



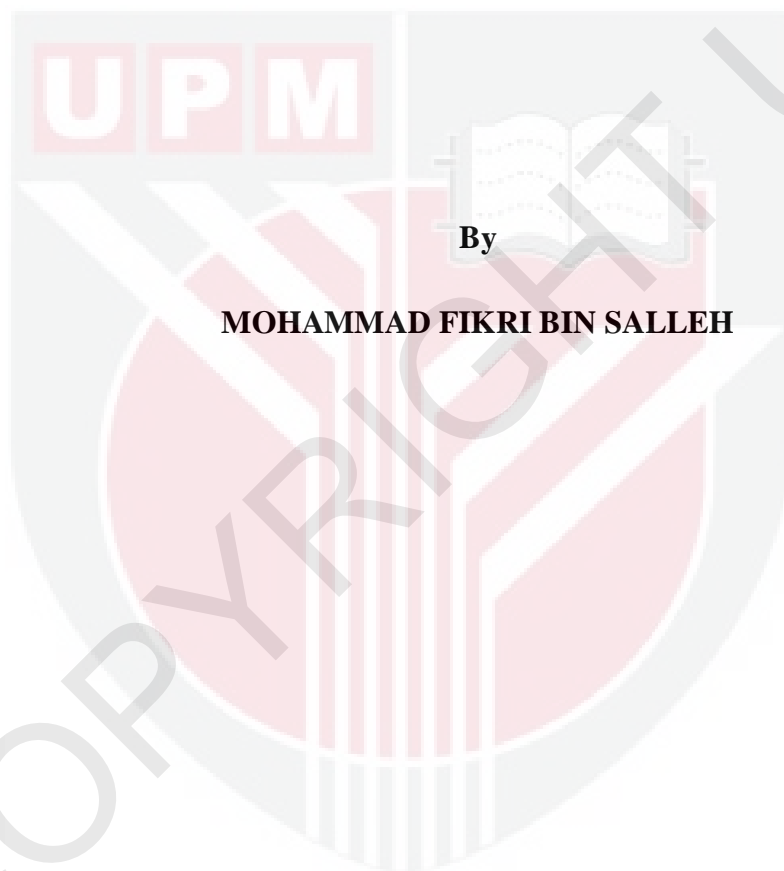
UNIVERSITI PUTRA MALAYSIA

***DIVERSITY OF FRESHWATER AQUATIC
MACHROPHYTES SUITABLE FOR AQUACULTURE
FOOD IN BINTULU, SARAWAK***

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FSPP 2023 6**

**DIVERSITY OF FRESHWATER AQUATIC MACHROPHYTES SUITABLE
FOR AQUACULTURE FOOD IN BINTULU, SARAWAK.**



MOHAMMAD FIKRI BIN SALLEH

**A Project Report Submitted in Partial Fulfilment of the Requirement
for the Degree of Bachelor Science Aquaculture in the Faculty of Agricultural and
Forestry Sciences University Putra Malaysia Bintulu Sarawak Campus**

2023

Dedicated to

My parents, Mr. Salleh Bin Salleh and Mdm. Nurhaidah Binti Innis

My brothers and sisters

Mohd Aqramin, Mohd Thermizi, Nurshafirah, Nursyazwani

My close friends

Shanie, Muzzammil, Shahwandi, Akifi,

all my lecturers and fellow friends.

ABSTRACT

Aquatic macrophytes are plants that float, emergent, and submergent near the water bodies. Macrophytes in their habitat can act as a shelter, substrate, produce oxygen and also as food for aquatic species. Other than that, it has other benefits towards the environment by improving water qualities. Although there are many research about aquatic macrophytes, this research focuses on the species that can be used as an alternative aquaculture feed. The rise of aquaculture industry has affected the increase in demand for aquaculture feed. High-quality protein at a reasonable price is needed. The increase in demands has affect the price due to the production cost. Hence, to minimise the production cost, this research has procured a list of aquatic macrophyte species that can be used as an alternative aquaculture feed. The list focuses on freshwater aquatic macrophytes species that can be used as alternative aquaculture feed. Aquatic macrophytes that are expected to usability as aquaculture feed were collected throughout Bintulu area. The species collected were then added into the recent database in Microsoft Access and made into herbarium for proof of collection. The species were also put together with fish in the aquarium to inspect whether the species can be used as feed or not. The species fish used are *Oreochromis niloticus*. Other than that, reading from articles and research papers were also used as a method to inspect the usability of the aquatic macrophyte species as alternative aquaculture feed. The total aquatic macrophyte species found in Bintulu area is 79 and only 11 species were confirmed to be able to use as alternative aquaculture feed. It has been found that from eight of the species self-collected, only two are not suitable for alternative aquaculture feed.

