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DIVERSITY, DISTRIBUTION AND CONTROL OF AQUATIC MACROPHYTES OF SOUTHERN GHANA WITH PARTICULAR REFERENCE TO THE ALIEN INVASIVES

BY

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DECLARATION

I hereby declare that with the exception of the duly cited references, this thesis is the result of an original research work carried out by me at the Department of Botany of the University of Ghana, Legon under the supervision of Professor G. K. Ameka.

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DEDICATION

This thesis is dedicated to my late father Nana Asare Asiamah II.

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INTEGRI PROCEDAMUS

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ABSTRACT

The diversity and distribution of aquatic macrophytes particularly the invasives were studied in southern Ghana. The study area covered six regions in Ghana and these were: Greater Accra, Central, Ashanti, Eastern, Volta and Western. Forty-four sampling sites were visited and voucher specimens were collected and deposited in the Ghana Herbarium. Sixty-two aquatic macrophytes were encountered during the study which belonged to 48 genera and 30 families. Also, the invasive and non-invasive aquatic macrophytes that were encountered were also grouped according to the families they belonged. The Cyperaceae family emerged as the most dominant with 9 species. The criteria of IUCN (2004) were used in the identification of whether a particular species was an invasive or not. Based on this, the encountered aquatic macrophytes were separated into invasives and non-invasives. Eleven of the species were identified as invasives whereas the remaining fifty-two aquatic species were non-invasives. The life forms of the aquatic macrophytes were also determined. Forty one species (67%) were emergent, eleven species (17%) were free-floating, eight species (13%) were submerged and two species (3%) were floating-leaved. Distribution maps were drawn for the eleven invasive aquatic plants that were encountered. *Pistia stratiotes* was the most distributed invasive aquatic plant within the Southern part of Ghana with a total of seven distribution spots. A database was also created for all the sixty-two invasive and non- invasive species encountered. These comprised the scientific name and photograph of the species, synonym, common name, family, description, reproduction, habitat, distribution and uses. For each of the invasive aquatic macrophytes, the method of control was reviewed so as to make use of the best methods available that would help in their control/management.

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CHAPTER ONE

1.0 INTRODUCTION

1.1 Background

Aquatic macrophytes are a diverse assembly of macroscopic plants including some relatively "large plants" living either in, or at the periphery of freshwaters (Sculthorpe, 1967). These aquatic macrophytes include ferns, mosses, macroalgae, angiosperms as well as large trees that require saturated soil conditions or access to standing fresh water to thrive (Sculthorpe, 1967). They are natural inhabitants of lakes, rivers and wetlands and play several important roles in maintaining ecosystem functioning (Sculthorpe, 1967). These plants colonize a variety of aquatic habitats and zones of water bodies and can be divided into the following life forms: submerged-plants that grow completely submerged and rooted or not rooted into the sediment (e.g., *Ceratophyllum demersum; Elodea canadensis*); free-floating plants that float on the water surface (e.g., *Eichhornia crassipes; Pistia stratiotes*); emergent-plants rooted in the sediment with a substantial portion of the plant extending above the water surface into the air (e.g., *Typha domingensis*); and the floating–leaved plants rooted in the sediment with leaves floating on the water surface (e.g., *Nymphaea lotus*).

Naturally, freshwater bodies create conditions that support some sort of flora (Westlake, 1981). Aquatic floras, including macrophytes, are important to any freshwater ecosystem. This is because they are primary producers (Cooper & Knight, 1985), a property they share with other photosynthetic organisms like planktonic and periphytonic algae. They may also provide food for other organisms like birds (Batzer *et al.*, 1993) and fish (Crowder & Cooper, 1982), as well as play other important roles in ecological processes such as decomposition and energy transfer (McQueen *et al.*, 1986; Dvorak, 1996).

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Aquatic macrophytes are able to use nutrients and thus influence water quality and also reflect the nutrient status of their immediate habitat by their presence/absence and abundance which can be used as a biological indicator in any available water body (Suominen, 1968; Uotilo, 1971). They may also control water quality by exuding various organic and mineral components into the water body. They also accumulate heavy metals from the water body in which they are found (Devlin, 1967). They also provide habitats for other organisms and also aid in the stability of sediments in the water bodies where they are found (Chung, 1974).

Within their natural habitat, they interact with the various organisms and as such have natural enemies that keep their population low so that they do not grow to nuisance proportions. Instances where invasive aquatic macrophytes are introduced into new environments where they have no natural enemies, and have a high dispersal rate, and short generation time, their population explodes and they often out-compete the native flora and thus reduce the levels of local biodiversity.

The International Union for Conservation of Nature (IUCN, 2004) describes invasive species as "animals, plants or other organisms introduced by man into places out of their natural range of distribution, where they become established and disperse, generating a negative impact on the local ecosystem and species." The invasion process starts when propagules or individuals are transferred to regions outside a taxon's current distribution range (Mooney & Cleland, 2001). The invasion process can be divided into four stages: introduction (transport to a new area), establishment (germination and/or survival in the new place), naturalization (self-sustaining population) and finally invasion (spread into natural habitats) (Mooney & Cleland, 2001). Invasive species are one of the largest threats

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to our terrestrial, coastal and freshwater ecosystems, as well as being a major global concern (Mooney & Cleland, 2001). Common sources of aquatic invasive species introductions include ballast water, hull fouling, aquaculture escapes, and accidental and/or intentional introductions, among others (MEA, 2005). The increasing introduction and spread of invasive species, global climate change and habitat alteration are the most serious threats to global biodiversity (MEA, 2005). These factors can produce a synergistic effect, where there is a rapid acceleration of the loss of biodiversity in a region and control efforts are not able to keep pace with the impacts of invasive species.

1.2 Problem statement

When alien aquatic macrophytes are established, they tend to prevent the growth of other native aquatic macrophytes or are completely replaced by one of them. They also tend to grow vigorously under conditions of reduced water flow rates created through water diversion or damming, or where nutrient levels have been boosted by agriculture or settlements and lack of natural enemies. In a nutrient rich environment, and with high proliferation rates, they grow vigorously and tend to block rivers gradually, causing local flooding, reduced available fish habitat and impede boats navigation and recreation (Boyd, 1971). They also affect the capacity of hydroelectric dams to generate hydro-electricity thereby affecting the effective energy production for the economic growth of the various countries facing such problems.

Invasive species can affect aquatic ecosystems directly or by affecting the land in ways that harm aquatic ecosystems. Invasive species represent the second leading cause of species extinction and loss of biodiversity in aquatic environments worldwide (CBD,

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2005). They also result in considerable economic effects through direct economic losses and management/control costs, while dramatically altering ecosystems, which support commercial and recreational activities. Effects on aquatic ecosystems result in decreased native populations, modified water tables, changes in run-off dynamics and fire frequency, among other alterations. These ecological changes in turn impact many recreational and commercial activities dependent on aquatic ecosystems (CBD, 2005).

1.3 Justification

With the current awareness being created as a result of the presence of invasive species worldwide and their ability to alter ecosystem functioning, it has now become a necessity for countries especially those with extensive water bodies to be surveyed and monitored for the presence of any of the invasive aquatic species. Ghana is no exception to this as there are numerous water bodies that run through the length and breadth of the entire country with some of these water bodies having their sources from neighbouring countries. It is therefore important to survey and evaluate the water bodies in the country and also discusss the appropriate methods required to control aquatic invasive species once they occur. Some water bodies in Ghana have the potential of habouring aquatic plants including the invasive types. For example the Lower Volta River System in Ghana, and the Abby-Ehy-Tano-Nveye lagoons and River in the Western Region have been infested with some invasive aquatic plants (deGraft-Johnson, 1991). It is therefore important to identify the invasive and non-invasive aquatic plants, where they occur, their methods of introduction and the appropriate methods of control or eradication methods to help control these invasive aquatic plants.

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This study will document diversity and distribution of invasive and non- invasive aquatic plants in southern Ghana. The results would also enable the monitoring of the major water bodies for quick identification of new alien aquatic macrophytes when they arrive.

1.4 Objective of the study

The objective for this study is to identify aquatic macrophytes, particularly the invasives, and where they occur and review their control or eradication methods in southern Ghana.

The specific objectives are to:

1 determine the diversity of invasive and non- invasive macrophytes in freshwater bodies in southern Ghana.

2 determine the distribution of invasive aquatic macrophytes found during the study, and

3 study the ecology and control methods for the invasive aquatic plants that would be encountered.

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CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Life forms and classification of aquatic macrophytes

Aquatic macrophytes are of various life forms and can be classified or grouped based on their location in water bodies and their characteristics. They may be placed in four groups: (i) free-floating aquatic macrophytes such as *Salvinia molesta* and *Pistia stratiotes*, (ii) floating–leaved but rooted plants such as *Nymphaea lotus*, (iii) submerged plants which are also described as true aquatics. These plants grow almost completely below the water surface and are generally attached to the bottom by roots or have their roots in the water. Examples include *Utricularia sp, Ceratophyllum demersum* and *Potamogeton octandrus*, (iv) emergents have their roots in the soil with substantial part of the body extending above the surface of the water. Some examples of emergents are *Typha domingensis*, *Vossia cuspidata*, and *Cyperus sp.*

On the basis of attachment of aquatic macrophytes to substratum, they are classified as haptophytes, rhizophytes, planophytes and pleustophytes. Haptophytes are attached to but do not penetrate the substrate. The basal parts of rhizophytes actually penetrate the substrate. Planophytes are free-floating plants with submerged or free-floating assimilatory organs. Pleustophytes like planophytes are free-floating but larger. They include macro-algae, liverworts, ferns and angiosperms (Sculthope, 1967).

2.2 Definition for invasive aquatic plants

There exist several definitions for aquatic invasive species. According to the Global Invasive Species Compendium (2012), alien invasive species means an alien species which becomes established in natural or semi-natural ecosystems or habitat, is an agent of

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change, and threatens native biological diversity. Likewise, the Invasive Species Compendium defines an Aquatic Invasive Species as an "alien species which becomes established in natural or semi-natural ecosystems or habitat, and threatens native biological diversity". With the above definitions, it is clear that all Alien Invasive Species are non-native to a particular habitat and after their introduction, they threaten native biological diversity.

A major objective of invasion biology is to understand why some species succeed in establishing new populations outside their native range and others fail (García-Berthou, 2007). In general, biological characteristics such as competitive ability, fecundity or environmental tolerance are invoked to explain invasion success (Kolar & Lodge, 2001). However, the ability to invade new environments can vary among populations of a species (Kelly *et al*., 2006), and genetic variability could be the crucial determinant of a population's ability to invade a new environment (Roman & Darling, 2007; Facon *et al*., 2008). Indeed, genetic variability is the substance for populations to adapt (through natural selection) to new ecological conditions encountered in new environments (Roman & Darling, 2007).

Although there is not one specific trait or a specific set of traits common to all invasive species, there is a suite of traits that invasive species often have. Not all invasive species will have all of these traits, but most invasive species seem to have one or more of these traits. According to the (IUCN, 2004) the traits include:

1) High rate of reproduction

2) Pioneer Species (able to colonize areas after they have been disturbed)

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3) Short generation times

4) Long-lived

5) High dispersal rates

6) Single-parent reproduction

7) Vegetative or clonal reproduction

8) High genetic variability

9) Broad native range / Tolerant of wide range of conditions / Habitat generalist (can live in many different types of habitats)

10) Abundant in native range

11) Gregarious

12) Human commensal (lives in close association with humans)

Another way to determine whether a particular species is invasive or not, is by carrying out any of the following:

1) Consult local natural resource guidebooks and field guides.

2) Consult web pages on the Internet that can help one identify invasive species.

3) Ask the elderly people in the community to help in the identification of that species.

4) Ask the Research Instituitions/organisations in your country.

5) Consult herbaria in your country of origin.

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Once that particular species has been identified as an alien, one could then proceed to determine the invasive status of the species based on the impact criterion or the geographical criterion. Although most invasive species are classified as alien, there are some species that are native to a particular area or region.

All invasive species have unique characteristics that enable them to thrive well in any new habitat they find themselves. These characteristics include the following criteria which have been adopted from IUCN (2004)**:**

1) Lack predators, pathogens, and diseases to keep population numbers in check.

2) Produce copious amounts of seed with a high viability of that seed.

3) Use successful dispersal mechanisms.

4) Very opportunistic.

5) Fast growing, allowing them to displace slower growing plants.

6) Produce chemicals that inhibit the growth of other plants near by.

7) Have longer photosynthetic periods.

8) Alter soil and habitat conditions where they grow to better suit their own survival and expansion.

9) Habitat generalists. They do not have specific or narrow growth requirements.

10) Resist management control efforts.

11) Spread easily and efficiently, usually by wind, water or animals.

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12) They have long dormancy periods.

2.3 Major river systems in Ghana and pathway of spread of invasive species

Ghana has eight major river systems: Volta, Tano, Ankobra, Pra, Kakum, Otchi, Ayensu and Densu. Ghana is well endowed with water resources, but the amount of water available changes markedly from season to season as well as from year to year. Also, the distribution within the country is far from uniform with the south-western part better watered than the coastal and northern regions. However, availability of water is decreasing owing to rainfall variability, rapid population growth, increased environmental degradation, pollution of rivers and draining of wetlands. All of Ghana's rivers drain southwards to the Gulf of Guinea. The Volta River, with a catchment area within Ghana of nearly 70% of the country, is by far the largest river draining the entire north, central and east of the country. The remaining rivers, all in the south and southwest, drain about 30% of the country. The major sub-basins of the Volta include the Black and White Volta Rivers, the Oti River and the Lower Volta, including Lake Volta. The South-Western River System comprises the Bia, Tano, Ankobra and Pra Rivers, while the Coastal Rivers System is made up of Otchi-Amissah, Otchi-Nakwa, Ayensu, Densu and Tordzie/Aka Rivers. The Volta River basin is shared with La Côte d'Ivoire, Burkina Faso, Togo, Benin and Mali. The Bia is shared with La Côte d'Ivoire, while the lower reaches of the Tano River also form part of the boundary with La Côte d'Ivoire. Some of these river systems have been dammed for potable water production, irrigation and fisheries. In nearly all the impoundments, serious aquatic macrophyte infestations have developed, affecting their proper use and management (deGraft-Johnson, 1991). Studies on aquatic vegetation and noxious weeds started in earnest with the establishment of the Volta Basin Research Project (VBRP) at the University of Ghana, Legon, in 1963. The studies were initiated during the implementation stage of the Volta River Project at Akosombo. The studies had

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been prompted by the experience of Lake Kariba on the Zambezi River in Zimbabwe, where an explosive development of the water fern, *Salvinia molesta* covered 22% of the surface of the reservoir in the early 1960s (Boughey, 1963; Ameka and deGraft-Johnson, 1998). Water hyacinth was first observed in Ghana in 1984 in a residence of Community l0 in the Tema Metropolis where it was being kept as an ornamental plant (deGraft-Johnson, 1996). By 1987, it had infested some drains in the Tema Metropolis as well as the Odaw River and its tributaries in Accra. It was in 1990 found in the Abby-Ehy-Tano-Nveye River and Lagoon complex in the Western Region and then 1998 in the Oti River Arm of Lake Volta and during 2003 in Kpong Headpond. The introduction of Water hyacinth into Ghana in 1984 and *Salvinia* in 1994 has further heightened fears as to the fate of the Ghanaian water bodies should these water weeds be allowed to invade and spread. The spread of water hyacinth has been reported from urban centres, such as Akosombo, Sekondi-Takoradi and Kumasi. Waterweeds have been recorded as problematic in Lake Volta (Hall *et al., 1969;* Lawson *et al.,* 1979); Lower Volta River (Hall and Pople, 1969; Ennin and deGraft-Johnson,1977); Barekese Reservoir (Fiakpornu, 1988); Weija Reservoir (deGraft-Johnson, 1977; Allen and Gaudet, 1979; Ameka, 1987; Ameka and deGraft-Johnson, 1998); Kpong Headpond (Gyimah-Amoako, 1988) and the irrigation reservoirs at Dawenya, Ashaiman, Okyereko and Mankesim (deGraft-Johnson, 1991).

Isolating the geographic origin and the pathways followed by species or their propagules to invade a new region (i.e. routes of invasion) are two related questions that have very important applied implications (Mack *et al*., 2000). Particularly, the identification of the origins (or sources) of invaders and the routes of invasion is of prime importance for

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designing strategies (e.g., monitoring, quarantine procedures) to prevent, reduce and/or control invasions (Mack *et al*., 2000; Gozlan *et al*., 2010).

The movement of species into new areas is a natural phenomenon that has occurred throughout evolutionary history (Tinner and Lotter, 2001; Graham *et al*., 1996). In modern times the movement of species has been augmented by humans operating in a globalized world. In the Great Lakes region, for example, intense vessel traffic from international trade is the major vector for introduction of non-native aquatic species. This region has the highest known introduction rate for freshwater ecosystems, with one new non-native species being discovered every 28 weeks (Ricciardi, 2006). San Francisco Bay has the highest overall introduction rate as recorded from 1961 to 1995, with one new non-native species introduced every 14 weeks (Cohen and Carlton, 1998). The actual number of non-native species introduced into the United States of America is unknown. Estimates range from 6,600 since European settlement of the United States of America (Cox, 1999) to 50,000 species (Pimentel *et al*., 2005).

There are many different pathways through which invasive species are intentionally and unintentionally introduced into Ghana. In the early colonial days, before we were much aware of the concept of invasive species, colonists brought many of their favorite plants and animals with them to Africa and then eventually to Gold Coast now called Ghana. Many of these species, although useful, have become problems over the years, or were carriers of other species (diseases, insects, seeds, etc.) that were invasive.

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Some species are (or have been in the past) deliberately brought into Ghana for specific reasons (such as biocontrol or for use as pets) and are either released into the wild on purpose or escape where they then unexpectedly become an invasive species problem. These are called intentional introductions.

Many species arrive here accidentally, without our knowledge. These are called unintentional introductions. Pathways for unintentional introductions include species arriving in foreign ballast water, hidden in wood packing material, hidden in other vegetation via the nursery trade, hidden aboard ships, hitchhiking on other species, and many other pathways.

With most of the aquatic invasive species in Ghana, they were introduced into the country from South America whereas others were also transported into the country from neighbouring countries. These aquatic plants are transported through fresh water bodies that flow from these neighbouring countries into Ghana.

2.4 The Role of climate change on invasive alien species

Climate change may produce more favourable conditions for invasive alien species. Once dominant species in native areas are no longer adapted to the environmental conditions of their habitat, it is likely that introduced species will displace them, thus drastically changing successional patterns, ecosystem function and resource distribution (McNeely, 1999; Tilman and Lehman, 2001). For example, Oberhauser and Peterson (2003) investigated the possible effects of global climate change on distributions of migratory populations of Monarch Butterflies *(Danaus piexippus* L.) and concluded that predicted

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changes do pose potentially significant threats to their survival. Climate, geographical area and other variables define the distribution limits of a species; however, with changes in climate these limits are expanding, and as such spreading species into higher latitudes and altitudes due to increased temperatures, humidity, precipitation and other climatic factors (McNeely, 1999; McNeely *et aI.,* 2001). Rouget *et al.,* (2002) noted that the current distribution of stands of invasive trees in South Africa was largely influenced by climatic factors. Warming trends may also allow for longer breeding seasons for invasive species, as observed for instance, in populations of the collared dove *(Streptopelia decaocto* Frivaldszky) in Europe (Crooks and Soule, 1999). Since the development of insects is temperature dependent, it has been predicted that increasing temperatures will enhance the winter survival of insects and facilitate population increases and expansions in geographic ranges (Crooks and Soule, 1999; Mooney and Hofgaard, 1999). Changes in climate and environmental factors may also allow existing introduced species to become invasive (Mooney and Hofgaard, 1999).

