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Water Quality Impact Christmas Tree Worms (*Spirobranchus* spp.) Distribution and Community Structure on Hard Corals at Sempu Island Nature Reserve, Malang, Indonesia

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ABSTRACT

The Christmas tree worm (*Spirobranchus* spp.) is a biota that lives in association with hermatypic corals. This bioeroder damages the structural integrity of corals, making them susceptible to breakage. Therefore, further investigation is required to determine the distribution, diversity, uniformity, and predominance of CTW on hard corals in the Sempu Island Nature Reserve's waters. The method used is the belt transect method, which refers to the reef check. CTW species will be identified based on their operculum, and corals will be identified based on their growth form, genus, and species. The data gathered were processed, and the abundance value and ecological index were obtained. The CTW species found at the five stations were *Spirobranchus gardineri, Spirobranchus cruciger, and Spirobranchus* spp., associated with massive corals of the genus Porites and genus Goniastrea. Water quality factors such as currents, sedimentation, and nitrates affect CTW's presence. Medium-to-fast currents circulate around Sempu Island, where high sedimentation rates of 73.73 mg/cm2/day decrease light penetration into the waterways. Additionally, elevated nitrate levels contribute to the growth of CTW operculum-covering turf algae. CTW abundance values ranged from 0.018 to 0.084 individuals/m2, diversity index (H') ranged from 0.403 to 0.760 (low), and uniformity index (E) ranged from 0.582 to 0.966 (unstable to stable). The dominance index (C) values ranged from 0.513 to 0.705 (medium). Based on the index value, it was found that the CTW in Sempu Island was in the unstable category, so there was moderate dominance.

Keywords: corals, belt transect method, christmas tree worms, water quality, ecological index, abundance index.

INTRODUCTION

The biotas of coral reef ecosystem is a community consisting with various trophic levels which has a role and depends on each other. Coral reefs are food-rich ecosystems with complex physical structures. They are attractive habitats for a wide variety of marine life, which is why coral reef inhabitants are so diverse. However, some resident marine life are known to weaken coral reefs and naturally transform massive reef structures into rubble, sand and sediment, which is called

as bioreosion (Tomascik et al., 1997). One of the main bioeroders in calcareous structures such as rocks, corals and shells comes from the Polychaeta Class. These biota cause hard substrates to degrade into small fragments which is a dynamic and destructive process (Çinar and Dagli 2021). Christmas tree worm (CTW) is a biota of the class Polychaeta with the genus *Spirobranchus* and associated with hermatypic corals (Glynn and Manzello 2015; Willette et al., 2015). The presence of CTW on corals can be detrimental to the host because it can damage the structural integrity of the coral, causing the host coral to break more easily (Hoeksema et al., 2019). However, CTW and corals can be mutually beneficial. The presence of these biota can increase water flow around the coral surface, preventing bleaching and helping corals find food (Perry et al., 2018).

CTW is founded in tropical waters, such as Sempu Island that is included in the Indonesian nature preserve that located in Malang Regency, East Java. The landscape of Sempu Island Nature Reserve from east to west has a length of about 3.9 km and from north to south has a length of about 3.6 km. Sempu Island was designated as a nature preserve with an area of around 877 hectares (Rindyastuti 2018). Coral reefs on Sempu Island were degraded, caused by high sedimentation in 2006–2009 due to the reclamation project for the expansion of Sendang Biru PPI, which caused a 50% decrease in coral cover. High sedimentation can affect the penetration of sunlight into the water and interfere with coral photosynthesis (Wibawa and Luthfi 2017). In 2010 and 2015 there was mass coral bleaching so that live coral cover stopped at around 37% based on the average data from 2009–2016 caused by El-Nino (Luthfi et al., 2018). Based on observations in 2018, there was a decrease in coral cover of around 8 to 31% so that coral cover was categorized as poor (Luthfi 2019). The decrease in coral cover can lead to a reduction in the number of associated biota on the coral (Rumkorem et al., 2019).CTWs were associated most abundantly with the genus *Porites*. However, CTWs were also found associated with corals of the genus *Pocillopora, Seriatopora, Stylophora, Acropora, Millepora*, and *Chypastrea* (Sapir, et al., 2018). Corals in Sempu Island Waters were found to be associated with CTW in the coral genus *Porites* (Luthfi 2019). Based on unpublished research in 2019, CTW was found on Sempu Island at Waru-waru and Watu Meja stations, there were *Spirobranchus corniculatus* and *Spirobranchus cruciger* species that was associate with massive corals with the genus *Porites* (Akbar 2019). The difference between this study and previous research is that it was more comprehensive, where CTWs were identified on corals based on coral species and more research stations were taken. The locations in this study have different characteristics, there are stations Jetty, Rumah Apung, Waru-waru, Watu Meja, and Banyu Tawar. Because this species can affect the coral reef ecosystem, it is necessary to conduct further research to determine the distribution, diversity, uniformity, and dominance of CTW in Sempu Island Nature Reserve's waters.

