

The Systematics of Heterobranchia (Gastropoda-Mollusca) on the Tiwoho Tidal Areas of Bunaken National Park, North Sulawesi

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Abstract : Bunaken National Park, North Sulawesi, features diverse coastal ecosystems, yet information on Heterobranchia diversity remains limited. This study aims to describe the species of Heterobranchia in the tidal zone and analyze their relationship with the substrate. The method used was an exploratory approach employing purposive sampling techniques in the tidal zone at depths of less than two meters. Observations were conducted through direct sweeping, snorkeling, and measurements of temperature, pH, and salinity. Species were identified based on external morphological characteristics and analyzed descriptively. Seven Heterobranchia species were described at this location. These consisted of six Doridida species and one Systellommatophora species on three types of substrate: coral reef edges, sand, and sponges. Most species were found on coral edge substrates.

Keywords: Bunaken Nasional Park; Heterobranchia; Substrates; Tiwoho

Introduction

Bunaken National Park is a marine conservation area spanning 73,973.12 hectares that encompasses small islands featuring coral reef, seagrass bed, and mangrove ecosystems (Bunaken National Park, 2024). The area is divided into a northern section, which includes Bunaken, Manado Tua, Mantehage, Siladen, Nain, and the coastal area from Tanjung Pisok to Tiwoho Village, and a southern section from Poopoh Village to Popareng Village (Londa, 2020). As a conservation area, this region is home to various macro-marine organisms such as coral reefs and their associated organisms, reef fish, mollusks, crustaceans, reptiles, and marine mammals, which are the subjects of research related to ecology, biodiversity, tourism, chemical composition, and pollution (Verisandria et al., 2018; Umacina et al., 2019; Bogdanov et al., 2020; Kamagi et al., 2022; Moelle et al., 2022; Tiranda et al., 2024). Tiwoho Village is located within the buffer zone of Bunaken National Park, which plays a crucial ecological and socio-economic role (BKKBN, 2025). Tiwoho Village in Wori District has a community-managed mangrove ecosystem spanning approximately 62,502 ha (Sondakh et al., 2019).

Heterobranchia is a subclass of Gastropoda characterized by morphological, physiological, and ecological diversity, featuring modifications to the respiratory system and shell forms ranging from reduced to absent (Bouchet et al., 2017; Papu et al., 2020). This subclass includes various orders such as Doridina, Sacoglossa, and Nudibranchia (Gosliner et al., 2018). In the context of benthic ecology, Heterobranchia prefer complex substrates that provide food sources and shelter (Bogdanov et al., 2017; Eisenbarth et al., 2018; Marpaung et al., 2019).

Research on Heterobranchia in Bunaken National Park has recorded 215 species, primarily found in coral reef habitats and the main islands of the area (Papu et al., 2020). However, information regarding the presence and distribution of Heterobranchia in coastal ecosystems, particularly in tidal zones, remains limited. Given that substrate characteristics

such as coral reefs, coral edges, algae, sponges, and sand play a role in determining the distribution and habitat preferences of *Heterobranchia* (Marpaung et al., 2019; Adiwijaya et al., 2021), exploration of the Tiwoho tidal zone is crucial for describing the species present in that location and analyzing their relationship with substrate characteristics

Methods

Time and Location of Research

This study was conducted in the Bunaken National Park (BNP) area in North Sulawesi Province. The sampling site was located on the beach in Tiwoho Village (**Figure 1**). The study was conducted from August to December 2025 during the lowest low tide, between 11:00 a.m. and 4:00 p.m. WITA, at depths of up to 2 meters.

