Borneo Journal of Resource Science and Technology (2015) 5(2): 53-61

SHORT COMMUNICATION

Red Seaweed *Gracilaria arcuata* in Cage Culture Area of Lawas, Sarawak

MUHAMMAD NUR ARIF OTHMAN[1*], RUHANA HASSAN[1],
MOHD NASARUDDIN HARITH[1] & AMIR SHAH RUDDIN MD SAH[2]

[1]Department of Aquatic Science, Faculty of Resource Science and Technology, Universiti Malaysia Sarawak, 94300 Kota Samarahan, Sarawak; [2]School of Biological Sciences, Universiti Sains Malaysia, 11800 Penang

ABSTRACT

Red seaweed *Gracilaria* sp. is known as 'Janggut Duyong' by the local people of Sarawak. This macroalgae is well-distributed in both temperate and tropical seawaters. *Gracilaria* sp. could be processed to produce agar for industrial purposes whereas some people consumed it directly and become part of their daily diet. In terms of ecology, G*racilaria* sp. is one of primary producer in the seawater and its presence can form habitats to support other aquatic organisms. Despite its socio-economic and ecological importance, little is known about *Gracilaria* sp. in Sarawak. Hence, this study is designed to: (i) determine the diversity and abundance of *Gracilaria* in cage culture of Lawas, Sarawak (ii) assess the water quality of the cage culture area where *Gracilaria* is found and (iii) determine other aquatic organisms that found within *Gracilaria* population. Three field samplings had been conducted from October 2013 to November 2014 at cage culture areas of Awat-Awat Village, Lawas, Sarawak. Only single species of *Gracilaria* was found namely *Gracilaria arcuata*. Besides *G. arcuata*, *Acanthophora* sp. and *Padina* sp. were also found but in small patches. In addition, five different groups of aquatic invertebrates were observed namely tunicates, bivalves, polychaetes, small crabs and brittle stars. The selected water quality parameters namely temperature, pH, dissolved oxygen, salinity, turbidity, total suspended solid, orthophosphate, silicate and chlorophyll *a* were significantly different ($p = 0.000$) during all the three field samplings except for nitrite ($p = 0.588$). However, the values recorded were within normal range of standard water quality for tropical estuarine area. Since healthy population of *Gracilaria* could be easily found here, therefore this area has the potential for future seaweed aquaculture.

Keywords: Ecology, *Gracilaria arcuata*, invertebrates, seaweed, water quality

Seaweed is defined as macroscopic and multicellular algae but certain life stages of seaweed like spore or zygote is categorized as unicellular and microscopic. According to Lobban & Harrison (1994), seaweed is divided into three groups which are green seaweed (Division Chlorophyta), brown seaweed (Division Phaeophyta) and red seaweed (Division Rhodophyta). The group of seaweed is classified according to type of pigment present, namely chlorophyll *a*, phycoerythrin, phycocyanin and other accessory pigments. Seaweed can be found in marine and brackish water, in intertidal and deep area, attach to substrate such as rock, dead coral, shells, pebbles and aquatic plant (Anantharaman, 2002). Seaweed has the same characteristic as terrestrial plant where both undergo photosynthesis and release oxygen.

Red seaweed (*Gracilaria* sp.) is known as 'Janggut Duyong' by the local people of Sarawak where it is widely distributed in temperate and tropical seawaters. According to Thomsen *et al*. (2005), more than 110 species of *Gracilaria* has been recorded around the world. The entire body of *Gracilaria* is known as thallus where it consists of holdfast, stipe and blade. *Gracilaria* undergoes photosynthesis with the aid of chlorophyll *a*, phycoerythrin, phycocyanin and allophycocyanin.

*Corresponding author: *mnurarif90@gmail.com*

Gracilaria has important roles in ecological and socio-economic aspects. It plays crucial part as one of primary producer especially in the area where the availability of light is low. Besides, juvenile fishes and marine invertebrates use this seaweed as protection against tides, predators, waves and also as food source. Hence, the presence of *Gracilaria* can form important habitats for aquatic organisms (Nyberg *et al*., 2009). From socio-economy point of view, *Gracilaria* is edible, consumed by human and its extraction is currently used in pharmaceutical and fertilizer industries. Recently, a study on extraction of methanolic from *Gracilaria* has shown positive result to be used in cancer treatment (Yeh *et al*., 2012). *Gracilaria* also contain phycocolloids such as agar, thus it becomes the main contributor in production of world agar due to its ability to form strong and high quality gel (Chan *et al*., 2002).