ABSTRAK

Akuatik makrofit adalah tumbuhan yang timbul, tenggelam dan separa tenggelam di air. Makrofit dihabitatnya dapat bertindak sebagai tempat berlindung, substrat, menghasilkan oksigen serta menjadi sumber makanan kepada spesis akuatik. Selain itu, makrofit juga mampu menambahbaik kualiti air dipersekitaran. Walaupun terdapat banyak kajian mengenai makrofit akuatik, kajian ini memfokuskan pada kebolehan makrofit untuk menjadi makanan alternatif akuakultur. Peningkatan sektor industri akuakultur menyebabkan peningkatan permintaan makanan akuakultur. Protin berkualiti tinggi pada harga yang berpatutan amatlah diperlukan. Jadi, bagi mengurangkan kos pembuatan, kajian ini telah menghasilkan senarai spesis makrofit akuatik yang boleh digunakan sebagai makanan alternatif akuakultur. Senarai ini memfokuskan kepada spesis tumbuhan akuatik makrofit air tawar yang sesuai digunakan sebagai makanan alternatif akuakultur. Spesis akuatik makrofit yang dijangkakan keperbolehanannya dalam menjadi makanan alternatif akuakultur dikutip diseluruh kawasan Bintulu. Spesis yang dikumpul kemudiannya ditambahkan kedalam senarai sedia ada menggunakan Microsoft Access dan dijadikan herbarium sebagai bukti fizikal. Spesis yang dikumpulkan juga diletakkan didalam akuarium bersama ikan tilapia untuk memantau kesesuaian spesis tersebut sebagai makanan alternatif akuakultur. Selain daripada itu, bacaan dari kajian saintifik serta artikel yang berkaitan juga digunakan bagi memastikan spesis yang dikumpulkan bersesuaian dalam menjadikannya makanan alternatif akuakultur. Sebanyak 79 spesis akuatik makrofit telah dijumpai dan dikumpulkan dari seluruh kawasan Bintulu dan hanya 11 sahaja dapat dipastikan kebolehanannya sebagai makanan alternatif akuakultur. Selain itu, daripada lapan spesis yang dikutip sendiri hanya dua sahaja tidak dapat digunakan sebagai makanan alternatif akuakultur

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APPROVAL SHEET

I certify that this research project report entitled “Diversity of freshwater Aquatic Macrophytes suitable for aquaculture food in Bintulu,Sarawak” has been examined and approved as a partial fulfillment of the requirement for the degree of Bachelor Science Aquaculture in the Faculty of Agricultural and Forestry Sciences, Universiti Putra Malaysia Bintulu Sarawak Campus.

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CHAPTER 1

1 Introduction

Aquatic macrophytes are plants that float, emergent, and submergent near the water bodies. Macrophytes act as a shelter for fish, a substrate for aquatic invertebrates, produce oxygen, and also supply food for some fish and other aquatic species. As a primary producer, macrophytes are the pillar of many organisms' food webs. They affect soil chemistry and light levels significantly by reducing water flow, catching pollutants, and trapping sediments. Plant stems, leaves, and roots slow down flow rates, allowing excess silt to settle into the benthos. Pollutants can also be absorbed by some plants via their tissue. Aquatic plants 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). The most favoured macrophyte are soft plant such as filamentous algae, submerged aquatic macrophytes, duckweed, and soft leave of terrestrial plant such as herbaceous plant and vegetables and grasses. (Lin 1954; anon,1980). Among the least favoured are fibrous and woody plant such as rushes and sedges and also larger floating aquatic macrophytes such as water lettuce (*Pistia statiotes*) and water hyacinth (*Eichhornia crassipes*) (Singh et al. 1967; Alabaster and Stott 1967).

Aquatic macrophytes are divided into several life forms, a somewhat arbitrary separation since there are plants which are intermediate, or which may change their life form depending on their stage of growth or on the depth of water (Penfound 1956; Mitchell 1969, 1974; Cook et al. 1974). Life forms frequently

grow in distinct zones, with emergent species thriving in shallow water and submerged species thriving in deeper water where light could still reach the bottom. Floating species are not dependent on soil or water depth (Penfound 1956; Mitchell 1974).

In the case of study, Aquaculture produces high-quality protein at a reasonable price. Not only has there been an increase in the demand for aquatic foods around the world, but there has also been an increase in the need for better diets for humans. As the industry grows, it will face rising feeding costs due to the high cost of aquafeed's core constituents, fishmeal and fish oil. In general, using feeds in aquaculture boosts productivity. However, in small-scale aquaculture, it is especially beneficial to employ locally available materials as constituents (raw materials) in compound aquafeeds or as sole feedstuffs to maximise cost effectiveness.

1.1 Problem statement

In recent times, farmers have been complaining about the increase in aquaculture feed which causes them to increase the price for their product. Fishmeal is the main ingredient source of protein in aquaculture feed. Protein is important for the fish growth and it is needed in large quantity. The optimum percentage of protein needed for fish growth range from 25% - 48% depending on the species. There has been a need to add another source of protein for aquaculture feed to reduce the cost and have a cheaper substitute for fishmeal.

1.2 Objectives

The main objective of this study is to determine the aquatic macrophyte species that can be used for alternative aquaculture feed found in Bintulu. It is also to generate a species list of aquatic macrophytes for further research and knowledge purposes.



CHAPTER 2

2 Literature Review

2.1 Aquatic macrophytes

Aquatic macrophytes are plant that has adapted to aquatic environment and are usually classifies them in four group systems which is emergent, floating, free-floating and submerged macrophytes. Macrophytes carries great importance towards aquatic ecosystem. Aquatic macrophytes are a key component for sustaining bird and insect communities in freshwater ecosystems (Scheffer, 2004; Bilton et al., 2006). Understanding the mechanisms that maintain macrophyte diversity in water sources is essential because they may serve as a sign for the preservation of the water sources biodiversity. Other benefits of aquatic macrophytes includes as an indicator of water quality for the water sources. Aquatic macrophytes can have a significant impact on habitat structure, fishability, recreational use, and nutrient dynamics where they are abundant. A problem with the water quality, such as elevated turbidity, herbicide use, or salinization, which all obstruct plant growth and development, may be the cause of the absence of macrophytes. High nutrient levels, however, can induce an overabundance of macrophytes, which can influence the health of the ecosystem, recreation facilities, and the aesthetic appeal.

