Zoological Studies **48**(4): 448-459 (2009)

Zoological Studies

Temporal Changes in Nudibranch Composition at a Coastal Site off Penghu (the Pescadores) in the Taiwan Strait

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(Accepted November 25, 2008)

Yeng Su, Li-Jin Huang, Yen-Wei Chang, and Hin-Kiu Mok (2009) Temporal changes in nudibranch composition at a coastal site off Penghu (the Pescadores) in the Taiwan Strait. *Zoological Studies* **48**(4): 448-459. In total, 74 nominal species and 7 possible new species of sea slugs were recorded at a site off the coast of Wai-an in Penghu (the Pescadores) in the Taiwan Strait from 20 survey dives (including 17 monthly surveys). The Chromodorididae and Phyllidiidae were the 2 most-speciose families. The mean number of species sighted per monthly survey was 12. The increase in new species recorded reached a plateau at the 18th survey. The number of families recorded per survey ranged 2-9. High nudibranch species diversity is a site-specific attribute of Wai-an. Except for 1 survey, no species at this site were considered dominant in terms of the abundance of individuals. Similarities in species composition for pair-wise monthly samples were low. No obvious trends in temporal changes in the number of species or species composition were noted.
http://zoolstud.sinica.edu.tw/Journals/48.4/448.pdf

Key words: Nudibranch, Biodiversity, Penghu.

Nudibranchs are shell-less gastropods. Their diverse color patterns, high diet specificity, and mechanical and chemical defensive attributes have rendered them photographic and research targets for underwater photographers, marine biologists, and biotechnologists. In addition some chemical compounds with potential pharmaceutical applications have been discovered from them (e.g., from the arminacean nudibranch *Leminda millecra*; Whibley et al. 2007). There are about 3000 species of nudibranchs worldwide (e.g., Wägele and Willan 2000), and they are classified into 4 suborders and 41 families according to the Sea Slug Forum (http://www.seaslugforum.net/specieslist.cfm): Doridina, 14 families; Aeolidina, 10 families; Arminina, 7 families; and Dentronotina, 10 families.

For example, about 235, 193, 279, and 127 species have respectively been recorded in western Australia, the South China Sea region, Okinawa, and Korea (Sachidhanandam et al. 2000, Ono 2004, Cobb and Willan 2006, Dong 2006). Gosliner (1992) and Gosliner and Drahein (1996) commented on and gave an overview of the diversity and biogeography of the Indo-Pacific opisthobranch fauna. Nevertheless, only scattered information on sea slugs from Taiwanese regions is available (e.g., Lou 1985, Tan et al. 1987, Chang 2006, Huang 2006, Jie 2008). Therefore, a systematic survey of these animals in Taiwan and associated islands (including Penghu (the Pescadores) to the west in the Taiwan Strait, Green I. (Ludao) and Orchid I. (Lanyu) to the southeast in the West Pacific, Liu-Chiu-Yu to the southwest in the South China Sea, and the Matsu and Kinmen (Quemoy) island groups adjacent to the southeastern Chinese coast in the Taiwan Strait) was carried out, and we focus our attention in the

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present paper on Penghu, close to the midline of the Taiwan Strait.

Nybakken (1978) conducted a 40 mo study of a nudibranch assemblage in an intertidal area of the Pacific coast of North America, and he found that 9 species, comprising 87% of the total number of individuals, shared dominance. The composition of the assemblage was stable, and there was no significant seasonal change. Most importantly, he found that a stable nudibranch assemblage was not merely a local phenomenon but a general one. Whether this generalization can be applied to a subtidal nudibranch assemblage remains to be seen as no data along this line are presently available.

The aims of this study at a site off Wai-an were (1) to confirm that this high species diversity attribute is not an occasional case, (2) to decipher temporal changes in species composition, (3) to estimate the rate of sightings of new records of species at this particular site, and (4) to look for any clear trend in temporal changes in the assemblage parameters.

MATERIALS AND METHODS

Study site and methods

Between Sept. 2004 and Dec. 2005, we conducted 2 general surveys at a total of 62 sites in the above-mentioned areas of Taiwan: Penghu (10 sites), Green I. (7 sites), Orchid I. (7 sites), Liu-Chiu-Yu (8 sites), northeastern Taiwan, (10 sites), and Nan-wan at the southern tip of Taiwan (20 sites; Fig. 1; Huang 2006). Among them, Wai-an in Penghu (Fig. 1) was the site with the highest number of species sighted during the 2 h search by 2 observers. Penghu, located close to the midline of the Taiwan Strait (Fig. 1), has an area of 127 km^2, and 320 km of coastline. We became interested in this site, and a monthly sampling began from Aug. 2006 to Dec. 2007.

The site off Wai-an is located at 22°33.70'N, 119°28.77'E (Fig. 1), and is about 10 m in depth. The general characteristics of the seafloor was rocky reef with encrusted reefs and coral patches (Fig. 2). The searched area was 30 x 30 m. Dongshih (23°26'39"N, 120°08'27"E) is the closest site to Wai-an where data on monthly sea surface temperature were available from the Central Weather Bureau (Fig. 3), and these data were used to represent the study site. As freshwater outflow is not present in this part of Penghu, the salinity fluctuated insignificantly from that of normal seawater. Two consecutive 1 h dives

