

Soft Corals (Octocorallia: Alcyonacea) from Southern Taiwan. II. Species Diversity and Distributional Patterns

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Yehuda Benayahu, Ming-Shiou Jeng, Shimrit Perkol-Finkel and Chang-Feng Dai (2004) Soft corals (Octocorallia: Alcyonacea) from southern Taiwan. II. species diversity and distributional patterns. *Zoological Studies* 43(3): 548-560. The geographic setting of Taiwan, between the West Pacific Ocean and East China Sea and at the crossroads of the Philippine-Japan I. Arc, has produced reefs of special biogeographical interest. It has been suggested that Taiwan may have served as a "stepping-stone" for the dispersal of shallow reef organisms. Soft corals from Nanwan Bay and Green I. (*Lutao* in Chinese), southern Taiwan, were studied during 1994 and 1998. Scuba collections were carried out to a depth of 33 m. Approximately 230 samples were collected, encompassing a variety of species found on these reefs. Visual estimates were made of the underwater abundance of species. The collection yielded 69 species of the families Helioporidae, Clavulariidae, Tubiporidae, Alcyoniidae, Nephtheidae, Xeniidae, and Briareidae. These included 1 new species and 43 new zoogeographical records for Taiwan. Among the 22 listed genera, the survey recorded 7 for the 1st time in Taiwanese reefs. The findings confirm the high soft-coral diversity of these reefs. The shallow reefs of Nanwan Bay are densely inhabited by species of the family Alcyoniidae. In contrast, the deep reefs are characterized only by sporadic colonies of Alcyoniidae, but abundant assemblages of azooxanthellate members of the families Nephtheidae and Nidaliidae. Soft corals of the family Xeniidae are abundant on the reefs of Green I. at a depth range of 3–10 m. Interestingly, species of the family Xeniidae were rarely observed at Nanwan Bay. The coral reefs of Taiwan and Japan are closely linked by the northward-flowing Kuroshio Current, which brings water and larvae from the reefs of the South China Sea. Therefore, we compared the generic affiliation and abundance estimates of the Alcyoniidae between southern Taiwan and the Ryukyu Archipelago (Japan), and found a close resemblance between these 2 reef areas. <http://www.sinica.edu.tw/zool/zoolstud/43.3/548.pdf>

Key words: Octocorallia, Taiwan, Coral reefs, Species diversity, Biogeography.

Taiwan, a continental island with several off-shore islets, has coral reefs that sit at the northern edge of the Southeast Asian center of biodiversity (Fujiwara et al. 2000). These reefs are known for their flourishing fringing reef communities (Wells 1988). The Taiwan Strait, situated to the west between Taiwan and mainland China, is a shallow channel, as opposed to the eastern region where the submarine topology drops steeply close to the nearby Ryukyu Archipelago (Chen 1999). The geographic setting of Taiwan, between the West Pacific Ocean and East China Sea and at the

crossroads of the Philippine-Japan I. Arc, has produced reefs of special biogeographical interest. This has led to the suggestion that Taiwan may have served as a "stepping-stone" for the northward and eastward dispersal of shallow reef organisms (Dai 1991a).

The octocoral fauna of Taiwan has been the subject of several studies. An early collection of soft corals conducted by Utinomi in 1938, resulted in the description of 3 new species: *Clavularia racemosa*, *Anthelia formosana*, and *Asterospicularia laurae* (Utinomi 1950a b 1951). This col-

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lection was carried out mainly along the southern coast of Taiwan, and yielded 21 octocoral species of the families Clavulariidae, Tubiporidae, Xenidiidae, Asterozoniidae, Alcyoniidae, Nephtheidae, Helioporidae, and Briareidae (Utinomi 1959). Later, Verseveldt (1982a) described an additional new species, *Siphonogorgia lobata* (family Nidaliidae), from Taiwan. The 18 species of gorgonians listed for southern Taiwan, all of which were found to be new records for the region (Chen and Chang 1991), are likewise notable, but are beyond the scope of the current paper. Fujiwara et al. (2000) reported that species diversity of the Taiwanese reefs is relatively high, with 70 soft-coral and gorgonian species.

Dai (1991a b) demonstrated that soft corals in Taiwan are abundant in the south, mainly on the western side of Nanwan Bay. The reefs of Kenting National Park in southern Taiwan are very rich, with extensively developed soft-coral communities. They dominate the benthos, comprising in some sites up to 70% of the total coral cover (Dai 1993). In these reefs, species of the genera *Lobophytum*, *Sarcophyton*, and *Sinularia* are highly abundant and found even in habitats exposed both to strong tidal currents and typhoons (Dai 1988 1991b). A checklist of the soft corals from southern Taiwan (Dai 1991a) included 42 species and an additional 7 species that remained unassigned. Among the identified species of this list, Utinomi (1959) had already reported 13 species, and therefore 29 species appeared to be new records for the region. At present, there is a gap in the knowledge of soft corals from other regions of Taiwan.

Intrigued by the early taxonomic reports on the soft corals of Taiwan (Utinomi 1950a b 1951 1959), their high abundance, and ecological importance (Dai 1988 1990 1991a b 1993; Fujiwara et al. 2000), we conducted a comprehensive soft-coral survey there. The present paper reports on reef sites located in both the East China Sea and the Pacific side of southern Taiwan. It provides a systematic list of soft-coral species, as well as information on their abundance and distributional patterns on the reefs. The blue coral *Heliopora coerulea* is abundant in some of the surveyed sites, and therefore it is also included in the study. Since the coral reefs of Taiwan and Japan are closely linked, we also compared the studied soft-coral fauna to those of reefs of the adjacent southern Ryukyu Archipelago and assessed their biogeographic affinities.