Aquatic macrophytes are now largely use for water treatment especially in highly populated area due to higher pollution in the water sources. Various conventional are used to control the water quality in the water sources. Many studies by various

researchers had been conducted to improve the water quality through natural means to overcome this problem. Boyd (1970a), Conwell et al. (1977), Scheffield (1967), Stewart (1970), Wooten and Dodd (1976) and Yount (1964) were among the pioneers to demonstrate the nutrient removal potential of aquatic plants. Seidal (1976), Wolverton and McDonald (1975, 1976), and Wolverton and Mckown (1976) experimentally proved the importance of aquatic plants in removing organic contaminants from aquatic environments. Boyd (1970a) observed that aquatic plants are suitable for wastewater treatment because they have tremendous capacity of absorbing nutrients and other substances from the water and hence bring the pollution load down.

2.2 Aquatic macrophyte habitat

In inland freshwater or brackish waterbodies, aquatic macrophytes are defined as "aquatic photosynthetic organisms, large enough to see with the naked eye, that actively grow permanently or intermittently submerged below, floating on, or up through the water surface (Chambers et al., 2008). Temporary and ephemeral waterbodies are more open to debate regarding their status as macrophyte habitats, but permanent inland waterbodies (including lakes, rivers, canals, reservoirs, and other inland waters that rarely, if ever, dry up) are self-evidently potential macrophyte habitats (Lukács et al., 2013). Aquatic macrophytes are generally assumed to show mostly broad world distributional ranges (Cook, 1985; Santamaría, 2002; Les et al., 2003).

2.3 Aquatic macrophyte life cycle

Although floating-leaved plants have a much lower biomass and a leaf area index that rarely exceeds $2\text{m}^2\text{m}^{-2}$, their photosynthetic capacity is still comparable to that of terrestrial herbaceous plants. Their relatively low accumulation of biomass is correlated with a higher rate of leaf biomass turnover or a shorter foliar life span. Floating leaves have a shorter life span than any other group of herbaceous macrophytes, typically between 13 and 35 days, according to the research. Due to the high availability of resources like light, water, and carbon, floating-leaved plants exhibit high photosynthetic rates despite having low biomass. Therefore, it is logical to assume that the biomass turnover rate is significantly higher than for other macrophyte groups. The high rate of biomass turnover of floating-leaved plants is probably significantly influenced by the high rates of leaf birth and loss. Leaf life span of *Hydrocharis dubia* was the shortest, while that of plants having a large number of roots is relatively long. The longest value, 55 days, reported for *Nymphaea tetragona* Georgi in a culture pot (Kunii 1988)

2.4 Aquaculture food

Aquaculture feeds are mainly produced with animal source protein. However, due to the increase in demand and price for animal source protein there are many research done to find an alternative source of protein in which to reduce the cost of feed while still giving enough protein from plant-based protein. In 2015, the soybean global production has increase exponentially due to the increase in demand. This is due to its high protein content which makes it a suitable alternative other than fish meal. It is considered the best protein source of

vegetal origin due to good protein content (40–51%), good amino acids profile, high digestibility and low cost (Zhou & Yue 2012; Ng & Romano 2013; Özkan et al. 2015).

Fish feeds represent over 50% of the total operating cost in intensive aquaculture. Studies has been conducted on the use of aquatic plant as an alternative food for fishes. For example, El-Sayed (1992) evaluated *Azolla pinnata* as a fishmeal replacer for Nile tilapia fingerlings and adults respectively, at 0–100% substitution levels. He found that fish fed with *Azolla pinnata* showed extremely poor performance even at the lowest inclusion level (25%). In contrast, Naegel (1997) found that up to 30% of FM-based diet fed to Nile tilapia could be successfully replaced with dried azolla meal.

2.5 Fish species

Herbivorous fish have a limited capability for converting organic material into biological matter and removing excess nutrients from the system. Herbivorous fish have a limited ability to convert plant material into animal tissue and to remove excess nutrients from the system. But being relatively efficient grazers and inefficient assimilators, they may play a significant part in initiating the internal, biologically mobilized nutrient source, or accelerate their recirculation (Prejs, 1984). Although there is high abundance of macrophytes and microalgae in many freshwater bodies, there are only a few herbivorous fish species taking advantage of these resources. Among them are silver carp (*Hypophthalmichthys molitrix* Val.), grass carp (*Ctenopharyngodon idella* Val.), African tilapia species and, to a lesser extent, also European roach (*Rutilus rutilus* L.) and rudd (*Scardinius erythrophthalmus* L.) (Niederholzer and Hofer, 1979). Other than

this herbivorous species, there are omnivorous fish that are able to utilize food source from various source for example Nile Tilapia (*Oreochromis niloticus*).
(Species in malaysia)

2.6 Fish Meal

Fish meal is a source of protein which is the most important nutrient for fish growth. It is also the costliest. Dietary protein is an essential but most expensive nutrient in fish diets that directly affect fish growth, feed intake and feed costs (Halver and Hardy,2004; Lee et al.,2002). Sufficient amount of protein is important for the fish as insufficient amount may cause health problems such as stunted growth and mortality. Too much feeding is also harmful for the fish as it can make the diet unbalanced and may result in extra feed costs, nitrogen excretion and aquatic pollution (Alam et al.,2008). Hence, it is important to make the feed with optimum quantities for the good of the fish and also to lower the cost.