Climatically induced stress on plants and other species also reduces their ability to resist invaders and thus make them more vulnerable to insect or pathogen damage (Mooney and Hofgaard, 1999; McNeely *et al.,* 2001). Climate change may change production patterns and trade in agricultural and forestry commodities by species being grown more competitively at higher latitudes and altitudes. Since invasive alien species establish more easily in habitats disturbed by humans, such changes can provide more opportunities for them to invade (McNeely *et al.,* 2001). Climate change also affects the frequency and intensity of extreme climatic events, which may have the greatest influence on invasive alien species by disturbing ecosystems and thus providing them with increased opportunities for dispersal and growth (McNeely *et al.,* 2001).

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In addition to the effects of climate change, increasing concentrations of greenhouse gases can have significant effects on the success of invasive alien species. Higher concentrations of carbon dioxide increase photosynthetic rates (Vitousek *et aI.*, 1997) and water use efficiency of plants (Mooney and Hofgaard, 1999). The resulting increased soil moisture has potential to provide habitat for late-season annuals, which may be invasive. Distributions of spruce budworm species in Oregon changed in relation to increased atmospheric CO_2 concentrations (Vitousek *et aI.*, 1997). However, increased levels of CO_2 affect plant species differently, and this is likely to result in substantial changes in the species composition and dynamics of terrestrial and aquatic ecosystems (Vitousek *et aI.*, 1997). Changes in the deposition of nitrates from the atmosphere through the burning of fossil fuels, has resulted in large changes in vegetation, as observed in Western Europe, which may favour the growth of some invasive alien species (Mooney and Hofgaard, 1999).

2.5 The economic impacts of invasive aquatic plants

Naturally, freshwater bodies create conditions that support some sort of flora (Westlake, 1981). Aquatic floras, including macrophytes, are important to any freshwater ecosystem. Invasive aquatic plants and their control are a worldwide problem, especially in climates, habitats, or plant forms in which plant dormancy and seasonal diebacks from freezing or drought are limited. There are a wide variety of species (submersed, floating, and emergent), however, and nearly any aquatic ecosystem is subject to invasion from some of them. These problems develop when non-native ("exotic") plants are introduced either intentionally or by accident into ecosystems in which they did not previously occur.

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Inspite of the positive benefits derived from these invasive aquatic plants, when they are left unchecked, they now become a nuisance to the water body, flora and fauna present in the water body as well as the human population especially those that live very close to the water. Rockwell (2003) summarized the literature on the economic impact of aquatic invasive weeds. Invasive aquatic plants create a wide impact including those on commercial and recreational fishing, boating, swimming, water quality, navigation, hydro power generation and ecological resources such as wildlife habitat. There is a wide variety in the types of water bodies impacted, the life cycles and characteristics of the plants, and the means of control. Control may be mechanical, biological, chemical or integrated. There are difficulties in estimating the economic impacts of aquatic weeds (or, conversely, the benefits of their control). In spite of these difficulties, it can be conservatively estimated that the values-at-risk from aquatic invasive plants in the United States of America is in the range of billions of dollars per year according to a study by the Office of Technology Assessment (1993). Significant sums, at least $100 million, are spent each year in the control of aquatic weeds; however, the estimated benefits of control are consistently reported to be much higher than these costs (Rockwell, 2003). Given the continuing spread of problem species and the difficulty of organizing collective action to control aquatic weeds, it seems likely that too little is being spent on control rather than too much. Furthermore, much could be done to facilitate the further development and use of aquatic weed control techniques.

For an example, water hyacinth grows rapidly, forming expansive colonies of interwoven floating plants. As its doubling time can be as little as one week, it blankets large bodies of water soon after it invades, creating impenetrable barriers and obstructing navigation. Floating mats block drainage, causing flooding or preventing subsidence of floodwaters.

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Large rafts accumulate where water channels narrow, sometimes causing bridges to collapse. Water hyacinth hinders irrigation by impeding water flow, by clogging irrigation pumps, and by interfering with weirs. Multimillion-dollar flood control and water supply projects, which require decades to construct, can be rendered useless by water hyacinth infestations. Infestations also block access to recreational areas and decrease waterfront property values, often impacting the economies of communities that depend upon fishing and water sports for revenue.

Other impacts include a negative effect on the quality and quantity of potable water, increased water loss due to evapo-transpiration, the depletion of oxygen in aquatic communities, ultimately affecting fisheries, and negative effects on biodiversity. Water hyacinth thus impacts all aspects of water resource utilization including fisheries, transport, hydropower generation and the quantity and quality of potable water. It also threatens the production of electricity through hydropower generation throughout Africa. For example, water hyacinth covered some 20 000 ha of Lake Victoria in 1988 (De Groote *et al*., 2003). The lake basin supports some 25 million people and has an estimated worth of some US$ 4 billion annually, with fishing benefiting the livelihood of at least 500 000 people and having a potential sustainable fishery export value of US$ 288 million De (Groote *et al*., 2003). Water hyacinth severely threatened the economic activities on the lake and the development of the region.

Water hyacinth also has some positive uses. It can be processed in many ways, including: as feed for cattle, sheep and pigs; mulch and compost for crop production; fibre for paper-making, weaving baskets and mats; biological filtration; and the production of biogas (methane) (De Groote *et al*., 2003). Large-scale processing of water hyacinth, however, is

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seldom commercially viable as the plant is 96% water and harvesting is thus very expensive (De Groote *et al*., 2003). It is possible, however, to make a living by processing water hyacinth on a small scale. The promotion of use for these benefits should probably be avoided, however, as no utilization programme will ever check the growth of water hyacinth, and promoting utilization will lead to the further spread of the weed as people become aware of its economic potential.

2.6 Methods for controlling invasive aquatic plants

The control of invasive alien species includes a number of options: exclusion, eradication, containment (control), mitigation and adaptation (Perrings, 2002). Exclusion implies the use of measures such as quarantine or blacklists to prevent the introduction of potentially invasive species. Eradication is typically, but not always, an option only in the early stages of the spread of an invasive species. Containment implies the restriction of the space occupied by an invasive species. Mitigation and adaptation imply measures to control or accommodate the invasive species. In addition to what has been mentioned above, there are three main methods for controlling invasive aquatic plants. These are the physical or mechanical method, chemical method and the biological method.

Physical control method includes the removal of the weeds by manual labour or by mechanical harvesters, the use of physical barriers such as floating booms and, where feasible, by draining the water body. These techniques are useful and sometimes essential in the short term. However, they are expensive and physical control will have to be a permanent operation if it is the only means of control used. An estimate of the cost of mechanical control for some aquatic weeds in the United States of America is approximately United States of America $ 21,000 ha-1 (Thayer and Ramey, 1986) (figures adjusted to 2005 United States of American dollars). Aquatic weed harvesting also entails

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transport and disposal of the biomass removed which can add considerably to the cost of control. Physical removal has obvious limitations of scale and re-infestation is certain to occur from plant fragments and seeds. It is environmentally "safe" and is a useful method for reducing small infestations and for maintaining canals or protecting turbines of electric dams (Taylor-Wood, 2003). However, sometimes physical removal can be quite damaging and non-selective. In Ghana, manual removal has been the first control option practiced throughout the country, usually implemented by individuals who need access to water, or by whole communities (deGraft-Johnson, 1991). In addition, physical barriers have been used to prevent water hyacinth blocking boat access to landing sites.

Herbicide control of water hyacinth has been practiced since the early 1900s (De Groote *et al*., 2003). Application of herbicides includes aerial spraying from a helicopter, fixed wing and micro-light aircraft (De Groote *et al*., 2003). High pressure motorized units mounted on boats and used in smaller infestations in navigable waters and knapsack sprayers are used along river banks in limited areas. Herbicide control of water hyacinth depends on skilled operators who maintain a long-term follow-up programme to continually control re-infestation from scattered plants and those germinating from seed. Therefore, any herbicide programme against the weed requires a commitment to an ongoing operation of unlimited duration. It is the lack of a rigorous follow-up regime that has often led to the failure of herbicide control programmes. The negative impacts of herbicides on the environment have often been used to promote alternative control methods for water hyacinth. These negative impacts include the potential threat to human health in rural areas of the world where communities used untreated water for domestic use; the threat of herbicide residues in the aquatic ecosystem; the threat of de-oxygenation of the water column following decomposition of large mats of water hyacinth following treatment; and

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the general perception that herbicides are poisons. The majority of herbicides currently being used in water hyacinth control, whilst not ecologically benign, impact the environment considerably less than mats of water hyacinth. However, the concern of spray drift onto non-target vegetation is real and demands responsible use of herbicides by highly trained personnel. In Ghana, chemical control using systemic glyphosate-based herbicides has been used in the Accra-Tema Metropolis, in the Abby-Ehy-Tano-Nveye River and Lagoon complex in Western Region, and in the new infestations in the Oti River Arm of the Lake Volta and Lower Volta River (Akpabey, 2012).

Biological control is the use of host-specific natural enemies to reduce the population density of a pest (Howard and Harley, 1998). Classical biological control involving the importation, colonization and establishment of exotic natural enemies (predators, parasites and pathogens) to reduce exotic pest populations and maintain them at, economically insignificant densities is the predominant approach to biological weed control (McFadyen, 1998). Biological control can be an economically sustainable, environmentally safe, long-term option to manage certain targeted aquatic weeds in multi-use waters. Biological agents have successfully controlled water hyacinth, *salvinia*, red water fern and water lettuce in a number of localities around the world, including Africa (Cilliers *et al.*, 2003; Coetzee *et al.*, 2009). Invasive aquatic weeds that colonize vast areas of water bodies in monotypic stands are ideal targets for biological control. However, biological control is not meant to eradicate a target weed, but merely to suppress the weed populations substantially below an economically or ecologically determined threshold, allowing native species to return (Charudattan, 200Ia). The biological control of water hyacinth has been extremely effective in some systems around the world, including the rapid reduction of the weed on Lake Victoria, Papua New Guinea, Benin, Malawi and several systems within

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South Africa (De Groote *et al*., 2003). However, it has been less effective in other areas, where the systems are nutrient-enriched or where the climates are more temperate.

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CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Study area

The study was conducted in southern Ghana which comprised six regions. These were Western, Eastern, Central, Ashanti, Greater Accra and Volta Regions of Ghana. The selection of sampling sites was based on accessibility by road and boat, the impact of the presence of the aquatic macrophytes and the use to which the fringing communities put the aquatic macrophytes.

Fig.1: The Major Sampling Sites of Water Bodies within southern Ghana

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The climate in southern Ghana is typically tropical; warm and comparatively dry along southeast coast, hot and humid in the southwest coast. The climate is also characterized by generally humid conditions. This is particularly so during the night, when 95 to 100 percent humidity is possible. There are two main raining seasons in southern Ghana. This is from April to July and September to October. In Table 3.1 is presented the sampling sites with their Geographical Positioning System (GPS) locations in southern Ghana.

Table 3.1 Localities and sampling sites

LOCALITY	SITE	LONGITUDE/ LATITUDE
Ada	Site 1:Dawa	05˚50.726N, 0˚14.533E
Ada	Site 2: Dawa	05˚52.055N, 0˚18.188E
Ada	Site 3: Sege	05˚52.792N, 0˚23.792E
Ada	Site 4: Bedeku	05˚53.672N, 0˚32.562E
Ada	Site 5:Big Ada road	05˚49.436N, 0˚36.690E
Mankesim	Site 1: Water works	05°17.425N, 1°00.982W
Avu lagoon	Site 1:Entrance of channel	05˚58.150N, 0˚42.845E
Avu lagoon	Site 2: Middle of channel	05˚58.538N, 0˚43.517E
Avu lagoon	Site 3: Main lagoon	05˚68.660N, 0˚44.051E
Jewi wharf	Site 1: Nveye	05°06.437N, 2°55.864W
Jewi wharf	Site 2: Asukro	05°05.651N, 2°53.552W
Kpong headpond	Site 1: Main dam	06°14.100N, 0°30.841E
Kpong headpond	Site 2: Main dam	06°07.185N, 0°06.139E
Kpong headpond	Site 3: Main dam	06°06.444N, 0°06.188E
Weija	Site 1: Edge of dam	05°34.108N, 0°20.389W
Lower Volta River	Site 1: Entrance of river	05°59.425N, 0°35.062E

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Table 3.1continued. Localities and sampling sites

LOCALITY	SITE	LONGITUDE/ LATITUDE
Lower Volta River	Site 2: Along bridge	05°59.425N, 0°35.097E
River Ayensu	Site 1: Channel of River	05°35.376N, 0°37.102W
River Ayensu	Site 2: Main rRiver	05°38.025N, 0°36.217W
Nungua	Beach road	05°60.322N, 0°07.977W
Prampram	Main road	05°70.671N, 0°11.340E
Tema	Community 10	05°67.668N, 0°02.449E
Samreboi	Main road	05°61.382N, 2°56.341W
Abura Village	Village	05°33.801N, 1°17.126E
Anum	Along the road	06°47.167N, 0°18.900E
Koforidua	Polytechnic	06°09.432N, 0°25.736E
Sakumono	Main road	05°62.524N, 0°06.043E
Keta	Main road	05°89.145N, 0°98.740E
Agbozume	Village	06°07.398N, 1°03.752E
Senchi	Asuogyaman	06°19.916N, 0°06.738E
Dawenya	Information, Centre	05°76.760N, 0°05.127E
Battor	Hospital	05°93.020N, 0°36.495E
Akotokyire	Main road	05°13.504N, 1°27.786W
Ejura Village	Village	07°38.159N, 1°36.348W
Wenchi - Techiman	Main road	07°73.974N, 2°11.152W
Afram Plains	Apea Memorial School	06°88.291N, 0°30.125E
Asutsuare	Mepe	06°09.155N, 0°19.560E
Atuabo	Along road	04°99.669N, 2°62.654W
Adawso	Along road	06°51.855N, 0°26.987W
Wiwi River	Kwame Nkrumah University	06°67.419N, 1°56.807W
Owabi Forest	Forest	06°43.045N, 1°38.163W
Ashaiman	Community 22	05°37.361N, 0°02.000W
Achimota Forest	Achimota Forest	05°37.361N, 0°12.479W
Cape coast-Nkafoa	Main road	05°07.534N, 1°16.461W

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3.2 Survey of aquatic plants

A survey of the aquatic macrophyte vegetation was carried out in southern Ghana. On a visit to any study area, the area was divided into sites, and the aquatic macrophytes were randomly sampled. The coordinates of the site were recorded using a Global Positioning System (GPS) Megallan Smart 5390 model. Identification numbers were then assigned to the various aquatic macrophytes encountered and also photographs of the encountered aquatic plants were taken for the creation of a database. The encountered aquatic plants were usually fertile specimen and these were assembled and placed in a herbarium press for drying. The plant samples in the herbarium press were regularly examined to ensure that the specimen dried quickly. After drying, the specimens were then mounted on mounting sheets at the Ghana herbarium. All invasive aquatic macrophytes that were encountered were identified on site and later confirmed at the Ghana Herbarium, Department of Botany, University of Ghana, Legon.

In the field, for each species the following information were provided. The locals were interviewed on the uses.

1. The scientific name of the macrophyte

2. Synonym

3. Common name

4. Family

5. Description

6. Reproduction

7. Place of collection

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8. Uses

3.3 Invasive aquatic macrophytes

Determination was made for each aquatic macrophyte encountered as to whether it is invasive or non-invasive. The following (IUCN, 2004) criteria were used for determining a species as invasives:

1) Lack predators, pathogens, and diseases to keep population numbers in check.

2) Produce copious amounts of seed with a high viability of that seed.

3) Use successful dispersal mechanisms.

4) Very opportunistic.

5) Fast growing, allowing them to displace slower growing plants.

6) Produce chemicals that inhibit the growth of other plants near by.

7) Have longer photosynthetic periods.

8) Alter soil and habitat conditions where they grow to better suit their own survival and expansion.

9) Habitat generalists. They do not have specific or narrow growth requirements.

10) Resist management control efforts.

11) Spread easily and efficiently, usually by wind, water or animals.

12) They have long dormancy periods.

3.4 Distribution of aquatic macrophytes

Visits to the various sampling sites enabled a distribution list for each aquatic macrophyte encountered to be generated.

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CHAPTER FOUR

4.0 RESULTS

4.1 Diversity of aquatic macrophytes

There were a total of 62 aquatic macrophytes encountered during the study which belonged to 48 genera in 30 families. This is presented in (Table 4.1). The aquatic macrophytes were found in freshwater, lagoons, ponds, river systems, headpond and seasonal pools.

Table 4.1 Aquatic plants of southern Ghana

SPECIES	FAMILY	GROWTH FORM
Aeschynomene elaphroxylon Guill & Perr.	Fabacee	Emergent
Alternanthera sessilis (L) DC	Amaranthaceae	Emergent
Aponogeton pectinatus L.	Aponogetonaceae	Emergent
Azolla africana Desv.	Azollaceae	Free-floating
Azolla filiculoides Lam.	Azollaceae	Free-floating
Celosia pseudovirgata Schinz	Amaranthaceae	Emergent
Celosia pseudovirgata Schinz	Amaranthaceae	Emergent
Ceratophyllum demersum L.	Ceratophyllaceae	Submerged
Ceratopteris cornuta (P. Beauv.) Lepr.	Parkeriaceae	Emergent
Chara canescens J.L.A. Loiseleur	Characeae	Submerged
Commelina diffusa Burm.f.	Commelinaceae	Emergent
Commelina nudiflora Linn.	Commelinaceae	Emergent
Cyclosorus striatus (Schum.) Ching	Thelypteridaceae	Emergent
Cyperus articulatus Linn.	Cyperaceae	Emergent
Cyperus distans Linn. f.	Cyperaceae	Emergent
Cyperus nudicaulis Poir	Cyperaceae	Emergent
Cyperus papyrus L.	Cyperaceae	Emergent
Echinochloa stagnina (Retz.) P.Beauvois	Poaceae	Emergent

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Table 4.1 continued. Aquatic plants of southern Ghana

Eichhornia crassipes (Mart.) Solms-Layb.	Pontederiaceae	Free-floating
Eichnochloa pyramidalis Lam. Hitchc.& Chase	Poaceae	Emergent
Eleocharis complanata Boeck.	Cyperaceae	Emergent
Fureina umbellata Rottb	Cyperaceae	Emergent
Ipomoea aquatica Forsk.	Convolvulaceae	Emergent
Ipomoea asarifolia (Desr.)Roem. &Schult	Convolvulacea	Emergent
Ipomoea carnea Jacq.	Convolvulaceae	Emergent
Leersia hexandra Sw.	Poaceae	Emergent
Lemna paucicostata var.membrabacea Hegelm.	Lemnaceae	Free-floating
Linmocharis flava (L.) Buchenau	Alismataceae	Free-floating
Linmophyton obtusifolium L.	Alismataceae	Emergent
Ludwigia erecta (L.) H.Hara	Onagraceae	Emergent
Ludwigia hyssopifolia (G Don) Exell	Onagraceae	Emergent
Ludwigia stolonifera Guill. &Perr. Raven	Onagraceae	Emergent
Luffa aegyptica Mill.	Cucurbitaceae	Emergent
Mariscus alternifolius Vahl	Cyperaceae	Emergent
Marsilea minuta L.	Marsileaceae	Free-floating
Marsilea polycarpa Hook. & Grev.	Marsileaceae	Emergent
Mimosa pigra L.	Mimosaceae	Emergent
Najas pectinata (Parl.)	Hydrocharitaceae	Submerged
Nauclea latifolia Sm.	Rubiaceae	Emergent
Neptunia oleraceae Lour.	Fabaceae	Emergent
Nymphaea lotus Linn	Nymphaceae	Floating-leaved
Nymphaea maculata Schumacher & Thonning	Nymphaceae	Floating-leaved
Oxycarium cubense (Poepp. &kunth)Lye	Cyperaceae	Emergent
Panicum maximum Jacq.	Poaceae	Emergent

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Table 4.1 continued. Aquatic plants of southern Ghana

Phragmites karka (Retz.) Trin.	Poaceae	Emergent
Pistia stratiotes Linn.	Araceae	free-floating
Polygonum lanigarum R.Br	Polygonaceae	Emergent
Polygonum senegalense Meins.	Polygonaceae	Emergent
Potamogeton octandrus Poir.	Potamogetonaceae	Submerged
Rhynchospora corymbosa (Linn.) Britt.	Cyperaceae	Emergent
Ruppia maritima L.	Ruppiaceae	Submerged
Salvinia molesta D.S Mitchell	Salviniaceae	Free-floating
Salvinia nymphellula Desv.	Salviniaceae	Free-floating
Sesbania sesban (L.) Merr.	Fabaceae	Emergent
Sida acuta Burm. f.	Malvaceae	Emergent
Sphenoclea zeylanica Gaertner	Sphenocleaceae	Emergent
Typha domingensis Pers.	Typhaceae	Emergent
Utricularia imflexa L.	Lentibulariaceae	Emergent
Utricularia reflexa L.	Lentibulariaceae	Submerged
Vallisneria aethiopica Fenzl.	Hydrocharitaceae	Submerged
Vossia cuspidata (Roxb.) Griff	Poaceae	Emergent
Wolfia arrhiza Benth.	Lemnaceae	Free-floating

In the families encountered, Cyperaceae was the dominant family. There were 9 different species belonging to this family. The second dominant family was Poaceae which was 6 and then Fabaceae was five. The predominant genera in the study were C*yperus* which had four members. This was followed by *Ipomoea* and *Ludwigia* which were both three.

