

Diverse Opisthobranchs and Polyclad Flatworms in Houwan, Kenting National Park, Southern Taiwan

Hsin-Drow Huang¹, Yung-chun Tsai², Cheng-Kuang Chen², Ho-Tien Hung¹, Jung-Chi Chen¹, Harry Lin¹, and Kwen-Shien Lee^{1*}

¹ Biology Department, Natural Museum of Natural Science, Taichung 40453, Taiwan

² Nanpei Diving Club, Hengchun, Pingtung 946, Taiwan

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Abstract. This study reports on a reef site with diverse sea slugs and polyclad flatworms in Houwan, Kenting National Park, southern Taiwan. From February 2013 to May 2015, 70 species of opisthobranchs and 15 species of polyclads were recorded on a reef with a 20 x 20-m area and at 15 m in depth. This site is adjacent to the outlet of Paoli Stream, which nourishes the local benthos with potential food for various sea slugs. When the water gets warmer in February, the sea slugs may aggregate in this area for foraging and mating. When the sea is calm from February to May, Houwan can be an ideal site to study the life history and behaviors of sea slugs.

Key words: sea slugs, polyclad flatworms, biodiversity, Kenting National Park, Taiwan.

INTRODUCTION

Sea slugs, mainly representing mollusk species of the subclass Opisthobranchia, are some of the most visually appealing yet least understood of all animals in the sea (Behrens 2005). As diving communities grow and underwater photography has become more common in recent years, our knowledge about sea slugs is significantly accumulating owing to observations by divers and biologists around the world (Behrens 2005; Huang 2010).

Often with as glorious coloration as opisthobranchs, polyclad flatworms are as shy and cryptic as sea slugs, yet even more fragile and difficult to study than the latter (Newman and Cannon, 2003). There are cases of polyclads that resemble toxic nudibranchs (Newman and Cannon 1994; Ang and Newman 1998) in coloration for the purpose of mimicry. These two animal groups may have similar life history traits.

However, the occurrence of most sea slugs is usually sparse, and it is difficult to anticipate the seasonality and their migration routes. A site with adequate food resources may attract sea slugs for foraging and mating. In the reproduction season, this may be an ideal location for studying the natural history and behavior of these animals.

In a survey dive in February 2013, a reef site with highly diverse sea slugs and polyclads was reported at 15 m deep in the nearshore area of Houwan in Kenting National Park, southern Taiwan. More than 20 species of sea slugs were observed in 1 day. This study investigated the biodiversity of sea slugs and polyclads in this area and the habitat which can support such diversity. The feasibility of conducting long-term sea slug monitoring in the area is also discussed.

MATERIALS AND METHODS

Study Site

This site at Houwan (21°57'50"N,

*Corresponding author. E-mail: kslee@mail.nmns.edu.tw

120°42'44"E) is approximately 3 km from the outlet of the Paoli River; tidal currents bring runoff sediments and cause water visibility to range 5~15 m throughout the year. It encompasses coral reefs and soft bottoms at depths of 15~20 m. At the site, reef corals are relatively less dominant, while benthos such as sponges, hydroids, octocorals, and ascidians flourish in the area; algae also thrive during winter and spring (Fig. 1).

Survey and Investigation

All surveys were conducted by scuba diving in an area of approximately 20 x 20 m at the site. Survey dives were conducted on March 6 and 7, and April 20, 2013, February 18 and October 21, 2014, and May 2, 2015. Divers searched for animals with the naked eye. Sea slugs, polyclads, and their surroundings were recorded with underwater cameras and camcorders. Images and videos were used to determine animal species according to references and field guides (Newman and Cannon 2003; Cobb and Willan 2006; Debelius and Kuitert 2007; Coleman 2008; Gosliner et al. 2008; Jie and Chan 2009; Jie and Kuo 2014). The behavior of these animals and the food foraged were also noted and documented.

