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Diversity and occurrence of nudibranchs in Thailand

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Abstract The diversity and occurrence of nudibranchs were studied during a 10-year survey in the Andaman Sea and the Gulf of Thailand, Thailand. We recorded 96 species in 40 genera and 17 families at 0–20 m depth, which resulted in a total of 136 species in Thai waters in combination with previous studies. The largest group was the suborder Doridina (81 % of the species), followed by the suborder Aeolidina (15 %). The Chromodorididae, Phyllidiidae, and Discodorididae were the most dominant families. During the surveys, 39 % of the nudibranch species was found on coral rubble, 28 % on sand, 8 % on rock, and 25 % in association with sessile organisms.

Keywords Nudibranch molluscs · Opisthobranchia · Thailand · Diversity · Distribution · Substrate

Introduction

Nudibranchs (Order Nudibranchia) are gastropod molluscs that form the major part of the sea slugs belonging to the Opistobranchia (Bouchet and Rocroi 2005). They can be found in a wide range of habitats, from polar regions to the tropics and from the intertidal to the deep sea (Clark 1975; Nybakken 1978; Gosliner and Draheim 1996; Cobb and Willan 2006; Debelius and Kuiter 2007; Su et al. 2009). A complete global pattern of nudibranch species diversity and abundance is difficult to assess, since some of these animals are difficult to identify, and they can be cryptic or camouflaged and therefore difficult to find. However, more than 2,000 nudibranch species are recorded in the Indo-Pacific (Gosliner et al. 2008). Despite their popularity as subjects for underwater photography and the presence of bioactive compounds (e.g., in the family Phyllidiidae), few studies have been conducted on their biology and ecology (e.g., Brunckhorst 1991; Yonow 1992; Gosliner and Draheim 1996; Gosliner 2000; van Alphen et al. 2011; van der Meij and Reijnen 2012). In Thailand, several studies on their diversity and distribution have been conducted (Jensen 1998, 2007; Sittithaweepat 2001; Swennen et al. 2001; Thamrongnawasawat et al. 2007; Chavanich et al. 2010). This paper documents the diversity of nudibranchs found during a 10-year survey in Thailand, with a distinction between the Andaman Sea and the Gulf of Thailand.

Materials and methods

The surveys were conducted in Thai waters, especially on coral reefs, both in the Gulf of Thailand and in the Andaman Sea, between 2001 and 2011 (Fig. 1). Thailand has a total of 153 km^2 of coral reefs, consisting of 75 km^2 in the Gulf of Thailand and 78 km^2 in the Andaman Sea (Chansang et al. 1999). More than 500 dives were carried out (approximately 270 in the Gulf of Thailand and 230 in the Andaman Sea), each of about 50 min, either general or nudibranch-specific. For nudibranch-specific surveys, per site the roving diving technique was applied (Munro 2005), covering an area as large as possible at 0–20 m depth. Once nudibranchs were spotted, photos were taken in situ. The animals were then collected and placed in plastic bags. In addition, specific benthic substrates were searched on which nudibranchs can