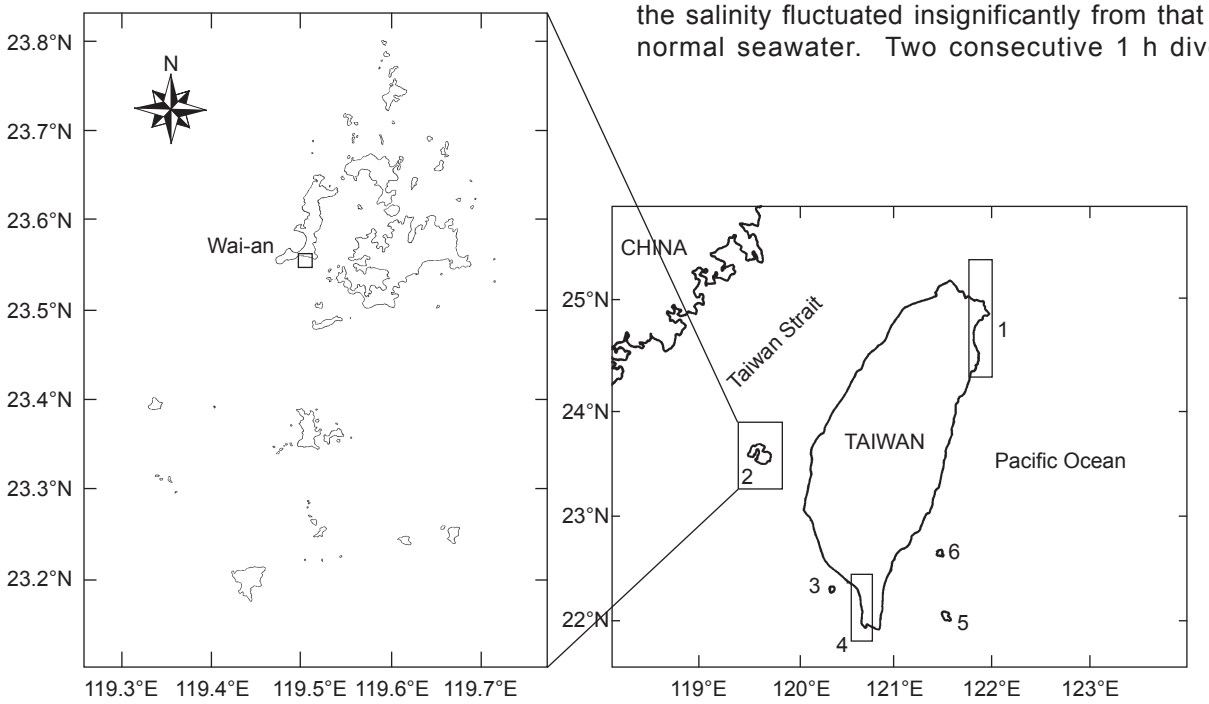

Fig. 1. Locations of the general survey areas in Taiwan and adjacent islands. **1:** Northeast coast; **2:** Penghu (the Pescadores); **3:** Liu-Chiu-Yu; **4:** Kenting and the Hengchun Peninsula; **5:** Orchid I. (Lanyu); **6:** Green I. (Ludao). The map on the left shows the location of Wai-an (22°33.70'N, 119°28.77'E) in Penghu.

were made during daytime on 1 d every month between Aug. 2006 and Dec. 2007. The 1st and 2nd authors together with 2 other divers took part in the field collections. All collecting dives were made by 3 divers from the same group and led by the 1st author. Divers searched the substrate along a straight path parallel to each other with a narrow overlapping search area between 2 adjacent divers. Divers looked for sea slugs on the substrate, on rocks, and inside crevices and only collected those nudibranch specimens sighted by them without disturbing the substrate. Species from these 2 dives were pooled to represent the composition of the survey. Specimens were identified to species using 3 guide books, *Opisthobranchs of Ryukyu Is*. (Ono 2004), *Undersea jewels. A colour guide to nudibranchs* (Cobb and Willan 2006), and *Sea slugs of Korea* (Dong 2006), and information from the sea slug forum (http://www.seaslugforum.net/). Photos of uncertain and possibly new species were sent to a nudibranch specialist to confirm the identification.

A photographic record of each nudibranch species seen in the field was made, and specimens were collected. Photos of the specimens were taken at the laboratory, and then specimens were preserved in 95% ethanol.

Numerical analysis

Species diversity of the sea slug assemblage from each survey was deciphered by the following community indices: Shannon's equitability (E_H) was calculated by dividing Shannon's diversity index (H) by H_{max} (H_{max} = ln S; where S is the total number of species in the assemblage; H_{max} quantifies the

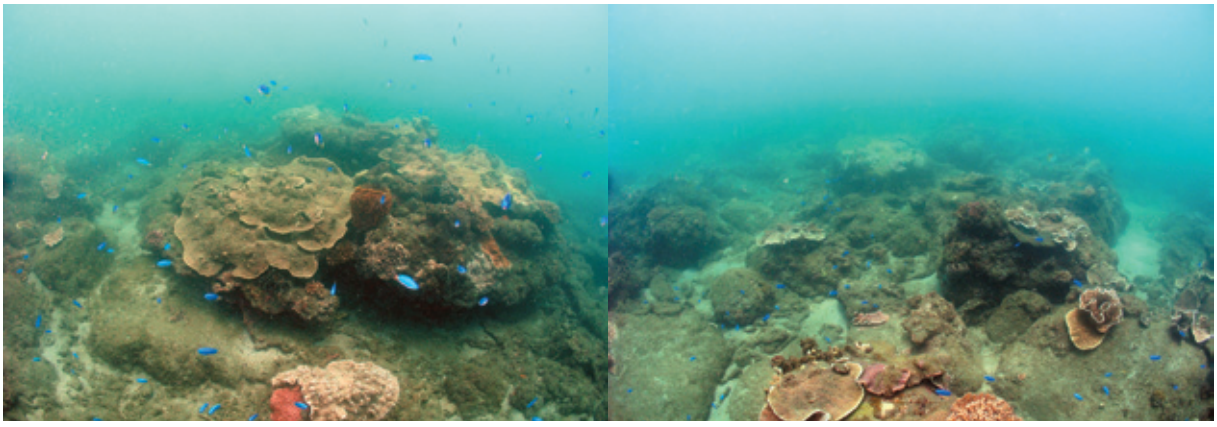

Fig. 2. Photographs showing the habitats of sampling sites at Wai-an.

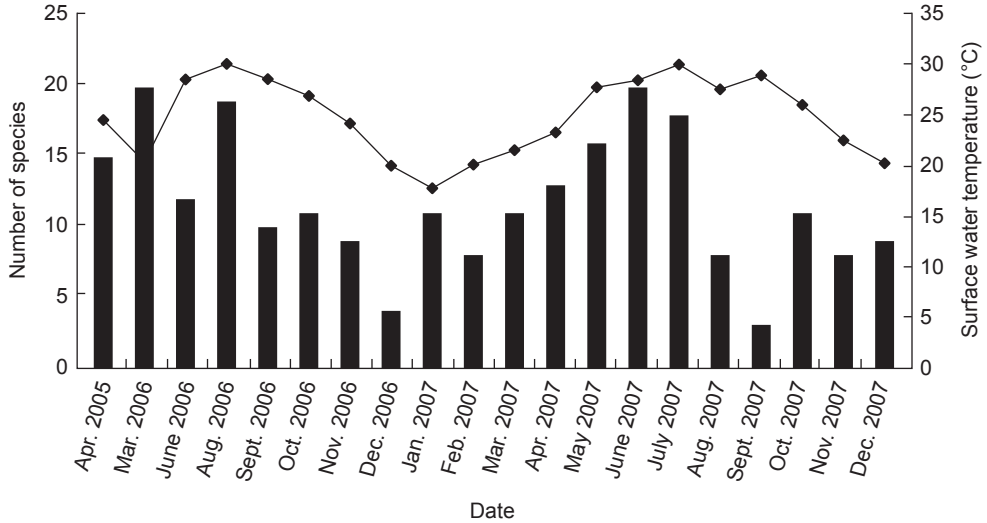

Fig. 3. Number of species and surface water temperature for each survey. Mean = 11.8 (12); range: 3-20. Samples in Apr. 2005, and Mar. and June 2006, were collected by 2 and the other samples were collected by 3 divers.

maximum diversity of the assemblage). Equitability assumes a value between 0 and 1, with 1 being complete evenness.

