

RESEARCH ARTICLE

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Hydroids (Cnidaria, Hydrozoa) from marine environments in Taiwan

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Abstract

Background: Hydroids were identified from extensive surveys of benthos, and especially from worm tubes, in the Danshuei River estuary (DRE), in the northeast Taiwan Strait (NETS), and on a reef in Nanwan Bay (NWB), Taiwan.

Results: A total of 33 species (12 of them identified to generic and 1 to family rank only), referable to 22 genera, 12 families, and 2 orders, were distinguished. The majority of them were referable to order Leptothecata (84.8%) with the remainder being assigned to order Anthoathecata (15.2%). The only species found at NETS was *Monoserius pennarius* (Linnaeus, 1758). *Plumularia habereri* (Stechow, 1909) was recorded at both DRE and NWB. The known range of *Dynamena nanshaensis* (Tang, 1991), recorded for the second time, is extended further north. Six species (*Aglaophenia latecarinata*, *Plumularia floridana*, *Diphasia palmata*, *Dynamena brevis*, *Dynamena obliqua*, *Synthecium elegans*) are recorded for the first time in waters adjacent to the Chinese mainland.

Conclusions: Species composition and abundances varied considerably from one environment to another and especially between DRE and NWB. This study provides the first taxonomic account of the hydroid fauna inhabiting the eastern Taiwan Strait region.

Keywords: Cnidaria; Hydroids; Reef; Worm tube; Taiwan; East China Sea; South China Sea

Background

Hydroids are largely sessile epibenthic cnidarians that inhabit all marine habitats from shallow to abyssal waters (Vervoort 1966). Since hydroids feed on plankton, they likely play an important role in marine ecosystems (Gili and Hughes 1995). Hydroids are often found growing on other marine organisms, including sponges (Calder 1991b), other hydroids (Tang 1991b), deep-sea corals (Henry 2001), molluscs (Kubota et al. 1999), arthropods (Genzano 2002), and macroalgae (Fraschetti et al. 2006; Cunha and Jacobucci 2010; Oliveira and Marques 2007). Except for the well-known association between probosciditylid polyps and sabellid polychaetes (Schuchert 2009), relatively, little attention has been given to worm tubes as substrates for hydroids.

Several studies on hydroids from temperate and tropical waters of the northwest Pacific have been carried out over the past few decades. These include the fauna

of Japan to the north (e.g., Hirohito 1988, 1995), the Yellow Sea (Tang and Huang 1986), the East China Sea (Tang and Xu 1978; Liu and Li 2002), the Taiwan Strait (Kubota et al. 1999; Xu and Huang 2004), the Philippine Islands (Hargitt 1924), and the South China Sea (Tang 1991a, b, 1998; Yeh 1995; Zhao 1998). Liu (2008) and Huang and Lin (2012) provided checklists and illustrations of Hydrozoa in waters adjacent to mainland China. A number of earlier reports explored the rich hydroid fauna of the western Pacific Ocean (for some references, see Vervoort 1995). Literature is scanty on hydroids from waters of northeast Taiwan (Jäderholm 1903), from the coast of southern Taiwan (Yeh 1995), around Taiwan (Hwang and Shao 1998), in the middle part of the western coast of Taiwan (Kubota et al. 1999), in the Taiwan Strait (Xu and Huang 2004), and from coral reef areas of the country (Fontana et al. 2012). So far, distribution and species composition of hydroids have not been explored in the eastern Taiwan Strait. The present study was undertaken to establish a baseline of information on the group in waters of Taiwan.

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Methods

Field sampling and samples treatment

Investigations on hydroids were undertaken in three environmentally distinct regions: (1) the Danshuei River estuary (DRE, 25°10' N, 121°24' E) in north Taiwan, (2) the northeastern Taiwan Strait (NETS, 24°48' N, 119°55' E), and (3) the reef zone in Nanwan Bay (NWB, 21°56' N, 120°46' E), south Taiwan (Figure 1, Table 1). Samples from DRE and NETS were collected by bottom trawl onboard the Ocean Research Vessel II and from a fishery vessel, respectively. At NWB, hydroid sampling on a coral reef was undertaken at 12 to 15 m depth using self-contained underwater with breathing apparatus (SCUBA) and at 100 m depth using a remotely operated vehicle (ROV). A total of 24 worm tube specimens collected at the coral reef site by SCUBA diving, and two additional ones using the ROV, were examined for hydroid associates. Specimens were preserved in seawater with 5% to 10% buffered formalin immediately after collection.