MATERIALS AND METHODS

Collecting trips were conducted in 2 regions (Fig. 1): Kenting National Park, Nanwan Bay in southern Taiwan (21°55'N; 120°45'E) during June-July 1994, Nov. 1998, and Mar. 2004; and the offshore Green I. (*Lutao* in Chinese), southeast of Taiwan (22°40'N; 121°29'E) during June-July 1994. In Nanwan Bay, collections were made on the fringing reefs including Banana Bay and Wanitun, mostly to a maximal depth of 12 m, and on the submerged offshore Sea Mount reef, down to 31 m. At Green I., collections were made along the western and southwestern sides down to a depth of 31 m. The reefs were mostly reached by boat, and careful examination of a variety of niches in the different sites was carried out by scuba diving. Approximately 230 samples were collected, encompassing the variety of species found on the reefs. Underwater abundance estimates of the genera were made visually and divided into 4 categories: rare, sporadic, abundant, and dominant (see also Benayahu 1995). Prior to collection, most of the colonies were in situ photographed, using a Nikonos V camera with a close-up attachment. Samples were fixed in 4% formalin in sea-

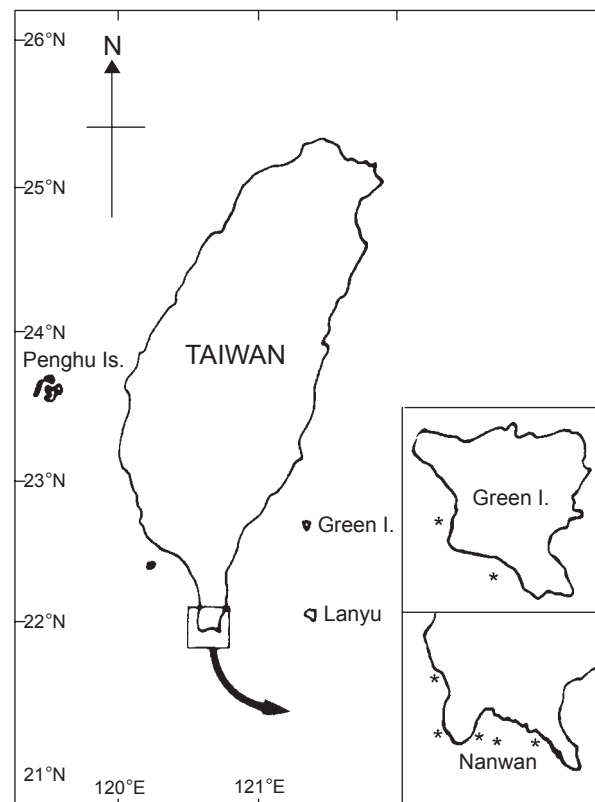


Fig. 1. Map of Taiwan with study sites indicated by asterisks.

water, rinsed in fresh water after 24 h, and then transferred to 70% ethyl alcohol. Sclerites were obtained by dissolving the tissues in 10% sodium hypochlorite.

Identification of the Alcyoniidae species of the collection was in great part facilitated by comparisons with permanent sclerite preparations from type material kept in the Zoological Museum, Department of Zoology, Tel Aviv University, Israel (ZMTAU) and at the Nationaal Natuurhistorisch Museum, formerly Rijksmuseum van Natuurlijke Historie, Leiden, The Netherlands. All material is housed in the Zoological Museum, Department of

Zoology, Tel Aviv University, Israel. Some members of the families Alcyoniidae, Nephtheidae, Nidaliidae, and Xenidae are still being examined.

RESULTS

The examined material yielded 69 species, of which 1 is a new species (Benayahu and Perkol-Finkel 2004) and 43 are new zoogeographical records for Taiwan (Table 1). Underwater photographs of some of the soft corals collected in the current study are presented as indicated below.

Table 1. List of the species of Octocorallia of the orders Helioporacea Bock, 1938 and Alcyonacea Lamouroux, 1816 from the reefs of Taiwan with indication of Museum inventory numbers (ZMTAU Co) and previous references. NR, new record; 1, Utinomi 1959; 2, Dai 1991a; * occurrence of members of the family Alcyoniidae in the southern Ryukyu Archipelago, Japan following Benayahu 1995 2002; ** see Benayahu and Perkol-Finkel 2004

Classification	References	Classification	References
Helioporidae Blainville, 1830		30252	
Genus <i>Heliopora</i> Moseley, 1786		<i>Lobophytum sarcophytoides</i> Moser, 1919	2
<i>Heliopora coerulea</i> (Pallas, 1766)	1, 2	ZMTAU Co 30239, 30250	
ZMTAU Co 30273		<i>Lobophytum venustum</i> Tixier-Durivault, 1957*	NR
Clavariidae Hickson, 1894		ZMTAU Co 29161, 29163, 29179, 30237,	
Genus <i>Clavularia</i> Blainville, 1830		30248	
<i>Clavularia inflata</i> Schenk, 1896	1	Genus <i>Paraminabea</i> (Williams & Alderslade, 1999)	
ZMTAU Co 29197		<i>Paraminabea aldersladei</i> (Williams, 1992)	NR
Tubiporidae Ehrenberg, 1828		ZMTAU Co 29184, 29185, 30278, 30289	
Genus <i>Tubipora</i> Linnaeus, 1758		Genus <i>Rhytisma</i> Alderslade, 2000	
<i>Tubipora musica</i> Linnaeus, 1758	1, 2	<i>Rhytisma fulvum fulvum</i> (Forskål, 1775)*	NR
ZMTAU Co 29193, 30169, 30256		ZMTAU Co 29200	
Alcyoniidae Lamouroux, 1812		Genus <i>Sarcophyton</i> Lesson, 1834	
Genus <i>Cladiella</i> Gray, 1869		<i>Sarcophyton buitendijki</i> Verseveldt, 1982	NR
<i>Cladiella australis</i> (Macfadyen, 1936)*	NR	ZMTAU Co 29169	
ZMTAU Co 28932, 28948, 28949, 30186,		<i>Sarcophyton crassocaule</i> Moser, 1919*	2
30188, 30220, 30223		ZMTAU Co 29173, 30254	
<i>Cladiella daphnae</i> Ofwegen & Benayahu, 1992	NR	<i>Sarcophyton ehrenbergi</i> von Marenzeller,	1, 2
ZMTAU Co 30258		1886*	
<i>Cladiella pachyclados</i> (Klunzinger, 1877)*	1, 2	ZMTAU Co 30241, 30261	
ZMTAU Co 30201		<i>Sarcophyton glaucum</i> (Quoy & Gaimard, 1833)*	1, 2
<i>Cladiella tuberculosa</i> (Quoy & Gaimard, 1833)	NR	ZMTAU Co 29170, 29172, 29174, 29180,	
ZMTAU Co 29158, 30240, 30260, 30267		30238, 30242, 30243, 30244, 30246, 30251,	
Genus <i>Eleutherobia</i> Putter, 1990		30268	
<i>Eleutherobia grayi</i> (Thomson & Dean, 1931)*	NR	<i>Sarcophyton infundibuliforme</i> Tixier-Durivault,	NR
ZMTAU Co 30271		1958*	
Genus <i>Klyxum</i> Alderslade, 2000		ZMTAU Co 29177, 30255	
<i>Klyxum simplex</i> (Thomson & Dean, 1931)*	2	<i>Sarcophyton nanwanensis</i> Benayahu &	**
ZMTAU Co 30195, 30219, 30245		Perkol-Finkel, 2004	
Genus <i>Lobophytum</i> von Marenzeller, 1886		ZMTAU Co 30253	
<i>Lobophytum crassum</i> von Marenzeller, 1886*	2	<i>Sarcophyton tenuispiculatum</i> Thomson &	NR
ZMTAU Co 28924, 29159, 29160, 29162,		Dean, 1931*	
29168		ZMTAU Co 29175	
<i>Lobophytum pauciflorum</i> (Ehrenberg, 1834)*	2	<i>Sarcophyton trocheliophorum</i> von Marenzeller,	1, 2
ZMTAU Co 29164, 29165, 29166, 29167,		1886*	

