chironephthya** | - | + | - | + | - | + | - | + | + | - | - | - | - | + | + | + | + |
| 16. *Nephthyigorgia** | - | - | - | - | - | - | - | - | - | - | - | - | - | - | + | - | - |
| 17. *Xenia* | + | - | - | - | - | - | - | - | + | - | - | - | - | - | + | + | - |
| 18. *Heteroxenia** | - | - | - | - | - | + | - | - | - | - | - | - | - | - | - | + | - |
| 19. *Sansibia** | + | - | - | - | - | - | - | - | - | - | - | - | - | + | - | - | - |
| Total | 8 | 9 | 5 | 8 | 4 | 13 | 1 | 8 | 5 | 2 | 5 | 6 | 3 | 5 | 6 | 12 | 4 |

on various habitats: true reefs, rocky shores, and submerged rocks. Moreover, they were found from shallow water with low visibility to deep water at over 40 m in depth with high visibility.

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

(C) This group was clearly separated from the other groups and was found on offshore islands of the AN. The genera present were *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 of over 30 m.

## Zonation preference patterns

In evaluating specific site preferences of soft corals at each habitat, it was found that soft corals tended to be associated with a particular zonation such as reef flat/upper zone, reef slope/lower zone, and fore reef. Cluster analysis and the MDS plot produced 4 different groups (Fig. 5) as follows.

(A) Soft corals in this group were found on reef slopes and the lower zone of rocky habitats. The genera present in this group were *Nidalia*, *Eleutherobia*, *Sansibia*, *Heteroxenia*, and *Nephthyigorgia*. All of these genera were found only in the AN, except for *Nephthyigorgia*. The reef slope/lower zone of the AN varied between 2 and 40 m in depth. Most of these soft corals are azooxanthellate groups except *Sansibia*, and occurred at 10-30 m in depth, whereas *Sansibia* was found on shallow reef slopes at 2-5 m in depth.

(B) Soft-coral genera of this group were found on the reef flat/upper zone and reef slope/lower zone. The genera present in this group were *Xenia*, *Chironephthya*, *Cladiella*, and *Dampia*. There were significant variations in depths of the reef flat/upper zone and reef slope/lower zone between the AN and GT. *Xenia* was found on the reef flat/upper zone to reef slope/lower zone, where it commonly had extensive cover at 2-10 m in depth. *Chironephthya*, an azooxanthellate, was found on shallow reefs or rocky habitat with low light intensity. *Cladiella*, a zooxanthellate group, dominated in the GT, and a few patches were found on reef slopes at over 40 m in depth in the