Aquatic macrophytes were also grouped into the various life forms based on their location in the water bodies encountered, 41 of the species were emergent, 11 were free floating, 8 were submerged whereas two of the encountered aquatic plants were floating-leaved.

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4.2 Systematics, diversity, morphology and distribution of aquatic macrophytes

Out of the 62 aquatic macrophytes encountered, 11 were identified as invasive aquatic macrophytes. The 11 invasive aquatic plants belonged to 11 different families. The families and species were: Pontederiaceae for *Eichhornia crassipes*, Cyperaceae for *Cyperus papyrus*. Poaceae for *Vossia cuspidata*, Azollaceae for *Azolla filiculoides*, Fabaceae for *Mimosa pigra*. Salviniaceae for *Salvinia molesta*, Ceratophyllaceae for *Ceratophyllum demersum*, Typhaceae for *Typha domingensis*, Hydrocharitaceae for *Vallisneria aethiopica*, Araceae for *Pistia stratiotes* and Alismataceae for *Limnocharis flava*.

The invasive aquatic macrophytes were also grouped into their various life forms. Six were free floating, four were emergent and one was submerged. *Pistia stratiotes* was the most distributed within southern Ghana with a total of 7 distribution spots (Fig.4.22). This was followed by *Vossia cuspidata* and *Ceratophyllum demersum* which both had 6 distribution spots. *Azolla filiculoides* and *Limnocharis flava* were the next with five spots for both species. *Eichhornia crassipes* had three spots whereas *Mimosa pigra* and *Vallisneria aethiopica* had two distribution spots. *Salvinia molesta* and *Cyperus papyrus* were restricted to Jewi wharf and the kpongheadpond respectively. Below are the systematics of the 11 encountered aquatic macrophytes and their distribution maps.

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4.2.1 *Eichhornia crassipes* (Mart.) Solms-Lamb

Synonym: *Eichhornia speciosa* kunth.

Common name: Water hyacinth

Family: Pontederiaceae

Description: Water hyacinth is a free-floating perennial aquatic plant. It has a broad, thick and ovate leaves. The leaves are 10-20 cm across, and float above the water surface. It has long, spongy and bulbous stalk. An erect stalk supports single spike 8-15 conspicuously attractive flowers, mostly lavender to pink in colour with size petals. It has a feathery, freely hanging roots and it is purple-black in colour. In Fig. 4.1 is shown the flower and plant of *Eichhornia crassipes* (Mart.) Solms-Lamb.

Reproduction: Water hyacinth reproduces primarily by way of runners or stolons, which eventually form daughter plants. Each plant can reproduce thousands of seeds each year, and these seeds can remain viable for more than 28 years. It is also known to double its population in two weeks.

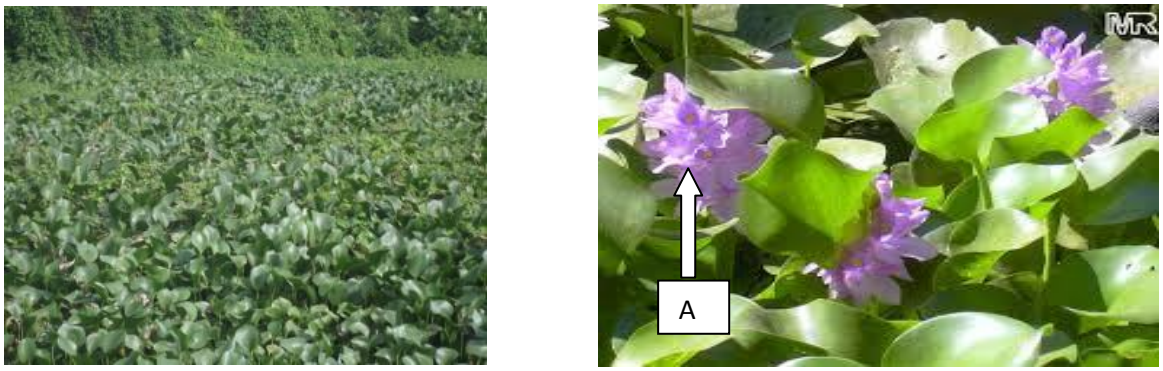

Fig. 4.1 *Eichhornia crassipes* (Mart.) Solms-Lamb. A **(Flower of *Eichhornia crassipes*)**

Uses: It can be used as fodder and manure. It is also used for biological filtration (De Groote *et al*., 2003).

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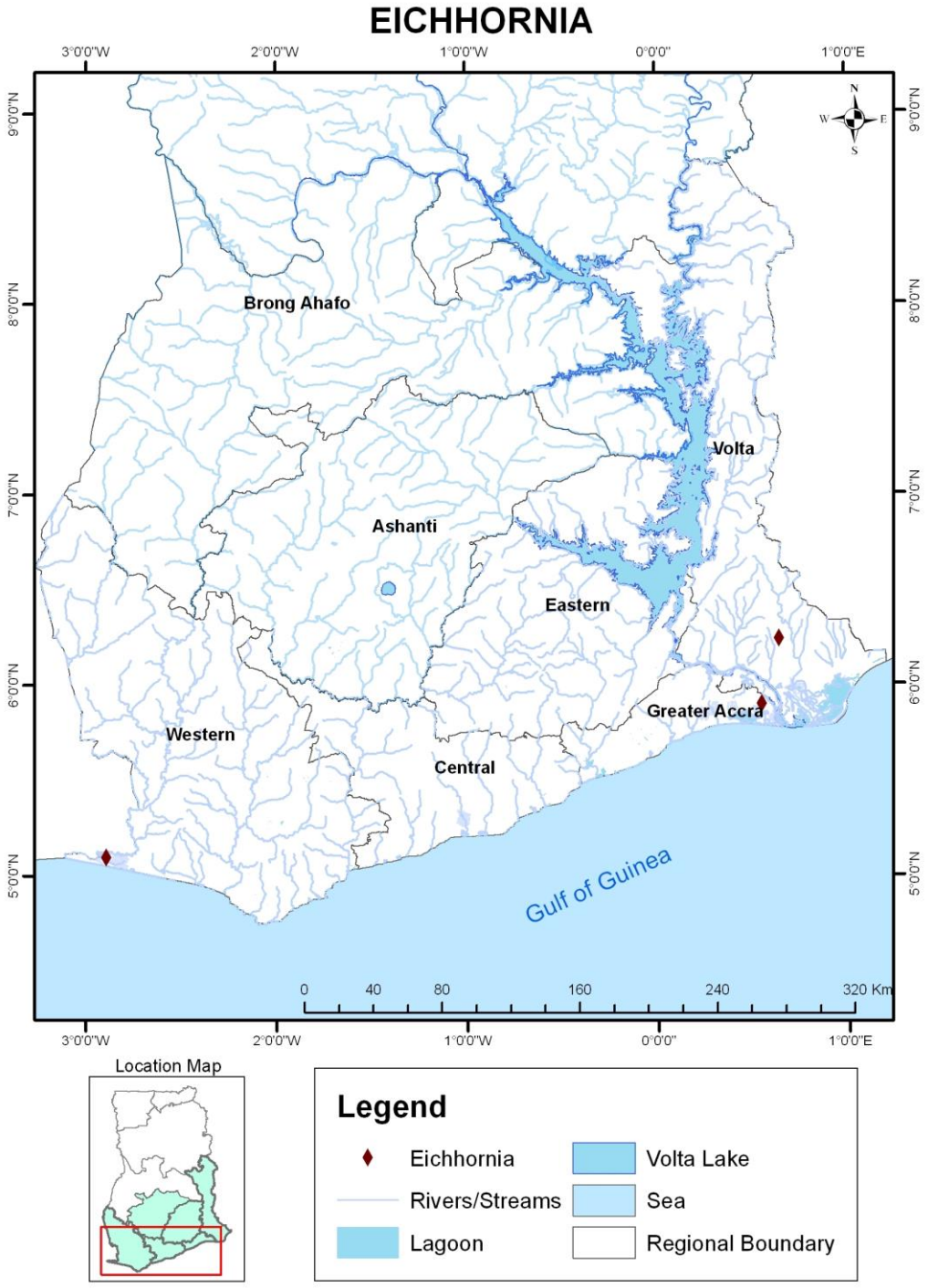

Fig. 4.2 Distribution of *Eichhornia crassipes*

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4.2.2 *Salvinia molesta* D.S Mitchell

Synonym: *Salvinia auriculata* Aubl

Common Names: Kariba weed, giant salvinia

Family: Salviniaceae

Description: *Salvinia molesta* is a floating aquatic fern that thrives in slow-moving nutrient-rich freshwater. It produces a horizontal rhizome and two types of fronds. The mature plant produces egg-shaped spore sacs containing infertile spores. It lacks true roots but its submerged fronds function as roots. The floating fronds are positioned in an opposite orientation to each other and are round to oblong in shape on their upper surface; they have rows of cylindrical papillae. The fronds are light to medium green, often with brownish edges in mature plants. In Fig 4.3 is shown the plant of *Salvinia molesta* D. S Mitchell.

Reproduction: It reproduces by a sexual reproduction. This is capable of growing extremely quickly starting with small fragments.

Fig. 4.3 *Salvinia molesta* D.S Mitchell

Uses: Fodder for ruminants (Howard and Harley, 1998).

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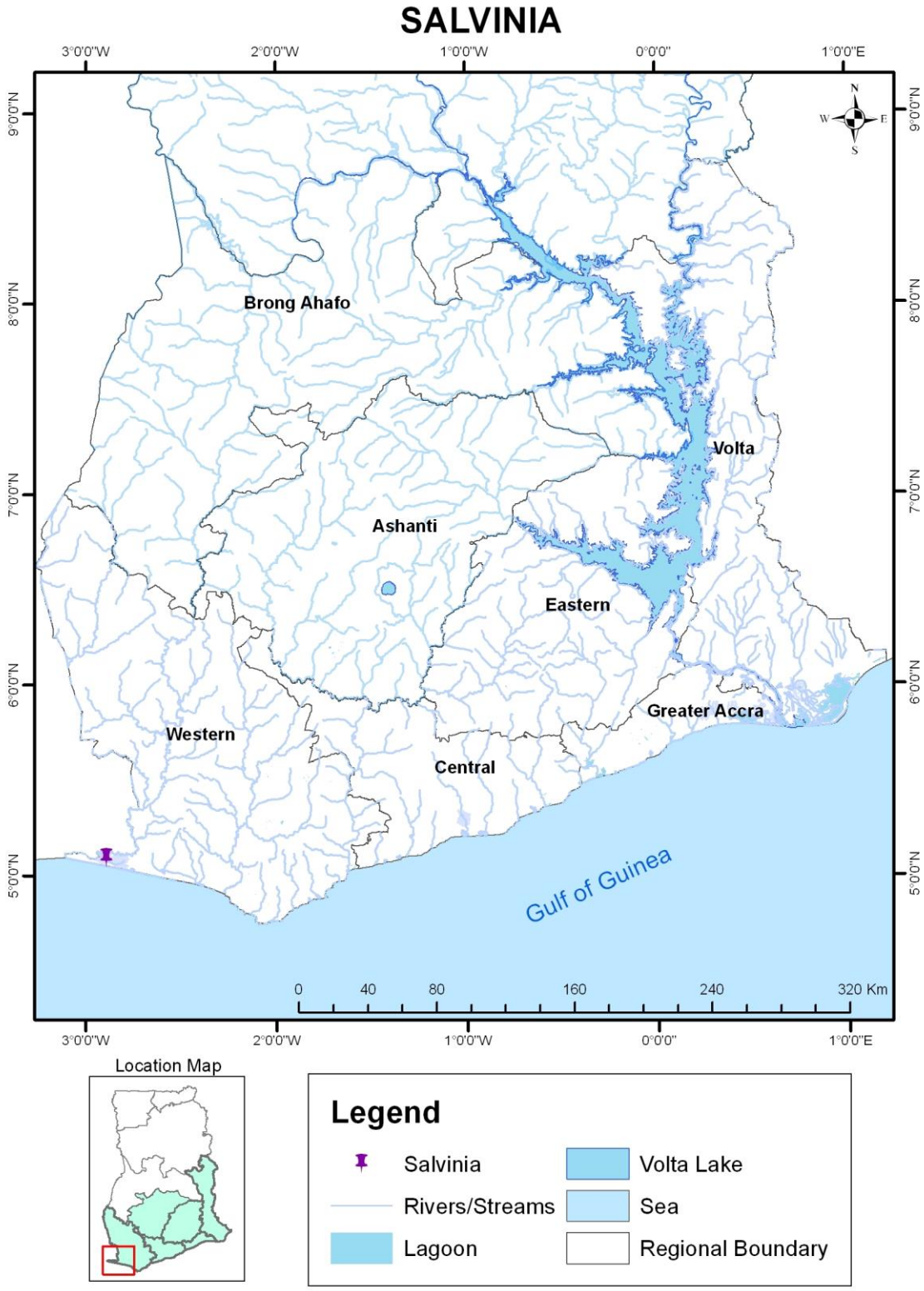

Fig. 4.4 Distribution for *Salvinia molesta*

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4.2.3 *Vossia cuspidata (*Roxb.) Griff.

Synonym: *Vossia cuspidata* var. polystachya

Common name: Hippo Grass

Family: Poaceae

Description: This is a perennial grass with hollow stems. The leaf blades are up to a metre in length and 2 cm in width, tapering gradually to a fine point at the tip, and narrowing slightly towards the base. The mid-rib is broad and white and the leaf margin is very rough. The leaf sheaths are often pinkish in colour, and frequently bear pricking hairs. The inflorescence is up to 30 cm long and has rather thick branches up to 20 cm long in which the spikelets are somewhat sunken. In Fig. 4.5 is presented the plant of *Vossia cuspidata*

Reproduction: It reproduces both sexually and vegetative.

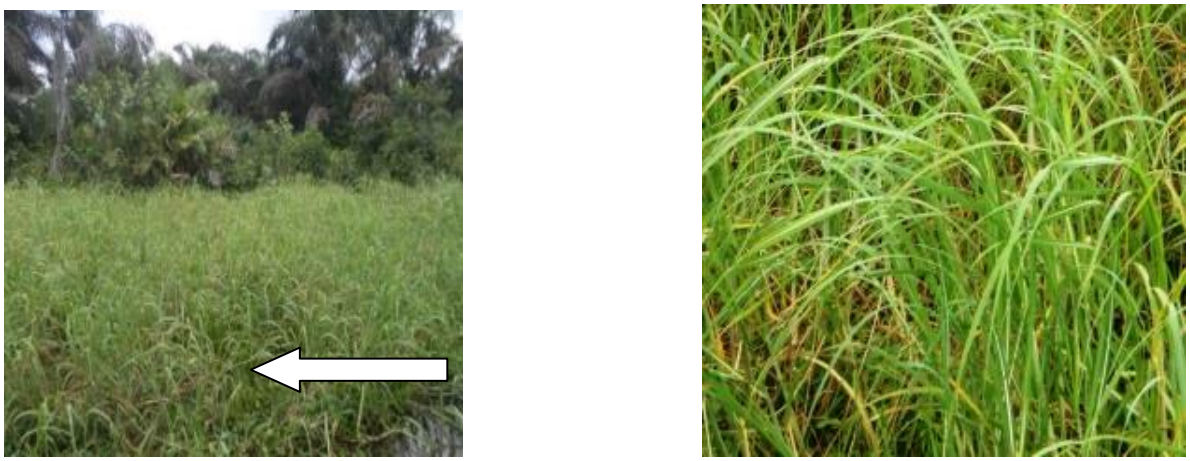

Fig. 4.5 *Vossia cuspidata (*Roxb.) Griff. (Arrow shows *Vossia cuspidata* with other plants in the background)

Uses: It is used as building material and for making paper (Bakshi, 1964).

