DISTRIBUTION AND COMPOSITION OF PLANT SPECIES WITH SPECIAL REFERENCE TO WEEDS IN TEMENGOR LAKE, PERAK

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2013

DISTRIBUTION AND COMPOSITION OF PLANT SPECIES WITH SPECIAL REFERENCE TO WEEDS IN TEMENGOR LAKE, PERAK

By

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Thesis submitted in the fulfilment of the requirements for the degree of Master of Science

OKTOBER 2013

ACKNOWLEDGEMENT

In the name of Allah, the Most Gracious and the Most Merciful. Alhamdulillah, all praises to Allah for the strengths and His blessing for me to complete the research in fulfilment of the requirement for the degree of Master of Science.

First of all, special appreciation goes to my supervisor, Prof Dr. Mashhor Mansor and my co-supervisor, Dr. Asyraf Mansor for their constant guidance, supervision and encouragement, valuable advice and suggestions throughout my duration of study until the day the thesis is completed.

I would like to express my appreciation to Dr. Zarul Hazrin Hashim, Mr. Mohd Rashid Othman, Mr. Mohd. Syaiful Mohammad, Mr. Ahmad Najmi Nik Hassan and Mr. Yahya Tahir who always have helped me for the field sampling, analyses and writing task. Sincere thanks are also extended to the late Mr. Ganesh for plant identifications and also to Tan Sri Mustapha Kamal from Pulau Banding Foundation who gave me the opportunity to conduct the research. Unforgettable deepest thanks to all my colleagues and also the support staffs in School of Biological Sciences for their endless help and moral encouragement. This research is sponsored by grant account 1001/PBIOLOGI/815070 and 1001/PBIOLOGI/816217.

Last but not least, I acknowledge my sincere indebtedness and gratitude to my parents; Mr. Ab. Razak bin Yusof and Mrs. Foziah binti Yaacob for the unconditional support, love and encouragement to pursue my interest. I appreciate all the parties above and thank you very much. May Allah bless all of us.

Nadia Ab. Razak.

TABLE OF CONTENT

ACKNOWLEDGEMENT **ii**

TABLE OF CONTENT **iii**

LIST OF TABLES **vii**

LIST OF FIGURES **viii**

LIST OF APPENDICES **x**

LIST OF SYMBOLS AND ABBREVIATIONS **xi**

ABSTRAK **xii**

ABSTRACT **xiii**

CHAPTER 1: INTRODUCTION **1**

1.1 An overview of weed species distribution and composition at lake and river ecosystems 1

1.2 An overview of weed species distribution and composition in Malaysia 1

1.3 Importance of study 2

1.4 Objectives of study 3

CHAPTER 2: LITERATURE REVIEW **4**

2.1 An overview of lake ecosystems 4

2.2 An overview of river ecosystems 6

2.3 Weed species 7

2.3.1 Weed definition 7

2.3.2 Weed classification 8

2.4 Noxious weed species 11

2.4.1 *Mimosa pigra* 12

2.5 Weed species invasion 13

2.5.1 Invasion process 13

2.5.2 Weed species invasion at lake ecosystems 14

2.5.3 Weed species invasion at river ecosystems 15

2.5.4 Weed species invasion at the other ecosystems 16

2.5.5 Weed species invasion throughout the world 17

2.6 Weed species invasion effect on aquatic ecosystems 19

2.7 Soil factors 20

2.7.1 Textures 20

2.7.2 pH 21

2.7.3 Water content 21

CHAPTER 3: METHODS 23

3.1 Sampling sites 23

3.2 Sampling method 26

3.2.1 Weed sampling 26

3.2.2 Soils sampling 27

3.2.3 *Mimosa pigra* infestation sampling 28

3.3 Laboratory analysis techniques 28

3.3.1 Soils textures 28

3.3.2 Soils pH 29

3.3.3 Soils water content 29

3.4 Data analysis 30

3.4.1 Density 31

3.4.2 Frequency 31

3.4.3 Dominance 32

3.4.4 Important Value Index (IVI) 33

3.4.5 Richness Index 33

3.4.6 Diversity Index 33

3.4.7 Evenness Index 34

3.4.8 Kruskal-Wallis H Test 35

3.4.9 Cluster Analysis 36

3.4.10 Pearson Correlation 38

CHAPTER 4: RESULTS 40

4.1 Weed species composition generally 40

4.2 Weed species composition from the entire study areas 48

4.2.1 Family and species 48

4.2.2 Species presence 49

4.2.3 Weed cover percentages 52

4.3 Richness, Diversity and Evenness Index 70

4.3.1 Richness Index 70

4.3.2 Diversity Index 70

4.3.3 Evenness Index 70

4.4 Kruskal-Wallis H Test 73

4.5 Cluster Analysis 74

4.5.1 Disturbed areas 74

4.5.2 Pristine areas 74

4.5.3 All sampling sites 75

4.6 Soil factors 78

4.7 *Mimosa pigra* infestation at the river mouth of Enam River 82

4.7.1 High water level season 82

4.7.2 Low water level season 82

CHAPTER 5: DISCUSSION 86

5.1 Weed species composition generally 88

5.2 Weed species composition from the entire study areas 90

5.2.1 Disturbed areas 91

5.2.2 Pristine areas 92

5.3 Richness, Diversity and Evenness Index 94

5.4 Kruskal-Wallis H Test 96

5.5 Cluster analysis 96

5.5.1 Disturbed areas 96

5.5.2 Pristine areas 98

5.5.3 All sampling sites 101

5.6 Soil factors impact 102

5.7 *Mimosa pigra* infestation at the river mouth of Enam River 103

5.7.1 High water level 103

5.7.2 Low water level 105

CHAPTER 6: CONCLUSION 106

REFERENCES 108

APPENDICES 123

LIST OF TABLES

Table 2.1	Ten noxious weed in the Southeast Asia	11
Table 3.1	List of 20 sampling sites at Temengor Lake, Perak	25
Table 4.1	Recorded weed species based on type and class from 20 sampling sites	41
Table 4.2	Dominant weed species presence from 20 sampling sites based on percentages of weed species presence and Important Value Index	51
Table 4.3	Weed cover percentages according to Braun-Blanquet Scale (1932)	55
Table 4.4	Richness, Diversity and Evenness Index values at six disturbed areas	71
Table 4.5	Richness, Diversity and Evenness Index values at 14 pristine areas	72
Table 4.6	Shows the mean rank values of number of individuals of each weed species among 20 sampling sites	73
Table 4.7	Soil textures at all sampling sites at Temengor Lake	79
Table 4.8	Correlation between numbers of weed species presence, total number of individuals, soil pH and soil water content percentages in all sampling sites	79

