UNIVERSITI PUTRA MALAYSIA

AQUATIC MACROPYHTES DIVERSITY AND UTILIZATION BY ETHNIC GROUP

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AQUATIC MACROPYHTES DIVERSITY AND UTILIZATION BY ETHNIC GROUP

By

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A Project Report Submitted in Partial Fulfillment of the Requirement
for the Degree of Bachelor of Science Bioindustry in the
Faculty of Agriculture and Food Sciences
Universiti Putra Malaysia Bintulu Sarawak Campus

2009

Dedicate especially to my beloved father,

Awang Sabli Awang Mustafa

and

my beloved mother,

Dayang Bedah Abang Kader

ABSTRACT

A study on ethnic utilization of aquatic macrophytes was carried out at native market in Sarawak. 26 species were identified in this study where most of the species are semi-aquatic macrophytes. The species are *Limnocharis flava, Polygonum minus, yperus malaccensis, Nelumbo nucifera, Eleocharis dulcis, Neptunia oleracea, Ipomoea aquatica, Hydrocotyle umbellata, Eichornia crassipes, Roripa nasturtium-aquaticum, Arthyrium esculentum, Stenochlaena palustris, ephrolepis bisserata, Oenanthe javanica, Portulaca oleracia, Plantago major, Altenanthera sesslis, Colocasia esculenta* and *Lycopodium cernuum* which is the aquatic fern. There was also marine macrophytes found utilized by Chinese people in Kuching native market for example *Laminaria japonica*. Iban and Bidayuh are the one that traded the aquatic macrophytes in the native market. The aquatic macrophytes on sale are as food item consumed by the local and at the same time as medicinal.

ABSTRAK

Satu kajian mengenai penggunaan secara etnik terhadap tumbuhan akuatik telah dijalankan di beberapa tamu di Sarawak. Lebih dari 26 spesies telah dikenalpasti sebagai tumbuhan akuatik di mana kebanyakkannya merupakan kategori separa akuatik. Tumbuhan tersebut adalah seperti *Limnocharis flava, Polygonum minus, Cyperus malaccensis, Nelumbo nucifera, Eleocharis dulcis, Neptunia oleracea, Ipomoea aquatica, Hydrocotyle umbellata, Eichornia crassipes, Roripa nasturtium-aquaticum, Arthyrium esculentum, Stenochlaena palustris, Nephrolepis bisserata, Oenanthe javanica, Portulaca oleracia, Plantago major, Altenanthera sesslis, Colocasia esculenta* dan *Lycopodium cernuum.* Terdapat juga tumbuhan akuatik marin ditemui di sesetengah tamu dimana ia banyak digunakan oleh kaum Cina seperti *Laminaria japonica.* Etnik yang paling banyak menjual tumbuhan akuatik merupakan kaum Iban dan Bidayuh. Ianya dijual bukan sahaja dimakan sebagai sayur-sayuran tetapi juga digunakan sebagai ubat-ubatan.

ACKNOWLEGDEMENTS

A very thankful to Allah s.w.t for giving me highly patience to finish my final year project.

I would like to express my appreciation and thank you to my supervisor, Assoc. Prof. Dr. Muta Harah Zakaria for her advice, guidance and patient in helping me during my research year. I would like also to thank Prof. Dr. Japar Sidik Bujang for his advices, ideas and criticisms.

Not forgotten to my beloved family and friends who have been supporting me all the way to finish my study and my research. Lastly I would like to appreciate to those I did not mention here and had been helping my project.

Thank you very much.

APPROVAL

I certify that research project report entitled "Aquatic Macrophytes Diversity and Utilization by Ethnic Group" has been examined and approved as a partial fulfillment of the requirement for the degree of Bachelor of Science Bioindustry in the Faculty of Agriculture and Food Sciences, Universiti Putra Malaysia Bintulu Sarawak Campus.

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Date: 5-06-2009

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CHAPTER 1
INTRODUCTION

1.1 Background

Aquatic macrophytes are aquatic photosynthetic organisms, large enough to see with the naked eye, that actively grow permanently or periodically submerged below, floating on or growing up through the water surface (Chambers *et al.*, 2007). They are also called as hydrophytes or aquatic plants (Figure 1). According to Denny (1985) and Pieterse (1990) aquatic macrophytes are represented or classified in seven plant divisions; Cyanobacteria, Chlorophyta, Rhodophyta, Xanthophyta, Bryophyta, Pteridophyta and Spermatophyta and they can be both fresh and marine water (Table 1).

Based on the seven plant divisions, aquatic macrophytes can be divided into four groups which are the emergent macrophytes (plants that are rooted in submersed soils or soils that are periodically swamped), floating-leaves macrophyte (plants rooted to the lake or stream bottom with leaves that float on the surface of the water), submersed macrophytes (plants with roots or root-analogues in, attached to, or closely associated with the substrate) and free-floating macrophytes (plants that typically float on or under the water surface) (Chamber *et al.*, 2007).

Some species of aquatic macrophyte can be occurring in ephemeral water bodies (seasonally filled and refilled water, such as floodplains and temporary ponds). These species of aquatic macrophyte can be included only if their environmental

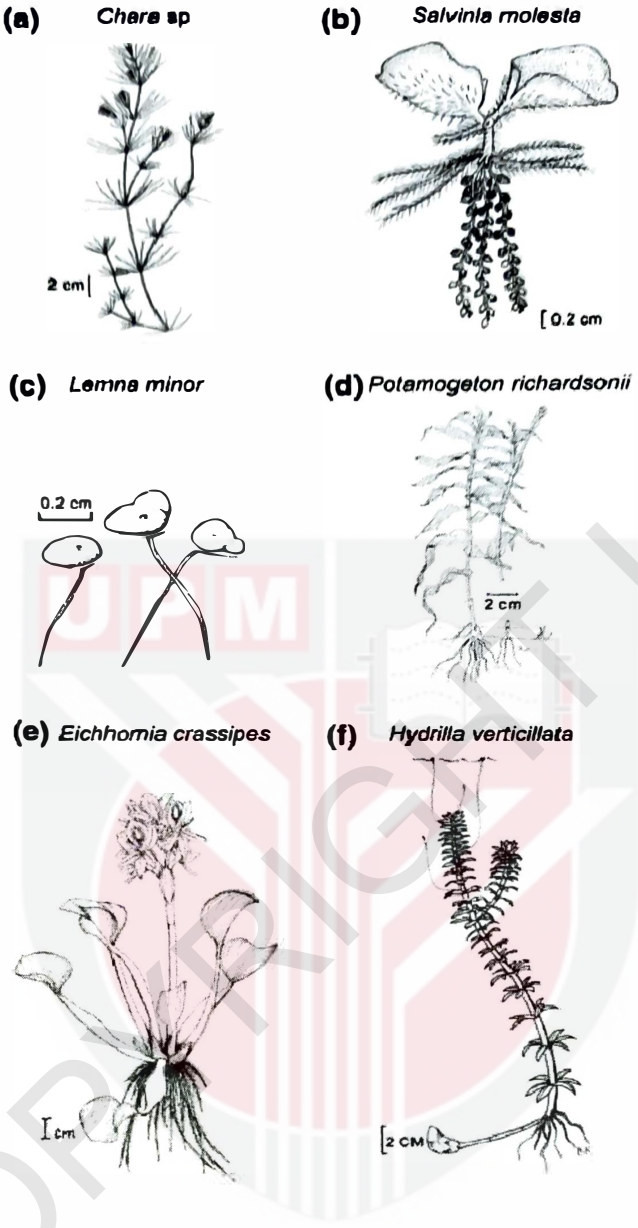

Figure 1: Example of aquatic macrophyte: (**a**) macroalgae *Chara* sp. (order Charales), (**b**) *Salvinia molesta* (Division Pteridophyta), (**c**) *Lemna minor* (angiosperm), (**d**) *Patamogeton richardsonii* (angiosperm), (**e**) Eichhornia crassipes (angiosperm) and (**f**) *Hydrilla verticillata* (angiosperm). (Source: Line drawings are from the University of Forida, IFAS Center for Aquatic and Invasive Plants)

Table 1: Aquatic macrophyte divisions and example of genera

Kingdom	Aquatic Macrophyte Division	Descriptive Term	Example of Aquatic Macrophyte Genera
Monera	Cyanobacteria	Blue-green algae	*Oscillatoria, Lyngbya*
Protista	Chlorophyta	Green algae	*Cladophora, Chara*
	Rhodophyta	Red algae	*Lemanea*
	Xanthophyta	Yellow-green algae	*Vaucheria*
Plantae	Bryophyta	Mosses and liverworts	*Fontinalis, Riella*
	Pteridophyta	Fern and allies	*Azolla, Salvinia*
	Spermatophyta	Seed-bearing plants	*Cabomba, Lemna, Utricularia, Nelumbo, Nymphaea, Eichhornia, Typha*

survival is clearly dependent upon regular refilling of their aquatic habitat with a source of fresh to brackish water.

The objective of this study is focus on the ethnic or indigenous people in Sarawak on how they utilize the aquatic macrophytes. The ethnic peoples, the Malay, Chinese, Iban, Bidayuh and Melanau mostly depend on plants and animals as the source of their food, medicine and generating income since the ancient time. One of their sources are the aquatic macrophytes especially those who lived near the wetland area, river or sea.

Their knowledge on the aquatic macrophytes was passed down from old generation or through their own experience living in the interior area. Nowadays our generation did not realize the value of these sources which are highly valuable. Most of them consumed the aquatic macrophytes as food, for their medicine and also use the aquatic plants to make handicrafts and as decorative items.

