Diversity and Distribution of Sea Slugs (Gastropods: Heterobranchia) in Sempu Strait, Indonesia

Diversity and Distribution of Sea Slugs (Gastropods: Heterobranchia) in Sempu Strait, Indonesia

Anthon Andrimida[1] and R Hermawan[2]

1 Department of Marine Affairs and Fisheries, Surabaya, Indonesia

2 Bhakti Alam Sendang Biru, Malang, Indonesia

anthonandrimida@gmail.com

Abstract. The heterobranch sea slugs are one of the most under-studied marine lifeforms found around the Sempu Strait Area. Currently, the records of their occurrences around this area are only known from the underwater macrophotography enthusiast's collection and have not been published on a scientific article. We conducted underwater surveys spanning from October 2017 to June 2019 at eleven dive sites of Sempu Strait and yielded 45 different species of heterobranch sea slugs, including 35 species of Nudibranchia, 6 Aplysiida (Anaspidea), 2 Cephalaspidea, and 2 Sacoglossa. The analysis of the sea slugs occurrence on Sempu Strait reveals that the areas around the Western Sempu Strait, including Rumah Apung, Kondang Buntung, Tiga Warna, and Stumbut have the most diverse sea slugs species, even though the majority of the species have a low sighting frequency. The analysis also revealed that roughly a third of the sea slugs encountered on the Sempu Strait areas are found on the coral rubble substrate. This study revealed that Sempu Strait has slightly lower sea slug species diversity than another nearby studied site. The records provided here hopefully could help to encourage macro-photography recreational dive activities to further develop the ecotourism sector around this area. **Keywords:** Distribution, Diversity, Heterobranch, Sea Slug, Sempu Strait

1. Introduction

The overall marine biodiversity of the Sempu Strait area is still scarcely documented, despite it is one of the oldest Nature Reserve (id: Cagar Alam) in Indonesia. There was a scientific survey that has been conducted at the Sempu Strait Waters, but it is still describing the most commonly present invertebrates that have been linked to the coral reef condition around this area [11]. Yet, the diversity status of heterobranch sea slug around this area remain unknown, as there was no study has been done around this area to assess their condition. Whereas, the presence of certain biodiversity of marine heterobranch sea slug could give evidences for the overall biodiversity around the coral reef ecosystem and the areas adjacent to it, as many of the heterobranch sea slugs are feeding exclusively on certain organisms, like poriferans, cindarians, ascidians, and algae that also associated within the coral reef ecosystem [10]. Hence, the diversity of the heterobranch sea slug also could be assessed to explain the broader diversity of the other taxa within a particular area.

While research around heterobranch sea slug's diversity has been conducted in Indonesian waters, they are mostly conducted at the eastern part of this country, such as Bunaken National Park [3] [10], Ambon [21], Manado Bay [17] and Lembeh Strait [16]. The study around heterobranch sea slug's occurrence and diversity around the Western Part of Indonesia is still much unknown, particularly

around the East Javanese Waters. There are a couple of studies regarding the heterobranch sea slug's occurrence around East Java, such as Situbondo [19] and Madura Strait [14]. Still there are not much studies done around the southern part of the region, leaving the detailed number about their diversity is very much unknown.

This study conducted on the Sempu Strait, a narrow water bodies that separate the Sempu Island from the Java Mainland. This strait is well-known for its fishing port, one of the most productive fishing port in the Southern Coast of East Java. The existence of this fishing port is inducing both economic boosts for the locals, and also an ecological stress for the marine biodiversity. Currently, there are growing demands on recreational dive activity around this area, mainly for its reef-based diving activity. This growing reef-based tourism activity is slowly making a promising alternative for the local economy. The diversity, striking coloration, and the slow moving, non-aggressive trait of heterobranch sea slug has proved to attract divers alike to have a close encounter with them [9]. So, increasing information around their existence and diversity around this strait could help to encourage non-reef based recreational SCUBA diving, mainly the underwater macrophotography to develop the ecotourism sector around this area.