Hydroids identification

In the laboratory, each sample for taxonomic identification was dissected on a glass slide with the help of a dissecting microscope. Identification of species was undertaken using

recent taxonomic keys and relevant references, including Vervoort (1966), Millard (1975), Rees and Vervoort (1987), Calder (1988, 1991a, 1997, 2012), Hirohito (1988, 1995), Cornelius (1995a, 1995b), Schuchert (1996, 1998, 2001, 2003, 2004), Marques (2001), and Vervoort and Watson (2003).

Results

Hydroids from DRE and NETS, collected by bottom trawl, were often found together with rocks. However, those actually attached to rock at DRE represented less than 30% ($N > 100$) of the total number of specimens. At NETS, hydroids were found tangled in the trawl net because most colonies were fragmented and longer than 40 cm. Worm tubes, an important substrate at NWB, supported a substantial growth of sessile organisms including hydroids, soft corals, ascidians, and red algae (Figure 2). As for hydroids, they were associated with worm tubes at the rate of 100% ($N = 24$). Most hydroids attached to middle and distal surfaces of the tube, while fewer were present at the base.

In our samples, 22 species were identified from river-bed environments at DRE, 11 epizoic species were found on worm tubes at NWB, and 1 species occurred in

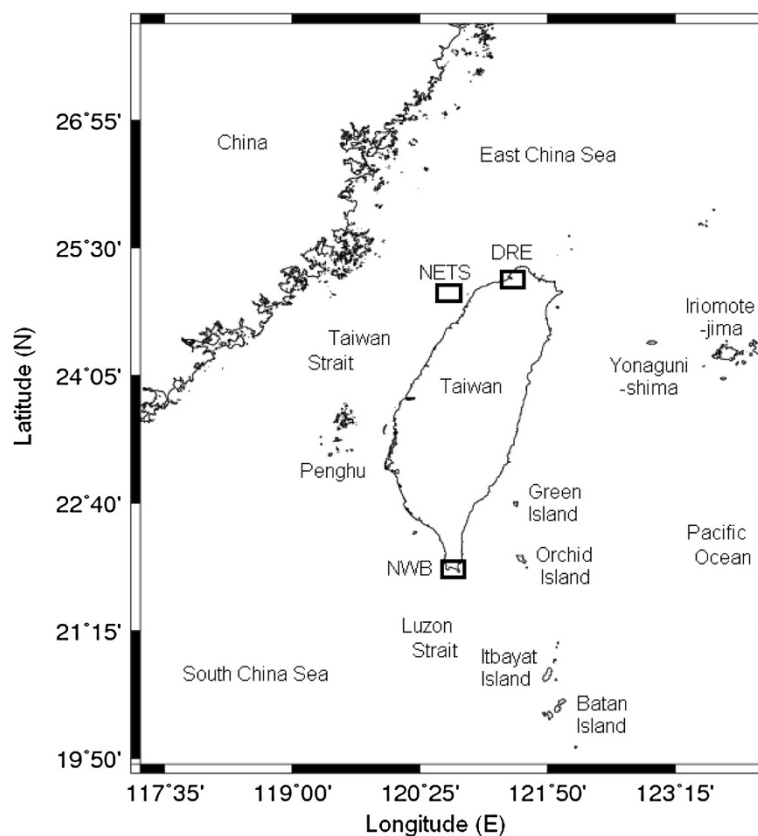


Figure 1 Map of Taiwan and vicinity, showing the three sampling locations. DRE, Danshuei River estuary; NETS, northeastern Taiwan Strait; NWB, Nan-Wan Bay.