2.7 Target Species

Scientific name	Country	Location found	Organism consuming this as feed	Characteristics	Benefit/nutritional content	Reference
<i>Lemna Minor</i>	Malaysia	Paya Indah Waterl and	Fish	Floating	The production was significantly higher in ponds with supply of duckweed than that of the ponds without supply of duckweed in monoculture of tilapia.	Bornali, 2004; Uddin et al., 2007; Chowdhury et al., 2008
<i>Azolla pinnata</i>	Malaysia	Paya Indah Waterl and	Tilapia	Floating	<i>A. pinnata</i> could be a sustainable alternative option to save the cost of Thai silver barb production and offer high-profit margins.	Mousami et al. 2018
<i>Eichhornia Crassipes</i>	Malaysia	Paya Indah Waterl and	Bivalve, Crustacean, Grass carp	Floating	The removal efficiency of Water Hyacinth was higher due to the biomass production.	Alvarado et al., 2008
<i>Ipomoea aquatica</i>	Malaysia	Pahang, Perak, Selangor or Wetland	Fish	Floating	The fish exhibited substantial improvement in growth when reared on feed supplemented by fermented plant ingredients	Bairagi et al., 2002, Ramachandran and Ray, 2007, Roy et al., 2014
<i>Nelumbo nucifera</i>	Malaysia	Pahang, Perak, Selangor or Waterl and	Fish	Floating	<i>Nelumbo nucifera</i> plant extract can improve fish growth and feed utilization efficiency.	Munglue et al 2014

<i>Wolffia globosa</i>	Malaysia	Selangor or Waterl and	Fish	Floating	<i>Wolffia sp.</i> should be used in improving the nutritional quality of practical feed of fish because more growth and good body composition gave in <i>L. rohita</i> fingerlings.	Sein et al 2020
<i>Pistia stratiotes L.</i>	Malaysia	Selangor, Penang,		Floating	The high starch, carbohydrate and lipid also supports the candidature of weeds as feedstock for bioenergy production.	Gusain & Suthar et al 2017



Figure 2.1 : A



Figure 2.2 : B



Figure 2.3 : C



Figure 2.4 : D

CHAPTER 3

Materials and Methods

3.1 Study Site

This study has been conducted in Bintulu, Sarawak. The study area has a lot of vegetation due to the numerous water bodies around the area. There are a number of lakes, pond and streams in the area. Therefore, this site is used for the study.

Table 3.1 List of sampling location

Station	Location	Coordinate
1	UPMKB AREA	- 3.2114272 N, 113.0910046 E
	- Recreation Pond	- 3.2078196 N, 113.0751575 E
	- Waterfall	- 3.2105719 N, 113.0823780 E
	- Hatchery	
2	Taman Muhibbah	3.2286771 N, 113.0733842 E
3	Kidurong Height	3.2208815 N, 113.0661161 E
4	Jalan Sebaru	3.164464 N, 113.079217 E
5	Kg Penan Muslim Bt10	3.213903 N, 113.143290 E



Figure 3.1 Map showing the study area (in yellow circle) located in Bintulu, Sarawak. (Source: Google Earth)

3.2 Sample collection

The sampling take place at the area mentioned in table 3.1.1. The sample was taken using different equipment according to macrophyte type. For floating types, the plants are taken using a fish net. For emergent and submergent plants, the plants are taken by hand if the water is shallow and using fish net with a long pole if the water is deep. The plants are taken as a whole to maintain its survivability. The samples are taken with quantity ranging from five to ten depending on the size and species. For example, *Azolla pinnata* will be taken 10 pieces but *Eichhornia crassipes* will be taken only 5 pieces. One of each species are used as herbarium preparation while the other pieces will be kept in tank with the experimental fish, *Oreochromis niloticus* to see if the plants can be used as an alternative aquaculture feed.

3.3 Laboratory preparation

After the sampling is done, the macrophytes taken will be put in aquarium according to its species. The aquarium was filled with tap water and anti-chlorine is used to treat the water to avoid the plants or the fish to die. The aquarium will also fill 1/10th with soil as a substrate and also to provide nutrients and support for the macrophytes. The aquarium will be place near the window to have sunlight for photosynthesis.

3.4 Herbarium preparation

Each species taken from sampling will have one piece used for herbarium preparation. The samples are first cleaned thoroughly to discards any soils or rotten part of the macrophytes. After cleaning, the samples are wipe dry using tissues before placing it on the plant press. The samples are put in between three layers of paper to absorb excess moisture. The plant press was tied tightly to press

the samples and remove the moisture from the plant. The finished specimen will be kept in the oven for two to three days with the temperature of 60°C. After the samples have dried completely, it was pasted on herbarium papers after which the samples will be labelled with its scientific names, common name and the place it was sampled.

3.5 Identification of Aquatic Macrophyte

The information on the aquatic macrophytes during sampling will be recorded. The identification of macrophytes species that has been taken was done by using the book “Pictorial Guide To Common Weeds Of Plantations And Their Control” and mobile applications such as Google Lens and PictureThis – Plant Identifier

3.6 Live culture maintenance

To maintain the specimen, the natural habitat was replicated such as putting substrate and placing it nearby the window to give enough sunlight for the plants to do photosynthesis. Each sample taken was put in separate containers and thoroughly cleanse before putting it in the aquarium. This process is to avoid damaging the plants thus can maintain its life span.

3.7 Database preparation of Freshwater Aquatic Macrophyte.

The database preparation of Freshwater Aquatic Macrophyte is documented using Microsoft Access. The data from previous collector can be updated and added in the recent research. The database can be used to identify and classify aquatic macrophyte. The previous database from AKU3106 Aquatic Botany students of semester 2 2021/2022 is used during this research to help locating the location to

find aquatic macrophytes. The detail of database contains the scientific name, common name of the aquatic species, date of sampling, name of the collector, herbarium photograph of the sample, and list of aquatic macrophytes suitable for aquaculture food. Other than that, the information from the data is also used for future research and references.

3.8 Calculation of suitable aquatic macrophyte for alternative aquaculture feed

The percentage of suitable aquatic macrophytes for alternative aquaculture feed will be calculated by using this formula

$$\text{Species suitable for aquaculture feed} / \text{total species} \times 100 = \text{percentage of species}$$

3.9 Method to determine the suitability of aquatic macrophyte as alternative feed

To determine the suitability of the aquatic macrophyte species as an alternative aquaculture feed, numerous scientific articles were used. The article related to the species collected were searched and evaluated to ensure that the species was suitable for aquaculture feed. Other than that, online advertisements on aquatic macrophytes were also used to determine the species suitable for aquaculture feed.