Aquatic plants often contain highly bioactive chemicals, so it is no surprise that these plants are often use by humankind. Numerous reports on traditional uses of aquatic plants as sources of poisons against fish and other animals appear in Costa (Pierce *et al.*, 1991) and several reports on the medicinal uses of aquatic plants. Yet most of the plant species in the world have not been surveyed in modern times for their chemical or biologically active constituents (Balandrin *et al.*, 1985; Cox and Balick, 1994). Bioactive plant chemicals from wetlands have been widely used in both "primitive" and "modern" cultures. A large fraction of plants traditionally

cultivated for medicinal purposes came from wetlands or had closely related wetland species (Stockberger, 1972).

In this study also we investigated the role of aquatic macrophyte in household economies of ethnic people and how far the importance of the plant to them. Some of the ethnic people traded their products they have collected from the forest, river or sea to earn money or income to support their livelihood. They usually sell their products as raw items or processed products such as handicraft.

Besides, we learn the different ethnic practices on collecting aquatic macrophyte for instance, application technique or equipment use. Ethnic peoples did not use any modern technology to help them collecting the macrophytes. Sometimes they have to risk their life during collecting the aquatic macrophytes especially in the area that have dangerous wild animals such as crocodiles or snakes.

1.2 Problem Statement

What is known regarding the uses of aquatic macrophyte especially in Sarawak? A comprehensive bibliography relating to all aspects of aquatic plant utilization has been published (Boyd, 1973). A large number of articles have appeared in scientific periodicals, magazines and newspaper emphasizing the need for utilization of various aquatic plants. Most of the uses of aquatic plants reported were from outside our country. However, information on ethnic utilizing the aquatic plant in Malaysia is lacking, although Burkill in his invaluable work, "The Economic Products of the Malay Peninsula", did report on the utilization of algae in Peninsular Malaysia.

The number of aquatic plants used in one way or another in this country is actually greater if it would be gathered from the present times. This is due to the lack of references in literature to the many species utilized by indigenous people in Malaysia especially in Sarawak. Besides, the identification of the species mentioned in literature could not be verified so that it is possible that other species than those cited may have economic application and rich in nutrient content. For instance, the young plants of *Neptunia oleracea* are cooked as a green vegetable but there are no data on its productivity. It may be rich in protein since it is a legume (Ruskin and Shipley, 1976)

1.3 Objectives

Based on review in Section 1.2, this study is to fulfill the information pertaining to the utilization of aquatic macrophytes in Sarawak where the objectives are:-

1. To examine the types of aquatic macrophytes traded by indigenous peoples.
2. To identify the uses of aquatic macrophytes by indigenous peoples

CHAPTER 2
LITERATURE REVIEW

2.1 Definition of Aquatic Macrophyte

Aquatic plants or macrophytes are considered as those which grow in a continuous supply of water or are at least present in soils which are covered with water during a major part of the growing season (Penfound, 1956; Cook *et al.*, 1974; Mitchell, 1974)

Aquatic macrophytes are also defined as the macroscopic (large enough to be observed by the naked eye) forms of aquatic and wetland plants found in or near water bodies (Saoepadmo, 1986; Kubitzki, 1998; Jiang and Kadono, 2001; Muta Harah *et al.*, 2005a) or in nature growing association with free standing water level is at or above the water surface of the soil (Kubitzki, 1998; Jiang and Kadono, 2001; Muta Harah *et al.*, 2005b).

The term aquatic macrophytes also refers to a diverse group of aquatic plants and encompasses flowering vascular plants, mosses, ferns and macroalgae (Cook and Urmi-König, 1983) and include plants whose photosynthetically active parts are submerged in water or floating on the water surface permanently or at least for several months each year (Cook *et al.*, 1974)

2.2 Division of Aquatic Macrophytes

Aquatic macrophytes of marine area include the macro algae of the divisions Chlorophyta (green algae), Xanthophyta (yellow-green algae) and Rhodophyta (red algae) and the ''blue-green algae'' (more correctly known as Cyanobacteria),

Bryophyta (mosses and liverworts), Pteridophyta (ferns) and Spermatophyta (seed-bearing plants), where the vegetative parts are actively grow either eternally or periodically (for at least several weeks each year) submerged below, floating on, or growing up through the water surface (Denny, 1985; Pieterse, 1990).

Aquatic macrophytes can be classified depending on their rooted substrate, leaf location in relation to the water surface (Helmut, 1982) and their growth (Cronk and Fennessy, 2001). The four groups of aquatic macrophytes are such (a) submersed: plant with roots in the soil and the upper part are always in the water (b) emergent: plants with roots in the soil and the upper part such as leaves are always in or above the water (c) floating: plants either have or devoid of roots are always floating on the water surface (d) semi-aquatic: plant are growing near the water areas (Pancho and Soerjani, 1978; Soepadmo, 1986; Mashhor, 1988; Muta Harah *et al.*, 2005a; 2005b)

Free-floating plants (e.g. water hyacinth) attract attention because of their massive infestations that are so obvious. They hindered river or lake navigation. They float free and never root in soil. Submersed plants (e.g. *Hydrilla*) complete their life cycle beneath the water. Emersed aquatic plants (e.g. cattail) grow with their root system anchored in bottom mud and have leaves and stems that float on water or stand above it. They grow in shallow water but all can impede flow, block boat movement, clog intake of electric power plants and irrigation system and hasten eutrophication (Zimdhal, 1993).

A good explanation of the complexity is offered by Mchabb and Anderson (1985), who subdivided the usual categories to provide more information about habit of growth and plant type (Table 2).

2.3 Uses of Aquatic Macrophyte

Aquatic macrophyte plays an important role in the structure and function of aquatic ecosystems, providing shelter and refuge, serving as food source and altering water and sediment quality (Chambers and Prepas, 1994; Sand-Jensen, 1998; Chambers *et al.*, 1994).

A number of aquatic weeds are used as animal feeds (Baldwin *et al.*, 1974; Little, 1968; Hora, 1951; Easley and Shirley, 1974). The importance of aquatic weeds as fish food is also well known (Bailey, 1972; Allsopp, 1969; Yeo, 1967; Opuszynski, 1972; Bardach *et al.*, 1972; Sutton, 1974) and several fishes and other animals have been recommended for weed control.

2.3.1 Food for Human

Duckweed (*Lemna* sp.) is one of the world's tiniest flowering plants. It is rich in protein and contains high level of all safe essential amino acids. It is also nutritious and lived abundantly in temperate and tropical regions, growing in thick green masses on surfaces of ponds and lakes. People in Thailand have consumed duckweed for generations. It can be harvested every 3 to 4 days and eaten in soup or stir-fried with other vegetable and meat. Duckweed may also become a valuable livestock feed as well (Zimdahl, 1993). Gopal and Sharma (1979) have been stated that *Ipomoea aquatica* shoots are used as vegetable.

Table 2: Classification of Aquatic Weeds (Source: Mchabb and Anderson, 1985)

Type of plant	Growth habit	Example
Algae	Unicellular or microscopic colony	Phytoplankton
	Free-floating attached to substrate	Diatoms
	Filamentous-green	Cladophora
	Colonial – attached or floating	Spirogyra
	Blue-green	Nostoc
Vascular plants	Completely submerged	Sago pondweeed, hydrilla
		Eurasian water milfoil
		Some mosses
	Submersed with floating leaves	Water lilies
		American pondweed, arrowhead
	Emergent	Cattail, bulrush
		Several grasses
	Free-floating	Water hyacinth
		Duckweed, Azolla
		Salvinia (a fern)

A number of macrophyte species are cultivated for human use for example rice (*Oryza* spp.), which is the world's most important main food. In 2005, China, India and Indonesia being the top three producers of rice where the production exceeded 6 x 10^8 Mt (FAO, 2006).

Aquatic plant including the seaweeds, have primary uses for food in the Orient (Pariser, 1971) and secondary uses as industrial stabilizing agents in processed foods (Krigsnon, 1967)

2.3.2 Feed for Animal

The white amur (*Ctenopharygodon idella*), an herbivorous fresh water fish often called the "Chinese grass eating carp", has the ability to utilize crude, fibrous aquatic vegetation while growing rapidly in relatively poor quality waters (Mehta and Shasma, 1972)

2.3.3 Medicinal Uses

Laksman (1987) reviewed evidence for the medicinal properties of chemicals from wetland plants for examples, polysaccharides extracted from *Typa* were shown to coagulate blood.

2.3.4 Agricultural Uses

As early as 1917, water hyacinth (*Eichhornia crassipes*) was recommended for use as fertilizer and compost (Finlow and McLean, 1917; Singh, 1962). In 1918, water hyacinth was considered as a valuable source of potash.

2.3.5 Ornamental

Many species of weeds have been used as ornamentals, and several species that are now weekly were first imported into the United States for ornamental purposes. One U.S study (William, 1980) documented 33 imported species that become weed. Of these, two were imported as herbs, 12 as hay or forage crops and 16 as ornamental.

