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Sipuncula (Peanut Worms) in Indonesia Waters: A Review

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Abstract

Sipunculans, or peanut worms, are unsegmented worm-like marine organisms with distinctive trunk-like bodies. They play important roles in marine ecosystems, such as bioerosion, bioturbation, and food sources. Sipunculans are also harvested as human food in some regions worldwide. Despite their importance, a comprehensive understanding of the Sipuncula in Indonesia is still limited. This work aimed to compile a study of the distribution, ecology, and potency of Sipuncula species in Indonesian waters. The distribution of Sipuncula species in Indonesian waters was recorded from the northernmost to the easternmost part of Indonesia. So far, nineteen species have been found in Indonesian waters and are dominated by Sipunculus nudus. In Indonesia, Sipuncula exhibits a diverse range of habitats, they can be found in seagrass, mangrove and coral reef ecosystems, in both sandy and muddy sediments. Sipunculans found in Indonesia have ecosystem function as bioturbator, shell-utilizer, and coral-symbiotic species. Sipuncula also has potency as a food and nutraceutical for human health maintenance because it contains highly nutritious such as protein, carbohydrates, ash, lipids, moisture, minerals, amino acids, and fatty acids. In some areas in Indonesia, local communities use Sipuncula as a traditional food source and fishing bait. Given its significance for marine ecosystems and human livelihoods in Indonesia, future management strategies should include regulations on catch size and management practices, data collection, promotion of sustainable fishing practices, and research on Sipuncula biology and ecology. Addressing these knowledge gaps will help to ensure the sustainable use and conservation of Sipuncula in Indonesia.

Keywords: *Sipunculus, distribution, ecological, nutrient, utilization*

Introduction

Indonesia has abundant potential marine organisms (Suharsono, 2014; Ambariyanto, 2017), and among these, the peanut worm (Sipuncula) is one indigenous fishery product that still needs to be unrevealed in its potential. Sipuncula is a small, species-poor class of unsegmented marine worms (Kawauchi *et al*., 2012; Hsueh and Tan, 2016). Sipuncula resides in burrows, tubes, and sheltered locations, from temperate to tropical regions (Kędra *et al*., 2018). They can survive at extreme depths of up to 7000 m (Murina, 1971; Maiorova and Adrianov, 2018). Most Sipuncula are deposit feeders, meaning they extract nutrients from organic particles in their surroundings (Murina, 1984).

Sipuncula has a crucial role in ecosystems. For examples, *Nephasoma* in the Nordic Sea can create an intricate network of capillaries. This network aids in the inward movement of surface sediments, contributing to bioturbation in those regions (Shields and Kedra, 2009). In Beibu Bay, *Sipunculus nudus* influences the composition of bacterial communities and biogeochemical processes, thereby impacting the overall ecosystem functioning (Li *et al*., 2019). Additionally, Sipuncula can help mitigate sediment organic waste (Li *et al*., 2015) and even affect the removal of calcium carbonate in Eastern Tropical Pacific coral reefs (Cardona-Gutiérrez and Londoño-Cruz, 2020). Furthermore, these organisms are a significant food source for higher trophic levels, highlighting their importance in the marine food web (Kędra and Włodarska-Kowalczuk, 2008).

Sipuncula also plays a role in socioeconomic aspects for humans. In China, Sipuncula has long been used as traditional Chinese medicine for antiaging and regulating stomach and spleen functions (Zhang and Dai, 2011). Similarly, in

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Vietnam, Sipuncula is recognized as both a culinary delicacy and a traditional medicinal resource (Ba *et al.,* 2022; Khoi, 2018).

Studies on Sipuncula in Indonesia primarily focus on its nutritional content (minerals, nutrient fatty acids) (Fakhrurrozi, 2011; Nurhikma *et al.,* 2017; Rahayu *et al*., 2019; Silaban, 2012, 2017, 2018; Silaban, 2019; Fatimah *et al.,* 2021; Yuslina, 2022). Limited research is available on the biological and ecological aspects of Sipuncula species (Hoeksema and Best, 1991; Erliani, 2021; Erliani *et al.,* 2021; Ferdinandus *et al.,* 2022; Matulessy, 2021), while studies related to the genetics and the influence of Sipuncula on ecosystems are almost nonexistent (Table 1.). Based on existing studies, this paper attempts to summarize the species distribution, habitat, utilization, and future management options and research for Sipuncula in Indonesia. This paper relies on peer-reviewed journals to present a comprehensive perspective on Sipuncula globally. Additionally, Google Scholar is utilized with the keywords "Sipuncula, Indonesia" to retrieve and analyze academic citations related to Sipuncula research in Indonesia. Furthermore, the species name of Sipuncula in this paper have been cross-checked and adjusted to valid names to the World Register of Marine Species (WORMs).

Distribution of Sipuncula

Sipuncula body are divided into trunk and introvert. The length of the body varies according to the species (Cutler, 1994) (Figure 1.). The adult body can be between 3 and 400 mm long, but it is usually between 15 and 30 mm, and its shape can range from a thin cylinder to spindle- or flask-shaped to virtually spherical. The epidermal features on the Sipuncula include papillae, hooks, and shields. In certain species, the introvert length is less than half that of the trunk, while in others, it can be several times as long. In members of the class Sipuncula, the mouth is located at the tip of the introvert and is encircled by tentacles. A zone behind the tentacular region may have posteriorly oriented hooks dispersed or grouped in regular rings in the Phascolosomatidea class. Internally, the esophagus and the intestine, which have the shape of a double helix, spiral toward the back of the body before moving anteriorly, via a rectum, to the mid-dorsal anus. Except for *Onchnesoma* and a few species of *Phascolion*, which is further away from the introvert, the anus is situated toward the anterior end of the trunk. Most species have a threadlike spindle muscle originating near the anus that extends through the middle of the gut coil (Cutler, 1994). The skin could be transparent white, pink, light brown, dark brown, or light brown and light pink.