Table 1 Sampling location, date, depth, and methods

Sampling area	Date	Depth (m)	Methods
Estuary of Danshuei River	21 Aug. 2009	10 to 15	ORII CR-1662, bottom trawling
Northeastern Taiwan Strait	14 Mar. 2009	50 to 60	Fishery boat, bottom trawling
Reef zone of Nan-Wan Bay	22 Dec. 2009	5 to 10	SCUBA diving
Reef zone of Nan-Wan Bay	Aug. 2008	100	Remotely operated vehicle

ORII, Ocean Research Vessel II.

samples from NETS (Table 2). Overall, a total of 33 hydroid species (12 of them identified solely to generic level and 1 to family level) referable to 22 genera, 12 families, and 2 orders, were discovered. Most of the species belonged to order Leptothecata (84.8%), with the remainder being referable to order Anthoathecata (15.2%). Taking samples from all study areas together, hydroids of the family Sertulariidae (comprising 14 species, with 3 identified to generic level only) contained the largest number of species. Six species (*Aglaophenia latecarinata* Allman, 1877; *Plumularia floridana* Nutting, 1900; *Dipsasia palmata* Nutting, 1905; *Dynamena brevis* (Fraser, 1935); *Dynamena obliqua* Lamouroux, 1816; and *Synthecium elegans* Allman, 1872) are recorded here for the first time from waters adjacent to mainland China (Table 2).

Hydroid species composition and abundance varied considerably between DRE and NWB. Only one species, *Plumularia habereri* Stechow, 1909, was found at both locations. Species found in the deep zone at NWB by the ROV were *P. habereri* and *Dynamena nanshaensis* Tang, 1991a. At NETS, only one species was found, the robust aglaopheniid *Monoserius pennarius* (Linnaeus, 1758). Its colony had a single stem, with pinnate side branches.

Discussion

Historical records of hydroids in coastal waters around Taiwan are limited. Yeh (1995) reported seven species of

Plumulariidae collected in the southern part of the island. Hwang and Shao (1998) described two venomous hydroids from the same location. Kubota et al. (1999) provided the first record of *Eugymnanthea japonica* (Yamada, 1950) (Leptothecata, Eirenidae), from western Taiwan, where it was associated with two bivalve species (*Crassostrea gigas* (Thunberg, 1793), *Perna viridis* (Linnaeus, 1758)). Recently, Fontana et al. (2012) reported what was believed to be a cosmopolitan and possibly genus-specific association between *Zanclaea* spp. and its coral hosts, based in part on hydroids from *Acropora* corals on reefs in Kenting and the Penghu Islands, Taiwan. Previous literature provided limited data of hydroids in this area, as shown in the extensive review on hydroid species in Chinese waters by Liu (2008). His report recorded 615 species of Hydrozoa in waters adjacent to mainland China, including the East China Sea, western Taiwan Strait, and South China Sea. Shortly after, Huang and Lin (2012) provided illustrations of 829 species of Hydrozoa in waters adjacent to mainland China. However, hydroids in the eastern Taiwan Strait were still inadequately known, and our study is the first to document the hydroid fauna in waters of the region.

The stinging hydroid *Aglaophenia cupressina* Lamouroux, 1816 is widely distributed on the coral reefs of the Bunaken area (Ricciardi 2007). Tang (1991a) noted that the sting of *A. cupressina*, frequent on reefs in the Indo-West Pacific area, produces an itchy rash in humans. Hwang and Shao

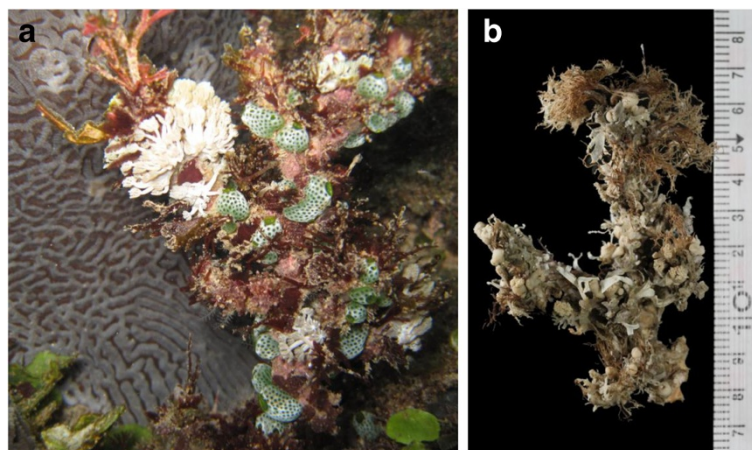


Figure 2 Photographs of worm tubes in field (a) and colony size (b) taken from the coast of Nan-Wan Bay.

