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Research Article

Observation of Wild Seaweed Species in Labuhanbua Waters, Indonesia: A Preliminary Assessment for Aquaculture Development

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ABSTRACT

Seaweed industry has been growing up and is supplied by either wild or cultivated seaweed crops. This study was aimed to investigated wild seaweed potency in Labuhanbua coastal waters, Sumbawa Regency, West Nusa Tenggara; and the potential use of important species as candidate for aquaculture commodities. 46 sampling stations were determined along line transects perpendicular to coastal line; and seaweed collections were conducted during low tide with 1 x 1 m^2 quadrat transect. Field data consist of in-situ parameter including number of seaweed species and coverage area of each species; and ex-situ parameters consist of carbohydrate, protein, total C, total N, and total P content of seaweeds. The results showed that 33 species were found and 3 species were dominant, i.e. *Padina* sp., *Gracilaria Salicornia, and Dictyota dichotoma* with the highest densities among other species, about 22.61 %, 9.35 %, and 7.88 %, respectively. They also have potencies for human food, livestock feed, nutraceuticals, cosmetics, and any other industries. These might be important species that should be develop as aquaculture commodities candidates through culture technology advancement. Commercial scale cultivation of those important seaweed species will contribute to industrial needs and prevent decreasing wild seaweed availability in natural ecosystem.

Keywords: *wild seaweed, aquaculture candidate species, Labuhanbua, West Nusa Tenggara*

1. Introduction

Government of Indonesia through Ministry of Marine Affairs and Fisheries (MMAF) has determined that national fisheries production targets about 31 million tons for next five year during 2015-2019; which consist of seaweed production about 22 million tons. Indonesian coastal area has a great natural seaweed resources. Mostly, natural seaweed habitat in Indonesia can be found along coastal waters with reef flat; where its abundance and distribution depend on the substrate types, seasonal hydrography conditions, and species competition (Kadi 2004). They were found attached to the bottom, in relatively shallow coastal waters areas up to 180 meter depth, on solid substrates such as rocks, dead corals, pebbles, shells, and plants (Sahayaraj et al. 2014).

Labuhanbua coastal waters is one of locations which has abundant natural seaweed species which distributed along the reef flat at intertidal zone. Along that coastal area can be found various natural ecosystems including reef flat, mangrove, seagrass, and seaweed bed. Generally, people who live around the Labuhanbua coastal area still did not aware on economic values of the natural seaweeds. *Sargassum* sp. is the only species that has exploited by harvesting from its natural habitat. Other major species which have high value substances are still commonly unrecognized by local people.

Nowadays, seaweed industry has grown up; it uses 7.5-8.0 million tons of wet seaweed annually, either from naturally growing (wild) or from cultivated (farmed) crops (McHugh 2003). The farming of seaweed has expanded rapidly while demand has exceeded the supply available from natural resources (McHugh 2003). Although wild harvest supports a significant portion of seaweed industry, there is an ever-increasing amount of seaweed production from aquaculture, principally in Asia and South America (Redmond et al. 2014a). Seaweed aquaculture makes up a significant portion of organisms cultured worldwide (~19 million metric tons) with a value of ~US $5.65 billion (FAO 2012). About 25 million tons of seaweeds and other algae are harvested annually for use as food, cosmetics and fertilizers, and are processed to extract thickening agents or used as an additive to animal feed (FAO 2014).

Seaweed cultivation is a major industry in many countries of Asia-Pacific region, in particular Japan, Korea, and China (Hwang et al. 2007). Also in Indonesia, seaweed production volume from aquaculture contribute about 54,15 – 62,67 % of national fisheries and aquaculture production during last five year (DGA-MMAF, 2014). Many seaweeds species have a great potency for food, feed, medicine, cosmetics and other industries, and mostly have been utilized at industrial level. But, there are limited number of seaweed species which have cultivated commercially in Indonesia, particularly some species from division of Rhodophyta such as *Kappaphycus alvarezii, K. striatum, Eucheuma denticulatum*, *Gracilaria gigas,* and *G. verrucosa*. On the other hand, the industries are still relying on seaweed supplies from natural resources; especially for certain species those are not yet cultivated.