The morphology and color characteristics of the *Sipunculus nudus* species found in Indonesia (Erliani, 2021), have a total length of 13-15 cm, maximum width of 9-11 mm; the skin is thick and dull brown. Longitudinal muscle bands (LMB) numbering 31-33 converge anteriorly in the introverted region; ventral and dorsal retractors arise from longitudinal

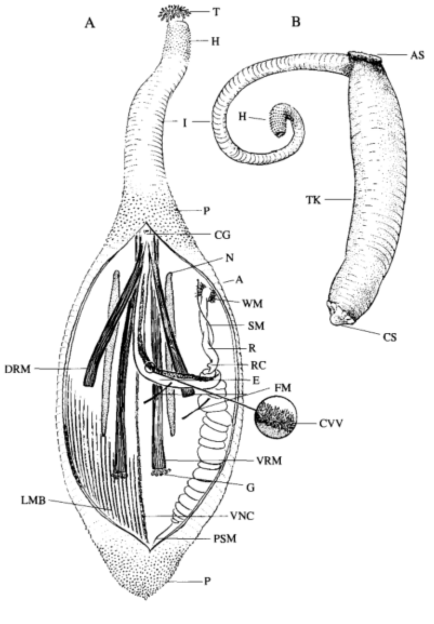

Figure 1. Generalized Sipunculan Morphology (Cutler, 1994)

Note: A. Internal amalgam. B. Aspidosiphonid. A, anus; AS, anal shield; CG,cerebral ganglion; CS, caudal shield; CVV,contractile vessel villi; DRM, dorsal retractor muscle; E, esophagus; FM, fixing muscle; G, gonad; H, hooks (scattered on A, in rings on B); I, introvert; LMB, longitudinal muscle bands; N,nephridia; P, papillae; PSM, posterior spindle muscle; R, rectum; RC, rectal caecum; SM, spindle muscle; T, tentacles; TK, trunk; VNC,ventral nerve cord; VRM, ventral retractor muscle; WM, wing muscle.

Table 1. Studies of Peanut worms in Indonesia

Category	Years	Primary studies		Secondary studies	
		Total Citation	Citations	Total Citation	Citations
Taxonomy	1990s	2	Cutler J and Cutler EB (1990) Cutler EB(1994)	1	Hoeksema and Best (1991)
	2000s	-	-	-	-
	2010s	1	Fakhrurrozi (2011)	-	-
	2020s	2	Erliani (2021) Erliani *et al.* (2021)	-	-
Ecology	1990s	-	-	1	Erftemeijer *et al.* (1993)
	2000s	-	-	2	Kastoro *et al.* (2007) Nordhaus *et al.* (2009)
	2010s	1	Fakhrurrozi (2011)	11	Taqwa (2010) Fajri (2013) Tasabaramo *et al.* (2013) Indrawan *et al.* (2016) Wardiatno *et al.* (2017) Moningkey *et al.* (2017) Kristiningsih *et al.* (2018) Swasta (2018) Lin *et al.* (2018) Rimadiyani *et al.* (2019) Asriani *et al.* (2019)
	2020s	4	Erliani (2021) Erliani *et al.* (2021) Matulessy *et al.* (2021) Ferdinandus *et al.* (2022)	3	Darmarini *et al.* (2021) Rumaida *et al.* (2021) Indarjani and Nurhayati (2022)
Nutrition/Utilization	1990s	-	-	-	-
	2000s	1	Fakhrurrozi *et al.* (2009)	-	-
	2010s	7	Fakhrurrozi (2011) Silaban (2012) Leiwakabessy *et al.* (2017) Nurhikma *et al.* (2017) Silaban (2017) Silaban (2019) Rahayu *et al.,* (2019)	-	-
	2020s	3	Fatimah *et al.* (2021) Erliani (2021) Yuslina (2022)	-	-

The investigation of Sipuncula in Indonesia is comprehensively outlined in this table. The research endeavors are systematically classified into distinct categories, including taxonomy, ecology, and utilization. Furthermore, they are differentiated into primary studies, where Sipuncula serves as the central subject of investigation, and secondary studies, where Sipuncula is not the primary focus.

muscle bands 2-6 and 8-12, respectively. The intestinal convolutions are 19 and attached to the body wall by several muscle attachments; the rectal diverticulum is present. The proximal quarter of the nephridia is attached to the body wall.