Checklists of marine algae particularly seaweeds of Malaysia have been published by several researchers, for examples Ahmad (1995), Chan *et al*. (2002), Phang (1998), Nurridan (2004), Nurridan (2007), Song *et al*. (2013) and Zakaria *et al*. (2006). In Sarawak, study has been done to document the seaweed resources from coastal waters (Nurridan, 2007). In addition, the list on seaweeds species and their life form from Golden Beach, Similajau National Park, Bintulu, Sarawak has also been documented by Zakaria *et al*. (2006).

All the available literatures on seaweeds from Sarawak focused only on species checklist in certain areas with some brief information on the ecology.

Furthermore, there is lack of specific documentation on seaweed from cage culture. Thus, this study is designed to assess the seaweed assemblages in cage culture of Lawas and water quality of the area. The specific objectives of the study are to: (i) determine the diversity and abundance of *Gracilaria* in cage culture of Lawas, Sarawak (ii) assess the water quality of the cage culture area where *Gracilaria* is found and (iii) determine other aquatic organisms that found within *Gracilaria* population.

Three field samplings had been carried out in cage culture area (Figure 1) of Awat-Awat Village, Lawas (N 04° 56'9.7", E 115° 14'6.8") (Figure 2) from October 2013 to November 2014. All samplings were done at daytime during flooding tide. Awat-Awat Village is built on top of water, located at the Batang Trusan estuary. The village is separated from the main road by a river and the only transportation to get there is using small boats. Awat-Awat Village is actually consists of four villages namely Kampung Ujong, Kampung Tengah, Kampung Masjid and Kampung Bangsal. This area has complete set of basic infrastructures such as school, mosque and mini market. The villagers depend on aquaculture and coastal fisheries as their main source of income. The area involved in this study comprised of 12 cages (2.5 m x 2.0 m x 3.0 m) rearing fishes like sea basses, groupers and red snappers.

During field sampling, water quality parameters namely dissolved oxygen (DO), temperature, turbidity, pH, conductivity and salinity were measured *in-situ*. DO and temperature were measured using DO meter (Hanna Instrument, 9142). Turbidity was taken using turbidity meter (Eutech Instrument, TN-100). Salinometer (Milwaukee Instrument, MA 887) was used to record salinity while pH meter (Hanna Instrument, HI 8424) was used to measure pH. Water transparency was recorded using secchi disk while the depth of water was measured using depth finder (Speedtech instrument, 65054). All the parameters were measured triplicates. Water samples were collected using 500 mL bottles for nutrients (nitrite, orthophosphate, silica), chlorophyll *a* (chl *a*) and total suspended solid (TSS). Triplicates water samples were collected and kept in cooler box with ice and brought back to laboratory at Universiti Malaysia Sarawak for further analysis using standard procedure (APHA, 1998). The values obtained were compared with Malaysian Marine Water Quality Criteria and Standard (MMWQCS) (DOE, 2010).

The whole thallus of *Gracilaria* sp. consists of holdfast and stipe was observed, collected and stored in plastic bag with seawater and brought back to laboratory for further analysis. Other species of seaweeds and macrofauna