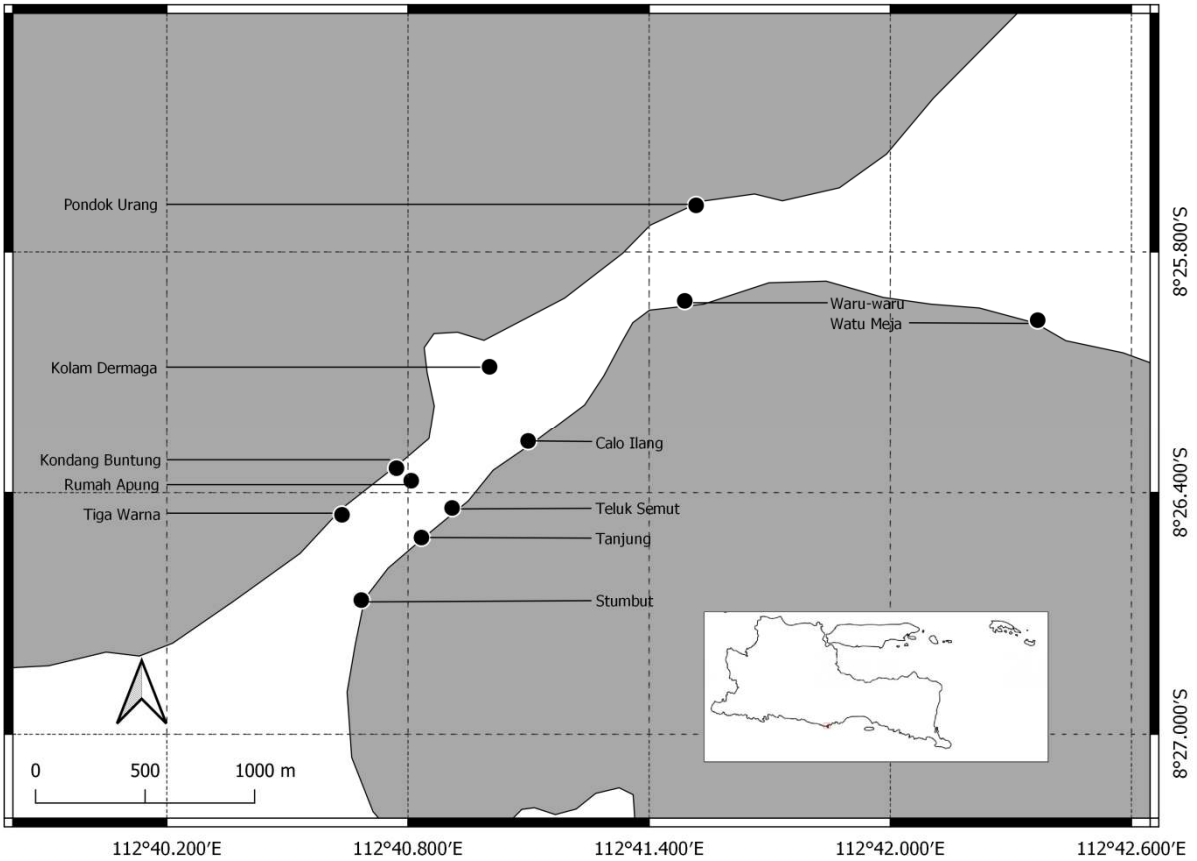

Figure 1 Sempu Strait featuring sample locations. Grey shade represents land, inset represents study location within East Java Province, Indonesia.

2. Materials and Methods

The surveys were conducted at eleven dive sites around the Sempu Strait waters. The sites were selected based on their underwater features, with the coral reefs and their adjacent areas were taken into priority. These surveys were conducted from October 2017 to June 2019 with a total of 35 dives were conducted involving 2-4 experienced divers. Because of the low abundance, scattered distribution and their uncertain occurrence, we conducted the surveys using the Roving Diver

Technique [13], covering areas from 0-25 meters depth with average survey time about 55 minutes. The sampling method that did in this study is only by taking a detailed feature photograph of the sea slugs that have been found around the waters. There is no sample collection or preservation conducted in this study. The data collected only from a series of photograph that has been taken during the dive using Olympus Tough TG-5 and Canon G7X Mark II Camera with a detailed shot at each specimen's features possible. Each photograph of the sea slugs are identified by comparing to book [1] [6], scientific publications [3] [10] [15] [21], and additionally the Sea Slug Forum [18] it also have the taxonomic structure verified by the World Register of Marine Species' [20].

The heterobranch sea slug's sighting data during the study then tabulated to create a dataset. The abundance of sea slug species were estimated using the species number of heterobranch sea slug within the dive sites. This abundance data also include "unique species" abundance within the dive sites, stating that the "unique species" sea slugs are sea slug species that only found at one dive site during this study. The occurrence frequency data represents the sea slug species' tally found on each different study sites. Hence if a species found on five dive sites, it is classified as "5", etc. The substrate data is acquired through the sea slug's photograph and manual record in which the sea slug found during the study to identify the substrate preference of heterobranch sea slugs at the study area.