Sipuncula found in Indonesian waters belongs to 5 families, including A Golfingiidae, Sipunculidae, Siphonosomatidae, Phascolosomatidae; 10 Genera spidosiphonidae, including *Apionsoma*, *Aspidosiphon*, *Golfingia*, *Phascolion*, *Phascolosoma*, *Sipunculus, Siphonosoma, Themiste, , Xenosiphon*; 19 species including *Apionsoma sp., Apionsoma (Apionsoma) trichocephalus, Aspidosiphon (Paraspidosiphon) grandis* valid as *Aspidosiphon (Paraspidosiphon) laevis, Aspidosiphon jukesi* valid as *Aspidosiphon (Aspidosiphon) muelleri muelleri, Aspidosiphon* sp., *Golfingia* sp., *Phascolosoma* sp., *Phascolosoma* sp1., *Phascolosoma lurco* valid as *Phascolosoma (Phascolosoma) arcuatum, Phascolosoma maculatum* valid as *Phascolosoma (Phascolosoma) maculatum, Phascolosoma pacificum* valid as *Phascolosoma (Phascolosoma) pacificum, Phascolosoma glabrum glabrum* valid as *Phascolosoma (Phascolosoma) glabrum, Phascolion* sp., *Sipunculus* sp., *Sipunculus nudus, Sipunculus* *robustus, Siphonosoma australe australe, Themiste* sp*., Xenosiphon* sp*.* The distribution of Sipuncula species in Indonesian waters was recorded in various waters and dominated by *Sipunculus nudus* (Figure 2.).

Sipunculans species are found in Indonesia in various habitats (Table 2.). They are commonly found in coastal areas, such as seagrass beds, mangrove forests, and coral reefs (Silaban, 2019). They have also been observed on the offshore seabed near beaches (Hoeksema and Best, 1991; Kastoro *et al*., 2007; Wardiatno *et al*., 2017) and in intertidal seaweed ponds (Indarjani and Nurhayati, 2022). Sipuncula in Indonesia can also live in intertidal to subtidal areas. For example, *Sipunculus robustus* has been found in the high tide zone (Erliani *et al*., 2021), while *Apionsoma* sp., *Sipunculus* sp., and *Aspidosiphon* sp. have been found at depths of 5 to 40 m (Kastoro *et al*., 2007). There are reports from local in Banda Neira that Sipuncula can be found in 200 m depth (Erliani, 2021). The adaptability of sipunculans to arid conditions in intertidal zones and their ability to survive in low-oxygen environments contribute to their extensive distribution (Pörtner *et al*., 1984).

Sipunculus nudus is a common species of Sipuncula in Indonesia, also found in sedimentary environments dominated by sand and seagrass beds (Table 2.). It prefers soft substrates and is most abundant in tropical and temperate regions. Although it has a broad depth range, it is mainly found in the littoral zone (Ferrero-Vicente *et al*., 2013).

Phascolosoma (Phascolosoma) arcuatum has been found in two distinct habitats. *P. arcuatum* has discovered in coastal areas of North Sulawesi, where it inhabits seagrass beds with varying sediment compositions, ranging from fine sand to coral rubble (Lin *et al*., 2018). According to Lin *et al*. (2018), all

