Seagrass as carbon holder in Waleo coastal waters, North Sulawesi, Indonesia

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Abstract. Seagrass bed is one of the coastal vegetations that can become solution to overcome the climate change. Seagrass can have a role in absorbing CO_2 in photosynthesis. This process yields biomass that provides important deposit of carbon. The reserves of carbon stored in vegetation are divided into carbon above the surface (above ground carbon) and sub-surface or underground carbon. This study aims to identify the species of seagrasses in Waleo coastal waters, to obtain the biomass of the seagrass with species, and to know the amount of carbon content in the root, rhizome, and leaf. High carbon content in the seagrass indicates how important is the seagrass role in storing carbon in relation with its contribution to environmental services to prevent global warming.
Key Words: species identification, biomass, carbon content, root, rhizome, leaf.

Introduction. Marine life is potential to help global warming prevention through the role of marine plants. These plants can absorb 2 billion tons of carbon dioxide from the atmosphere every year, and plankton is mostly responsible for the absorption, but only small part falls to the sea bottom as carbon storage. Although the entire seagrass beds only cover 1% of total ocean basin, it could hold more than half the carbon buried in the sea bottom (Kawaroe 2009). Seagrass bed is a complex and productive ecosystem in marine and coastal ecosystem (Green & Short 2003). One of the main roles of seagrass is carbon sink with unique characteristics (Kennedy & Björk 2009).

Various efforts have been done to reduce the impact of global warming, such as refinement program, energy saving, and the use of various Carbon Capture and Storage (CCS) technologies (Kiswara 2010). One of the factors that could reduce CO_2 accumulation in the air is absorption by the vegetation, which requires CO_2 in photosynthesis. Seagrass bed is one of the coastal vegetations in which marine plants can become solution for climate change prevention. Plants have the ability to absorb CO_2 from atmosphere to be useful energy for life through photosynthesis. Fourqurean et al (2012) found that seagrass beds can store carbon up to 83,000 metric tons km^{-2}. Most of carbon is stored in the soil between the seagrasses. As comparison, forest usually can store 30,000 metric tons of carbon km^{-2} (Jorda et al 2012).

Seagrass bed has various ecological roles, such as spawning ground, nursery ground, feeding ground, and migratory area for various fishes and other marine organisms (Azkab 2000). Besides, seagrass can also absorb carbon in the form of dissolved carbon dioxide and store it in biomass form, such as root, rhizome, and leaf. Carbon storage capacity can be seen from the productivity level (Kawaroe 2009). Productivity is defined as growth rate of seagrass biomass in the form of carbon at certain time interval (g C m^{-2} hr^{-2}). The stored carbon is the entire carbon content inside the biomass and substrate at certain time (Duarte & Chiscano 1999).

Kiswara (2010) found that carbon content of *Enhalus acoroides, Cymodocea rotundata,* and *Thalassia hemprichii* in Flores Sea ranged between 31.0-32.5% C and 26.2-32.9% C at the lower part (root and rhizome) and the upper part (leaf). Various studies on seagrass ecosystem were conducted on seagrass density ecology (Blanchet et al 2004; Azkab 2008), seagrass growth rate (Cebrian et al 1998; Paling & McComb 2000;

El-Naggar et al 2007), organism association in the seagrass ecosystem and sediment quality relationship with nutrient content of the seagrass (Bologna & Heck Jr. 1999; Alfaro 2006). However, studies on the capacity of seagrass bed in carbon storage and absorption are still very few, especially in Indonesia waters.

Waleo coast exists in north Sulawesi, possesses sufficiently good seagrass condition and therefore, its occurrence is very important to maintain in order to balance the carbon emission rate to the atmosphere. Seagrass bed in Waleo coast is often used as research object and location. This study attempts to know the capacity of seagrass bed to store and absorb carbon.

Material and Method

Sample collection. This study was conducted in Waleo village, Manado, North Sulawesi. Observations were done at the geographic position of 1º17'51"N to 1º20'17"N and 125º 00'14"E to 125º04'7"E. Three sampling locations were selected with distance interval of 500 m. The work was done for 6 months covering field work and laboratory analysis. Sampling was done in January, 2017, and laboratory work in February to June, 2017. Observation on seagrass community structure used *S*eagrass Watch method (McKenzie & Yoshida 2009) using line transect and quadrat. There were 3 sampling sites and 4 transect lines placed perpendicular to the coastal line. Length of the line was dependent upon the seagrass area and the distance between the transect lines.