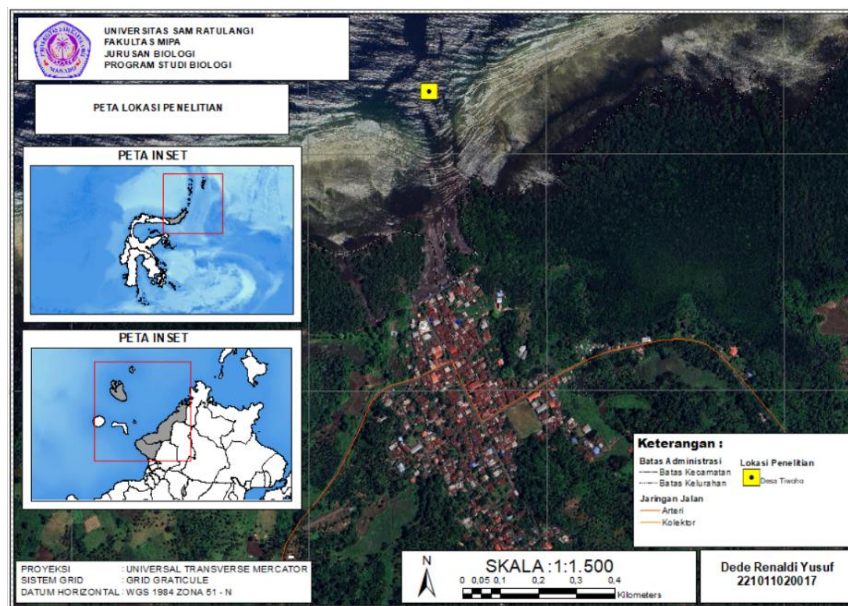


Figure 1. Research location

Tools and Materials

The tools and materials used in this research were: snorkeling gear, writing utensils, identification guides, an Olympus camera, a ruler, litmus paper, a 600-cm W.S. Tyler sieve, a portable refractometer (ATC), the e-Tide app, and a thermometer.

Research procedures

The study was conducted in the Bunaken National Park area, North Sulawesi Province, with sampling sites at Tiwoho Village Beach from August to December 2025 during tidal conditions between 11:00 a.m. and 4:00 p.m. WITA at depths of up to 2 meters. The method used was exploratory purposive sampling, with sampling locations determined in areas suspected to be the preferred habitat and food source of *Heterobranchia*. Site descriptions were recorded by documenting field conditions during the study, while temperature, pH, and salinity measurements were taken in situ, and tidal information was obtained via the e-Tides app by Elecont software. Data collection was conducted through direct exploration of the tidal zone, including combing the mangrove edges, snorkeling on coral reefs at depths greater than 0.5 meters, and surveying rocks, coral reefs, sponges, and sand; each individual found was photographed along with its substrate for identification purposes.

The specimens collected were identified based on external morphology, including body shape, coloration patterns, rhinophore, cerata structure (if present), respiratory organs, and other body parts that could be described with reference to several sources (Debelius, H., & Kuitert, R. H. 2007; Gosliner et al. 2018), as well as the World Register of Marine Species (WoRMS) and the Global Biodiversity Information Facility (GBIF) databases to determine species distribution; the substrate was also identified to clarify its association with the discovered species.

Data Analysis

Data analysis was conducted descriptively by describing the characteristics of Heterobranchia species, the types of substrates they occupy, and the relationship between the species and their substrates. The data were then organized into tables to show the frequency of species occurrence on each substrate type in order to identify trends in habitat preferences and the intensity of the species' association with the substrate. Each species was described with reference to the original description (type specimen) and non-type specimens, and was explained or commented on based on the results of this research.

Results and Discussions

Description of the Research Site Conditions

Data collection was conducted three times between September 30 and October 26, 2025, from 11:00 a.m. to 4:00 p.m. WITA during the lowest low tide at Tiwoho Beach. The site features a habitat characterized by mangroves, seagrass beds, and expanses of coral reefs and coral fragments overgrown with algae and sessile organisms such as sponges (**Figure 2**). Water temperature at the site ranged from 30–31°C with a pH of 7, while salinity ranged from 29–35 ppm (**Table 1**).

Table 1. Environmental Conditions at Tiwoho Beach

Type	Temperature (°C)	pH	Salinity (ppm)
Tiwoho	31	7	35
	30	7	33
	30	7	29
Average	30	7	32



Figure 2. Characteristics of Tiwoho Beach

Heterobranchia Found on Tiwoho Beach

A total of seven Heterobranchia species were successfully identified, belonging to two orders and four genera (**Table 2**). This composition consists of six Dorididae and one Systellommatophora. The identified species include *Phyllidiella nigra*, *Phyllidiella pustulosa*, *Phyllidia varicosa*, *Phyllidia picta*, *Nembrotha cristata*, *Nembrotha kubaryana*, and *Peronia verruculata* (**Figure 3**). The external morphological descriptions of each species correspond with the diagnostic characters reported for each substrate; no new species were found at the study sites, and Heterobranchia were primarily found along the edges of the coral.