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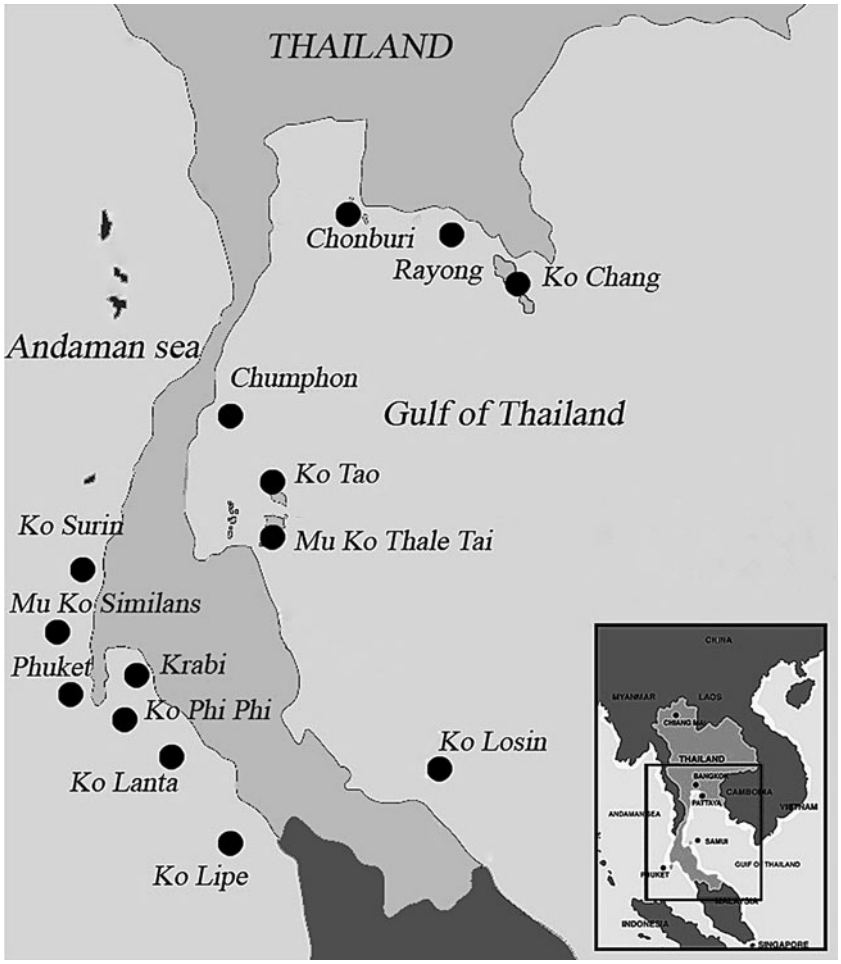

Fig. 1 The collection sites

usually be found. The samples were transported to the laboratory for further identification. For preservation, the sea slugs were first relaxed using solutions of magnesium sulphate, magnesium chloride, or menthol in seawater, and later fixed in 70-95 % ethanol. Then, a species list was compiled and compared with the database and reference collections of other studies (Jensen 1998, 2007; Debelius 2001; Malaidang 2007; Thamrongnawasawat et al. 2007; www.seaslugforum.net) to determine whether a species was previously recorded for Thailand. Changes in species names and synonymies were based on most recent references (Gosliner et al. 2008; Yonow 2008, 2011, 2012), Sea Slug Forum (www.seaslugforum.net), and www.nudipixel.net.

Results

A total of 96 nudibranch species in 40 genera and 17 families were recorded in our collections (Table 1). The most speciose group was the suborder Doridina (81 % of the total number), followed by the suborder Aeolidina (15 %). Comparison of the list with recordings from previous studies, resulted in 40 additional species for Thailand (Table 1). However, in the present survey, 8 specimens could be identified to genus level only (Fig. 2). The species with the highest frequency of encounters was *Jorunna funebris* (Kelaart, 1858). A total of 30 species was found in the Andaman Sea (n=30), while 19 species were recorded in the Gulf of Thailand, and 47 species in both areas (Table 1).

Our data also revealed that the Chromodorididae, Phyllidiidae, and Discodorididae were the most dominant families. The Chromodorididae accounted for 35 % of the total number of species (n=33), followed by Phyllidiidae (n=16), and Discodorididae (n=14), respectively (Table 1). The field observations showed that the majority of nudibranchs (39 %) were found on rubble, followed by 28 % on sand, 8 % on rock, and 25 % in association with sessile organisms (Fig. 3).

Discussion

Based on the present survey and earlier studies (Jensen 1998, 2007; Debelius 2001; Malaidang 2007; Thamrongnawasawat

Table 1 List of nudibranch species found in a 10-year survey and records from other sources