$H = -\Sigma p_i \ln p_i$;
$E_H = H/H_{max} = H/\ln S$; and
R (redundancy) = 1 - E_H.

Between-sample (or between-visit) similarities in species composition were estimated using the Jaccard coefficient, and a dendrogram was constructed by the unweighted pair-group clustering method using arithmetic averages (UPGMA clustering method; Romesburg 1984) using the Primer 6.0 software package (Clarke et al. 2006).

RESULTS

The 1st survey dive at Wai-an was made in Apr. 2005, for which 15 nudibranch species were recorded (Table 1, Fig. 3), and the 2nd dive was made in Mar. 2006 with 20 recorded species (Fig. 3). The mean number of species sighted per monthly survey was 12 species (range, 3-20 species; Fig. 3). The average monthly increment of new record of species was 4 (range, 0-15 species; Fig. 4), and this number decreased with time (i.e., with visits; Fig. 4). Increments in the

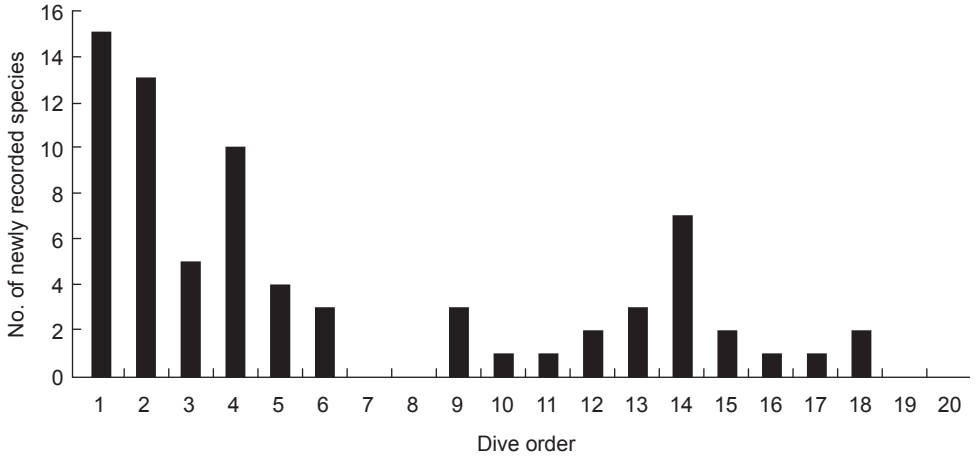

Fig. 4. Number of newly recorded species in each survey. Mean, 3.65 (4); range, 0-15.

Table. 1. Matrices of species composition data for the 20 surveys from the site off Wai-an, with species number and diversity indices

Families	Species	Source (NSYSUIN)	Apr. 2005	Mar. 2006	June 2006	Aug. 2006	Sept. 2006	Oct. 2006	Nov. 2006	Dec. 2006	Jan. 2007	Feb. 2007
Chromodorididae	*Cadlinella ornatissima*	No.284	1	0	0	0	0	0	0	0	0	0
	Ceratosoma tenue	No.306	0	0	0	1	0	0	0	0	0	0
	Chromodoris albonares	No.323	0	0	1	1	0	0	0	0	0	0
	Chromodoris fidelis	No.454	0	1	0	0	0	0	0	0	0	0
	Chromodoris geometrica	No.662	1	0	1	0	0	0	0	0	0	0
	Chromodoris orientalis	No.203	1	1	0	1	0	0	0	1	0	0
	Chromodoris rubrocornuta	No.514	0	0	0	0	0	0	0	0	0	0
	Chromodoris rufomaculata	No.208	0	0	0	0	0	0	0	0	0	0
	Chromodoris aureopurpure	No.539	1	1	0	0	0	0	0	0	0	0
	Chromodoris sinensis	No.622	0	1	0	0	0	0	0	0	1	0
	Chromodoris sp.	No.320	0	0	0	1	0	0	0	0	0	0
	Chromodoris verrieri	No.225	1	1	0	1	1	1	1	0	0	0
	Glossodoris atromarginata	No.354	0	1	0	0	0	1	0	0	0	1
	Glossodoris cincta	No.256	0	0	0	1	0	1	0	0	0	0
	Glossodoris cruenta	No.953	0	0	0	0	0	0	0	0	0	0

Table. 1. (Cont.)