RESULTS AND DISCUSSION

According to investigations up to May 2015, 70 species of opisthobranchs representing 18 families and 15 polyclad flatworms of two families were documented at the site (Tables 1, 2). This is by far the highest diversity of sea slugs



Fig. 1. Scene from the study site. Sessile invertebrates flourish in the area. The visibility of the water ranges 5~15 m throughout the year.

ever recorded at a single site in Taiwanese waters. In the surveys, sea slugs were witnessed foraging on algae and various benthic animals such as sponges, corals, and ascidians; we also observed several nudibranchs tailing each other and mating between February and May, which indicated their ongoing breeding season.

Since sea slugs with diverse trophic traits occurred in this area, we assumed that the site provides adequate food diversity for different species. The runoff from the Paoli River brings sediments, which limits the growth of reef corals, but other sessile invertebrates such as sponges, cnidarians, and ascidians benefit from the food particles brought by currents and therefore flourish in the area. The diverse benthic fauna in the area provides adequate food for various sea slugs. They may also gather at the feeding ground by tracking other sea slugs for mates, and also for prey.

In this study, we also recorded a mutually mimicking sea slug and polyclad at the site. The nudibranch *Chromodoris strigata* resembles an unidentified polyclad *Pseudoceros* sp. (as *Pseudoceros* sp. 2 in Table 2) with almost the



Fig. 2. A sea slug and polyclad flatworm that resemble each other recorded in the study: The nudibranch *Chromodoris strigata* (A) and an unidentified flatworm *Pseudoceros* sp. (B).

same coloration (Fig. 2). Many brightly colored sea slugs employ chemical defenses to repel predators (Cimino and Ghiselin 1999). Whether this flatworm itself is toxic or merely mimics the coloration of the sea slug needs further investigation.

The rich shallow-water molluscan fauna of Kenting National Park has been surveyed, but the opisthobranchs were not included (Lee and Chao 2004). On the west coast of Kenting, underwater photographers have recorded many sea slugs, including some rare species despite their rarity and sparse occurrence, which indicates that the rich biodiversity of sea slugs needs further systematic investigation. The present observations indicate that such sites may attract diverse opisthobranchs to feed and mate, which makes Houwan an ideal site to study their behavior and life style during the aggregation season.

ACKNOWLEDGEMENTS

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REFERENCES










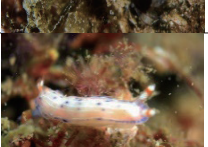


- Ang, H.P. and L.J. Newman. 1998. Warning colouration in pseudocerotid flatworms (Platyhelminthes, Polycladida). A preliminary study. *Hydrobiologia* 383: 29-33.
- Behrens, D.W. 2005. Nudibranch behavior. 176 pp. New World Publications, Jacksonville, FL.
- Cimino, G. and M.T. Ghiselin. 1999. Chemical defense and evolutionary trends in biosynthetic capacity among dorid nudibranchs (Mollusca: Gastropoda: Opisthobranchia). *Chemoecology* 9(4): 187-207.
- Cobb, G. and R.C. Willan. 2006. Undersea jewels: a color guide to nudibranchs. 310 pp. Australian Biological Resources Study, Canberra, Australia.
- Coleman, N. 2008. Nudibranchs encyclopedia: catalogue of Asia/Indo-Pacific sea slugs. 416 pp. Neville Coleman's Underwater Geographic, Sprintwood, Australia.
- Debelius H. and R.H. Kuitert. 2007. Nudibranchs of the world. 360 pp. IKAN-Unterwasserarchiv, Frankfurt, Germany.
- Gosliner, T.M., D.W. Behrens, and Á. Valdés. 2008. Indo-Pacific nudibranchs and sea slugs: a field guide to the world's most diverse fauna. 426 pp. Sea Challengers Natural History Books, Gig Harbor, WA.
- Huang, H.-D. 2010. Field observations of group reproduction in *Gymnodoris ceylonica* (Kelaart, 1858) (Gastropoda: Nudibranchia) at Lanyu (Orchid Is.), Taiwan. *Coll. Res.* 23: 37-41.
- Jie, W.-B. and C.-Y. Chan. 2009. Taiwan nudibranchs. 309 pp. National Museum of Marine Biology and Aquarium, Pingtung, Taiwan. (in Chinese).
- Jie, W.-B. and S.-C. Kuo. 2014. Flamboyant dancers: Taiwan polyclad flatworms. 104 pp. National Museum of Marine Biology and Aquarium, Pingtung, Taiwan. (in Chinese).
- Lee, S.-C. and S.-M. Chao. 2004. Shallow-water marine shells from Kenting National Park, Taiwan. *Coll. Res.* 17: 33-57.
- Newman, L.J. and L.R.G. Cannon. 1994. A new flatworm (Platyhelminthes: Polycladida) which mimics a phyllidiid nudibranch (Mollusca, Nudibranchia). *Zool. J. Linn. Soc.* 110: 19-25.
- Newman, L.J. and L.R.G. Cannon. 2003. Marine flatworms: the world of polyclad flatworms. 97 pp. CSIRO Publishing, Collinwood, Australia.