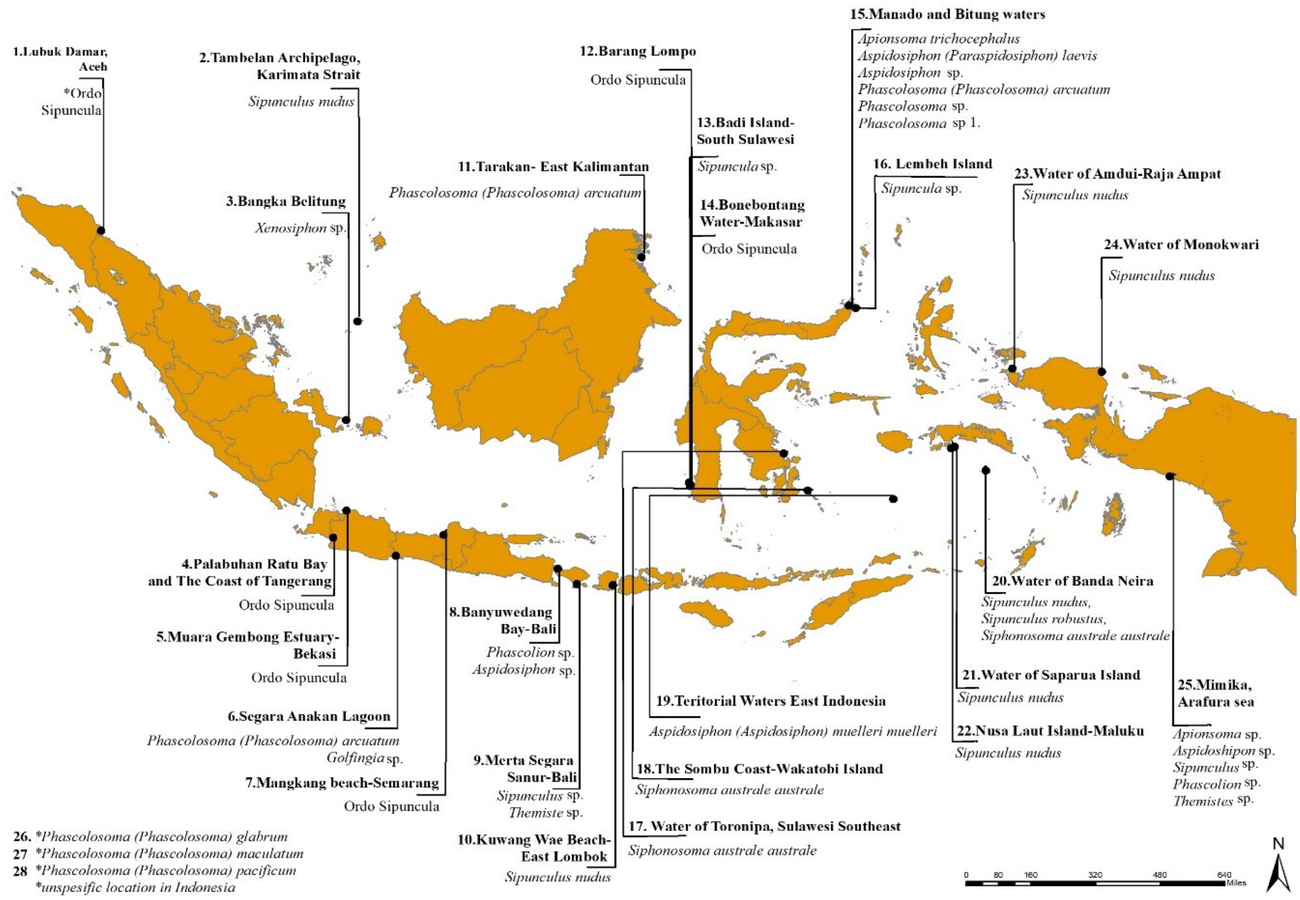

Figure 2. Distribution Map of Sipuncula species in Indonesia
Citations : [1](Darmarini *et al*., 2021); [2](Rumaida *et al*., 2021) ; [3](Fakhrurrozi, 2011); [4](Wardiatno *et al*., 2017); [5](Indarjani and Nurhayati, 2022); [6](Nordhaus *et al*., 2009; Rimadiyani *et al*., 2019); [7](Kristiningsih *et al*., 2018); [8](Swasta, 2018); [9](Indrawan *et al*., 2016); [10](Fajri, 2013); [11](Taqwa, 2010); [12] (Erftemeijer *et al*., 1993); [13](Asriani *et al*., 2019); [14](Tasabaramo *et al*., 2013); [15](Lin *et al*., 2018); [16](Moningkey et al., 2017); [17](Nurhikma *et al*., 2017; Suwarjoyowirayatno *et al*., 2019); [18](Rahayu *et al*., 2019); [19](Hoeksema and Best, 1991); [20](Erliani et al., 2021); [21](Matulessy *et al*., 2021); [22](R. Silaban, 2019; Ferdinandus *et al*., 2022); [23,24](Leiwakabessy *et al*., 2017); [25](Kastoro *et al*., 2007); [26,27,28] (Cutler J and Cutler EB, 1990).

Table 2. Habitat of Sipuncula Species in Indonesia

Species	Habitat
Apionsoma sp.	Offshore sea sediments ranging from sand to mud. (Kastoro *et al.,* 2007)
Apionsoma (Apionsoma) trichocephalus	Seagrass bed with heterogeneous sediment (Lin *et al., 20*18)
Aspidosiphon sp.	• Seagrass bed with heterogeneous sediment (Lin *et al.,* 2018) • Bottom of offshore sea with various sediments such as sand, sandy mud, and muddy sand (Kastoro *et al.,* 2007) • Muddy sediment in mangrove ecosystem (Swasta, 2018)
Aspidosiphon jukesi valid as *Aspidosiphon (Aspidosiphon) muelleri muelleri*	Coral reef ecosystem. Living in the gastropod shell and inside the coral genera *Heterocyathus* and *Heteropsammia* (Hoeksema and Best, 1991)
Aspidosiphon (Paraspidosiphon) grandis valid as *Aspidosiphon (Paraspidosiphon) laevis*	Seagrass bed with heterogeneous sediment (Lin *et al., 2018*)
Golfingia sp.	Muddy lagoon bottoms with rich organic content (Rimadiyani *et al.,* 2019)
Phascolion sp.	• Muddy sediment in mangrove ecosystem (Swasta, 2018) • Offshore sea sediments ranging from sand to mud. (Kastoro et al., 2007)
Phascolosoma (Phascolosoma) arcuatum	Seagrass bed with heterogeneous sediment (Lin *et al.,* 2018)
Phascolosoma arcuatum valid as *Phascolosoma (Phascolosoma) arcuatum*	Muddy substrates in mangrove swamps (Nordhaus *et al.,* 2009)
Phascolosoma lurco valid as *Phascolosoma (Phacolosoma) arcuatum*	Sandy clay substrate in the mangrove ecosystem (Taqwa, 2010).
Siphonosoma sp.	The intertidal zone with muddy sandy substrate and seagrass meadows (Erliani, 2021)
Siphonosoma australe australe	• Soft substrate with seagrass meadows in the low tide zone (Erliani, 2021) • Sandy areas with seagrass (Nurhikma *et al.,* 2017; Rahayu, 2019)
Sipunculus sp.	• Seagrass ecosystem with coarse and sandy sand sediment (Indrawan *et al.,* 2016) • Bottom of the offshore sea with sand, sandy mud and muddy sand sediment (Kastoro *et al.,* 2007)
Sipunculus nudus	• Intertidal zone with varying sediments from coral fragments to mud in a seagrass ecosystem (Erliani, 2021). • Rocky beach with sandy substrate (Fajri, 2013). • Sandy rock sediment (Ferdinandus *et al*., 2022). • Sandy sediment (Rumaida *et al.,* 2021). • Seagrass ecosystem with sandy-rocky sediment, living in sand dunes (Matulessy *et al.,* 2021). • Living in sandy sediment with the *Cymodocea rotundata* and *Thalassia hemprichii* seagrass species (Silaban, 2019).
Sipunculus robustus	In the high tide zone, sandy and rocky substrate in a seagrass ecosystem (Erliani, 2021).
Themiste sp.	• Coarse and sandy sand in the seagrass ecosystem (Indrawan *et al.,* 2016) • Offshore sea sediments ranging from sand to mud. (Kastoro *et al.,* 2007)
Thysanocardia sp. valid as *Phascolosoma* sp.	Intertidal area with rocky substrate (Erliani et al., 2021)
Xenosiphon sp.	Sandy beach (Fakhrurrozi, 2011)
Ordo Sipuncula	• Seagrass bed on a sandy reef flat (Erftemeijer *et al.,* 1993) • Seaweed pond near mangrove area (Indarjani and Nurhayati, 2022). • Sandyloam substrate type in mangrove ecosystem (Darmini *et al.,* 2021) • Soft bottom sediment in two different costal area (Wardiatno *et al.,* 2017)