Many efforts on seaweed research and development have been conducted to obtain cultivation technique of other potential seaweed species. Some species have been successfully cultivated, but large numbers of wild species are still not be able to cultivated well. *Codium fragile,* an edible green alga has been farmed in Korea using seed stock produced from artificial seed production and nursery culture (Hwang et al. 2007). *Undaria pinnatifida* cultivation was largely developed in Korea for human consumption (Park et al. 2007). *Gelidium* has been cultured in Korea since 1989, but there is still no current commercial cultivation of this Gelidiales species (Friedlander 2007). There are still lack of study regarding the wild seaweed species around West Nusa Tenggara, specifically along Sumbawa coastal area.

Investigation on potential wild species for "new-aquaculture commodities" is now very important to be conducted, considering the wild seaweed ecosystem degradation caused by growing of industrial needs. While, industries need many kinds of substances from many seaweed species, yet the cultured species are still very limited. This study was aimed to investigate wild seaweed potency and the potential used of important species from Labuhanbua coastal waters, Sumbawa Regency, West Nusa Tenggara. It is expected that they can be developed as candidate species for next aquaculture commodities.

2. Materials and Methods

Study Site

The study was conducted at Labuhanbua coastal waters, Sumbawa Regency, West Nusa Tenggara Province, Indonesia (Figure 1a). This observation was conducted as a preliminary study to get initial information regarding wild seaweed varieties and their availability in Labuhanbua coastal ecosystem. Field data were collected on September 2014 with total wide area that have been observed about 173 ha.

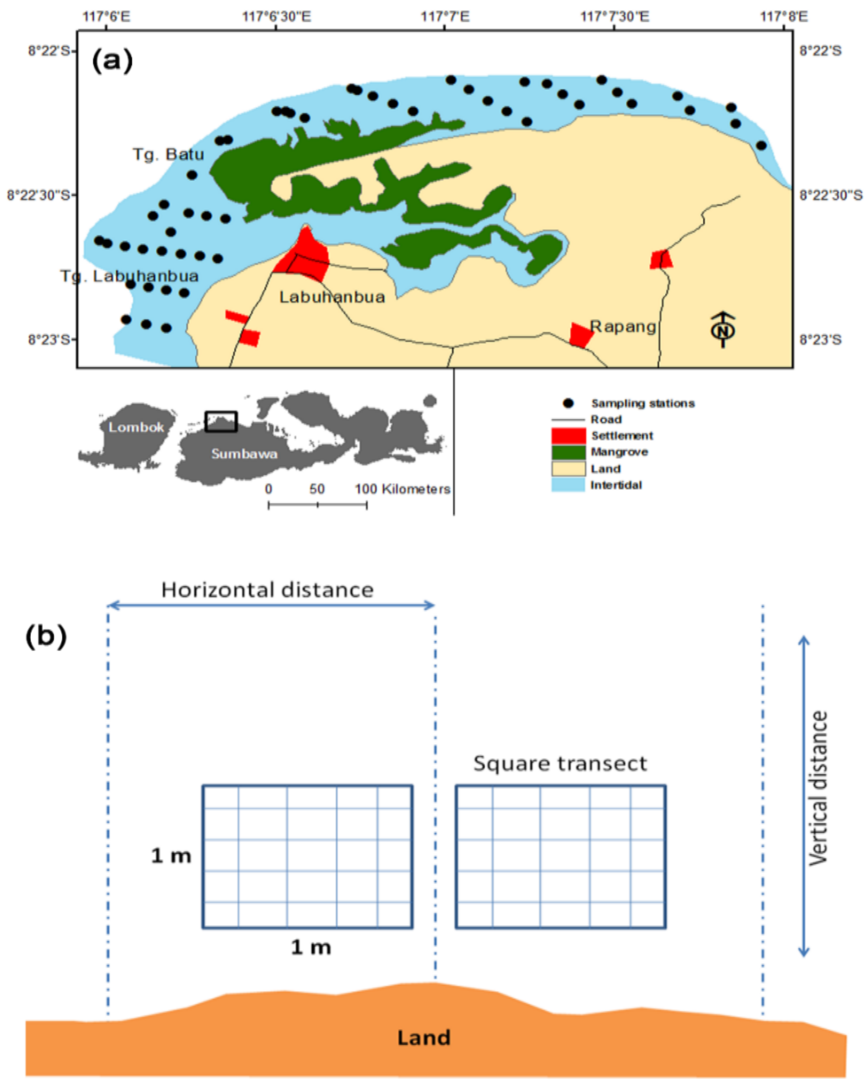

Figure 1. (a) Study location at Labuhanbua coastal waters, Sumbawa Regency, West Nusa Tenggara Province, and sampling stations distribution along the study location; (b) quadrat transects position on each sampling station