2.3.6 Insect or Disease Traps

More than 2000 plants are known to have pest-control chemical (Balandrin *et al.*, 1985; Grainge and Ahmed, 1988). Much of the information on pest-control chemicals in wetland and aquatic plants is from ecomically important rice. Iyegar (1944) reported that water hyacinth could control malaria by regulating mosquito breeding. The aquatic fern, *Salvinia auriculata* also inhibited the breeding of the mosquito *Anopheles albimanus* (Hobbs and Molina, 1983)

2.3.7 Pollution Control

The latest development in the utilization of aquatic weeds is their usefulness in sewage filtration and pollution abatement largely because these plants are known to accumulate large quantities of certain elements (Sinha and Sinha, 1969; Steward, 1970; Seidel, 1971; Culley and Epps, 1973; Wolverton *et al.*, 1975b)

Water hyacinth can be used in bioremediation, to remove nutrients from water and reduce eutrophication (Rogers and Davis, 1972). It will remove the heavy metals selenium, manganese and chromium from water and may be useful for detecting them. It concentrates heavy metals up to 2000 times the level found in water. Because water hyacinth can be used for bioremediation when there is heavy metal

pollution, others have looked at it as a way to harvest valuable heavy metals. Limited research indicates that an acre of water hyacinth could yield 0.45 kg of silver every 4 days, and work on gold harvest has been done (Anonymous, 1976). It is also the same thing with the bulrush which has been identified as a way to remove pollutants from water (Zandstra and Motooka, 1978)

Several aquatic and wetland plants, especially floating ones such as *Azolla* and the water hyacinth, have been shown to have metal-binding peptides (Zolotukhina *et al.*, 1989), to absorb heavy metals from the water, to accumulate them in their roots and upper parts (Wolverton and McDonald, 1978; Sela *et al.*, 1988), and to have some resistance to their toxicity (Nir *et al.*, 1990). Similar observation has been reported for the emergent macrophytes *Sparganium androcladum* (Balch and Jones, 1991).

2.3.8 Other Uses

During recent years, the use of aquatic weeds has been extended to manufacture of paper (Gloor and Gloor, 1950; Rudescu *et al.*, 1965; Bagnall *et al.*, 1974; Morton, 1975), yeast (Oyakawa et al., 1965) and biogas (Wolverton *et al.*, 1975a; Singh, R. B., 1972). In the Alleppey district of Kerala State (India), a paper mill has been set up to utilize *Salvinia*, a serious weed in that state (Gopal and Sharma, 1979).

Since water hyacinth fiber is chemically and physically similar to sugar cane, the possibility has been raised that water hyacinth could be processed to form paper pulp or hard board.

2.4 Nutrient of Aquatic Macrophyte

The pioneering efforts in England, spanning two decades of research on leaf protein recovery, nutritive value and utilization (Pirie, 1966, 1967) has been expanded by numerous investigators with a variety of leaf sources, including water weeds (Boyd, 1968, 1969, 1973). In general, these techniques involve grinding the fresh leaf material with or without added water or alkali, pressing to remove the readily soluble components and using heat and/ or isoelectric precipitation to coagulate the crude protein from the press juice. The insoluble fibrous plant material is suitable for ruminants, while the crude protein can be dehydrated and employed directly or solvent extracted to reduce colour and off-flavour and further concentrate the protein. (Hartman *et al.*, 1967; Arckoll, 1969; Oelschgel *et al.*, 1969; Huang *et al.*, 1971).

The quantity and quality of aquatic leaf protein has been investigated extensively (Boyd, 1969). As with similar studies of terrestrial leaf matter (Byer and Sturrock, 1965; Oelschlegel *et al.*, 1969), protein content varies considerably from species to species and is highly dependent on season, location and plant morphology. Nevertheless, limited animal and human feeding experiments are encouraging (Doraiswany *et al.*, 1969; Subba Rao *et al.*, 1969; 1972).

Curly dock (*Rumex crispus*) has more vitamin C than orange, and extracts of its yellow root have been used to treat jaundice. It is a perennial weed, usually grows in wet areas and is frequently associated with over watering or standing water in low areas. Curly dock leaves have also been boiled in vinegar to soften the fibers and

then combined with lard to make an ointment for treatment of inflammation (Zimdahl, 1993)

CHAPTER 3
METHODOLOGY

3.1 Study Site

The study was conducted in several native markets or wet markets which are in Bau, Kuching, Serian, Saratok, Sarikei, Sibu and Bintulu, Sarawak (Figure 2). Several visits were conducted at the selected native market to observe and collect data and records on aquatic macrophytes traded in these native market.

3.2 Sample Collecting

Fresh samples in each native market were acquired for species identification. Data such as the ethnic uses were recorded based on interviews conducted on the traders (Appendix A). The selected samples were brought to the laboratory and washed using tap water for herbarium purposes.

3.3 Morphological and Identification

The samples collected were identified according to the features such as leaf, petiole, stem, inflorescence and roots. All the features were noted and photographed.

3.4 Herbarium

The samples were washed using fresh water to remove excess dirt and were placed on the newspaper layer by layer. Then the sample were placed between newspapers was press with heavy material or tightening using board. The sample was left to dry in a circulation oven at temperature 40°C for one week. Dried sample were then

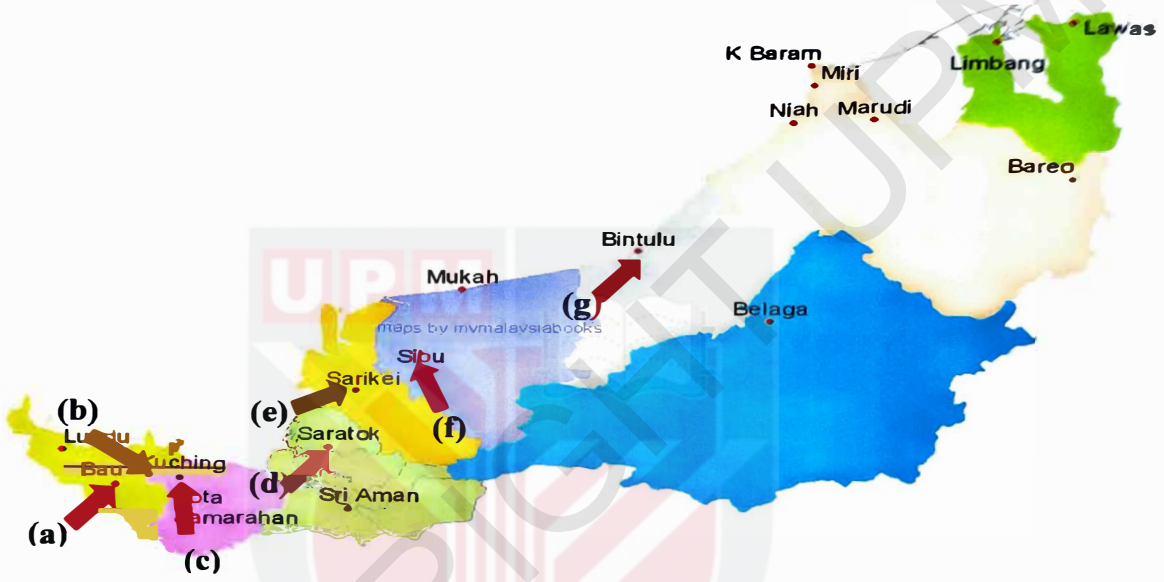

Figure 2 : Sampling site: (a) Bau Tamu, (b) DBKU Tamu, Kuching, (c) Serian Tamu, (d) Saratok Tamu, (e) Nyelong Tamu, Sarikei, (f) Pasar Sentral, Sibu, (g) Bintulu tamu

affixed on the herbarium sheet. The processing of samples to herbarium is employed following the method of Mencz *et al.* (1983).

3.5 Data Analysis

Data analysis was done based on the sample collected. The samples were categorized into its species, occurrence and distribution, uses and the value that it gives to the human.

CHAPTER 4

RESULTS

4.1 Diversity of Aquatic Macrophytes

There are five types of aquatic macrophytes were recorded comprising three freshwater macrophytes, one marine macrophyte and aquatic fern respectively. The freshwater macrophytes are emergent, floating and semi-aquatic plants while the marine macrophyte is seaweed. Emergent macrophyte consist of five species, floating macrophyte six species, semi-aquatic with eleven species, seaweed with three species and only one species of fern (Table 3).

All the species recorded have different and variety of local name which represented also in Table 3. Individually, Sibu, Kuching and Bintulu native market had 19, 18 and 14 aquatic macrophyte species respectively which means Sibu native market being the highest number of species followed by the two native markets (Figure 3).

Eight species, *Polygonum minus, Eleocharis dulcis, Ipomoea aquatica, Arthyrium esculentum, Stenochlaena palustris, Nephrolepis bisserata, Oenanthe javanica* and *Colocasia esculenta* were found in all native markets. Whereas, eleven species were restricted only in certain native market such as *Portulaca oleracea, Hydropuntia edulis, Coptosapelta griffithii*, Daun anggan at Kuching native market, *Neptunia oleracea, Eichhornia crassipes* at Sarikei native market, *Cyperus malaccensis, Lycopodium cernuum, Vitis hastata* and Daun katok jail at Sibu native market and *Nelumbo nucifera* at Bintulu native market.