Table 2 Taxonomic list of hydroids collected from north and south Taiwan

Scientific classification	Present study	Recorded in Liu (2008)
Hydrozoa		
Order Anthoathecata Cornelius, 1992		
Bougainvilliidae Lütken, 1850		
<i>Bimeria</i> sp.	NWB	-
Eudendriidae L. Agassiz, 1862		
<i>Eudendrium</i> sp. 1	DRE	-
<i>Eudendrium</i> sp. 2	DRE	-
<i>Eudendrium</i> sp. 3	NWB	-
Pennariidae McCrady, 1859		
<i>Pennaria disticha</i> Goldfuss, 1820	NWB	ECS, SCS, CTR-STR, MEDIT
Order Leptothecata Cornelius, 1992		
Aglaopheniidae Marktanner-Turneretscher, 1890		
<i>Aglaophenia cupressina</i> Lamouroux, 1816	NWB	XSHA, NSHA, SAFRI, EAFRI, INMA, AU
<i>Aglaophenia latecarinata</i> Allman, 1877 ^a	DRE	-
<i>Macrorhynchia philippina</i> Kirchenpauer, 1872	DRE	SCS, CTR-STR
<i>Monoserius pennarius</i> (Linnaeus, 1758)	NETS	ECS, SCS, IWPAC
Campanulariidae Johnston, 1836		
Campanulariidae indet.	DRE	-
<i>Obelia dichotoma</i> (Linnaeus, 1758)	DRE	YS, ECS, SCS, COSMOP
Halopterididae Millard, 1962		
<i>Halopteris</i> sp.	NWB	-
Hebellidae Fraser, 1912		
<i>Hebella</i> sp.	DRE	-
Kirchenpaueriidae Stechow, 1921		
<i>Kirchenpaueria</i> sp.	DRE	-
Lafoeidae Hincks, 1868		
<i>Zygophylax</i> sp.	DRE	-
Plumulariidae Agassiz, 1862		
<i>Nemertesia</i> sp.	DRE	-
<i>Plumularia habererii</i> Stechow, 1909	DRE, NWB (ROV)	SCS, ID, JP, CARIB
<i>Plumularia floridana</i> Nutting, 1900 ^a	NWB	-
Sertulariidae Lamouroux, 1812		
<i>Diphasia digitalis</i> (Busk, 1852)	DRE	SCS, CTR-STR
<i>Diphasia palmata</i> Nutting, 1905 ^a	DRE	-
<i>Dynamena brevis</i> (Fraser, 1935) ^a	DRE	-
<i>Dynamena crisioides</i> Lamouroux, 1824	NWB	ECS, SCS, CTR-STR
<i>Dynamena disticha</i> (Bosc, 1802)	DRE	ECS, SCS, ID, JP, BM, BR (Synonym, <i>Dynamena cornicina</i> McCrady, 1859)
<i>Dynamena nanshaensis</i> Tang, 1991	NWB (ROV)	NSHA
<i>Dynamena obliqua</i> Lamouroux, 1816 ^a	DRE	-
<i>Dynamena quadridentata</i> (Ellis and Solander, 1786)	DRE	ZJ, FJN, HK, TKG, CTR-STR
<i>Idiellana pristis</i> (Lamouroux, 1816)	DRE	ECS, SCS, CTR-STR
<i>Salacia</i> sp.	NWB	-
<i>Sertularella diaphana</i> (Allman, 1885)	DRE	ECS, CTR-STR

Table 2 Taxonomic list of hydroids collected from north and south Taiwan (Continued)

<i>Sertularella</i> sp.	NWB	-
<i>Sertularia loculosa</i> Busk, 1852	DRE	SCS, WAFRI, SAFRI, LK, ID, JP (Synonym, <i>Sertularia ligulata</i> Thornely, 1904)
<i>Sertularia</i> sp.	DRE	-
Syntheciidae Marktanner-Turneretscher, 1890		
<i>Synthecium elegans</i> Allman, 1872 ^a	DRE	-