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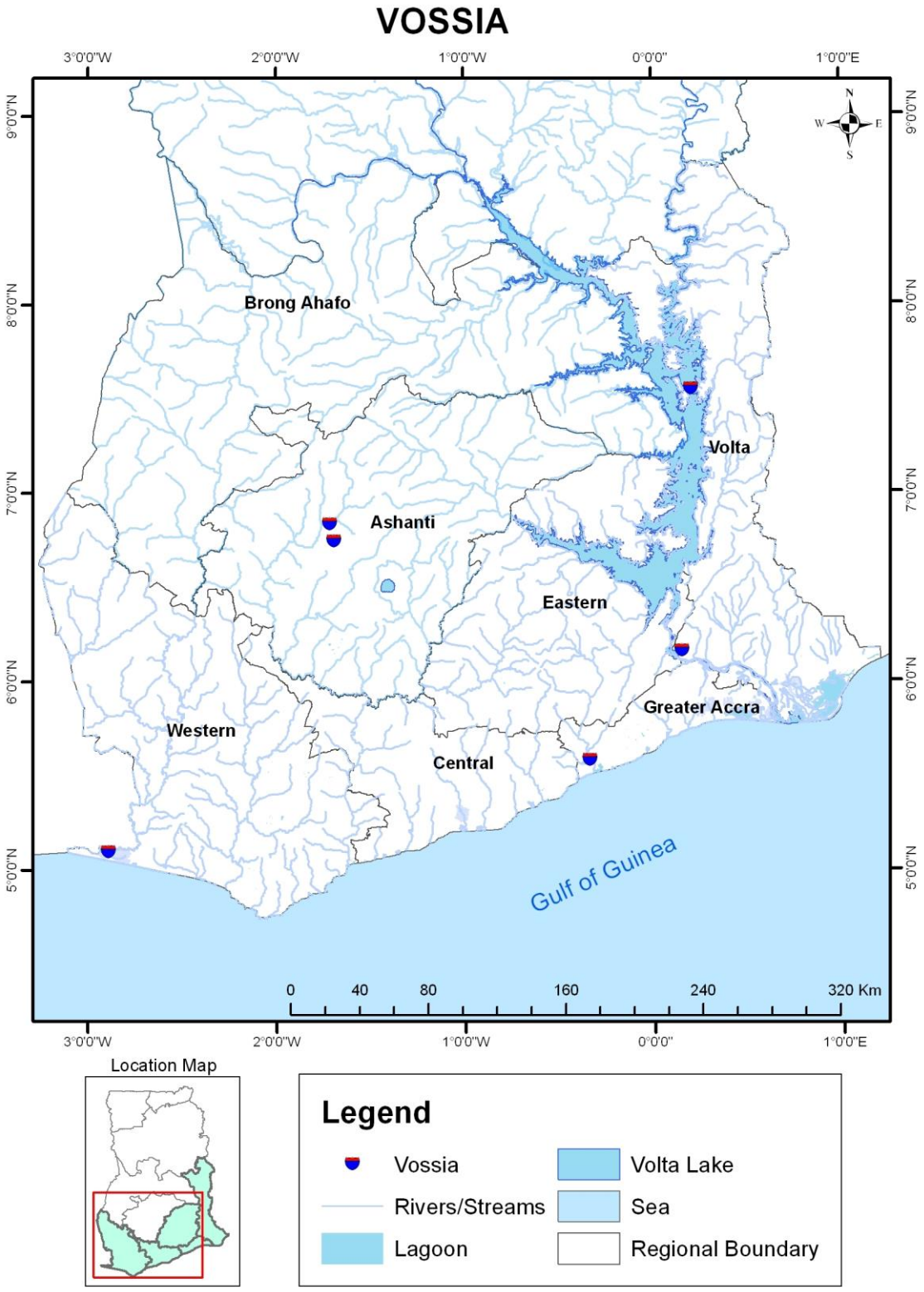

Fig. 4.6 Distribution for *Vossia cuspidata* within Southern Ghana

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4.2.4 *Azolla filiculoides* Desv.

Synonym: *Azolla africana* Desv.

Common Name: Mosquito fern

Family: Azollaceae

Description: The leafy shoots of this small fern lie prostrate on the surface of the water with the roots hanging down from it. Each frond (shoots) is more or less triangular in outline, 1-2 cm long and about the same across. The main stem and the regular pinnate branches are very slender and delicate, about 0.2 mm in diameter, and are completely covered by the two rows of tiny overlapping leaves which are attached to each other. The leaf is about 1mm long and consists of two lobes. The upper lobe is green and covered with small lumps which prevent its surface from being wetted when it is pushed below the water. The lower lobe is thin and flat. The roots are up to 30 cm long and are about the same thickness as the stem. In Fig. 4.7 is shown the plant of *Azolla filiculoides*.

Reproduction: *Azolla* reproduces sexually. It can also reproduce asexually by splitting.

Fig. 4.7 *Azolla filiculoides* Desv.

Uses: For food, and also used for biofuel (Mata *et al*., 2010).

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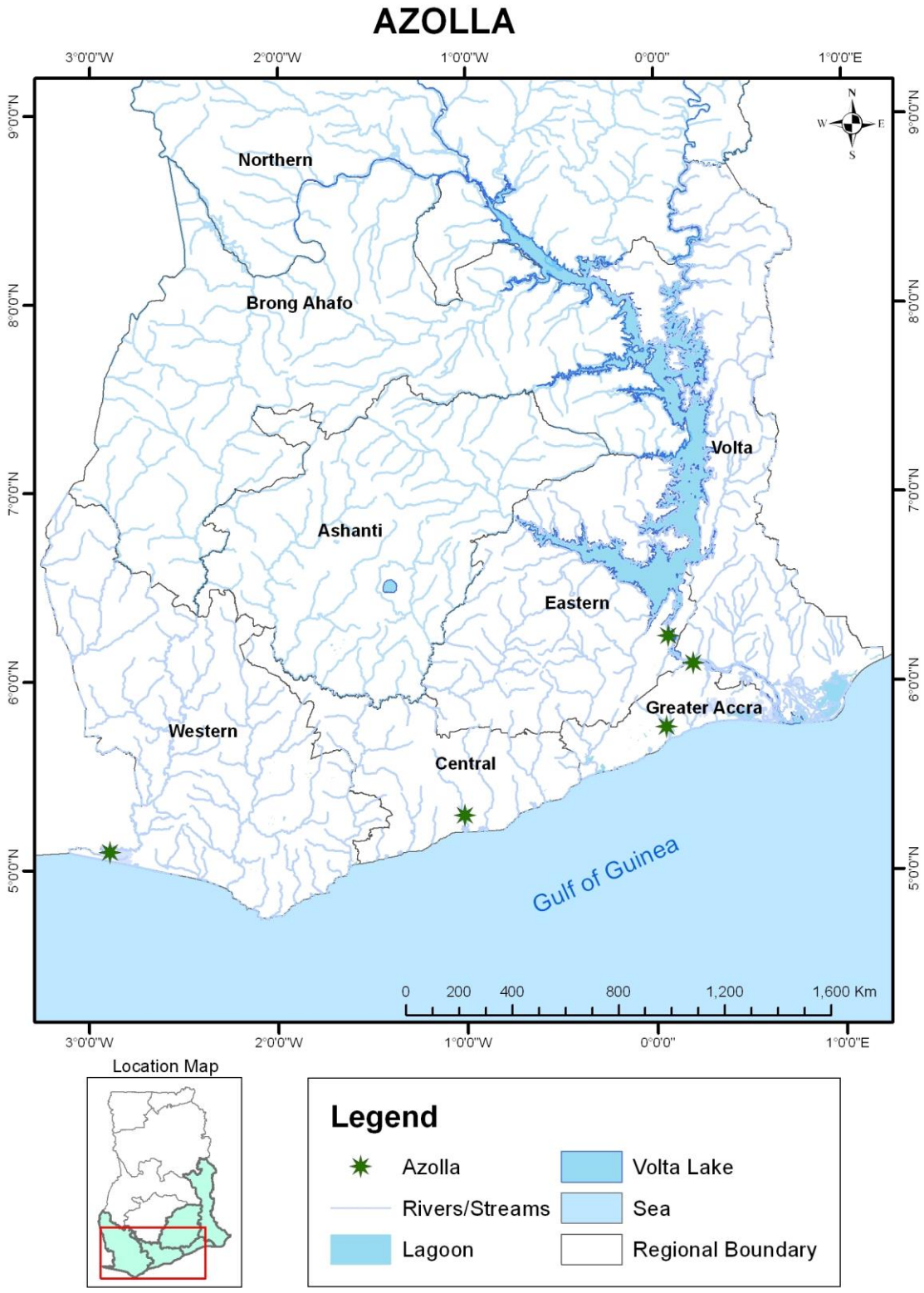

Fig. 4.8 Distribution of *Azolla filiculoides* within southern Ghana

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4.2.5 *Ceratophyllum demersum* L.

Synonym: *Ceratophyllum apiculatum cham*

Common name: Common hornwort

Family: Ceratophyllaceae

Description: *Ceratophyllum demersum* is a submerged aquatic plant which has a stem length of about 1-3 m, with numerous sides shoots making a single specimen appear as a large, bushy mass. The leaves are produced in whorls of six to twelve; each leaf is about 8-40 mm long, simple, or forked into two to eight thread-like segments edged with spiny teeth. It is monoecious with separate male and female flowers produced on the same plant. The fruit is a small nut 4-5 mm long, usually with three spines, two basal and one apical, 1-2 mm long. In Fig. 4.9 is presented the plant of *Ceratophyllum demersum*

Reproduction: It occurs by fragmentation of its brittle stems.

Fig. 4.9 *Ceratophyllum demersum* L.

Local name: Wokli (Dangme)

Uses: It is used as a floating freshwater plant in both cold water and tropical aquarium. It is also used to remove heavy metals from polluted freshwater bodies.

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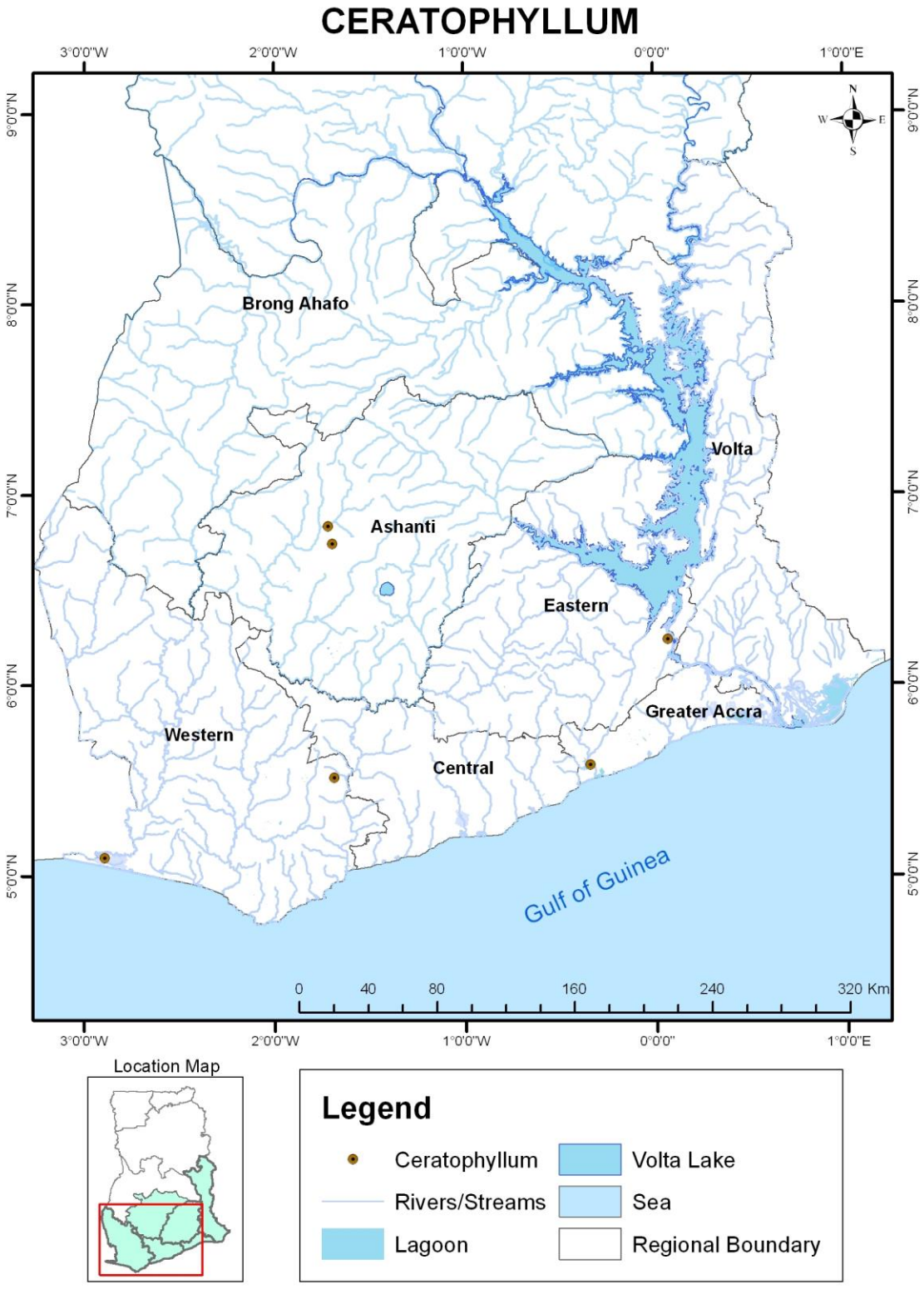

Fig. 4.10 Distribution of *Ceratophyllum demersum* within southern Ghana

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4.2.6 *Typha domingensis* Pers.

Synonym: *Typha angustata* Bory-chaubard

Common name: Southern cattail

Family: Typhaceae

Description: This is a perennial that grows to about 3 m. The flowers are monoecious (individual flowers are either male or female, but both sexes can be found on the same plant and are pollinated by wind. It has extensive root system for stabilizing wet banks of rivers. In Fig 4.11 is shown the plant of *Typha domingensis*

Reproduction: It can be propagated by seed and vegetative propagation.

Fig. 4.11 *Typha domingensis* Pers

B (Fruit of *Typha domingensis*)

Uses: For making mats, stems and leaves for making thatch and also has medicinal uses.

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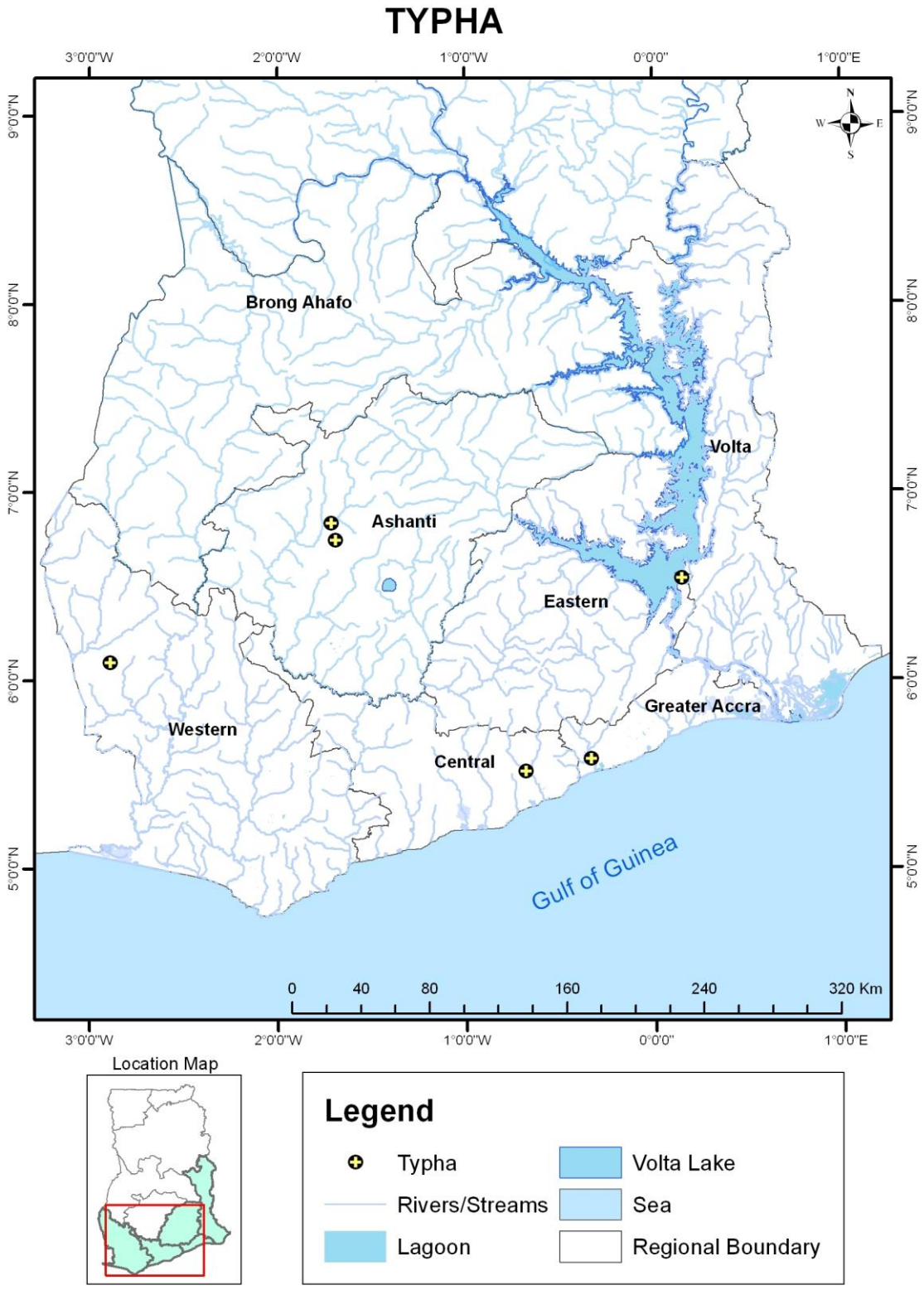

Fig. 4.12 Distribution of *Typha domingensis*

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4.2.7 *Mimosa pigra* L.

Synonym: *Mimosa pellita*

Common name: Catclaw mimosa

Family: Fabaceae

Description: This is a leguminous shrub, which can reach up to 6 m in height. The stem is greenish in young plants but becomes woody as the plant mature. The leaves are bright green and pinnate, consisting of a central prickly rachis 20-25 cm long with up to 16 pairs of pinnae 5 cm long. Flowers are mauve or pink. In Fig. 4.13 is presented the plant of *Mimosa pigra*.

Reproduction: By seed

Fig. 4.13 *Mimosa pigra* L.

Uses: Fuel wood

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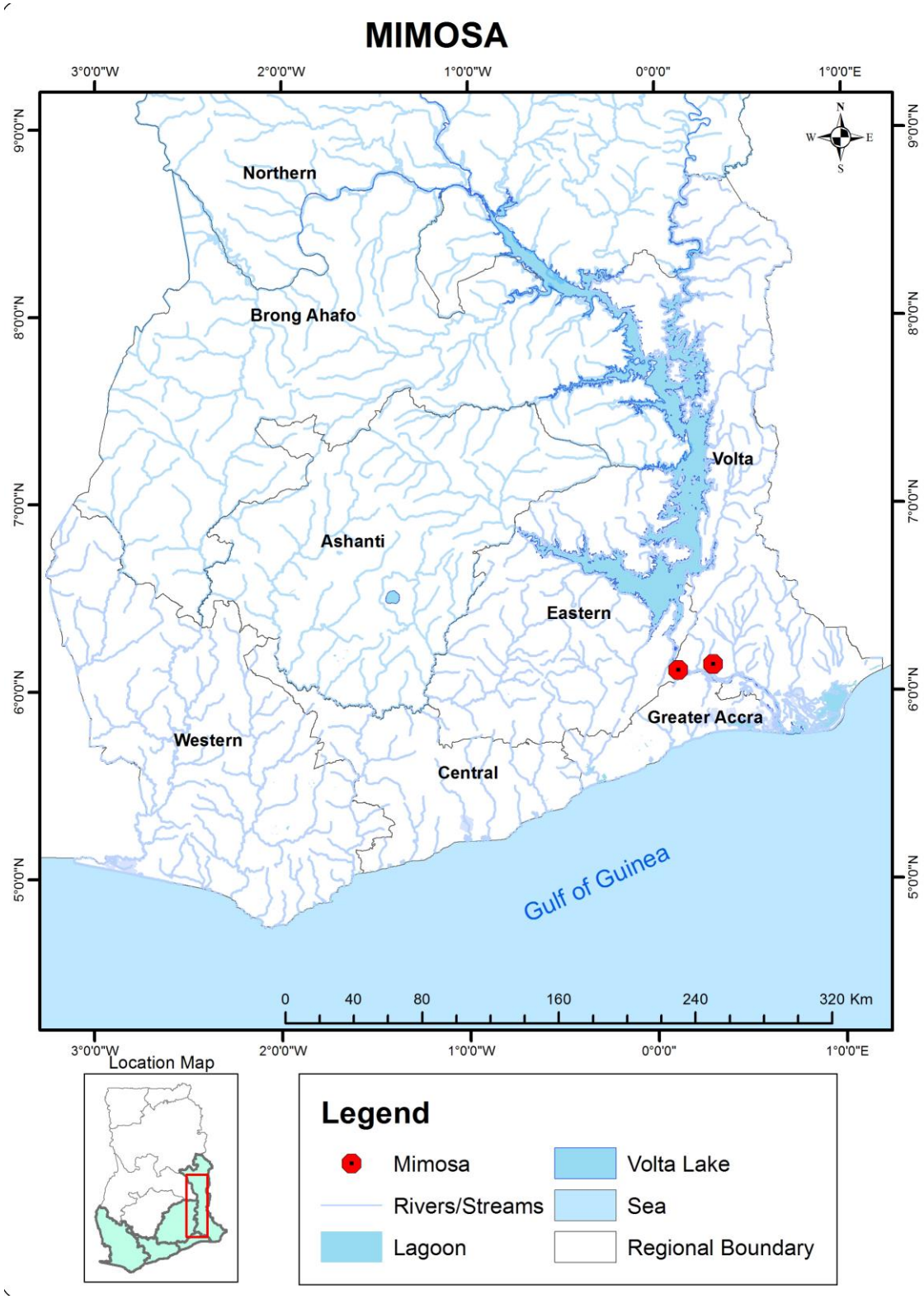

Fig. 4.14 Distribution of *Mimosa pigra* within southern Ghana

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4.2.8 *Cyperus papyrus* L.

