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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 offshore 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, Xeniidae, Asterospiculariidae, 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-

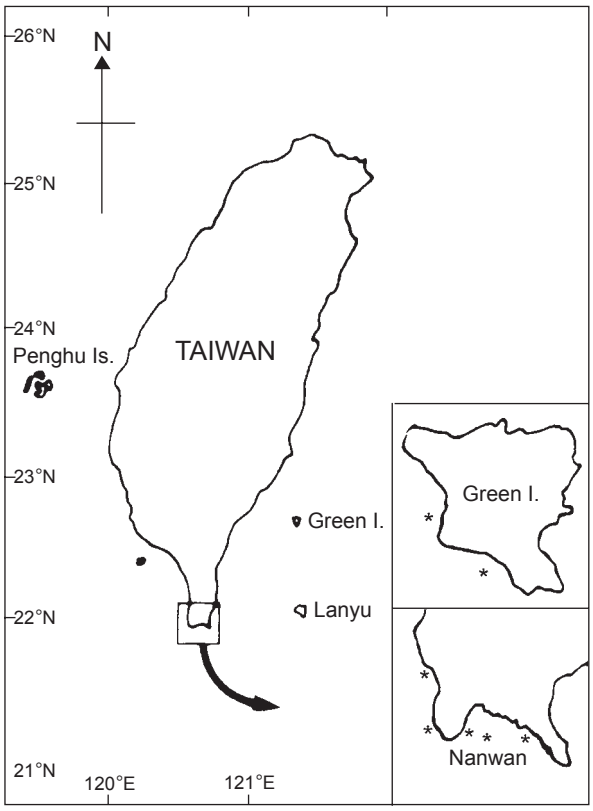

Fig. 1. Map of Taiwan with study sites indicated by asterisks.

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

Table 1. (Cont.)