Species	This study	Other sources
Suborder Doridina		
Family Actinocyclidae		
Hallaxa fuscescens (Pease, 1871)	AG	
Family Chromodorididae		
Cadlinella ornatissima (Risbec, 1928)	AG	
Ceratosoma sinuatum (van Hasselt, 1824)		A[b]
C. trilobatum (JE Gray, 1827)	AG	
Chromodoris albonares Rudman, 1990	G	
C. annae Bergh, 1877	A	
C. annulata Eliot, 1904	A	
C. aureopurpurea Collingwood, 1881	AG	
C. coi (Risbec, 1956)		A[e]
C. decora (Pease, 1860)		A[e]
C. elisabethina Bergh, 1877		A[e]
C. fidelis (Kelaart, 1858)	AG	
C. geminus Rudman, 1987	A	
C. geometrica Risbec, 1928	AG	
C. gleniei (Kelaart, 1858)		A[e]
C. hintuanensis Gosliner & Behrens, 1998	A	
C. kuniei Pruvot-Fol, 1930	A	
C. lineolata (van Hasselt, 1824)	AG	
C. mandapamensis Valdés, Mollo & Ortea, 1999		G[f]
C. preciosa (Kelaart, 1858)	AG	
C. roboi Gosliner & Behrens, 1998		A[e]
C. rufomaculata Pease, 1871		A[e]
C. sinensis Rudman, 1985	G	
C. strigata Rudman, 1982	A	
C. tinctoria (Rüppell & Leuckart, 1828)	A	
C. tumulifera Collingwood, 1881	G	
Chromodoris sp.	A	
Durvilledoris lemniscata (Quoy & Gaimard, 1832)		A[a]
D. similaris Rudman, 1986		A[d]
Glossodoris atromarginata (Cuvier, 1804)	AG	
G. cincta (Bergh, 1888)	AG	
G. hikuerensis (Pruvot-Fol, 1954)	A	
G. pallida (Rüppell & Leuckart, 1828)		A[e]
G. rufomarginata (Bergh, 1890)	A	
Hypselodoris bollandi Gosliner & Johnson, 1999		A[e]
H. bullockii (Collingwood, 1881)	AG	
H. emma Rudman, 1977		A[e]
H. iacula Gosliner & Johnson, 1999	A	
H. infucata (Rüppell & Leuckart, 1830)	AG	
H. kanga Rudman, 1977	AG	
H. krakatoa Gosliner & Johnson, 1999		A[e]
H. maculosa (Pease, 1871)	A	
H. nigrostriata (Eliot, 1904)		A[c,d]
H. obscura Stimpson, 1855	G	
Hypselodoris sp. 1	A	
Hypselodoris sp. 2	A	
Mexichromis multituberculata (Baba, 1953)	AG	
Risbecia pulchella (Rüppell & Leuckart, 1828)	AG	
R. tryoni (Garrett, 1873)	AG	
Thorunna australis (Risbec, 1928)		A[e]
Family Dendrodorididae		
Dendrodoris denisoni (Angas, 1864)	AG	
D. fumata (Rüppell & Leuckart, 1830)	G	
D. nigra (Stimpson, 1855)	AG	
D. tuberculosa (Quoy & Gaimard, 1832)		A[e]
Doriopsilla carneola (Angus, 1864)	G	
D. pallida Bergh, 1902		G[a]
Family Discodorididae		
Asteronotus cespitosus (van Hasselt, 1824)	G	
Discodoris boholiensis Bergh, 1877	G	
Halgerda bacalusia Fahey & Gosliner 1999	A	
H. stricklandi Fahey & Gosliner, 1999	A	
H. tessellata (Bergh, 1880)	AG	
H. willeyi Eliot, 1904		A[e]
Hoplodoris nodulosa (Angas, 1864)	AG	
Jorunna funebris (Kelaart, 1858)	AG	
J. rubescens Bergh, 1876	A	
Peltodoris rubra (Bergh, 1905)	A	
Platydoris annulata Dorgan, Valdes & Gosliner, 2002		A[b]
P. dierythros Fahey & Valdés, 2003	G	
P. scabra (Cuvier, 1804)	G	
Platydoris sp.	G	
Rostanga orientalis Rudman & Avern, 1989	G	
Sebadoris fragilis (Alder & Hancock, 1864)	G	
Thordisa villosa (Alder & Hancock, 1864)		G[a]
Family Doridiidae		
Aldisa erwinkoehleri Perrone, 2001		A[e]
Doriopsis pecten (Collingwood, 1881)	G	
Family Goniodorididae		
Okenia plebeia Bergh, 1902		G[a]
Family Gymnodorididae		
Gymnodoris alba (Bergh, 1877)	AG	
G. citrina (Bergh, 1875)	AG	
G. ceylonica (Kelaart, 1858)		A[e]
G. impudica (Rüppell & Leuckart, 1828)	AG	
G. pattani Swennen, 1996		G[a]
G. striata (Eliot, 1908)		A[a]
Hexabranchus sanguineus (Rüppell & Leuckart, 1828)	A	
Family Phyllidiidae		
Phyllidia coelestis Bergh, 1905	AG	
P. elegans Bergh, 1869	AG	