LIST OF FIGURES

Figure 2.1	Four distinct zones in lake ecosystems	5
Figure 3.1	Location of 20 sampling sites at Temengor Lake, Perak	24
Figure 4.1	Number and percentage of weed species based on their classification	46
Figure 4.2	Noxious weed species presence at 20 sampling sites	46
Figure 4.3	Number of noxious weed species composition at 20 sampling sites	47
Figure 4.4	Number of weed species composition at 20 sampling sites	49
Figure 4.5	Weed species composition according to species presence	50
Figure 4.6	Cluster analysis dendogram at disturbed areas sampling sites	76
Figure 4.7	Cluster analysis dendogram at pristine areas sampling sites	76
Figure 4.8	Cluster analysis dendogram at all sampling sites	77
Figure 4.9	The soils pH mean (± SD) values at all sampling sites at Temengor Lake	80
Figure 4.10	The soils water content percentages (%) mean (± SD) values at all sampling sites at Temengor Lake	81
Figure 4.11	Water level was rising during high water level at the river bank and river mouth of Enam River	83

Figure 4.12	Low *Mimosa pigra* infestation at the river bank and river mouth of Enam River	83
Figure 4.13	Water level was decreasing during low water level at the river bank and river mouth of Enam River	84
Figure 4.14	High *Mimosa pigra* infestation at the river bank and river mouth of Enam River	84
Figure 4.15	The phenomenon of water level trigger the growth of *Mimosa pigra* population	85

LIST OF APPENDICES

Appendix A	Pictures taken during sampling period	123
Appendix B	Weed species	125
Appendix C	Soil textures	126
Appendix D	Curriculum vitae	127

LIST OF SYMBOLS AND ABBREVIATIONS

^{o}C	=	Degree Celsius
cm	=	centimetres
DI	=	Diversity Index
EI	=	Evenness Index
g	=	gram
H’	=	Shannon Index
ha	=	hectare
IVI	=	Important Value Index
kg	=	kilograms
km	=	kilometres
km^2	=	kilometres square
km^3	=	kilometres cube
m	=	metres
m^3	=	metres cube
ml	=	millilitres
mm	=	millimetres
n	=	Total number of individuals of each species in a sample
RI	=	Richness Index
S	=	Total number of species in a sample

TABURAN DAN KOMPOSISI SPESIES TUMBUHAN DENGAN PENGKHUSUSAN KEPADA RUMPAI DI TASIK TEMENGOR, PERAK.

ABSTRAK

Matlamat penyelidikan ini ialah untuk mengkaji corak taburan dan komposisi spesies rumpai di ekosistem sungai yang terpilih di Tasik Temengor, Perak. Kajian ini dijalankan pada 23 November 2011 sehingga 5 Oktober 2012 menggunakan kaedah transek garisan dan quadrat. Terdapat 20 kawasan kajian yang telah dikelaskan kepada dua kelas: kawasan terganggu (enam kawasan) dan tidak terganggu (14 kawasan). Ujian Kruskal-Wallis H menunjukkan terdapat perbezaan yang signifikan ($p<0.05$) dalam bilangan individu bagi setiap spesies rumpai yang hadir pada 20 kawasan kajian. Seratus sembilan puluh dua spesies rumpai direkodkan di kawasan terganggu manakala 183 spesies rumpai direkodkan di kawasan tidak terganggu. Skala peratusan litupan rumpai menunjukkan *Cyperus pilosus, Ludwigia hyssopifolia, Mikania micrantha* dan *Mimosa pigra* tinggi di kawasan terganggu manakala *Clidermia hirta, Melastoma malabatrichum* dan *Mikania micrantha* tinggi di kawasan tidak terganggu. Antara semua spesies rumpai yang dikenal pasti dan direkodkan, hanya sembilan spesies sahaja yang dominan berdasarkan peratusan kehadiran spesies dan Indeks Nilai Penting (IVI). Antara sembilan spesies ini, *Clidermia hirta* (75%, 477.81) dan *Mikania micrantha* (70%, 434.72) mencatatkan peratusan kehadiran spesies dan nilai IVI yang tertinggi iaitu masing – masing sebanyak 15 dan 14 kawasan kajian. Analisis Kluster menunjukkan persamaan faktor tanah, corak taburan dan komposisi spesies rumpai dan juga kehadiran spesies rumpai di antara kawasan kajian. Dua kluster utama dibentuk dan diikuti kluster yang terasing di setiap dendogram. Berdasarkan Korelasi Pearson, tiga korelasi postif dan tiga kolerasi negatif dibentuk antara jumlah spesies rumpai yang hadir, jumlah bilangan individu, pH tanah dan kandungan air tanah pada semua kawasan kajian. Populasi *Mimosa pigra* di muara Sungai Enam sangat padat sewaktu air surut berbanding air pasang.

DISTRIBUTION AND COMPOSITION OF PLANT SPECIES WITH SPECIAL REFERENCE TO WEEDS IN TEMENGOR LAKE, PERAK.

ABSTRACT

The aim of this research was to study the distribution and composition pattern of weed species at selected rivers in Temengor Lake, Perak. This study was conducted from 23rd November 2011 to 5th October 2012 by using line transect and quadrat methods. There were 20 sampling sites which were classified into two classes; disturbed (six sites) and pristine (14 sites) areas. Kruskal-Wallis H Test, indicated that there was significant differences ($p<0.05$) in the number of individuals for each weed species presence in the 20 sampling sites. One hundred and ninety two weed species were recorded at disturbed areas whereas 183 weed species were recorded at pristine areas. Weed cover percentages scale showed that *Cyperus pilosus, Ludwigia hyssopifolia, Mikania micrantha* and *Mimosa pigra* were the highest at disturbed areas whereas *Clidermia hirta, Melastoma malabatrichum* and *Mikania micrantha* were the highest at pristine areas. Among all weed species identified and recorded, nine species were considered as dominant species based on species presence percentages and Important Value Index (IVI). Among these nine species, *Clidermia hirta* (75%, 477.81) and *Mikania micrantha* (70%, 434.72) recorded the highest species presence percentages and IVI values in 15 and 14 sampling sites, respectively. Cluster Analysis revealed the similarities of soil factors, distribution and composition pattern of weed species and weed species presence between the sampling sites. Two main clustered were formed which then followed by isolating groups in each dendogram. Based on Pearson Correlation coefficient, there were three positive and three negative correlations between the numbers of weed species presence, total number of individuals, soil pH and soil water content in all sampling sites. *Mimosa pigra* infestation was highly populated at the river mouth of Enam River during low water level compared to high water level period.