Classification	References
ZMTAU Co 29171, 29176, 29178, 30247	
Genus *Sinularia* May, 1898	
Sinularia brassica May, 1898*	NR
ZMTAU Co 28926, 30193, 30233	
Sinularia compacta Tixier-Durivault, 1970	NR
ZMTAU Co 30229	
Sinularia compressa Tixier-Durivault, 1945*	NR
ZMTAU Co 28940	
Sinularia discrepans Tixier-Durivault, 1970	NR
ZMTAU Co 28941	
Sinularia dissecta Tixier-Durivault, 1945	NR
ZMTAU Co 30236	
Sinularia erecta Tixier-Durivault, 1945*	NR
ZMTAU Co 30187, 30208, 30225	
Sinularia exilis Tixier-Durivault, 1970	2
ZMTAU Co 30217	
Sinularia facile Tixier-Durivault, 1970	2
ZMTAU Co 30200	
Sinularia flexibilis (Quoy & Gaimard, 1833)*	2
ZMTAU Co 28923, 28927, 30191, 30209, 30262	
Sinularia gibberosa Tixier-Durivault, 1970*	2
ZMTAU Co 28930, 28938, 28939, 30190	
Sinularia granosa Tixier-Durivault, 1970	2
ZMTAU Co 30192, 30214, 30285	
Sinularia grayi Tixier-Durivault, 1945	NR
ZMTAU Co 28925	
Sinularia higai Benayahu, 2002*	NR
ZMTAU Co 30227	
Sinularia humesi Verseveldt, 1968*	NR
ZMTAU Co 30206	
Sinularia intacta Tixier-Durivault, 1970	NR
ZMTAU Co 30216	
Sinularia leptoclados (Ehrenberg, 1834)*	NR
ZMTAU Co 28922, 28933, 28936, 28947, 30198, 30189, 30205, 30210, 30221, 30228, 30234, 30235	
Sinularia lochmodes Kolonko, 1926*	2
ZMTAU Co 28944, 28945, 30194, 30196	
Sinularia manaarensis Verseveldt, 1980	NR
ZMTAU Co 28935, 30212	
Sinularia maxima Verseveldt, 1971	NR
ZMTAU Co 30232	
Sinularia mollis Kolonko, 1926*	2
ZMTAU Co 28931, 28946	
Sinularia nanolobata Verseveldt, 1977	NR
ZMTAU Co 30224	
Sinularia notanda Tixier-Durivault, 1966	NR
ZMTAU Co 28928, 28929, 30213	
Sinularia numerosa Tixier-Durivault, 1970*	2
ZMTAU Co 30197, 30202, 30226, 30230	
Sinularia ovispiculata Tixier-Durivault, 1970*	NR
ZMTAU Co 28943	
Sinularia polydactyla (Ehrenberg, 1834)*	1, 2
ZMTAU Co 30335	
Sinularia querciformis (Pratt, 1903)*	NR
ZMTAU Co 28913, 28919, 30199, 30207, 30218	
Sinularia rigida (Dana, 1846)	NR
ZMTAU Co 28934	
Sinularia triangula Tixier-Durivault, 1970	NR
ZMTAU Co 30203, 30337	
Sinularia variabilis Tixier-Durivault, 1945*	NR
ZMTAU Co 28942, 30204, 30182, 30215, 30222, 30231	
Nephtheidae Gray, 1862	
Genus *Capnella* Gray, 1869	
Capnella fungiformis Kükenthal, 1904	NR
ZMTAU Co 28911, 28893, 28894	
Genus Lemnalia Gray, 1868	
Lemnalia flava (May, 1898)	NR
ZMTAU Co 28909	
Genus *Paralemnalia* Kükenthal, 1913	
Paralemnalia thyrsoides (Ehrenberg, 1834)	1, 2
ZMTAU Co 28905, 28906	
Genus *Scleronephthya* Studer, 1887	
Scleronephthya gracillimum (Kükenthal, 1906)	NR
ZMTAU Co 29196, 29199	
Xeniidae Ehrenberg, 1828	
Genus *Anthelia* Lamarck, 1816	
Anthelia glauca Lamarck, 1816	NR
ZMTAU Co 28883, 28888	
Genus *Asterospicularia* Utinomi, 1951	
Asterospicularia laurae Utinomi, 1951	
ZMTAU Co 32318	
Genus *Cespitularia* Milne-Edwards, 1857	
Cespitularia caerulea May, 1898	NR
ZMTAU Co 28886, 28877, 28880	
Cespitularia stolonifera Gohar, 1938	1, 2
ZMTAU Co 30277	
Genus *Heteroxenia* Kölliker, 1874	
Heteroxenia medioensis Roxas, 1933	NR
ZMTAU Co 30266	
Heteroxenia pinnata Roxas, 1933	NR
ZMTAU Co 28878	
Genus *Sansibia* Aldersalde, 2000	
Sansibia flava (May, 1899)	NR
ZMTAU Co 28881, 28884, 28892, 30269	
Genus *Xenia* Lammarck, 1816	
Xenia hicksoni Ashworth, 1899	NR
ZMTAU Co 28890	
Xenia kükenthali Roxas, 1993	NR
ZMTAU Co 28889, 28891	
Xenia lillieae Roxas, 1933 NR	
ZMTAU Co 30259	
Xenia puerto-galerae Roxas, 1933 NR	
ZMTAU Co 28882	
Briareidae Blainville, 1830	
Genus *Briareum* Blainville, 1830	
Briareum excavatum (Nutting, 1911)	NR
ZMTAU Co 28784, 29194, 29195, 30249, 30265, 30283	
Briareum violacea (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 Xeniidae 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 Xeniidae, including *Clavularia inflata* (Fig. 19), *Capnella fungiformis* (Fig. 20), *Lemnalia flava* (Fig. 21), and *Paralemnalia thyrsoides*. None of the 4 latter species was found in Nanwan Bay. In contrast, species of the family Xeniidae 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 Xeniidae (see Alderslade 2001) has rarely been found in Nanwan Bay.