Seagrass collection for biomass estimation was done from the set plot following English et al (1994). This technique was applied to be able to minimize seagrass destruction from plant removals. The samples were then washed to be free of dirt and epiphyte, put into the plastic bag, placed in a cool-box, brought to the laboratory for further analysis (Hutagalung & Rozak 1997). The transect line was placed with 10 quadrats, and the first was laid near the shore where the first seagrass was found, and the last quadrat was put on the peripheral end of the seagrass found, and other eight quadrats were randomly systematically set along the transect line. The seagrass bed position was already determined using a Geographic Positioning System (GPS) a reference for the next 16 sampling activities. A quadrat of 100 x 100 cm was divided into 25 plots of 10 x 10 cm.

The seagrasses in the quadrat were identified to species level. Seagrass samples were then brought to the laboratory of Fisheries Hydrobiology and Fisheries Resources Management for species identification. It followed identification method of Lanyon (1986) and Philips & Menez (1988), and then calculated the number of individuals with species. Determination of an individual in the quadrat is taken if it consists of root, stem, and leaf on each rhizome. Before weighing the seagrass, the leaf was firstly cleansed manually from attached dirt or sand or epiphytes. The sample weight was recorded in fresh form using a OHAUSS balance of 0.01 gr.

Carbon content analysis. The effective and efficient method to obtain representative carbon content used the method of Loss-on-Ignition (LOI) method of Nelson & Somers (1996). All seagrass samples were separated with species and sites. The clean seagrass was separated into leaf, rhizome, and root. Each part was then weighed and wrapped in paper. Fresh weight of ±300 g sample was prepared referring to SNI-7724/2011 (Herawati 2008). It was wrapped and dried in an oven at stable temperature of 80^{o}C up to having constant weight, and recorded the dry weight data. The seagrass samples were then placed in a weighed Petri disc, and cremated for 20 min, at 600^{o}C in the furnace to obtain ash weight of the seagrass sample.

Data analysis. The seagrass ash was weighed, and carbon content was obtained through conversion using the following formula (Nellemann et al 2009):

$$\text{Ash content (\%)} = \left[\frac{C-A}{B}\right] \times 100 \quad (1)$$

$$\text{C – Organic (\%)} = \left[\frac{B-C}{B}\right] : 1{,}724 \times 100 \quad (2)$$

where: A = empty Petri disc weight, B = net dry weight after dried in oven at 80^{o}C, C = sample after roasted at 600^{o}C, and 1,724 = standard formula (C content of 58%).

This value is obtained from the formula above in which the value of 58% is carbon content in easily oxidized substrate that the plant cannot possibly contain more than 58% of carbon.

Results and Discussion

Seagrass species. Observations in 3 locations found a total of 6 seagrass species and showed different species composition. Location I is near the local community residential area and a site used for fishermen's fishing boat tether. In location II occur mangroves as nutrient trapping area considered as in good condition and unpolluted by human and tourism activities. Location III is near the port. Their occurrence was not uniform and not all species presented in each station. Six species of seagrasses were found in Waleo waters in shallow waters or lagoon between coral reefs and coast (Table 1).

Table 1

Seagrass species and number of individuals in the study site

Division: Spermatophyta	*No. ind. with site*		
Class: Angiospermae	*I*	*II*	*III*
Family: Hydrocharitaceae			
I. *Thallasia hemprichii*	1,131	2,565	1,074
II. *Enhalus acoroides*	464	349	320
III. *Halophila ovalis*	-	155	-
Family: Potamogetonaceae			
I. *Cymodocea serrulata*	379	410	639
II. *C. rotundata*	762	402	742
III. *Sryngodium isoetifolium*	69	134	249

Note: I - near residential area and fishermen's boat site; II - near mangrove area; III - near hotel and port.

In location I, only 5 species were recorded, *T. hemprichii, E. acoroides, C. serrulata, C. rotundata* and *S. isoetifolium.* It could be caused by the environmental condition on site, where the area is passing lane of the fishermen's fishing boats and there are domestic waste disposal activities that give sufficient influence on the seagrass growth.