CHAPTER 1

INTRODUCTION

1.1 An overview of weed species distribution and composition at lake and river ecosystems

Lake and river ecosystems were highly infested and dominated by weed species population (Wild, 1961; Boughey, 1963; Little, 1966; Holm *et al.*, 1969; Lagler, 1969; Mitchell, 1969; White, 1969; Lawson, 1970; Mitchell, 1973; Baki, 1982; Mansor *et al.*, 1983; Mansor, 1996; Naylor and Lutman, 2002; Marambe *et al.*, 2004; Samouth, 2004; Triet *et al.*, 2004; Travnick, 2008 and Mansor and Crawley, 2011). In addition, weed species were highly and seriously invading contaminated and disturbed areas as reported by Connell (1978), Huston (1979), Miller (1982), Haslam (1987), Smith (1992), Lonsdale (1999), Naylor and Lutman, (2002), Ough (2002), Parson and Cuthbertson (2004), Lindenmayer (2009), Mansor and Crawley (2011) and Romanowski (2011). Weed distribution and composition are usually found in the contaminated water bodies, rivers and streams due to the pollution from industry or anthropogenic activities (Ough and Murphy, 2004 and Briggs, 2009). Many weed species were able to spread widely in disturbed lake and river ecosystems including introduced species (Whelan, 1995 and Mabey (2010),).

1.2 An overview of weed species distribution and composition in Malaysia

Although there are several studies on the weed species composition and distribution in Malaysia including Azmi and Anwar (1988), Azmi and Supaad (1986), Sahid

(1989), Azmi (1991), Mansor (1994), Mansor (1996), Mansor (2001), Mansor and Crawley (2011) and Chauhan (2012), however, there are still limited studies on the weed species composition and distribution at different river and lake ecosystems since most of the findings were focused on the agriculture area such as paddy fields. Therefore, a study on the distribution and composition of weed species at selected river ecosystems in Temengor Lake, Perak was initiated.

1.3 Importance of study

They have been many reports and findings on the worst effects of weed species infestation and population at lakes and rivers throughout the world (Farb, 1971; Gangstad, 1978; Swarbick and Mercado, 1987; Nebel, 1993; Marambe *et al.*, 2000; Petr, 2000; Samouth, 2004; Sulistyawan and Hartono, 2004; Triet *et al.*, 2004; Mansor, 2010; Tumbare, 2010 and Govorushko, 2012) which contribute to the unhealthy ecosystems. Thus, this research was conducted to study the distribution and composition of weed species at Temengor Lake. In addition, this study focused on disturbed areas such as logging, recovered logged and anthropogenic activities and also pristine areas which have no disturbance at all. This study also includes the population and infestation of *Mimosa pigra* at the river mouth of Enam River, Temengor Lake. Since this gigantic sensitive plant was aggressively dominated and established well along Mekong River which contributes to unhealthy ecosystems, thus their populations at Temengor Lake need to be monitored. This noxious species and as well as other weed species might contribute negative effect on Temengor Lake ecosystem if no well control and manage. Therefore, the importance of this study is to investigate risky and harmful weed species distribution and composition

patterns at selected river ecosystems which also influence by soil factors such as texture, pH and water content at Temengor Lake, Perak.

1.4 Objectives of study

There were three objectives in order to investigate weed species distribution and composition patterns at selected river ecosystems at Temengor Lake:

(i) To study and compare the distribution and composition of weed species between disturbed and pristine areas.

(ii) To correlate between soil pH and soil water content percentages with the distribution and composition of weed species.

(iii) To study *Mimosa pigra* infestation at the river mouth of Enam River during high water level and low water level.

CHAPTER 2

LITERATURE REVIEW

2.1 An overview of lake ecosystems

There are 12 million estimated lakes on earth with total area of 2,700,000 km^2 and 166,000 km^3 of total volumes. There are 33% of the area and as much as 90% of volume in lake of the corresponding world (Kuusisto and Hyvarinen, 2000).

Lake ecosystems play a major role in a society (Thornton *et al.,* 1996 and World Commission on Dams, 2000). Lake ecosystems provide accessible quantities of good qualities water for human needs such as daily life, agriculture and industry (Jorgensen *et al.,* 2005).

Miller and Spoolman (2012) stated that there are varieties of size, depth and nutrient contents in the freshwater lakes. There are four distinct zones (Figure 2.1) in this lentic bodies which are defined by their distance from the shore and depth. Littoral zone may form a narrow or broad fringing area, with extensive areas of aquatic plants sorted by their tolerances to different water depth. The zone is close to the shore and the light reaches all the way to the bottom. The producers are plants rooted to the bottom and algae attached to plants and to any other solid substrate. Limnetic zone is the open surface layer which away from the shore and could be penetrated by sunlight. Profundal zone is a deep layer and too dark that does not suitable for photosynthesis process. The bottom layer is a benthic zone which is filled with decomposers and detritus feeders.