Table 3: Categories of aquatic macrophytes found in different native market

No.	Types and species of aquatic macrophyte	Family	Local name	Location						
				Bau	Kuching	Serian	Saratok	Sarikei	Sibu	Bintulu
Emergent										
1.	*Limnocharis flava* Buchenau	Butomaceae	Jinjir, paku rawan		+			+	+	+
2.	*Polygonum minus* Hudson	Polyganaceae	Daun kesom	+	+	+	+	+	+	+
3.	*Cyperus malaccensis* Lamk.	Cyperaceae	Tali bundong						+	
4.	*Nelumbo nucifera* Gaertn.	Nelumbonaceae	Teratai							+
5.	*Eleocharis dulcis* (Burme.f.)Trin. Ex Hensche	Cyperaceae	Matai	+	+	+	+	+	+	+
Floating										
6.	*Neptunia oleracea* Lour	Legumenoceae	Kangkung puteri						+	
7.	*Ipomoea aquatica* Forrsk	Convolvulaceae	Kangkung air	+	+	+	+	+	+	+
8.	*Hydrocotyle umbellata* L.	Apiaceae	Pegaga Thailand	+	+	+				
9.	*Eichhornia crassipes* (Mart.) Solms	Pontederiaceae	Keladi bunting					+		
10.	*Roripa nasturtium-aquaticum* Hayek		Semanggi		+				+	+
11.	*Vitis hastata* Miq	Brassicaceae	Daun riang						+	
Semi-aquatic										
12.	*Arthyrium esculentum* Retz.	Arthyriaceae	Paku ikan	+	+	+	+	+	+	+
13.	*Stenochleana palustris* (Burm. F) Bedd	Blechnaceae	Paku miding	+	+	+	+	+	+	+
14.	*Nephrolepis biserrata* (S.w) Schott	Nephrolepidaceae	Paku uban, paku kubuk	+	+	+	+	+	+	+
15.	*Oenanthe javanica* (Blume) DC.	Umbelliferae	Daun selom	+	+	+	+	+	+	+
16.	*Portulaca oleracea* L.	Portulacaceae	Daun keremi/ beremi		+					
17.	*Plantago major* L.	Plantaginaceae	Ekor anjing						+	

No.	Types and species of aquatic macrophyte	Family	Local name	Location						
				Bau	Kuching	Serian	Sarawak	Sarikei	Sibu	Bintulu
18.	*Altenanthera sessilis* D.C	Amaranthaceae	Keremak		+		+		+	+
19.	*Colocasia esculenta* (L.) Schott	Araceae	Keladi	+	+	+	+	+	+	+
20.	*Coptosapelta griffithii* Hook.f.	Asteridae	Pucuk malong		+		+			
21.			Daun anggan		+					
22.			Daun katok jail						+	
Seaweed										
23.	*Laminaria japonica* (Aresch)	Laminariaceae	"Haidai"		+		+	+	+	+
24.	*Hydropuntia edulis* (Gmel.) Gurgel & Fredericq	Gracilariaceae	Janggut duyung		+					
25.	*Porphyra* sp.	Bangiaceae	"Si chok", nori		+		+	+	+	+
Fern										
26.	*Lycopodium cernuum* L.	Lycopodiaceae	Pokok tapok-tapok						+	

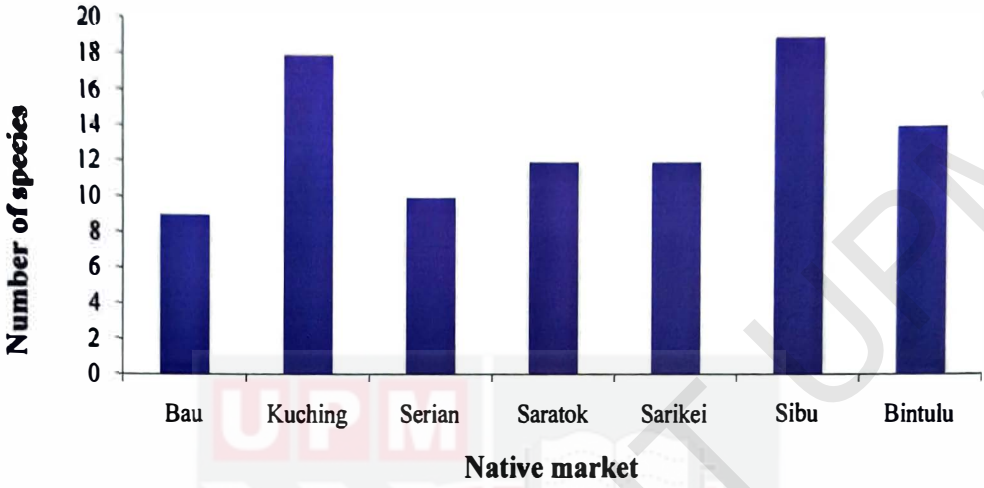

Figure 3: Total species in each native market

4.2 Aquatic Macrophytes Sold by Ethnic Groups

The Bidayuh and Iban community was outstandingly involved in the collection of aquatic macrophytes and selling them in the native market. *Arthyrium esculentum*, *Stenochlaena palustris*, *Nephrolepis hisserata* and *Ipomoea aquatica* were sold in relatively high quantities; therefore higher numbers of traders were involved in their sale (Table 4). This indicated that Bidayuh and Iban were also the most ethnic that lived at the interior area or near the aquatic macrophyte sources.

Malay and Chinese became the second number of ethnic involved in marketing the aquatic macrophytes. Generally Malay becomes the middlemen of selling the aquatic macrophytes. Other collectors sell small quantities to different traders in the native market in order to sell them easily.

Chinese usually sells marine macrophyte such as *Laminaria japonica* and *Porphyra* sp. rather than freshwater macrophyte. *Hydropuntia edulis* was sold by Malay ethnic where the source was come from Malay's village. The marine macrophyte sold by Chinese is usually imported from outside country such as China and Japan. Melanau is among the other ethnic involved in selling aquatic plants. The aquatic macrophytes sold by different ethnic also been expressed in Figure 4.

4.3 Uses of the Aquatic Macrophyte

Each of the aquatic macrophyte has known uses based on the ethnic utilization. Most of them are known to have more medicinal values than utilized as food items.

Table 4: Aquatic macrophyte in seven native market as clustered by ethnic group

No.	Species	Ethnic				
		Malay	Bidayuh	Iban	Melanau	Chinese
1.	*Limnocharis flava* Buchenau		3	6	1	
2.	*Polygonum minus* Hudson	7	4	11	3	2
3.	*Cyperus malaccensis* Lamk.					2
4.	*Nelumbo nucifera* Gaertn.					2
5.	*Eleocharis dulcis* (Burme.f.)Trin. Ex Henschel	6				5
6.	*Neptunia oleracea* Lour			5	2	
7.	*Ipomea aquatica* Forrsk	5	16	7		5
8.	*Hydrocotyle umbellate* L.	2	2			
9.	*Eichhornia crassipes* (Mart.) Solms			1		
10.	*Roripa nasturtium-aquaticum* Hayek	2				3
11.	*Vitis hastata* Miq.			1	1	
12.	*Arthyrum esculentum* Retz.	3	18	13	4	3
13.	*Stenochlaena palustris* (Burm. F) Bedd	3	18	12	4	3
14.	*Nephrolepis biserrata* (S.w) Schott	7	13	10	4	
15.	*Oenanthe javanica* (Blume) DC.	1	1	1		
16.	*Portulaca oleracia* L	1				
17.	*Plantago major* L.			2	1	
18.	*Altenanthera sessilis* D.C	1		3		2
19.	*Colocasia esculenta* (L.) Schott	4	12	8	4	1
20.	*Coptosapelta griffithii* Hook.f.	1		1		

No.	Species	Ethnic				
		Malay	Bidayuh	Iban	Melanau	Chinese
22.	Daun katok jail			1		
23.	*Laminaria japonica* (Aresch)					10
24.	*Hydropuntia edulis* (Gmel.) Gurgel & Fredericq	1				
25.	*Porphyra* sp.					10
26.	*Lycopodium cernuum* Linn.					2
	Total	**45**	**87**	**82**	**24**	**50**