Data collection

Distribution of sampling stations was designed by Geographic Information System (GIS) using line transects perpendicular to coastal line along the intertidal area (Figure 1b). Distance between two neighboring line transect (horizontal distance) was about 250 m. 46 sampling stations were determined along line transects which separated about 100 m of each other (vertical distance). Seaweed samplings were conducted during low tide with 1 x 1 m^2 quadrat transect that was subdivided into 20 x 20 cm^2 unit by string (Dawes, 1981; Dadolahi-Sohrab *et al.*, 2012). Quadrat transects were placed at two sides of line transect at each sampling station for repetition data collection. Both of data obtained were calculated to get average value for each station. Data collection included number of seaweed species and percentage of coverage area of every single species at each quadrat transect for all of sampling stations. Seaweed species identification was based on Dhargalkar & Kavlekar (2004) and Kalsum (2012).

Fifteen seaweed species were found in large quantities throughout the sampling stations, were collected by hand from their habitat and stored in plastic bags; then the seaweed samples were dried for laboratory analysis. Biochemical parameters were measured including total nitrogen (TN), total phosphorus (TP), total carbon (TC), carbohydrate, and protein contents of each species as percent dry weight (% DW) with duplex-analysis methods for each parameter. TN and protein contents were measured using Kjeldahl method, while TP and TC using

HNO3-HClO4 spectrophotometric and Walkey & Black method, respectively (AOAC, 2005).

Data analysis

Collected data were analyzed using descriptive statistic methods and showed in tables and graphics. Field data obtained for each seaweed species were calculated following the formula below (Dawes, 1981; Dhargalkar & Kavlekar, 2004) :

$$\text{Frequency} = \frac{\text{number of occupied quadrats}}{\text{number of quadrats}}$$

$$\text{Abundance (\%)} = \frac{\text{total number of individual plants}}{\text{number of occupied quadrats}} \times 100$$

$$\text{Density (\%)} = \frac{\text{total number of individual plants}}{\text{total number of quadrats}} \times 100$$

3. Results and Discussion

Condition of sampling location

Labuhanbua coastal water has great varieties of wild seaweed along the intertidal area. Seaweed species were distributed from coastline toward the reef edge area where the water depth about 0 – 3 meters. Sea-bottom substrates were composed by sand, mud, pebbles, and coral stone. Measurement of some important water quality parameters described the characteristics of Labuhanbua water area where various seaweed species spread and grow. The range of salinity measured were about 34 – 37 ppt; turbidity from 0.30 – 9.00 NTU; total N 0.16 – 0.95 mg/L; and total P about 0.01 – 1.15 mg/L. Nitrogen and phosphorus are primary elements for plant growth (Dawes, 1981).

Ecological assessment of wild seaweed

Labuhanbua coastal waters which located at Sumbawa Regency, West Nusa Tenggara Province has fairly large diversity of natural seaweed ecosystem. Thirty three species were collected from 46 sampling stations along the coastal waters of Labuhanbua which consist of three divisions of natural seaweeds, namely Rhodophyta (8 species), Phaeophyta (8 species), and Chlorophyta (13 species); and also four species were found as unidentified species. Distribution of seaweed species is shown in Figure 2. A species from division of Phaeophyta, *Padina* sp., was the most widely distributed which was found at 28 stations out of 46 total number of sampling stations (Figure 2). The result of ecological quantitative analysis on each seaweed species also showed that *Padina* sp. had the highest frequency (0.61) which mean that the species was found at 61 % of the total sampling stations (Table 1). *Dictyota dichotoma*, species of Phaeophyta was the second widely distributed which was found at 14 sampling stations. *Gracilaria salicornia* from division of Rhodophyta followed as the third widely distributed species, that was found at 11 stations. Several species of Chlorophyta and some unidentified species were only distributed at limited stations which ranged from 1 - 8 stations along that coastal waters with frequencies range about 0.02 – 0.17 (Table 1, Figure 2). A regular distribution of species and communities is particularly obvious on rocky shore, as has long been recognized by marine biologist (Neto, 2000). Fleshy brown macroalgae, including *Padina* and *Dictyota* are abundantly found on shallow inshore reef flat (Diaz-Pulido & McCook, 2008). Seaweeds species will be distributed differently on natural ecosystem depend on their types and adaptation capability on the environmental conditions. Seaweed growth and distribution are affected by environmental factors such as salinity and light; as well as substrate characteristics may also be important factor to influence the distribution of seaweed types (Dawes, 1981; Tyler, 2010).