3. Results

In total, 45 species of heterobranch sea slugs are recorded during this study (Table 1), which 35 species belong to the Nudibranchia order, 6 species belong to the Aplysiida (Anaspidea) order, 2 species belong to the Cephalaspidea order, and 2 species belong to the Sacoglossa superorder. However, in this study, there are two species of Nudibranchia that only could be identified to its genus level (Fig. 2).

Figure 3 shows that the Rumah Apung site has the highest species abundance (19 species), in which 15 of them are unique species, means that they are only found at Rumah Apung during our study. The second site with most species abundance is Stumbut with 17 species, in which 10 of them are unique, followed by Kondang Buntung Site with 8 species in which 3 of them are unique. Other sites that include a unique heterobranch sea slugs species are Pondok Urang, Kolam Dermaga, and Watu Meja with 1 species each. Figure 4 shows that about 69% of the heterobranch sea slugs (31 species) had only been found at one site on the Sempu Strait during this survey. The most widely distributed species throughout the survey area is *Phyllidiella pustulosa*, in which had been found at 5 sites at the Sempu Waters, followed by *Hypselodoris tryoni* which had been found at 4 sites (Tab. 1).

The substrate data counted from every single encounter of each sea slug species on each dive site (n=69) during the study, where it is revealed that 36,2% of the heterobranch sea slugs were found at coral rubble substrate, followed by 20,3% on sand/silt, 17,4% on algae clump, 15,9% on rock, 5,8% among the hydroids, and 4,3% found on man-made substrate like debris and driftwood (Fig. 5).

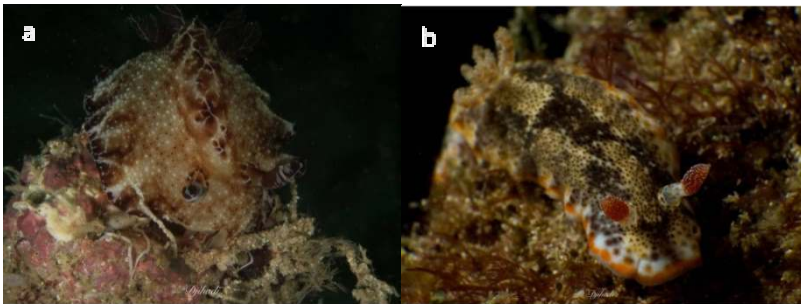

Figure 2 Species that could not be identified during this study. Images taken by Djihadi at Stumbut during an expedition with the author. a) Halgerda sp. b) Chromodoris sp.

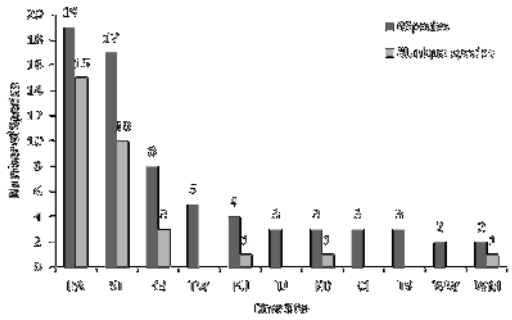

Figure 3 Abundance of heterobranch sea slug species per dive site in Sempu Strait