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				
Heliopora	1	-	Sporadic	-
Family Clavulariidae				
Clavularia	-	1	-	Rare
Family Tubiporidae				
Tubipora	1	1	Rare	Rare
Family Alcyoniidae				
Cladiella	4	-	Sporadic	-
Eleutherobia	1	-	Rare	-
Klyxum	1	-	Sporadic	-
Lobophytum	4	1	Abundant	Rare
Paraminabea	1	1	Rare	Rare
Rhytisma	-	1	-	Rare
Sarcophyton	7	2	Abundant	Sporadic
Sinularia	30	-	Dominant	-
Family Nephtheidae				
Capnella	-	1	-	Rare
Lemnalia	-	1	-	Rare
Paralemnalia	-	1	-	Sporadic
Scleronephthya	-	1		Sporadic
Family Xeniidae				
Anthelia	-	1	-	Rare
Asterospicularia	1	-	Rare	-
Cespitularia	1	1	Rare	Dominant
Heteroxenia	1	1	Rare	Rare
Sansibia	1	1	Sporadic	Sporadic
Xenia	1	3	Rare	Dominant
Family Briareidae				
Briareum	2	1	Sporadic	Sporadic
Total	57	19		

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

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, Xeniidae, 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 (*Sarcopyhton 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 Xeniidae (Alderslade 2001). Emendations following the taxonomic revision by Verseveldt (1982b) of *Sarcophyton* and assessments by Fabricius and Alderslade (2001) assigning *Pachycalvularia* 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*, *Lobophtum 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 Xeniidae 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 Xeniidae 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 Xeniidae 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 *Sarcophytom 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 Xeniidae. 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.

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		
Cladiella	4	4
Eleutherobia	1	1
Klyxum	1	2
Lobophytum	4	8
Paraminabea	1	-
Protodendron	-	1
Rhytisma	1	1
Sarcophyton	7	9
Sinularia	30	25
Total	49	51

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.