Table 1. (Cont.)

Classification	References	Classification	References
ZMTAU Co 29171, 29176, 29178, 30247		30218	
Genus <i>Sinularia</i> May, 1898		<i>Sinularia rigida</i> (Dana, 1846)	NR
<i>Sinularia brassica</i> May, 1898*	NR	ZMTAU Co 28934	
ZMTAU Co 28926, 30193, 30233		<i>Sinularia triangula</i> Tixier-Durivault, 1970	NR
<i>Sinularia compacta</i> Tixier-Durivault, 1970	NR	ZMTAU Co 30203, 30337	
ZMTAU Co 30229		<i>Sinularia variabilis</i> Tixier-Durivault, 1945*	NR
<i>Sinularia compressa</i> Tixier-Durivault, 1945*	NR	ZMTAU Co 28942, 30204, 30182, 30215, 30222, 30231	
ZMTAU Co 28940		Nephtheidae Gray, 1862	
<i>Sinularia discrepans</i> Tixier-Durivault, 1970	NR	Genus <i>Capnella</i> Gray, 1869	
ZMTAU Co 28941		<i>Capnella fungiformis</i> Kükenthal, 1904	NR
<i>Sinularia dissecta</i> Tixier-Durivault, 1945	NR	ZMTAU Co 28911, 28893, 28894	
ZMTAU Co 30236		Genus <i>Lemnalia</i> Gray, 1868	
<i>Sinularia erecta</i> Tixier-Durivault, 1945*	NR	<i>Lemnalia flava</i> (May, 1898)	NR
ZMTAU Co 30187, 30208, 30225		ZMTAU Co 28909	
<i>Sinularia exilis</i> Tixier-Durivault, 1970	2	Genus <i>Paralemnalia</i> Kükenthal, 1913	
ZMTAU Co 30217		<i>Paralemnalia thyrsoidea</i> (Ehrenberg, 1834)	1, 2
<i>Sinularia facile</i> Tixier-Durivault, 1970	2	ZMTAU Co 28905, 28906	
ZMTAU Co 30200		Genus <i>Scleronephthya</i> Studer, 1887	
<i>Sinularia flexibilis</i> (Quoy & Gaimard, 1833)*	2	<i>Scleronephthya gracillimum</i> (Kükenthal, 1906)	NR
ZMTAU Co 28923, 28927, 30191, 30209, 30262		ZMTAU Co 29196, 29199	
<i>Sinularia gibberosa</i> Tixier-Durivault, 1970*	2	Xeniidae Ehrenberg, 1828	
ZMTAU Co 28930, 28938, 28939, 30190		Genus <i>Anthelia</i> Lamarck, 1816	
<i>Sinularia granosa</i> Tixier-Durivault, 1970	2	<i>Anthelia glauca</i> Lamarck, 1816	NR
ZMTAU Co 30192, 30214, 30285		ZMTAU Co 28883, 28888	
<i>Sinularia grayi</i> Tixier-Durivault, 1945	NR	Genus <i>Asterospicularia</i> Utinomi, 1951	
ZMTAU Co 28925		<i>Asterospicularia laurae</i> Utinomi, 1951	
<i>Sinularia higai</i> Benayahu, 2002*	NR	ZMTAU Co 32318	
ZMTAU Co 30227		Genus <i>Cespitularia</i> Milne-Edwards, 1857	
<i>Sinularia humesi</i> Verseveldt, 1968*	NR	<i>Cespitularia caerulea</i> May, 1898	NR
ZMTAU Co 30206		ZMTAU Co 28886, 28877, 28880	
<i>Sinularia intacta</i> Tixier-Durivault, 1970	NR	<i>Cespitularia stolonifera</i> Gohar, 1938	1, 2
ZMTAU Co 30216		ZMTAU Co 30277	
<i>Sinularia leptoclados</i> (Ehrenberg, 1834)*	NR	Genus <i>Heteroxenia</i> Kolliker, 1874	
ZMTAU Co 28922, 28933, 28936, 28947, 30198, 30189, 30205, 30210, 30221, 30228, 30234, 30235		<i>Heteroxenia medioensis</i> Roxas, 1933	NR
<i>Sinularia lochmodes</i> Kolonko, 1926*	2	ZMTAU Co 30266	
ZMTAU Co 28944, 28945, 30194, 30196		<i>Heteroxenia pinnata</i> Roxas, 1933	NR
<i>Sinularia manaarensis</i> Verseveldt, 1980	NR	ZMTAU Co 28878	
ZMTAU Co 28935, 30212		Genus <i>Sansibia</i> Aldersalde, 2000	
<i>Sinularia maxima</i> Verseveldt, 1971	NR	<i>Sansibia flava</i> (May, 1899)	NR
ZMTAU Co 30232		ZMTAU Co 28881, 28884, 28892, 30269	
<i>Sinularia mollis</i> Kolonko, 1926*	2	Genus <i>Xenia</i> Lamarck, 1816	
ZMTAU Co 28931, 28946		<i>Xenia hicksoni</i> Ashworth, 1899	NR
<i>Sinularia nanolobata</i> Verseveldt, 1977	NR	ZMTAU Co 28890	
ZMTAU Co 30224		<i>Xenia kükenthali</i> Roxas, 1993	NR
<i>Sinularia notanda</i> Tixier-Durivault, 1966	NR	ZMTAU Co 28889, 28891	
ZMTAU Co 28928, 28929, 30213		<i>Xenia lillieae</i> Roxas, 1933	NR
<i>Sinularia numerosa</i> Tixier-Durivault, 1970*	2	ZMTAU Co 30259	
ZMTAU Co 30197, 30202, 30226, 30230		<i>Xenia puerto-galerae</i> Roxas, 1933	NR
<i>Sinularia ovispiculata</i> Tixier-Durivault, 1970*	NR	ZMTAU Co 28882	
ZMTAU Co 28943		Briareidae Blainville, 1830	
<i>Sinularia polydactyla</i> (Ehrenberg, 1834)*	1, 2	Genus <i>Briareum</i> Blainville, 1830	
ZMTAU Co 30335		<i>Briareum excavatum</i> (Nutting, 1911)	NR
<i>Sinularia querciformis</i> (Pratt, 1903)*	NR	ZMTAU Co 28784, 29194, 29195, 30249, 30265, 30283	
ZMTAU Co 28913, 28919, 30199, 30207,		<i>Briareum violacea</i> (Quoy and Gaimard, 1883)	1
		ZMTAU Co 28724, 30272, 30274, 30279	