sipunculans species in that region are infaunal burrowers and detritivores. On the other hand, *P. arcuatum* that was found in Segara Anakan (Nordhaus *et al*., 2009) and in the mangrove forest of Tarakan, East Kalimantan resided an area characterized by brackish water and mangrove habitats. According Adrianov and Maiorova (2012), Ba *et al.* (2022), Haldar (1989), and Pagola-Carte and Saiz-Salinas (2000) these worms are commonly encountered in brackish waters and mangrove estuaries and dwell in burrows within muddy sediments within the mangrove habitat.

Ecological Function of Sipuncula

Sipunculans play an important role in the food chain. They are preyed upon by a variety of animals, including fish, sea stars, moluscs, worms, crustaceans, anemones, and even humans. Sipunculans themselves consume detritus, excrement, bacteria, algae, protozoans, and small invertebrates (Kędra and Włodarska-Kowalczuk, 2008; Adrianov and Maiorova, 2012).

This paper classify Sipuncula found in Indonesia into four ecological groups based on feeding habits and movement by Murina's classification (1984). The four groups are burrowers, shelter-dwelling worms, sestonophages, and semi-mobile. However, the category has certain constraints due to limitations in species identification and detailed information about behaviours and habits. The first ecological group of Sipuncula in Indonesia is burrowers. They are active worms that live in soft, silty, or sandy environments. They ingest sediments through their pharynx and are considered deposit feeders. Their burrowing activities play an essential role in bioturbation, redistributing matter from the sediment surface into their burrows and influencing oxygen levels, oxidation-reduction potentials, and bacterial communities in intertidal regions (Li *et al*., 2015, 2019).

Several species have been discovered in Indonesia within this particular group, including *Golfingia* sp*., Siphonosoma australe australe, Siphonosoma* sp*., Sipunculus nudus, S. robustus, Sipunculus* sp*., Xenosiphon* sp*., and Apionsoma* sp*.* These species are predominantly found dwelling within sedimentary environments. *Xenosiphon* sp. found in Bangka Belitung exhibits distinctive burrows resembling dog pawprints and forms J-shaped trails (Fakhrurrozi, 2011). *Sipunculus* species often construct multiple burrows surrounding their habitats, serving as both camouflage and trap homes (Erliani *et al*., 2021). *S. nudus*, on the other hand, is known to inhabit the depths of sand, actively burying itself (Fajri, 2013) and forming dunes beneath seagrass roots for nesting purposes (Matulessy *et al*., 2021).

The shelter-dwelling Sipuncula in the second group utilizes empty mollusc shells and polychaeta tubes as protective shelters. They upgrade to larger shelters by sealing the entrance with a sticky substance made of mud, sand, or silt (Murina, 1984; Cutler, 1994). These worms are predominantly found in the sublittoral zone, preferring coarse-grained sand as their substrate. Once settled, they remain stationary (Ferrero-Vicente *et al*., 2013).

Aspidosiphon jukesi valid as *Aspidosiphon (Aspidosiphon) muelleri muelleri* has been observed in the southwestern waters of Sulawesi, where it forms a mutualistic symbiotic relationship with free-living corals (Hoeksema and Best, 1991). The sipunculans act as a host by occupying a borrowed shell, while the coral larvae settle on shells already inhabited by the worm. The sipunculans contribute to the coral's stability, and the coral protects the sipunculan within its colony. The occurrence of this group is influenced by the availability of suitable shells that align with the morphological requirements of shelter-dwelling Sipuncula (Ferrero-Vicente *et al*., 2013; Oshiro *et al*., 2022).

The third group consists of sestonophage worms. These worms have intricate tentacle crowns with ciliary mucous that capture detritus (Murina, 1984). The distinctive characteristic of this group is that they are filter feeders. In Indonesia, *Themiste* sp. has been observed in intertidal seagrass areas with coarse sediments (Indrawan *et al*., 2016).

The final group is semi-mobile worms. They live in cracks and cavities within hard substrates and can tunnel into rocks to expand their dwelling space (Murina, 1984). They use rows of hooks or conical papillae to scrape detritus particles from the substrate. They are also bioeroders, which induce erosion on calcareous substrates (Acik, 2019). The primary habitat for these burrowing sipunculans is the deteriorating coral reef ecosystem (Williams and Margolis, 1974). Potential species belonging to this group in Indonesia include *Phascolosoma* and *Aspidosiphon* found in seagrass ecosystems connected to coral reefs (Lin *et al*., 2018).