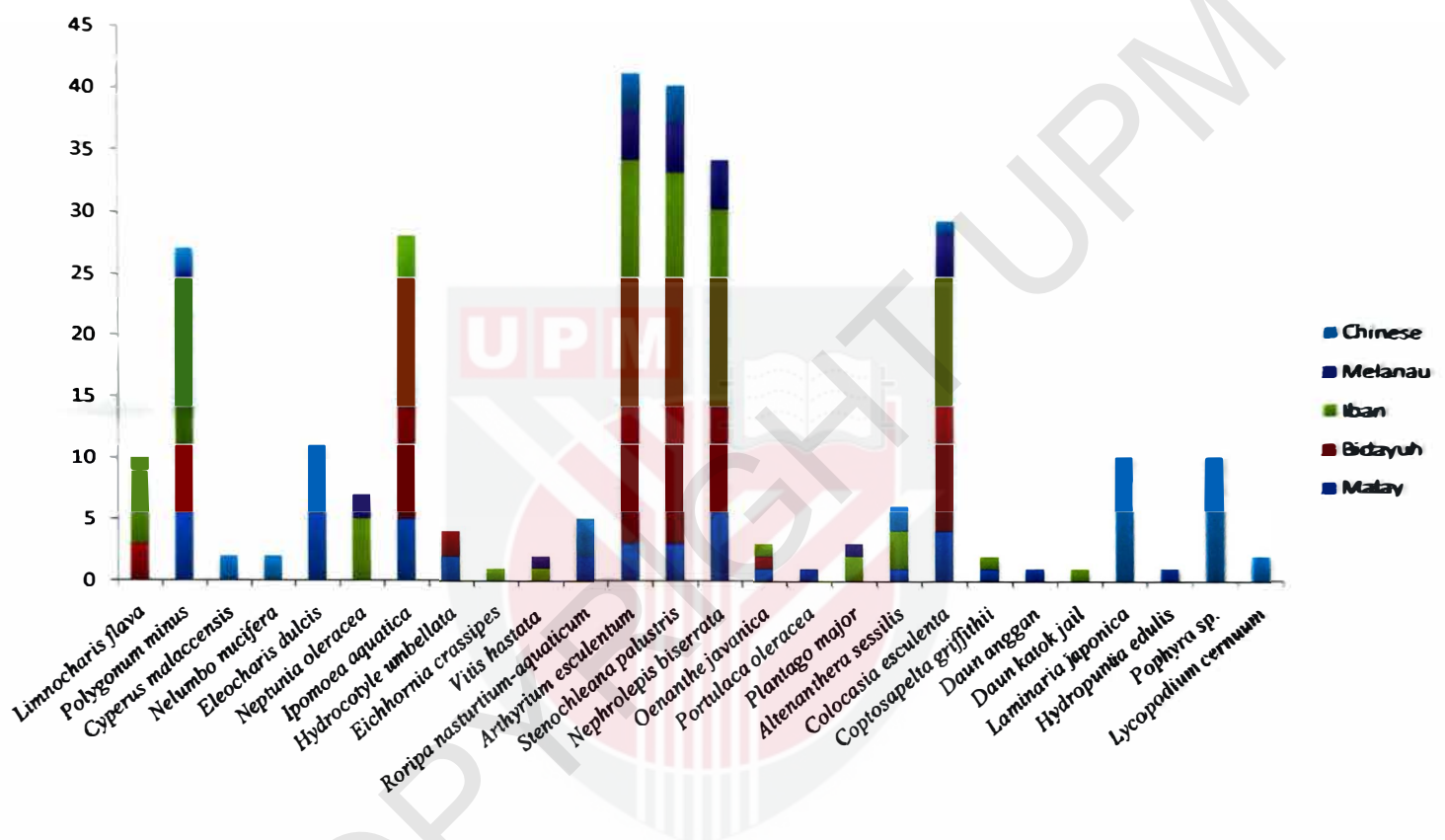

Figure 4: Aquatic macrophyte sold by different ethnic

The different plant parts used of each species are indicated in Table 5. Young leaves and stem are most commonly used for food and medicine. All the species were collected wild. Seven species, *Neptunia oleracea, Ipomoea aquatica, Hydrocotyle umbellata, Eichhornia crassipes, Oenanthe javanica, Portulaca olerace* and *Colocasia esculenta* are known can be cultivated for house consumption as food, medicine, ornamental or other uses. *Eichhornia crassipes* is used for ornamental while *Cyperus malaccensis* is use for other purposes. The whole parts of seaweed species were use as food and both *Laminaria japonica* and *Porphyra* sp. have the medicinal value.

***Limnocharis flava* Buchenau**

Common name: Yellow bur-head

Local name: Paku rawan, jinjir

Ethnic: Iban, Melanau

Uses: The young leaves, petiole and inflorescence (Plate 1a) are eaten as vegetable, salad or dipped in shrimp paste. It is usually cooked for a short time before consumption.

***Polygonum minus* Hudson.**

Common name: Small water-pepper

Local name: Kesum, Cenohom

Ethnic: Malay, Bidayuh, Iban, Melanau, Chinese

Uses: The shoot and young leaves (Plate 1b) are eaten raw as salad together with some shrimp paste. It is also used as a spice or ingredient in preparing food and adds a rich aroma to the peppery hot soup in dishes such as *asam laksa, asam pedas* and

Table 5: Part utilized and uses of different species of aquatic macrophytes

No.	Species	Wild / cultivated	Part utilized	Uses
1.	*Limnocharis flava* Buchenau	W	Young leaves, stem and inflorescence	Food
2.	*Polygonum minus* Hudson	W	Leaves	Food
3.	*Cyperus malaccensis* Lamk.	W	Stem	Other
4.	*Nelumbo nucifera* Gaertn.	W	Seeds	Food
5.	*Eleocharis dulcis* (Burme.f.)Trin. Ex Henschel	W	Corm	Food
6.	*Neptunia oleracea* Lour	W/C	Leaves and stem	Food / Medicine
7.	*Ipomea aquatica* Forrsk	W/C	Leaves and stem	Food
8.	*Hydrocotyle umbellate* L.	W/C	Whole plant	Food / Medicine
9.	*Eichhornia crassipes* (Mart.) Solms	W/C	Whole plant	Ornamental
10.	*Roripa nasturtium-aquaticum* Hayek	W	Leaves and stem	Food
11.	*Vitis hastata* Miq.	W	Leaves	Food
12.	*Arthyrum esculentum* Retz.	W	Young shoot	Food
13.	*Stenochlaena palustris* (Burm. F) Bedd	W	Young shoot	Food
14.	*Nephrolepis biserrata* (S.w) Schott	W	Young shoot	Food
15.	*Oenanthe javanica* (Blume) DC.	W/C	Leaves and stem	Food
16.	*Portulaca oleracia* L	W/C	Leaves and stem	Food / Medicine
17.	*Plantago major* L.	W	Leaves and stem	Food
18.	*Altenanthera sessilis* D.C	W	Leaves	Food / Medicine
19.	*Colocasia esculenta* (L.) Schott	W/C	Young shoot and tuber	Food
20.	*Coptosapelta griffithii* Hook.f.	W	Young shoot and stem	Food / Medicine
21.	Daun anggan	W	Leaves	Food
22.	Daun katok jail	W	Young shoot	Food
23.	*Laminaria japonica* (Aresch)	W	Leaves blade	Food
24.	*Hydropuntia edulis* (Gmel.) Gurgel & Fredericq	W	Whole plant	Food
25	*Porphyra* sp.	W	Whole plant	Food
26.	*Lycopodium cernuum* Linn.	W	Whole plant	Medicine

Plate 1: (a) Young shoot and inflorescence of *Limnocharis flava* (b) *Polygonum minus* sold in all native market

tom yam soup. In traditional medicine, a decoction of the leaves is taken to provide relief from indigestion. It is also taken after childbirth as post-natal tonic, for the general well-being of the mother. To get rid of dandruff, the leaves are pounded to extract the *kesum* oil that is used as a scalp and hair wash.

Cyperus malaccensis Lamk.

Local name: Tali bundong

Ethnic: Chinese

Uses: This plant (Plate 2a) is dried to produce string by Chinese people and they use it to tie food wrapping during moon cake season.

***Nelumbo nucifera* Gaertn.**

Common name: Lotus

Local name: Teratai

Ethnic: Malay, Chinese

Uses: The seeds of *N. nucifera* can be eaten raw or boiled. It tastes like groundnuts. This plant can be used as ornamental or cultivate for food and traditional Chinese medicinal.

***Eleocharis dulcis* (Burme.f.)Trin. Ex Henschel**

Common name: Chinese water chestnut

Local name: Matai

Ethnic: Malay, Chinese

Uses: It is an essential ingredient in certain Chinese dishes such as dim sum or stir-

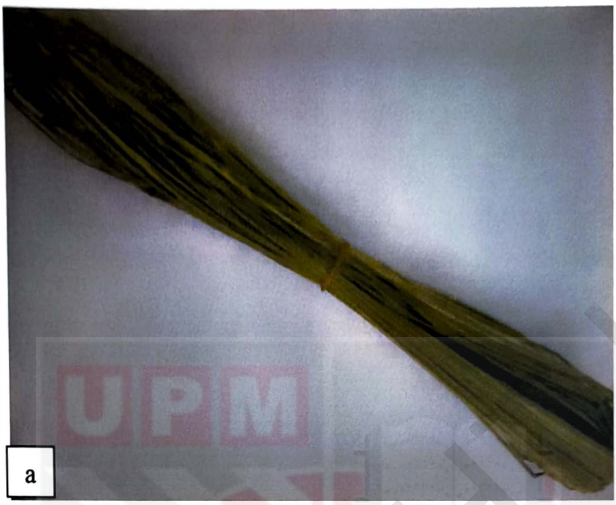

Plate 2: (a) The stem of *Cyperus malaccensis* produced as *Tali bundong* used by Chinese

fried mixtures. It can also be used raw and in drinks. The corm is boiled before it can be eaten.

***Neptunia oleracea* Lour**

Local name: Kangkung puteri, Daun tangki, Akar keman hantu

Ethnic: Malay, Iban, Melanau

Uses: The shoots and young leaves of *N. oleracea* (Plate 3a) are eaten raw as salad, dipped in shrimp paste. It also can be eat as vegetable which fried with anchovies. In local traditional medicine in Malaysia, an infusion of the roots is mixed with rice flour and rubbed all over the body as a treatment for fever. The juice of the roots is applied into the ear for treatment of infection of the ears and also as treatment in the late stages of syphilis.

***Ipomoea aquatica* Forrsk.**

Common name: Water spinach

Local name: Kangkung air

Ethnic: Malay, Bidayuh, Iban, Melanau, Chinese

Uses: The shoots and young leaves of *I. aquatica* (Plate 3b) are eaten raw or blanched in hot water as salad, dipped in shrimp paste. It is also a popular vegetable that is stir-fried with shrimp paste or garlic, together with anchovies or dried prawn. It is added as ingredient in the preparation for a vegetable fruit salad called *rojak*. In traditional medicine in Malaysia, it is eaten to relieve headache, as a laxative and as a cure for insomnia. It is also a good food source for rabbits.

Plate 3: (a) *Neptunia oleracea* sold at Sibu native market, (*b) Ipomoea aquatic* sold in all native market

***Hydrocotyle umbellata* L.**

Common name: Marsh pennywort, money plant

Local name: Pegaga air, pegaga cina, pegaga Thailand

Family: Malay, Bidayuh, Iban, Melanau, Chinese

Uses: *Hydrocotyle umbellata* (Plate 4a, b and c) is very taste when eaten raw as salad especially dipped with shrimp paste. Sometimes it can be cooked with fish or *lemak cili api* or made as mixed salad. *Hydrocotyle umbellata* is believed to reduce high blood pressure. This plant can also be applied to the body to reduce body heat or cure fever.

***Eichhornia crassipes* (Mart.) Solms**

Common name: Water hyacinth

Local name: Keladi bunting

Family: Pontederiaceae

Uses: Can be use as an ornamental and help to filter the water in drains or ditches (Plate 4d).