MATERIALS AND METHODS

Study area

The research was conducted in April 2023 on Sempu Island, Malang Regency at five stations. The stations taken in this study were Watu Meja, Waru-waru, Banyu Tawar, Rumah Apung, and Jetty (Figure 1). Station 1 is Watu Meja, which is close to the mouth of the strait and far from the influence of anthropogenic activities and tourism activities. Station 2 is Waru-waru which is a tourist spot. Station 3 is Banyu Tawar, which has low salinity because of freshwater input. Station 4, Jetty Port, is a location that is directly impacted by activities such as fisheries and harbor activities. Station 5 is Rumah Apung, which is impacted by household waste caused by its proximity to residential areas.

Data collection

Christmas tree worm data collected using the belt transect method with a self-contained underwater breathing apparatus that refers to a reef check (Figure 2). Observers moved in a zigzag plot with transects laid out along 100 meters and Christmas tree worm that were found associated with corals were immediately identified and documented. Christmas tree worm are identified by the operculum based of journal "*On the genus Spirobranchus (Annelida, Serpulidae) from the northern Red Sea, and a description of a new species*" (Bronstein et al., 2018). Coral identification begins with coral life forms that refer to the book "Survey Manual for Tropical Marine Resource 2nd Edition" by English, Wilkinson and Baker (1997) and then compared with the book "Jenis-jenis Karang di Indonesia" to determine coral species by Suharsono (2008).

This study measured the quality of water parameters including temperature, salinity, pH, DO,

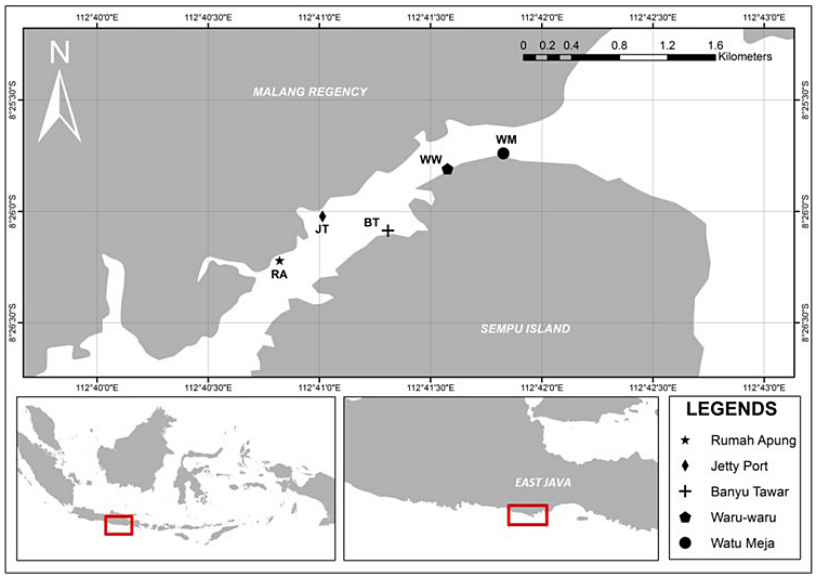

Figure 1. Research site map

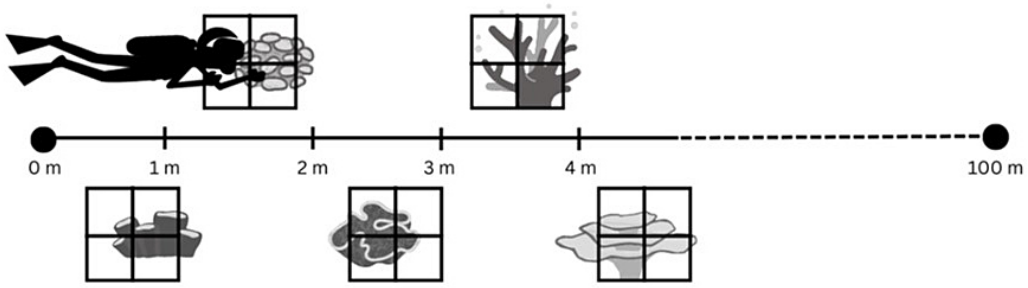

Figure 2. Belt transcet method

depth, waves, current, brightness, nitrate, phosphate, and sedimentation. Temperature, DO, salinity and pH parameters were measured using AAQ Rinko 1183s-F, water clarity measured using a secchi disk, tidal waves measured using a scale staff, sedimentation rate measured using a sediment trap, and currents from the secondary data obtained from the OSCAR website processed using the Surfer 10 application. The christmas tree worm data will be calculated to obtain indices of abundance, diversity, uniformity and dominance.