There are remarkable differences between the soft-coral diversity and generic composition of Nanwan Bay and Green I., with the former being richer (Table 2, 57 and 19 species, respectively). Although several species were recorded in both areas, such as *Lobophytum venustum*, *Paraminabea aldersladei*, *Sarcophyton crassocaule* (Fig. 2), *Sansibia flava*, and *Briareum excavatum* (Fig. 3), each region appears to have its own unique faunistic components (Table 2). Species of the family Alcyoniidae are dominant inhabitants of Nanwan Bay (Figs. 4, 5), comprising 88% of the total number of species there. The genus *Sinularia* is very common there, represented by 30 species including some of the most-widespread species of the genus, i.e., *S. leptoclados* (Fig. 6), *S. polydactyla* (Fig. 7), *S. brassica*, and *S.*

flexibilis (Fig. 8) (see also Ofwegen 2002). In addition, other widespread alcyoniid species known in other Indo-Pacific reefs were found there, i.e., *Cladiella australis* (Fig. 9), *Klyxum simplex* (Fig. 10), *Lobophytum crassum*, (Fig. 11) *L. pauciflorum* (Fig. 12), *Sarcophyton ehrenbergi* (Fig. 13), *S. glaucum* (Fig. 14), *S. infundibuliforme* (Fig. 15), and *Sinularia variabilis* (see also Benayahu 2002). Green I. stands in stark contrast, with the complete absence of any species of the genus *Sinularia*. This finding, along with the absence of *Cladiella* and *Klyxum* species and the lower number of *Lobophytum* and *Sarcophyton* species around Green I., primarily accounts for the lower number of species there. Soft corals of the family Xenidiidae constitute the main soft corals on the reefs there, where they are represented by a variety of species (Table 1) such as *Cespitularia caerulea* (Fig. 16), *Xenia kükenthali*, *X. puerto-galerae*, and *Anthelia glauca* (Fig. 17). The xeniid assemblages are abundant on the reefs of the western and southwestern sides of Green I., where they form a high living coverage at a depth range of 3~10 m (Fig. 18). Other soft corals are found intermingled within the Xenidiidae, including *Clavularia inflata* (Fig. 19), *Capnella fungiformis* (Fig. 20), *Lemnalia flava* (Fig. 21), and *Paralemnalia thyrsoidea*. None of the 4 latter species was found in Nanwan Bay. In contrast, species of the family Xenidiidae in Nanwan Bay were observed only in shallow reef habitats, as they also were in the tidal pools in Banana Bay. Interestingly, *Sansibia flava* was sporadically collected in both study regions. *Asterospicularia laurae* (Fig. 22) also of the family Xenidiidae (see Alderslade 2001) has rarely been found in Nanwan Bay.

The shallow fringing reefs of Nanwan Bay (3~12 m) are densely inhabited mainly by species of the family Alcyoniidae in the genera *Cladiella*, *Klyxum*, *Lobophytum*, *Sarcophyton*, and *Sinularia*, (Figs. 4, 5). They form large monospecific aggregations that monopolize the substrate and occasionally even become the most-dominant benthic component on the reefs (see "Discussion"). In contrast, the deep reef habitat of Nanwan Bay (at "Sea Mount") is characterized by sporadic colonies of the Alcyoniidae, mainly in the genera *Lobophytum* and *Sarcophyton* (Fig. 23). They are also smaller in size compared to those of the shallower reef (e.g., Figs. 4, 7, 15). They become scarcer below 18~20 m, where we mostly recorded assemblages of azooxanthellate species of the genera *Dendronephthya* (Fig. 24), *Stereonephthya*, *Umbellulifera* (family Nephtheidae), and

Table 2. Generic affiliation and abundance estimates of soft-coral genera of Nanwan Bay and Green I. Taiwan

Taxa	Number of species		Abundance	
	Nanwan Bay	Green I.	Nanwan Bay	Green I.
Family Helioporidae				
<i>Heliopora</i>	1	-	Sporadic	-
Family Clavulariidae				
<i>Clavularia</i>	-	1	-	Rare
Family Tubiporidae				
<i>Tubipora</i>	1	1	Rare	Rare
Family Alcyoniidae				
<i>Cladiella</i>	4	-	Sporadic	-
<i>Eleutherobia</i>	1	-	Rare	-
<i>Klyxum</i>	1	-	Sporadic	-
<i>Lobophytum</i>	4	1	Abundant	Rare
<i>Paraminabea</i>	1	1	Rare	Rare
<i>Rhytisma</i>	-	1	-	Rare
<i>Sarcophyton</i>	7	2	Abundant	Sporadic
<i>Sinularia</i>	30	-	Dominant	-
Family Nephtheidae				
<i>Capnella</i>	-	1	-	Rare
<i>Lemnalia</i>	-	1	-	Rare
<i>Paralemnalia</i>	-	1	-	Sporadic
<i>Scleronephthya</i>	-	1	-	Sporadic
Family Xenidiidae				
<i>Anthelia</i>	-	1	-	Rare
<i>Asterospicularia</i>	1	-	Rare	-
<i>Cespitularia</i>	1	1	Rare	Dominant
<i>Heteroxenia</i>	1	1	Rare	Rare
<i>Sansibia</i>	1	1	Sporadic	Sporadic
<i>Xenia</i>	1	3	Rare	Dominant
Family Briareidae				
<i>Briareum</i>	2	1	Sporadic	Sporadic
Total	57	19		