In location II, 6 species of seagrasses were recorded, *T. hemprichii, E. acoroides, C. serrulata, C. rotundata, H. ovalis* and *S. isoetifolium*, because the environmental condition was good and supported the growth of various seagrass species.

Observation in location III showed similar condition to location I since the area was near the hotel and got the impact of hotel activities so that the seagrass growth was also disturbed. The species found were also *T. hemprichii, E. acoroides, C. serrulata, C. rotundata* and *S. isoetifolium.*

Seagrasses are distributed from the coast to the steep edge in all study sites and belong to mixed vegetation due to coexistence in two species or more in one habitat and usually in shallow subtidal. They were dominated by *T. hemprichii, C. rotundata, C. serrulata,* and *E. acoroides*.

E. acoroides and *T. hemprichii* were found almost in each location indicating that seagrass communities in Tongkaina waters were around climax succession phase. In succession process, large-sized seagrass species is usually called as climax species, while small-sized one as pioneer species (Hemminga & Duarte 2000). *E. acoroides* is the largest-sized tropical seagrass species (Waycott et al 2004), followed by *T. hemprichii.*

Nevertheless, *T. hemprichii* has the most extensive distribution and often grows in the substrate with thin mud content. High density of *T. hemprichii* is in association with its adaptation ability to fine sandy substrate to coarse sand substrate in the study sites. This condition is in agreement with Den Hartog (1970) that *T. hemprichii* can live in all substrate types, from coral rubbles to soft substrate. This species also has extensive vertical distribution range from shallow intertidal to lower subtidal zone, and can survive in nearly all substrate types.

E. acoroides, *C. rotundata,* and *C. serrulata* are also widely distributed, particularly in fine substrate, muddy, but capable of living in stony substrate. *E. acoroides* is often found heterogeneously growing with other species or as monospecific vegetation in diverse habitats from sift muddy bottom, muddy sandy to coarse carbonate sediment. *E. acoroides*, despite being able to adapt to various substrate types, this species possesses relatively low density. This condition is related with water depth and slant topography so that numerous seagrass beds are opened in low tide. As a result, this species is distributed only in submerged area.

The occurrence of *C. rotundata* is also in agreement with Tomascik et al (1997) that this species presents in fine to coarse sandy bottom of the intertidal and subtidal zones. *C. rotundata* lives in coral debris-covered shallow water and has high tolerance to drought (open area).

S. isoetifolium possesses low density. This species can only tolerate the drought in short time, and is usually found between other dominant seagrass (Phillips & Menez 1998).

H. ovalis occurs in the lowest density in all study sites. This species is found together with *S. isoetifolium* and *T. hemprichii* as reported by Brazier (1975) in Philips & Menez (1988) that these four seagrass genera form a "Thalassia Association", particularly in the tropical area. Besides, Mathieson & Nienhuis (1991) found that these genera are often seen as starting genera inhabiting the sandy substrate. In this study, *H. ovalis* was only found in location II, since this location got low disturbance of human activities.

Biomass and carbon content. Carbon absorbed and stored in the body parts of the seagrass possesses different concentration. Species found were *T. hemprichii, E. acoroides, C. serrulata, C. rotundata, H. ovalis* and *S. isoetifolium.* Carbon content was measured in different body parts, root, rhizome, and leaf. The organic carbon content in each body part is presented in Table 2.

Location I demonstrated the percent of carbon content in rhizome ranged from 20.12% for *S. isoetifolium* to 47.46% for *T. hemprichii*. The carbon content in the leaf ranged from 15.75% for *S. isoetifolium* to 34.64% for *T. hemprichii,* while in the root, it ranged from 19.86% for *S. isoetifolium* to 38.54% for *T. hemprichii*.

Percent carbon content in location II revealed that the highest carbon content was recorded in rhizome, from 20.50% for *H. ovalis* to 57.42% for *T. hemprichii,* respectively. The carbon content in the leaf ranged from 17.84% for *H. ovalis* to 53.78% for *T. hemprichii,* while those in the root ranged from 19.85% for *H. ovalis* to 42.15% for *T. hemprichii*.

Location III showed that the highest carbon content occurred in rhizome, 24.76% (*S. isoetifolium*) to 45.73% (*T. hemprichii*). Carbon content in the leaf ranged from 22.87% (*S. isoetifolium*) to 35.6% (*C. rotundata*), while in root, it ranged from 20.14% (*S. isoetifolium*) to 33.80% (*C. serrulata*).