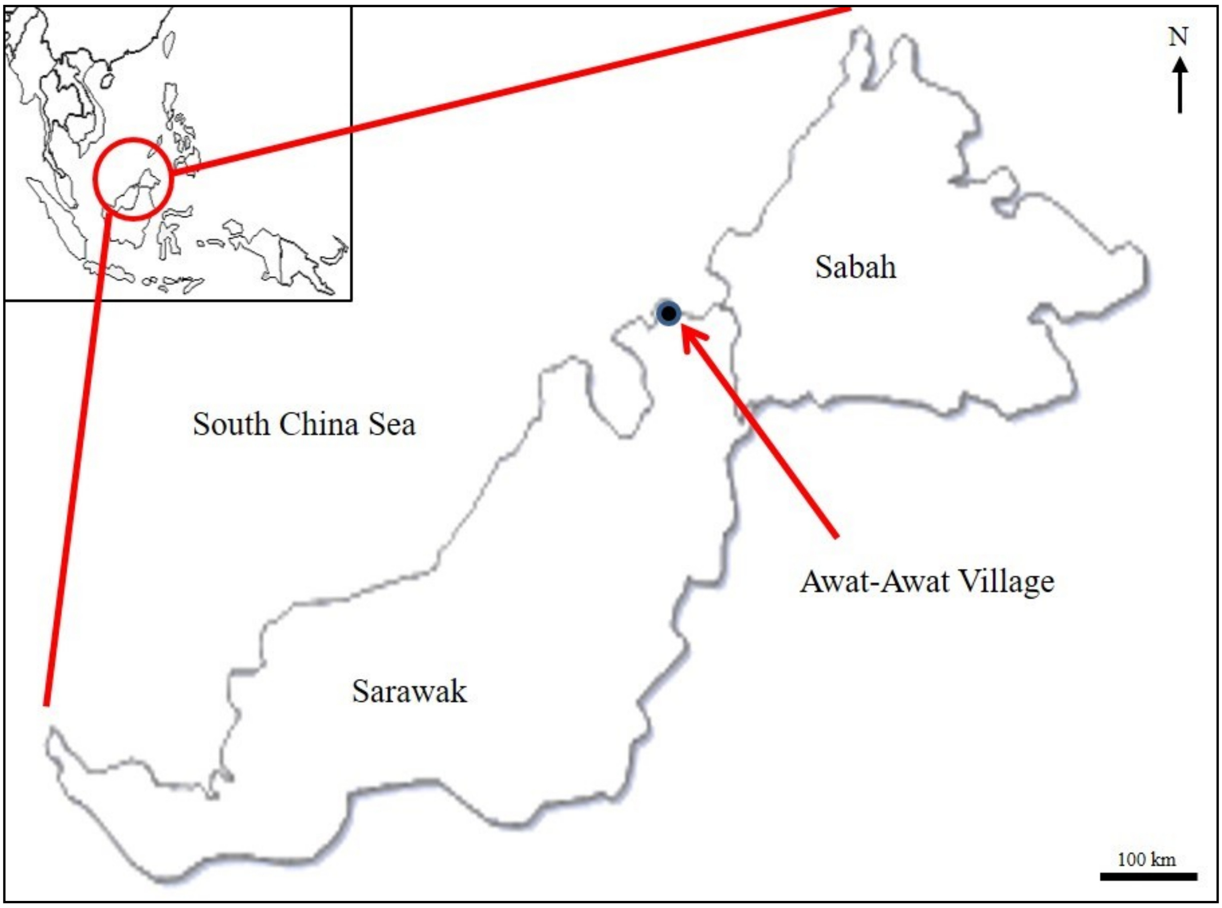

Figure 1. Location of Awat-Awat Village Lawas, Sarawak (Source: Google Map).

Figure 2. View of Awat-Awat village (a) residential area, (b) cage culture (sampling site), (c) observation and collection of *Gracilaria.*

found within *Gracilaria* assemblages were observed, collected and stored in plastic bag with seawater and brought back to laboratory for identification. Percentage cover of seaweeds were observed using transparency grid (0.21 m x 0.29 m) at two different cages in November 2014. Only single cage was observed for abundance of seaweed in October 2013 and June 2014. One-way analysis of variance (ANOVA) was performed to test the significant difference of water parameters between field sampling. The test is significant at $p<0.05$.

In the laboratory, wet preservation and dry preservation were done for preservation of seaweed (Dhargalkar & Kavlekar, 2004). The seaweeds were washed first using tap water while the dust, sand and organisms were removed. For wet preservation, the samples were fixed in 10% formalin and then in 70% ethanol for long term preservation. Preparation of herbarium (dry preservation) was done using method as suggested by Dhargalkar & Kavlekar (2004). Identification of *Gracilaria* sp. and other seaweeds were based on identification key from Dhargalkar & Kavlekar (2004), Nurridan (2007) and Lin (2009).

Only one species of *Gracilaria* was found at cage culture of Awat-Awat village, Lawas. Based on the morphological characteristics, the species was *G. arcuata* (Dhargalkar & Kavlekar, 2004; Lin, 2009; Nurridan, 2007) (Figure 3).