There are numerous advertisements on social media and e-commerce proved that some aquatic macrophyte species are suitable for alternative aquaculture feed for example *Azolla pinnata*, *Lemna minor*, *Hydrilla sp.* which are widely used for ornamental fish and some crustaceans.

CHAPTER 4

Results

4.1 Aquatic Macrophytes found in Bintulu, Sarawak.

A total of 8 species of aquatic macrophytes was obtained from the study area.

There is 1 species from Sebaru Road (3.164264°E,113.070264°N); *Lemna minor*,

1 species from Muhibbah Lake (3.212108°E,113.055260°N); *Ceratophyllum*

demersum , 1 species from Road Tun Dato Haji Bujang lake

(3.229015°E,113.073336°N); *Hydrilla verticillata* , 2 species from Penan muslim

village pond Bt10 (3.222763°E,113.145221°N); *Azolla pinnata* , *Lemna* , 1

species from Department pond UPMKB (3.205303°E, , 113.092905°N);

Hydrocharis morsus-ranae , 1 species from Waterfall park UPMKB (3.207714°E,

, 113.075090°N); *Nymphaeaceae pubescens* , and 1 species from Road Tun Dato

Haji Bujang lake (3.228848°E, , 113.073512°N); *Nymphaeaceae pubescens* .

Table 4.1 List of aquatic macrophytes from Bintulu, Sarawak

NO	SCIENTIFIC NAME	COMMON NAME	LOCATION
1	<i>Lemna minor</i>	duckweed	Road sebaru
2	<i>Ceratophyllum demersum</i>	Hornwort	Muhibah lake
3	<i>Hydrilla verticillata</i>	waterthyme	Road Tun Dato Haji Bujang lake
4	<i>Azolla pinnata</i>	azolla	Penan muslim village pond bt10
5	<i>Lemna minor</i>	duckweed	Penan muslim village pond bt10
6	<i>Nymphaeaceae pubescens</i>	Water lily	Waterfall park UPMKB
7	<i>Nymphaeaceae pubescens</i>	water lily	Road Tun Dato Haji Bujang lake
8	<i>Hydrocharis morsus-ranae</i>	Frogbits	Department pond UPMKB



Figure 4.1 Fresh sample collected from Bintulu, Sarawak.

Table 4.2 List of sample collected and scientific classification



Figure 4.2 : *Lemna minor*

Kingdom : Lemna minor

Class : Plantae

Superorder : Lilianae

Order : Alismatales

Family : Araceae

Genus ; *Lemna L.*



Figure 4.3 : *Ceratophyllum demersum*

Superoder :Ceratophyllanae

Order : Ceratophyllales

Family : Ceratophyllaceae - hornwort

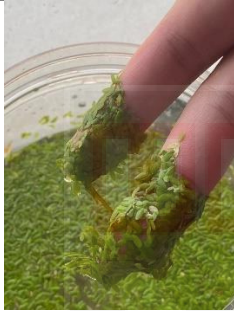
Genus ; *Ceratophyllum L.*

Species *Ceratophyllum demersum L.* - Coonstai



Superoder : Lilianae
Order : Alismatales
Family : Hydrocharitaceae
Genus ; Hydrilla Rich
Species : *Hydrilla verticillate* (L.F) Royle

Figure 4.4 :
Hydrilla verticillata



Kingdom : Lemna minor
Class : Plantae
Superorder : Lilianae
Order : Alismatales
Family : Araceae
Genus ; *Lemna L.*

Figure 4.5 : Lemna minor



Subclass : Polypodiidae
Order : Saluinales
Family : Azolla ceae
Genus : *Azolla Lam.*
Species : *Azolla pinnata* R.Br – Mosquito fern

Figure 4.6 : Azolla pinnata



Superoder : Lilianae
Order : Alismatales
Family : Hydrocharitaceae – frog's bit
Genus ; *Hydrocharis L.*
Species : *Hydrocharis morsus-ranae L.* – common frogbit

Figure 4.7 :
Hydrocharis morsus-ranae



Figure 4.8 :
Nymphaeaceae
pubescens

Kingdom : Plantae
Clade : Tracheophytes
Clade : Angiosperms
Order : Nymphaeales
Family :Nymphaeaceae
Genus : Nymphaea
Species : *N. pubescens*



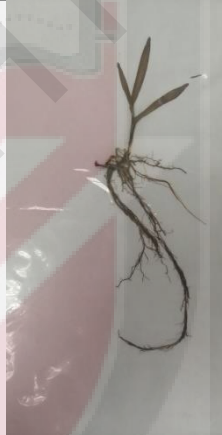


Figure 4.9 :
Nymphaeaceae
pubescens

Kingdom : Plantae
Clade : Tracheophytes
Clade : Angiosperms
Order : Nymphaeales
Family :Nymphaeaceae
Genus : Nymphaea
Species : *N. pubescens*

4.2 Database of aquatic macrophytes collected in Bintulu, Sarawak.

The database shows the aquatic species that have been collected throughout Bintulu. The database is from many other collectors including new samples this project has included as new data. A total of 79 aquatic macrophyte species were collected throughout the Bintulu area with only 11 species identified as suitable as alternative aquaculture feed

Table 4.3 Species found and list of used aquaculture feed

SCIENTIFIC NAME	COMMON NAME	LOCATION	HERBARIUM	USED AS AQUACULTURE FEED
<i>Isachne globosa</i>	oil grass, rounded isachne	Air Terjun UPMKB		
<i>Ipomoea triloda</i>	Kangkung	Air Terjun UPMKB		
<i>Fimbristylis globulosa</i>	Globular fimbristylis, globe fimbry	Air Terjun UPMKB		

Fuirena umbellate
Rottb

Hairy blue
sedge

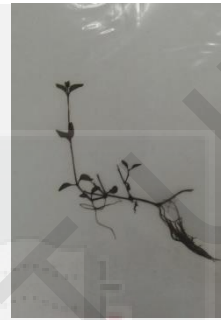
Air Terjun
UPMKB



*Lindernia
Crustacea*

Malaysian
false
pimperne

Air Terjun
UPMKB



*Fimbristylis
acuminate*

Pointed
fimbristylis

Air Terjun
UPMKB



Leucobryum sp.