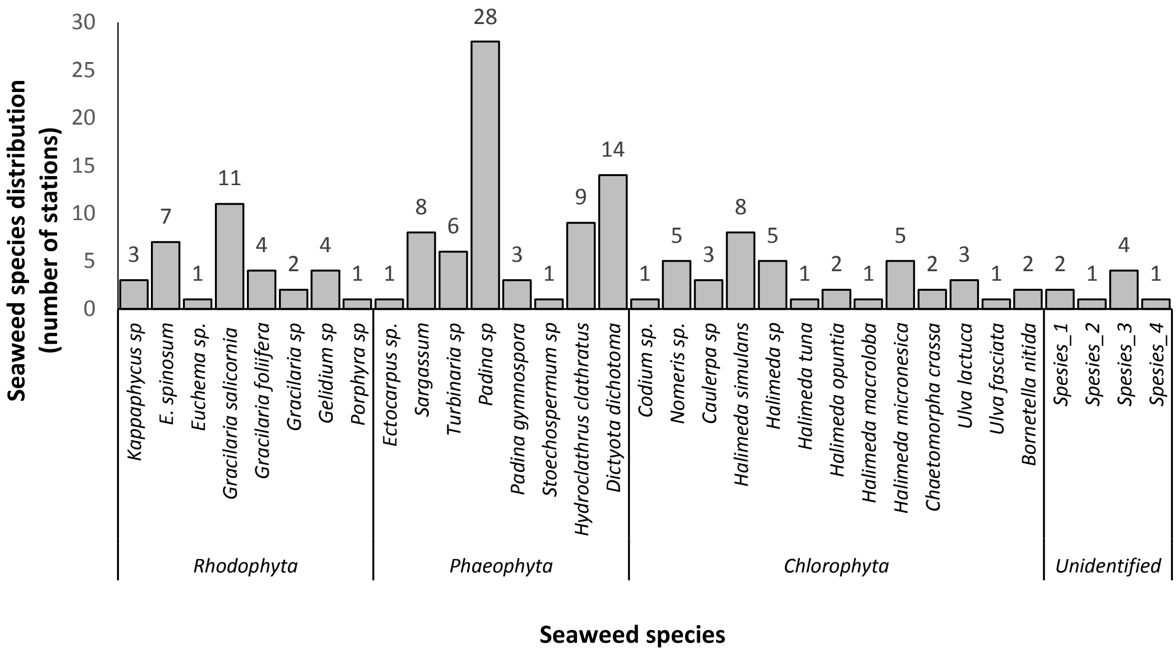

Figure 2. Seaweed species distribution of total 46 observation stations at Labuhanbua coastal waters, Sumbawa Regency, West Nusa Tenggara Province

Seaweed species abundance describes average number of a species on several stations where that species was found. *Eucheuma* sp. was found as the highest abundance species of Rhodophyta division at Labuhanbua coastal water. This species had average abundance about 50 % of the occupied quadrats; but its density only 1.09 % of the total sampling station observed (Table 1). *Ectocarpus* sp. was the highest abundance species of Phaeophyta; its abundance attained 100 % (Table 1). Based on field observation, this species was only found at one station and occupied spread all over the quadrats; thereby its density only 2.17 % of the total observation area (Table 1). Some species of Chlorophyta were found with high abundance. Those species were including *Ulva fasciata, Chaetomorpha crassa, U. lactuca,* and *Codium* sp. with their abundance about 60.00 %, 56.25 %, 50.83 %, and 50.00 %, respectively. However, their densities were not the highest among other species at the same division which ranged about 1.09 – 3.32 %. Two Chlorophyta species were found in highest density including *Halimeda* sp. and *H. simulans* with densities of 7.61 % and 7.28 %, respectively (Table 1). In addition, four unidentified species were also found at study location which had abundance range about 25.00 – 84.75 % and densities of 0.54 – 7,37 % (Table 1). In context of the sustainability of seaweed fishery, the exploitation has to consider its distribution and abundance before authorizing the harvesting of natural populations (Vásquez, 2007).