Description: the thallus of *G. arcuata* observed in Lawas was reddish brown when fresh and could grew up to 120 mm tall. The holdfast was discoid and the branches were cylindrical, irregular and had diameter

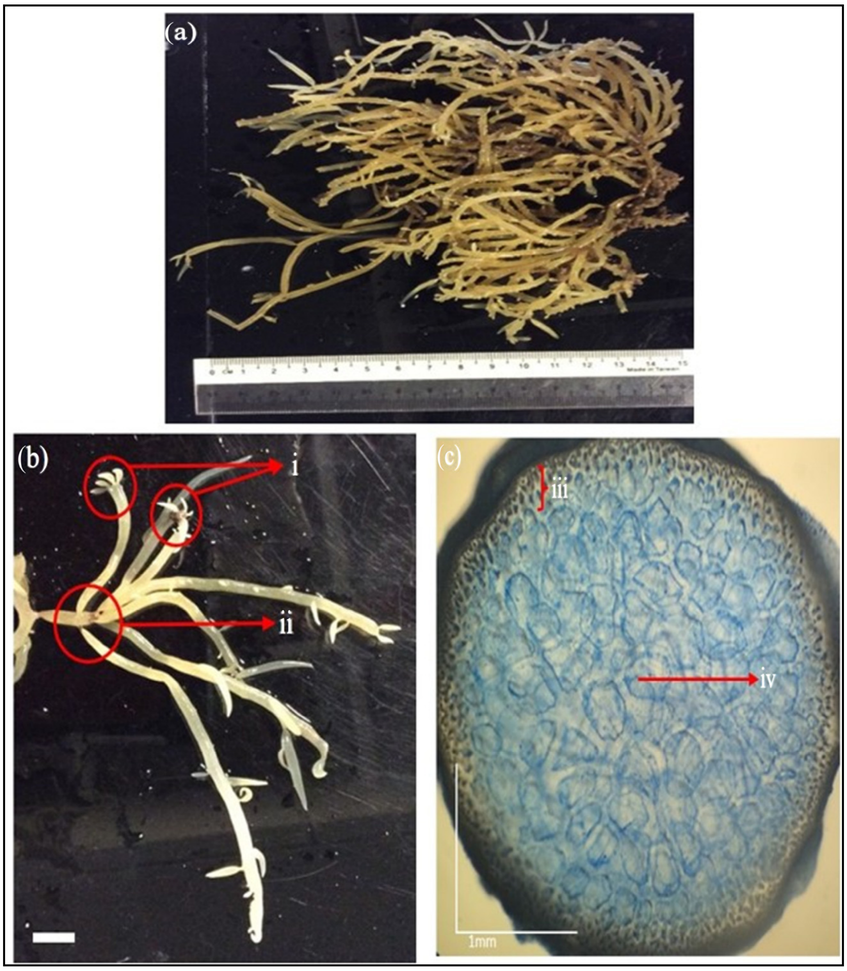

Figure 3. (a) Whole body of *G. arcuata* preserved in 70% ethanol; (b) Branching pattern of *G. arcuata* (scale bar = 10 mm) (i) Formation of two to five short stubby spinose branchlets (ii) Constriction at base; (c) Cross section showing (iii) Cortical layer and (iv) Medulla of branch (scale bar = 1 mm).

between 2-3 mm. The branches were slightly constrict at the base, enlarged at the middle and become attenuate at the tip (Figure 3b). Primary branches were short compare to secondary branches and could reach up to 45 mm long while secondary branch could reach up to 77 mm. The tip of branches give rise two to five short stubby spinose branchlets (Figure 3b). At secondary branches, frequent formation of a single new branch with pointed tip was observed. The cross section of stipe shows that the medulla is composed of large cells and surround by small rounded cells at the cortical layer (Lin, 2009) (Figure 3c).

Type of locality: Lawas, Sarawak

Remarks: *G. arcuata* was identified based on identification keys by Dhargalkar and Kavlekar (2004), Lin (2009) and Nurridan (2007). The species is placed under Order Gracilariales, Family Gracilariaceae. The specimen was found attach to net of cage culture in Lawas. Nurridan (2007) reported that *G. arcuata* attach to coral or rock and grow in shallow and subtidal areas. This showed that the species can grow on both natural and man-made substrate.