Nutrition Content of Sipuncula from Indonesia

Today, many recent studies have already stated that marine resources (such as sea urchins, mollusc, sea cucumber, fish) are known to have nutrient content that provides benefits to human health as a source of diet (Usydus *et al*., 2011; Pangestuti and Arifin, 2018; Chamika *et al*., 2021; Moniruzzaman *et al*., 2021) , including Sipuncula (Wu *et al*., 2014). Table 3 shows Sipuncula nutrient content (proximate and minerals composition) from Indonesian waters. The proximate analysis was based on protein, lipid, carbohydrate, ash, and moisture composition. The dried sample of *Sipunculus nudus* from Raja Ampat - West Papua has a higher amount of protein and carbohydrate content than *Siphonosoma australe australe* from Konawe Southeast Sulawesi and has a slightly different higher from Manokwari - West Papua (in dried sample). While in fresh samples,

Table 3. Proximate and minerals composition of Sipuncula from Indonesian waters

Species	Location	Sample	Proximates (%)					Minerals (mg.100 g^{-1})					
			M	A	P	L	Ch	Fe	Ca	K	Na	Mg	Zn
Sipunculus nudus	[1]Raja ampat, West Papua	dried	7.10-7.26	-	81.76-83.15	1.19-2.21	6.58-7.02	4.52-17.61	300.37-449.83	26.69-39.18			
Sipunculus nudus	[1]Manokwari, west Papua	dried	8.03-8.09	-	80.15-81.50	1.10-1.57	640-8.12	4.37-8.95	144.21-449.8	198.11-216.84			
Siphonosoma austral australe	[2]Konawe, southest Sulawesi	dried	13.69	15.08	56.35	9.82	5.06						
Sipunculus nudus	[3]Nusalaut, Maluku	Fresh	74.96-79.12	2.41-3.06	16.88-17.23	0.22-0.28	1.03-3.86						
Siphonosoma australe australe	[2]Konawe, southest Sulawesi	Fresh	82.25	3.03	10.11	0.54	1.07						
Siphonosoma australe australe	[4]Wakatobi, southest Sulawesi	Fresh	79,59	0,64	17.39	1.28	-						
Xenosiphon sp.	[5]Bangka Belitung Island, west Sumatra	Fresh	76.47	2.20	10.61	0.18	10.02						
Sipunculus robustus	[6]Banda Naira, Maluku	Fresh	79.87	2.20	17.61	0.29	0.03						
Siphonosoma	[6]Banda Naira, Maluku	Fresh	82.23	1.55	15.61	0.37	0.24						
Sipunculus nudus	[6]Banda Naira, Maluku	Fresh	82.33	1.68	14.60	0.35	1.04	1.836	7158.709	367.647	1093.068	636.099	4.893
		[7]Whole egg (in dried)						7.34	235	579	595	50.3	5.41

Citations: [1](Leiwakabessy *et al.*, 2017); [2](Nurhikma *et al.*, 2017); [3](Silaban, 2019); [4](Rahayu *et al.,* 2019); [5](Fakhrurrozi, 2011); [6](Erliani, 2021); [7](Wu *et al.*, 2014). Abbreviation : M (moisture), A (Ash), P (Protein), L (Lipid), Ch (Charbohydrate), Fe (Iron), Ca (Calcium), K (Potassium), Na (Sodium), Mg (Magnesium), Zn (Zinc)

protein percentages varied from 10.11 to 17.61%, *Sipunculus robustus* from Banda Naira - Maluku is the highest. Lipid percentages varied from 1.10 to 9.82% (dried) and 0.18 to 1.28% (fresh). Carbohydrate percentages varied from 5.06 to 8.12% (dried) and 0.03 to 10.02% (fresh). The difference in proximate composition among species is probably because of the habitat species' different nutrients. Kazangeldina *et al.* (2022) said the difference in nutrition quality among raw species could happen due to habitat, season, and maturity factors.

Besides proximates, dietary minerals in a food source are required by a living organism, and needed in body cells to ensure our internal function efficiently to maintain optimal health (Morakinyo *et al.*, 2016). Table 3 shows a variety of mineral compositions of Sipuncula, which has an abundant Ca composition compared to other minerals, especially for *Sipunculus nudus* from Papua contains higher levels of Ca and iron than whole eggs.

Other nutrition evaluations of sipunculans are shown as amino acids in Table 4. Most cellular activity is performed by amino acids, which are also essential for the structure, function, and regulation of the body's tissues and organs (Sudhakararao *et al.*, 2019). The body cannot synthesize an essential amino acid (Kazangeldina *et al.*, 2022), while others could be synthesized (Sudhakararao *et al.*, 2019).