Table 1 (continued)

Species	This study	Other sources
P. exquisita Bruncknorst, 1993		A[a]
P. marindica (Yonow & Hayward, 1991)	AG	
P. picta (Pruvot-Fol, 1957)	AG	
P. ocellata Cuvier, 1804	AG	
P. varicosa Lamarck, 1801	AG	
Phyllidiella nigra (van Hasselt, 1824)	AG	
P. pustulosa (Cuvier, 1804)	AG	
P. rudmani Brunckhorst, 1993	AG	
P. zeylanica (Kelaart, 1859)	A	
Phyllidiopsis annae Brunckhorst, 1993		A[a]
P. gemmata Pruvot-Fol, 1957		A[a]
P. krempfi Pruvot-Fol, 1957	AG	
P. phiphiensis Brunckhorst, 1993	A	
P. pipeki Brunckhorst, 1993	A	
P. shireenae Brunckhorst, 1993	A	
P. xishaensis (Lin, 1983)	AG	
Reticulidia suzanneae Valdes & Behrens, 2002	A	
Family Polyceridae		
Kalinga ornata Alder & Hancock, 1864		A[b]
Roboastra gracilis (Bergh, 1877)	A	
R. luteolineata (Baba, 1936)	A	
Tambja affinis (Eliot, 1904)		A[c,d]
T. morosa (Bergh, 1877)	A	
T. victoriae Pola, Cervera & Gosliner, 2005	A	
Thecacera pennigera (Montagu, 1815)	AG	
Suborder Dendronotina		
Family Bornellidae		
Bornella anguilla Johnson, 1984		A[d]
B. excepta Bergh, 1884		G[a]
B. stellifer (Adam & Reeve, 1848)	AG	
Family Lomanotidae		
Lomanotus vermiformis Eliot, 1908		A[d]
Family Tethydidae		
Melibe bucephala Bergh, 1902		G[a]
Family Tritoniidae		
Marionia chloanthes Bergh, 1902		G[a]
Tritoniopsis elegans (Audouin, 1826)		A[d]
Suborder Arminina		
Family Arminidae		
Armina semperi (Bergh, 1861)	AG	
Dermatobranchus gonatophora van Hasselt, 1824		A[c,d]
D. ornatus (Bergh, 1874)	A	
Family Zephyrinidae		
Janolus sp.	G	
Suborder Aeolidina		
Family Aeolidiidae		
Cerberilla incola Burn, 1974	G	
Cerberilla sp.	G	

Table 1 (continued)

Species	This study	Other sources
Family Eubranchidae		
Baeolidia japonica Baba, 1933	G	
Family Facellinidae		
Phidiana indica (Bergh, 1896)		AG[d]
P. militaris (Alder & Hancock, 1864)		A[e]
Phyllodesmium magnum Rudman, 1991	AG	
Pteraeolidia ianthina (Angas,1864)	AG	
Family Flabellinidae		
Flabellina bicolor (Kelaart, 1858)	AG	
F. exoptata Gosliner & Willan, 1991	AG	
F. rubrolineata (O'Donoghue, 1929)	AG	
Family Glaucidae		
Facelina sp.	AG	
Family Tergipedidae		
Cuthona sibogae (Bergh, 1905)	AG	
Cuthona sp.	G	
Phestilla lugubris (Bergh, 1870)	AG	
P. melanobrachia Bergh, 1874	A	
P. minor Rudman, 1981	G	

A Andaman Sea, *G* Gulf of Thailand

[a] Jensen (1998), [b] Jensen (2007), [c] Debelius (2001), [d] Rudman WB (The sea slug forum http://www.seaslugforum.net), [e] Thamrongnawasawat et al. (2007), [f] Malaidang (2007)

et al. 2007; www.seaslugforum.net), 136 species of nudibranchs were listed in Thai waters, none of which is endemic. During the present 10-year survey, 96 nudibranch species were encountered, many of which also occur in adjacent waters, such as the South China Sea (Gosliner 1992; Sachidhanandam et al. 2000; Yonow 2011) and the Indian Ocean (Yonow 2012).