Abundance index

The abundance index is the number of individual units per unit area using the following formula (Krebs 2014):

$$Di = \left(\frac{ni}{A}\right) \quad (1)$$

where: *Di* – abundance index; *Ni* – total number of individuals of type – i; *A* – observation area

DIVERSITY INDEX (H')

The diversity index shows the diversity of species in a community calculated using the Shannon-Wiener index which is entered into the following formula (Krebs 2014):

$$H' = -\sum_{i=1}^{s} p_i \ln p_i \quad (2)$$

$$Pi = \frac{Ni}{n} \quad (3)$$

where: *H'*– Shannon-Wiener diversity index; *Pi* – ratio of the proportion of the number of individuals with the species – i; *Ni* – number of individuals of the species – i; *n* – total number of individuals of the species found

The criteria for the value of Shannon-Wiener diversity (H') are as follows:

- $H' \leq 1{,}0$ – low diversity
- $1 < H' < 3$ – medium diversity
- $H' \geq 3$ – high diversity

Uniformity index (E)

Uniformity index to determine how much similarity in the distribution of the number of individuals of each species which is calculated using the Shannon-Wiener index which is entered into the following (Krebs 2014):

$$E = \frac{H'}{In\ S} \quad (4)$$

where: E – uniformity index; H' – diversity index; S – number of spesies.

The criteria for the Shannon-Wiener uniformity value (H'), which is as folows:

- $0.00 < E < 0.50$ – depressed community,
- $0.50 < E \leq 0.75$ – unstable community,
- $0.75 < E \leq 1.00$ – stable community.

Dominance index

Calculation of the dominance index is used to determine which species dominate in a community using the following formula (Odum, 1996):

$$C = \left(\frac{ni}{n}\right)^2 \quad (5)$$

where: C – dominance index; Ni – number of CTW individuals of type-i; n = total number of CTW dominance index criteria which is as follows:

- $0 < C \leq 0.5$ – low dominance of biota,
- $0.5 < C \leq 0.75$ – moderate dominance of biota,
- $0.75 < C \leq 1$ – high dominance of biota.

RESULTS AND DISCUSSION

Water quality of sempu island nature reserve's waters

The water quality parameters that were collected contained temperature, salinity, pH, brightness, dissolved oxygen (DO), depth, waves, currents, nitrate, phosphate, and sedimentation rate. Parameters were taken using a secchi disk to measure brightness, AAQ Rinko 1183s-F for salinity, temperature, and pH, a scale staff for waves, and sedimentation rate using a sediment trap. The following parameter measurement results can be seen in Table 1. The values of temperature, salinity, pH, DO are considered optimal for coral growth based on the quality standards of PP No. 22 of 2021 which can be seen in Table 1. The pH parameter of waters generally has a value of 7 to 8.5 which is the limit of tolerance for living things. A pH value of less than 7 can increase the acidity of seawater and affect phytoplankton associated with corals (Wahab et al., 2021). Temperatures that can be tolerated by corals in Indonesian waters range from 28 to 30 °C. A two degree celcius increase in temperature can reduce coral productivity (Barus et al., 2018). CTWs can live in tropical and sub-tropical areas so that tidal CTW has a significant relationship with temperature because it has good adaptability to water temperature. Good salinity in waters remains above 30 ppt but below 35 ppt, if low salinity values are low, it can cause death to the

Table 1. Water quality parameter of Sempu Island Nature Reserve's Waters

Parameter	Unit	Station					Average	Quality standarts
		WM	WW	BT	RA	JT		
Temperature	°C	29.4	29.8	29.7	29.7	29.6	29.6	28 – 30[a]
Salinity	‰	32.4	32.4	32.1	32.2	32.1	32.2	33 – 34[a]
pH	-	8.3	8.2	8.2	8.0	8.3	8.2	7 – 8.5[a]
DO	mg/L	6.4	6.3	6.3	6.4	6.4	6.4	>5[a]
Wave	m	1.30	1.32	0.74	0.85	0.81	1.0	-
Current	m/s	0.49	0.5	0.47	0.45	0.38	0.46	Slow: 0–0.25[b] m/s[b] Moderate: 0.25–0.50 m/s Fast: 0.50–1 m/s Very fast: >1 m/s
Brightness	m	3.0	2.4	2.0	2.2	2.7	2.4	>5[a]
Sedimentation	mg/cm/day	74.73	85.49	61.05	58.13	89.27	73.73	1–10 slight-moderate[c] 10–50 moderate-severe >50 severe-catastrophic
Nitrate	mg/L	0.550	0.347	0.010	0.027	0.021	0.234	0,06[a]
Phosphate	mg/L	0.303	0.287	0.008	0.019	0.011	0.154	0,015[a]