Chironephthya (Fig. 25) and *Siphonogorgia* (family Nidaliidae). Identification to species level of these specimens awaits future studies, and therefore they do not appear in Table 2. The azooxanthellate species *Eleutherobia grayi* (Fig. 26) and *Paraminabea aldersladei* (family Alcyoniidae) were found in both study regions, mostly growing on reef overhangs. At Green I., aggregations of the azooxanthellate species *Scleronephthya gracillimum* (Fig. 27) are abundant along a wide depth gradient, mainly in niches that lack direct sun radiation, such as reef overhangs (Fig. 28), or beneath colonies of branching stony corals (Fig. 29).

Despite the differences in the faunistic features of soft corals between Nanwan Bay and Green I. (Table 2), in both regions they constitute an important faunistic component that significantly contributes to the living coverage.

DISCUSSION

The overall objective of the present survey was to investigate the soft-coral fauna of southern Taiwan. The results indicate that soft corals are abundant in both Nanwan Bay (East China Sea) and around Green I. (Pacific Ocean), totaling 69 species of the families Helioporidae, Clavulariidae, Tubiporidae, Alcyoniidae, Nephtheidae, Xenidiidae, and Briareidae (Tables 1, 2). Among the 22 listed genera of these families, the survey records 7 for the 1st time from Taiwanese reefs, i.e., *Eleutherobia*, *Paraminabea*, *Rhytisma*, *Capnella*, *Lemnalia*, *Scleronephthya*, and *Sansibia*. The current survey also yielded a new species (*Sarcophyton nanwanensis* Benayahu and Perkol-Finkel, 2004) and 43 new zoogeographical records, which constitute 63% of the total number of species identified in the present study.

The present collection shares 25 species with previous studies by Utinomi (1959) and Dai (1991a). Noteworthy is the recent collection (Mar. 2004) of *Asterospicularia laurae* (Table 1), whose type locality is the southern tip of Taiwan (Utinomi 1951). The family Asterospiculariidae has recently been abandoned, and the genus *Asterospicularia* has been transferred to the Xenidiidae (Alderslade 2001). Emendations following the taxonomic revision by Verseveldt (1982b) of *Sarcophyton* and assessments by Fabricius and Alderslade (2001) assigning *Pachyclavularia* to *Briareum*, reduce to 5 the number of species from Utinomi's (1959) list that were not found in the present collection (i.e., *Clavularia racemosa*, *Anthelia formosana*,

Heteroxenia elisabethae, *Sinularia mayi*, and *Cladiella sphaerophora*; but excluding *Nephthea erecta*, the genus of which is not included in the present study). Sixteen species listed by Dai (1991a) were not recorded in the current survey (i.e., *Cladiella sphaerophora*, *Klyxum molle*, *K. rotundum*, *Lobophytum batarum*, *L. mirabile*, *L. solidum*, *Sarcophyton stellatum*, *S. tortuosum*, *Sinularia densa*, *S. grandilobata*, *S. halversoni*, *S. inexplicita*, *S. mayi*, *S. muralis*, *S. scabra*, and *Heteroxenia elisabethae*, as emended following Alderslade 2000). Three of these species appear in Utinomi's (1959) list but were not found in the present survey. Absence of previously recorded species (Utinomi 1959, Dai 1991a) in our survey may reflect temporal changes in soft-coral species composition due to natural or man-made perturbations occurring on Taiwanese reefs (see below). Nonetheless, our findings provide a firm indication of the high soft-coral diversity on Taiwanese reefs.

Species of the family Alcyoniidae are dominant in Nanwan Bay, with a remarkably high diversity of *Sinularia* (Table 2). The 30 species of this genus recorded in our survey place the Taiwanese reefs among other Indo-Pacific sites known for their high scores of *Sinularia* species (Ofwegen 2002). Our field observations confirmed previous findings (Dai 1991a b 1993) that on certain reefs in this region, species assemblages of this family form high living coverage of up to 60%~70% of the total surface area. They often propagate by colony fission (Figs. 30, 31) and consequently form large monospecific aggregations on reefs. Contrasting abundance patterns of the Xenidiidae in Nanwan Bay and Green I. probably reflect different environmental regimes prevailing in each of these 2 regions. Nanwan Bay suffers from occasional typhoons in summer and autumn, which the rigid colonies of the family Alcyoniidae are able to withstand (see also Dai 1988 1993). Even after severe storms, the remnants of these colonies undergo rapid regeneration, which enables them to effectively reoccupy space, and may account for their dominance on storm-swept reefs (Dai 1991b). Species of the family Xenidiidae tend to prefer more-protected reefs and calmer habitats than other soft-coral species (Y.B., pers. observ.). Due to their fast asexual propagation by runner-like stolons (Fig. 32), they can successfully exploit reef substrate, and consequently even exclude other reef dwellers (e.g., Benayahu and Loya 1987, Karlson et al. 1996). Interestingly, southern Taiwan and Green I. possess similar stony-coral distributions of both *Acropora* and *Faviidae*

species (Chen 1999) and of reef fishes (Shao et al. 1997), suggesting that soft corals of the families Alcyoniidae and Xenidae are more sensitive to the differential environmental regime around Taiwan compared to other taxa.