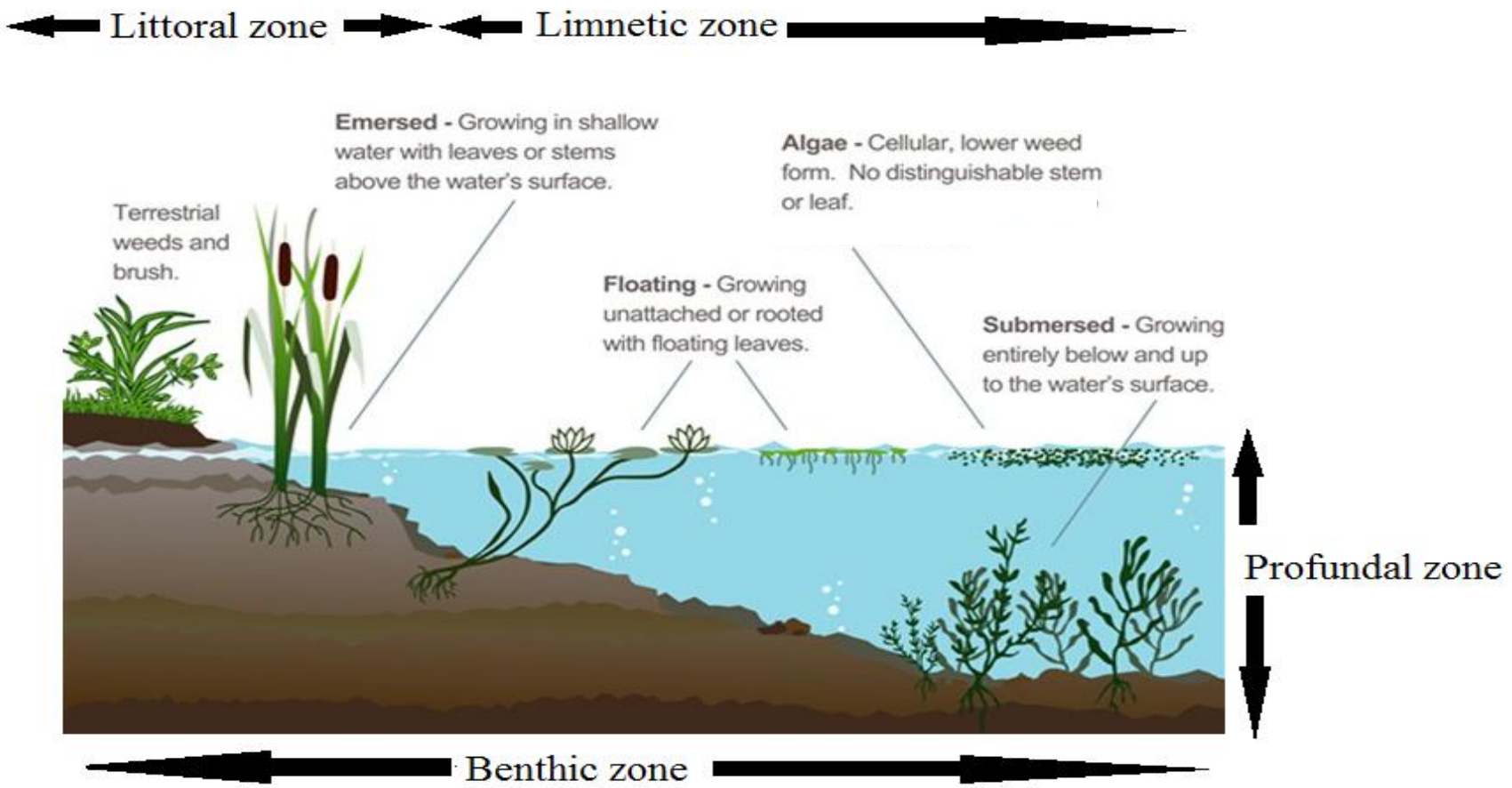

Figure 2.1: Four distinct zones in lake ecosystems

2.2 An overview of river ecosystems

A river is a flow of fresh water that moves from one place to another through the landscape (Anonymous, 2004b; Green, 2009; Kalman, 2009). They usually flow from higher place such as hills or mountains and heading downhill such as sea, lake or swamp and transport along soils, rocks, minerals, nutrient-rich and as well as water (Anonymous, 2004b). This flowing freshwater is called as lotic bodies since the water movement is response to gravity which leads to move along the slope (Wetzel, 2001).

According to Fisher and Sponseller (2009), river is a thin, long and has a large volume and surface ratio. They also reported river has no natural length resulting in no starting and ending points. The length of the river segment is an arbitrary which was influenced by the ratio of water flow to volume.

Rivers are greatly varied in size, volume and shape but similar in characteristics. Each river has its own headwater which located in a hilly or mountainous region (Anonymous, 2004b). Usually swift currents prevail and waterfalls are common near the headwaters and have rapid drop due to the gradient slope which lead to rapid flow in the river. As the river reaching the river mouth, it losses the gradient and becomes sluggish which then allow the loading sediments at the bottom and may clog the channel. The river then responds towards sediments deposit forming delta (Anonymous, 2004b).

2.3 Weed species

2.3.1 Weed Definition

The definitions of weed species are general and depend on the location, time and the environments. Early studies on weed species conducted by researchers such as Bailey and Bailey (1941), Hilderbrand (1946), Thomas *et al.* (2002) and Reichard (2011) stated that weed species are plants that grow and lead to negative impact in the areas. According to Swarbick and Mercado (1987), a plant may be a weed to one person, in one place and one time of a year and also a weed may be a useful plant to another person, at another place and another season. These weed species are problem-causing plants that disrupt the lake and river ecosystems and as well as plantation areas.

According to Harper (1977), weed species are spontaneously grow plants in a habitat which is greatly modified by human activities. In addition, weed species are adapted well in the human-induced changes environment such as disturbance areas (Harlan, 2001; Pyke and Knick, 2003; Hoobs *et al.,* 2006). Movement and disruption from humans and equipments and as well as recreational activities such as camp sites may lead to drastic changes in lake and river ecosystems (Mack and Lonsdale, 2001; Carlson, 2002).

Invasive weed species defined as non-native species in the ecosystems, move rapidly into a new area and spread quickly once established (Mashhadi and Radosevich, 2003; Travnick, 2008) and likely to cause economic and environmental harm towards the areas (Clinton, 1999).

Gray (1879) had described weed species as a plant that has high competitive and aggressive behaviour. They also are highly persistence and resistance to control. The weed species grow rapidly and luxuriantly and form huge populations which then potentially suppress the resident populations (Navas, 1991). According to Sahid (1989), weed are plant that not sown or cultivated. Unintentionally, these species had been accidentally grown during planting and sowing crops. Weed species may cause loss in many ways in lake and as well as river ecosystem (Sagar, 1968). Monaco *et al.* (2002) stated weed species are plants that well adapted to any stressed conditions such as drought, limited light intensity and high pest levels.

Liebman *et al.* (2004) reported weed species are long distance colonization, simultaneously grow and spread widely from one place to another. Therefore, it might continuously contribute and increase the evolution, invasion, competition, distribution and composition of weed species in the areas.

2.3.2 Weed classification

Although there are species classifications based on plant taxonomy, these classifications are not suitable in weed species. Weed species are usually classified into morphology, habitat and also life cycle. The main purpose of the classification is to identify and classify the weed that obtains similarities in both morphology and life cycle (Sahid, 1989).

Weed is classified into eight types based on morphology, habitat and life cycle: (i) Grasses are monocotyledon plants from Gramineae or Poaceae family. They are parts

of class Monocotyledonae, which belong to the subclass of Lilidae, one of the members of the suborder Commelinanae and part of the order Poales (Sanchez-Moreiras *et al.,* 2004). Grasses recorded at about 10,000 species and also cover a vast area (Duistermatt, 2005). Grasses are found throughout the world and usually inhabit agriculture areas and water catchment areas. Most of them are grow well via seeds vegetation although some of the species are capable to breed by stolon and rhizomes. Stolons are creeping on the ground while rhizomes are creeping underground (Sahid, 1989).