^aFirst record of the species in waters adjacent Mainland China. DRE, Danshuei River estuary; NETS, northeastern Taiwan Strait; NWB, Nan-Wan Bay. Distributions of certain species as recorded in Liu (2008). AU, Australia; BM, Bermuda; BR, Brazil; CARIB, Caribbean; COSMOP, Cosmopolitan; CTR-STR, Circumtropical-Subtropical; EAFRI, East Africa; ECS, East China Sea; FJN, Fujian; HK, Hong Kong; ID, Indonesia; INMA, Indo-Malaysia; IWPAC, Indo-West Pacific; JP, Japan; LK, Sri Lanka; MEDIT, Mediterranean; NSHA, Nansha Islands; SAFRI, South Africa; SCS, South China Sea; TKG, Tonkin Gulf; WAFRI, West Africa; XSHA, Xisha Islands; YS, Yellow Sea; ZJ, Zhejiang.

(1998) reported *A. cupressina* and the feather hydroid *Halocordyle disticha* (a synonym of *Pennaria disticha* Goldfuss, 1820), both venomous to humans, in Taiwan. Eldredge and Smith (2001) noted that the sting of *P. disticha* causes mild irritation in humans. The two species were recorded on worm tubes from NWB in our study.

The colonial hydroid *P. habereri* was found in a riverbed environment at DRE and by ROV in NWB. This species is widely distributed in the South China Sea, Indonesia, and Japan (Liu 2008) at varied depth ranges, e.g., 10 to 35 m (Schuchert 2003) and 1 to 4 m (Calder and Kirkendale 2005). In our study, the species was collected at a depth of 100 m, the deepest ever recorded. In addition, waters in the estuarine environment at DRE have a wide range of salinities. We conclude that *P. habereri* is a euryhaline species.

A noteworthy discovery in our samples was *D. nanshaensis*, collected from hard substrates on the reef at NWB. This is only the second record of the species since its original description from the Nansha Islands (Tang 1991a). Thus far, *D. nanshaensis* is known only from the South China Sea, specifically from the type locality (Nansha Islands, about 10° N) and now from our study in Nanwan Bay (about 21°56' N), south Taiwan, the northernmost record of the species.

The macrobenthic hydroid *M. pennarius* was especially abundant at Nansha Island (Zhao 1998; Tang 1991b). Its dense population there establishes an ecological environment described as an 'imitative steppe on sea floor' (Zhao 1998) and a 'sea-floor prairie' (Tang 1991b). *M. pennarius* is widely distributed in the Indo-Malayan and Sino-Japanese subregions of the Indo-West Pacific region (Tang 1991b), including India, Ceylon, Indonesia, Philippines, Taiwan, southern Japan, Palau, and New Zealand (Schuchert 2003). It is a species of warm waters and high salinity in the East China Sea (Liu and Li 2002). Common macrobenthic communities there include: *Callianassa* spp., *M. pennarius-Stellaster equestris* (Tang and Xu 1978), and *S. equestris*, *M. pennarius-Callianassa japonica* (Liu and Li 2002). Our material from NETS confirmed that colony length of *M. pennarius* ranges from 30 to 100 cm and that it inhabits

muddy-sandy seabeds at depths of 50 to 100 m (Tang 1991b; Schuchert 2003; Vervoort and Watson 2003).