The largest carbon content was recorded *below ground,* particularly rhizome, reflecting that rhizome and root were the body parts holding carbon at the most due to denser body structure than that above ground. Muchtar (1994) found that carbon content of *E. acoroides* was 37.98% in the leaf and 35.46% in the root, while Hemminga & Duarte (2000) stated that mean carbon stored was 30-40% of the dry weight. The highest carbon content in the rhizome in 3 body parts, rhizome, leaf, and root, was recorded in *T. hemprichii* (Table 2).

The largest carbon stored in the seagrass bed was recorded in *T. hemprichii,* especially in rhizome below the ground in location II. The seagrass part below ground has very important role in accumulating the photosynthetic output and nutrient so that it could store more organic materials, beside denser body structure of root and rhizome than leaf makes the carbon stored below ground be higher. The body parts capable of accumulating high carbon content in the seagrass occurred in rhizome and root compared with that in leaf based upon the amount of carbon stored. Carbon content in different parts of seagrass is given in Figures 1, 2 and 3, indicating that carbon content is higher in rhizome than that in root and leaf. In spite of that, the difference in carbon content in location III is not quite significant. Researches on biomass below the sediment revealed that seagrass root and rhizome contributed most of the organic matters into the sediment in Atlantic Ocean (Zieman & Wetzel 1980). Also, Hemminga & Duarte (2000) presented their hypothesis that the organic matters functionally came from seagrass root and rhizome production.

Table 2

Carbon content (%) of seagrass species in the study sites

Site	*Species*	*Carbon content (%)*		
		Leaf	*Rhizome*	*Root*
I	*E. acoroides*	30.76	41.63	29.76
	T. hemprichii	34.64	47.46	31.54
	C. serrulata	29.00	39.86	27.85
	C. rotundata	30.58	37.86	38.54
	S. isoetifolium	15.75	20.12	19.86
II	*E. acoroides*	29.83	39.87	28.56
	T. hemprichii	53.78	57.42	42.15
	C. serrulata	24.58	33.50	25.76
	C. rotundata	27.87	33.85	35.94
	S. isoetifolium	18.65	22.76	20.98
	H. ovalis	17.84	20.50	19.85
III	*E. acoroides*	28.75	37.42	26.85
	T. hemprichii	33.89	45.73	29.86
	C. serrulata	26.54	35.40	33.80
	C. rotundata	35.60	37.85	33.21
	S. isoetifolium	22.87	24.76	20.14

Carbon stored in the seagrass had relationship with total biomass in dry weight (g m^{-1}) (Appendix 1). The highest carbon stored in *T. hemprichii* in location II was 7,281.905 g C m^{-2}, and the lowest mean total biomass was 27.634 g C m^{-2} in *H. ovalis* in location II.

High biomass of *T. hemprichii* could result from high number of individuals despite smaller morphology than *E. acoroides.* Leaf size of *E. acoroides* ranges from 65 to 160 cm long and 1.2-2.0 cm wide and that of *T. hemprichii* ranges from 3.6 to 25 cm long and 0.17-1.7 cm wide (Kiswara 1992).

H. ovalis is the species having relatively larger above ground biomass than that of under ground. *T. hemprichii* and *C. rotundata* are seagrass species possessing relatively same biomass ratio between underground and above the ground. Duarte & Chiscano (1999) estimated mean biomass of seagrass bed in the world about 460 g BK m^{-2}. The amount of seagrass biomass can be seen from the number of leaves bud^{-1}, cover size, and density (Table 3).

Location II had the highest seagrass density recorded in *T. hemprichii,* 256.5 ind m^{-2} and the lowest in *S. isoetifolium,* 13.4 ind m^{-2}. The highest percent cover was also found in location II. Fortes (1989) stated that the size of the seagrass biomass is not only a function of the plant size, but also the function of density, and thus, the magnitude of density and the amount of leaves per bud in the two locations yield high biomass.