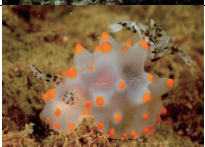


Table 1. Species list of opisthobranchs in Houwan, Kenting, southern Taiwan.







Suborder	Family	Species
CEPHALASPIDEA	Aglajidae	<i>Philinopsis reticulata</i> (Eliot, 1903)















CEPHALASPIDEA	Gastropteridae	<i>Sagaminopteron psychedelicum</i> Carlson & Hoff, 1974	
NOTASPIDEA	Pleurobranchidae	<i>Berthella martensi</i> (Pilsbry, 1896)	
NUDIBRANCHIA	Arminidae	<i>Dermatobranchus gonatophora</i> van Hasselt, 1824	
NUDIBRANCHIA	Bornellidae	<i>Bornella anguilla</i> Johnson, 1984	
NUDIBRANCHIA	Chromodorididae	<i>Cadlinella ornatissima</i> (Risbec, 1928)	
NUDIBRANCHIA	Chromodorididae	<i>Chromodoris albonares</i> Rudman, 1990	
NUDIBRANCHIA	Chromodorididae	<i>Chromodoris aureopurpurea</i> Collingwood, 1881	
NUDIBRANCHIA	Chromodorididae	<i>Chromodoris collingwoodi</i> Rudman, 1987	
NUDIBRANCHIA	Chromodorididae	<i>Chromodoris decora</i> Pease, 1860	
NUDIBRANCHIA	Chromodorididae	<i>Chromodoris fidelis</i> (Kelaart, 1858)	
NUDIBRANCHIA	Chromodorididae	<i>Chromodoris geometrica</i> Risbec, 1928	
NUDIBRANCHIA	Chromodorididae	<i>Chromodoris kunei</i> Pruvot-Fol, 1930	

NUDIBRANCHIA	Chromodorididae	<i>Chromodoris strigata</i> Rudman, 1982	
NUDIBRANCHIA	Chromodorididae	<i>Chromodoris tinctoria</i> (Ruppell & Leuckart, 1828)	
NUDIBRANCHIA	Chromodorididae	<i>Chromodoris verrieri</i> (Crosse, 1875)	
NUDIBRANCHIA	Chromodorididae	<i>Durvilledoris pusilla</i> (Bergh, 1874)	
NUDIBRANCHIA	Chromodorididae	<i>Glossodoris atromarginata</i> (Cuvier, 1804)	
NUDIBRANCHIA	Chromodorididae	<i>Glossodoris cincta</i> (Bergh, 1888)	
NUDIBRANCHIA	Chromodorididae	<i>Glossodoris rufomarginata</i> (Bergh, 1890)	
NUDIBRANCHIA	Chromodorididae	<i>Hypselodoris apolegma</i> Yonow, 2001	
NUDIBRANCHIA	Chromodorididae	<i>Hypselodoris bullockii</i> (Collingwood, 1881)	
NUDIBRANCHIA	Chromodorididae	<i>Hypselodoris carnea</i> (Bergh, 1889)	
NUDIBRANCHIA	Chromodorididae	<i>Hypselodoris emmae</i> Rudman, 1977	
NUDIBRANCHIA	Chromodorididae	<i>Hypselodoris iacula</i> Gosliner & Johnson, 1999	