Note: [a] Government Regulation, 2021; [b] Ramlah et al., 2015; [c] Pastorok and Bilyard, 1985.

corals (Moira et al., 2020). The range of currents in Sempu Island Waters is categorized as moderate. Currents that are too strong can affect the settlement process of CTW larvae in the water. Normal nitrate levels in marine waters generally range from 0.001–0.007 mg/L (Patty et al., 2015) and phosphate levels range from 0.27–5.51 mg/L (Ilyas et al., 2017). Excess nitrate can cause algae blooming, which adversely affects environmental conditions (Yolanda et al., 2016).

Identification of Christmas tree worm

The following are the results of the CTW assistance obtained in this study (Figure 3). *Spirobranchus crudiger* has three spines (S) with a secondary spine (SS) at each end except for the central spine. This species also has a pair of tines (size like the secondary spine, perpendicular to the spine and located below the spine) (Figure 3A). *Spirobranchus gardineri* has an oval-shaped operculum with one shaft extending in the center with two dorsal and one midventral spine branching at the end, all pointing upwards (Figure 3B) (Bronstein, et al., 2018). In Figure 3C, the operculum of the CTW is covered with algae. Turf algae, sponges, and spirobes are often found in the CTW operculum (Perry, et al., 2018). The operculum functions like a door, making it easier for organisms such as turf algae to easily attach to the operculum (Akbar 2019). Radiole crown colour found in this study is different with unique and interesting colours, but CTW cannot be identified through the colour of its radiole crown (Willette et al., 2015). Radiole crown colour does not affect the distribution of CTW on coral species and the position of CTW on corals but is thought to be due to a combination of abiotic factors with their genetics. Sessile invertebrates can affect the flow around the surface area of the coral, affecting the nutrients available to CTW (Whalan et al., 2015).

Distribution of Christmas tree worm on hard corals

Christmas tree worm found living in Sempu Island waters at a depth of 3 to 6 meters. There are species of *Spirobranchus cruciger, Spirobranchus gardineri*, and *Spirobranchus* spp. which cannot be identified visually due to the operculum covered by algae. CTW species found at the study site can be seen in Table 2.

CTW at the study site was found as many as 144 individuals with the highest number of individuals found at the Rumah Apung station as many as 42 individuals and the lowest at the Jetty station as many as 9 individuals. The species found most were *Spirobranchus* spp. as many as 80 individuals and the lowest was *Spirobranchus gardineri* species as many as 1 individual.

Based on unpublished research in 2019, CTW found at Watu Meja and Banyu Tawar stations in Sempu Island were 108 individuals with *Spirobranchus corniculatus* species as many as 73 individuals, *Spirobranchus cruciger* as many as 6 individuals and *Spirobranchus* spp. 29 individuals

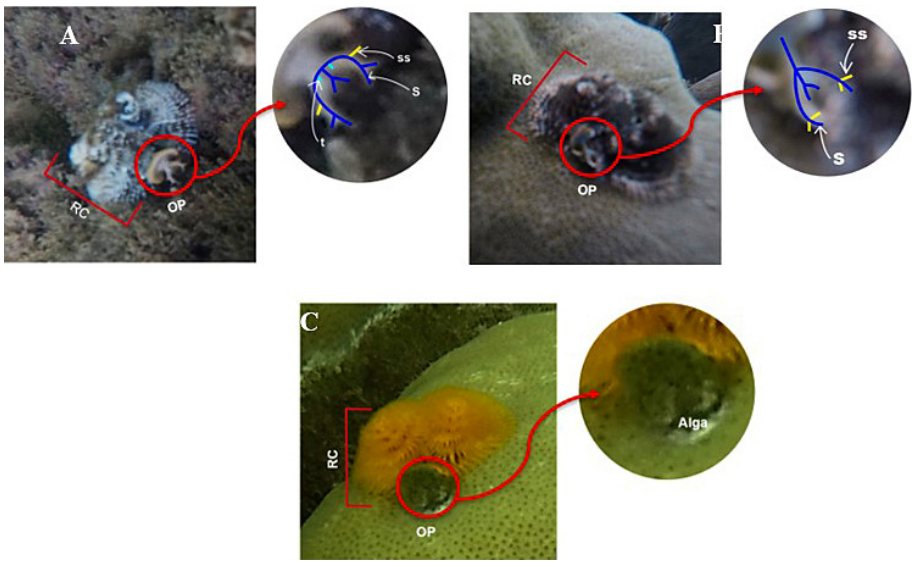

Figure 3. Identification of Christmas tree worm: RC – radiole crown, S – spine, SS– secondary spine, t – tine, OP – operculum