Table 2. Heterobranchia found on Tiwoho Beach

Ordo	Species	Substrate		
		Coral reef edge	Sand	sponge
Doridida	<i>Phyllidiella nigra</i> (van Hasselt, 1824)	X	X	X
	<i>Phyllidiella pustulosa</i> (Cuvier, 1804)	X		X
	<i>Phyllidia varicosa</i> Lamarck, 1801	X		
	<i>Phyllidia picta</i> Pruvot-Fol, 1957	X		
	<i>Nembrotha cristata</i> Bergh, 1877	X		
	<i>Nembrotha kubaryana</i> Bergh, 1877	X		
Systellommatophora	<i>Peronia verruculata</i> Cuvier, 1830	X	X	



(a)



(b)



(c)



(d)

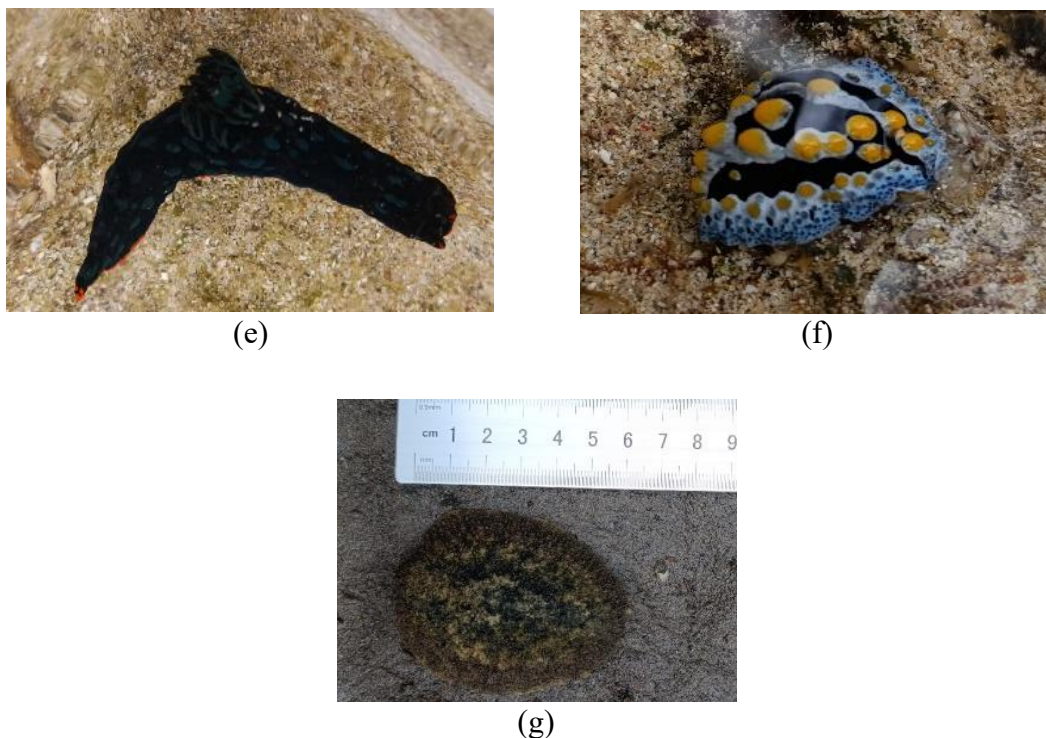


Figure 3. Heterobranch species found: (a) *Phyllidiella nigra*; (b) *Phyllidiella pustulosa*; (c) *Phyllidia varicosa*; (d) *Nembrotha cristata*; (e) *Nembrotha kubaryana*; (f) *Phyllidia picta*; (g) *Peronia verruculata*.

Description of the Heterobranchia Species

Phyllidiella nigra (van Hasselt, 1824)

Synonymy and distribution: Synonymized with *Phyllidia nigra* as the holotype, *Phyllidia serenai* as the lectotype, and *Phyllidia bataviae* (Brunckhorst, 1993; WoRMS, 2026). Found in the waters of Vietnam, Indonesia, and the Philippines; waters of Australia and Southeast Asia (Eastern Indian Ocean and Western Pacific Ocean) with a very limited distribution (GBIF, 2025).

Description: Elongated oval body with a blackish-purple background; legs and ventral surface blackish-blue. The mantle surface is covered with irregular protrusions, ranging from small conical tubercles to larger, rounded, fused protrusions, colored white to pink. The rhinophore and oral tentacles are generally black, while the notum has a black anal pore that is sometimes located between two small protrusions. The foot pads are gray to black. Some tubercles are gray, pink, or green. This coloration is related to its diet (Brunckhorst, 1993; Debelius & Kuitert, 2007; Stoffels et al., 2016; Papu et al., 2022).