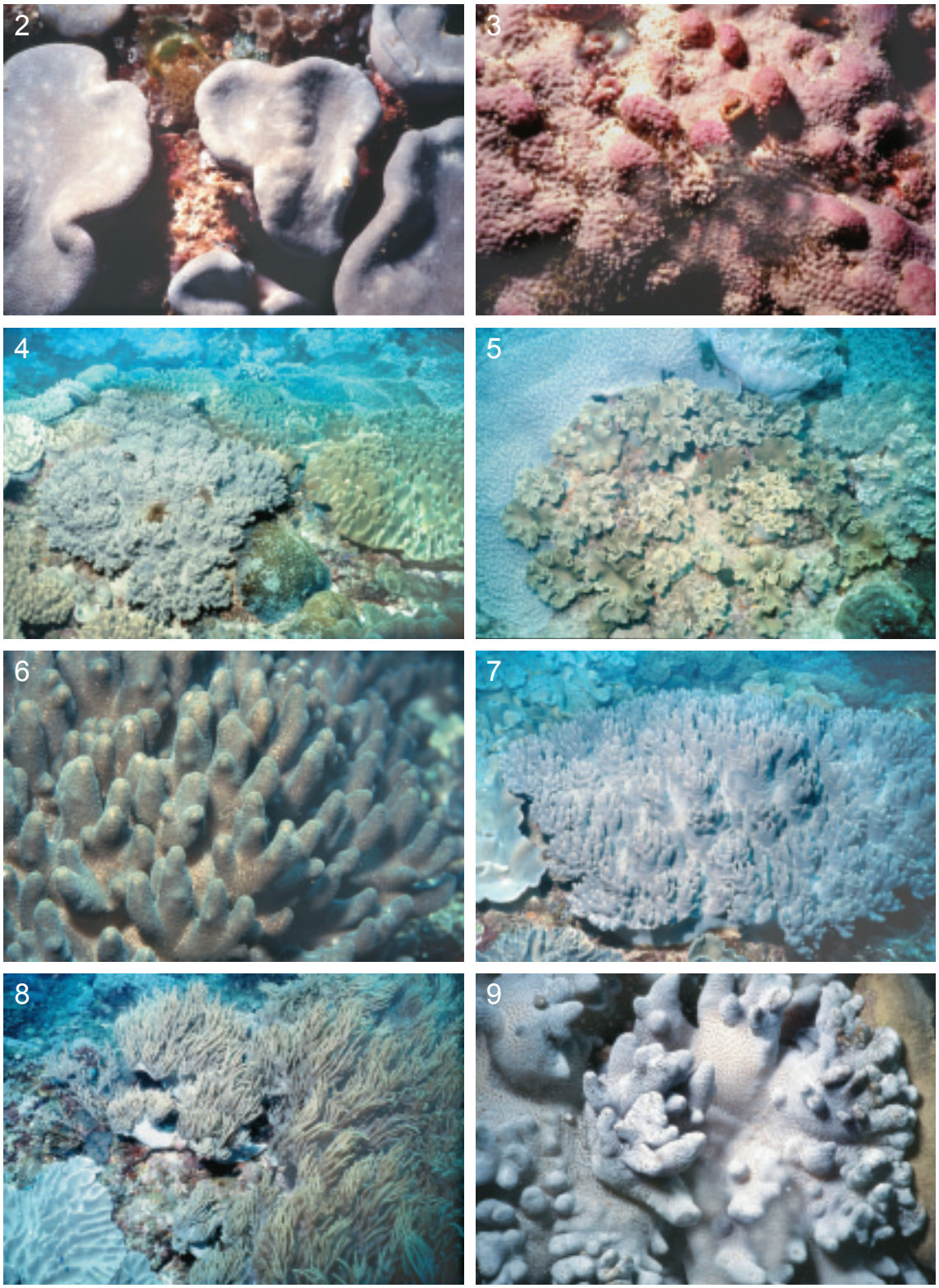

Fig. 2. *Sarcophyton crassocaule* Moser, 1919.
Fig. 3. *Briareum excavatum* (Nutting, 1911).
Fig. 4. Reef area in Nanwan Bay covered by *Sinularia* and *Lobophytum*.
Fig. 5. Reef area in Nanwan Bay covered by *Sarcophyton* and *Sinularia*.
Fig. 6. *Sinularia leptoclados* (Ehrenberg, 1834).
Fig. 7. *Sinularia polydactyla* (Ehrenberg, 1834).
Fig. 8. Aggregations of *Sinularia flexibilis* (Quoy and Gaimard, 1833).
Fig. 9. *Cladiella australis* (Macfadyen, 1936).