Lumut

Air Terjun
UPMKB



*Cyperus
sanguinolentus*

Purple-
glume flat
sedge

Air Terjun
UPMKB



*Torenia
polygonoides*

Malayan
eyebright

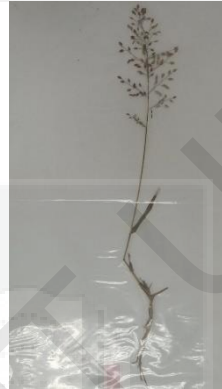
Air Terjun
UPMKB



*Eragrostis
unioloides*

Chinese
lovegrass

Air Terjun
UPMKB



*Eleocharis
ochrostachys*

Puron

Air Terjun
UPMKB



*Lycomodium
cernuum*

Rumput
Serani,
Rumput
kenarus

Air Terjun
UPMKB



Nymphaea nauchali

Waterlily

Air Terjun
UPMKB



Utricularia aurea

Lumut

Parit Airport
Lama,
Bintulu



Hydrilla verticillata

waterthyme

Parit Airport
Lama,
Bintulu



✓

Phyllanthus debilis

Niruri

Parit Airport
Lama,
Bintulu



Eleocharis acutangula

Rumput

Parit Airport
Lama,
Bintulu



Eriocaulon longifolium

Rumput
bebola api

Parit Airport
Lama,
Bintulu



Nephrolepis biserrata

Broad sword
fern

Kolam
Bintulu



Cyperus brevifolius

Greater
kyllingia

Kolam
Bintulu



*Echinochloa
colonum*

Jungle rice

Kolam
Bintulu



Mimosa pudica

Touch-me-
not

Kolam
Bintulu



Eclipta prostrata

Keramak

Kg. Sg.
Seterus-
Kuala Tatau,
Bintulu



*Eriocaulon
longifolium*

Rumput
butang

Tanjung
Kidurong
Mining,
Bintulu



Eleocharis dulcis

Chinese
water
chestnut,
ground
chestnut, Ubi
puron

Tanjung
Kidurong
Mining,
Bintulu



Eleocharis genicula

Canada
Spikeweed

UPMKB
library area



Thalictrum pubescens

Tall meadow-
rue

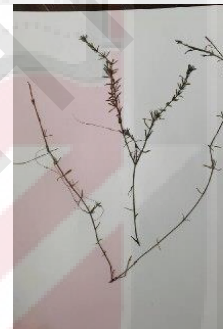
UPMKB
library area



Elodea canadensis

Canada
Waterseed

Bintulu
Stadium



Cyperus esculentus

Yellow
nutsedge

Bintulu
Stadium area



Cabomba caroliniana

Carolina
water - shield

Bintulu
Stadium
Area



Asystasia gangetica

Chinese violet

Bintulu Stadium Area



Eleocharis schoenoides

Marsh dweller

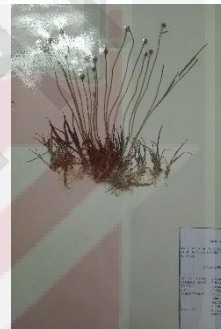
Reservoir UPMKB



Eriocaulon cinereum

Babawangan

At the bank of the lake on the terrestrial



Blyxa auberti Rich

Ulam pelamah

Kolam



Digitaria fuscescens

Rumput

Parit Jepak



Hydrilla verticillate

waterhyme

Taman
Tumbina
Bintulu



✓

Desmodium triflorum

Rumput
berek sisik
putih

Taman
Tumbina



Torenia polygonoides

Kerak nasi

Taman
Tumbina
Bintulu



Salvania molesta

Water fern

Jabatan sains
haiwan dan
perikanan,
UPMKB



Thalictrum pubescens

Tall meadow-
rue

Dewan
Kuliah,
UPMKB



Pilea microphylla

Artillery plant

Food Court,
UPMKB



Eclipta alba

False Daisy

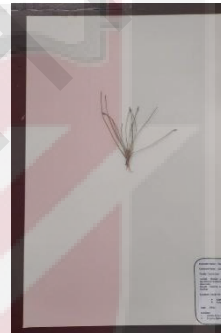
Dewan
Kuliah,
UPMKB



Eleocharis geniculata

Canada
spikesedge

Dewan Sri
Kenyalang,
UPMKB



Cyperus esculentus

Yellow
nutsedge

Stadium
Bintulu



Ericaulon cinereum

Pipewort

Stadium
Bintulu



Elodea canadensis

Canadian
waterseed

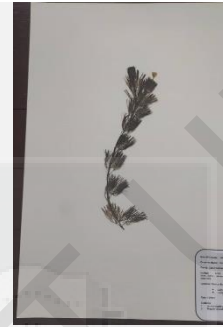
Stadium
Bintulu



*Cabomba
caroliniana*

Carolina
Spikesedge

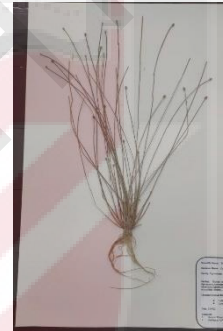
Stadium
Bintulu



*Eleocharis
geniculata*

Canada
spikesedge

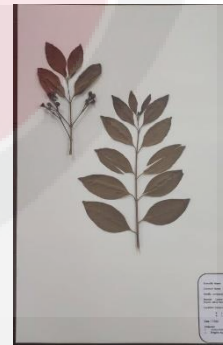
Stadium
Bintulu



*Volkameria
inermis*

Glory bower

Kampung
Jepak,
Bintulu



*Asystasia
gangetica*

Chinese
violet

Stadium
Bintulu



*Eleocharis
schoenoides*

Lalang

Ladang PPP,
UPMKB



Cyperus odoratus

Rusty
Flatsedge

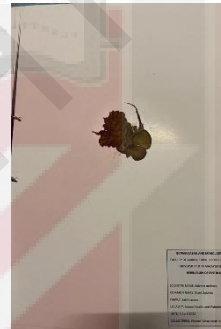
Ladang PPP,
UPMKB



Salvinia molesta

Giant salvinia

Animal
Health and
Fisheries
Department,
UPMKB



*Nymphoides
aquatica*

Banana lily

Ladang PPP,
UPMKB



Lemnoideae sp.

Duckweed

Animal
Health and
Fisheries
Department,
UPMKB



Digitaria fuscescens

Yellow crab
grass

Stadium
Bintulu



Ipomea aquatica

Kangkung,
Water
spinach

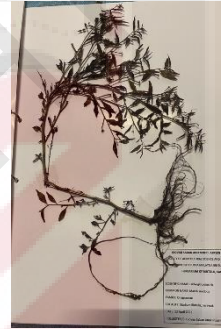