Families	Species	Source (NSYSUIN)	Apr. 2005	Mar. 2006	June 2006	Aug. 2006	Sept. 2006	Oct. 2006	Nov. 2006	Dec. 2006	Jan. 2007	Feb. 2007
	Glossodoris hikuerensis	No.495	0	1	0	0	0	0	0	0	0	0
	Glossodoris rufomarginata	No.384	1	0	0	0	0	0	1	0	0	0
	Glossodoris sp. 1	No.299	0	0	1	0	0	0	0	0	0	0
	Hypselodoris festiva	No.205	1	1	0	0	0	0	0	0	0	0
	Hypselodoris krakatoa	No.230	0	1	0	0	0	0	0	0	0	0
	Hypselodoris maculosa	No.229	0	1	1	1	0	1	0	0	0	1
	Hypselodoris whitei	No.397	0	1	0	0	0	0	0	0	1	1
	Hypselodoris zephyra	No.401	0	1	1	1	1	0	1	0	1	0
	Hypselodoris cf. *carnea*	No.200	1	1	1	0	0	0	0	0	0	1
	Hypselodoris sp.	No.481	0	0	0	0	0	0	0	0	0	0
	Mexichromis multituberculata	No.547	0	1	1	0	0	0	1	0	1	0
	Noumea angustolutea	No.584	0	0	0	0	0	1	1	0	0	0
	Noumea crocea	No.309	0	0	0	1	0	0	0	0	0	0
	Noumea flava	No.569	0	0	0	0	0	0	0	0	0	0
	Noumea hongkongiensis	No.638	0	0	0	0	0	0	0	0	0	0
	Noumea nivalis	No.428	0	0	0	0	0	0	0	0	0	1
	Noumea simplex	No.461	0	0	0	0	0	0	0	0	0	0
	Risbecia tryoni	No.207	0	1	1	0	1	0	0	0	0	0
	Thorunna australis	No.321	0	0	0	1	0	0	0	0	0	0
	Thorunna daniellae	No.294	0	0	1	0	0	1	0	0	0	0
	Thorunna halourga	No.402	0	0	0	0	0	0	0	0	1	0
Onchidorididae	*Diaphorodoris mitsuii*	No.210	1	1	0	0	0	0	0	0	0	0
Dendrodorididae	*Dendrodoris tuberculosa*	No.398	0	0	0	0	0	0	0	0	1	0
Tritoniidae	*Tritoniopsis elegans*	No.410	0	0	0	0	1	0	0	0	1	1
Discodorididae	*Discodoris boholiensis*	No.519	0	0	0	0	0	0	0	0	0	0
	Halgerda tessellata	No.295	0	0	1	0	0	1	0	0	0	0
	Halgerda willeyi	No.317	1	0	0	1	0	0	0	0	0	0
Goniodorididae	*Okenia japonica*	No.328	0	1	0	1	1	0	0	1	0	0
	Goniodoridella savignyi	No.524	0	0	0	0	0	0	0	0	0	0
Gymnodorididae	*Analogium amakusanum*	No.541	0	0	0	0	0	0	0	0	0	0
	Gymnodoris alba	No.436	0	0	0	1	0	0	0	0	1	0
	Gymnodoris citrina	No.236	0	0	0	1	0	0	0	0	0	0
	Gymnodoris okinawae	No.408	0	0	0	0	0	0	0	0	1	0
Hexabranchidae	*Hexabranchus sanguineus*	No.544	0	0	0	1	0	0	0	0	1	0
Phyllidiidae	*Phyllidia picta*	No.627	0	0	0	0	0	1	1	0	1	0
	Phyllidia varicosa	No.358	0	0	0	0	0	1	1	0	0	0
	Phyllidia ocellata	No.368	0	0	0	1	1	1	1	1	0	0
	Phyllidiella lizae	No.591	0	0	0	0	0	0	0	0	0	0
	Phyllidella cooraburrama	No.588	1	1	0	0	1	0	0	0	0	1
	Phyllidiella pustulosa	No.345	1	0	1	1	0	1	1	1	0	0
	Phyllidiopsis annae	No.329	0	0	0	0	1	0	0	0	0	0
Polyceridae	*Thecacera pacifica*	No.471	0	0	1	1	0	0	0	0	0	0
	Tambja cf. *verconis*	No.538	0	0	0	0	0	0	0	0	0	0
	Tambja morosa	No.587	1	0	0	0	0	0	0	0	0	0
	Tambja sp.	No.536	0	0	0	0	0	0	0	0	0	0
	Nembrotha milleri	No.325	0	0	0	1	0	0	0	0	0	0
	Nembrotha livingstonei	No.330	0	0	0	0	1	0	0	0	0	0
Aeolidiidae	*Aeolidiella alba*	No.955	0	0	0	0	0	0	0	0	0	0
Glaucidae	*Favorinus tsuruganus*	No.479	0	0	0	0	0	0	0	0	0	0
	Phidiana indica	No.532	0	0	0	0	0	0	0	0	0	0
	Pteraeolidia ianthina	No.565	1	0	0	0	0	0	0	0	0	0
	Phyllodesmium poindimiei	No.333	0	0	0	0	1	0	0	0	0	0

Table. 1. (Cont.)

Families	Species	Source (NSYSUIN)	Apr. 2005	Mar. 2006	June 2006	Aug. 2006	Sept. 2006	Oct. 2006	Nov. 2006	Dec. 2006	Jan. 2007	Feb. 2007
Flabellinidae	*Flabellina bicolor*	No.573	0	0	0	0	0	0	0	0	0	0
	Flabellina rubrolineata	No.214	0	1	0	0	0	0	0	0	0	0
	Flabellina marcusorum	No.132	1	0	0	0	0	0	0	0	0	0
Tergipedidae	*Trinchesia ornata*	No.501	0	0	0	0	0	0	0	0	0	0
	Cuthona sp.	No.497	0	0	0	0	0	0	0	0	0	0
Arminidae	*Dermatobranchus* sp. 1	No.216	0	1	0	0	0	0	0	0	0	1
	Dermatobranchus sp. 2	No.954	0	0	0	0	0	0	0	0	0	0
Number of species			15	20	12	19	10	11	9	4	11	8
Accumulative of species			15	28	33	43	47	50	50	50	53	54
Number of newly recorder species			15	13	5	10	4	3	0	0	3	1
Diversity (*H*)			2.32	2.84	2.22	1.58	2.21	1.92	1.68	1.24	2.13	1.93
Diversity (E_H)			0.86	0.95	0.89	0.54	0.96	0.8	0.76	0.9	0.89	0.93
Diversity (*R*)			0.14	0.05	0.11	0.46	0.04	0.2	0.24	0.1	0.11	0.07
Number of families			7	6	4	7	6	3	2	3	6	4

Families	Species	Source (NSYSUIN)	Mar. 2007	Apr. 2007	May 2007	June 2007	July 2007	Aug. 2007	Sept. 2007	Oct. 2007	Nov. 2007	Dec. 2007
Chromodorididae	*Cadlinella ornatissima*	No.284	0	0	0	0	0	0	0	0	0	0
	Ceratosoma tenue	No.306	0	0	0	0	0	0	0	0	0	0
	Chromodoris albonares	No.323	0	0	0	0	1	0	0	1	1	0
	Chromodoris fidelis	No.454	0	1	1	1	0	0	0	0	0	0
	Chromodoris geometrica	No.662	0	0	0	0	0	0	0	0	1	0
	Chromodoris orientalis	No.203	0	0	1	0	1	0	0	0	1	0
	Chromodoris rubrocornuta	No.514	0	1	0	1	0	0	0	0	0	0
	Chromodoris rufomaculata	No.208	1	0	0	0	0	0	0	0	1	0
	Chromodoris aureopurpure	No.539	0	0	0	0	0	0	0	0	0	0
	Chromodoris sinensis	No.622	1	0	1	1	0	0	0	0	0	0
	Chromodoris sp.	No.320	0	0	0	0	0	0	0	0	0	0
	Chromodoris verrieri	No.225	1	0	0	0	0	0	0	0	0	0
	Glossodoris atromarginata	No.354	0	1	1	1	1	1	0	0	1	0
	Glossodoris cincta	No.256	0	0	1	1	1	0	0	0	0	0
	Glossodoris cruenta	No.953	0	0	0	0	0	0	0	1	0	0
	Glossodoris hikuerensis	No.495	0	1	0	0	0	0	0	0	0	0
	Glossodoris rufomarginata	No.384	0	0	0	1	0	0	0	0	1	0
	Glossodoris sp. 1	No.299	0	0	0	0	0	0	0	0	0	0
	Hypselodoris festiva	No.205	1	0	1	0	0	1	0	1	1	0
	Hypselodoris krakatoa	No.230	0	0	0	0	0	0	0	0	0	0
	Hypselodoris maculosa	No.229	0	0	1	1	0	0	0	1	0	1
	Hypselodoris whitei	No.397	1	1	0	0	0	0	0	0	0	0
	Hypselodoris zephyra	No.401	0	0	1	0	0	0	0	0	0	1
	Hypselodoris cf. *carnea*	No.200	0	1	1	1	0	0	0	0	0	0
	Hypselodoris sp.	No.481	0	0	1	0	0	0	0	0	0	0
	Mexichromis multituberculata	No.547	1	0	0	0	1	0	0	0	0	0
	Noumea angustolutea	No.584	0	0	0	0	1	0	0	0	0	0
	Noumea crocea	No.309	0	0	0	0	0	0	0	0	0	0
	Noumea flava	No.569	0	0	0	0	1	0	0	0	0	0
	Noumea hongkongiensis	No.638	0	0	0	0	0	1	0	0	0	0
	Noumea nivalis	No.428	1	0	0	0	0	0	0	0	0	0