Remarks: Found with a length of 2–5 cm. The body is predominantly black with gray tubercles and a black rhinophore, consistent with the description of the type specimen. The tubercle pattern is random, dominated by small tubercles, with some nearly fused to form a circle. The mantle margin is surrounded by small tubercles, and the foot is pale gray with a black margin.

Phyllidiella pustulosa (Cuvier, 1804)

Synonymy and distribution: Synonymous with *Fryeria variabilis* Collingwood, 1881; *Phyllidia melanocera* Yonow, 1986; *Phyllidia nobilis* Bergh, 1869, including the variety *nobilis*

var. *rotunda* Eliot, 1904; *Phyllidia rotunda* Eliot, 1904; *Phyllidia spectabilis* Collingwood, 1881; *Phyllidia verrucosa* van Hasselt, 1824; and *Phyllidiella nobilis* Bergh, 1869 (WoRMS, 2026). Widely distributed in the Indo-Pacific region and the eastern Indian Ocean to the western and central Pacific Ocean (GBIF, 2026).

Description: Body elliptical to oval with a black dorsal background and round to conical tubercles that are scattered or clustered. Cuvier (1804) noted the presence of pale yellow round tubercles on a black background. (Yonow, 2020) reported pink tubercles arranged in five or six median groups with lateral rings and pink edges, lacking black lines on the soles. Papu et al. (2022) added that the tubercles are relatively small, generally in groups of two or three with color variations ranging from pale to dark pink or greenish; the rhinophore and anal pore are black, the gills dark gray to pink, and the soles pale gray to white.

Remarks: Specimens were found measuring 1.9–2.1 cm with a dark black base color. The tubercle groups consist of 2–3 single tubercles ranging in color from gray to green. There is a straight vertical pattern from dorsal to ventral, with varying numbers of tubercles but showing a nearly uniform pattern among individuals. The rhinophore is jet black, the mantle margin is covered with small clustered tubercles, and the feet are gray with faint black margins; this specimen more closely resembles the *Phpu18Ko8* type specimen by Papu et al., 2022.

Phyllidia varicosa Lamarck, 1801

Synonymy and distribution: *Phyllidia borbonica* Cuvier, 1804 (holotype), *Phyllidia honloni* Risbec, 1956 (lectotype), syntypes such as *Phyllidia trilineata* Cuvier, 1804, *Phyllidia quinquelineata* Blainville, 1816, *Phyllidia arabica* Ehrenberg, 1831, and *Phyllidia fasciolata* Bergh, 1869 (WoRMS, 2026). Found in the Indo-Pacific (GBIF, 2026).

Description: Oval to elongated body with a thick, veined mantle and a convex back bearing conical protuberances that may be separate or clustered (Lamarck, 1801; Brunckhorst, 1993). Ground color black to bluish-gray with yellow protuberances; the mantle margin bears small, black-lined protuberances. The rhinophore is black or yellow with 22–30 lamellae, the oral tentacles are gray with yellow tips, and the ventral side is characterized by a black longitudinal line. Size 8–115 mm (Brunckhorst, 1993; Papu et al., 2022; Andrimida, 2021).

Remarks: Specimens were found measuring 3–6 cm in length, with a black mantle, yellow rhinophore, wavy margins, and a pale gray ventral surface with black stripes. The tubercles are yellow with a white base, arranged in three main groups on the notum, with surfaces ranging from blunt to semicircular.

Nembrotha cristata Bergh, 1877

Synonymy and distribution: *Nembrotha cristata* Bergh, 1877 is the holotype. *Nembrotha guttata* Yonow, 1994 and *Nembrotha yonowae* Goethel & Debelius, 1992 are similar species to *N. cristata* (WoRMS, 2026). It can be found in Tanzania, the Philippines, the Maldives, Palau, Indonesia, Australia, Malaysia, the Marshall Islands, Micronesia, the Solomon Islands, and Papua New Guinea (GBIF, 2026).

Description: A robust, limaciform body with a deep black ground color and a length of up to ±120 mm (Bergh, 1877; Pola et al., 2008). The dorsal surface is covered with round, emerald-green protrusions on the back, sides of the body, and edges of the head, serving as a diagnostic feature (Yonow, 1990; Gosliner et al., 2018). The rhinophore are retractable and green-pigmented; the gills consist of five large, green, multipinnate branches, and the anus is located on a papilla between the gill branches (Pola et al., 2008). This species differs from *Nembrotha kubaryana* in the absence of orange pigmentation and from *Nembrotha milleri*, which has a green base (Yonow, 1990).