To date, among the soft corals, species of the family Alcyoniidae are undoubtedly the best known throughout the Indo-Pacific region, mainly due to the taxonomic revisions of the 3 most common genera of this family, *Sinularia*, *Sarcophyton*, and *Lobophytum* (Verseveldt 1980 1982b 1983). These revisions have contributed to increased knowledge of the species of the respective genera and their distributions among Indo-Pacific reefs, particularly of *Sinularia*, the largest shallow-water soft-coral genus (Ofwegen 2002 and references therein). The coral reefs of Taiwan and Japan are closely linked by the northward flowing Kuroshio Current, which brings warm water and larvae from reefs of the South China Sea and the Philippines (Fujiwara et al. 2000). Therefore, it is not surprising that Imahara (1996) established a joint octocoral list for Japan and the adjacent seas including those of Taiwan. Data obtained on the Alcyoniidae soft corals from southern Taiwan (this study) and from the southern Ryukyu Archipelago, Japan (Benayahu 1995, 2002) enabled us to compare the generic affiliations and abundance estimates within this family in the 2 regions (Table 3). In both regions, the Alcyoniidae constitute the most-dominant soft-coral component. There is a close resemblance between their respective faunas in terms of generic composition, abundance, and number of species. Furthermore, 30 species of

the Alcyoniidae are found in common in both Taiwan and the Ryukyu Archipelago. It is also interesting to note that *Sinularia higai*, which has recently been described from the southern Ryukyu Archipelago (Benayahu 2002), was also recorded in this study (Table 1, Fig. 33). Furthermore, even *Sarcophyton nanwanensis* which was recently described from southern Taiwan, is also found in Okinawa (Benayahu and Perkol-Finkel 2004). It is anticipated that similar patterns also exist for the 2 other important soft-coral families, Nephtheidae and Xenidae. A biogeographic analysis of soft corals in the West Pacific Ocean and East China Sea should undoubtedly also include the Philippines (see also Chen 1999). Only a few papers have been published on the soft corals of the latter's reefs (Ofwegen 2002), and therefore at this stage, no conclusions can be made concerning their real diversity or on the distributional patterns of the soft-coral fauna throughout the entire Philippine-Japan I. Arc. It is worthy of note that *Cladiella daphnae* was recorded in southern Taiwan (Table 1). This is the 1st record of this species away from Tanzania, which is the species type locality (Ofwegen and Benayahu 1992). Such a distributional pattern of a species, from both sides of the Indo-Pacific region, is an indication of the need for further soft-coral surveys that will determine the true range of distribution of various soft coral taxa.

The coral reefs of Taiwan increasingly suffer from man-made perturbations due to coastal construction, dredging, destructive fishing practices, coral collection, unregulated tourist activities, and anchoring (Dai 1997, Fujiwara et al. 2000, Dai et al. 2002). In addition, pollution of various types, primarily derived from a nuclear power plant in Nanwan Bay, has been considered a potential threat to the well-being of the adjacent reefs (Jan et al. 2001, Dai et al. 2002). Some of the reefs of southern Taiwan suffered from extensive bleaching during 1998 (Fig. 34), at which time coral cover was substantially reduced (Fujiwara et al. 2000). The likelihood of devastating effects occurring as a result of the above-mentioned factors threatens the biodiversity of Taiwanese reefs, and strongly necessitates the promotion of conservation and sustainable use of the reef resources there. The current high diversity of the soft corals found in this survey further reinforces the need to implement effective conservation policies and management programs in order to promote maintenance and preservation for this unique reef ecosystem.

Table 3. Number of species of the family Alcyoniidae in Taiwan (this study) and the southern Ryukyu Archipelago (Benayahu 1995 2002)

Taxa	Number of species	
	Taiwan	Southern Ryukyu Archipelago
Family Alcyoniidae		
<i>Cladiella</i>	4	4
<i>Eleutherobia</i>	1	1
<i>Klyxum</i>	1	2
<i>Lobophytum</i>	4	8
<i>Paraminabea</i>	1	-
<i>Protodendron</i>	-	1
<i>Rhytisma</i>	1	1
<i>Sarcophyton</i>	7	9
<i>Sinularia</i>	30	25
Total	49	51