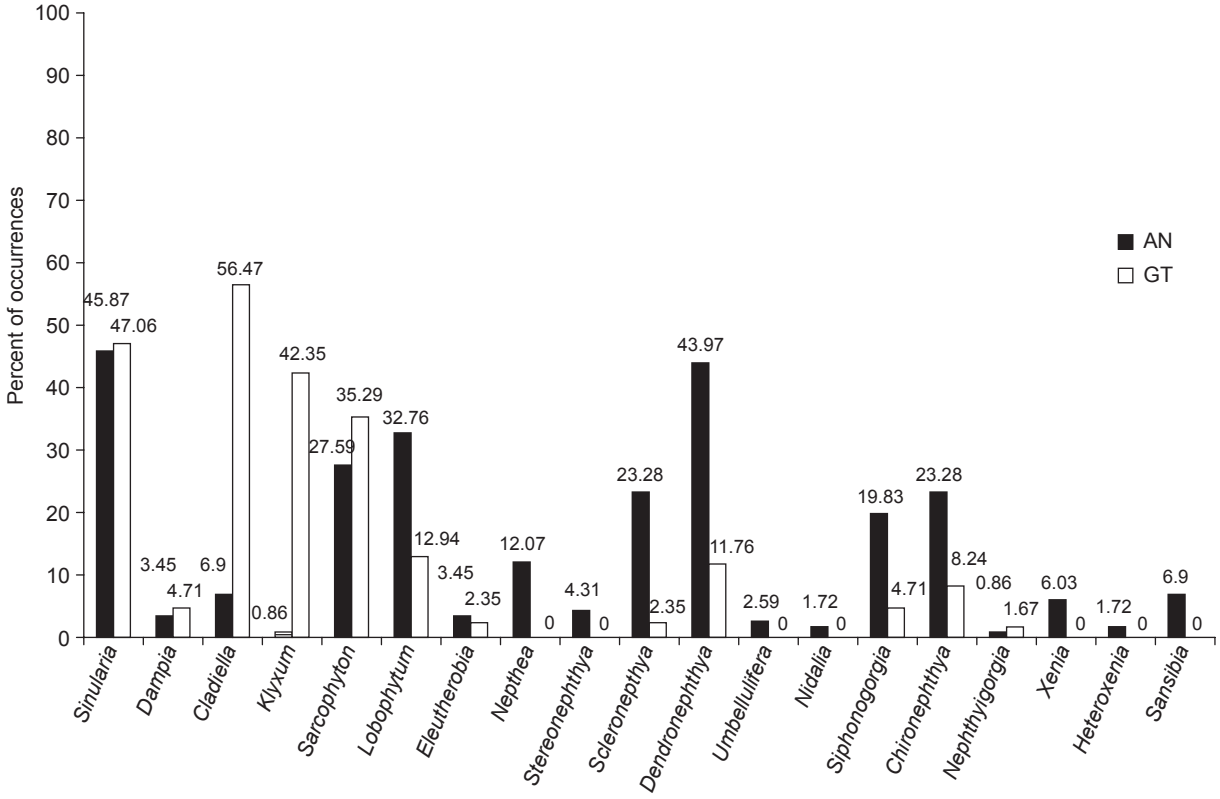


**Fig. 3.** Total percent of occurrences, in the Andaman Sea (AN) and Gulf of Thailand (GT), of genera occurring in Thai waters.

AN. *Dampia* was found in shallow water of 2-5 m in depth.

(C) This was the largest group distributed in all habitat zones, and occurred at 0-40 m in depth. The genera in this group were *Siphonogorgia*, *Dendronephthya*, *Scleronephthya*, *Nephthea*, *Lobophytum*, *Sarcophyton*, *Klyxum*, and *Sinularia*. All are dominant genera of soft corals in Thai waters.

(D) This was the azooxanthellate group which was only found on fore reefs at 15-40 m in depth. *Umbellulifera* was found on sandy bottoms, while *Stereonephthya* was attached to rubble or dead coral fragments.

**Habitat preference based on the angle of the substrate**

The MDS plot of the angle of the substrate is shown in figure 6. Cluster analysis and an MDS plot produced the following 5 groups.

(A) *Sansibia*, *Heteroxenia*, *Nephthyigorgia*, and *Stereonephthya* were found on horizontal and ~45°-angled substrates.

(B) *Umbellulifera* was the only group occurring on horizontal substrate exclusively on fore reefs/sand floors.

(C) This group was characterized by 3 features: horizontal, ~45°, and 90° angled substrates. It included *Xenia*, *Nephthea*, *Lobophytum*, *Sarcophyton*, *Klyxum*, *Cladiella*, *Dampia*, and *Sinularia*.

(D) This group included soft corals which grew on substrates at all angles from horizontal to overhanging, and they were well distributed on rocky shores, especially submerged rock and crevices. The genera in this group were *Scleronephthya*, *Eleutherobia*, *Chironephthya*, *Nidalia*, and *Dendronephthya*.

(E) *Siphonogorgia* was only found attached to substrates at all angles except overhanging substrate.

Finally, the effect of water transparency on genera richness was determined using a regression analysis. The generic richness was not significantly related to water transparency ($r^2$ = 0.19, $p < 0.0001$, $n$ = 152, Y = 0.1173X + 1.8766).

## DISCUSSION

This is the most extensive study to focus on the distribution of soft corals, and it is the first revision of the soft coral taxa in Thai waters. In total, 19 genera of soft corals were found (Tables 1, 2). There were 9 newly recorded genera: *Dampia*, *Eleutherobia*, *Stereonepthya*, *Nidalia*, *Siphonogorgia*, *Chironephthya*, *Nepthyigorgia*, *Heteroxenia*, and *Sansibia*.