Kampung
Jepak,
Bintulu



Lugwigia palustris

Marsh
Seedbox

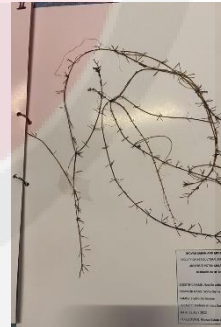
Stadium
Bintulu



Hydrilla verticillata

Waterhyme

Stadium
Bintulu



*Ceratophyllum
demersum*

Hornwort
coontail

Stadium
Bintulu



Tridax procumdes

Tridax daisy

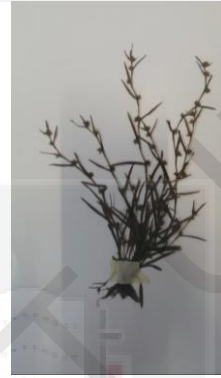
Stadium
Bintulu



*Eleocharis
montevidensis*

Sand
spikerush

TPU,
UPMKB



*Halimeda
macroloba*

Coralline
alga

TPU,
UPMKB



*Selaginellaceae
kraussiana*

Mat spike-
moss

TPU,
UPMKB



<i>Laminaria flexicaulis</i>	Oarweed	Kampung Jepak, Bintulu, Sarawak	
<i>Carex leptalea</i>	Bristly-stalked sedge	TPU, UPMKB	
<i>Hydrocleys nymphoides</i>	water poppy	TPU, UPMKB	
<i>Acrosiphonia arcta</i>	Green Tarantula Weed	Stadium Bintulu, Sarawak	

<i>Cryptocoryne nurii</i>	Ruffle Sword Ruffle	Stadium Bintulu, Sarawak		
<i>Cyperus odoratus</i>	fragrant flatsedge	Kampung Jepak, Bintulu, Sarawak		
<i>Ludwigia palustris</i>	marsh seedbox	Kampung Jepak, Bintulu, Sarawak		
<i>Lemna minor</i>	duckweed	jalan sebaru		✓

<i>Ceratophyllum demersum</i>	Hornwort	Tasik muhibah		✓
<i>Hydrilla verticillata</i>	waterhyme	Tasik jalan tun dato hj Bujang		✓
<i>Azolla pinnata</i>	azolla	Kolam kg penan muslim bt10		✓
<i>Lemna</i>	duckweeds	kolam kg penan muslim bt10		✓
<i>Nymphaeaceae pubescens</i>	Water lily	Taman air terjun UPMKB		

<i>Nymphaeaceae pubescens</i>	water lily	Tasik jalan tun dato haji bujang	
<i>Hydrocharis morsus-ranae</i>	Frogbits	Kolam jabatan UPMKB	

The table shows the database for the aquatic species that has been gathered throughout Bintulu. The database is from many other collectors including new samples of herbarium. A total of 79 aquatic macrophyte species has been collected throughout the Bintulu area with only 11 species identified as suitable as an alternative aquaculture feed. Only 14% of the total species collected is deemed suitable.

$$\text{Species suitable for aquaculture feed} / \text{total species} \times 100 = \text{percentage of}$$

$$11/79 \times 100 = 14\%$$

4.3 Biodiversity of Aquatic Macrophytes suitable for aquaculture feed found in Bintulu, Sarawak

The aquatic macrophytes species collected has multi range of biodiversity. There are species that float, emergent and submergent near the water bodies of the site collection. During the collection, the location was observed as to see what types of biodiversity that is suitable for the aquatic macrophytes. For example, the *Lemna sp.* is found at a swamp with a lot of decomposing matters. *Lemna sp.* can grow at a very quick pace, hence the need for nutrition is higher. Other than that, it is a floating aquatic macrophytes. If the water in the location is lacking of

nutrient, it will not reproduce as much as the location where the nutrient in the water is higher since the roots are in the water and not in the substrate. Unlike *Hydrilla sp.* that has been found, the clear water is needed for it to thrive as it needs to do the photosynthesis process. *Hydrilla sp.* is a submergent aquatic macrophyte, the roots are grounded to the substrate in the water bodies hence the nutrient can be absorbed directly from the substrate. *Nymphaea pubescens*, water lily is an emergent plant. This type of aquatic macrophyte can usually be found in the lake or slow flowing water bodies and open area with a lot of sunlight. The diverse location of the aquatic macrophytes also helps in identifying the types of aquatic macrophytes that can be found as observed during the sample collection.