According to Song *et al*. (2013), 20 species of *Gracilaria* has been recorded in Malaysia and the common species found namely *G. changii*, *G. edulis*, *G. salicornia* and *G. tenuistipitata* In Sarawak, seven species of *Gracilaria* have been recorded namely *G. arcuata, G. changii, G. coronopifolia*, *G. blodgetti, G. salicornia* and the remaining were identified as *Gracilaria* sp. and *Gracilaria* sp.1 (Nurridan, 2007).

The seaweeds were found growing on the cage net and only restricted at the surface of the water and down to 0.3 m deep. Based on Figure 4, approximately 85% of the top part of cage net was covered by seaweeds in October 2013 while the percentage cover had slightly decreased to approximately 80% in June 2014. The percentage cover of seaweeds then increase to approximately 90% in November 2014. The slightly decrease of percentage cover of seaweeds during second sampling is probably due to wave action that remove the seaweeds. The decrease in coverage may also due to predators as rabbit fishes, crabs, bivalves, gastropods and polychaetes (Briggs & Smith, 1993). Based on the observation during fieldtrips, the percentage of seaweeds did not differ much for all the samplings probably due to following reasons: (i) the cages are rarely used by the owner and the owner does not regularly clean or remove foreign substances trapped on the cage net (ii) the seaweeds present do not have any commercial value therefore not collected for consumption or sale. Based on brief interview with local people during fieldtrips, they claimed that nobody eats *Gracilaria* in Lawas. In contrast with Asajaya and Santubong, the seaweeds are collected for domestic use or to be sold in the market.

Three taxa of seaweeds namely *G. arcuata* and *Acanthophora* sp. (red seaweed) and *Padina* sp. (brown seaweed) were found on the fish cage net. In November 2014, approximately 65.5% of the upper part of cage nets was covered by *G. arcuata*, 14.5% were covered by *Padina* sp. and only 10% were covered by *Acanthophora* sp. Therefore, *G. arcuata* was the dominant compare to the other two species.

All the water quality parameters are significantly different among the three field samplings (p=0.000) except for nitrite (p=0.588). Based on Table 1, the temperature of study site had a ranged between 29.9°C to 31.2°C whereas pH had values between 7.04 to 7.76. The study site had recorded the highest value of DO in June 2014 (4.64 mg/L). For salinity, the lowest reading was recorded in October 2013 (14 PSU) most probably because the seawater been diluted with freshwater (Suratman *et al*., 2014). The salinity reading for the other two samplings were similar.

Turbidity showed the highest value in October 2013 (20.29 NTU) and the lowest in November 2014 (5.06 NTU). The turbidity is high in October 2013 due to water runoff from upstream which bring sand and silt. Depth, transparency and conductivity were recorded in November 2014 with reading of 10.63 m, 1.28 m and 39.03 mS respectively. There is no available data for the three water quality parameters in October 2013 and June 2014 due to technical problem.

Table 1. Selected water quality parameters measured *in-situ* during the study.

	Temperature (°C)	pH	DO (mg/L)	Salinity (PSU)	Turbidity (NTU)	Depth (m)	Transparency (m)	Conductivity (mS)
October 2013	31.20±0.06	7.40±0.02	4.04±0.07	14.00±1.00	20.29±2.30	N/A	N/A	N/A
June 2014	30.10±0.00	7.76±0.12	4.64±0.07	27.33±0.58	11.08±2.02	N/A	N/A	N/A
November 2014	29.90±0.00	7.04±0.12	4.48±0.07	27.67±1.53	5.06±1.00	10.63±0.32	1.28±0.05	39.03±0.67

N/A = Not available, DO = Dissolved Oxygen.

Table 2. Selected water quality parameters measured *ex-situ* during the study.

	TSS (mg/L)	NO_2 (mg/L)	PO_4^3 (mg/L)	SiO_2 (mg/L)	Chlorophyll *a* (mg/m^3)
October 2013	65.67±8.14	0.004±0.003	0.097±0.02	0.543±0.069	2.43±0.324
June 2014	16.67±3.33	0.004±0.003	0.057±0.02	0.282±0.037	7.50±4.010
November 2014	41.33±9.24	0.006±0.001	0.043±0.03	0.591±0.054	2.04±0.310

TSS = Total Suspended Solid, NO_2 = Nitrite, PO_4^3 = Orthophosphate, SiO_2 = Silicate.