Twelve genera were widely distributed throughout the GT and AN: *Sinularia*, *Dampia*, *Cladiella*, *Klyxum*, *Sarcophyton*, *Lobophytum*,

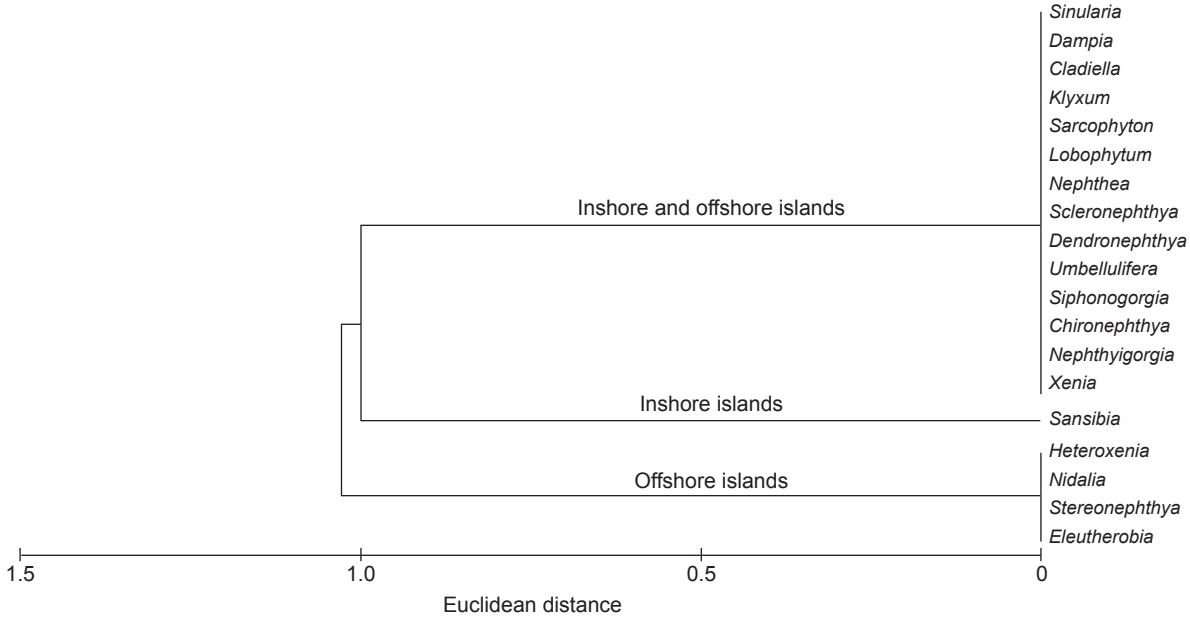


**Fig. 4.** Multidimensional scaling of the distribution of soft corals in Thai waters showing genera grouped within inshore and offshore islands. The analysis was based on binary data from all study stations.

*Eleutherobia*, *Scleronephthya*, *Dendronephthya*, *Siphonogorgia*, *Chironephthya*, and *Nephthyigorgia*. Some genera occurred in restricted locations and with low populations. The rare genera found in the GT were *Dendronephthya*, *Scleronephthya*, *Nephthyigorgia*, and *Eleutherobia*. All of them were found at GT12. Another 3 genera were rare in the AN: *Nidalia* at AN04 and AN06; *Heteroxenia* at AN06 and AN16; and *Nephthyigorgia* at AN15.

The "hot spot" of soft-coral diversity in the GT was located at GT12, where 10 genera were found. It is an offshore reef about 80 km from the mainland. The "hot spot" in the AN was located at AN06 which contains offshore reefs at 70 km from the mainland, and 13 genera were recorded.