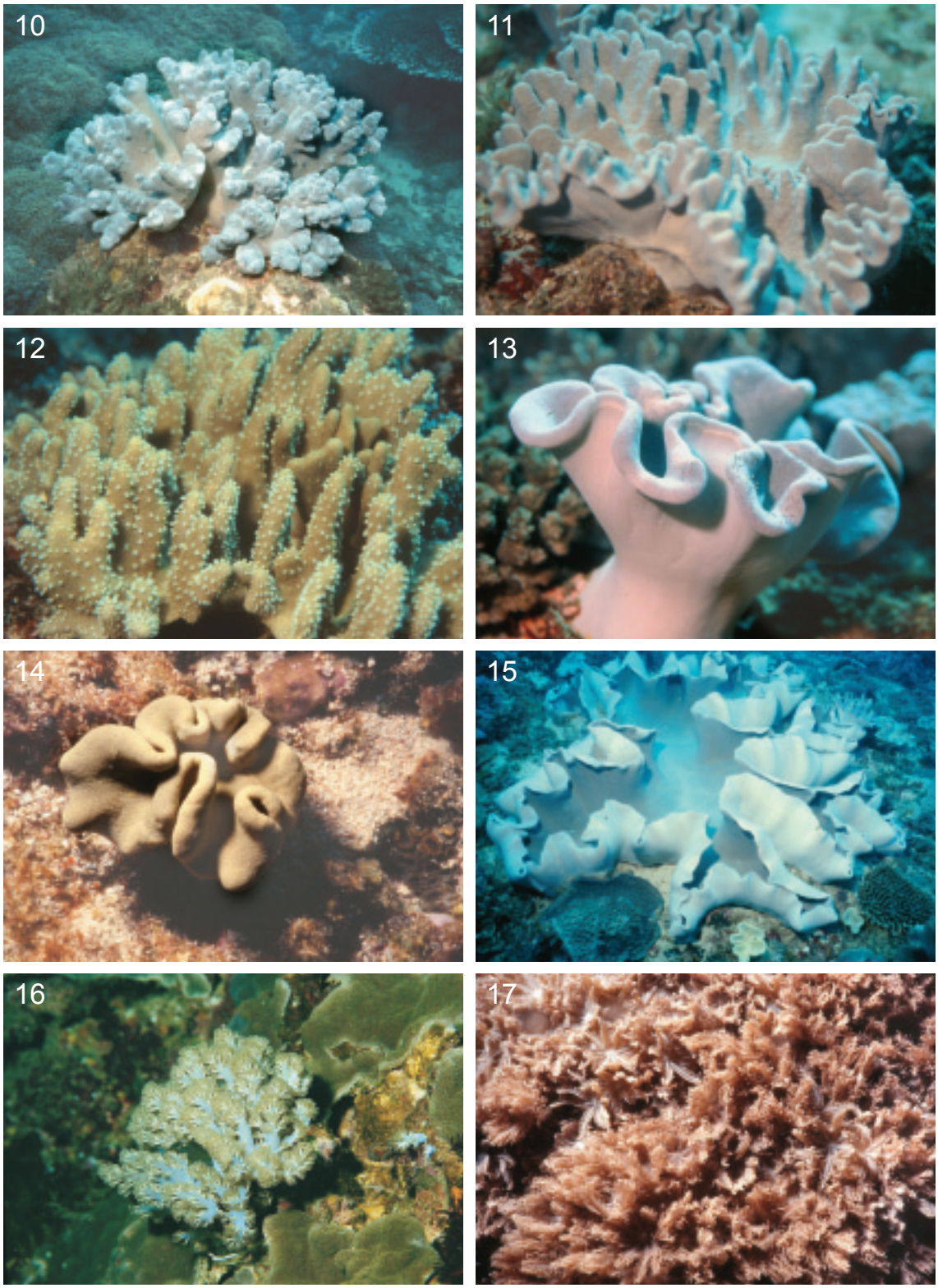

Fig. 10. *Klyxum simplex* (Thomson and Dean, 1931).
Fig. 11. *Lobophytum crassum* von Marenzeller, 1886.
Fig. 12. *Lobophytum pauciflorum* (Ehrenberg, 1834).
Fig. 13. *Sarcophyton ehrenbergi* von Marenzeller, 1886.
Fig. 14. *Sarcophyton glaucum* (Quoy and Gaimard, 1833).
Fig. 15. *Sarcophyton infundibuliforme* Tixier-Durivault, 1958.
Fig. 16. *Cespitularia caerulea* May, 1898.
Fig. 17. *Anthelia glauca* Lamarck, 1816.