The quantities of amino acids depend on the origin of the organic matter and can make up less than 1 to 50% (Hassan *et al.*, 2014). The total of essential amino acids of *Siphonosoma australe australe* (southeast Sulawesi) was 13.65, and the non-essential amino acids was 17.51. The most abundant amino acids of this species were arginine, leucine, glutamic acid, and glycine, respectively. The total of essential amino acids of *Xenosiphon* sp. (west Sumatra) was 2.961 and the non-essential amino acids was 2.176. The majority of amino acids of this species were valine, leucine, glutamic acid, and aspartic acid, respectively. Leucine and glutamate are abundant in both species and play a role in synthesis mechanism performance in the body. Specifically, leucine was responsible for synthesizing muscle protein (Kari *et al.*, 2022) and glutamate acid was responsible for the umami flavor (Machado *et al.*, 2020). From Table 4, the amino acid level of these species is still less than comparable ideal for the requirements recommended by FAO/WHO standards, nevertheless, Sipuncula has potency as a protein source (based on protein content in Table 2 up to 50 to 81% (for dried) and 14 to 17% (for fresh).

Table 4. Amino acids (%) of *Sipuncula* from Indonesian water

Nutrition		*Siphonosoma australe australe*[1]	*Xenosiphon* sp.[2]	AA scoring pattern (g.100 gr protein^{-1})[3]	*Sipunculus* sp.[4]
Amino acids					
Essential	Histidine	0.37	0.139	1.5	
	Arginine	3.04	0.228		
	Threonine	1.78	0.346	0.6	
	Metyonine	0.75	0.257	1.6	
	Valine	1.08	0.581	3.9	
	Phenylalanine	0.84	0.31		
	I-Leusine	1.11	0.215	3	
	Leusine	2.49	0.459	5.9	
	Lisine	2.19	0.426	4.5	
	Tryptophan	nd	nd	0.6	
	Phe+Tyr	nd	nd	3.8	
	Met+Cys	nd	nd	2.2	
	Total of EAA	13.65	2.961	27.7	
Non-Essential	Aspartic Acid	3.08	0.511		
	Glutamic acid	6.53	0.687		
	Serine	1.26	0.196		
	Glisine	3.29	0.18		
	Alanine	2.38	0.273		
	Tyrosine	0.97	0.329		
	Total of NEAA	17.51	2.176		

Citations: [1](Nurhikma *et al.,* 2017), [2](Fakhrurrozi, 2011), [3](WHO, 2007), [4](Silaban, 2017)

Table 5 shows the fatty acids composition of Sipuncula. The advantages of fatty acids are improving brain function, delaying the ageing process, and preventing many diseases (such as cardiovascular disease, inflammation, hypertension, obesity, cancer, diabetes, and neurological disorder) (Shi *et al*., 2020; Ramos *et al*., 2021; Shehzad *et al*., 2021). *Siphonosoma australe australe* (Konawe-southeast Sulawesi) has higher saturated fatty acids (6.40%) than mono and polyunsaturated acids. The important components in polyunsaturated acids, eicosapentaenoic acid/EPA and docosahexaenoic/DHA were found at about 0.52% and 0.51%, respectively, while *Sipunculus* sp. from Nusalaut coastal has detected only for eicosapentaenoic acid/EPA for about 1.13%. Based on Tables 3, 4 and 5, it can be inferred that Sipuncula, a marine resource from Indonesia water, offers a wide range of nutritional potential for human consumption for health maintenance or as a protein food potential from marine resources.

Sipuncula Utilization

Peanut worm is a common name for Sipuncula and has a different local name. In Vietnam, people call Sipuncula as *sasung, dia sam, mat cat* (Ba *et al*., 2022). In Indonesia, Sipuncula also has a specific name. For example, fishers in Maluku call Sipuncula as *sia-sia*; in Kepulauan Banda as *kariong*; in Bangka Belitung as *kekuak* (Silaban, 2019); in Wakatobi as *honingka* (Rahayu *et al*., 2019) or *tihou* (corresponding with fisheries extension worker 2019), in Kowane as *sipou* (Fatimah *et al*., 2021), and in Kepulauan Riau Regency as *ulat tanah* (Yuslina, 2022).

Sipuncula has been used for a long time in some countries. According to Khoi (2018) in Vietnam, Sipuncula is processed as a delicious food and as a specific food for fishers. Cleaned Sipuncula is marinated in vinegar and spices to serve as an appetizer. Sipuncula in Indonesia are utilized for food and as bait for fishing (Fakhrurrozi, 2011; Silaban, 2019). As a food, fresh Sipuncula was cleaned, cut into small pieces, and poured with coconut and spices (Silaban, 2012). In Nusalaut Island, Sipuncula is used as food especially replaced fish-protein when the fishers could not fish because the weather was rough (Silaban, 2019).

For many generations, sipunculans have been found in specific areas and caught by people(Fakhrurrozi, 2011; Fatimah *et al*., 2021;Silaban, 2019). Caught is usually done at low tide (*meti*). At this time, the mound where the sipunculan hides can be seen. An indicator of the presence of Sipuncula is observing sand mounds with mildly elevated seagrass roots or sand formations along with fragmented coral (Silaban, 2019).

The tools for catching Sipuncula are very simple. Generally, people use a crowbar, a piece of wood with a sharp end, or a machete. On Bangka the local name of tools for catching sipuncula are *cucol, rangkang* and *serempang* (Fakhrurrozi *et al*., 2009).