Synonym: Paper reed

Common name: Egyptian paper plant

Family: Cyperaceae

Description: This is a tall robust and leafless aquatic plant, which can grow 4 to 5 m high. It forms a grass-like clump of triangular green stems that rise up from thick woody rhizomes. Each stem is topped by a dense cluster of thin, bright green, thread-like stems around 10 to 30 cm in length, resembling a feature cluster when the plant is young. Greenish- brown flower clusters eventually appear at the end of the rays, giving way to brown, nut like fruits. In Fig 4.15 is shown the plant of *Cyperus papyrus*.

Reproduction: By seed

Fig. 4.15 *Cyperus papyrus* L.

Uses: For making paper

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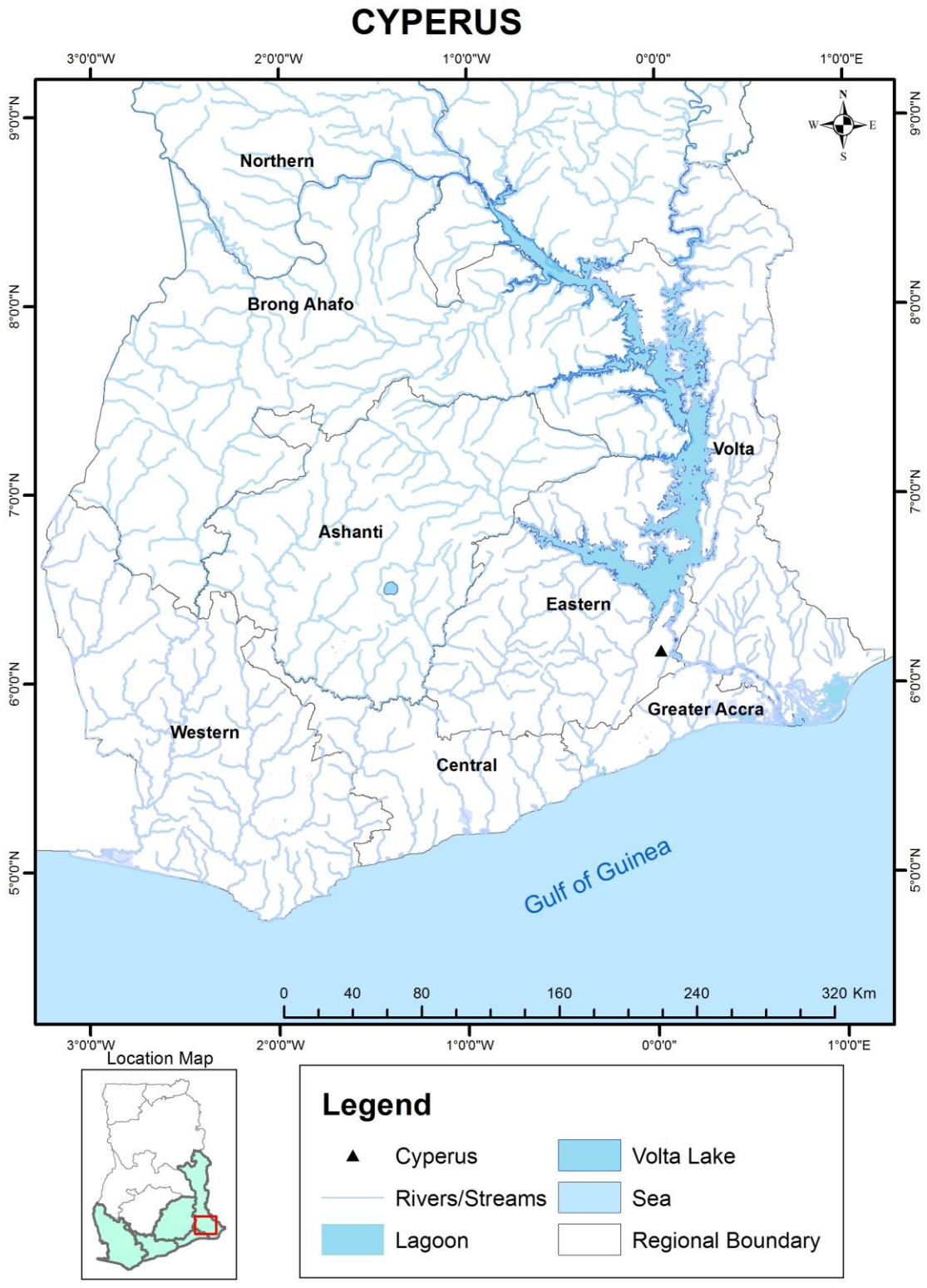

Fig. 4.16 Distribution of *Cyperus papyrus* within southern Ghana

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4.2.9 *Vallisneria aethiopica* Fenzl.

Common name: Tape grass/ Eel grass

Family: Hydrocharitaceae

Description: This is a submerged plant that spreads by runners and sometimes forms a tall under water meadows. Leaves arise in clusters from their tips. Leaves have rounded tips and definite raised veins. Single white flowers grow to the water surface on very long stems. In Fig 4.17 is shown the plant of *Vallisneria aethiopica*.

Reproduction: Asexual reproduction.

Fig. 4.17 *Vallisneria aethiopica* Fenzl.

Uses: For fodder

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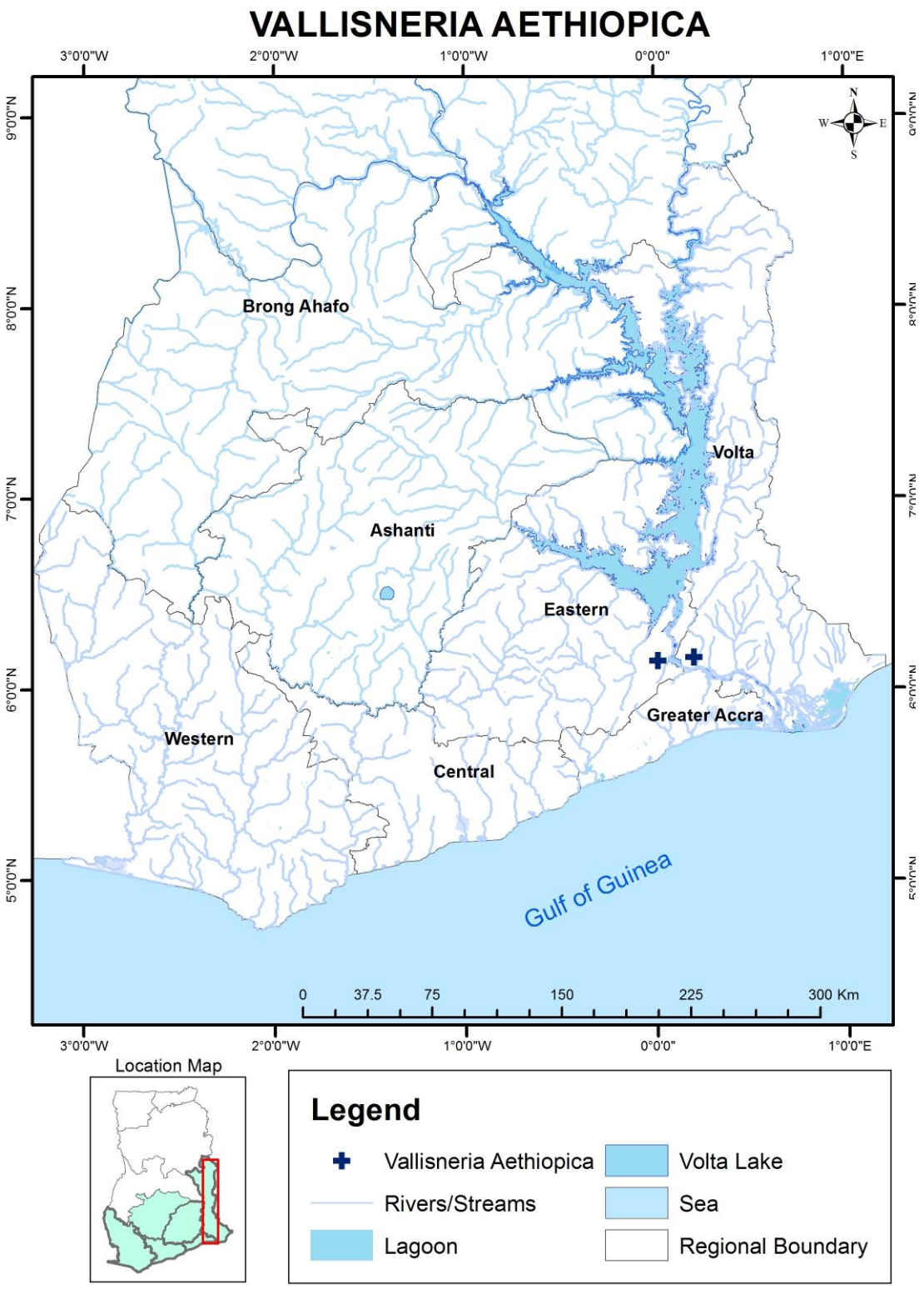

Fig. 4.18 Distribution of *Vallisneria aethiopica* within southern Ghana

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4.2.10 *Limnocharis flava* L.

Synonym: *Limnocharis emarginata* H.B. & K.Pl. aequin

Common name: Yellow sawah lettuce

Family: Alismataceae

Description: *Limnocharis flava* is a perennial herb that is partially submerged, and rooted in the substrate. The roots are fibrous white or brown. Stems are rounded, glabrous, hollow or spongy. Stipules are absent and the Petiole is triangular in shape. Leaves alternate distichous, margin entire, orbicular, more than 2 cm long/wide, glabrous, and apex rounded or emarginated. Base of the leaf is clasped, cordate, or rounded. Leaf sheath is present and it is rounded or compressed in cross section. Flowers are bisexual, grouped together in a terminal lax umbel. It has a stalk, three petals which are yellow in colour, and has many stamens. Its fruits are spherical and made up of crescent shaped segments that eventually split off, and are carried by water currents to disperse seeds to new locations. In Fig 4.19 is shown the plant of *Limnocharis flava*.

Reproduction: By seed

Fig. 4.19 *Limnocharis flava* L.

Uses: Fresh young leaves are eaten as Vegetable **(**Abhilash, 2004).

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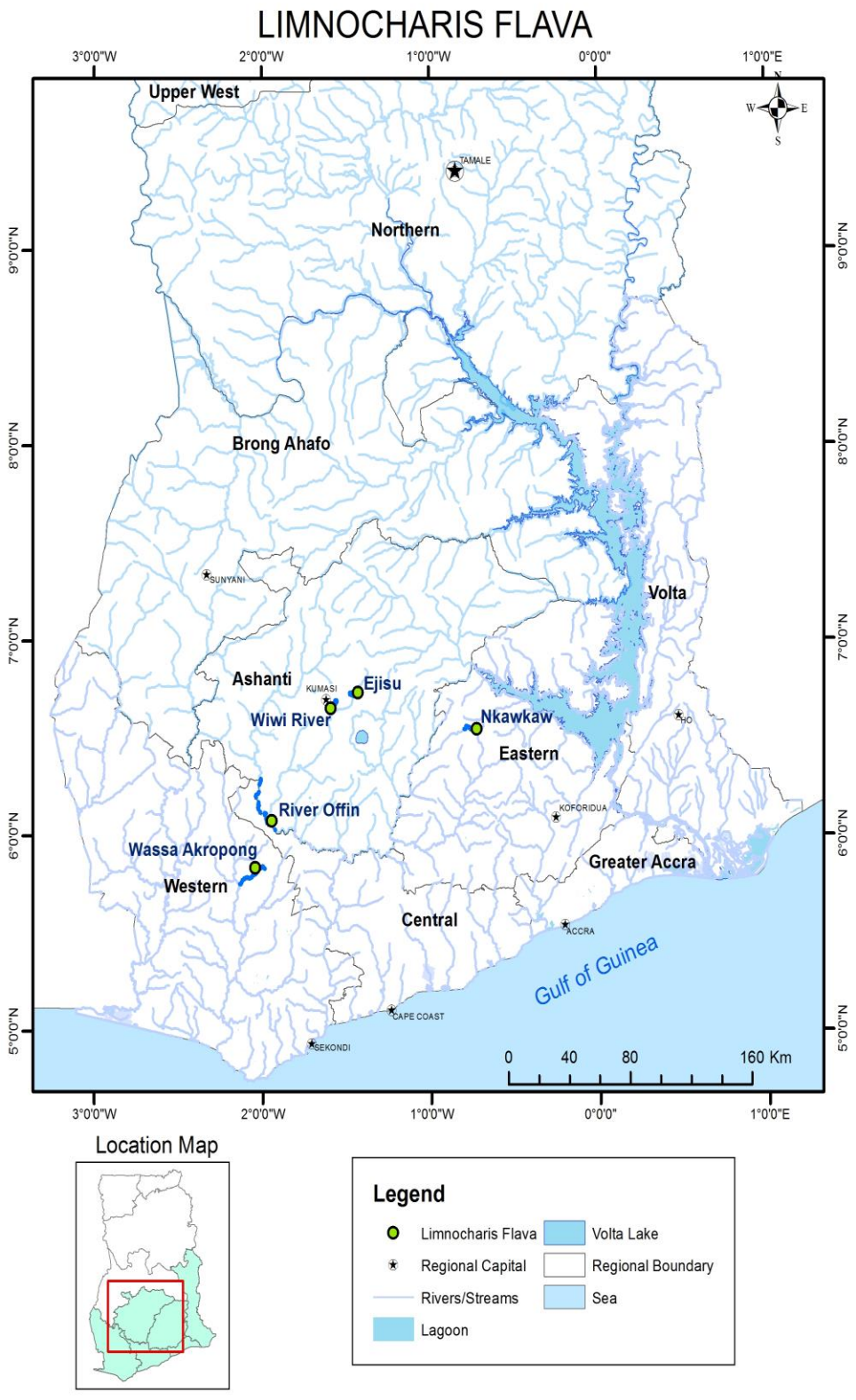

Fig. 4.20 Distribution of *Limnocharis flava* within southern Ghana

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4.2.11 *Pistia stratiotes* Linn.

Synonym: *Pistia stratiotes* var.cuneata Engl.

Common names: Water cabbage, water lettuce

Family: Araceae

Description: This plant floats freely on the surface of the water and sometimes grows on mud. The leaves are thick, spongy and covered by short velvety hairs which prevent the leaf from becoming wet when pushed under the water. The roots are up to 50 cm long, numerous, slender, with many small branches which give them a feathery appearance when looked at in the water. In Fig 4.21 is presented the plant of *Pistia stratiotes*.

Reproduction: Sexual reproduction.

Fig. 4.21 *Pistia stratiotes* Linn.

Uses: Water lettuce is often used in tropical aquariums to provide cover for fry and small fish. It's also helpful as it out competes algae for nutrients in water, thus preventing algae growth.

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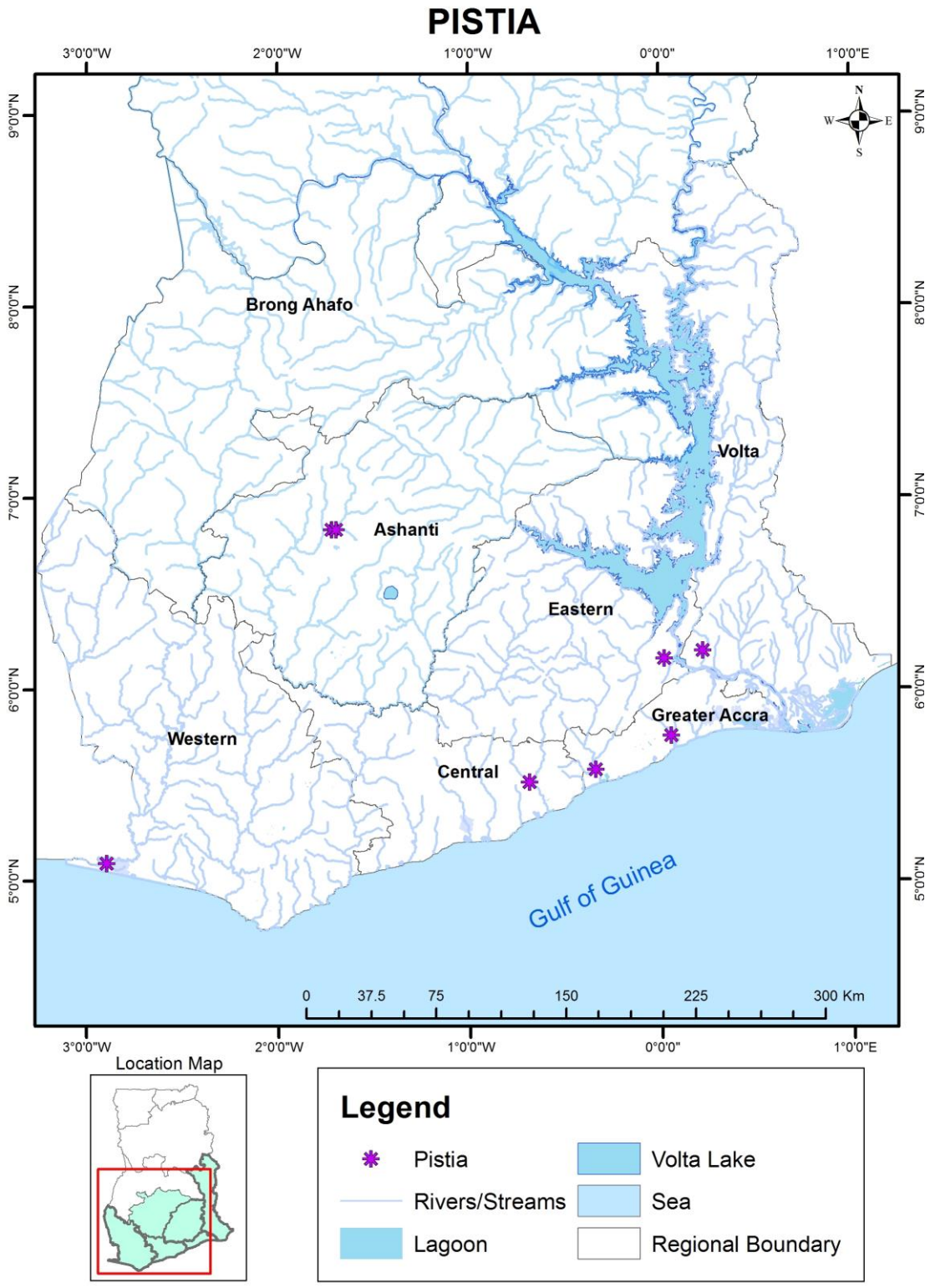

Fig. 4.22 Distribution for *Pistia stratiotes* within southern Ghana

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4.3 Systematics, distribution and uses of aquatic macrophytes (non-invasives)

The systematics, morphology (refer to photos), distribution and uses of the encountered aquatic macrophytes are presented in this section. Fifty-one species were identified as non-invasive aquatic macrophytes (Table 4.1). For each species entry the following information is presented: species name, synonym, common name, description of plant, reproduction, distribution, habitat and uses.