Table. 1. (Cont.)

Families	Species	Source (NSYSUIN)	Mar. 2007	Apr. 2007	May 2007	June 2007	July 2007	Aug. 2007	Sept. 2007	Oct. 2007	Nov. 2007	Dec. 2007
	Noumea simplex	No.461	0	1	0	0	0	0	0	0	0	1
	Risbecia tryoni	No.207	0	0	0	0	0	0	0	0	0	0
	Thorunna australis	No.321	0	0	0	0	0	0	0	0	0	0
	Thorunna daniellae	No.294	0	1	0	0	1	0	0	0	0	0
	Thorunna halourga	No.402	0	0	0	0	0	0	1	0	0	0
Onchidoridiidae	*Diaphorodoris mitsuii*	No.210	1	1	0	1	0	0	0	0	0	0
Dendrodoridiidae	*Dendrodoris tuberculosa*	No.398	0	0	0	0	0	0	0	0	0	0
Tritoniidae	*Tritoniopsis elegans*	No.410	1	0	0	1	0	0	0	0	0	1
Discodoridiidae	*Discodoris boholiensis*	No.519	0	0	0	1	0	0	0	1	0	0
	Halgerda tessellata	No.295	0	0	0	0	0	0	0	0	0	0
	Halgerda willeyi	No.317	0	0	0	0	0	1	0	1	0	0
Goniodoridiidae	*Okenia japonica*	No.328	0	1	0	1	1	1	0	0	0	0
	Goniodoridella savignyi	No.524	0	0	0	1	0	0	0	0	0	0
Gymnodoridiidae	*Analogium amakusanum*	No.541	0	0	1	0	0	0	0	0	0	0
	Gymnodoris alba	No.436	1	0	0	0	0	0	0	0	0	0
	Gymnodoris citrina	No.236	0	0	0	0	0	0	0	0	0	0
	Gymnodoris okinawae	No.408	0	0	0	0	0	0	1	0	0	0
Hexabranchidae	*Hexabranchus sanguineus*	No.544	0	0	0	0	0	0	0	0	1	0
Phyllidiidae	*Phyllidia picta*	No.627	0	0	0	0	1	0	0	0	0	1
	Phyllidia varicosa	No.358	0	1	0	0	1	0	0	0	0	0
	Phyllidia ocellata	No.368	0	0	1	0	1	0	0	1	0	0
	Phyllidiella lizae	No.591	0	0	0	0	1	0	0	0	0	1
	Phyllidella cooraburrama	No.588	0	0	0	1	1	1	0	1	0	1
	Phyllidiella pustulosa	No.345	0	1	1	1	1	1	0	1	1	1
	Phyllidiopsis annae	No.329	0	0	0	0	0	0	0	0	0	0
Polyceridae	*Thecacera pacifica*	No.471	0	0	1	0	1	1	0	0	0	0
	Tambja cf. *verconis*	No.538	0	0	0	1	0	0	0	0	0	0
	Tambja morosa	No.587	1	1	0	0	1	0	0	1	0	0
	Tambja sp.	No.536	0	0	0	1	0	0	0	0	0	0
	Nembrotha milleri	No.325	0	0	0	0	0	0	0	0	0	0
	Nembrotha livingstonei	No.330	0	0	0	0	0	0	0	0	0	0
Aeolidiidae	*Aeolidiella alba*	No.955	0	0	0	0	0	0	1	0	0	1
Glaucidae	*Favorinus tsuruganus*	No.479	0	0	1	0	0	0	0	0	0	0
	Phidiana indica	No.532	0	0	0	1	0	0	0	0	0	0
	Pteraeolidia ianthina	No.565	0	0	1	0	0	0	0	0	0	0
	Phyllodesmium poindimiei	No.333	0	0	0	0	0	0	0	0	0	0
Flabellinidae	*Flabellina bicolor*	No.573	0	0	0	0	1	0	0	0	0	0
	Flabellina rubrolineata	No.214	0	0	0	0	0	0	0	0	0	0
	Flabellina marcusorum	No.132	0	0	0	0	0	0	0	0	0	0
Tergipedidae	*Trinchesia ornata*	No.501	0	0	0	1	0	0	0	0	0	0
	Cuthona sp.	No.497	0	0	0	1	0	0	0	0	0	0
Arminidae	*Dermatobranchus* sp. 1	No.216	0	0	0	0	0	0	0	0	0	0
	Dermatobranchus sp. 2	No.954	0	0	0	0	0	0	0	1	0	0
Number of species			11	13	16	20	18	8	3	11	8	9
Accumulative of species			55	57	60	67	70	71	72	74	74	74
Number of newly recorded species			1	2	3	7	3	1	1	2	0	0
Diversity (*H*)			2.31	2.51	2.66	2.67	2.16	1.28	1.1	2.4	1.97	2.16
Diversity (E_H)			0.96	0.98	0.96	0.89	0.75	0.61	1	1	0.95	0.98
Diversity (*R*)			0.04	0.02	0.04	0.11	0.25	0.39	0	0	0.05	0.02
Number of families			5	5	5	9	5	5	5	5	3	4