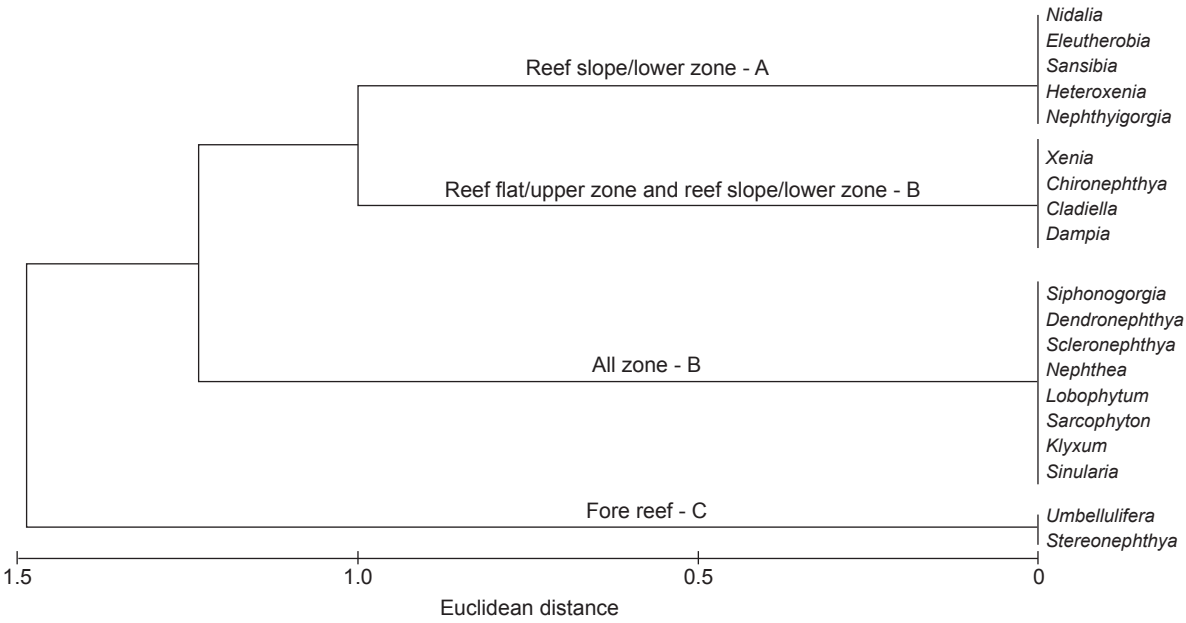


**Fig. 5.** Multidimensional scaling of the zonation of soft corals based on binary data from all study stations. It shows grouping of zonation preferences of all genera of soft corals.

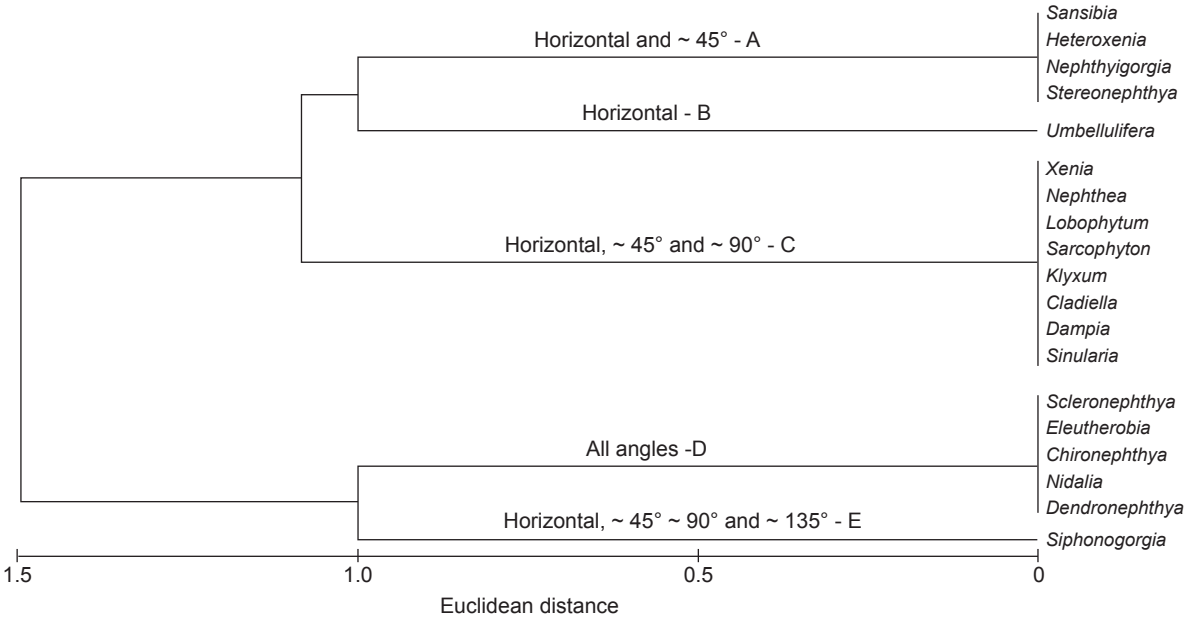


**Fig. 6.** Multidimensional scaling of habitat preferences for the angle of the substrate based on binary data from all study stations.

The dominant genera of soft corals in Thai waters were in the families Alcyoniidae (*Sinularia*, *Sarcophyton*, and *Cladiella*) and Nephtheidae (*Dendronepthya* and *Scleronepthya*) (Fig. 2). The Alcyoniidae was the dominant family in the GT, whereas the Nephtheidae was the dominant family in the AN (Fig. 3).