NUDIBRANCHIA	Chromodorididae	<i>Hypselodoris maculosa</i> (Pease, 1871)	
NUDIBRANCHIA	Chromodorididae	<i>Hypselodoris nigrostriata</i> (Eliot, 1904)	
NUDIBRANCHIA	Chromodorididae	<i>Hypselodoris purpureomaculosa</i> Hamatani, 1995	
NUDIBRANCHIA	Chromodorididae	<i>Hypselodoris zephyra</i> Gosliner & Johnson, 1999	
NUDIBRANCHIA	Chromodorididae	<i>Noumea angustolutea</i> Rudman, 1990	
NUDIBRANCHIA	Chromodorididae	<i>Risbecia tryoni</i> (Garret, 1873)	
NUDIBRANCHIA	Chromodorididae	<i>Thorunna australis</i> (Risbec, 1928)	
NUDIBRANCHIA	Chromodorididae	<i>Thorunna daniellae</i> (Kay & Young, 1969)	
NUDIBRANCHIA	Chromodorididae	<i>Thorunna halourga</i> Johnson & Gosliner, 2001	
NUDIBRANCHIA	Discodorididae	<i>Halgerda carlsoni</i> Rudman, 1978	
NUDIBRANCHIA	Discodorididae	<i>Halgerda willeyi</i> Eliot, 1904	
NUDIBRANCHIA	Discodorididae	<i>Jorunna funebris</i> (Kelaart, 1858)	

NUDIBRANCHIA	Discodorididae	<i>Jorunna parva</i> (Baba, 1938)	
NUDIBRANCHIA	Discodorididae	<i>Jorunna ramicola</i> Miller, 1996	
NUDIBRANCHIA	Discodorididae	<i>Mexichromis multituberculata</i> (Baba, 1953)	
NUDIBRANCHIA	Eubranchidae	<i>Eubranchus</i> sp.	
NUDIBRANCHIA	Facelinidae	<i>Cratena lineata</i> (Eliot, 1905)	
NUDIBRANCHIA	Facelinidae	<i>Favorinus tsuruganus</i> Baba & Abe, 1964	
NUDIBRANCHIA	Flabellinidae	<i>Flabellina bicolor</i> (Keelart, 1858)	
NUDIBRANCHIA	Flabellinidae	<i>Flabellina riwo</i> Gosliner & Willan, 1991	
NUDIBRANCHIA	Hexabanchidae	<i>Hexabanchus sanguineus</i> (Ruppell & Leuckart, 1828) ²	
NUDIBRANCHIA	Onchidorididae	<i>Diaphorodoris mitsuui</i> (Baba, 1838)	
NUDIBRANCHIA	Phyllidiidae	<i>Phyllidia coelestis</i> Bergh, 1905	
NUDIBRANCHIA	Phyllidiidae	<i>Phyllidia exquisita</i> Brunckhorst, 1993	

NUDIBRANCHIA	Phyllidiidae	<i>Phyllidia ocellata</i> Cuvier, 1804	
NUDIBRANCHIA	Phyllidiidae	<i>Phyllidia varicosa</i> Lamarck, 1801	
NUDIBRANCHIA	Phyllidiidae	<i>Phyllidia willani</i> Brunckhorst, 1993	
NUDIBRANCHIA	Phyllidiidae	<i>Phyllidiella pustulosa</i> (Cuvier, 1804)	
NUDIBRANCHIA	Phyllidiidae	<i>Phyllidiopsis krempfi</i> Pruvot-Fol, 1957	
NUDIBRANCHIA	Phyllidiidae	<i>Phyllidiopsis shireenae</i> Brunckhorst, 1993	
NUDIBRANCHIA	Phyllidiidae	<i>Phyllidiopsis striata</i> Bergh, 1888	
NUDIBRANCHIA	Phyllidiidae	<i>Reticulidia fungia</i> Brunckhorst & Gosliner, 1993	
NUDIBRANCHIA	Polyceridae	<i>Nembrotha</i> sp.	
NUDIBRANCHIA	Polyceridae	<i>Roboastra gracilis</i> (Bergh, 1877)	
NUDIBRANCHIA	Polyceridae	<i>Roboastra luteolineata</i> (Baba, 1936)	
NUDIBRANCHIA	Polyceridae	<i>Tambja morosa</i> (Bergh, 1877)	