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4.3.1 *Nymphaea lotus* Linn.

Synonyms: *Nymphaea dentata* Schumach

Common Names: Tiger lotus, White lotus, Egyptian white water lily.

Description: This species of water lily has leaves which float on the water, and flower which rises above the water. It is perennial and grows to about 45 cm in height. The colour of the flower is white, sometimes tinged with pink and opens only at night. *Nymphaea lotus* has larger leaves up to 30 cm across, with a strongly toothed margin. It also has a short sterm which is firmly anchored to the sediment by long roots which contain large airspaces. From the stem, the long leaf-stalks extend right up to the water surface. They are smooth, flexible, and soft and contain abundant air spaces. In Fig. 4.23 is presented photos of *Nymphaea lotus* showing mainly leaf shape and inflorescence.

Reproduction: *Nymphaea lotus* can undergo both sexual and vegetative reproduction.

Fig. 4.23 *Nymphaea lotus* Linn.

Distribution: Widely distributed: Ada-Accra road, Weija, Accra-Winneba road, Barekese, Avu lagoon, the Volta Lake, Mankesim, Kpong Headpond.

Habitat: It is found in ponds, and margins of freshwater lagoons.

Uses: In some parts of Africa, the rhizomes and tubers are eaten for the starch they contain. The flower buds and seeds are eaten as food, medicine or to cause hallucination

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4.3.2 *Cyperus distans* Linn.

Synonymys: *Cyperus nutams Presi, Cyperus elatus Rottb*
Common name: Slender cyperus

Family: Cyperaceae

Description: *Cyperus distans* is a perennial growing to about 0.5 m. The stem is triangular in cross section and about 5 mm wide. Each plant consists of several stems growing from a single root stock. The dark green leaves arise from the base of the erect stem but their tubular sheaths, which surround the stem, are of different lengths. So the leaves appear to arise from different heights on the stem. Leaf blade is up to 5 mm wide and 30 cm long. Although they are dark green above; they are pale whitish green below. They are V-shape in section along the midrib. There are no hairs on leaves or stem. The inflorescence which terminates the stem is surrounded by leaf-like bracts up to 25 cm long. The inflorescence consists of several branches bearing many reddish-coloured spikelets which are needle-like when young and 1-2 cm long by 1 mm wide when fully grown. The scales of the spikelet are quite well-separated from each other-hence the name distans. In Fig 4.24 is presented the plant of *Cyperus distans*.

Reproduction: This species reproduces sexually and vegetatively.

Fig. 4.24 *Cyperus distans* Linn.

Habitat: Fresh water and terrestrial habitat.

Distribution: Hohoe, Nungua, Prampram, Tema, Ashaiman.

Uses: For food and medicine.

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4.3.3 *Polygonum senegalensis* Meins

Synonym: *Persicaria senegalensis*

Common Name: Manding - Maninka. (Sierra Leone)

Family: Polygonaceae

Description: The leaves are 20-30 cm long by 4-5 cm broad, and taper to a point at either end. The leaf stalk is attached to the outside of a smooth tubular sheath, which extends up to 3-4 cm from its origin at the node. The flowers are small about 4 mm long, pink and white and bome in spikes on a branching inflorescence at the top of the stem. In Fig.4.25 is presented photos of the plant *Polygonum senegalensis*.

Reproduction: By seeds

Fig. 4.25 *Polygonum senegalensis* Meins

Habitat: Found in a wide variety of habitats, being found submerged or as helophyte.

Distribution: Mankesim, Volta system, Tano, Owabi, Barekese, Brimsu

Uses: For food and medicine.

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4.3.4 *Oxycarium cubense* (Poepp. &Kunth) Lye

Synonym: *Oxycaryum cubense* (Poepp & Kunth)

Commom names: Alligator weed, burhead sedge (English)

Family: Cyperaceae

Description: *Oxycarium cubense* is perennial, rhizomatous, emergent sedge that has slender, triangular erect stem about 0.31-0.90 m in height. The inflorescence consists of 1-13 globos or ovoid heads each with five or more spikelet and may be umbellate or monocephalous, and produce pale or red-brown beaked seeds that are ovoid. In Fig. 4.26 is presented the plant *oxycarium cubense*.

Reproduction: *Oxycarium cubense* reproduces by rhizomes/stolons and by the production of achenes

Fig. 4.26 *Oxycarium cubense* (Poepp. &Kunth) Lye

Habitat: It is found in rivers; streams, swamps marshes, ponds and other forms of standing water. It may be on the water's edge or may detach from the land and float freely.

Distribution: Volta System, Weija, Tano, Barekese, Owabi, Mankesim

Uses: Food for ducks and important in the cycling of detritus.

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4.3.5 *Utricularia imflexa* L.

Synonym: *Utricularia imflexa* forssk

Common name: Bladderwort

Family: Lentibulariaceae

Description: *Utricularia imflexa* commonly called bladderworts is a genus of carnivorous plants that grows completely submerged in water and has narrowly divided leaves. The leaves are softer and finer and bear large numbers of bladders which are small, rounded structures about 1 mm across. The colours of the bladders are green when they are newly-formed and empty, but the older ones are blackish because they contain the remains of tiny water animals. It also has yellow or purple flowers which are easy to see because they are carried above the water surface on a stalk that is supported by a ring of spongy air-filled floats. In Fig. 4.27 is presented photos of the plant *Utricularia imflexa* L.

Reproduction: Bladderwort can reproduce asexually by vegetative reproduction and sexually by seed formation.

Fig. 4.27 *Utricularia imflexa* L.

Habitat: *Utricularia* can survive almost anywhere there is fresh water for at least part of the year.

Distribution: Tano lagoon, Avu lagoon, Kpong Headpond

Uses: The dried leaves are used to make medicinal tea.

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4.3.6 *Lemna paucicostata* var.*membrabacea Hegelm*

Synonym: *Staurogeton* (Rchb) Schur

Common name: Duck weed

Family: Araceae

Description: *Lemna paucicostata* is a small free-floating aquatic plant from the duck weed family. The stems and leaves are not clearly distinguishable. *Lemna* has flattened oval fronds 2-3.5 mm long and 1.5-2 mm broad with a single root growing to 1 cm or more long from close to one end of the frond. In Fig.4.28 shows the plant of *lemna paucicostata*.

Reproduction: The plant grows mainly by vegetative reproduction; two daughter plants bud off from the adult plant. This form of growth allows very rapid colonisation of new water.

Fig. 4.28 *Lemna paucicostata* var. *membrabacea Hegelm*

Habitat: It can found in lakes, ponds and slow moving rivers.

Distribution: Akotokyir, Takoradi, Samreboi, Abura, Mankesim, Avu lagoon and Tano.

Uses: For food.

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4.3.7 *Nymphaea maculata* Schumacher & Thonning

Synonyms: *Nymphaea heudelotii* var. nana,

Common name: African tiger lotus

Family: Nymphaeaceae

Description: This is a delicate aquatic herb with elongated rhizome. They are either perennials or annuals with floating leaves. It has a stout stem, slender stolons, corms or tubers. The flowers are born singly, and held above the water surface on stout pedicels. There are actually two types of this plant, the Red Tiger lotus and the Green Tiger lotus. Although colouration is different, the leaf shape is exactly the same and they produce similar flowers. They are classified as specimen plant and should be given plenty of room in the aquarium to grow. If flowers are not required, the flower stems can be pinched off before they reach the water surface. In Fig. 4.29 is shown the leaf shape and plant of *Nymphaea maculata*.

Reproduction: *Nymphaea maculata* can reproduce from the bulb.

Fig. 4.29 *Nymphaea maculata* Schumacher & Thonning

Habitat: It can be found in lakes, ponds, and slow moving rivers and in aquariums.

Distribution: Ada, Mankesim

Uses: The rhizomes, flower buds and seed are eaten as food.

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4.3.8 *Neptunia oleraceae* Lour.

Synonyms: *Mimosa prostrate* lam

Common name: Water mimosa

Family: Fabaceae

Description: It is an aquatic herb with creeping stems often swollen and floating. Leaves are sensitive, bipinnate with 2-4 pairs. The flower has a subspherical axillary heads about 1.5-2.5 cm in diameter and bright yellow in colour. The fruits are flat pods, bent at an angle to a short basal stipe. In Fig.4.30 is presented the plant of *Neptunia oleraceae* Lour.

Reproduction: This can be propagated from seeds, but the conventional horticultural method is by stem cutting.

Fig. 4.30 *Neptunia oleraceae* Lour. C (Flower of *Neptunia oleraceae* Lour)

Habitat: Primarily found growing prostrate in wet soils near the water's edge or floating on the water in relatively still-water areas.

Distribution: Ada, Mankesim, Avu lagoon,

Uses: Food for humans (leaves and shoots), also used as medicine for curing ear-ache and syphilis.

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4.3.9 *Polygonum lanigerum* R.Br

Synonyms: *Persicaria lanigeria* (R. Br.) Sojak

Common name: Knotweed, Bistort

Family: Polygonaceae

Description: This is an erect annual or perennial herb. Leaves are mostly alternate and the stipules are united into a membranous sheath (ochrea). The ochreas are inconspicuous and translucent or translucent or conspicuous and membranous. The flowers are bisexual or rarely unisexual and are radially symmetrical. Sepals and petals alike, forming a perianth. The flowers are small and pink in colour. The stem is also erect or bonding upwards with many nodes on the stem. In Fig. 4.31 is shown the plant of *Polygonum lanigerum* R.Br.

Reproduction: By seed or vegetative propagation.

Fig. 4.31 *Polygonum lanigerum* R.Br

Habitat: Wet areas, depressions, and edges of swamps

Distribution: Mankesim, Avu lagoon, Tano River and lagoon,

Uses: Food for humans

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4.3.10 *Marsilea minuta* Linnaeus *M. diffusa* leprieur ex. A. Braun

Synonym: *Marsilea diffusa* A. Braun

Common name: Water clover

Family: Marsileaceae

Description: This is a small plant of unusual appearance and do not resemble common ferns. It has a long stalk with four clover-like lobes and are either held above water or submerged. The leaves are borne alternately along the upper side of the rhizome at the nodes. One or more adventitious roots are borne at each node on the underside of the rhizome. The adventitious roots may arise even from internodes. Sporocarps are usually crowded or rarely in groups of 2 or 3, very rarely solitary, broadly oblong to broadly elliptic in lateral view. In Fig. 4.32 is shown the plant of *Marsilea minuta* Linnaeus *M. diffusa* leprieur ex. A. Braun.

Reproduction: This is by vegetative and sexual methods.

Fig. 4.32 *Marsilea minuta* Linnaeus *M. diffusa* leprieur ex. A. Braun

Habitat: Shallow pools, at the edges of rivers, canals and ditches, most abundant in temporarily flooded places where it may form large and dense colonies which can be become locally dominant.

Distribution: Mankesim, Volta River system

Uses: For making medicine.

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4.3.11 *Ludwigia stolonifera* Guill. & Perr. Raven

Synonym: *Jussiaea diffusa* Forssk.

Common name: Creeping ludwigia

Family: Onagraceae

Description: This is a perennial creeping herb which roots at the nodes. It is a floating aquatic and has stems often purple-red, prostrate or ascending. The leaves are narrowly lanceolate, shiny dark green. The flowers are solitary in the upper leaf axils, pale yellow with a darker spot at the base of the petals. Sepals and petals are five in number with the stamen numbering ten. In Fig. 4.33 is presented the plant of *Ludwigia stolonifera* Guill. & Perr. Raven.

Reproduction: By seeds

Fig. 4.33 *Ludwigia stolonifera* Guill. & Perr. Raven

Habitat: It can be found in lakes, shallow waters, ditches and rivers.

Distribution: Volta system, Owabi, Kwanyarko, Weija, Barekese, Mankesim

Uses: Food for humans

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4.3.12 *Eleocharis complanata* Boeck

Synonym: *Eleocharis anceps* Ridl.

Common name: No common name associated with taxon yet

Family: Cyperaceae

Description: This is annual sedge with a fibrous root system. The leaves have bladeless sheaths which are limited to the base of the stem, which is greenish above, purple or brown below. Inflorescence is pale to pinkish, oval (with ovoid, pale or pinkish). Spikelets are 3-5 cm long and 1.5-2 mm wide, but stretching to 15 mm long and 3 mm wide when old. In Fig. 4.34 is shown the plant of *Eleocharis complanata* Boeck.

Reproduction: By seeds

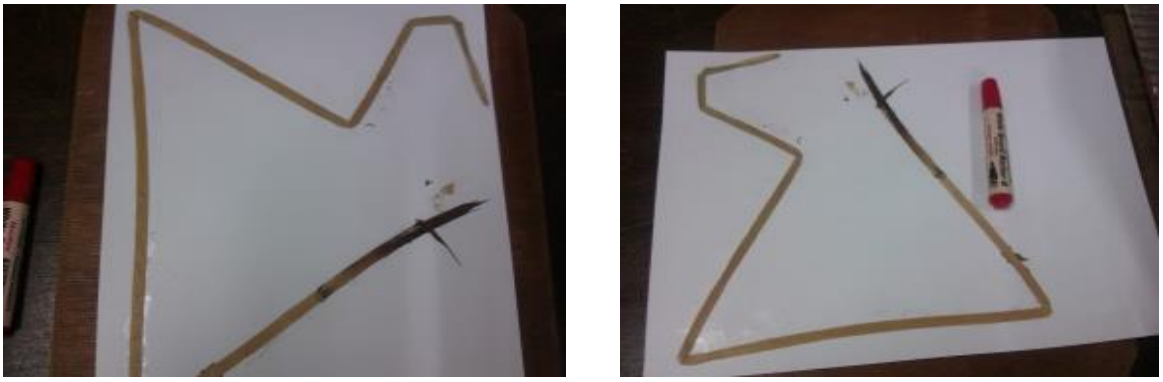

Fig. 4.34 *Eleocharis complanata* Boeck

Habitat: Rice fields, pools and other marshy places.

Distribution: Anum –Asikuma, Mankesim,

Uses: For making mat

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4.3.13 *Ceratopteris cornuta* (P. Beauv.) Lepr.

Synonym: *Parkeria*

Common name: Water sprite

Family: Pteridaceae

Description: This is an erect aquatic or subaquatic fern of moderate size. It has a short rhizome which is either rooted or free-floating with distinctive deeply lobbed, pinnate leaves. Leaves in a rossete, entire to one or more pinnate, and up to 40 cm long. The stipes is succulent and brittle with the lower blade sterile and often developing buds on the margins. Stem is much reduced, bearing few scales and numerous roots. In Fig. 4.35 is shown the plant of *Ceratopteris cornuta* (P. Beauv.) Lepr.

Reproduction: By vegetative propagation.

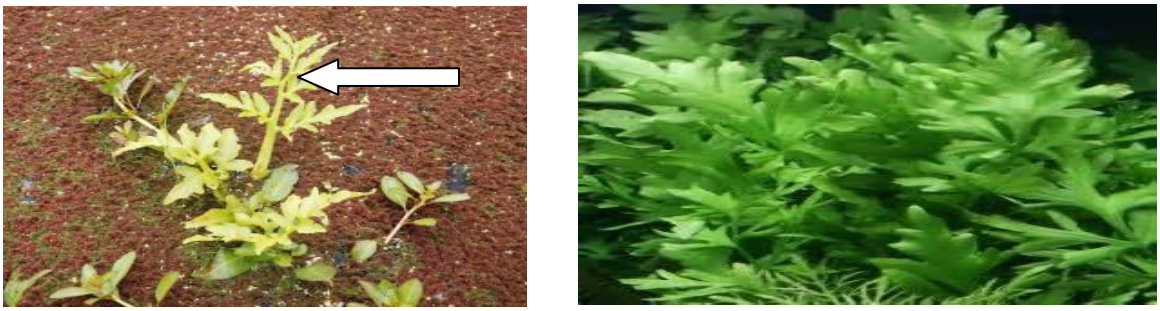

Fig. 4.35 *Ceratopteris cornuta* (P. Beauv.) Lepr.

Habitat: Usually found in permanent or semi-permanent water and in mats of floating vegetation, free floating plants are sometimes found in canals and ditches.

Distribution: Volta system, Mankesim,

Uses: For ornament in aquariums

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4.3.14 *Cyperus articulatus* Linn.

Synonym: *Cyperus articulatus*

Common name: Jointed flatsedge

Family: Cyperaceae

Description: This is a tall marsh grass that grows in small clusters and routinely reaches over six feet 2 m in height. The stem is fibrous, cylindrical, and hollow and can be as large as three/quarters of an inch in diameter at the base. The stem narrows as it grows upward turning into spiked blades of shiny grass, which range in colour from bright yellow-green to dark forest green. Involucral bracts scale-like and 5-15 mm long. The inflorescence is a compound panicle, consisting of 1-3 sessile spikes and 2-10 stalked spikes with or without secondary spikes. In Fig.4.36 is shown the plant of *Cyperus articulatus* Linn.

Reproduction: By seeds.

Fig. 4.36 *Cyperus articulatus* Linn.

Habitat: Grows near the edges of lakes, ponds, swamps, rivers, streams, wetlands and other damp soil areas.

Distribution: Cape Coast, Koforidua, Sakumo II lagoon, Weija, Keta, Ada, Mankesim

Uses: Rhizome for making medicine and culms for making mat.

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4.3.15 *Cyclosorus striatus* (Schum.) Ching

Synonym: *Cyclosorus striatus* (Schum.) Ching

Common name: Sierra Leone: *KISSI* konjo-konjoalso

Family: Thelypteridaceae

Description: This is a perennial fern that grows on terrestrial or on rock. The stem is creeping to erect and scaly at the apex. The leaves are monomorphic or somewhat dimorphic and pinnately shaped. In Fig. 4.37 is presented the plant of *Cyclosorus striatus* (Schum.) Ching.

Reproduction: Asexual reproduction reproduces via spores with no seeds or flowers

Fig. 4.37 *Cyclosorus striatus* (Schum.) Ching

Habitat: Marshy areas, swamps, and riverine bush land.

Distribution: Volta system, Tano, Weija, Barekese, Kwanyarko,

Uses: For treating burns.

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4.3.16 *Utricularia reflexa* L.

Common name: Floating bladderwort

Family: Lentibulariaceae

Description: This is a small floating aquatic herb which is carnivorous. It has a long stolon, branched and glabrous. The leaves are all alike and about 5-6 inches apart. Leaves are usually two partite from or near the base and it is dichotomously multified. It has bladders that are conspicuous and are up to eight on a leaf usually from the forks of the leaf divisions. It has two flowered which is usually yellow in colour. In Fig.4.38 is shown the plant of *Utricularia reflexa* L.

Reproduction: A sexual reproduction.