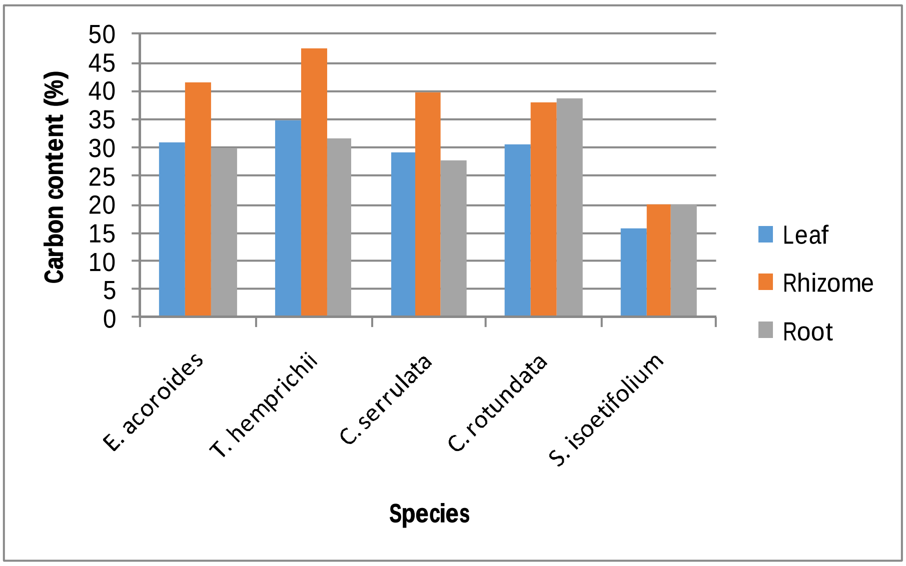

Figure 1. Carbon content in seagrass body parts in location I.

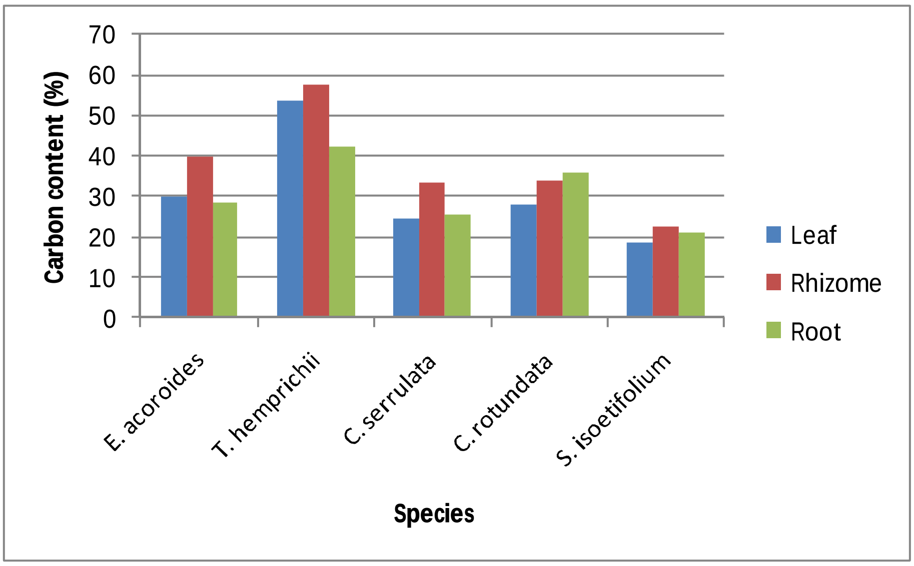

Figure 2. Carbon content in seagrass body parts in location II.