Table 2. Distribution of Christmas tree worm in Sempu Island Nature Reserve's Waters

No	Stasion	Species of Christmas tree worm			Total
		Spirobranchus cruciger	*Spirobranchus gardineri*	*Spirobrancus* spp.	
1	Watu Meja	22	1	12	35
2	Waru-waru	7	-	32	39
3	Banyu Tawar	6	-	13	19
4	Jetty	3	-	6	9
5	Rumah Apung	25	-	17	42
Total		63	1	80	144

(Akbar 2019). In the previous study, *Spirobranchus corniculatus* species were found, while this study did not find these species. This could be due to the large number of CTW operculum covered by algae in this study, so CTW could not be identified. In the waters of the Gulf of Eliat, CTW species *Spirobranchus corniculatus, Spirobranchus tetraceros, Spirobranchus gardineri* and *Spirobranchus* spp. were found (Perry, et al., 2018). CTWs live in calcareous tubes during their adult life that are made by the species by drilling on hard corals (Scleractinia). Hard corals found associated with CTWs in Sempu Island Waters can be seen in Table 3.

Based on Table 3, it was found that the distribution of CTW was not randomly associated with coral species. There are only three coral species that are often found associated, one coral species that is rarely found associated, and many coral species that are not found associated with CTW. CTWs can be abundant on some coral species, rare, or absent altogether. The preference of corals to live on may differ by each CTW and by biogeographic region as well (Perry et al., 2018). Coral species that are often found associated with CTWs are *Porites lobata* with five colonies with 93 CTW individuals, *Porites lutea* with three colonies with 19 CTW individuals and *Porites mayeri* with four colonies with 27 CTW individuals. Coral species that are rarely found associated with CTW are *Goniastrea minuta* as much as one colony with 3 CTW individuals. Based on the research of Dai and Yang (1995) in Nanwan Bay in South China waters, it was found that coral species that are often associated with CTW are *Porites lutea, Porites lobata* and *Montipora informis*. *Porites lutea* found 1,123 CTW individuals