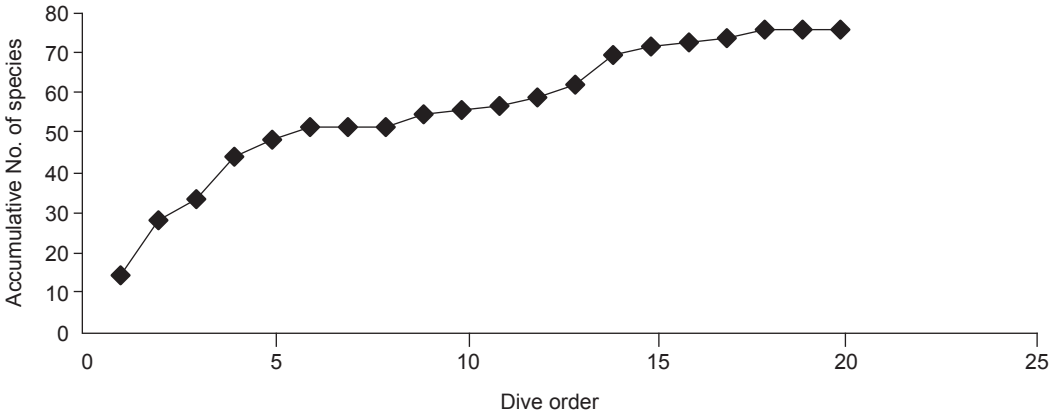

Fig. 5. Changes in the cumulative number of species with survey time.

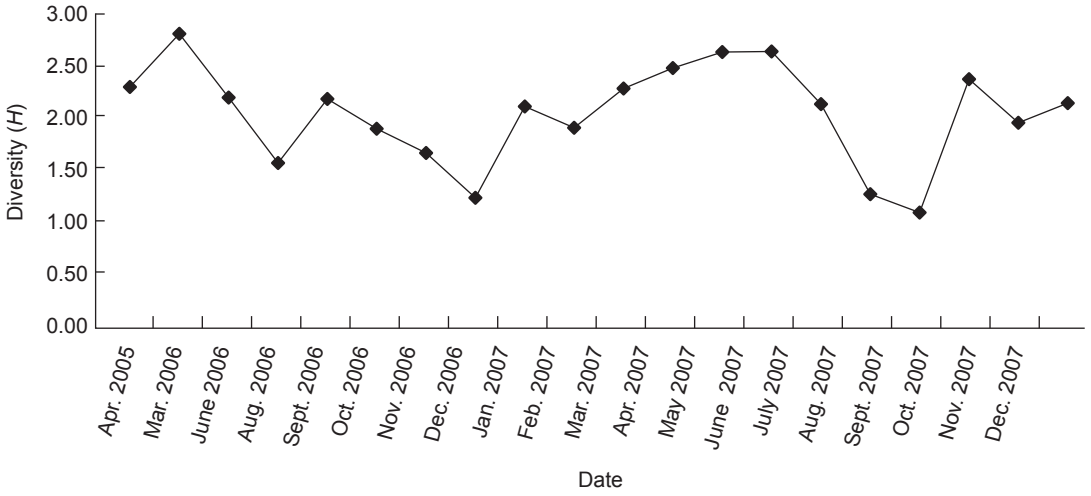

Fig. 6. Diversity (*H*) of each survey. Mean, 2.06; range, 1.10-2.84.

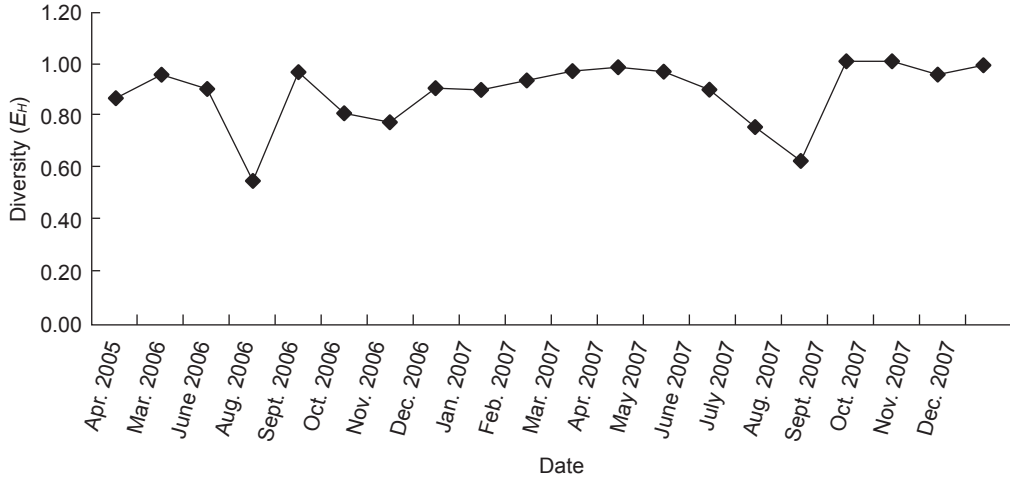

Fig. 7. Diversity (E_H) of each survey. Mean, 0.88; range, 0.54-1.00.

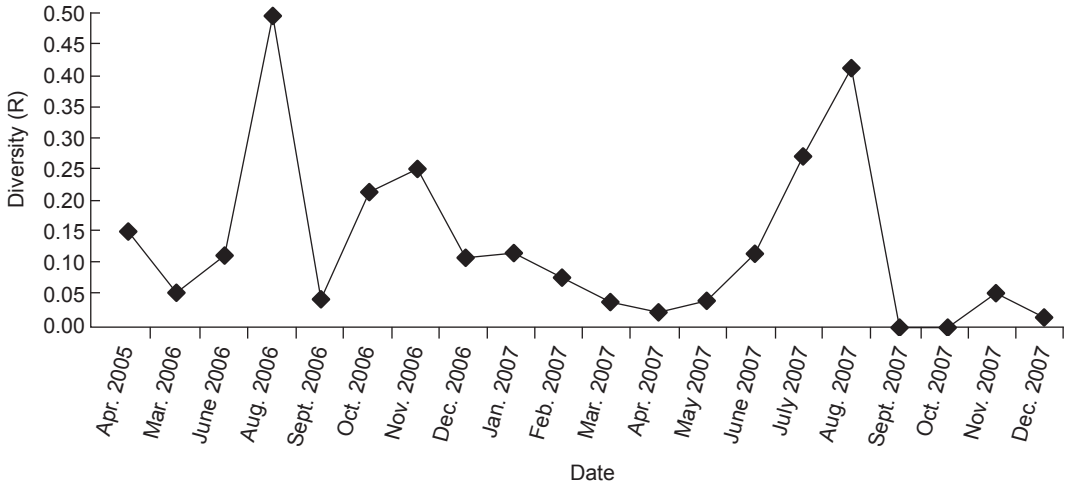

Fig. 8. Diversity (*R*) of each survey. Mean, 0.12; range, 0-0.46.