(ii) Sedges are monocotyledon plants from Cyperaceae family which have 3,000 to 4,000 species. Sedges resembles grasses but can be distinguished by their triangular of circular stems, the absence of ligules and the fusion of the leaf sheaths to form tubes around the stem. Although sedges grow well at dry areas, but the most favourable habitat are damp and moist areas. Sedges weed species germinated by seeds and vegetative such as *Cyperus pilosus* and *Fimbristylis miliaceae.*

(iii) Broadleaves weed are dicotyledons but there are also some monocotyledons weed species. Dicotyledons plants could either grow creeping or erect on the land and woody stalk that can be clearly seen. They have toothed or divided broad leaves with netted venation. The leaves also have blades and distinct petioles and may be arranged along the stem singly, in pairs and rarely in whorls or in basal rosettes (Swarbick and Mercado, 1987).

(iv) Valier (1995) reported that true ferns are primitive plants**.** They undergo reproduction process by dustlike spores instead of seeds or flowers. The spores are

form in capsules and called as *sporangia*. They are usually found on the underside of the mature fronds. However, there are some ferns that have spores only on special (fertile) fronds. The collections of sporangia are called *sori* which are usually in the brownish to blackish clusters on the undersides of fronds. The sori are protected by various shape of flaps in different types of ferns and called *indusium.*

(v) Aquatic weed species are classified into two types (Rao, 2000). There are algae and hydrophytes. Algae usually inhabit the surface of saline and fresh waters which are exposed to the sunlight. They are adapted well on ponds, reservoirs, streams and lakes. Besides, they are also some algae found on solid and terrestrial surfaces. Meanwhile the hydrophytes are vascular plants and can be grouped as submerged, emerged, marginal and floating weed. Submerged weed are plants that produce their vegetative growth underwater. They are vascular weed and have true roots, stems and leaves. Emerged weed are plants that rooted beneath the water surface while leaves and stems at or above the water surface. They grow well below the water level to about half the height of the plants. Marginal weed are the emerged weed that can grow above the water surface on saturated soil areas. They are usually found at the moist areas and vary in shape, habitat and size. Floating weed has floating leaves above the water surface either singly or in rosettes form. Some of the plants are rooted in bottom mud and have floating leaves while the rest are free-floating plants.

(vi) Annual species are plants that successfully complete their life cycle in less than a year or within one cropping season. They are usually reproduced by seeds and easy to control. However, the millions numbers of seeds produce and their rapidly growth had cause their wide infestation. (vii) Biennial plants complete their life cycle in two

years. They are undergoes reproduction process by vegetative and known as rosette stage during first year. Meanwhile, during second year, bolting stage occur with rising of flower stalks. (viii) Perennial plants complete their life cycle more than two years. They propagate by seeds and underground organs such as stolons, rhizomes, tubers and bulbs.

2.4 Noxious weed species

Holm *et al.* (1977) recorded that there were ten noxious weed throughout the world. Meanwhile Mercado (1979) reported that these ten noxious weed (Table 2.1) were recorded at the Southeast Asia including Malaysia. However, each country and each place especially in Malaysia recorded different noxious weed from these ten noxious weed species. This is depended on their ecosystem and environment.

Table 2.1: Ten noxious weed in the Southeast Asia (Mercado, 1979)

No	Scientific Name	English name	Local name
1.	*Cyperus rotundus*	Nut grass	Rumput halia hitam
2.	*Cynodon dactylon*	Bermuda grass	Rumput minyak
3.	*Echinochloa colona*	Jungle rice	Padi burung
4.	*Eichhornia crassipes*	Water hyacinth	Keladi bunting
5.	*Echinochloa cruss-galli*	Barnyard grass	Rumput sambau
6.	*Eleusine indica*	Crow's foot grass	Rumput sambari
7.	*Imperata clindrica*	Sword grass	Lalang
8.	*Lantana camara*	Prickly *Lantana*	Bunga tahi ayam
9.	*Mimosa pigra*	Giant sensitive plant	Kemang gajah
10.	*Panicum maximum*	Guinea grass	Rumput bengala

Mercado (1979) reported five characteristics of noxious weed species:

(i) Weed could grow aggressively especially by vegetative.

(ii) Weed may undergoes asexual and sexual breeding

(iii) Weed are easily adapted to any and extreme environments

(iv) Seeds and propagules of weed species could easily become dormant in any unsuitable environment

(v) Weed could bring harm and damage towards low density areas

Usually noxious weed are resistant towards several types of weed control especially annual weed species. They could produce millions of seeds which could adapt to any environments and have high dormancy state. Therefore, noxious weed could resist towards any types of herbicides used.

2.4.1 *Mimosa pigra*

Mimosa pigra was first described by Linnaeus (1759). This leguminous plant is from Mimosaceae family. *Mimosa pigra* is also known as a giant sensitive plant which originated from tropical America and had been widespread throughout the tropics.

The bipinnate leaves are sensitive to touch and each leaflet consists of 20 – 42 pairs per pinna. The leaves venations are parallel with midrib and the margins are often bearing minute bristles. *Mimosa pigra* inflorescence is tight and subglobose pendunculate heads 1 cm in diameter are together in the upper axils. Each head contains 100 flowers which are in mauve or pink colour. The clustered pods are brown colour, densely bristle and containing estimated at 9103 number of *M. pigra* seeds per m^2 per year in a typical mature stand (Cronk and Fuller, 1995). *Mimosa pigra* seeds are in light brown colour, oblong shape, light and very tiny size. The seeds might be dispersed to the entire places by water with floating for an indefinite period or attach towards humans or animals (Cronk and Fuller, 1995).

Under ideal conditions, after 12 weeks of planting, *M. pigra* could begin flowering at the average of 77 cm height (Marambe *et al.*, 2004). However, *M. pigra* does not produce seeds after first flowering and there are not more than two flowers per plant at the beginning of growth. The pods produce only from flowers at 18 weeks of germination process. In a typical *M. pigra* infestation is comprises of one plant per square metre and could produces 9,000 seeds per square metre of canopy (Anonymous, 2001). However, compared to the isolated *M. pigra* plant, there were covered in larger areas and produce up to 220,000 seeds per year. According to Robert (1982), in only one year, *M. pigra* could grow well up to 3 m height.

2.5 Weed species invasion

2.5.1 Invasion process

Invasion process is a plant that success to invade, establish, germinate, spread and integrate with the other plants in a community. Weed species are able to accomplish the processes and face any of the barriers (Williamson, 1999 and Richardson *et al.* 2000).