NUDIBRANCHIA	Polyceridae	<i>Tambja sagamiana</i> (Baba, 1955)	
NUDIBRANCHIA	Polyceridae	<i>Thecacera picta</i> Baba, 1972	
NUDIBRANCHIA	Scyllaeidae	<i>Crosslandia viridis</i> Eliot, 1902	
NUDIBRANCHIA	Tergipedidae	<i>Phestilla melanobranchia</i> Bergh, 1874	
NUDIBRANCHIA	Tergipedidae	<i>Trinchesia concinna</i> (Alder & Hancock, 1843)	
SACOGLOSSA	Limapontiidae	<i>Stiliger smaragdinus</i> Baba, 1949	
SACOGLOSSA	Plakobranchidae	<i>Elysia obtusa</i> Baba, 1938	
SACOGLOSSA	Plakobranchidae	<i>Thuridilla albopustulosa</i> Gosliner, 1995	
SACOGLOSSA	Plakobranchidae	<i>Thuridilla gracilis</i> (Risbec, 1928)	

Note: 1. Pictures of all species in this table were taken at the study site during the investigation.

2. The organism of *Hexabranhus sanguineus* recorded in the study is a juvenile.

Table 2. Species list of polyclad flatworms in Houwan, Kenting, southern Taiwan.

Suborder	Family	Species	
COTYLEA	Euryleptidae	<i>Cycloporus venetus</i> Newman & Cannon, 2002	
COTYLEA	Euryleptidae	<i>Eulepta</i> sp.	
COTYLEA	Pseudoceroadae	<i>Pseudoceros indicus</i> Newman & Schupp, 2002	
COTYLEA	Pseudoceroadae	<i>Pseudoceros intermittus</i> Newman & Cannon, 1995	
COTYLEA	Pseudoceroadae	<i>Pseudoceros prudhoei</i> Newman & Cannon, 1994	
COTYLEA	Pseudoceroadae	<i>Pseudoceros scintillatus</i> Newman & Cannon, 1994	
COTYLEA	Pseudoceroadae	<i>Pseudoceros scriptus</i> Newman & Cannon, 1998	
COTYLEA	Pseudoceroadae	<i>Pseudoceros uniborensis</i> Newman & Cannon, 1994	
COTYLEA	Pseudoceroadae	<i>Pseudoceros</i> sp 1	
COTYLEA	Pseudoceroadae	<i>Pseudoceros</i> sp 2	
COTYLEA	Pseudoceroadae	<i>Pseudoceros</i> sp 3	

COTYLEA	Pseudoceroadae	<i>Pseudoceros</i> sp 4	
COTYLEA	Pseudoceroadae	<i>Pseudoceros</i> sp 5	
COTYLEA	Pseudoceroadae	<i>Thysanozoon nigropapillosum</i> (Hyman, 1959)	
COTYLEA	Pseudoceroadae	<i>Tytthosoceros lizardensis</i> Newman & Cannon, 1996	

Note: Pictures of all species in this table were taken at the study site during the investigation.

墾丁後灣多樣的後鰓類與多歧腸海扁蟲

黃興倬¹、蔡永春²、陳正光²、洪和田¹、陳榮基¹、林杰煜¹、李坤瑄¹

¹國立自然科學博物館生物學組，臺灣臺中市404館前路1號

²屏東恆春南北潛水俱樂部

本研究報導墾丁國家公園後灣地區後鰓類海蛞蝓與多歧腸海扁蟲的多樣性。從2013年2月到2015年5月期間，在此地一處水深15公尺、20公尺見方的珊瑚礁，共發現了70種海蛞蝓與15種海扁蟲。後灣因為鄰近射寮溪出海口，使得當地海域底棲生態豐富，提供多種海蛞蝓的食物來源。當每年2月期間水溫開始回升，海蛞蝓便匯集於此處活動攝食，並尋覓交配對象，為即將來臨的繁殖季做準備。由於此地海況2月至5月期間浪況較為穩定，並可觀察到多種海蛞蝓活動，未來可作為長期研究海蛞蝓生態的熱點之一。

關鍵詞：海蛞蝓、海扁蟲、生物多樣性、墾丁國家公園、臺灣。