***Roripa nasturtium-aquaticum* Hayek**

Common name: Watercress

Local name: Semanggi, selada air

Ethnic: Malay

Uses: The edible parts of this plant are the leaves and seeds. The leaves can be eaten can be eaten raw or cooked.

Plate 4: *Hydrocotyle umbellata,* (a) found in natural place, (b) grow abundantly in drain, (c) sold in *tamu*, (d) *Eichhornia crassipes* at natural place

***Vitis hastata* Miq.**

Local name: Daun riang

Ethnic: Iban, Melanau

Uses: This plant (Plate 5a) is one of the tortoise foods where the leaves are sour like tamarind. The leaves are cooked or mixed with fish dishes. It can help to reduce the fishy smell.

***Arthyrium esculentum* Retz.**

Local name: *Paku ikan*

Ethnic: Malay, Bidayuh, Iban, Melanau

Uses: Usually *Arthyrium esculentum* (Plate 5b) is eaten as salad, mixed salad or *masak lemak.*

***Stenochleana palustris* (Burm. F) Bedd**

Local name: Paku miding

Ethnic: Malay, Bidayuh, Iban, Melanau

Uses: This plant (Plate 5c) can be eaten by frying it with shrimp paste and anchovy.

***Nephrolepis biserrata* (S.w) Schott**

Local name: Paku uban, Paku kubuk

Ethnic: Malay, Bidayuh, Iban

Uses: This plant (Plate 5d) can be half boiled and be eaten as salad or fried with shrimp paste.

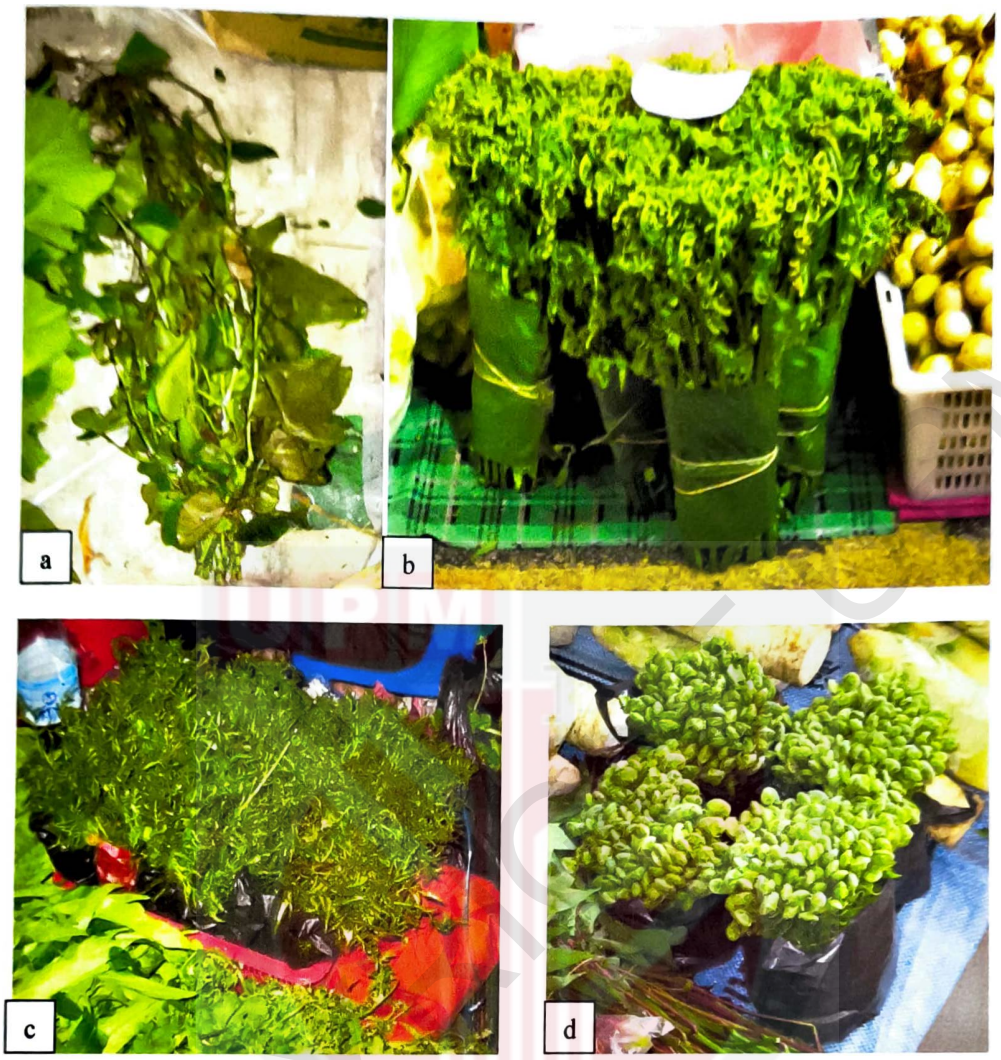

Plate 5: (a) *Vitis hastata* sold at Sibu native market, Semi-aquatic macrophytes sold in all native market (b) *Arthyrium esculentum* (c) *Stenochlaena palustris* (d) *Nephrolepis biserrata*

***Oenanthe javanica* (Blume) DC.**

Common name: Water dropwort or water celery

Local name: Selom

Family: Umbelliferae

Uses: The shoot and young leaves are eaten raw as salad, dipped in shrimp paste. It is widely used in the flavouring of food. The other uses of *O. javanica* is to prevent the growth of weed as it is a ground cover plant where usually can be grown with other plants especially shrubs and trees.

***Portulaca oleracea* L.**

Common name: Purslane

Local name: Daun keremi

Family: Portulacaceae

Uses: The taste of this plant is very bitter. It is eaten as salad which is half-boiled. This plant also can be made as mixed salad, mix with *Phaeomoria speciosa,* anchovy, chilies and onion. *Portulaca oleracea* have medicinal value where it can be used to cure high blood and diabetes because of its bitterness. It can also be used for poulticing swollen joints.

***Plantago major* L.**

Common name: Plaintain

Local name: Ekor anjing

Ethnic: Malay, Iban, Melanau

Plate 6: (a) *Oenanthe javanica* sold in all native market, (b) *Portulaca oleracea* found at Bintawa, Kuching

Uses: The young leaves of *P. major* can be eaten by boiling it where it has a lot of fiber content.

***Altenanthera sessilis* D.C**

Common name: Joyweed

Ethnic: Malay, Iban, Melanau, Chinese

Uses: The leaves of *A. sessilis* (Plate 7a) are eaten as a cooked vegetable or raw as a salad. This plant is also used to cure heart disease or simple stomach disorder. It also can be use as ornamental where it can be grow to decorate an aquarium.

***Colocasia esculenta* (L.) Schott**

Common name: Taro, yam

Local name: Keladi

Ethnic: Malay, Bidayuh, Iban, Melanau, Chinese

Uses: The stem of this plant are cook with tamarind to reduce the itchy taste. Its tuber and stem can be cooked together fried or *masak lemak*. The tuber can be cut slice and fried as crisp. It can also mixed or cook as porridge.

***Coptosapelta griffithii* Hook.f.**

Local name: Pucuk malong

Ethnic: Malay, Iban

Uses: The shoot and young leaves of this plant (Plate 7b, c and d) can be fried as vegetable and mixed with tamarind because it has stingy taste like *Colocasia* sp. which can cause itchy to our tongue. This plant can also cure high blood.

Plate 7: (a) *Altenanthera sessilis* found at Saratok, *Coptosapelta griffithii* (b) grow near water bodies at Saratok, (c) at Kampung Gita,Kuching, (d) sold in Kuching native market

Local name: Daun anggan

Ethnic: Malay

Uses: The young shoot (Plate 8a) can be eaten as vegetable by fried it with anchovy and shrimp paste and it has sweet taste. It can be eaten as salad. This plant has white rubber which cannot be eaten by animal as it can cause death.

Local name: Daun katok jail

Ethnic: Iban

Uses: This plant has a little bit sweet taste. It is cooked fried with anchovy and shrimp paste. It cannot be eaten raw as it result an itchy to tongue. This plant can be mixed into fish dishes or smoked fish.

Laminaria japonica (Aresch)

Local name: 'Haidai'(Chinese)

Ethnic: Chinese

Uses: *Laminaria japonica* (Plate 8b) are imported and mostly eaten by Chinese. They usually fried this seaweed or mixed it in soup. It can help to reduce body heat and the present of iodine in the *L. japonica* is to prevent thyroid gland disorders and goiters. It can also be use as an agent in textile, printing, medical and food manufacturing industries.

Plate 8: (a) Daun anggan found at Kampung Tabuan Melayu, Kuching, (b) *Laminaria japonica* found at Nyelong native market, Sarikei

***Hydropuntia edulis* (Gmel.) Gurgel & Fredericq**

Local name: Janggut duyung

Family: Gracilariaceae

Uses: People usually eat this seaweed (Plate 9a) raw as salad or made it as mixed salad

***Porphyra* sp.**

Local name: "Si chok" (Chinese), sayur laut

Ethnic: Chinese

Uses: This seaweed (Plate 9b) usually cooks or mixed in soup. It is believe to reduce body heat.

***Lycopodium cernuum* Linn.**

Local name: Pokok tapok-tapok

Ethnic: Chinese

Uses: This plant (Plate 9c) is believed to have medicinal value especially in the cure of diabetes by boiling the plant and drink its water.