The Alcyoniidae is a dominant family of soft corals in the Indo-Pacific as reported in several locations such as the Great Barrier Reef (Dinesen 1983, Fabricius and Déath 2001), South Africa (Schleyer and Celliers 2003), and southern Taiwan (Dai 1991b, Benayahu et al. 2004). In Thai waters, the Alcyoniidae was found to be widely distributed in all habitat types ranging from reef flats to fore reefs, to over 40 m in depth, covering true reefs and rocky substrates, and found on both inshore and offshore islands. Furthermore, it members often formed patches and covered large areas in monospecific carpets. At most of the inshore islands in the GT where the Alcyoniidae was dominant, genera (i.e., *Cladiella*, *Sinularia*, *Klyxum*, and *Sarcophyton*) were affected by sedimentation. They were able to survive under heavy sediment loads (Schleyer and Celliers 2003), and they produce toxic secondary metabolites (Tursch and Tursch 1982, Sammarco et al. 1983, Wylie and Paul 1989, Van Alstyne et al. 1992). In addition, they are able to compete with scleractinian corals for space which is an important defense mechanism for surviving on reef habitats (Griffith 1997). Therefore, soft corals of the family Alcyoniidae have a greater probability than other families of occupying diverse habitats, especially in turbid environments of Thai waters.

The Nephtheidae, such as *Dendronephthya* and *Scleronephthya*, was the 2nd most abundant family with a wide-ranging distribution especially in the AN (Fig. 3). The distinctive feature which supports a wide-ranging distribution of this family is the presence of vigorous asexual propagators (Dahan and Benayahu 1997) which can grow to become large monospecific stands on rocky shores and submerged rocks, especially *Dendronephthya* which rapidly overgrows and spreads over substrates by vigorous asexual propagators (Fabricius et al. 1995b, Dahan and Benayahu 1997). The ability to settle on substrates at all angles including crevices is also an advantage for the Nephtheidae. Crevices and overhangs are suitable microhabitats for the Nephtheidae which is an azooxanthellate group. They can grow under limited light which is an advantage compared to other families of soft corals. The Nephtheidae, such as *Dendronepthya* and *Scleronepthya*, occurs more frequently on rocky habitats than on true reef habitats. Moreover, submerged rocks which are generally located in areas of strong currents and turbulence are also a suitable environment for the growth of soft corals in the family Nephtheidae (Dai

**Table 2.** Survey locations in the Gulf of Thailand and taxa present at each location, including true reefs, rocky shores, and submerged rocks (+, present; -, absent; *, new record; in, inshore island; of, offshore island)

| | Location | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Taxa | GT01 (in) | GT02 (in) | GT03 (in) | GT04 (in) | GT05 (in) | GT06 (in) | GT07 (of) | GT08 (in) | GT09 (of) | GT10 (in) | GT11 (in) | GT12 (of) |
| 1. *Sinalaria* | + | + | - | + | + | + | + | - | + | - | - | + |
| 2. *Dampia** | - | + | - | - | - | - | + | - | - | - | - | + |
| 3. *Cladiella* | + | + | + | + | + | - | + | + | + | + | - | + |
| 4. *Klyxum* | + | + | + | + | + | + | + | - | + | - | - | - |
| 5. *Sarcophyton* | + | + | + | - | + | - | + | - | + | - | - | + |
| 6. *Lobophytum* | + | + | - | - | - | - | + | - | - | - | - | - |
| 7. *Eleutherobia** | - | - | - | - | - | - | - | - | - | - | - | + |
| 8. *Scleronephthya* | - | - | - | - | - | - | - | - | - | - | - | + |
| 9. *Dendronephthya* | - | + | - | - | - | - | + | - | - | - | - | + |
| 10. *Siphonogorgia** | + | - | - | - | - | - | - | - | - | - | - | + |
| 11. *Chironephthya** | + | + | - | - | - | - | - | - | - | - | + | + |
| 12. *Nephthyigorgia** | - | - | - | - | - | - | - | - | - | - | - | + |
| Total | 7 | 8 | 3 | 3 | 4 | 2 | 7 | 1 | 4 | 1 | 1 | 10 |

1993). Most rocky habitats, including submerged rocks in the surveyed area were exposed to relatively strong currents or turbulent water. Soft corals of the Nephtheidae are suspension feeders, feeding on phytoplankton (Fabricius et al. 1995a), and plankton is more available in these areas than on true reef habitats. In addition, water movements can wash away sediments from their colonies (Riegl 1995). Interestingly, at a few sites around AN16, an azooxanthellate member of the Nephtheidae, *Dendronephthya*, was found on the shallow reef at about 1 m in depth. Most reports indicate that this genus is confined to relatively deeper waters (Fabricius and Alderslade 2001, Mahadi et al. 2004).