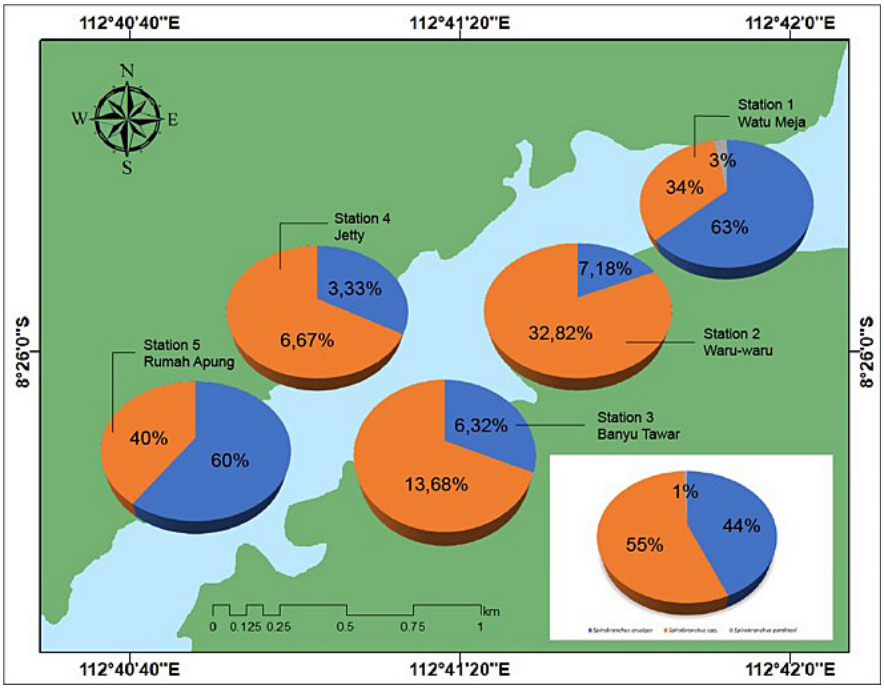

Figure 4. Abundance of CTW in Sempu Island Nature Reserve's Waters

Table 3. Distribution of CTW in hard corals

Station	Life form	Colony	Coral species	CTW species	Total
Watu Meja	Massive	1	Porites lobata	*Spirobranchus cruciger*	14
				Spirobranchus gardineri	1
				Spirobranchus spp.	5
		2	Porites lobata	*Spirobranchus cruciger*	8
				Spirobranchus spp.	7
Waru-waru	Massive	1	Porites lobata	*Spirobranchus cruciger*	3
				Spirobranchus spp.	24
		2	Porites lutea	*Spirobranchus cruciger*	2
		3	Porites lutea	*Spirobranchus* spp.	5
				Spirobranchus cruciger	2
				Spirobranchus spp.	3
Banyu Tawar	Massive	1	Porites lobata	*Spirobranchus cruciger*	1
				Spirobranchus spp.	3
		2	Porites mayeri	*Spirobranchus cruciger*	3
		3	Porites mayeri	*Spirobranchus* spp.	4
				Spirobranchus cruciger	2
				Spirobranchus spp.	5
		4	Rock	*Spirobranchus* spp.	1
Jetty Port	Massive	1	Goniastrea minuta	*Spirobranchus cruciger*	2
				Spirobranchus spp.	1
		2	Porites mayeri	*Spirobranchus cruciger*	1
				Spirobranchus spp.	4
		3	Rock	*Spirobranchus* spp.	1
Rumah Apung	Massive	1	Porites Mayeri	*Spirobranchus cruciger*	3
				Spirobranchus spp.	5
		2	Porites Lobata	*Spirobranchus cruciger*	17
				Spirobranchus spp.	10
		3	Porites Lutea	*Spirobranchus cruciger*	4
				Spirobranchus spp.	3

with 29 coral colonies*, Porites lobata* found 333 CTW individuals with 27 colonies and *Montipora informis* found 19 CTW individuals with 14 coral colonies. CTW distribution on corals was found to be a result of substrate selection by larvae before settlement and mortality after settlement. Before settlement, larvae may be attracted by exudates carried by certain coral species. This is only an initial preference for larvae to settle and additional stimuli are required to successfully settle on a coral (Marsden and Meeuwig 1990). Corals can be aggressive towards other organisms and compete for resources using their tentacles. Therefore, less aggressive corals such as *Porites lutea, Porites lobata*, and *Porites lichen* are most commonly found associated with CTW compared to more aggressive corals such as *Mycedium elephantotus* (Perry et al., 2018) and *Goniastrea* spp. Corals with the genus Porites are generally found in shallow waters and belong to a group that is very weak when competing with other species (Thamrin 2017). CTW planktonic larvae may be susceptible to nematocytes (stinging cells) on the tentacles of aggressive corals. Thus, CTW larvae prefer to live on less aggressive corals as it is associated with lower mortality while living on such corals (Dai and Yang 1995). The life cycle of CTW has a larval stage and an adult phase. CTW are broadcast spawners, which means that they release eggs into the water that will be fertilized in the water column (Majer 2019). The planktonic larval phase of CTW lasts for hours to weeks depending on the environment. During the larval phase, CTW eat plankton to survive. There is a settlement process where the larvae select a substrate for benthic life. After the larvae choose

a substrate, there will be drastic changes in morphology and physiology called metamorphosis into juveniles. As a place to live, the larvae will form a calcareous tube where the base of the carbonate tube can be developed (Qian 1999). The following corals associated with CTW in Sempu Island have a massive life form that comes from the Poritidae (*Porites*) family and Faviidae (*Goniastrea*) family (Figure 5). *Porites lobata* has a large size with a greyish brown colour. The coral surface of this species is relatively rough with large corallites that have columella and septa that have two tentacles. CTW species found in this species are *Spirobranchus cruciger, Spirobranchus gardineri*, and *Spirobranchus* spp. *Porites mayeri* has a size that can reach several meters with brown or yellowish colour. The coral surface of this species looks like a bump where the corallite with pali is clearly visible. The Christmas tree worm species found in this species are *Spirobranchus cruciger* and *Spirobranchus* spp. *Porites lutea* has a large dome-like shape or microatoll with dark or light colour. The surface of this species is smooth with uniformly shaped corallites. *Goniastrea minuta* is a massive creeping colony with brown, yellow, to greenish colours. This species has a ceroid corallite shape with sharp and uniform angles. There are long septa and there are also short ones intermittently Besides being found on hard corals, CTWs are also found associated with rock.

CTWs are often found on massive corals because there will be enough space to build calcareous tubes and provide better protection for CTWs. Massive corals also have a long life span so that CTW living on these corals have higher health (Hunte et al., 1990). Adult CTW mortality can be caused by coral damage, especially corals with branching life forms that have higher mortality rates than massive corals due to natural factors (Schoepf et al., 2015). CTWs do not always live associated with hard corals which can also live on octocorals, rubble, rocks, and substrates such as oil buoys or pier pillars (Hoeksema and ten Hove 2015). However, the settlement of CTW on corals can indeed be beneficially mutualistic. These worms, are known to form associations with various stony coral species (Muller et al., 2020) and can promote coral health by aiding in water circulation across coral polyps, influencing coral nutrition, growth, and recovery, and even providing protection from predators (Hawkins et al., 2020). Additionally, the presence of CTW has been observed to positively stimulate calcification, metabolism, and respiration of corals (Herrán et al., 2022).