Plate 9: Seaweed species found in Kuching native market (a) *Hydropuntia edulis* (b), *Porphyra* sp. (c) *Lycopodium cernuum* sold in Sibu native market

CHAPTER 5
DISCUSSION

5.1 Diversity of Aquatic Macrophytes

Aquatic macrophytes were sold by ethnic people from the interior. Those aquatic macrophyte usually growth in natural places and only few of them were cultivated by ethnic peoples. Hydrocotyle umbellata, Portulaca oleracea and Eichhornia crassipes can be cultivated for ornamental purposes but in the same time H.umbellata and P. oleracea can also be a source of medicine.

Janaki Ammal (1955-56) and Malhotra *et al.* (1992a, b) stated that the livelihood of the rural people is not only dependent on the agricultural and animal produce, but also on the forests and other natural resources. In Sarawak, most of the rural people are dependent upon aquatic macrophytes or other forest product for their subsistence living.

The aquatic plants are very easily grown and become the most distributed items at any native market in Sarawak. Plant species with broad distribution where more than 30 sellers are involved are such as *Artyrium esculentum*, *Stenoclaena palustris*, *Nephrolepis biserrata* and *Ipomoea aquatica*. Various type of aquatic macrophytes found in native market are related with their settlement environment where the plants grew in abundant.

Interview with the collectors and sellers revealed that most of the edible aquatic plants were collected directly from the natural place or forest for instance *A.*

esculentum, S. palustris and N. hiserrata. Generally people with subsistence economy among lower income groups were involved with the collection of species.

While market surveys revealed that more than seven species were always available in the markets, showing the high diversity of the aquatic plant species consumed in particular area. It is also known that the aquatic plants are consumed in large quantities during the period of scarcity of commercial vegetables especially in smaller native market such as Bau whereas Sharma *et al.* (1992) stated that in rural markets the demand for the goods is less due to the low purchasing power of the rural dwellers.

The Iban and Bidayuh community was prominently involved in the collection of *Arthyrium esculentum, Stenochlaena palustris* and *Nephrolepis biserrata* and selling them in local markets where the species produced a good quantity. They were always brought in large quantities to market during weekend. For most of the aquatic macrophyte species, a few of them, particularly the medicine ones, were sold in much smaller quantities for instance *Lycopodium cernuum.*

5.2 Ethnic Group and Uses of Aquatic Macrophytes

Each of ethnic group has their own way of collecting and selling the aquatic macrophytes species. As been report by Sundriyal and Sundriyal (2002), the knowledge about wild edible plants is spread from one generation to next generation practical collection. However, interview had revealed that most of the old generation said during their childhood, they collect a number of aquatic macrophyte species

from natural habitat and taste them for fun. Based on the experience, they knew how to utilized the particular plant and passed them to their child but recently many young generation did not continuing passing the knowledge.

It was noted that the plants sold in large quantities were species in high demand (Sundriyal and Sundriyal, 2002) but the large quantities of certain species at native market is due to the abundant of species growing at the natural place. Primarily the ethnic groups of low economic profile are involved with the collection and selling of various aquatic plants. This is similar to Amazonian forests report by Browder (1990) and Phillips (1993). The ethnic usually visit the forest or natural habitat several times in search of 26 species that have market potential.

All the 26 species are consumed as food and few of them have other uses but the important thing is the value of each species that can be profit by consumers. On the medicinal side, most of the aquatic plant gives a medicinal value. For example, *Neptunia oleracea* have and antibiotic compound, help to remove worms, laxative and can removed persistent cough and blood in urine as been mentioned by Britta *et al* (2002). While based on the interview, *N. oleracea* are believed can cure diabetes and high blood pressure. This indicated that different place and different people have different way of using the aquatic plant.

CHAPTER 6

CONCLUSION

In this study there are five types of aquatic macrophytes were determined for both fresh and marine water. They are such as emergent, floating, semi-aquatic, seaweed and aquatic fern with total of 26 species with 25 different families. For most of the aquatic macrophyte species, most of them were consumed as food, medicine and a few for ornamental purpose. Part of plant that was utilized mostly young shoot, petiole and leaves. The aquatic plants also been collected wild and directly sell to the native market or through the middlemen.

Sibu native market have the highest number of species, 19 followed by Kuching 18 species and Bintulu 14 species. Eight species, *Polygonum minus, Eleocharis dulcis, Ipomoea aquatica, Arthyrium esculentum, Stenochlaena palustris, Nephrolepis bisserata, Oenanthe javanica* and *Colocasia esculenta* were found in all native markets. The Bidayuh and Iban were the major ethnic involved in marketing of aquatic macrophyte with 87 and 82 respectively, followed by Chinese 50, Malay 45 and Melanau 24. *Neptunia oleracea, Ipomoea aquatica, Hydrocotyle umbellata, Eichhornia crassipes, Oenanthe javanica, Portulaca olerace* and *Colocasia esculenta* are known can be cultivated for house consumption as food, medicine, ornamental or other uses. *Eichhornia crassipes* is used for ornamental while *Cyperus malaccensis* is use for other purposes. The whole parts of seaweed species were use as food and both *Laminaria japonica* and *Porphyra* sp. have the medicinal value.

REFERENCES

Allsopp, W.H.L. 1969. Aquatic weed control by manatee-its prospects and problems. *In* L. Obeng, ed. Man Made Lakes – The Accra symposium. Ghana University Press, Accra.

Anonymous. 1976. Roots of water hyacinth may be harvested for gold. *Weed, Trees and Turf* **15 (2)**: 50.

Bagnall, L.O., R.L. Shirley and J. F. Hentges. 1973. Processing, chemical composition and nutritive value of aquatic weeds. Water Resources Reservation Center, University Florida, Gainesveille, Published 25.

Balandrin., M.F., J.A. Klocke, E. S. Wurtele and W. H. Bollinger. 1985. Natural plant chemicals: Source of industrial and medicinal materials. *Science* **228**: 1154-1160.

Balch, G.C. and R. Jones. 1991. Zinc in plants, sediments, snow and ice around a galvanized electrical transmission tower in a beaver pond. *Water, Air, Soil, Pollution* **59**: 145-152.

Bailey, W.M. 1972. Arkansas evaluation of the desirability of introducing the white Amur (*Cteno-Pharyngodon idella*) for control of aquatic weeds. *Arkansas Game and Fish Commercial Mimeo.* 59.

Baldwin, J.A., J.F. Hentges, and L.O. Bagnall. 1974. Preservation and cattle acceptability of water hyacinth silage. *Hyacinth Control* J. **12**: 79.

Bardach, J.D., J.H. Rhyther and W.O. McLarney. 1972. Aquaculture: The Farming and Husbandryof Freshwater and Marine Organisms. Wiley Interscience, New York.

Boyd, C.E. 1973. A bibliography of interest in the utilization of vascular aquatic plants. *Economic Botany* **26:** 74-84.

Britta, M.O., H.T. Tuyet, H.N. Duyet and Dung N.N.X. 2002. Food, Feed or Medicine: The multiple functions of edible wild plants in Vietnam. *Economic Botany* **57(1):** 103-117.

Browder, J.O. 1990. Extractive reserves will not save the tropics. *Bioscience* **40:** 640.

Chambers, P.A. and E.E. Prepas. 1994. Nutrient dynamics in riverbeds: The impact of sewage effluent and aquatic macrophytes. *Water Research* **28:** 453–464.

Chambers, P. A., P. Lacuol, K. J. Murphy and S.M. Thomaz. 2007. Global Biodiversity of Aquatic Macrophyte in Freshwater: *Hydrobiologia.* **595**: 9-26.

Chambers, P.A., RE. DeWreede, E. A. Irlandi and H. Vandermeulen. 1999. Management issues in aquatic macrophyte ecology: a Canadian perspective. *Canadian Journal of Botany* **77:** 471–487.

Cook, C. D.K., B. Gut, E.M. Rix, J. Schneller and M. Seitz. 1974. Water plants of the world: A manual for the Identification of the Genera of Freshwater Macrophytes. Dr. W. Junk B. V., The Hagne. 561p.

Cook, C.D.K. and K. Urmi-König. 1983. A revision of the genus *Otellia* (Hydrocharitaceae) 2: the species of Eurasia, Australia and America. *Aquatic Botany* **20:** 131-147.

Cox, P.A. and M. J. Balick. 1994. The ethnobotanical approach to drug discovery. *Science American.* **270**: 60-65.

Cronk, J.K. and M.S. Fennessy. 2001. Wetland Plants Biology and Ecology. America: Lewis Publisher.

Culley, D.D. and E.A. Epps. 1973. Use of duckweed for waste treatment and animal feed. *Journal of Water Pollution Control Federation.* **45**: 337-347.

Denny, P. 1985. The Ecology and Management of African Wetland Vegetation. W. Junk, The Hague.

Easley, J.F. and R.L. Shirley. 1974. Nutrient element of livestock in aquatic plants. *Hyacinth Control Journal* **12**: 82.

FAO (Food and Agriculture Organization of the United Nations), 2006. FAOSTAT. Published on the Internet; http://faostat.fao.org/

Finlow, R. S. and K. McLean.1917. Water hyacinth and its value as a fertilizer. Government Printing Press, Calcutta. 16 pp.

Fisheries Research Institute, Sarawak Branch, (Malaysian Fisheries Department). 2008. Seaweed Resources of Sarawak, Published on the internet; http://www.fri.gov.my/friswak/eseaweed.htm.

Gloor, A.M. and R.P. Gloor. 1950. Improvement in the manufacture of paper pulp and of paper. *Australian Patent* **138**: 426.

Gopal, B. and K.P. Sharma. 1979. Aquatic Weed Control Versus Utilisation. New York Botanical Garden, Bronx, New York. pp. 340-346.