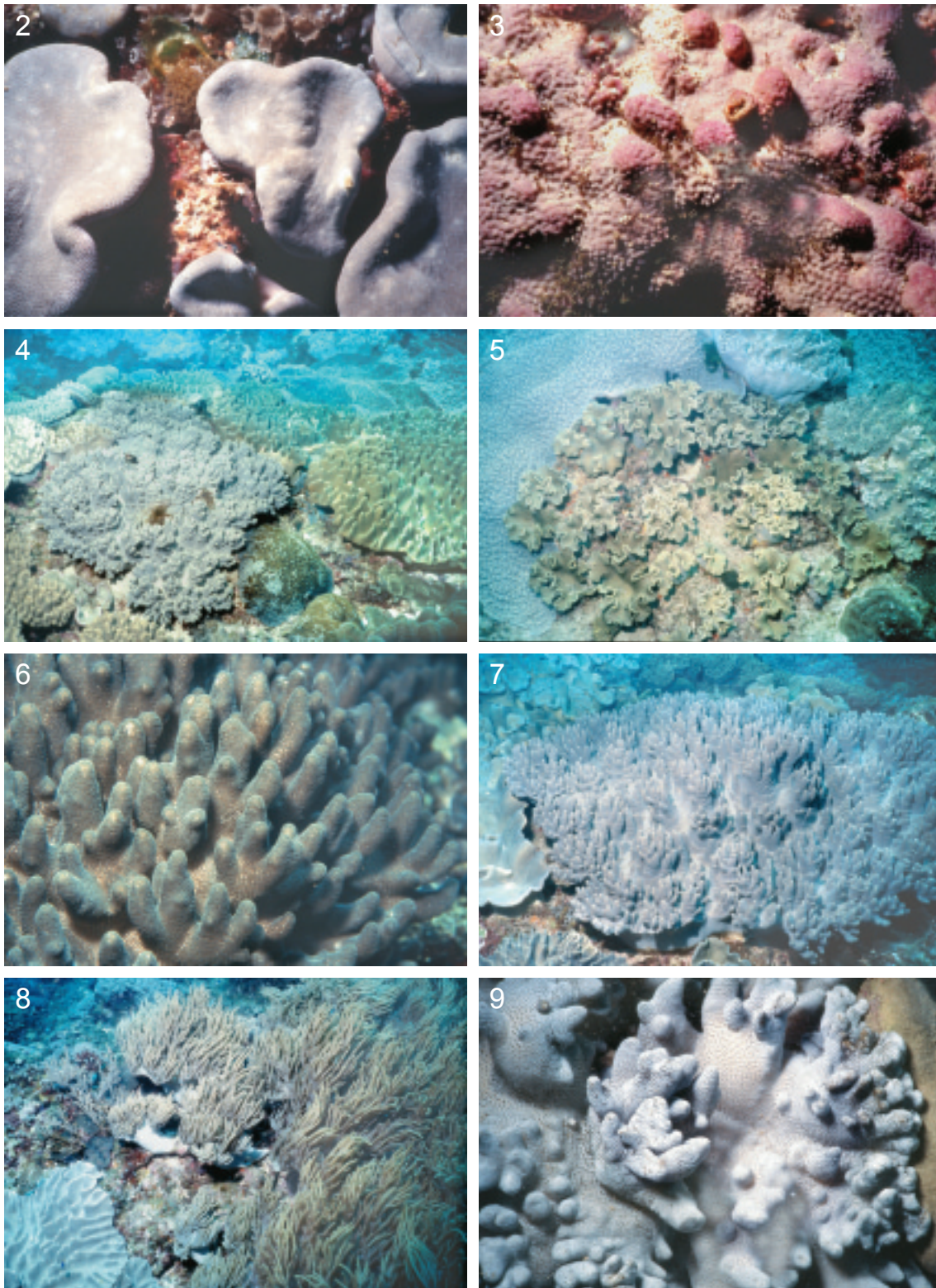


Fig. 2. *Sarcophyton crassocaule* Moser, 1919.

Fig. 4. Reef area in Nanwan Bay covered by *Sinularia* and *Lobophytum*.

Fig. 6. *Sinularia leptoclados* (Ehrenberg, 1834).

Fig. 8. Aggregations of *Sinularia flexibilis* (Quoy and Gaimard, 1833).

Fig. 3. *Briareum excavatum* (Nutting, 1911).

Fig. 5. Reef area in Nanwan Bay covered by *Sarcophyton* and *Sinularia*.

Fig. 7. *Sinularia polydactyla* (Ehrenberg, 1834).

Fig. 9. *Cladiella australis* (Macfadyen, 1936).

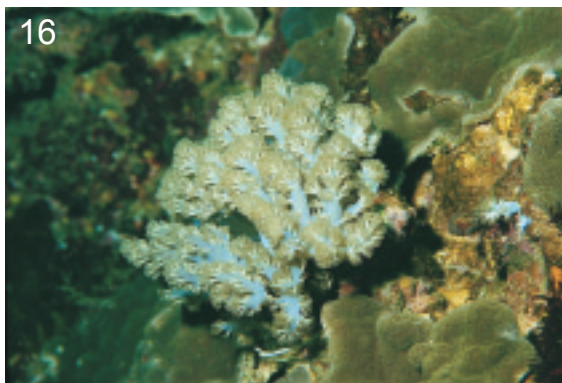
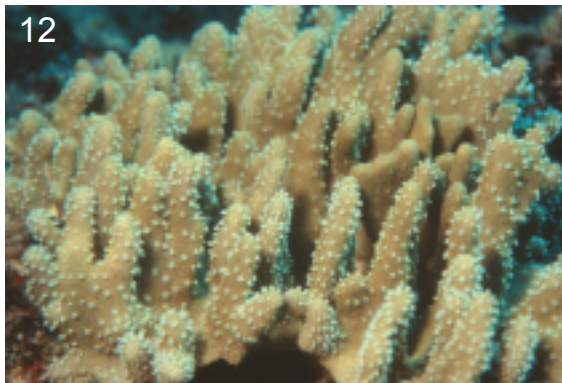


Fig. 10. *Klyxum simplex* (Thomson and Dean, 1931).

Fig. 12. *Lobophytum pauciflorum* (Ehrenberg, 1834).

Fig. 14. *Sarcophyton glaucum* (Quoy and Gaimard, 1833).

Fig. 16. *Cespitularia caerulea* May, 1898.

Fig. 11. *Lobophytum crassum* von Marenzeller, 1886.

Fig. 13. *Sarcophyton ehrenbergi* von Marenzeller, 1886.

Fig. 15. *Sarcophyton infundibuliforme* Tixier-Durivault, 1958.

Fig. 17. *Anthelia glauca* Lamarck, 1816.

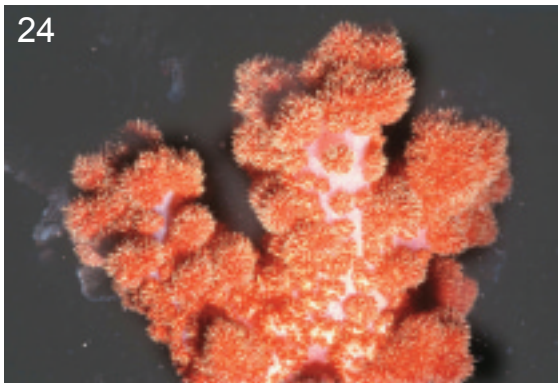
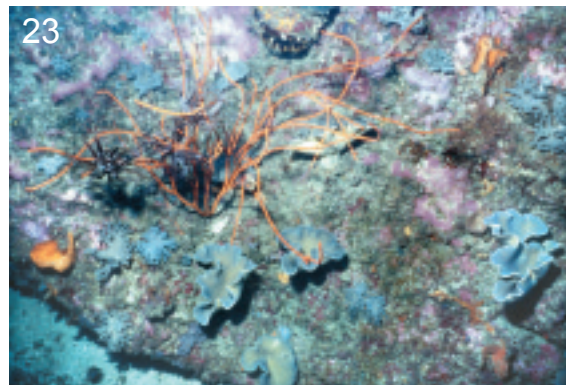
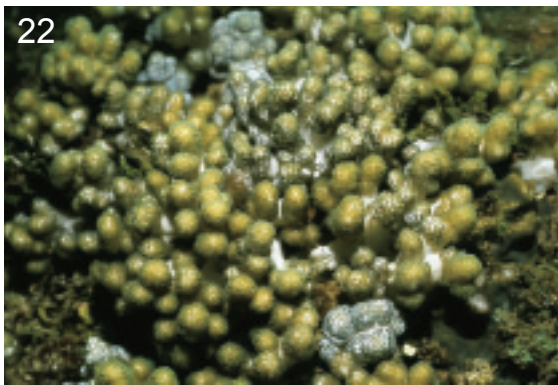
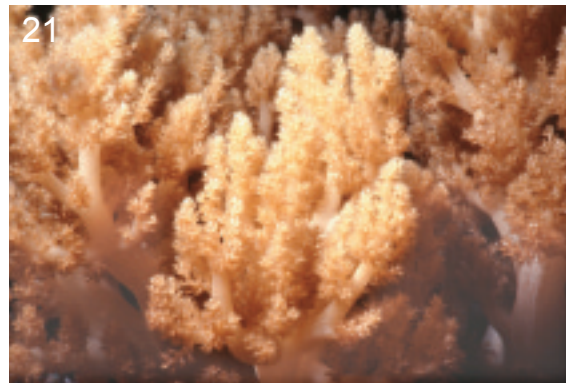
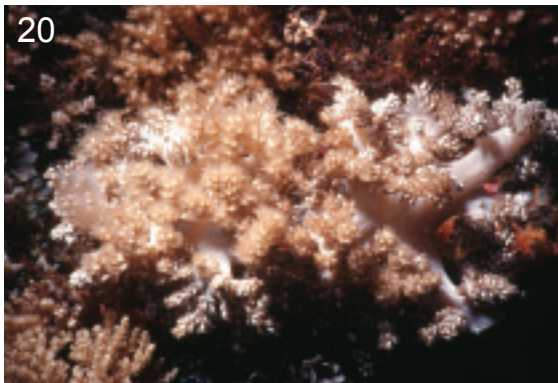
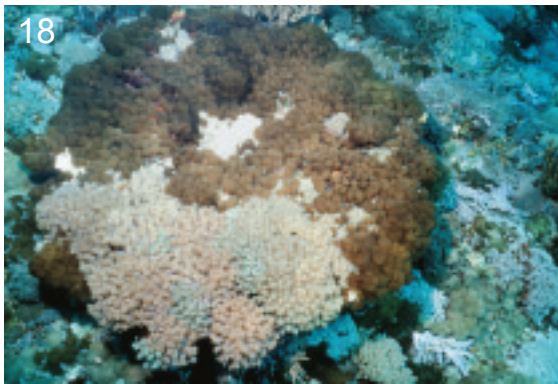