Remarks: The specimen was found to be 3 cm long. The dominant color is black with green protrusions on the mantle and green edges on the feet. The protrusions are almost arranged in a straight line from head to tail. No orange pigmentation was found, as seen in *N. kubaryana*, nor does it possess body folds like *N. milleri*.

Nembrotha kubaryana Bergh, 1877

Synonyms and distribution: This species has one synonym, *Nembrotha nigerrima* Bergh, 1877 (WoRMS, 2026). It is found in Indonesia, the Philippines, Malaysia, Australia, Chinese Taipei, Japan, Mauritius, Papua New Guinea, the Solomon Islands, Timor-Leste, Tanzania, Portugal, and the Marshall Islands (GBIF, 2026).

Description: The body is purple to greenish-black with the back adorned with neatly arranged green lines that may branch anteriorly to form bands. The body surface may be smooth or bumpy with a texture resembling black velvet, accompanied by green spots or lines that are either separate or fused longitudinally. The rhinofore is layered and contractile, with the rhinofore, oral tentacles, rhinofore sheath, edges, and tips of the leg bright orange. The gills are generally green and may be mixed with orange pigment, while the feet range in color from bluish-green to pale black (Bergh, 1877; Xiang et al., 2017; Gosliner et al., 2018).

Remarks: The specimen was found measuring 4.2 cm and had a dominant bluish-green color with tubercles on the mantle surface. A striking difference from *N. cristata* lies in the tips of the rhinofore, the mantle margins, and the tips of the oral tentacles, which are bright orange in *N. kubaryana*, whereas in *N. cristata* these parts are green. The rhinofore and gills are green, the tubercles and gill ribs are pale green, and in this specimen the tubercles do not appear elongated. The feet are pale black.

Phyllidia picta Pruvot-Fol, 1957

Synonymy and distribution: *Phyllidia picta* Pruvot-Fol, 1957 is the valid name (holotype). *Fryeria menindie* (Brunckhorst, 1993) was declared a junior synonym following examination of the holotype by Yonow (1996). Thus, *Fryeria picta* (Pruvot-Fol, 1957) and *Phyllidia menindie* (Brunckhorst, 1993) are merely synonyms that are not accepted (WoRMS, 2026). Historically, this species has been reported from Saudi Arabia, the Arabian Sea, Thailand, Vietnam, Singapore, Malaysia, the Philippines, Papua New Guinea, Palau, Micronesia, Guam, Australia, the Solomon Sea, Vanuatu, Fiji, and New Caledonia (GBIF, 2026).

Description: The body is oval-shaped with a blue to pale gray base accompanied by a contrasting black reticulated pattern. The tubercles are broad-based conical, blue in color with yellow to orange tips, arranged in three median rows, and the rhinofore are yellow, similar to the tubercles. The mantle margin forms a blue semicircle that sometimes contains one or two yellow tubercles. Body size 13–30 mm with foot pads lacking black lines. The combination of the characteristic black pattern, blue base, and rows of yellow–orange tubercles support the identification of this species (Pruvot-Fol, 1957; Papu et al., 2022; Undap et al., 2019).

Remarks: The specimen found measured 2.8 cm with an oval body. The body is black with a yellow rhinofore and yellow tubercles on a grayish-white background. On the dorsal side, there are two rows of tubercles and a single tubercle at the top. The mantle margin is surrounded by small yellow tubercles with a white base, and there are small black spots beneath the marginal tubercles. The ventral surface is bluish-black with a white margin.

Peronia verruculata Cuvier, 1830

Synonym dan distribution: It has had many names assigned to it, including *Onchidium ferrugineum*, *O. branchiferum*, *O. elberti*, *Scaphis viridis*, *S. carbonaria*, *O. astridae*, as well as names from the Red Sea such as *Peronia savignii*, *P. anomala*, and *O. durum*, which have been declared junior synonyms (WoRMS, 2026). Dayrat et al. (2020) also confirmed that the lectotype of *Paraperonia gondwanae* with a type I loop is a synonym, so *Peronia verruculata* remains the valid name. Widely distributed across Mozambique, Kenya, the British Indian Ocean Territory, South Africa, India, Oman, Pakistan, Iran, Djibouti, the Maldives, Bangladesh, Australia, Papua New Guinea, Singapore, Myanmar, Malaysia, Thailand, Indonesia, the United States, New Caledonia, Niue, Fiji, Chinese Taipei, China, Japan, and Hong Kong (GBIF, 2026).