Groves (1986) reported there are three phases in invasion process. Firstly is an introduction. Seeds and propagules are dispersed throughout the areas beyond their previous geographic ranges and established the populations of adult plants. Secondly is colonization. Adult plants and grew well seeds could reproduce into new plants which lead to increase the number of species, dominate and as well as colonize the areas. Thirdly is naturalization. The colonized and established plants undergo widespread dispersal and becomes incorporated within the other plants in the areas.

Weed species invasion could be observed in various countries throughout the world as reported by several studies and researches.

2.5.2 Weed species invasion at lake ecosystems

Weed populations on the manmade lakes have been discussed by Little (1966), Holm *et al.* (1969), Lagler (1969), Mitchell (1969), White (1969), Naylor and Lutman (2002) and Travnick (2008). The fluctuations in lake level and the depth of the water are the crucial factors in determined the type of plant infestation that could grow well (Mitchell, 1973). For example, *Ipomoea aquatica* as an emergent weed species occur at the shallow water or damp soil along the shoreline meanwhile submerged weed species such as *Hydrilla verticillata* generally establish at depth less than 10 m. Floating weed species, *Eichhornia crassipes* grow well at the lake surface. *Ludwigia hyssopifolia* and *Cyperus pilosus* are the most possible species that populate at manmade lakes and as well as rivers as reported by Wild (1961); Boughey (1963); Mitchell (1969) and Lawson (1970).

Mansor (1996) reported the distribution of floating weed species at five lakes in Malaysia. *Eichhornia crassipes* highly infested at Bukit Merah, Chenderoh, Ringlet and Aman Lake. *Pistia stratiotes* were abundant at Chenderoh Lake meanwhile *Lemna perpusilla* was observed moderately at some part of Temengor Lake. These massive of minute floating weed clogged the irrigation and blocked the water supply. *Eichhornia crassipes* is the major problems weed towards drainage and irrigation canals in Malaysia (Baki, 1982).

Mansor and Crawley (2011) reported *M. pigra* populations at Temengor, Pergau and Kenyir lakes should be monitored frequently. This is because; ecological processes and economical activities might be affected by the uncontrolled *M. pigra* invasions.

2.5.3 Weed species invasion at river ecosystems

Mansor *et al.* (1983) reported there was massive infestation of *E. crassipes* in Perak River which is one of the longest rivers in Malaysia. In addition, *M. pigra* were highly invaded and populated at wetland habitats especially river mouth, floodplains and reservoirs (Marambe *et al.* 2004; Samouth, 2004; Triet *et al.*, 2004).

Connell (1978), Huston, (1979), Miller (1982), and Mabey (2010) reported disturbances such as logging and anthropogenic activities and the ability of species to survive during unfavourable conditions result in high proliferation and population of weed species. Logging activities at the river ecosystems could reduce the survival of vegetation forest plants and at the same time may stimulate weed species to grow well and fill the gap throughout the areas by germinating process (Ough and Murphy, 2004; Ough, 2002 and Lindenmayer, 2009). Impacts of logging and anthropogenic activities, the seeds could widely infest the disturbed areas by breaking their seeds dormancy, dispersed in form outside areas and survive deep buried rhizomes (Haslam, 1987; Smith, 1992; Whelan, 1995; Parson and Cuthbertson, 2004; Lindenmayer, 2009 and Mabey, 2010).

Furthermore, there are significant impacts towards vegetation during high water flow and low water flow at streams or rivers (Anonymous, 2004a). Water temperature and

plant growth may increase rapidly during low water level. During this low flow periods, some weed species could grow well and widely infest meanwhile some of the species might undergo dormancy state which is resting state due to the stress conditions (Anonymous, 2004a). The dried rivers may lead to the increasing of competition among the weed species and the other plants in order to obtain nutrients and spaces.

In addition, according to Lonsdale (1999), there was high diversity and high populations of weed species at disturbed areas compared to pristine areas. There are low distribution of weed species especially *M. pigra* at natural areas meanwhile there are mainly and highly distributed at disturbed areas and abandoned land (Naylor and Lutman, 2002; Mansor and Crawley, 2011 and Romanowski, 2011).

2.5.4 Weed species invasion at the other ecosystems

Weed is economic pest as they are recognized worldwide as undesirable plants especially in plantation area (Sahid, 1989; Steven *et al.*, 2007). Weed could grow higher, bigger and rapidly and suppress the crop plants (Mansor, 1994; Chauhan, 2012). The aggressiveness of weed makes them easily infest and dominate in an area (Liebman *et al.*, 2004; Wang and Lu, 2013). Unfortunately, the farmers are mere concern towards the abundance of weed species rather than the presence. For instance, a few numbers of isolated weed species are usually of less concern although they are noxious weed. Therefore the relative abundance, potential use of the land they occupy and the location of weed species needs to be considered (Aldrich, 1984; Steven *et al.*, 1997 and Wang and Lu, 2013). Azmi and Anwar (1988) reported

Fimbristylis miliaceae and *Monochoria vaginalis* were the most dominant sedges and broadleaves weed species in paddy field areas at Seberang Perai and Sg. Manik/Kerian. Besides, *Echinochloa cruss-galli* was also a dominant weed species at Muda area (Azmi and Supaad, 1986). A research conducted by Azmi (1991) recorded *Echinochloa cruss-galli, Fimbristylis miliaceae, Monochoria vaginalis* and *Sagittaria guyanensis* were the most dominant weed species in transplanted and direct seeded rice granary areas in Peninsular Malaysia. In addition, Mansor (2001) recorded *Hydrilla verticillata* highly infested and dominated rice fields areas which harmful to water and drainage systems. This aquatic weed species, was abundance and recorded Scale 4 (50% $\leq$ Weed cover percentage < 75%) weed cover percentage based on Braunn-Blanquet Scale (1932).

2.5.5 Weed species invasion throughout the world

As reported by Gangstad (1978), floating aquatic plants such as *Eichhornia crassipes, Pistia stratiotes* and *Salvinia cucullata* were observed in various different locations at Lower Mekong River Basin. *Eichhornia crassipes* was originated from Amazon basin, *Pistia stratioes* was originated from South America while *Salivinia culcullata* was originated from South America. These weed species tend to forms bogs and mats which then grow and develop well at the entire areas. According to Swarbick and Mercado (1987), *M. pigra* was well established on the headwaters of Mekong River might infest naturally down towards Laos, Cambodia and Vietnam rivers. This noxious weed species aggressively and rapidly dominate the areas and could invade to the nearby areas too. It is difficult to stop *Mimosa pigra* from spreading throughout the areas once they are introduced and established. According

to Triet *et al.* (2004), *M. pigra* was found commonly along water edges of streams, rivers, canals and lake ecosystems. There are found mainly in the freshwater zone, less common in brackish water and does not found at all in the saline zone.