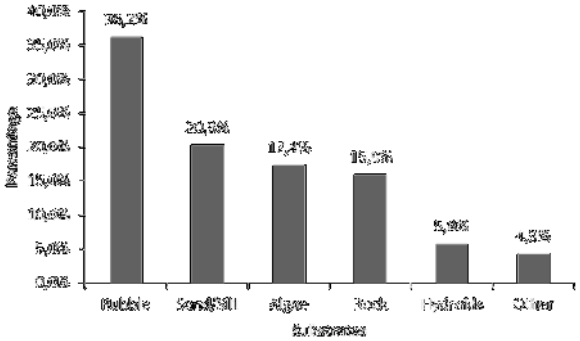

Figure 5 Substrate preference of heterobranch sea slug found during this study

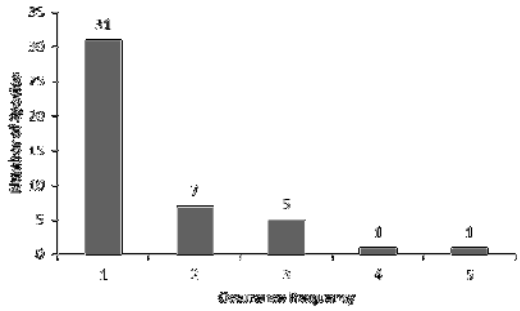

Figure 4 Occurence frequency of sea slugs species per site

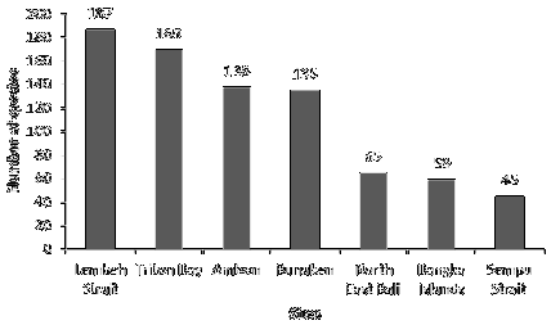

Figure 6 Heterobranch sea slug species abundance around Indonesian dive sites

4. Discussion

During the present study, a total of 45 species of heterobranch sea slug were found in the Sempu Strait Waters. Nudibranch species made the biggest proportion of the total species recorded, covering about 78% (35 species) of all heterobranch sea slug species found during the study, while the remaining small portion belong to the non-nudibranch species, with 13% (6 species) classified under Aplysiida (Anaspidea), 4% (2 species) classified under Cephalaspidea, and 4% (2 species) classified under Sacoglossa.

Table 1 Distribution of Heterobranch sea slug species within dive sites at Sempu Strait

Family	Species number within dive sites											
	WW	KD	CI	WM	KB	TS	RA	TW	PU	TJ	ST	Total
Aglajidae					1							1
Aplysiidae		2					5					7
Arminidae							1					1
Bornellidae							1					1
Bullidae							1					1
Chromodorididae					6	1	2	2	2	3	11	27
Dendrodoridae							2					2
Discodorididae											1	1
Eubranchidae							1					1
Facelinidae					1	1	3	1	1			7
Flabellinidae								1			2	3
Phyllidiidae	2	1	3	1		1		1	1		2	12
Plakobranchidae							1				1	2
Samlidae				1								1
Scyllaeidae							1					1
Tethydae							1					1
Total	2	3	3	2	8	3	19	5	4	3	17	69

Table 2 Species list and distribution of heterobranch sea slug found during the survey

Species	Distribution
Order Nudibranchia	
Family Arminidae	
Dermatobranchus albus (Elliot, 1904)	RA
Family Bornellidae	
Bornella anguilla (S. Johnson, 1984)	RA
Family Chromodorididae	
Chromodoris aspersa (Gould, 1852)	ST
Chromodoris sp.	ST
Dorisprismatica atromarginata (Cuvier, 1804)	KB, ST
Goniobranchus geometricus Risbec, 1928)	ST
Goniobranchus tinctorius (Rüppell & Leuckart, 1830)	ST
Goniobranchus tumuliferus (Collingwood, 1881)	KB
Goniobranchus verrieri (Crosse, 1875)	ST
Hypselodoris apolegma (Collingwood, 1881)	KB, ST
Hypselodoris emma (Rudman, 1977)	KB
Hypselodoris infucata (Rüppell & Leuckart, 1830)	KB, ST, TW
Hypselodoris kanga (Rudman, 1977)	ST
Hypselodoris maculosa (Pease, 1871)	RA, TJ
Hypselodoris pulchella (Rüppell & Leuckart, 1830)	TW, PU, TJ
Hypselodoris tryoni (Garrett, 1873)	KB, TS, TJ, ST
Thorunna daniellae (Kay & Young, 1969)	TJ
Thorunna florens (Baba, 1949)	RA, ST
Family Dendrodoridae	
Dendrodoris denisoni (Angas, 1864)	RA
Dendrodoris nigra (Stimpson, 1855)	RA
Family Discodorididae	
Halgerda sp. 1	ST
Family Eubranchidae	
Eubranchus mandapamensis (K. P. Rao, 1968)	RA
Family Facelinidae	
Cratena simba (Edmunds, 1970)	RA, PU
Phidiana militaris (Alder & Hancock, 1864)	RA
Phyllodesmium poindimiei (Risbec, 1928)	RA
Pteraeolidia ianthina (Angas, 1864)	KB, TS, TW
Family Flabellinidae	
Coryphellina exoptata (Gosliner & Willan, 1991)	ST
Coryphellina rubrolineata (O'Donoghue, 1929)	TW, ST
Family Phyllidiidae	
Phyllidia ocellata (Cuvier, 1804)	ST
Phyllidia varicosa (Lamarck, 1801)	WW, KD, CI
Phyllidiella pustulosa (Cuvier, 1804)	WW, CI, TW, PU, ST
Phyllidiopsis fissurata (Brunckhorst, 1993)	CI, WM, TS
Family Samlidae	
Samla bicolor (Kelaart, 1858)	WM
Family Scyllaeidae	
Scyllaea fulva (Linnaeus, 1758)	RA
Family Tethydae	
Melibe viridis (Kelaart, 1858)	RA
Order Cephalaspidea	
Family Aglajidae	
Tubulophilinopsis pilsbryi (Eliot, 1900)	KB
Family Bullidae	
Bulla ampulla (Linnaeus, 1758)	RA
Order Aplysiida	
Family Aplysiidae	
Aplysia oculifera (A. Adams & Reeve, 1850)	KD, RA
Bursatella leachii (Blainville, 1817)	RA
Dolabella auricularia (Lightfoot, 1786)	KD
Notarchus indicus (Schweigger, 1820)	RA
Stylocheilus longicauda (Quoy & Gaimard, 1832)	RA
Stylocheilus striatus (Quoy & Gaimard, 1832)	RA
Superorder Sacoglossa	
Family Plakobranchidae	
Elysia marginata (Pease, 1871)	RA
Thuridilla lineolata (Bergh, 1905)	ST