This study indicates that different genera of soft corals show habitat preferences. It was found that the Nephtheidae was more widely distributed on rocky shores and submerged rocks than on true reefs, whereas the Alcyoniidae was more widely distributed on true reefs than on rocky habitats. These findings show that soft-coral growth is strongly site specific, such as zonation on reefs. Soft corals are often found on slope areas and sand floors. The occurrence of soft corals was greater in the reef slope/lower zone than the reef flat/upper zone or sand floors in the AN. The depth of the reef slope/lower zone varies between 3 and 10 m on inshore reefs, and reaches 10-40 m on offshore reefs. However, in the GT, the majority occur in the slope/lower zone, at 3-30 m in depth. On the reef flat or upper zone, soft corals would encounter highly variable environments. Strong wave action is a limiting factor for colonization and distribution of soft corals, 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 highly stressful environments of intertidal reef flats or the upper zone of rocky shores during spring tides, where a few genera of the Alcyoniidae (*Sinularia*, *Cladiella*, and *Lobophytum*) can be found. Colony shapes of genera in these areas are predominantly short lobe, encrusting, and massive forms.

The angle of the substrate has an influence on the distribution and abundance of soft corals. The zooxanthellate group, a light-dependent group, requires long exposure to photosynthetically active radiation, especially in turbid waters or at greater depths. The Alcyoniidae was found on substrates with varying angles ranging from horizontal to ~90°. In this study, azooxanthellate genera of the Neptheidae and Nidaliidae were found attached to substrates at all angles. They are suspension feeders and do not require light. Thus they can colonize shady undersides of overhangs and crevices, making them more-successful space colonizers than light-dependent groups.

Generic differences between the AN and GT may have been due to causes other than differences in habitat environments. The past history of marine organism 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, which connects the Pacific and Indian Oceans. There are few comparisons of diversity of marine fauna between the AN and GT. Satapoomin (2000 2002) showed that besides a higher diversity of reef fish communities in the AN, the taxonomic composition of the communities also differed. This study also showed that soft-coral genera in the AN were more diverse than those of the GT, and there were some differences in the dominant genera. Sea level fluctuations during the Pleistocene, due to glaciation, are considered an important cause of these differences. During glaciation, some parts of the Sunda Shelf, including parts of the AN and GT, were exposed (Haq et al. 1987, Voris 2000). A map of the region during the Pleistocene in Voris (2000) shows the sea level at 120 m below the present and indicates that the eastern part of the Indian Ocean (the Andaman Sea) had a narrower shelf, while the GT was largely exposed. All habitats in this study were fully exposed during this glaciation, and the success of colonization by marine organisms in the post-glacial period depended upon the patterns of sea level rise as well as dispersal of organisms from point sources. The width of the continental shelf and the environments of the newly flooded area would have affected dispersal and colonization of benthic sessile fauna.

At present, the GT is characterized by low salinity, high turbidity, and a muddy bottom, compared to conditions in the AN which are more oceanic, with more-extensively developed reefs. Based on oceanic circulation models (see figure 3 in Carpenter and Springer 2005), the source of present-day soft corals in the GT must have dispersed from the South China Sea/Pacific Ocean. That assumption may give a clear explanation of the boundary of soft coral distribution. GT12, which is situated in a more-oceanic environment in the southern part of the GT, has the highest genera richness in the GT. At that position, it may be a sink area for planula from other sources in the South China Sea and served as a “stepping stone”

for the dispersal of soft corals within the GT. In the AN, the source of soft corals must have dispersed from the western part of the Andaman Sea/Indian Ocean. Unfortunately, no information on soft coral distributions at the generic level within the South China Sea or eastern Indian Ocean is available to support this hypothesis.

In conclusion, this study shows that soft corals are more diverse in the Andaman Sea than in the Gulf of Thailand. The family Alcyoniidae had the highest percentage of occurrence in Thai waters, and *Sinularia*, *Dendronephthya*, *Sarcophyton*, and *Cladiella* were the dominant genera. This study suggests that different genera of soft corals show habitat preferences in term of location (inshore vs. offshore islands), zones on habitats (reef flat/upper zone, reef slope/lower zone, and fore reef), and angles of the substratum. The "hot spot" of soft coral diversity in the Gulf of Thailand is located at GT12, where 10 genera were found, and is at AN06 in the Andaman Sea where 13 genera were found.

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