Community structure of CTW in Sempu Island Nature Reserve's Waters

Abundance of CTW is a unit of the number of individuals that have the same type divided by the transect area at each research station which will

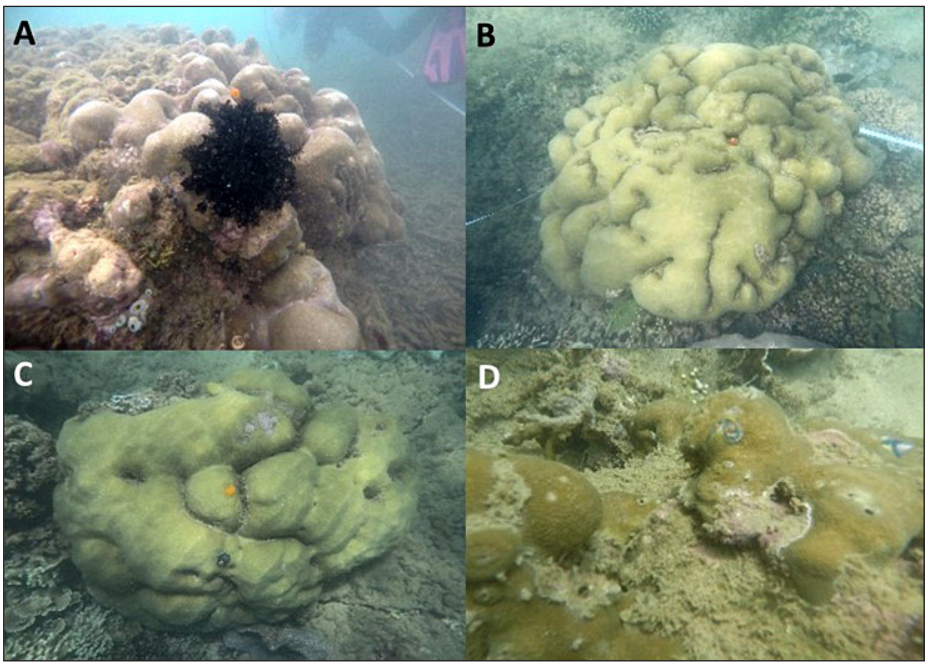

Figure 5. Abundance of CTW in Sempu Island Nature Reserve's Waters

get an area unit value, CTW abundance can be seen in Table 4. In this study, the CTW abundance value ranged from 0.018 to 0.084 individuals/m^2 with the highest value at the Rumah Apung station and the lowest at the Jetty station. The diversity index value (H') ranged from 0.403 to 0.760 with low criteria at all stations. The diversity index is used to express the relationship between the abundance of species in a community (Krebs 2014). Diversity is seen from many or the number of species with the number of individual distributions in each species depending on the abundance of individual species (Storch and Okie 2017).

The value of the uniformity index (E) ranged from 0.582 to 0.966 with Banyu Tawar and Rumah Apung stations included in the stable criteria and at Watu Meja, Waru-waru and Jetty stations included in the unstable criteria. The dominance index (C) value ranged from 0.513 to 0.705, indicating that the dominance of CTW at all stations was in the medium category but close to the high category. If the uniformity index value is close to 0.00, then the ecosystem is in a depressed condition where there is a tendency for species dominance caused by environmental and population factors. If the uniformity index value is close to 1.00, it shows that the ecosystem is in a stable condition where the number of each individual is relatively the same or there is no dominance tendency. The smaller the uniformity index value of a species, the distribution of the number of individuals of each species is not the same, namely there is a tendency for the community to be dominated by certain species. Conversely, the greater uniformity index value, the abundance of each species can be said to be not much different and there is no dominance in the community (Suwartimah et al., 2017).

During the planktonic larval stage, environmental factors such as currents, light intensity, water chemistry parameters and the nature of the substrate have a major influence on larval habitat selection for benthic organism (Sakai et al., 2020). CTWs are most commonly found associated with corals that have massive growth forms (Petrocelly 2023). In Sempu Island, the largest live coral cover was found on massive corals, making it suitable for CTWs that are found on these corals. Coral growth forms are influenced by currents, where strong currents affect the dominance of coral growth forms into massive corals (Isdianto 2022).