Description: The body is oval to elongated with a thick, shield-like mantle that widens to cover the legs and can cover the head when contracted. The surface of the notum is covered with small to medium-sized papillae without a clear diagnostic pattern. Branched dorsal papillae function as gill structures and constitute a distinctive external characteristic. The ventral side features broad, smooth feet, while the anus and respiratory openings are located beneath the posterior edge of the mantle. Body color varies from brown, gray, to greenish (Cuvier, 1830; Dayrat et al., 2020).

Remarks: The specimen found on Tiwoho Beach measured 6 cm with a rounded body that can elongate. The mantle has a brown base color with the upper notum bearing irregular black markings and is capable of covering the entire lower body. The papillae on the upper notum are larger and relatively sparse, while the mantle margin is densely covered with numerous small papillae encircling the mantle. The inner mantle is green with pale yellow margins; the ventral surface is pale yellow; and there is a movable membrane at the mouth of similar color.

Substrate Preferences of Heterobranchia

Substrate distribution revealed three types: coral edges, sand, and sponges (**Table 2**). Most species were found on coral edge substrates. Dorididae species such as *Phyllidiella nigra*, *Phyllidiella pustulosa*, *Phyllidia varicosa*, *Phyllidia picta*, *Nembrotha cristata*, and *Nembrotha kubaryana* were recorded as dominant on coral edges. Only two species were found on sandy substrates: *Peronia verruculata* and *P. nigra*. Meanwhile, only two species were found on sponge substrates: *P. nigra* and *P. pustulosa*. Their presence on these substrates aligns with Papu et al. (2020), who stated that Heterobranchia are found near their food sources. The complexity of reef edge substrates, which are colonized by algae and sessile organisms, supports the presence of benthic communities (Andrimida et al., 2025) and influences the composition of Heterobranchia, as the substrate serves as a habitat, food source, and protective medium (Adiwijaya et al., 2021).

Based on the research results, the order Doridida is the most commonly found group and shows a strong preference for coral reef and sponge substrates. The six identified Doridida species *Phyllidiella nigra*, *Phyllidiella pustulosa*, *Phyllidia varicosa*, *Nembrotha cristata*, *Nembrotha kubaryana*, and *Phyllidia picta* were primarily found on coral edge substrates, with some species also encountered on sponges and sand. These findings align with research in Lembeh Strait indicating that coral fringes and sponges are the dominant habitats for Dorididae, with coral fringes being the most utilized substrate (Marpaung et al., 2019). Other studies have also reported a positive correlation between the presence of dorids and coral fringe and sponge substrates (Amelia et al., 2022). In this study, coral edges were heavily colonized by sessile organisms such as sponges, which serve as the primary food source for most Dorididae. A study by Wu et al. (2019) showed that species of *Phyllidiella* and *Phyllidia* possess metabolite profiles

similar to those of their sponge prey, indicating a trophic relationship between dorids and the substrates where their prey grows. In the genus *Nembrotha*, all species are found on coral reef substrates. Fisch et al. (2017) reported that *Nembrotha* preys on Tunicata, while Karuso & Scheuer (2002) showed that secondary metabolites in *Nembrotha* are associated with the consumption of Ascidia and Bryozoa.

In the Order Systellommatophora, only one species was found, namely *Peronia verruculata*, which was recorded on sandy substrates and coral fringes (Table 2). Habitat documentation by Dayrat et al. (2020) indicates that *P. verruculata* is found in mangrove and rocky ecosystems. Solanki et al. (2017) explain that this species is often found in the tidal zone, feeding on algae growing on rocks and encountered in mangrove mud during low tide. In this study, the presence of *P. verruculata* on coral and sandy edges aligns with its preference for substrates that support algal growth as a food source. Gajera et al. (2022) state that *P. verruculata* possesses a taenioglossan radula type characteristic of herbivores, supporting its association with algal-rich substrates in the tidal zone.

Conclusion

Based on the results of an exploratory study in the tidal zone of Tiwoho Beach, Bunaken National Park, seven species of Heterobranchia were found, classified into two orders and four genera: six Dorididae and one Systellommatophora. Environmental conditions during the study indicated an average temperature of 30°C, a pH of 7, and a salinity of 32 ppm at the site. Heterobranchia were found on three types of substrates: coral edges, sand, and sponges. Most species were associated with coral edge substrates, which were also the most dominant substrate at the study site. These findings indicate a tendency for Heterobranchia to be associated with complex substrates and demonstrate a relationship between substrate type and species presence in the tidal zone of Tiwoho Beach.

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