Table 5. Fatty acids (%) of *Sipuncula* from Indonesian water

Nutrition	*Siphonosoma australe australe*[1]	*Xenosiphon* sp.[2]	*Sipunculus* sp.[3]
Saturated fatty acids (SFA)			
Decanoic acid (C10:0)			0.18
Lauric acid (C12:0)	0.04		1.63
Tridecanoic acid (C13:0)	0.04		
Myristic acid (C14:0)	0.75		2.55
Pentadecanoic acid (C15:0)	0.21		
Palmitic acid (C16:0)	1.96		
Heptadecanoic acid (C17:0)	0.77		
Stearic acid (C18:0)	1.9		62.81
Arachidonic (C20:0)	0.12		
Heneicosanoic acid (C21:0)	0.21		
Behenic acid (C22:0)	0.2		
Tricosanoic acid (C23:0)	0.08		
Lignoceric acid (C24:0)	0.12		
SFA total	6.4		67.17
Monounsaturated Fatty Acids (MUFA)			
Palmitoleic acid (C16:1)	0.31		15.8
Heptadecanoic acid (C17:1)	0.12		
Eicosanoic acid (C20:1)	0.05		
MUFA total	0.48		
Polyunsaturated Fatty Acids (PUFA)			
Elaidic acid (C18:1n9t)	0.06		
Oleic acid (C18:1n9c)	1.19		
Linoleic acid (C18:3n3)	0.16		5.33
Linolenic acid (C18:2n6c)	1.34		
Eicosatrienoic acid (C20:3n6)	0.14		
Erucic acid (C22:1n9)	0.06		
Arachidonic acid (C20:4n6)	2.8		
Eicosapentaenoic acid (C20:5n3)	0.52		1.13
Docosahexaenoic (C22:6n3)	0.15		
PUFA total	6.26		22.26

Citations: [1](Nurhikma *et al.,* 2017), [2](Fakhrurrozi, 2011), [3](Silaban, 2017)

Crowbars are stuck around the sand dune with a slope of 45° and ± 30 cm deep. This action is to hold the sipunculan from getting into the sand. After that, the crowbar is pushed above the ground and pulled quickly by hand. If taken too late, this worm will escape and burrow its body deeper into its hiding hole.

Around 2005-2006 in Vietnam, the value of peanut worms became known not only for food but also for traditional medicine. This increased demand for Sipuncula, significantly increasing its exploitation (Ba *et al.*, 2022). Similarly, the massive exploitation of Sipuncula in Indonesia is also driven by market demand, particularly from China (as indicated by an interview with a fisheries extension worker from DKP Kabupaten Wakatobi in 2022). This trend is evident in the trading flow within the region. Trading flow started from fishers. They take sipuncula around the seagrass ecosystem at Wangi-Wangi, Kaledupa, Tomia, and Binongko Islands. Furthermore, fresh sipuncula was sold to collectors in Wangi-Wangi Island. Collectors buy fresh Sipuncula, which price at IDR 60,000.kg^{-1}. In the collector, Sipuncula was processed by boiling in fresh water for 20-30 minutes, then dried with sunlight for several days to reach suitable dryness. Dried sipunculans were sold with a prize of IDR 600,000.kg^{-1} to exported who were domiciled in Jakarta through Bau-bau City or directly exported to China. Each shipment ranges from 500 kg to 1 ton, but information on the total volume, frequency, and destination of shipments has not been adequately recorded. The flow of Sipuncula trade from fishermen to exports in the Wakatobi Regency is illustrated in Figure 3.

Future Consideration

From the description above, it is known that sipunculans have important value, both as food, medicine, and a source of income. Therefore, for the utilization to be sustainable, it is necessary to carry out management efforts. Some of the steps that need to be taken to carry out management are as follows:

Figure 3. Sipuncula trading-flow in Wakatobi Regency

Identification of Sipuncula catch location

The objective of location identification is to ascertain the spread of catch locations. This knowledge helps us pinpoint areas that may be facing increased pressure. Due the limited number of marine experts compared to the extensive marine area in Indonesia, leveraging citizen science can help overcame the challenge of data collection (Zhang *et al*., 2023). By utilizing practical tools like applications, the public can be trained to collect data effectively.

Research on bio-reproduction of Sipuncula

Collecting information about the reproductive cycle of Sipuncula is crucial for determining their maturity level and setting catch sizes. Research institutions and universities have an essential role in studying the life cycle of Sipuncula.

Sipuncula data collection

Collecting data on Sipuncula is crucial as it serves as the baseline data for managing these biotas. When collecting data, one should consider important parameters such as production volume, export frequencies, and the size of Sipuncula. These activities could be performed by the Fish Quarantine and Inspection Agency-Minister of Marine Affair and Fisheries, exporter, or trader.

Establish regulation

It is suggested to establish regulation for Sipuncula, which should include catch size and catch management (open-closed area). The Indonesian government has already created a National Action Plan for Conservation and Management for Shark and Ray 2016-2020 (Ministry of Marine Affairs and Fisheries, 2015), which can be used as a reference for setting up Sipuncula regulation. It is also important to identify the stakeholders who will be responsible for implementing and enforcing the regulations.

Conclusion

Rapid population growth has significant implications for food needs and income, especially for coastal communities. Currently, various fishery products such as fish, shrimp, sea cucumber, crabs, and molluscs are utilized as a source of food and income. However, to diversify the food source, it is essential to develop other types of fishery resources, such as sea worms especially Sipuncula or the peanut worm. However, it is important to consider future management steps for Sipuncula by formulating regulations related to these organisms. This includes identifying their distribution locations, conducting research related to their bio-reproduction, collecting production data, and establishing rules regarding the procedures for using Sipuncula in Indonesia.

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