TSS ranged between 16.67 mg/L to 65.67 mg/L for the three samplings (Table 2). The amount of nitrite found in the water did not differ much for all the samplings. Orthophosphate and silicate had recorded the highest reading in October 2013 (0.097 mg/L) and November 2014 (0.591 mg/L). Chlorophyll *a* reading was the highest in June 2014 (7.50 mg/m^3). Overall, the water quality parameters of Lawas cage culture is under Class II of MMWQCS.

High nutrients in water namely phosphorus and nitrogen can inhibit the fishes growth,reduce the capability of fishes to breed and cause losses to fish farm owner (Breitburg, 2002; Diaz *et al*., 2012) due to formation of algae blooms. The presence of seaweed (*Gracilaria*) could help reduce the excess amount of nutrients, which later give positive impacts to cage culture as it has ability to absorb nutrient from the water (Abreu *et al*., 2011; Kang *et al*., 2011; Macchiavello & Bulboa, 2014). It is recommended that local people incorporate seaweed culture in their cage culture system in order to achieve sustainable aquaculture.

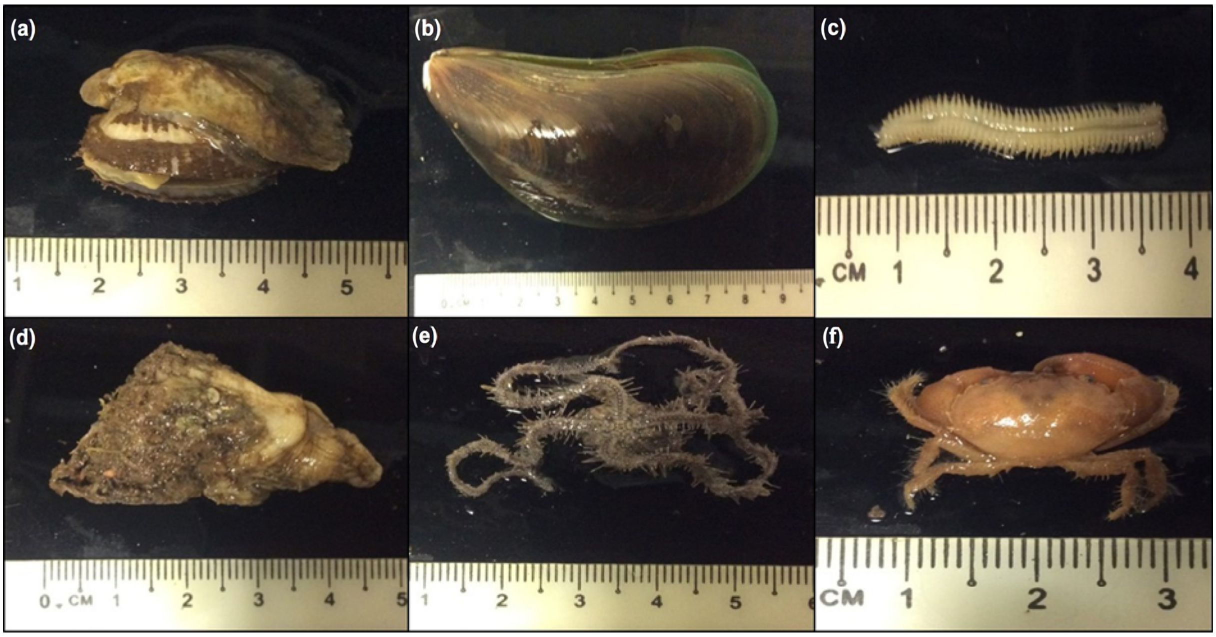

Figure 4. Macrofauna that found within *G. arcuata* in Lawas cage area (a) cockle (Cardiidae); (b) green mussel (*Perna* sp.); (c) polychaete (Polychaeta); (d) tunicate (Ascidiacea); (e) brittle star (Ophiurida); (f) small crab.