From the present study combined with the earlier studies, the highest diversity was recorded in the Andaman Sea (n=108), which is 33 more than in the Gulf of Thailand (n=75), which has more freshwater inflow and terrigenous impact. Assemblages of nudibranchs in this study were characterized by the dominant families, Chromodorididae, Phyllidiidae, and Discodorididae, which belong to the suborder Doridina, which is considered the most abundant group in many regions (Gosliner 1992). The chance of encounters with individuals of the brightly-colored Phyllidiidae is high because they are active throughout the day (Brunckhorst 1991; Cobb and Willan 2006; Gosliner et al. 2008; Hervé 2010). The common occurrence of *Jorunna funebris* (family Discodorididae) can be attributed to the high abundance of sponges, such as *Xestospongia* spp., on which *J. funebris* preys. Thus, the availability of food may be reflected in the distribution of nudibranchs (Darumas et al. 2007).

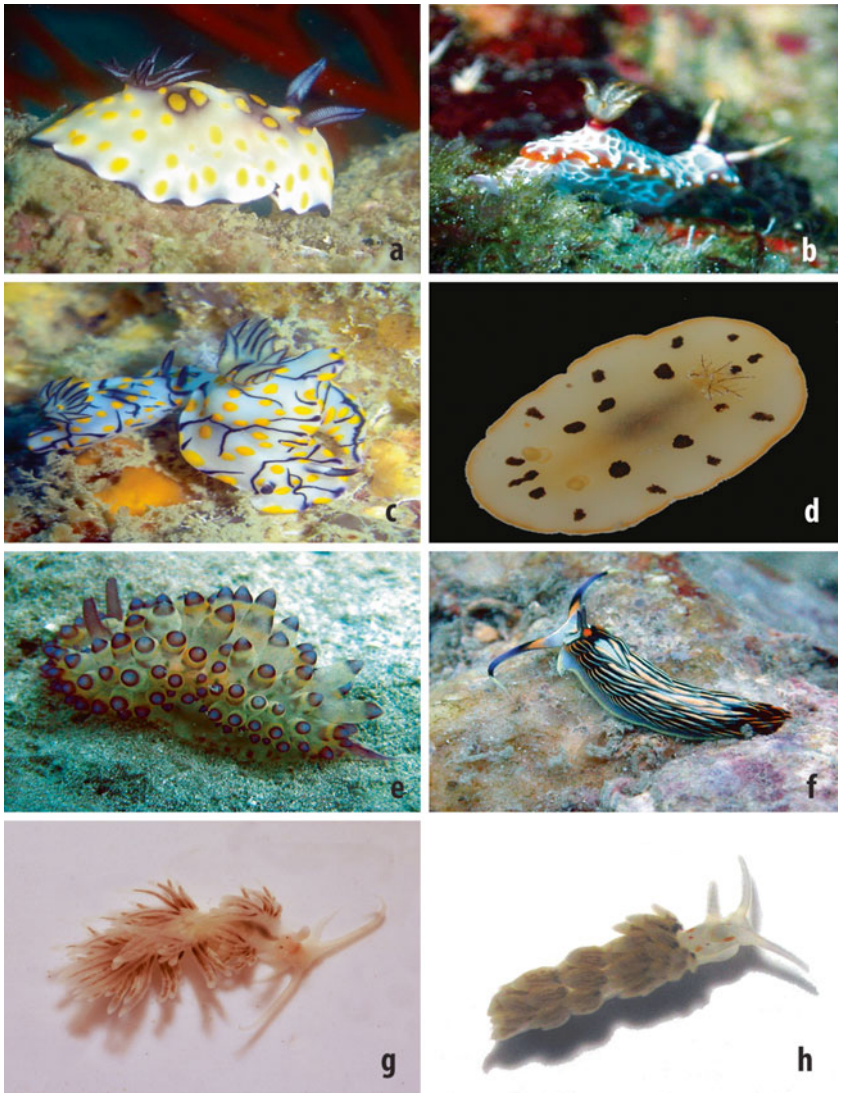

Fig. 2 Unidentified nudibranchs found in this study: **a** *Chromodoris* sp., **b** *Hypselodoris* sp. 1, **c** *Hypselodoris* sp. 2, **d** *Platydoris* sp., **e** *Janolus* sp., **f** *Cerberilla* sp., **g** *Facelina* sp., **h** *Cuthona* sp