A study conducted by Gangstad (1978) at Republic of the Philippines reported that, *Eichhornia crassipes*, *Pistia stratiotes* and *Ottelia alismoides* were the most prevalent aquatic plants. These aquatic plants growth become established in quantity and changed the characteristics of the river basins in term of storage, drainage and navigation capacity.

Marambe *et al.* (2000) reported the flowing water and the river sand for construction purposes areas were the major pathway of *Mimosa pigra* seeds to spread in Sri Lanka. In addition, *M. pigra* had colonized and dominated along the rivers and canals that flow through the Central Province of Sri Lanka and many water bodies.

One of the problematic weed in Tonle Sap Lake, Cambodia is a *M. pigra* (Samouth, 2004). This mono-species invasive weed species formed large infestation and caused economic damage primarily towards fisheries. *Mimosa pigra* was widely distributed up to 2,100 km^2 or 20% of potential areas flooding zone. The excessively invasion of *Mimosa pigra* indicated unhealthy situation and denote as a major problem.

Tumbare (2010) reported *Eichhornia crassipes* and *Salivinia molesta* were two major invasive weed species which dominated in Kariba Lake. The proliferation of these two aquatic weed species contributed to the operational problem on hydropower production. In addition, lake navigation and fisheries were also negatively affected.

Mimosa pigra grows well and prefers humid and wet habitats along of the river bank and lake esosystems in Wansur National Park, Indonesia (Sulistyawan and Hartono, 2004). Potential areas of *M. pigra* infestation along the river bank in Wansur National Park were about 35 ha. This finding showed serious population of this noxious weed species along of the river bank and lake ecosystems and would double the areas of infestation if both banks were invaded.

2.6 Weed species invasion effects on aquatic ecosystems

There are three worst effects of weed species invasion towards lakes and rivers ecosystems. (i) Weed species might clog rivers channels and lakes water flow (Petr, 2000; Govorushko, 2012). The presence of noxious and aquatic species such as *Eichhornia crassipes* might decrease and disrupt the water flow to pass through large accumulation and weed clusters. For example, accumulation of *E. crassipes* might block water flow to Owen Falls Dam which leads to a reduction of power generation and decreases in pressure in Uganda and Kenya (Govorushko, 2012).

(ii) Navigation and shipping becomes impossible when development of weed species occurred (Petr, 2000; Govorushko, 2012). According to Petr (2000) navigation and shipping was stopped because of the disruption by weed species with their wide population. Boating on the Congo River (Farb, 1971), Mississippi River (Nebel, 1993) and Victoria Lake (Govorushko, 2012) were also obstructed by weed species presence.

(iii) Weed species infestation significantly affects fishing activities (Govorushko, 2012). A dense and large population of weed species on the water surface greatly makes impossible and complicated towards fisherman to use seines, nets and other fishing gear. Petr (2000) reported there were only few fish found amongst weed species population in lake and river ecosystems such as in Orange Lake, Florida.

2.7 Soil factors

2.7.1 Textures

Soil texture having various particle sizes of soil (Datta, 1981) which reflects the proportions of sand, silt and clay (Maschmedt *et al.,* 2001). Soil consists of coarse, medium or fine texture which depends on the predominant particle size. Soil textures play important role such as to storage the water, air flow in the soil and the soil's capability to supply nutrients towards plants. Therefore soil textures act as indicator to determine whether the areas or lands are suitable for plant growth.

Clay soil contains high clay content and organic matter which are important towards plant growth as well as weed species (Datta, 1981). Meanwhile White (2006) reported clay soil hold more water than sandy soil and could provide and supply sufficient water towards plant growth process and as well as weed species. Therefore, based on these findings by the researchers, plants and especially weed species will rapidly germinate and grow at the clay soil areas.

2.7.2 pH

Soil pH is used to determine the hydrogen (H^+) activity and act as indicator whether the soil solution are in acidity, alkalinity or neutrality condition (Slattery *et al.,* 2001). Soil pH values are important to evaluate soil classification and plants growth and as well as weed species growth (Hossner, 2008).

Soil solutions are more acidic than pH 4 and rarely more alkaline than pH 9 even in any extreme cases. Hossner (2008) reported the optimum soil pH values for suitable and favourable plants growth are between 5.5 and 8.3. Free aluminium (Al^{3+}) and manganese (Mn^{2+}) that presence in the soil which lies under pH 5.5 could reduce the plants growth by absorbing these dangerous toxic elements. Soil above pH 8.3 contains excessive Na^+ which could bring adverse impacts towards soil properties and plants growth (Thomas, 2002).

2.7.3 Water content

Soil water content is the amount of water contain in the soil pores which then absorbed into the soil particles. Soil water content indicates percents of the dry soil weight or the volumes of soil bulk (Unger, 2008). Rao (2000) reported soil water content affects mass flow, rate of transpiration process and molecular diffusion. Therefore, soil water content might control the nutrients rate and water uptake by roots of each weed species.

According to Hakansson (2003), less or decrease soil water content percentages leads to decrease germination process, seedling growth and as well as population of vegetation. In addition, soil water content was depends and influenced by soil factors such as soil textures (Anonymous, 2002; Hakansson, 2003). Thus soil water content percentages play a crucial role in weed species growth and infestation in the areas.

CHAPTER 3

METHODS

3.1 Sampling Sites

Total catchment areas for Temengor Lake encompass of Belum Forest Reserve (BFR) with 134,167 ha, Temengor Forest Reserve (TFR) with 148,870 ha and Gerik Forest Reserve (GFR) with 37,220 ha (Figure 3.1) (Hashim *et al.*, 2011a). Temengor Lake is bigger than the state of Perlis (821 km^2) and three times the size of Singapore (710 km^2). This manmade lake is the second largest lake in Peninsular Malaysia (Mansor, 1996) and also important as a hydroelectricity source since it is created due to Temengor Dam (152.1 km^2) (Appendix A) (Likens, 2010).

There were 20 sampling sites in this study. Eighteen sites were located within the river mouth areas and another two sites were located on existing deltas (Table 3.1). These 20 sites also were divided into disturbed (6 sampling sites) and pristine (14 sampling sites) areas (Table 3.1).

Among all sampling sites, Banum River is the only river that impacted by logging activities. Kedah River and Gadong River are categorized as logging areas since there are logging activities which occurred 30 to 40 years ago (Hashim *et al.*, 2011b). Meanwhile Delta A and Delta B at Enam River are categorised as disturbed areas with major impact of anthropogenic activities by humans (Appendix A).