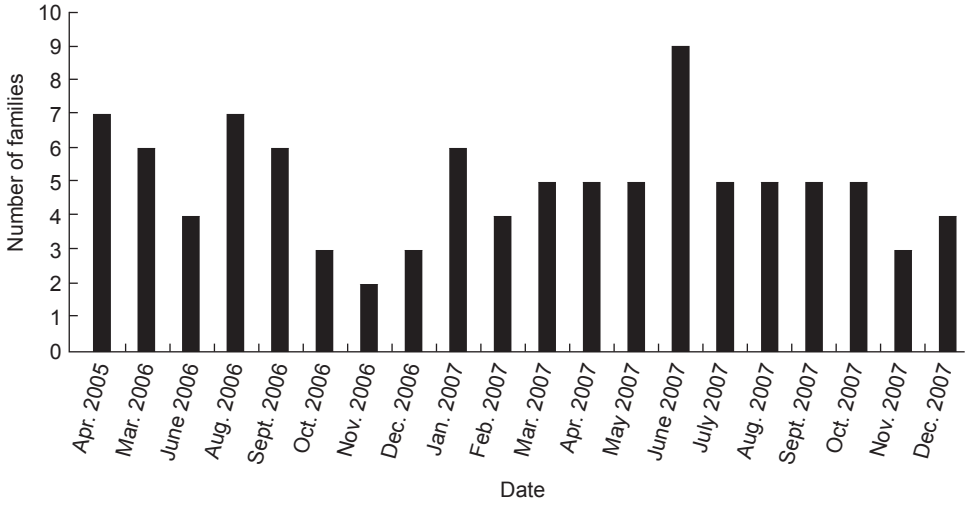

Fig. 9. Number of families in each survey. Mean, 4.95 (5); range, 2-9.

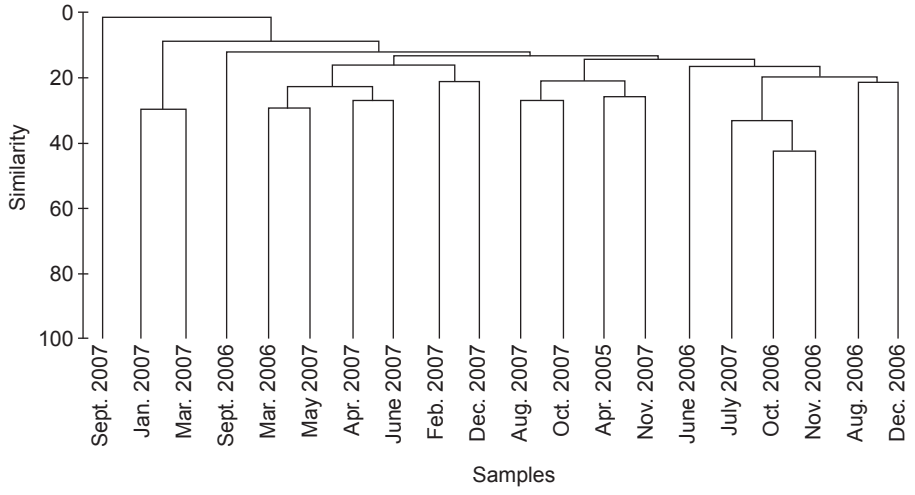

Fig. 10. Dendrogram for hierarchical clustering of the 20 surveys, using group-average linking of Jacard coefficients.

number of newly recorded species reached a plateau starting from the 18th survey, and only 1 new record was reported thereafter (Fig. 5).

Indices for nudibranch assemblage diversity are listed in Table 1: $\bar{H}$ = 2.06 (range, 1.1-2.84); $\bar{E}_H$ = 0.88 (range, 0.54-1.0); and $\bar{R}$ = 0.12 (range, 0-0.46) (Figs. 6-8).

The number of families per survey ranged 2-9 (mode, 5 families; Fig. 9). Regarding the species composition at the family level, 53% of the samples in Apr. 2005 were chromodoridids, and 13% were phyllidids, while the other 34% belonged to the remaining 5 families (Fig. 9, Table 1).

Similarity indices for pair-wise monthly samples were low (range, 21%-43%; Fig. 10). A trend was observed that months in the same season tended to be more similar to each other in species composition, particularly in spring (Fig. 10).

In total, 74 nominal species from 20 surveys between Sept. 2004 and Dec. 2007 were recorded from this site; this number accounts for 85% of the 87 species so far recorded from Penghu (Table 1). None of these 74 species was recorded only at this site. Among them, 13 valid species (*Ceratosoma tenue*, *Hyselodoris maritima*, *Noumea flava*, *Thorunna halourga*, *Tritoniopsis alba*, *Discodoris boholiensis*, *Goniodoridella savignyi*, *Analogium amakusanum*, *Nembrotha livingstonei*, *Favorinus tsuruganus*, *Phyllodesmium poindimiei*, *Flabellina rubrolineata*, and *Trinchesia ornata*), and 7 additional possible new species (Fig. 11) (*Tambja*