Samples from DRE included the cosmopolitan species *Dynamena disticha* (Bosc, 1802). Liu (2008) reported *D. disticha* from the East China Sea, South China Sea, Indonesia, Japan, Bermuda, and Brazil. Puce et al. (2009) reported that *D. disticha* can be found in association with algae, hydroids, barnacles, rocks, and concretions in the Mediterranean Sea. This suggests high adaptability to diverse environments, and indeed, *D. disticha* has a broad distribution. Some hydroids form communities in association with other co-occurring marine organisms. Frascchetti et al. (2006) reported *D. disticha* and *Obelia dichotoma* (Linnaeus, 1758) in association with brown algae *Cystoseira amentacea* (C.Agardh) Bory de Saint-Vincent, 1832 in the Mediterranean Sea. Both hydroid species were recorded from DRE in this study. Cunha and Jacobucci (2010) reported 16 species of hydroids on fronds of the alga *Sargassum cymosum* C.Agardh, 1820 in subtropical Brazil. Among species in their list, *A. latecarinata*, *D. disticha*, and *O. dichotoma* were also found in our study. Gravier-Bonnet and Bourmaud (2006) recorded 95 hydroid species from a reef zone in the southwest Indian Ocean, with *P. disticha*, *A. cupressina*, *Macrorhynchia philippina*, and *Dynamena crisioides* being common to abundant. Three of these species (*P. disticha*, *A. cupressina*, and *D. crisioides*) were also identified from samples in the reef zone at NWB.

Notably, six species (*A. latecarinata*, *P. floridana*, *D. palmata*, *D. brevis*, *D. obliqua*, and *S. elegans*) identified from DRE have never been recorded previously in seas of China (Liu 2008). This reveals that the assemblage of hydroids in the eastern Taiwan Strait differs significantly from those in coastal waters of mainland China. Shao (1998) estimated that the number of marine species around Taiwan represented 10% of the total number known worldwide. The island of Taiwan, located in the west Pacific Ocean, has a total of 1,566 kilometers of coastline (including the Penghu Islands) (Tung 2006), and complex current systems influence the island (Tseng et al. 2013a, b). Diverse water masses of the East China

Sea, South China Sea, China Coastal Current, and Kuroshio Current have a pronounced effect on the endemic marine biota. Varied marine habitats promote a highly diversity biota around Taiwan Island (Shao 2009). Expanding the geographic scope and frequency of marine surveys would potentially show that the indigenous hydroid fauna in waters around Taiwan is even richer.

Conclusions

The study documents a unique and heterogeneous assemblage of hydroids found in three quite dissimilar marine environments in Taiwan (DRE, NETS, and NWB). The DRE riverbed system supports a comparatively richer hydroid fauna than a group of species associated with worm tubes from NWB. The three sampling sites differed significantly in faunal composition and numbers of species. Differences are attributed primarily to disparities in substrate types and salinity characteristics among the sites. Studies on developmental stages of hydroids under laboratory conditions are needed to better understand their life cycles in nature.

Competing interests

The authors declare that they have no competing interests.

Authors' contributions

Specimen collection at DRE and NETS was carried out by CHW. At NWB, samples were collected using SCUBA by LCT and CHW, while ROV samples were collected by WHT. ZCT completed the taxonomic work of hydroid species identification. LCT and CHW took photographs of worm tubes in the field and in the laboratory, respectively. LCT analyzed the data, prepared figures and tables, and drafted the manuscript. LCT and JSH finalized the manuscript. All authors read and approved the final manuscript.

Acknowledgements

This manuscript was completed thanks in large part to Professor Z.-C. Tang, who passed away on 18 August 2011 during the study. His efforts and dedication to the taxonomic component of the work are greatly appreciated. Thanks to Mrs. Tang (Mei-Jun Huang) for assisting in screening hydroid samples. Thanks are due to Professor Santosh Kumar Sarkar (Department of Marine Science, University of Calcutta, India), whose comments and advice improved the paper. We thank two anonymous referees for their editing and suggestions that substantially improved the quality of the manuscript. We are grateful for financial support from the Ministry of Science and Technology of Taiwan via projects NSC 100-2611-M-019-010; NSC 101-2611-M-019-011 and NSC 102-2611-M-019-003 to J.-S. Hwang. Our appreciation is extended to members of J.-S. Hwang's laboratory and to the captain and technicians of Ocean Research Vessel II for their assistance during field sampling of hydroids in Danshuei River estuary.

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Received: 17 February 2014 Accepted: 19 May 2014

Published online: 10 June 2014

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doi:10.1186/s40555-014-0029-z

Cite this article as: Tseng et al.: Hydroids (Cnidaria, Hydrozoa) from marine environments in Taiwan. *Zoological Studies* 2014 **53**:29.

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