Five different taxa of aquatic macroinvertebrates were found co-exist with G. *arcuata* namely cockle (Cardiidae), green mussel (*Perna* sp.), polychaete (Polychaeta), tunicate (Ascidiacea), brittle star (Ophiurida) and small crab (Figure 4). Similarly, Nyberg *et al*. (2009) reported that organisms such as class Malacostraca, Gastropoda, Bivalvia, Florideophyceae and amphipods were found living in *G. vermiculophylla*.

This showed that seaweed assemblages is one of the important habitat that supports wide range of living organisms (Christie *et al*., 2009; Nyberg *et al*., 2009; Wernberg *et al*., 2013). Besides, juvenile fishes and marine invertebrates use *Gracilaria* as protection against tides, predators, waves and also as food source (McHugh, 2003; Christie *et al*., 2009).

Lately, seaweed culture has been introduced to support the high demand on the world market and nowdays has becoming popular due to overexploitation of wild stocks and disturbance that reduce their number in natural habitat (McHugh, 2003; Werner & Kraan, 2004; Ahemad *et al*., 2006). Unlike fish culture, seaweed culture is easier to operate because it does not need high complicated technology system. It can be operated at low cost, does not cause pollution but instead it can act as natural biological filters. Lawas has the potential as the first site for mass seaweed culture in Sarawak due to presence of healthy seaweeds population and the river has relatively good water quality. The seaweed culture can give current benefit to local people economy. It is recommended that the state of government, agencies, Fisheries Department Malaysia and other non-governmental organisation (NGO) to introduce and assist the local people embarking in this new seaweed culture.

In Lawas, the seaweeds assemblage is dominated by *G. arcuata* followed by *Acanthophora* sp. and *Padina* sp. The water quality of the cage area is within the range of normal water quality of estuary. Six species of aquatic macroinvertebrates were found living within *G. arcuata* namely tunicates, cockle, mussel, polychaetes, small crab and brittle star. Based on findings of this study, Lawas has the potential for mass seaweed culture in the future.

ACKNOWLEDGEMENTS

This work is supported by Ministry of Education Malaysia through Research Acculturation Collaborative Effort (RACE) Grant Scheme RACE/g(2)891/2012(09). Authors would like to thank local people of Awat-Awat Village Lawas for their kind assistance during sampling trips. Thank you to UNIMAS for laboratory facilities and transportation. The first author is the recipient of MyBrain 15 scholarship and Zamalah Siswazah UNIMAS (ZSU) scholarship.

REFERENCES

Abreu, M.H., Pereira, R., Yarish, C., Buschmann, A. H., & Pinto, I. S. (2011). IMTA with *Gracilaria vermiculophylla*: Productivity and nutrient removal performance of the seaweed in a land-based pilot scale system. *Aquaculture*, 312: 77-87.

Ahmad, I. (1995). *Rumpai laut Malaysia*. Kuala Lumpur: Dewan Bahasa dan Pustaka.

Ahemad, S., Ismail, A., & Mohammad, R.M. A. (2006). The seaweed industry in Sabah, East Malaysia. *Journal of Southeast Asian Studies*, 11: 97-107.

Anantharaman, P. (2002). Manual on identification of seaweeds. All India coordinated project on survey and inventorization of coastal and marine biodiversity (East coast). *Journal of the Marine Biological Association of India*, 29: 102-110.

APHA. (1998). *Standard methods of water and waste water analysis*. Washington D.C: American Public Health Association.

Briggs, M.R.P. & Smith, J.F. (1993). Macroalgae in aquaculture: an overview and their possible roles in shrimp culture. Paper presented at the conference on Marine Biotechnology in the Asia Pacific Region, Bangkok, Thailand.

Breitburg, D. (2002). Effects of hypoxia, and the balance between hypoxia and enrichment, on coastal fishes and fisheries. *Estuarine Research Federation*, 25: 767-781.

Chan, C.X., Ho, C.L., Rofina, Y.O., & Phang, S.M. (2002). Total RNA extraction for the red seaweed *Gracilaria changii* (Gracilariales, Rhodophyta). *University of Malaya Maritime Research Centre*, 477-487.

Christie, H., Norderhaug, K., & Fredriksen, S. (2009). Macrophytes as habitat for fauna. *Marine Ecology Progress Series*, 396: 221-233.

Dhargalkar, V.K. & Kavlekar, D. (2004). *Seaweeds – a field manual*. Goa: National Institute of Oceanography.