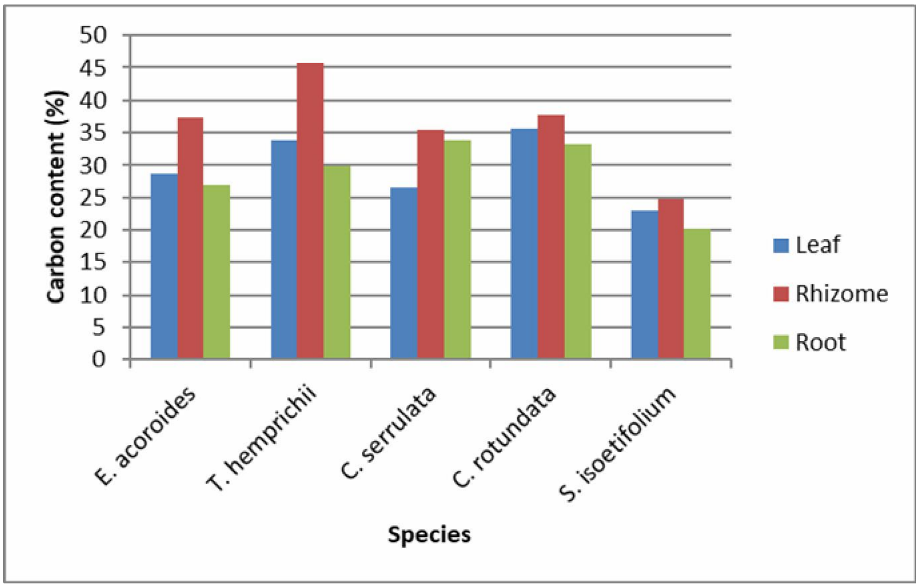

Figure 3. Carbon content in seagrass body parts in location III.

Table 3

Number of leaves, seagrass cover, and density

Site	Species	Range		
		∑ leaf/bud	% cover	Density (ind m^{-2})
1	*E. acoroides*	4	20-40	46.4
	T. hemprichii	2-4	50-75	113.1
	C. serrulata	1-3	30-45	63.9
	C. rotundata	1-3	35-50	76.2
	S. isoetifolium	1-3	35-40	6.9
2	*E. acoroides*	4	20-40	34.9
	T. hemprichii	2-5	80-90	256.5
	C. serrulata	1-3	20-40	37.9
	C. rotundata	2-4	35-60	40.2
	S. isoetifolium	1-3	5-20	13.4
	H. ovalis	1-3	5-20	15.5
3	*E. acoroides*	4	20-40	32
	T. hemprichii	2-4	40-75	107.4
	C. serrulata	1-3	30-40	41
	C. rotundata	1-3	20-40	24.9
	S .isoetifolium	1-3	20-40	74.2

Conclusions. This study found 6 seagrass species, *T. hemprichii, E. acoroides, C. rotundata, C. serrulata, S. isoetifolium* and *H. ovalis.* The highest density was recorded in *T. hemprichii* in all locations. The highest carbon content was found in rhizome, followed by leaf, and root, respectively. Carbon content with seagrass species from the lowest to highest was *H. ovalis, S. isoetifolium, C. rotundata, C. serrulata, E. acoroides,* and *T. hemprichii.* These results reflect that seagrass has very important role in ecosystem balance, particularly in preventing global warming.

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Appendix 1

Biomass data (gr) of different body parts (root, rhizome and leaf)

Location	Species	Dry weight (g)				Ash weight (g)			
		Root	Rhizome	Leaf	Total	Root	Rhizome	Leaf	Total
I	*E. acoroides*	10.5	20.21	11.65	42.36	8.87	17.26	8.30	34.35
	C. serrulata	3.94	8.96	4.17	17.07	1.85	5.01	2.03	8.89
	S. isoetifolium	2.14	5.30	2.15	9.59	1.01	3.85	0.02	4.88
	C. rotundata	4.50	9.85	5.25	19.6	2.25	6.92	3.06	12.23
	T. hemprichii	14.58	35.2	11.45	61.23	10.95	32.34	8.05	51.34
II	*E. acoroides*	11.50	27.85	14.85	54.2	8.68	23.75	11.01	43.45
	S. isoetifolium	4.15	5.85	2.01	12.01	2.17	3.77	1.87	7.82
	C. serrulata	2.85	7.81	3.59	14.25	1.98	4.08	1.27	7.33
	C. rotundata	2.48	7.90	4.01	14.39	1.07	5.98	1.19	8.25
	T. hemprichii	20.68	31.10	10.47	62.25	17.01	29.93	7.27	54.22
	H. ovalis	1.85	2.85	0.93	5.63	0.98	1.51	0.02	2.52
III	*E. acoroides*	10.97	25.71	14.54	51.22	7.45	22.35	10.09	39.90
	C. serrulata	4.53	8.82	5.42	18.77	1.21	5.65	2.03	8.90
	C. rotundata	3.98	9.18	7.81	20.97	1.91	6.98	5.86	14.76
	S. isoetifolium	3.24	7.21	6.21	16.66	1.65	4.97	4.71	11.34
	T. hemprichii	10.33	38.18	11.18	59.69	6.91	32.15	9.04	48.11

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