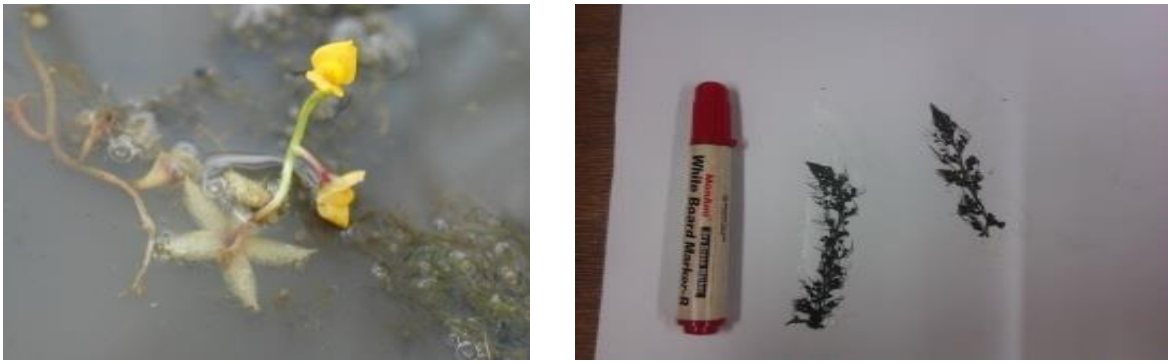

Fig. 4.38 *Utricularia reflexa* L.

Habitat: It can be found in deep or shallow still or flowing water, often entangled with other aquatic plants.

Distribution: Avu lagoon, Volta system.

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4.3.17 *Ipomoea aquatica* Forsk.

Synonym: *Convolvulus repens* Vahl,

Common name: Water spinach

Family: Convolvulaceae

Description: This is a semi aquatic plant with stems about 2-3 metres or more long. It roots at the nodes, hollow and can float. The leaves vary from typically arrow head shape to lanceolate. It is 5-15 cm long and 2-8 cm broad. The flowers are trumpet shaped, 3-5 cm in diameter, and usually white in colour with a mauve centre. In Fig.4. 39 is shown the plant of *Ipomoea aquatica* Forsk.

Reproduction: Propagation is either by planting cuttings of the stem shoots that will root along nodes or planting the seeds from flowers that produce seed pods.

Fig. 4.39 *Ipomoea aquatica* Forsk. D (Flower of *Ipomoea aquatica* Forsk)

Local name: Anagogbe (Ada, Ewe)

Habitat: Can be found in ponds, pools and edges of ponds.

Distribution: Owabi, Barekese, Tano, Weija, Volta system, Avu lagoon

Uses: Food for humans.

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4.3.18 *Echinochloa pyramidalis* (lam.) Hitchc. & chase

Synonym: *Echinochloa holubii* (stapf)

Common name: Antelope grass

Family: Poaceae

Description: This is a reed- like perennial with height of about 300 cm high. The leaves are blade shaped, stiff, expanded or folded; 8-60 cm long and 2-25 mm wide. Leaf sheaths can be hairy or glabrous. Inflorescences are raceme borne along a central axis. It has a very strong fasciculate root system that is able to spread quickly throughout the soil. In Fig.4.40 is presented the plant of *Echinochloa pyramidalis* (lam.) Hitchc. & chase.

Reproduction: It is propagated by cuttings.

Fig. 4.40 *Echinochloa pyramidalis* (lam.) Hitchc. & chase

Habitat: Seasonally flooded grassland, shores and floating meadows

Distribution: Cape Coast, SakumoII lagoon, Agbozume, Senchi, Mankesim

Uses: For food.

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4.3.19 *Salvinia nymphellula* Desv.

Family: Salviniaceae

Description: This is a free floating aquatic plant with leaves in whorls of three, with two floating leaves and a third leaf which is submerged. The floating leaves are round to oblong, about 20 mm long and 13 mm wide. The upper surfaces of the floating leaves are usually covered small, stiff hairs that make it not to become wet. The stems are irregularly branched. In Fig. 4.41 is shown the plant of *Salvinia nymphellula* Desv.

Reproduction: Reproduces from spores.

Fig. 4.41 *Salvinia nymphellula* Desv.

Habitat: It can be found on surface of ponds and stagnant waters

Distribution: Volta River system, Avu lagoon.

Uses: Medicinal

University of Ghana http://ugspace.ug.edu.gh

4.3.20 *Sphenoclea zeylanica* Gaertner

Synonyms: *Gaertnera pongati* Retz, Pongatium indicum Lam.,

Common name: Gooseweed

Family: Sphenocleaceae

Description: This is an erect, branched herb which is about 7-150 cm tall. It has a simple and spirally arranged light green leaves. The blade is oblong to lance- shaped, which narrows at the tips and is about 10 cm long. It is borne on short stalk. Inflorescence is green and cylindrical in shape, about 7.5 cm long and has a dense terminal spike. The flowers are densely crowded, white to greenish, sessile. The fruit is a flat globular capsule about 4-5 mm long with the seeds being yellowish brown in colour. In Fig 4.42 is shown the plant of *Sphenoclea zeylanica* Desv.

Reproduction: This is by seed

Fig. 4.42 *Sphenoclea zeylanica* Desv.

Habitat: This species occurs in seasonally wet areas, on moist soil or on low riverbanks, along ditches, marshes, dry riverbeds and ponds.

Distribution: Weija, Volta River system, Ada,

Uses: The young shoots and tips of older plants are eaten as vegetables.

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4.3.21 *Sesbania sesban* (L.) Merr.

Synonym: *Aeschynomene sesban* L

Family: Fabaceae

Common name: Egyptian rattle pod

Description: This is a deciduous, Short-lived shrub or tree about 8 m tall. It has a red-brown bark and a compound leave which is about 12 cm long. There are 12-25 pairs of leaflets and each leaflet is about 2 cm long. It has a pale yellow flower. In Fig. 4.43 is presented the plant of *Sesbania sesban* (L.) Merr.

Reproduction: Reproduces by seed.

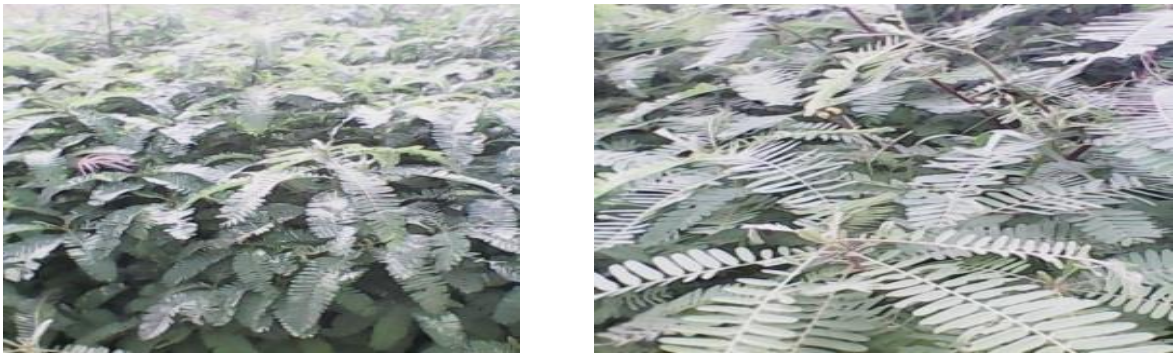

Fig. 4.43 *Sesbania sesban* (L.) Merr

Habitat: Common along rivers, found on the shores of fresh water lakes.

Distribution: Volta River System, Mankesim, Ada, Ashaiman

Uses: Firewood, aid in nitrogen fixation and the leaves for making soap.

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4.3.22 *Limnophyton obtusifolium* L.

Synonym: *Lophotocarpus guayanensis* chevalierCommon name: Arrow head

Family: Alismataceae

Description: This species can either be an annual or perennial when in deep water. The petiole is about 20-30 cm long, without hairs and the leave blade is ovate to arrow shaped or triangular. It is 6-9 cm long with the petiole attachment. The inflorescence is a whorl which usually comprises of 2-7 flowers. In Fig. 4.44 is shown the plant of *Limnophyton obtusifolium* L.

Reproduction: By seed.

Fig. 4.44 *Limnophyton obtusifolium* L.

Habitat: Shallow water in temporary and permanent ponds, ditches and swamps.

Distribution: Ada

Uses: Medicinal

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4.3.23 *Alternanthera sessilis* (L.) R.Br

Synonym: *Alternanthera denticulata* R. Brown

Common name: Sessile joyweed

Family: Amaranthaceae

Description: This is an annual or perennial herb with stems prostrate and usually much branched, with a narrow line of whitish hairs along each side of the stem. The leaves are in opposite pairs, sessil or nearly so. The blades are lanceolate to spatulate or oval. The flower heads are paired or rarely in clusters of five. In Fig.4.45 is shown the plant of *Alternanthera sessilis* (L.) R.Br

Reproduction: By seeds.

Fig. 4.45 *Alternanthera sessilis* (L.) R.Br

Habitat: Common at the edges of pools, and rivers.

Distribution: Ada

Uses: It is used as a vegetable in Asia and also medicinal.

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4.3.24 *Ludwigia erecta* L.

Synonym: *Jussiaea acuminata*

Common name: Yerba de jicotea

Family: Onagraceae

Description: This is an annual herb or nearly so with stems erect, branched or rarely simple. It is about 3-30 cm tall, which is sharply angled or sometimes cylindrical and somewhat woody and swollen at the base. The leaves are alternate whereas the blade is elliptic to lanceolate. The flowers are sessile or nearly so and are bright yellow in colour. In Fig.4.46 is presented the plant of *Ludwigia erecta* L.

Reproduction: Sexual reproduction.

Fig. 4.46 *Ludwigia erecta* L.

Habitat: seasonally inundated areas or wet places particularly along rivers and on pond margins

Distribution: Kpong Headpond, Volta River System, Weija, Kwanyarko

Uses: Used as a forage.

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4.3.25 *Heteranthera callifolia* Rchb.ex Kunth

Synonym: *Schollera callifolia* Rchb.ex Kunth

Common name: Water plantain

Family: Pontederiaceae

Description: Glabrous aquatic plant 13-50 cm tall. Lower stems creeping and rooting in the mud, sometimes almost free-floating. Leaves erect or ascending or sometimes floating, broadly ovate, subobtuse or shortly and obtusely pointed. Inflorescence a spike 5-10 cm long. It has small sessile flowers with a membranous spathe at its base subtended by the leaf sheath. In Fig.4.47 is shown the plant of *Heteranthera callifolia* Rchb.ex Kunth.

Reproduction: By seed.

Fig. 4.47 *Heteranthera callifolia* Rchb.ex Kunth

Habitat: Wet and muddy places

Distribution: Wiwi River, Volta River system.

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4.3.26 *Aeschynomene elaphroxylon* (Guill & Perr.)

Synonym: *Aerminiera elaphroxylon* Guill & Perr.

Common name: Balsa wood tree

Family: Fabaceae

Description: Tree or shrub about 9 m tall with a swollen, pithy, often conical stem. Branches with sticky grandular hairs and armed with short sharp spines. Leaves are pinnate with 20-40 cm oblong, often emarginated leaflets, mostly hairless above, blue green and pubescent. In Fig.4.48 is shown the plant of *Aeschynomene elaphroxylon* (Guill & Perr.).

Reproduction: By seed.

Fig. 4.48 *Aeschynomene elaphroxylon* (Guill & Perr.)

Habitat: Typically grows by water and in water logged soils

Distribution: Lower Volta, Dabala

Uses: Fixation of nitrogen, and for fuel wood

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4.3.27 *Nauclea latifolia* Sm.

Synonym: *Sarcocephalus latifolius* (Sm.)

Common name: African peach

Family: Rubiaceae

Description: This is a tree or shrub with simple leaves and is usually entire, and is opposite or sometimes whorled. Stipules are present and interpetiolar. The flowers are nearly bisexual and actinomorphic, often heterostylous and usually are in a cymose inflorescence. In Fig.4.49 is presented the plant of *Nauclea latifolia* Sm.

Reproduction: By seed.

Fig. 4.49 *Nauclea latifolia* Sm

Habitat: Found in dry savannah and thickets

Distribution: Kpong Headpond

Uses: used in the treatment of diabetics.

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4.3.28 *Panicum maximum* Jacq

Synonym: *Megathyrsus maximus* (Jacq)

Common name: Guinea grass

Family: Poaceae

Description: This is a perennial, tufted grass with a short, creeping rhizome. The stems of this robust grass can reach a height of up to 2 m. As the stems bend and the nodes touch the ground, roots and new plants are formed. The leaf sheaths are found at the bases of the stems and covered in fine hairs. The leaf blades are up to 35 mm wide and taper to a long fine point. Inflorescence is a large multi- branched, open panicle with loose, flexous branches. In Fig.4. 50 is shown the plant of *Panicum maximum* Jacq

Reproduction: From seeds and vegetative.

Fig. 4.50 *Panicum maximum* Jacq

Habitat: Grows especially well in shaded, damp areas under trees and shrubs and is often seen along rivers.

Distribution: Kumasi, Adawso, Weija, Dawenya

Uses: Fodder plant.

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4.3.29 *Rhynchospora corymbosa* (Linn.)

Synonym: *Scirpus corymbosus* Linn.

Common name: Golden beaksedge

Family: Cyperaceae

Description: Stout shortly rhizomatous perennial. Leaves 8–20 mm wide; sheaths of cauline leaves with an obtuse contraligule opposite leaf blade. Inflorescence of 2–5 distant compound partial inflorescences, with branches to 12 cm long, 20–40 cm long; involucral bracts 10–30 cm long. Spikelets numerous, in clusters of 2–5, terete, and 2 or 3 flowered, 6–8 mm long. In Fig.4.51 is shown the plant of *Rhynchospora corymbosa* Linn.

Reproduction: By seed and vegetative means

Fig. 4.51 *Rhynchospora corymbosa* Linn.

Habitat: Found in brackish and swampy areas

Distribution: Volta River System, Weija, Owabi, Mankesim

Uses: Medicinal

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4.3.30 *Sida acuta* Burm .f.

Synonym: *Sida carpinifolia*

Common name: wire weed

Family: Malvaceae

Description: Shrubby perennial semi- woody herb, usually growing 30-100 cm tall. Stem is either upright or spreading in nature. They are sparsely covered with five, star-shaped hairs. The leaves are alternately arranged along the stems and borne on short, hairy stalk. The leaves are yellowish green and are about 12- 15 mm long and 3-40 mm wide and are usually enlongated in shape with toothed margins and pointed tips. They are hairless, and yellow flowers are borne singly or in small clusters in the upper leaf fork. In Fig.4.52 is presented the plant of *Sida acuta* Burm .f.

Reproduction: By seed.

Fig. 4.52 *Sida acuta* Burm .f.

Habitat: It invades open woodlands, pastures, and water ways

Distribution: Kpong Headpond

Uses: Medicinal

University of Ghana http://ugspace.ug.edu.gh

4.3.31 *Spirodela polyrrhiza* Linn.

Synonym: *Lemna polyrrhiza* Linn

Common name: Giant duck weed

Family: Araceae

Description: This is a free floating aquatic plant which has two –three rounded leaves, which are usually connected. It has several roots (up to nine) hanging beneath each leaf. The under surface of *Spirodela* is dark red. In Fig.4. 53 is shown the plant of *Spirodela polyrrhiza* Linn.

Reproduction: A sexual budding and by seed.

Fig. 4.53 *Spirodela polyrrhiza* Linn.

Habitat: Found growing in rivers, ponds and lakes

Distribution: Volta River System, Weija, Owabi, Tano River and lagoon.

Uses: Medicinal

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4.3.32 *Wolffia arrhiza* L.

Synonym: *Lemna arrhiza* L

Common name: Spotless water meal

Family: Lemnaceae

Description: This is a free floating aquatic plant which has Ovoid to nearly spherical shape. It has a distinctly flattened, dark green dorsal surface (transparent below). In Fig.4. 54 is shown the plant of *Wolffia arrhiza* L.

Reproduction: Vegetative.

Fig. 4.54 *Wolffia arrhiza* L.

Habitat: Floating at surface of quiet streams and ponds

Distribution: Kpong headpond

Uses: Fodder for cattles and ducks.

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4.3.33 *Najas pectinata* Parl.

Synonym: *Caulinia pectinata* Parl.

Common name: Saw weed

Family: Hydrocharitaceae

Description: Submerged perennial plant forming dense brownish cumps 30-100 cm high. The stems are ramified, rooting at the nodes. Leaves aggregated in upper axils, spreading to falcate from above the sheath, narrowly linear, 2-3 cm long, 0.5-1 mm broad. The flowers are deciduous. In Fig.4. 55 is shown the plant of *Najas pectinata* Parl.

Reproduction: By seed.

Fig. 4.55 *Najas pectinata Parl.*

Habitat: Occurs in fresh and brackish waters

Distribution: Ada, Volta River System, Mankesim

Uses: For composting

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4.3.34 *Eichhornia natans* (P.Beauv)

Synonym: *Eichhornia diversifolia* (Vahl)

Common name: Anchored water hyacinth

Family: Pontederiaceae

Description: An aquatic herb rooted, sometimes forming dense submerged mats in freshwater 1-2 m deep. Stems are submerged and branched, to 2 m long, rooting at lower nodes. The roots are long with numerous rootlets. Juvenile leaves are submerged and borne along stems. Adult leaves alternate, dimorphic and submerged once are linear. Inflorescences reduce to a single flower. In Fig.4.56 is presented the plant of *Eichhornia natans* (P.Beauv).

Reproduction: By seed and stolons.

Fig. 4.56 *Eichhornia natans* (P.Beauv)

Habitat: Found in ponds, lakes and pools

Distribution: Samreboi

Uses: For aquarium use

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4.3.35 *Phragmites karka* (Retz) Trin ex Steund

Synonym: *Aroundo roxbughii*

Common name: Tall reed

Family: Poaceae

Description: A perennial reed with long rhizomes and robust, erect culms up to 3 m. The leaves are 15-30 cm long and nearly 25 cm broad. Inflorescence is a large plume like particle with capillary branches. In Fig. 4.57 is shown the plant of *Phragmites karka* (Retz) Trin ex Steund

Reproduction: By seed.

Fig. 4.57 *Phragmites karka* (Retz) Trin ex Steund

Habitat: Ponds, lakes

Distribution: Avu lagoon, Volta River System

Uses: Construction of traditional houses.

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4.3.36 *Potamogeton octandrus* Poir

Synonym: *Potamogeton javanicus* Hassk.

Common name: Afrikansk nate

Family: Potamogetonaceae

Description: An aquatic herb 20-100 cm high, from a creeping rhizome. Leaves dimorphic, submerged 30-70 mm, linear to narrowly linear lanceolate, alternate, translucent. Spikes are longer than leaves and the flower usually two per whorl, with 3-7 whorls per spike. In fig.4.58 is presented the plant of *Potamogeton octandrus* Poir

Reproduction: By seed.

Fig. 4.58 *Potamogeton octandrus* Poir

Habitat: commonly found in lakes and ponds

Distribution: Volta River System, Battor

Uses: For composting

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4.3.37 *Leersia hexandra* Sw.

Synonym*:* *Homaloconchrus hexandrus* (sw.)

Common name: Southern cut grass

Family: Poaceae

Description: This species is a perennial grass growing from rhizomes and stolons. The hollow stems are decumbent and creeping and roots easily when their nodes contact the substrate. Shoots are erect blades up to 30 cm long and which are flat or rolled its edges sometimes rolling at night or when the blade dries. In Fig.4.59 is shown the plant of *Leersia hexandra* Sw.

Reproduction: Vegetative and by seed.

Fig. 4.59 *Leersia hexandra* Sw.

Habitat: Abundant in wet areas

Distribution: Nungua, Volta River System, Tano River and lagoon, Barekese, Weija, Owabi, kwanyarko

Uses: Fodder plant.

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4.3.38 *Commelina diffusa* Burm.

Synonym: *Commelina diffusa* var.