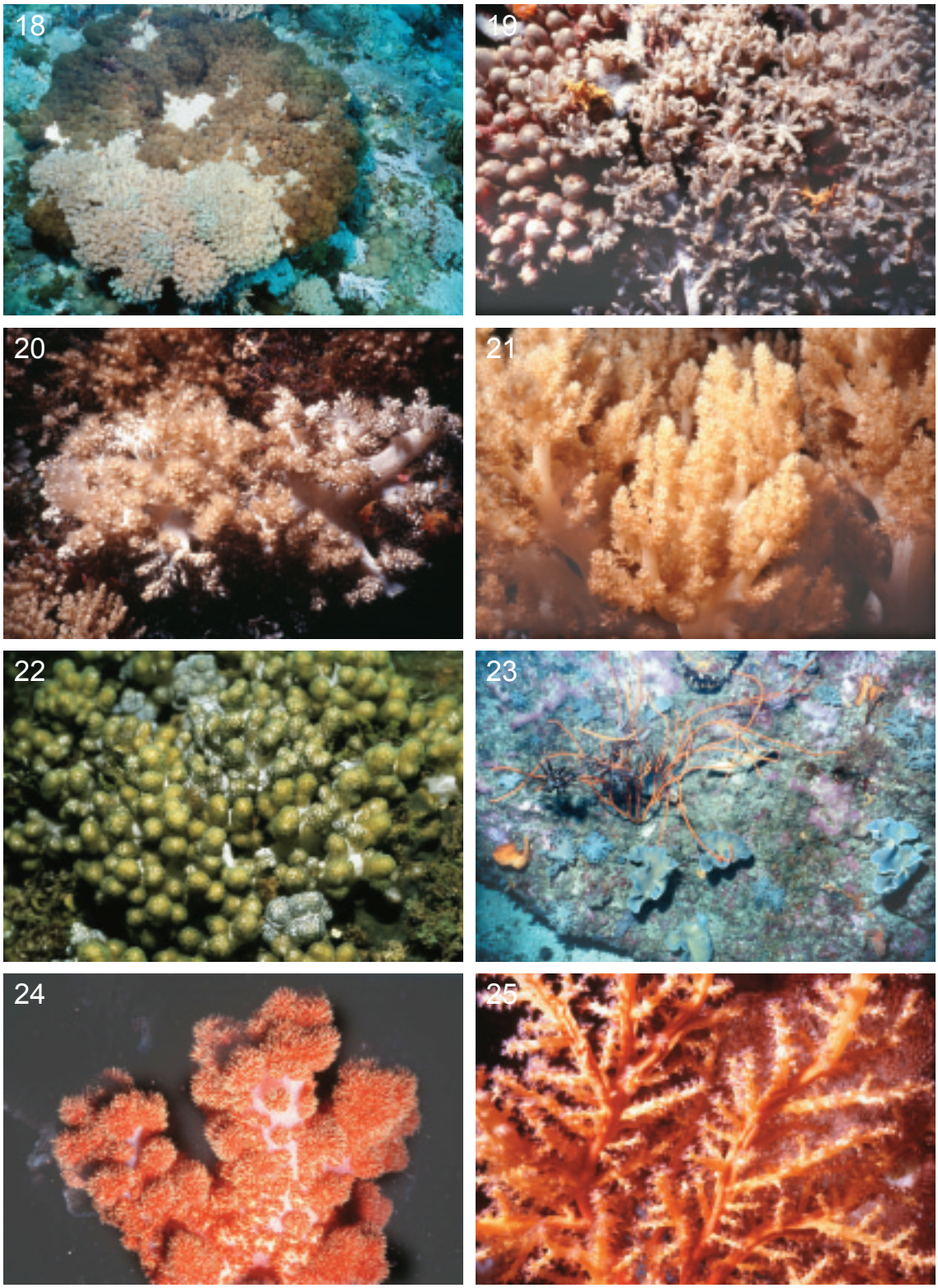

Fig. 18. Assemblages of Xeniidae on reefs on the western side of Green I.
Fig. 19. *Clavularia inflata* Schenk, 1896.
Fig. 20. *Capnella fungiformis* Kükenthal, 1904.
Fig. 21. *Lemnalia flava* (May, 1898).
Fig. 22. *Asterospicularia laurae* Utinomi, 1951.
Fig. 23. Deep reef habitat of Nanwan Bay (at "Sea Mount") with colonies of Alcyoniidae.
Fig. 24. *Dendronephthya* sp. from the deep reef of Nanwan Bay.
Fig. 25. *Chironephthya* sp. from the deep reef of Nanwan Bay.