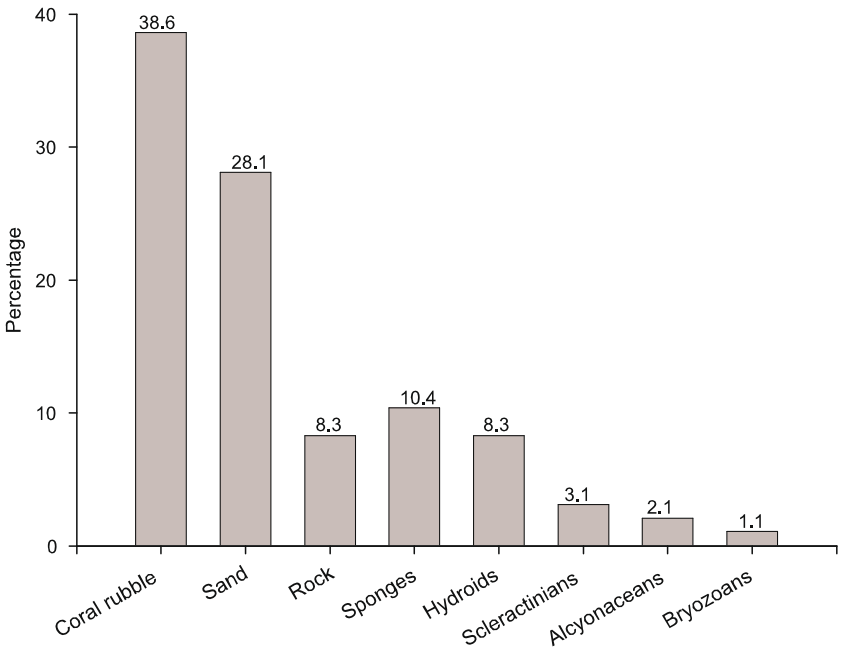

Fig. 3 Relative percentages of nudibranch species recorded on different substrates

Various nudibranch species are small, camouflaged or just rare (Gosliner and Draheim 1996; Jensen 1998, 2007). Moreover, species may be difficult to find because they have a cryptic lifestyle or a short-life history, or they are only nocturnally active (Miller 1962; Thompson 1964; Clark 1975). Therefore, it is likely that the present number of Thai nudibranchs is an underestimation and that additional species will be discovered in the future.

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References

Bouchet P, Rocroi J-P (2005) Classification and nomenclature of gastropod families. Malacologia 47:1–397

Brunckhorst D (1991) Do phyllidiid nudibranchs demonstrate behaviour consistent with their apparent warning coloration?—some field observations. J Moll Stud 57:481–489

Chansang H, Satapoomin U, Poovachiranon S (eds) (1999) Maps of coral reefs in Thai waters, volumes 1 and 2. Department of Fishery, Phuket, Thailand (in Thai)

Chavanich S, Harris LG, Viyakarn V (2010) Nudibranchs of Thailand. Biodiversity research and training program, Bangkok

Clark KB (1975) Nudibranch life cycles in the north-west Anlantic and their relationship to the ecology of fouling communities. Helgol Wiss Meeresunters 27:28–69

Cobb G, Willan RC (2006) Undersea Jewels. A colour guide to nudibranchs. Australian Biological Resources Study, Canberra

Darumas U, Chavanich S, Suwanborirux K (2007) Distribution patterns of the renieramycin-producing sponge *Xestospongia* sp. and its association with other reef organisms in the Gulf of Thailand. Zool Stud 46:695–704

Debelius H (2001) Nudibranchs and sea snails: Indo-Pacific field guide. IKAN-Unterwasserarchiv, Frankfurt