CI Calo Ilang, *KB* Kondang Buntung, *KD* Kolam Dermaga, *PU* Pondok Urang, *RA* Rumah Apung, *ST* Stumbut, *TJ* Tanjung, *TS* Teluk Semut, *TW* Tiga Warna, *WM* Watu Meja, *WW* Waru Waru.

The most dominant families of heterobranch sea slug found during the study are Chromodorididae, Phyllidiidae, Facelinidae, and Aplysiidae (Table 1). The Chromodorididae family that belongs to the Nudibranchia order, is considered as the most abundant heterobranch sea slug's family in Indo-Pacific Region [5]. The Phyllidiidae family is the second most abundant heterobranch family found in Sempu Strait Waters. This family tends to be more active throughout the daylight hours [2], hence it is one of the most easily encountered family within the area, as most of the surveys are conducted during the daytime. The third most abundant family is the Aplysiidae, which belong to the Aplysiida (Anaspidea) Order. This family is found in abundance at Sempu Strait during the peak dry season where the algae are also growing in abundant. This herbivore sea slug are feeding on algae, and commonly found inhabit the intertidal and sub-littoral zone where their activity is influence by the daylight-dark cycle [12].

There are two species found in this study that only could be identified to its genus level. The images with its genus-level identification are listed in Fig 2a and 2b. The unidentified individuals found during the study were not counted towards new records, but only they were not fit into any specific species based on their morphology. The first individual listed in Fig 2a is showing a robust morphology of the Nudibranch species from the Genus *Halgerda,* but with much darker coloration and it has white-colored ridge. The member of this genus, has a relatively high body profile with a network of angular ridge on the dorsal side. The dorsal side of the body also firm and tend to be felt rough when touched [8]. The second individual listed in Fig 2b is likely resembles *Chromodoris striatella* color variations, which is lack the dark stripes, but covered with dark spotts instead. The rhinopores are red and its mantle margin is covered with orange stripe. Its coloration resembles the *Chromodoris* sp. 13 [6] and one specimen from the Sea Slug Forum [4].

Species diversity comparison in Fig. 6 retreived from various sources showed that Lembeh Strait has the most heterobranch sea slug species number in Indonesia with 187 species [7], followed by Triton Bay, West Papua with 169 species [7], Ambon with 138 species [22], Bunakken with 135 species [10], North East Bali with 65 species, Bangka Islands with 59 species [7], and Sempu Strait with 45 species found during this study. The comparison also shows that the dive sites around the Western Part of Indonesia has relatively lower number of heterobranch sea slug species diversity, dwarfed by their eastern counterparts where the heterobranch sea slug's species is relatively high.