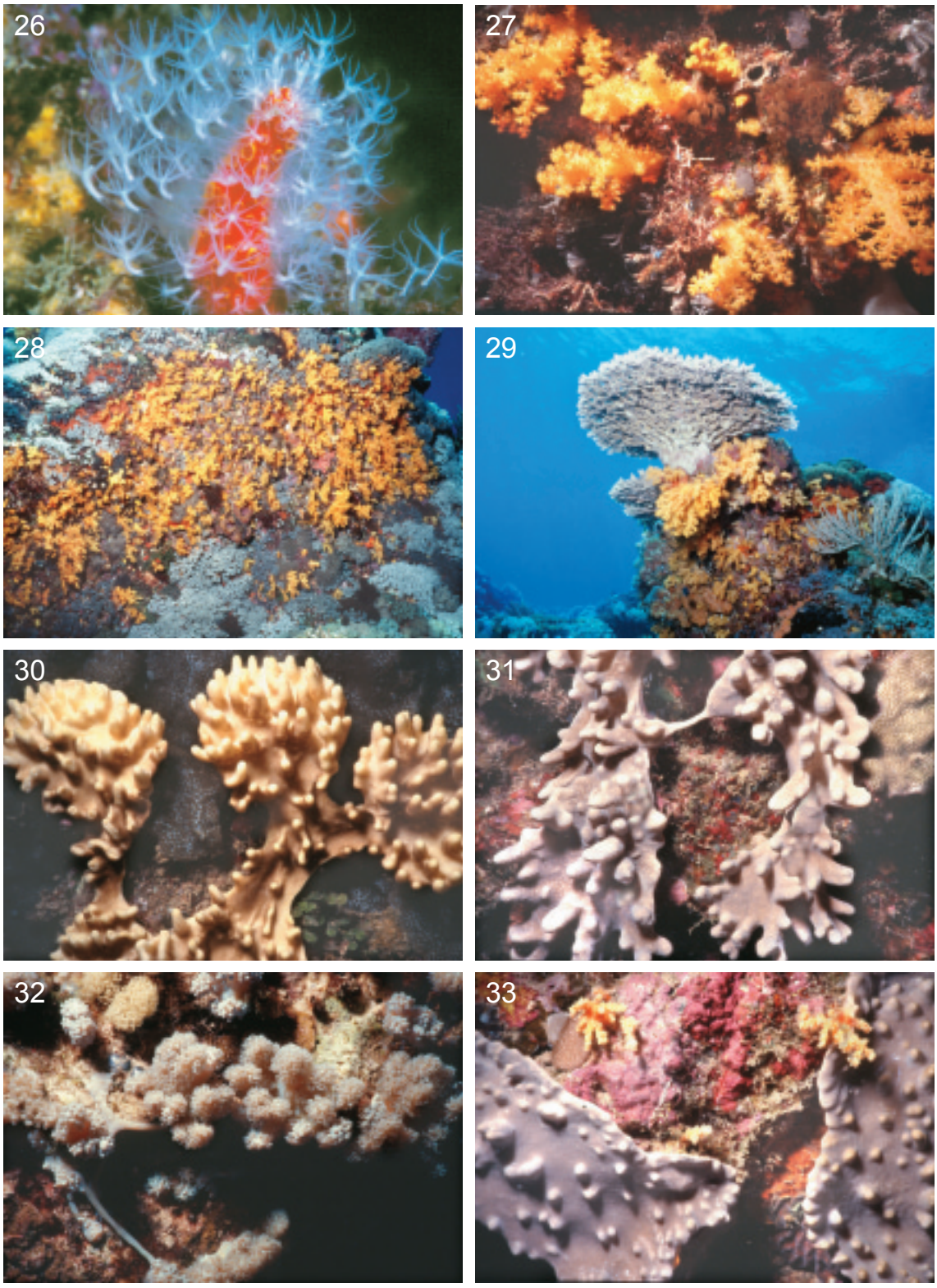

Fig. 26. *Eleutherobia grayi* (Thomson and Dean, 1931) with polyps expanded.
Fig. 27. *Scleronephthya gracillimum* (Kükenthal, 1906) with polyps expanded.
Fig. 28. Aggregations of *Scleronephthya gracillimum* (Kükenthal, 1906) growing on a reef overhang.
Fig. 29. Aggregations of *Scleronephthya gracillimum* (Kükenthal, 1906) growing beneath colonies of the stony coral *Acropora*.
Fig. 30. Fission of a *Sinularia* colony.
Fig. 31. Fission of a *Sinularia* colony.
Fig. 32. Asexual propagation by runner-like stolons of *Cespitularia*.
Fig. 33. *Sinularia higai* Benayahu, 2002.

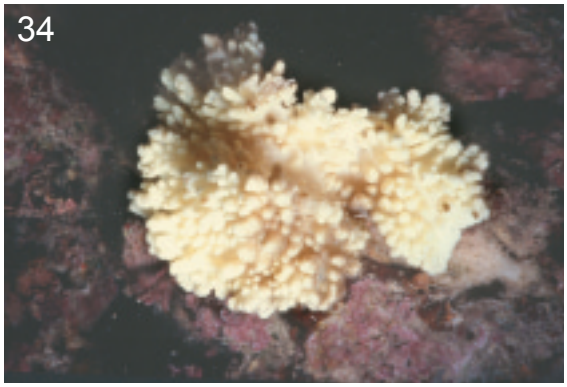

Fig. 34. Bleached colony of *Sinularia* sp. in Nanwan Bay.

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