Table 1. Ecological quantitative assessment of seaweed species at Labuhanbua coastal waters, Sumbawa Regency, West Nusa Tenggara Province

No.	Seaweed species	Frequency	Abundance (%)	Density (%)
	Rhodophyta			
1	*Kappaphycus* sp.	0.07	15.83	1.03
2	*Eucheuma spinosum*	0.15	23.57	3.59
3	*Eucheuma* sp.	0.02	**50.00**	1.09
4	*Gracilaria salicornia*	**0.24**	39.09	**9.35**
5	*Gracilaria foliifera*	0.09	33.13	2.88
6	*Gracilaria* sp.	0.04	10.00	0.43
7	*Gelidium* sp.	0.09	16.88	1.47
8	*Porphyra* sp.	0.02	6.00	0.13
	Phaeophyta			
9	*Ectocarpus* sp.	0.02	**100.00**	2.17
10	*Sargassum* sp.	0.17	31.25	5.43
11	*Turbinaria* sp.	0.13	16.67	2.17
12	*Padina* sp.	**0.61**	37.14	**22.61**
13	*Padina gymnospora*	0.07	26.67	1.74
14	*Stoechospermum* sp.	0.02	25.00	0.54
15	*Hydroclathrus clathratus*	0.20	33.89	6.63
16	*Dictyota dichotoma*	**0.30**	25.89	7.88
	Chlorophyta			
17	*Codium* sp.	0.02	**50.00**	1.09
18	*Nomeris* sp.	0.11	28.50	3.10
19	*Caulerpa* sp.	0.07	38.33	2.50
20	*Halimeda simulans*	**0.17**	41.88	**7.28**
21	*Halimeda sp.*	0.11	70.00	**7.61**
22	*Halimeda tuna*	0.02	10.00	0.22
23	*Halimeda opuntia*	0.04	23.75	1.03
24	*Halimeda macroloba*	0.02	22.50	0.49
25	*Halimeda micronesica*	0.11	48.00	5.22
26	*Chaetomorpha crassa*	0.04	**56.25**	2.45
27	*Ulva lactuca*	0.07	**50.83**	3.32
28	*Ulva fasciata*	0.02	**60.00**	1.30
29	*Bornetella nitida*	0.04	11.25	0.49
	Unidentified			
30	Spesies_1	0.04	35.00	1.52
31	Spesies_2	0.02	30.00	0.65
32	Spesies_3	**0.09**	**84.75**	**7.37**
33	Spesies_4	0.02	25.00	0.54

Biochemical contents of dominant seaweed species

Several numbers of macrophytes species have been a part of human food source (Sharp *et al.*, 2007, Hwang *et al.*, 2007). A large resources of wild seaweed is available at Labuhanbua coastal waters. These also have great potencies for further management and possible development related to market demand including several needs for human food, animal feed, biofuel, cosmetics, pharmaceutical, and carbon sink agent (McHugh, 2003; Erlania & Radiarta, 2014). Seaweeds found to be good sources of proteins, carbohydrates, vitamins, and minerals in human nutrition; marine algae contain various carbohydrates different from those in higher land plants, and in addition, high protein content has been reported (Chakraborty & Santra, 2008; Manivannan, 2008; Pise & Sabale, 2010). Three broad group of seaweed classified based on pigmentation also show their potencies to produce valuable pigment substances including chlorophylls-a, b, c, and d; phycoerythrin, phycocyanin, α-carotene, β-carotene, lutein, fucoxanthin, etc. (Dawes, 1981; Naguit & Tisera, 2009; Thirumaran, 2009).

Fifteen dominant species were found at Labuhanbua waters. Some primary biochemical contents have been analyzed including parameters of carbohydrate, protein, total N, total P, and total C contents (Table 2). Several species of seaweed accumulate high level of carbohydrate. Total carbohydrate content varied from 1.15 – 19.09 % biomass. There were three species, *Caulerpa* sp., *Gracilaria salicornia* and *Halimeda* sp., contain the highest number of carbohydrate in their tissues among other species that ranged about 15.89 – 19.09 % (Table 2). Production of carbohydrate rich plant biomass is needed; biofuels such as bioethanol or butanol derived from carbohydrates fermentation of plant biomass (Kraan, 2013). Macroalgal polysaccharides (polymer of carbohydrate) are used in the food, cosmetics, paint, crop, textile, paper, rubber and building industries (Dere *et al.*, 2003). Main polysaccharide extracts from seaweed, called phycocolloids/hydrocolllids, that are not found in terrestrial plants, includes carrageenan, agar, and algin which account for about 95 % of the commercially available seaweed extracts; and the rest consist of furcellarin, funoran, and porphyran (Dawes, 1981; Carlsson *et al.,* 2007). Total protein content of several dominant seaweed at Labuhanbua coastal waters were vary in different species and ranged from 3.25 – 12.63 % DW (Table 2). The highest protein contents were found in *Caulerpa* sp. (12.63 %) and *Gracilaria* sp. (10.75 %). Chakraborty & Santra (2008) found that protein content of eight seaweed species at Sunderban coastal waters, India showed significant individual variation from 3.33 % (*Dictyota ceylanica*) to 40.87 % (*Lola capillaris*) of dry weight.