Debelius H, Kuiter R (2007) Nudibranchs of the world. IKAN Unterwasserarchiv, Frankfurt

Gosliner TM (1992) Biodiversity of tropical opisthobranch gastropod fauna. Proc 7th Int Coral Reef Symp 2:702–709

Gosliner TM (2000) Biodiversity, endemism, and evolution of Opisthobranch gastropods on Indo- Pacific coral reefs. Proc 9th Int Coral Reef Symp 2:937–940

Gosliner TM, Draheim R (1996) Indo-Pacific opisthobranch gastropod biogeography: how do we know what we don't know? Am Malacol Bull 12:37–43

Gosliner TM, Behrens DW, Valdés A (2008) Indo-Pacific nudibranchs and sea slugs. A field guide to the world's most diverse fauna. Sea challengers natural history books, Gig Harbor, Washington, and California Academy of Sciences, San Francisco

Hervé JF (2010) Guide des Nudibranches de Nouvelle Calédonie et autres Opisthobranches. ÉditionsCatherine Ledru, Nouméa, Nouvelle Calédonie

Jensen KR (1998) Anatomy of some opisthobranch molluscs from Phuket, Thailand, with a list of Opisthobranchia recorded from Thailand. Spec Publ Phuket Mar Biol Cent 18:243–262

Jensen KR (2007) The opisthobranch molluscs collected during the Thai-Danish BIOSHELF project in the Andaman Sea, Thailand. Spec Publ Phuket Mar Biol Cent 68:21–30

Malaidang N (2007) The study of nudibranch (order Nudibranchia) in Chaolao coral reef and Nomsao island, Chanthaburi province. Senior Project. Burapha University, Thailand

Miller MC (1962) Annual cycles of some Manx nudibranchs, with a discussion of the problem of migration. J Anim Ecol 31:545–569

Munro C (2005) Diving systems. In: Eleftheriou A, McIntyre A (eds) Methods for the Study of Marine Benthos, 3rd edn. Blackwell, Oxford, pp 112–159

Nybakken J (1978) Abundance, diversity, and temporal variability in a California intertidal nudibranch assemblage. Mar Biol 45:129–146

Sachidhanandam U, Willan RC, Chou LM (2000) Checklist of the nudibranchs (Opisthobranchia: Nudibranchia) of the South China Sea. Raffles Bull Zool Suppl 8:513–537

Sittithaweepat N (2001) Study of species richness and distribution of nudibranchs in Thai coral reef. Master Thesis, Kasetsart University, Thailand

Su Y, Huang LJ, Chang YW, Mok HK (2009) Temporal changes in nudibranch composition at a coastal site off Penghu (the Pescadores) in the Taiwan Strait. Zool Stud 48:448–459

Swennen C, Moolenbeck RG, Ruttanadakul N, Hobbelink H, Dekker H, Hajisamae S (2001) The molluscs of the Southern Gulf of Thailand. Thai Stud Biodivers 4:1–210

Thamrongnawasawat T, Duangdee T, Sittithaweepat N (2007) Marine mollusks in Thailand. Office of the Higher Education Commission, Bangkok (in Thai)

Thompson TE (1964) Grazing and the life cycles of British nudibranchs. Br Ecol Soc Symp 4:275–297

Van Alphen J, de Voogd NJ, Hoeksema BW (2011) Differential feeding strategies in phyllidiid nudibranchs on coral reefs at Halmahera, northern Moluccas. Coral Reefs 30:59

Van der Meij SET, Reijnen BT (2012) First observations of attempted nudibranch predation by sea anemones. Mar Biodiv 41:281–283

Yonow N (1992) Observations on the diet of *Philinopsis cyanea* (Martens) (Cephalaspidea, Aglajidae). J Conchol 34:199–204

Yonow N (2008) Sea Slugs of the Red Sea. Pensoft, Sofia

Yonow N (2011) Results of the Rumphius biohistorical expedition to Ambon (1990). Part 15. The suborder Doridina (Mollusca, Gastropoda, Opisthobranchia, Nudibranchia). Zool Meded Leiden 85:905–956

Yonow N (2012) Opisthobranchs from the western Indian ocean, with descriptions of two new species and ten new records (Mollusca, Gastropoda). ZooKeys 197:1–130