5. Conclusion

Knowledge around the occurrence, diversity, and distribution of heterobranch sea slug from Sempu Strait Waters is very limited. Even the overall heterobranch sea slug from the nearby region also still under-studied according to the very limited scientific publications available. This study indicates that the Sempu Strait Waters have a relatively high heterobranch sea slug diversity. However, the records is still ongoing, with new records is still found even after the study indicates that in the future, there would be a greater number of heterobranch sea slug described around this area. More long-term monitoring should be conducted to assure the species number and also their distribution throughout the strait. Also with the current dynamic of heterobranch sea slug's classification, it is likely that in the near future, the species listed in this study would be reclassified, and thus made the current name invalid.

The informations around the occurrence of heterobranch sea slug in Sempu Strait is very important, considering that there are a growing number of recreational diving, as well as the non-reef based macro-photography SCUBA diving activities. These informations are very helpful for the local guides alike to better explain the status of heterobranch sea slug condition around the strait as the main objects hunted by the macro-photographers. Furthermore, the diversity and distribution of heterobranch sea slug around Sempu Strait could help the academics alike to better understanding the

reef ecosystem around the area, thus helping to encourage the sustainable management of local marine and fisheries resources.

6. Acknowledgment

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References

[1] Britayev T and Antokhina T 2012 *Benthic fauna of the Bay of Nhatrang, Southern Vietnam. Vol. 2.* Moscow: KMK.
[2] Brunckhorst D J 1993 *Records of the Australian Museum* 1-107.
[3] Burghardt I, Carvalho R, Eheberg D, Gerung G, Kaligis F, Mamangkey G 2006 *Journal of Zoological Society Wallacea* **2** 29-43.
[4] Fraser V 2000 *Spotted from of Chromodoris striatella*. Retrieved July 6, 2019, from Sea Slug Forum: http://www.seaslugforum.net/message/2841
[5] Gosliner T M 2000 *Proceedings 9th International Coral Reef Symposium* 937–940.
[6] Gosliner T M, Valdes A, Behrens D W 2018 *Nudibranch & Sea Slug Identification Indo-Pacific: 2nd Edition.* Jacksonville, Florida: New World Publications, Inc.
[7] Holley A and Trenque J 2019 *Welcome To Anthony's Nudibranch*. Retrieved July 24, 2019, from Anthony's Nudibranch: http://www.holleyuwphoto.com/
[8] Immanuel T, Goutham-Bharati M P, Kiruba-Sankar R 2016 *Journal of Threatened Taxa* **8 (3)** 8626–8628.
[9] Jensen K R 2013 *Aquatic Science & Management* **1(2)** 100-110.
[10] Kaligis F., Eisenbarth, J.-H., Schilo, D., Dialao, J., Schaberle, T. F., Bohringer, N., et al. (2018). Second survey of heterobranch sea slugs (Mollusca, Gastropoda, Heterobranchia) from Bunaken National Park, North Sulawesi, Indonesia - how much do we know after 12 years? *Marine Biodiversity Records Vol. 11 No. 2*, 1-20.
[11] Luthfi O M, Dewi C S, Sasmitha R D, Alim D S, Putranto D B, Yulianto F 2018 *Journal of Fisheries and Marine Reearch* 138-148.
[12] Lyons L C 2011 *Frontiers in Molecular Neuroscience* 1-6.
[13] Munro C 2005 *Methods for the Study of Marine Benthos Third Edition* Oxford: Blackwell Science Ltd.
[14] Muzaki F K and Saptarini D 2011 *Makalah Kongres dan Seminar MATAKI* **1** 1-12.
[15] Nimbs M J and Smith S D 2016 *The Royal Society of Victoria* **128** 44-113.
[16] Ompi M, Lumoindong F, Undap N, Papu A, Wägele H 2019 *AACL Bioflux* **12(2)** 664-677.
[17] Purba A, Kusen J D and Mamangkey N *Aquatic Science & Management* **1(1)** 21-25.
[18] Rudman W B 2010 *The Sea Slug Forum - Species List*. Retrieved August 27, 2018, from The Sea Slug Forum: http://www.seaslugforum.net/specieslist.htm
[19] Sari L N and Aunurohim 2013 *JURNAL SAINS DAN SENI POMITS* **2(2)** 2337-3520.
[20] WoRMS 2018 *WoRMS - World Register of Marine Species*. Retrieved August 27, 2018, from WoRMS - World Register of Marine Species: http://www.marinespecies.org/
[21] Yonow N 2001 *Zool Meded.* 1-50.
[22] Yonow N and Jensen K R 2018 *Archiv für Molluskenkunde* **147** 1–48.