4.4 Ways to determine the species is used for live feed

To determine the suitability of the aquatic macrophytes as aquaculture feed, we have gathered numerous info from research papers, aquaculture farmers, social media such as Facebook and also online shopping platform like Shopee.

Table 4.4 List of macrophytes found in Bintulu that are suitable as live feed from literatures.

Scientific name	Ways to determine
<i>Hydrilla verticillata</i>	<p>Sutton, D. L., Vandiver, V. V., & Hill, J. (1986). <i>Grass carp: A fish for biological management of hydrilla and other aquatic weeds in Florida</i>. Gainesville: University of Florida.</p> <p>The research used grass carp with sufficient stocking density to control aquatic weeds. From the research, it has shown that <i>Hydrilla verticillata</i> has the highest preference for the grass carp to feed on.</p>
<i>Ceratophyllum demersum</i>	<p>Hajra, A. (1987). Biochemical investigations on the protein-calorie availability in grass carp (<i>Ctenopharyngodon idella</i> Val.) from an aquatic weed (<i>Ceratophyllum demersum</i> Linn.) in the tropics. <i>Aquaculture</i>, 61(2), 113-120.</p> <p>The research used <i>Ceratophyllum demersum</i> as feed for two stages of grass carp fingerlings. The 'feed merit' of the aquatic weed was poor, which might be due to the lesser supply of</p>

	digestible dry matter and protein-calorie to grass carp on voluntary intake (Hajra, 1987).
<i>Ipomoea aquatica</i>	Mandal, R. N., Saha, G. S., Kalita, P., & Mukhopadhyay, P. K. (2008). <i>Ipomoea aquatica</i> —an aquaculture friendly macrophyte. <i>Aquaculture Asia</i> . Nutritional analysis of <i>Ipomoea aquatica</i> has shown that it contains high amount of crude protein and organic matter, along with low amount of crude fibre, making it a suitable potential aquaculture feed content (Mandal, 2008).
<i>Azolla pinnata</i>	Das, M., Rahim, F. I., & Hossain, M. A. (2018). Evaluation of fresh <i>Azolla pinnata</i> as a low-cost supplemental feed for Thai Silver Barb <i>Barbonymus gonionotus</i> . <i>Fishes</i> , 3(1), 15. Aquatic fern <i>Azolla pinnata</i> comprises significant high food value with a good proportion of protein, vitamins, and minerals (Das et al., 2018)
<i>Lemna sp.</i>	Sońta, M., Rekiel, A., & Batorska, M. (2019). Use of duckweed (<i>Lemna L.</i>) in sustainable livestock production and aquaculture—a review. <i>Annals of Animal Science</i> , 19(2), 257-271. Duckweed is commercially produced mainly in tropical countries, where meal is produced from it after dehydration and deoiling (Haustein et al., 1994; Bairagi et al., 2002).
<i>Hydrocharis morsus-ranae</i>	Facebook and E-commerce platform This aquatic macrophyte is advertised that it can be used as aquaculture feed for crayfish.

CHAPTER 5

5 Discussion

Bintulu has diverse water bodies which makes it a great location for this research. From this location we have gathered many types of aquatic macrophytes and classify them into suitable and non-suitable aquatic macrophyte for aquaculture feed. Although not all the aquatic macrophytes are suitable to substitute commercial aquaculture feed, but suitable species may help farmers to reduce the cost of feed by mixing the aquatic macrophytes with the commercial feed. Out of 79 species collected, only 14% were suitable to be used as alternative aquaculture feed. The aquatic macrophyte species are suitable for culturing herbivorous fish such as grass carp and may also used for omnivorous fish such as Nile tilapia. Other than that, it is also suitable for crustaceans such as crayfish because most crustaceans are scavenger hence it may eat any biological matter.

Further research may be conducted using the aquatic macrophyte classified in the database to further evaluate the suitability of the aquatic macrophyte as aquaculture feed. Nutrient analysis towards each of the species is important as the first step to ensure the species is suitable. For example, the *Ipomoea aquatica* has shown that its nutrient analysis prove that it is suitable for aquaculture feed due to its high crude protein and minerals also with low crude fibre (Mandal, 2008).

Moreover, the species collected may not be efficient if used raw. Some of the species may need to be processed to ensure that it can be used as aquaculture feed such as duckweed where meal is produced from it after dehydration and deoiling (Haustein et al., 1994; Bairagi et al., 2002). In research done by Cruz-Velásquez in 2014 on evaluation of *Cachama blanca* and *Oreochromis niloticus* fed with fermented aquatic plant in a polyculture all of the production parameters appeared to be unaffected by the substitution

with duckweeds. As a result, it is highly recommended as a less expensive feed component in rural production.



CHAPTER 6

6 Conclusion

- In conclusion, the species of aquatic macrophytes in Bintulu can be collected, identified and classified for its suitability as an aquaculture feed. A total of 79 aquatic macrophyte species has been collected throughout the Bintulu area with only 11 species identified as suitable as an alternative aquaculture feed. While for self collection, a total of 8 species is collected and six species is suitable for alternative aquaculture feed. The database for aquatic macrophytes has also been updated by this research. Further research may be conducted with the help of this research

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