Fig. 18. Assemblages of Xeniidae on reefs on the western side of Green I.

Fig. 20. *Capnella fungiformis* Kükenthal, 1904.

Fig. 22. *Astrospicularia laurae* Utinomi, 1951.

Fig. 24. *Dendronephthya* sp. from the deep reef of Nanwan Bay.

Fig. 19. *Clavularia inflata* Schenk, 1896.

Fig. 21. *Lemnalia flava* (May, 1898).

Fig. 23. Deep reef habitat of Nanwan Bay (at “Sea Mount”) with colonies of Alcyoniidae.

Fig. 25. *Chironephthya* sp. from the deep reef of Nanwan Bay.

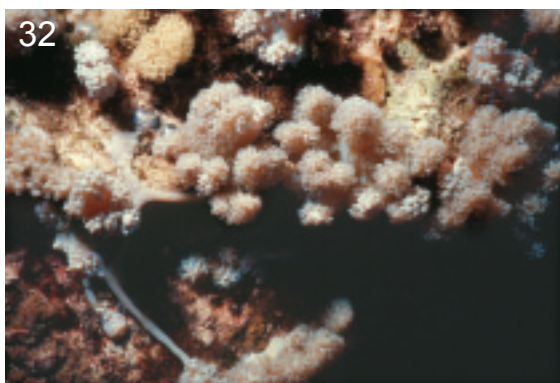
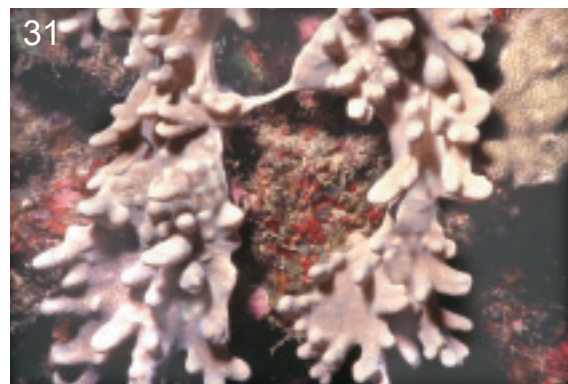
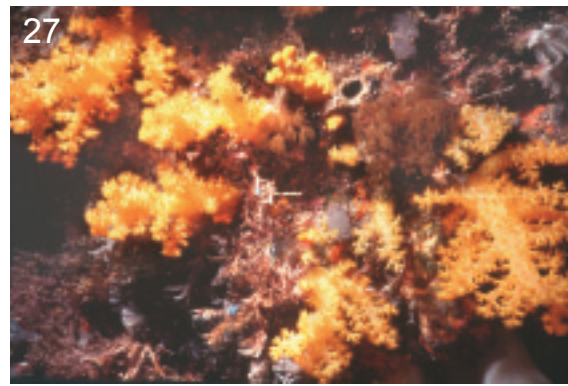


Fig. 26. *Eleutherobia grayi* (Thomson and Dean, 1931) with polyps expanded.

Fig. 28. Aggregations of *Scleronephthya gracillimum* (Kükenthal, 1906) growing on a reef overhang.

Fig. 30. Fission of a *Sinularia* colony.

Fig. 32. Asexual propagation by runner-like stolons of *Cespitularia*.

Fig. 27. *Scleronephthya gracillimum* (Kükenthal, 1906) with polyps expanded.

Fig. 29. Aggregations of *Scleronephthya gracillimum* (Kükenthal, 1906) growing beneath colonies of the stony coral *Acropora*.

Fig. 31. Fission of a *Sinularia* colony.

Fig. 33. *Sinularia higai* Benayahu, 2002.

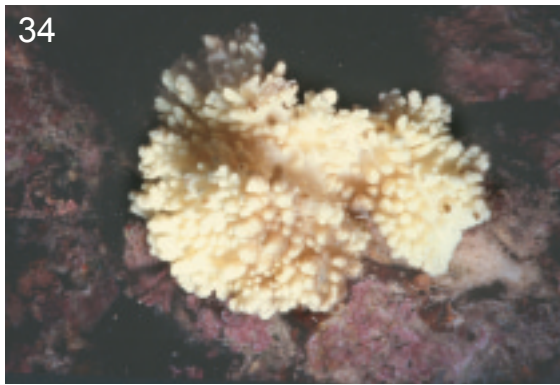


Fig. 34. Bleached colony of *Sinularia* sp. in Nanwan Bay.

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