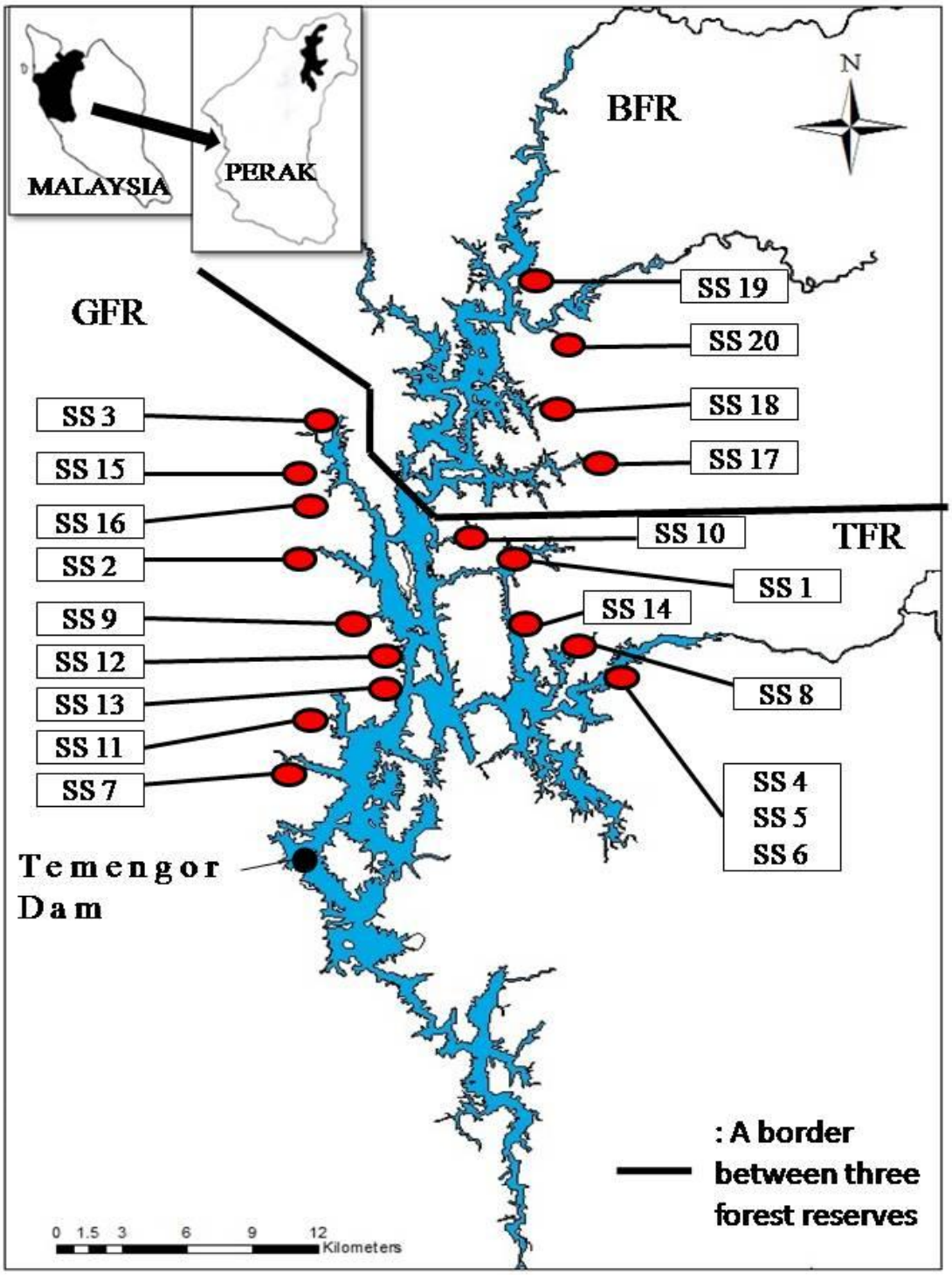

Figure 3.1: Location of 20 sampling sites at Temengor Lake, Perak

Notes:
BFR: Belum Forest Reserve TFR: Temengor Forest Reserve,
GFR: Gerik Forest Reserve SS: Sampling site

Table 3.1: List of 20 sampling sites at Temengor Lake, Perak

Sites	Location	Sites status	Description	GPS coordinate
SS 1	Banum River	Disturbed River	Logged area	5°33’37.33” N 101°23’19.18” E
SS 2	Kedah River	Disturbed River	Recovered logged area	5°33’08.20” N 101°19’30.24” E
SS 3	Gadong River	Disturbed River	Recovered logged area	5°36’40.26” N 101°18’36.65” E
SS 4	Enam River	Disturbed River	Anthropogenic activities	5°28’53.21” N 101°17’15.25” E
SS 5	Delta A (Enam River)	Disturbed River	Anthropogenic activities	5°29’08.98” N 101°24’22.25” E
SS 6	Delta B (Enam River)	Disturbed River	Anthropogenic activities	5°29’13.67” N 101°24’56.36” E
SS 7	Telang River	Pristine River	Natural area	5°30’19.16” N 101°27’54.92” E
SS 8	Halong River	Pristine River	Natural area	5°30’32.16” N 101°24’40.68” E
SS 9	Paloh River	Pristine River	Natural area	5°31’51.28” N 101°20’05.56” E
SS 10	Tekam River	Pristine River	Natural area	5°33’52.34” N 101°21’25.61” E
SS 11	Rokan River	Pristine River	Natural area	5°28’28.87” N 101°19’09.82” E
SS 12	Ular River	Pristine River	Natural area	5°31’00.65” N 101°20’34.53” E
SS 13	Kuda River	Pristine River	Natural area	5°30’15.95” N 101°20’37.59” E
SS 14	Dua River	Pristine River	Natural area	5°30’06.45” N 101°23’47.09” E
SS 15	Kenyir River	Pristine River	Natural area	5°36’01.63” N 101°18’46.72” E
SS 16	Ketir River	Pristine River	Natural area	5°35’37.87” N 101°18’59.21” E
SS 17	Ruok River	Pristine River	Natural area	5°35’40.13” N 101°21’31.40” E
SS 18	Papan River	Pristine River	Natural area	5°36’55.35” N 101°21’31.40” E
SS 19	Lubuk Tapong River	Pristine River	Natural area	5°41’06.11” N 101°23’09.82” E
SS 20	Ke’o River	Pristine River	Natural area	5°40’05.35” N 101°23’08.23” E