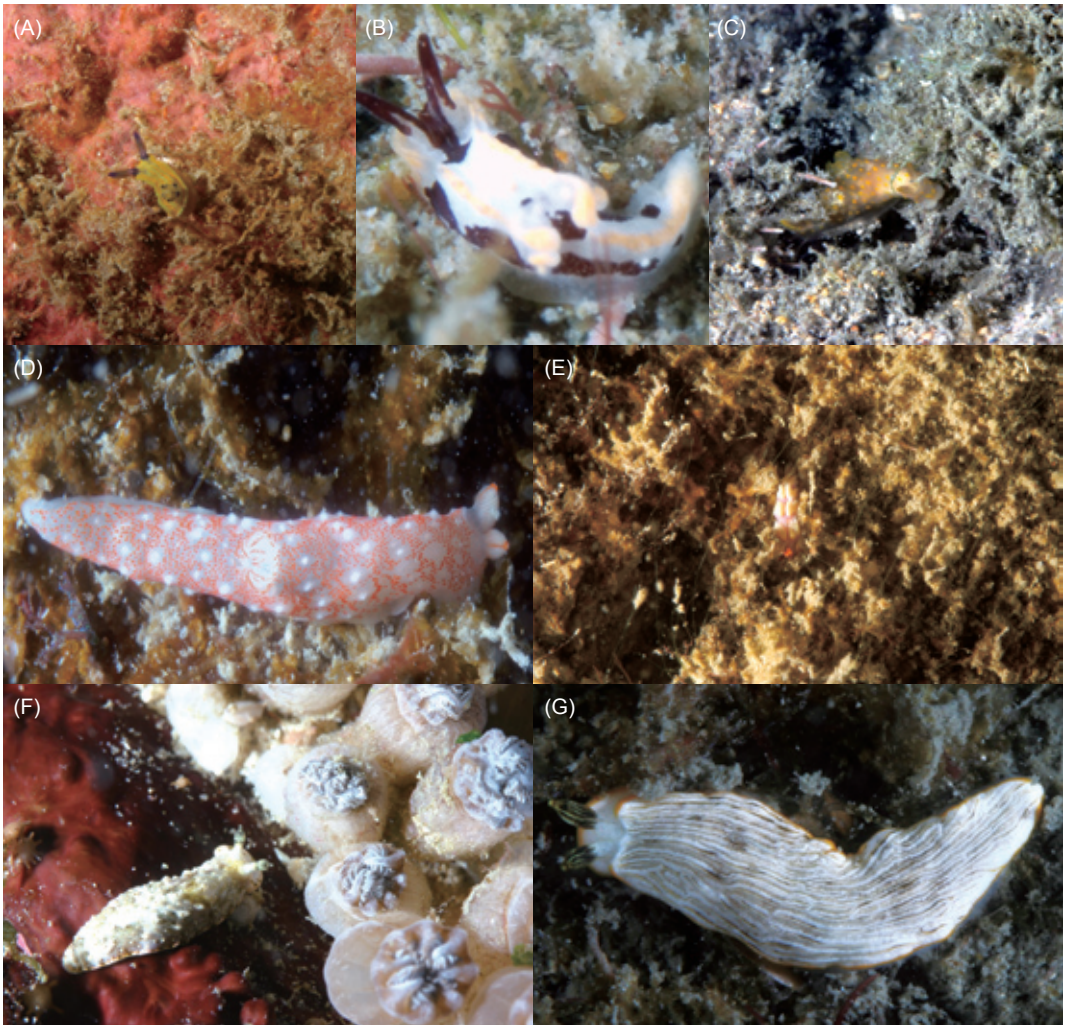

Fig. 11. Seven possible new species. (A) *Tambja* sp. (7 mm); (B) *Goniodoridella* sp. (10 mm); (C) *Gymnodoris* sp. 1 (8 mm); (D) *Gymnodoris* sp. 2 (6 mm); (E) *Cuthona* sp. (5 mm); (F) *Dermatobranchus* sp. 1 (11 mm); (G) *Dermatobranchus* sp. 2. (15 mm). Numbers in parentheses are approximate body lengths of the specimens.

sp., *Goniodoridella* sp., *Gymnodoris* sp.1, *Gymnodoris* sp. 2, *Cuthona* sp., *Dermatobranchus* sp.1, and *Dermatobranchus* sp. 2) were only reported at Penghu (including Wai-an and other sites in Penghu; Mok personal unpubl. data). No species at this site was considered dominant in terms of the number of individuals. *Phyllidiella pustulosa* was the most often sighted species during the study period (18 of 20 surveys; Table 1).

DISCUSSION

Among the 62 dives in a general survey of Taiwan including Green I., Orchid I., Penghu, Liu-Chiu-Yu, Kenting on the Hengchun Peninsula, and the northeast coast (Huang 2006), the number of species sighted per 2 h dive ranged from 1 to 15 (average, 5 species; 28 (45.16%) of the 62 dives reported 6 or fewer species). According to the present study, an average number of 12 species sighted per survey at Wai-an can be considered high.

Comparison between data from Wai-an taken in Aug. 2006-Dec. 2007 and those from the general survey (i.e., Apr. 2005 and Mar. 2006) should be made with caution as a result of differences in sampling effort (3 vs. 2 divers). However, despite having an additional diver engaged in collecting in Apr. 2007 compared to Apr. 2005, fewer species were reported in the former collection (13 vs. 15 species, respectively; Fig. 3).

Diversities of the nudibranch assemblages at Wai-an were characterized by a lack of dominant species. Only 1 exception was shown in the Aug. 2006 assemblage which was characterized by an overwhelming dominance of *Okenia japonica*. A high species diversity of nudibranchs can be considered a site-specific attribute of Wai-an. Wai-an is also characterized by an absence of clear seasonal differences in the number of species and diversity.

For Wai-an, there was no obvious seasonal peak in species richness. It took about 20 visits with a between-visit interval of approximately 1 mo to approach a reliable estimation of the species composition. This duration is informative as an index for comparing temporal differences in species biodiversity of nudibranchs.

The Chromodorididae and Phyllidiidae were the top 2 speciose families at Wai-an. Chromodoridid species made up 17%-75% (average, 48%) of the species recorded in 1 survey, and phyllidiid species made up 0%-67% (average, 18.8%). No obvious trend in temporal changes in numbers of species in these families or species composition were noted. Similarly, no trend in temporal change in the species composition was noted.

Results of the present survey may have been subjected to temporal patterns of nudibranch mollusk activity; differences in abundances and diversities of nudibranchs based on day and night sampling on the same shallow sub-tidal reef were reported by Johnson (1989). He noted that abundances were greater during daytime sampling, but diversity was greater at night, as diurnal species tend to be brightly colored and contrast with their surrounding, whereas nocturnal species are cryptic and difficult to sight in day or night. As such, species diversities in the Wai-an nudibranch assemblages, which were deciphered by data from daytime searches, are expected to be underestimated since nocturnal species might not have been included.

In their natural context, phyllidiids are generally exposed during the day (Brunckhorst 1991), reducing the chance of missing individuals in the sampling area. As such, the results of species diversity can be considered reliable.

Many nudibranchs are very small, cryptic, and nocturnal; therefore, the methods employed in this study (i.e., species sighted by the divers in the daytime) give only an incomplete and partial survey view of the total nudibranch assemblage of the site (mainly middle to large, aposematic, and diurnal species) and likely underestimated the total number of species present.

At higher latitudes, species compositions may be related to season as the population of the species with 2 or several generations a year are generally smallest in winter, and seasonal variation is greatest on the shore (Miller 1962). On the other hand, no evidence has been reported to show that diversity of species composition in coastal regions is affected by the shoreward migration for breeding, and colonization of the shore is normally by pelagic larvae (Miller 1962).

Acknowledgments: This work was funded by a grant Aimed for The Top University Plan (94C030221, 95C030221, 96C030221) from the Ministry of Education (R.O.C.) through the Kuroshio Research Group, Asia-Pacific Ocean Research Center, National Sun Yat-sen University. This paper represents Contribution number 22 of the Kuroshio Research Group, Asia-Pacific Ocean Research Center. We thank R. Willan for a critical

revision of the manuscript.

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