Diaz, R., Rabalais, N.N., & Breitburg, D.L. (2012). Agriculture's impact on aquaculture: Hypoxia and eutrophication in marine waters. http://www.oecd.org/tad/sustainable-agriculture/49841630.pdf. Downloaded on 23.9.2015.

DOE (2010). Malaysia Marine Water Quality Criteria and Standard. Available at http://www.doe.gov.my/malaysia-interim-marine-water quality-standard. Downloaded on 15.3.2015.

Kang, Y.H., Park, S.R., & Chung, I.K. (2011). Biofiltration efficiency and biochemical composition of three seaweed species cultivated in a fish-seaweed integrated culture. *The Korean Society of Phycology*, 26: 97-108.

Lin, S.M. (2009). *Marine benthic macroalgal flora of Taiwan*. Taiwan: National Taiwan Ocean University Publication.

Lobban, C.S. & Harrison, P.J. (1994). *Seaweed ecology and physiology*. Cambridge, United Kingdom: Cambridge University Press.

Macchiavello, J. & Bulboa, C. (2014). Nutrient uptake efficiency of *Gracilaria chilensis* and *Ulva lactuca* in an IMTA system with the red abalone *Haliotis rufescens*. *Latin American Journal of Aquatic Research*, 42: 523-533.

McHugh, D.J. (2003). *A guide to the seaweed industry*. Canberra, Australia: FAO.

Nurridan, A.H. (2004) *Seaweed and seagrass communities of Pulau Layang-layang Lagoon, Malaysia. Marine Biodiversity of Pulau Layang Layang Malaysia*. Malaysia: Fisheries Research Institute.

Nurridan, A.H. (2007). *Seaweeds of Sarawak Malaysia Borneo*. Malaysia: Fisheries Research Institute.

Nyberg, C.D., Thomsen, M.S., & Wallentinus, I. (2009). Flora and fauna associated with the introduced red alga *Gracilaria vermiculophylla*. *European Journal Phycology*, 44: 395-403.

Phang, S.M. (1998). The seaweed resource of Malaysia. In Critchley, A.T. & Ohno, M (Eds.). *Seaweed resources of the world*. Yokusuka, Japan: International Cooperation Agency.

Song, S.L., Lim, P.E., Phang, S.M., Lee, W.W., Lewmanomont, K., Largo, D.B., & Nurridan, A.H. (2013). Microsatellite markers from expressed sequence tags (ESTs) of seaweeds in differentiating various *Gracilaria* species. *Journal of Applied Phycology*, 25: 839-846.

Suratman, S., Hussein, A.N.A.R., Latif, M.T., & Weston, K. (2014). Reassessment of physico-chemical water quality in Setiu Wetland, Malaysia. *Sains Malaysiana*, 43: 1127-1131.

Thomsen, M.S., Gurgel, C.F.D., Fredericq, S., & McGlathery, K.J. (2005). *Gracilaria vermiculophylla* (Rhodophyta, Gracilariales) in Hog Island Bay, Virginia: A cryptic alien and invasive macroalga and taxanomic correction. *Phycological Society of America*, 42: 139-141.

Werner, A. & Kraan, S. (2004). Review of the potential mechanisation of kelp harvesting in Ireland. Available at http://oar.marine.ie/handle/10793/261. Downloaded on 23.9.2015.

Wernberg, T., Thomsen, M.S., & Kotta, J. (2013). Complex plant-herbivore-predator interactions in a brackish water seaweed habitat. *Journal of Experimental Marine Biology and Ecology*, 449: 51-56.

Yeh, C.C., Yang, J.L., Lee, J.C., Tseng, C.N., Chan, Y.C., Hseu, Y.C., Tang, J.Y., Chuang, L.Y., Huang, H.W., Chang, F.R., & Chang, H.W. (2012). Anti- proliferative effect of methanolic extract of *Gracilaria tenuistipitata* on oral cancer cells involves apoptosis, DNA damage and oxidative stress. *Complementary and Alternative Medicine*, 12: 1-9.

Zakaria, M.H., Bujang, J.S., Amit, R., Awing, S.A., & Ogawa, H. (2006). Marine macrophytes: Macroalgae species and life forms from Golden Beach, Similajau National Park, Bintulu, Sarawak, Malaysia. *Coastal Marine Science*, 30: 243-246.