Nitrogen, phosphorus, and carbon are very important elements for seaweed growth. Seaweed tissue carbon would be present in species variability (Muraoka, 2004; Kaladharan, 2009; Erlania & Radiarta, 2014a). Seaweed capture carbon as CO_2 during photosynthesis process and convert it into carbohydrate for biomass production (Dawes, 1981; Erlania & Radiarta, 2014b). This macroalgae can represent major progress in several senses including: higher carbohydrate levels and biomass yields, their widespread availability, the absence of a competition with agricultural area, the high quality of the by-products, their use as a mean to capture CO_2, and their suitability for integrating in wastewater treatments to reduce pollution (Kraan, 2013).

Table 2. Carbohydrate, protein, TC, TN, and TP content (% DW) of dominant seaweed species found at Labuhanbua coastal waters, Sumbawa Regency, West Nusa Tenggara Province

No.	Seaweed species	Carbohydrate	Protein	TC	TN	TP
1	*Caulerpa* sp.	**19.09**	**12.63**	**25.66**	**2.02**	**0.103**
2	*Gracilaria salicornia*	**17.55**	5.38	**23.00**	0.86	0.074
3	*Halimeda* sp.	**15.89**	7.00	9.82	1.12	0.080
4	*Ulva reticulata*	9.46	5.94	20.37	0.95	**0.107**
5	*Gracilaria* sp.	9.41	**10.75**	19.59	**1.72**	0.082
6	*Eucheuma spinosum*	9.18	7.19	16.47	1.15	0.058
7	*Turbinaria* sp.	7.82	5.81	**22.04**	0.93	0.056
8	*Gelidium* sp.	7.72	7.56	16.41	**1.21**	0.066
9	*Bornetella nitida*	6.32	5.38	9.07	0.86	0.037
10	*Dictyota dichotoma*	6.07	7.56	18.69	**1.21**	**0.091**
11	*Sargassum* sp.	4.17	5.94	16.41	0.95	0.073
12	*Padina* sp.	4.10	8.88	14.18	**1.42**	0.079
13	*Halimeda micronesica*	1.66	3.25	4.53	0.52	0.041
14	*Hydroclathrus clatratus*	1.15	8.63	11.78	**1.38**	0.086

Seaweeds also absorb nutrient from seawater including N and P for their growth. N and P contents of wild seaweed species were found in individual variation. Variability of seaweed tissue N and P can also be explained by coastal oceanographic process; N and P contents in the seaweeds correspond with a seasonal increase in N and P concentrations in the seawater (Robertson-Andersson *et al.,* 2007). Fifteen analyzed seaweed species have N content ranged about 0,52 – 2,02 %; P about 0,041 – 0,107 %; and C about 4,53 – 25,66 % (Table 2). Concerned with nutrients, the surface ocean contains almost $2x10^{15}$ metric tonnes of nitrogen in a usable form by seaweed (Kraan, 2013). The potential nitrogen removal may be larger by developing seaweed farming area. Nitrogen is one of important elements to form pigment structure of seaweed including chlorophylls, phycobilins, carotenoids; photosynthetic pigments in seaweed (Dawes, 1981), thus variation of N and C contents in seaweed species are related to variation of pigments level. Chakraborty & Santra (2008) showed that the quantity of carbohydrate and chlorophyll-a contents in benthic macroalgae displayed significant individual differences, respectively, ranged about 14,34 – 35,27 % of dry weight and 0,37 – 2,45 mg/g.