Grainge, M. and S. Ahmed. 1988. Handbook of plants with pest-control properties. John Wiley and Sons, New York.

Helmut, M. 1982. The Complete Guide to Water Plants. London: EP Publishing Limited. Hora, S. L. 1951. The water hyacinth problem and pig farming. *Science Culture*. **17:** 231-232.

Hobbs, J.H. and P.A. Molin a 1983. The influence of the aquatic fern *Salvinia auriculata* on the breeding of *Anopheles albimanus* in coastal Guatermala. *American Mosquito Control Association*. **43**: 456-459.

Iyengar, M.O.T. 1944. Problem relating to malaria control in deltaic Bengal. *Journal Malaria Institute India*. **5:** 435-448.

Janaki Ammal, E.K. 1955-56. An introduction to subsistence economy of India. Background Paper No. 10. Wenner-Gren Foundation. International Symposium. Pages 324-335 in L.T. William, Jr., ed., Man's role in changing the face of earth. University of Chicago Press, Chicago.

Jiang, M. and Y. Kadono. 2001. Seasonal growth and reproductive ecology of two threatened aquatic macrophyte, *Blyxa aubertii* and *B. echinosperma.* (Hydrocharitaceae), in irrigation pons of South-Western Japan. *Ecological Research Journal* **16**: 249-256.

Kirgsnan, J.G. 1967. Alginates: The versatile modifying agents for foods. *Food Technology Australia*. **19:** 556-561.

Kubitski, K. 1998. The Families and Genera of Vascular Plants CIV Flowering plants. Monocotyledons: *Alismatanae and Commelinanae* (except *Gramineae*). Berlin: Springer.

Laksman, G. 1987. Ecotechnological opportunities for aquatic plants: A survey of utilization options. Pp. 49-68 *in* K. R. Reddy & W. H. Smith (eds.), Aquatic plants for water treatment and recovery. Magnolia Publishing, Orlando, FL.

Little, E.C.S. 1967. Progress report on transpiration of some tropical water weeds. PANS, Section C, *Weed Control* **13:**127-132.

Malhorta, K.C., M. Poffenberger, A. Bhattacharya and D. Dev. 1992a. Rapid appraisal methodology trials in South-west Bengal: Assessing natural forest generation patterns and non-wood forest product harvesting practices. *Forests, Trees and People Newsletter* **15/16:** 18-147

Malhorta, K.C, D. Deb and M. Dutta. 1992b. Role of non-timber forest produce in village economy: A house-hold survey in Jumboni Range, Midnapore district, West Bengal. Working Paper of the Indian Institute of Biology. Social Research and Development.

Mashhor, M. 1988. Aquatic weed in rice water ways. In *Proceedings of the National Seminar and Workshop on Rice Field Weed Management*, p. 69-76. Penang: Universiti Sains Malaysia.

Mchabb, T. and L.W.J. Anderson. 1985. Aquatic weed control, pp. 440-455 in "Principal of Weed Control in California." Thomson, Fresno, California.

Mehta, I. and R.K. Shasma. 1972. Control of aquatic weeds by the white amur in Rajasthan, India. *Hyacinth control* J. **10:** 16-19.

Mitchell, D. S. 1974. Aquatic vegetarian and its use and control. Unesco, Parrs, 135p.

Morton, J.F. 1975. Cattails (*Typha* spp.) - weed problem or potential crop? *Economic Botany*. **29**: 7-29.

Muta Harah, Z., B. Japar Sidik, A. Raesah, C. Maini and A.Suzalina Akma. 2005a. Aquatic macrophyte in natural and man made water bodies. *Bio-Science Research Bulletin* **21 (1)**: 27-36.

Muta Harah, Z., B. Japar Sidik and A. Suzalina Akma. 2005b. Distribution, diversity and uses of aquatic macrophytes. *Buletin UPMKB* **4**: 7-10.

Nir, R., A. Gasith and A. S. Perry. 1990. Cadmium uptake and toxicity to water hyacinth: Effect of repeated exposures under controlled conditions. *Bulletin Environmental Contamination Toxicology*. **44:** 149-157.

Opuszynski, K. 1972. Use of phytophagous fish to control aquatic plant. *Aquaculture* **5:** 61-63.

Oyakawa, N., W. Olandi, and E. O. L. Valente. 1965. The use of *Eichhornia crassipes* in the production of yeast, animal rations and forage. Proceeding IX International. *Grassland Congress, Sao Paulo* **2**: 1707.

Pancho, J.V. and M. Soerjani. 1987. Aquatic Weeds of Southeast Asia. A Systematic Account of Common Southeast Asian Aquatic Weeds. Philiphine: National Publishing Cooperative Incorporated.

Pariser, E.R. 1971. The potential, the problem and the status of using proteins of aquatic origin as human food. *Food Technology*. **25**: 1162-174.

Penfound, W.T. 1956. Primary productivity of vascular aquatic plants. *Limnology Oceanography*. **1**: 92-101

Phillips, Oliver. 1993. The potential for harvesting fruits in tropical rainforests: New data from Amazonian Peru. *Biodiversity and Conservation* **2:** 18-38.

Pieterse A.H. 1990. Introduction (Chapter 1). In Pieterse A.H., & K. J. Murphy (eds), Aquatic Weeds. Oxford University Press, Oxford, UK: 3–16.

Pirie, N.W. 1960. Water hyacinth – a curse or a crop. *Nature* **185:** 116.

Rogers, H.H. and D.E. Davis. 1972. Nutrient removal by water hyacinth. *Weed Science.* **20**: 423-428

Ruskin, F.R. and D.W. Shipley. 1976. Making Aquatic Weeds Useful: Some Perspectives for Developing Countries. National Academy of Sciences, Washington, D.C.

Sand-Jensen, K. 1998. Influence of submerged macrophytes on sediment composition and near-bed flow in lowland streams. Freshwater Biology **39**: 663–679.

Sela, M., E. Tel-Or, E. Fritz and A. Huttermann. 1988. Localization and toxic effects of cadmium, copper and uranium in *Azolla. Pl. Physiol.* **88:** 30-36.

Sharma, E., R.C. Sundriyal, S.C. Rai, Y.K. Bhatt, L.K. Rai, R. Sharma and Y.K. Rai. 1992. Intergrated watershed management. Gyanodaya Prakashan, National, U.P. India.

Siedel, K. 1971. Macrophytes as functional elements in environment of man. *Hidrobiologia* **12**: 121-130.

Singh, S.B. 1962. Preliminary experiments on the relative manorial values of some aquatic weeds as compost. pp. 82-86. *In* E. C. S. Little, ed. Handbook of Utilization of Aquatic Plants. United Nations, Food and Agriculture Organization, Rome.

Singh, R. B. 1972. Building a biogas plant. *Compost Science.* **13**:12-16.

Sinha, S.N. and L.P. Sinha. 1969. Studies on the use of water hyacinth culture in oxidation ponds treating digested sugar wastes and effluent of septic tank. Environment Health **11**: 197-207.

Soepadmo, E. 1986. Aquatic Flowering Plants. In *Nature Malaysiana.* **11(3):** 16-25.

Steward, K.K. 1970. Nutrient removal potentials of various aquatic plants. *Hyacinth Control Journal.* **8**: 34-35.

Stockberger, W.W. 1927. Drug plants under cultivation. U.S.D.A., Farmer's Bull. No.663, Washington, DC.

Sundriyal, M., Sundriyal R.C. 2002. Wild Edible Plants of the Sikkim Himalaya : Marketing, Value Addition and Implication for Management. Economic Botany 58(2): 300-315

Sutton, D.I. 1974. Utilisation of Hydrilla by the white amur. Hyacinth Control Journal. 12: 66 70.

Wolverton, B.C. and R.C. McDonald. 1978. Water hyacinth sorption rates of lead, mercury and cadmium, NASA Technical Memorandum TM 78-26715, Bay Saint Louis, MS.

Wolverton, B.C., R.C. McDonald and J. Gorton. 1975a. Bioconversion of water hyacinth into methane gas. PT I & II. NASA Tech. Memo., Bay Saint Louis, Mississipi.

Yeo R.R. 1967. Silver dollar fish for biological control of submerged aquatic weeds. *Weeds* 15: 27-31

Zandstra, H.B., and P.S. Motooka. 1978. Beneficial effects of weeds in pest management-A review. PANS 24: 333-338.

Zimdahl, R.L. 1993. Fundementals of Weed Science. Academic Press.

Zolotukhina, E., E.E. Garrilenko and K.S. Burdin. 1989. Binding of copper and cadnium with proteins from aquatic macrophytes. *Dokl. An.* S.S.S.R. 305-: 249-253 (in Russian)

Appendix A

RESEARCH & INQUIRE FORM

Place:
Date:

1. Local name/language of the aquatic macrophyte.

2. Source of the aquatic macrophyte collected.

3. Characteristic of the collection site.

4. Collected from wild or domesticated?

5. Uses of the aquatic macrophyte (food / medicinal).

6. Processing procedure of the aquatic macrophyte.

7. Using aquatic macrophyte as ritual or spiritual.

PUBLICATION OF THE PROJECT UNDERTAKING

This is to certify that i have no objection to publish the project entitled "Aquatic Macrophyte Diversity and Utilization of Ethnic Group" by the supervisor in a joint authoship. However, it has to be evaluated by the Faculty Agriculture and Food Sciences, Universiti Putra Malaysia Bintulu Sarawak Campus and published in the form approved by the Faculty.

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DAYANG'KU ALIFAH BT AWG SABLI

Date: 19/05/09