Current and brightness factors can also affect the presence of CTW. CTW larvae have a slow swimming speed of 1.7 to 2.5 mm/s (Marsden and Meeuwig 1990) so they cannot swim against strong currents, as a result the larvae will behave as passive particles in the water (Qian 1999) and the larvae of this species are positively phototactive so they are responsive to light (Petrocelly 2023). Swimming behaviour will play an active role in substrate selection only when the larvae are carried by the current closer to the substrate. The current in the waters of Sempu Island is categorized as moderate, with an average value of 0.46 m/s. Currents on coral reefs work to maintain the flow of nutrient-containing water and reduce sediment levels. Sediment is a big problem in the waters because it breaks down the penetration of sunlight into the waters and disrupts the photosynthesis process of corals. The results of the sedimentation rate in this research are high with an average value of 73.73 mg/cm^2/day. Marine waters covered with sediment with a value of 100 mg/cm^2 can reduce light entering the water by 75%. High sedimentation will affect the attachment of sessile animals to the substrate during larval stages, and can even cause the death of corals as hosts (Erftemeijer et al., 2012). Salinity can affect the respiration system and photosynthesis rate of corals, a decrease in normal salinity values to reach 20% can cause coral fertility to decrease by up to 86%. Salinity can also affect the abundance and distribution of phytoplankton (Wibawa and Luthfi 2017) which is known that CTW eat by preying on plankton and other particles (Rowley 2008). Nitrification occurs when the pH of a water body is low (Wibawa and Luthfi 2017). Nitrate and phosphate are organic materials that are utilized by marine

Table 4. Abundance of CTW in Sempu Island

Station	Abundance (individual/m^2)			Total
	Spirobranchus cruciger	*Spirorbanchus gardineri*	*Spirobranchus* spp.	
Watu Meja	0.044	0.002	0.024	0.070
Waru-waru	0.140	-	0.064	0.078
Banyu Tawar	0.012	-	0.026	0.038
Jetty	0.006	-	0.012	0.018
Rumah Apung	0.050	-	0.034	0.084

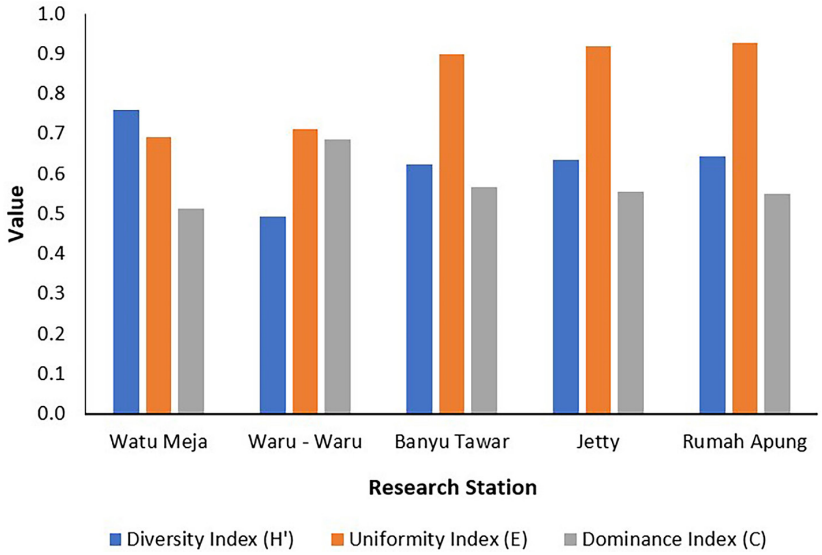

Figure 6. Community structure of CTW

organisms but their presence must be maintained (Hamzah et al., 2015). An overload of nitrate can cause algae growth, which adversely affects environmental conditions (Yolanda et al., 2016). CTW is affected by nitrate because its operculum is covered by turf algae in this study. Organic matter is obtained from various sources such as aquaculture, industry, settlements, harbours and human activities that enter from river flow (Alif et al., 2017). Based on the location of the research station, that station 4, which is Jetty, is a port that has many human activities. So that coral cover and CTW found at this station are the least.

CONCLUSIONS

Christmas tree worm that found in the five stations there are 3 species, namely *Spirobranchus cruciger, Spirobranchus gardineri* and *Spirobranchus* spp. CTW identified based on the operculum it has. The distribution of CTW is not randomly associated with all coral species because it is only found in some coral species. There are coral species that are often found associated with CTW, namely *Porites lobata*, *Porites lutea* and *Porites mayeri*. There are species that are rarely found associated with CTW, namely Goniastrea minuta. CTW abundance values ranged from 0.018 to 0.084 individuals/m^2, diversity index (H') ranged from 0.403 to 0.760 (low), uniformity index (E) ranged from 0.582 to 0.966 (unstable to stable). The dominance index (C) values ranged from 0.513 to 0.705 (medium). Based on these index values, it is found that the uniformity of CTW in Sempu Island waters tends to be unstable so that there is a medium dominance that is close to high in these waters. Water quality conditions, including currents, sedimentation, and nitrates, can influence this condition. Nitrates affect the growth of turf algae that cover the operculum of CTW.

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