Development opportunity of important seaweed species in aquaculture

Algal biomass can be used for sustainable production of bioethanol and a great variety of other pruducts, including plastics, protein, and other valuable chemicals such as pigments (Kraan, 2013). Amongst about 33 seaweed species found in Labuhanbua coastal waters, some species have been widely utilized in various purpose, including *Kappaphycus* sp., *Eucheuma* sp., *Gracilaria* sp., *Caulerpa* sp., *Gelidium* sp., *Sargassum* sp., *Codium* sp., and *Ulva* sp.; and the rest are not yet commercially utilized (Tabel 3). *Gelidium* sp. is such an excellent source of high quality agar (McHugh, 2003). *Gelidium* sp. also has been used in papermaking; where pulp of high brightness can be produced by extracting mucilaginous carbohydrates of this red algae; and the by-products from processing have been converted into bioethanol; *Ulva* has high level of polysaccharide, a carbohydrate compound, that has been used in ethanol and methane production (Kraan, 2013; Seo *et al.*, 2010). Shibu & Dhanam (2013) reported that five marine algae species (*Caulerpa recemosa, Turbinaria conoides, Halimeda micronesica, Padina gymnospora,* and *Sargassum polycystum)* showed their antibacterial activities at different concentrations against the following bacteria *Staphylococcus aureus, Bacillus cereus, Micrococcus luteus, Escherichia coli, Aeromonas hytrophila. Porphyra (*known commonly as nori in Japan, zicai in China, and purple laver in Great Britain) is a source of seafood for humans (Varela-Álvarez, 2007).

Increasing of market demand on seaweed for industrial uses will cause over exploitation and decreasing of seaweed natural stock. Restoration of the original ecosystem conditions will need a long-term process, while the seaweed industry lacked for continuous raw material supply. Important seaweed species need to be produced artificially by growing-out them using cultivation technology. Seaweed grow-out technology can be made in several methods. They can be grown with a simple system vegetatively in open waters on the bottom bays, estuaries or reef flat; on lines, ropes or nets; in ponds; or in tanks (McHugh, 2003). Every seaweed culture system requires a few main ingredients for successful culture; the three most important components of a culture system are seawater media (seawater and nutrients), temperature and light; seaweed must be placed at some depth below the surface of the water that will provide sufficient amount of sunlight (Redmond *et al,* 2014a).

Table 3. Utilization and potential uses of wild seaweed species

Seaweed species	Human Food	Livestock Feed	Nutraceutical	Cosmetic	Other purposes	Remarks
Rhodophyta						
Kappaphycus sp. (cottonii)	+	+	+	+	toothpaste industry	cultivated
Eucheuma spinosum (cottonii)	+	+	+	+	toothpaste	cultivated
Eucheuma sp. (cottonii)	+	+	+	+	toothpaste	cultivated
Gracilaria salicornia	+	+	+	+	agarose	cultivated
Gracilaria foliifera	+	+	+	+	agarose	cultivated
Gracilaria sp.	+	+	+	+	agarose, iodine, vit. C	cultivated
Gelidium sp.	+	+	-	-	pulp industry, bioethanol	cultivated
Porphyra sp. (nori)	+	-	-	-		cultivated
Phaeophyta						
Ectocarpus sp.	-	-	-	-		natural
Dictyota dichotoma	+	+	+	-	fucoidan	natural
Padina sp.	+	+	+	-	fucoidan	natural
Padina gymnospora	-	-	-	-		natural
Stoechospermum sp.	-	-	+	-		natural
Hydroclathrus clathratus	-	-	+	-	fucoidan	natural
Turbinaria sp.	+	-	+	+	pulp & textile industry, fucoidan, polyphenol, fucosterol	natural
Sargassum sp.	+	+	+	+	algin, tanin, phenol, iodine, vit. C, biofuel, manure, pulp, textile	cultivated
Chlorophyta						
Codium sp.	+	-	+	-		cultivated
Nomeris sp.	-	-	-	-		natural
Caulerpa sp.	+	-	+	+	vit. C, mineral	cultivated
Halimeda simulans	-	-	-	-	source of carbonate	natural
Halimeda sp.	-	-	+	-	source of carbonate	natural
Halimeda tuna	-	-	-	-	source of carbonate	natural
Halimeda opuntia	-	-	-	-	source of carbonate	natural
Halimeda macroloba	-	-	+	-	source of carbonate, growth factor	natural
Halimeda micronesica	-	-	+	-	source of carbonate	natural
Chaetomorpha crassa	-	+	-	-	biogas	cultivated
Ulva lactuca	+	+	+	+	Ethanol, methane	cultivated
Ulva fasciata	+	+	+	+	Ethanol, methane, algicidal compound	cultivated
Bornetella nitida	-	-	-	-		natural

Source: Dawes (1981), Rajathi *et al.* (2003), Kadi (2004), Hwang *et al*. (2007), Alamsjah *et al*. (2007), Kumar *et al.* (2009), Kantachumpoo & Chirapart (2010), Leliaert *et al.* (2011), Sangeetha *et al.* (2011), Vijayabaskar & Shiyamala (2012), Kalsum (2012), Kraan (2013), Redmond *et al.* (2014a), Redmond *et al.* (2014b)

Seaweed is a major source of income for thousands of small Indonesian farmers, as well as collectors, traders, exporters, and producers. Some species have been tried to cultivate using either vegetative or generative cultivation methods, with natural and artificial seeding technique. Over the last couple of decades different seaweeds cultivation systems have been developed. The cultivation technique developed and improved starting from intertidal fixed and floating bottom farms for *Eucheuma, Kappaphycus* and *Gracilaria* in Philippines, Vietnam, and Thailand; then to elaborate floating net structures for *Porphyra*; and long-line systems for kelp in China, Korea and Japan (Kraan, 2013). Some species were successfully cultivated, and others still need technical improvement. *Gelidium* has been cultivated in Korea, China, Spain, Portugal, South Africa, and Israel (Friedlander, 2007). In Indonesia, only three main taxa which have been commonly developed with artificial methods, that are *Kappaphycus, Eucheuma,* and *Gracilaria*; some other potential species still in research and development level process. In Asia, native species have been isolated from wild populations; strains have been selected for desirable traits and are maintained as seed cultures (Redmond *et al.,* 2014a; Redmond *et al.,* 2014b). Several seaweeds species have been successfully incorporated into a number of demonstration and pilot scale IMTA (integrated multi-trophic aquaculture) and nutrient bio-extraction systems (Barrington *et al.*, 2009; Troell, 2009; Redmond *et al.,* 2014a; Radiarta et al., 2014).

Several important seaweed species from Labuhanbua coastal water which have a high economical value by producing many substances for human food as well as industrial supplies; need to be developed and cultured intensively. Nine Rhodophyta species of five genera found are belonged to economically important seaweed species that have been cultivated, including *Kappaphycus*, *Eucheuma, Gracilaria, Gelidium,* and *Porphyra*; but only one from total eight Phaeophyta species have been cultivated, i.e *Sargassum* sp. (Table 3). Thirteen Chlorophyta species found at Labuhanbua; only four species have been cultivated including *Codium* sp., *Caulerpa* sp., *U. lactuca,* and *U. fasciata.* Other non-cultivated species have their specific economic value that come from each substance that can be produced (Table 3). Phaeophyta species including *Turbinaria, Dictyota, Padina, Stoechospermum,* and *Hydroclathrus*; and Chlorophyta species including *Halimeda* and *Chaetomorpha* might be some species that could be observed and developed as aquaculture species candidates among the species that were found along this study location. *Halimeda* sp. has good carbohydrate content about 15,89 %, and *Turbinaria* sp. were found with high carbon content about 22,04 % (Tabel 2); *Dictyota* sp. and *Padina* sp. consist sulfated polysaccharide; fucoidan; which have function as antimicrobial substance (Kantachumpoo & Chirapart, 2010). Those species have potencies as human food, livestock feed, nutraceuticals, cosmetics, pulp, textile, biofuel and any other industries; conversely, they were found in lower density at Labuhanbua coastal waters (Table 1 and 3). Seaweed aquaculture development should be assisted by technological support. Major efforts towards the introduction of seaweeds into commercial cultivation have to involve genetic improvement through selection, breeding, and possibly genetic engineering (Friedlander, 2007). Commercial scale cultivation of those important seaweed species will contribute to industrial supply needs and prevent decreasing of wild seaweed availability on natural ecosystem. This also can help local people around coastal area to increase their economic level. In addition, the development of seaweed aquaculture through commodities diversifying will enhance Indonesian fisheries production and encourage national production target attainment to double of 2014 production volume, during next five years in 2019.

4. Conclusions

Seven important seaweed species including *Turbinaria, Dictyota, Padina, Stoechospermum, Hydroclathrus*, *Halimeda,* and *Chaetomorpha*, were found at Labuhanbua coastal waters which are not yet cultivated; which could be observed and developed as aquaculture species candidates. These species contain several high value substances that can be utilized for any purpose i.e. human food, livestock feed, nutraceuticals, cosmetics, pulp, textile, biofuel and any other industries. Commercial scale cultivation of these important seaweed species will contribute to industrial supply needs and prevent decreasing of wild seaweed availability on natural ecosystem; also can help local people around coastal area to increase their economic level. Seaweed aquaculture commodities diversification are expected to support national seaweed production target attainment in 2019 about 22 million tons.

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