Common name: Climbing day flower

Family: Commelinaceae

Description: Annual herb which creeps along the ground, branching heavily and rooted at the nodes, obtaining stem length of 1 m. The leaf blades are relatively variable, ranging from lanceolate to ovate; with proximal leaves tending to be more oblong. Flowers are arranged into scorpiod cymes. In Fig.4. 60 is presented the plant of *Commelina diffusa* Burm.

Reproduction: By seed.

Fig. 4.60 *Commelina diffusa* Burm.

Habitat: Found in damp places

Distribution: Kpong Headpond, Volta Lake

Uses: Medicinal herb.

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4.3.39 *Celosia pseudovirgata* Schinz

Synonym: *Celosia angustifolia*

Common name: Cocks comb

Family: Amaranthaceae

Description: Herbs or shrubs, erect or sometimes clambering or scandent. Leaves alternate, petiolate and blade is simple. Stipules are absent. Flowers are bisexual, pedicellate or sessile, clustered in cymes, which are arranged along terminal or axillary spikes, panicles, or thyrses. Sepals are 5, subequal and free. The stamens are 5, the filaments united at the base to form a short crateriform tube; interstaminal appendages dentate or absent; ovary superior, unilocular, subglobose, ovoid or cylindrical. The style elongate or the stigmas elongate or capitate. Ovules 2 or more numerous. In Fig.4.61 is shown the plant of *Celosia pseudovirgata* Schinz

Reproduction: By seed.

Fig. 4.61 *Celosia pseudovirgata* Schinz

Habitat: Found in moist and damp places

Distribution: Kpong Headpond

Uses: Medicinal.

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4.3.40 *Commelina nudiflora* Linn.

Synonym: *Commelina caroliniana*

Common name: Creeping dry flower

Family: Commelinaceae

Description: This is a slender, nearly smooth, creeping annual or perennial herb. The stem is simple to branched 15-30 cm long, reclining on the ground with rooting at the nodes. The roots are fibrous, leaves are rather thick, linear to oblong, and alternate narrowed into a base sheath, entire, acute, tapering to a point with sides incurved, measuring 3-10 cm long and 4-10 cm wide. In Fig. 4.62 is shown the plant of *Commelina nudiflora* Linn.

Reproduction: By seed.

Fig. 4.62 *Commelina nudiflora* Linn.

Habitat: Found in moist and damp areas

Distribution: Kpong Headpond

Uses: Medicinal

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4.3.41 *Cyperus nudicaulis* Poir

Synonym: *Cyperus pectinatus* Vahl

Common name: Swamp flat sedge

Family: Cyperaceae

Description: Glabrous, floating aquatic plant with long rhizome about 1/8 in diameter. Stems tufted, 1–2 1/2 ft. long, at the top 1/25 in diameter, round trigonous. Leaf-sheaths pale-brown or reddish, and the uppermost produced on one side 0– 1/2 in diameter but hardly green. Head 1, of 1–12 sessile spikelets; bracts 1–3, lowest often suberect, and shorter than the head, as though a continuation of the stem. In Fig.4.63 is presented the plant of *Cyperus nudicaulis* Poir.

Reproduction: By seed.

Fig. 4.63 *Cyperus nudicaulis* Poir

Habitat: Found at the edges of water bodies

Distribution: Akotokyire, Kpong Headpond

Uses: Fodder.

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4.3.42 *Fuirena umbellata* Rottb.

Synonym: *Scirpus umbellatus* (Rottb.) Kuntze

Common name: Yefen

Family: Cyperaceae

Description: Erect, rhizomatous perennial herbs, 40-97 cm tall; rhizome short, thick, horizontal; culms sharply 4- or 5-angular, several noded, glabrous except below inflorescence. Leaves cauline, 7-18 x 0.5-1.2 cm, lanceolate to linear-lanceolate, base rounded, and apex acute, 5-nerved, glabrous or ciliate at base. The inflorescence is paniculiform, with 3 to 10 glomerulous clusters of sessile spikelets; each glomerule bearing 4 to 10 spikelets. In Fig.4.64 is shown the plant of *Fuirena umbellate* Rottb.

Reproduction: By seed.

Fig. 4.64 *Fuirena umbellata* Rottb.

Habitat: It is common on river banks, moist places and swampy localities.

Distribution: Kpong Headpond, Atuabo, Ejura.

Uses: For composting

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4.3.43 *Echinochloa stagnina* (Retz) P. Beauvois

Synonym: *Panicum stagninum* Retz.

Common name: Burgu grass

Family: Poaceae

Description: This is a perennial, or sometimes annual, semi-aquatic tropical grass. It reaches up to 10 m in length when floating, most of the plant being under water. It has stout floating rhizomes. Culms are decumbent, 2.5 cm in diameter, rooting and branching at the lower nodes. Leaves are 10-60 cm long and blade-shaped. Racemic inflorescences 6-35 cm long are the only part of the plant above the water surface. In Fig 4.65 is shown the plant of *Echinochloa stagnina* (Retz) P. Beauvois.

Reproduction: By seed.

Fig. 4.65 *Echinochloa stagnina* (Retz) P. Beauvois

Habitat: It grows along rivers, in lakes and lagoons

Distribution: Kpong Headpond, Volta River System

Uses: Fodder.

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4.3 44 *Ipomoea asarifolia* (Ders) Roem & Schult

Synonym: *Convolvulus repens* Vahl,

Common name: Ginger leaf morning glory

Family: Convolvulaceae

Description: The stems is herbaceous, decumbent and the tips, twining, rooting at the nodes, glabrous. Leaves alternate, rounded- cordate to subreniform, and 4-8 cm long. This is basally cordate, apically rounded, and glabrescent. Inflorescences of solitary flowers or in axillary or terminal. There are flowers on pedicels which are 14-24 mm long. Fruits tardily dehiscent capsules, subglobose, 10-12 mm long, brown, glabrous; seeds brown to dark brown, 6-7 mm long, minutely gray-pubescent. In Fig. 4.66 is presented the flower of *Ipomoea asarifolia* (Ders) Roem & Schult

Reproduction: By seed.

Fig. 4.66 *Ipomoea asarifolia* (Ders) Roem & Schult

Habitat: Damp fields

Distribution: Kpong Headpond

Uses: Medicinal

University of Ghana http://ugspace.ug.edu.gh

4.3.45 *Ipomoea carnea* Jacq.

Synonym: *Ipomoea fistulosa*

Common name: Besharam

Family: Convolvulaceae

Description: An erect, sparsely branched shrub growing about eight feet. tall; leaves with a long stalk, the blades essentially hairless, lanceolate, five to eight inches long and about two inches broad, with a long-tapering tip and a truncated or shallowly heart-shaped base; flowers borne in small clusters in the axils of the uppermost leaves, funnel-shaped with five shallow lobes on the margin, three to four inches across, pink to lavender or purple but darker in the throat, opening only in the morning. In Fig.4.67 is shown the plant of *Ipomoea carnea* Jacq.

Reproduction: By seed.

Fig. 4.67 *Ipomoea carnea* Jacq

Habitat: Grows in dense populations along river beds

Distribution: Kpong Headpond, Wiwi River, Ada

Uses: For making paper.

University of Ghana http://ugspace.ug.edu.gh

4.3.46 *Ludwigia hyssopifolia* (G Don). Exell

Synonym: *Jussiaea hyssopifolia* G.Don

Common name: linear leaf water primrose

Family: Onagraceae

Description: An erect annual herb, 15-150-cm tall and minutely hairy during early stage of growth. Stem is often 3 to 4 angled, green or purplish, and with white spongy pneumatophores arising from submerged roots. Leaf is lance-shaped, petioled, and up to 9-cm-long. Inflorescence: solitary flowers, borne at axils of leaves; 4 yellow petals, elliptic, up to 3-mm-long. In Fig.4. 68 is shown the plant of *Ludwigia hyssopifolia* (G Don). Exell

Reproduction: By seed.

Fig. 4.68 *Ludwigia hyssopifolia* (G Don). Exell

Habitat: Found around river banks and slow moving streams

Distribution: Volta River System, Weija, Barekese, Kwanyarko

Uses: Medicinal.

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4.3.47 *Luffa aegyptiaca* Mill

Synonym: *Cucurbita luffa* hort

Common name: Sponge gourd

Family: Cucurbitaceae

Description: This a rampant, fast growing annual vine that produces pretty yellow flowers and strange looking fruits that are edible. It is used as back scrubbers or sponges when fully mature. The vine can get more than 30 ft 9 m long and scrambles over anything in its path. The large leaves are lobed and have silvery patches on the topsides. The flowers are showy and conspicuous, about 5-7.6 cm. The fruits are green, up to 61 cm long and 3- 7.6 cm in diameter; they are cylindrical and smooth, and shaped like a club, slighter wider on one end. Small fruits look like okra or little cucumbers. In Fig.4.69 is shown the plant of *Luffa aegyptiaca* Mill

Reproduction: By seed.

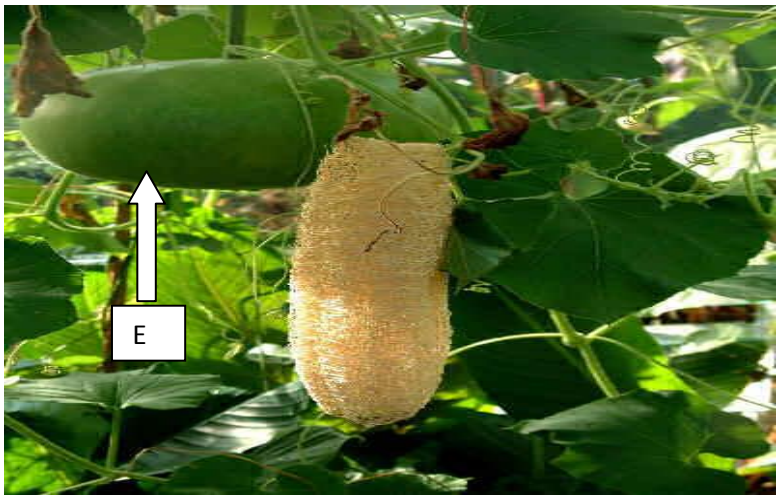

Fig. 4.69 E is the fruit of *Luffa aegyptiaca* Mill

Habitat: Forest gaps and edges, agricultural lands and other disturbed areas.

Distribution: Volta River system, Weija, Barekese

Uses: Food

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4.3.48 *Mariscus alternifolius* Vahl

Synonym: *Mariscus umbellatus* (Rottboll) Vahl.

Common name: Pacific island flatsedge

Family: Cyperaceae

Description: This is a tufted plant with a short woody rhizome more or less composed of swollen stem bases. The leaf sheath is purple and the inflorescence variable; rays more or less well developed and bearing spikes of more or less crowded small greenish or reddish one or two flowered spikelets. In Fig. 4.70 is shown the plant of *Mariscus alternifolius* Vahl

Reproduction: By seed.

Fig. 4.70 *Mariscus alternifolius* Vahl

Habitat: Common in damp grassy places

Distribution: Volta River System, Achimota, Wenchi to techiman, Afram plains

Uses: Fodder

University of Ghana http://ugspace.ug.edu.gh

4.3.49 *Marsilea polycarpa* Hook& Grev.

Synonym: *Zaluzianska polycarpa* Hook & Grev

Common name: Guayanan Water clover

Family: Marsileaceae

Description: This is a four clover aquatic plant and has a sporocarp which is bean-shape to ovoid-nut like structure, attach to the basal part of the petiole with the help of a stalk. It is green and soft when young, but tend dark brown and hard at maturity. In Fig. 4.71 is presented the plant of *Marsilea polycarpa* Hook& Grev.

Reproduction: Vegetative and by seed.

Fig. 4.71 *Marsilea polycarpa* Hook& Grev.

Habitat: Pools, streams, and lakes

Distribution: Volta River system

Uses: For food.

University of Ghana http://ugspace.ug.edu.gh

4.3.50 *Aponogeton subconjugatus* Schum & Thonning

Synonym: Aponogeton heudelotii (Kunth)

Common name: Iranian Short-fingered Gecko

Family: Aponogetonaceae

Description: The bulb is subrotund and truncate. Leaves are long and petioled. The petioles are semiterete below, and terete above. Also the blade is 5–12 inches long, 1 1/2–1 3/4 inches broad, and elongate-oblong. The base is either obtuse or cordate and often speckled with brown below yellowish. The stamens are 6 and unequal with carpels 3–5 in number, ovoid, compressed, and tapering into a short style. In Fig. 4.72 is shown the plant of *Aponogeton subconjugatus* Schum & Thonning

Reproduction: By seed.

Fig. 4.72 *Aponogeton subconjugatus* Schum & Thonning

Photo credit: Wikepedia, the free encyclopedia

Habitat: Shallow and sometimes temporary freshwater pools.

Distribution: Achimota, Accra-Ada, Kpong Headpond, Volta system

Uses: Food for human beings

University of Ghana http://ugspace.ug.edu.gh

4.3.51 *Chara canescens* J.L.A. Loiseleur Deslongschamps

Synonym: *Chara fragilis* var. scapillacea (Thuillier) Miquel

Common name: Musk grasses

Family: Characeae

Description: The leaves are true leaves; six to 16 leaf-like branchlets of equal length grow in whorls around the stem, and are never divided. These branchlets often bear tiny thorn-like projections, which give the plant a rough or prickly appearance when magnified. Algae lack true stems. The round, stem-like structure varies from 5 cm to over 1 m in length. Musk grasses may be attached to the bottom by root-like structures called holdfasts. Algae do not produce fruits. Tiny spores are produced in fruiting bodies. In some species the fruiting bodies are orange and very conspicuous. In Fig. 4.73 is shown the plant of *Chara canescens* J.L.A. Loiseleur Deslongschamps

Reproduction: Vegetative and sexually.

Fig. 4.73 *Chara canescens* J.L.A. Loiseleur Deslongschamps

Habitat: Fresh to brackish water, inland and coastal, in both shallow and deep water. Some species found in alkaline lakes and slow-moving streams

Distribution: Asutsuare, Volta River irrigation systems

Uses: Food for water fowls.

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4.3.52 *Azolla africana* Desv.

Synonym: *Azolla africana* Desv.

Common name: Mosquito fern

Family: Azollaceae

Description: The leafy shoots of this small fern lie prostrate on the surface of the water with the roots hanging down from it. Each frond (shoots) is more or less triangular in outline, 1-2 cm long and about the same across. The main stem and the regular pinnate branches are very slender and delicate , about 0.2 mm in diameter, and are completely covered by the two rows of tiny overlapping leaves which are attached to each other. The leaf is about 1 mm long and consists of two lobes. The upper lobe is green and covered with small lumps which prevent its surface from being wetted when it is pushed below the water. The lower lobe is thin and flat. The roots are up to 30 cm long and are about the same thickness as the stem and do not have any tiny branches. In Fig.4.74 is presented the plant of *Azolla africana* Desv.

Reproduction: *Azolla* reproduces sexually and asexually by splitting.

Fig. 4.74 *Azolla africana* Desv.

Habitat: Found in ponds and slow moving water bodies

Distribution: Avu lagoon, Mankesim

Uses: For food, and also used for biofuel.

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The aquatic macrophytes encountered were grouped into aquatic and semi aquatic plants. This was based on how much they were dependent on the water body in which they were found. The aquatic plants were those whose lives depend solely in the presence of water to be able to carry out their life cycle. In the absence of water, they die off. For the semi aquatic plants, they were able to carry out their life cycle even in the absence of water. They now adapt to the changes in their environment and continue to grow as land plants. Out of the 62 aquatic macrophytes encountered, 25 were aquatic plants whereas the remaining 37 were semi aquatic plants.

Characteristic species that were encountered were *Utricularia reflexa* which was a member of Lentibulariaceae family and *Ceratopteris cornuta* of the Parkeriaceae family. These particular species were found only in the Avu lagoon in the Volta Region and Mankesim in the Central Region respectively.

4.4 Description of the vegetation of the selected major freshwater bodies within southern Ghana

For the various sampling sites, voucher specimens were collected and they were deposited at the Ghana Herbarium. In Western Region for example, there were the presence of both aquatic and semi aquatic plant species along the entry to Nveye which was part of the Tano lagoon complex. One could easily see the sudd community which basically did comprise of *Vossia-Oxycarium.* The plant species varied both in life form and their distribution along the Tano lagoon complex. One other invasive aquatic plant that could be easily identified was *Eichhornia crassipes.* The population of *Eichhornia crassipes* was under control as a result of an on going biological control programme. The biological

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control agent *Neochetina bruchi*, used could be observed both on the surface and beneath the leaf of water hyacinth.

In the Kpong Headpond, the Southern section was densely populated by both aquatic and semi aquatic plants. From the edge of the deep water of the Headpond, the life forms encountered were emergent, free- floating, floating-leaved and submerged. Plant species could be observed at different zones of the Headpond such as coves, shallow waters, deep waters, sudds and on the fringes of islands. The most dominant aquatic plant species were *Typha domingensis, Ceratophyllum demersum Nymphaea lotus* and *Leersia hexandra*.

At Avu lagoon in Adutor, along the channel to the main water body, there were several aquatic and semi aquatic plants that were identified. Some of the aquatic species were also floating freely whereas others were at the edges of the channel. Tiny flowers of *Utricularia imflexa* and *Azolla filiculoides* were the most dominant along the channel. In the main water body, there were several aquatic plants and the most dominant was *Ceratophyllum demersum*. From a distance, one could easily say that you were approaching an island only to meet a large mass of *Ceratophyllum demersum.*

At Ada, most of the sampling sites were seasonal pools. The most dominant aquatic plant in these seasonal pools was *Nymphaea lotus*. At the bridge which was located at Bedeku, a few number of *Eichhornia crassipes* were identified in the water body beneath the bridge.

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In Mankesim, sampling was done in a large pool and the most dominant species was *Azolla filiculoides* which was in a bloom and reddish in colour. Several sedges like *Cyperus articulatus, Eleocharis complanata* were observed both within and at the edges of the pool. Some rice farms were also observed at the Mankesim sampling site. Some farmers even testify to the Nitrogen richness of *Azolla filiculoides* which they said they harvested and drop the *Azolla* species onto their rice farms to add nitrogen to the soil and this resulted in higher yields.

At Weija, the most dominant species was *Typha domingensis*. This was observed within the main water body and also at the edges of the Weija. *Ceratophyllum demersum* and *Vossia cuspidata* were also readily observed at the Weija sampling site.

4.5 Classification of Encountered Aquatic Plants into their Families

The aquatic macrophytes encountered were classified into their families, 9 species belonged to Cyperaceae, 6 species belonged to Poaceae, 5 species belonged to Fabaceae, 3 species belonged to Convolvulaceae, Lemnaceae, and Onagraceae. Two species belonged to Amaranthaceae, Azollaceae, Commelinaceae, Pontederiaceae, Marsileaceae, Nymphaceae, Polygonaceae, Salvinaiceae, Lentibulariaceae, Alismataceae and Hydrocharitaceae, one species belonged to Aponogetonaceae, Parkeriaceae, Ceratophyllaceae, Thelypteridaceae, Cucurbitaceae, Rubiaceae, Typhaceae, Araceae, Potamogetonaceae, Ruppiaceae, Malvaceae, Sphenocleaceae and Characeae.

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CHAPTER FIVE

5.0 Discussion

5.1 Systematics of aquatic macrophytes present in the study

Sixty two aquatic macrophytes belonging to 48 genera were encountered. Eleven were identified as invasives. The 11 invasive species belonged to 11 different families. Amissah (2010) on his study of aquatic macrophytes in the Kpong headpond also recorded 50 aquatic macrophytes belonging to 26 families. Amissah (2010) also recorded 17 invasive aquatic species in the Kpong headpond. There were six aquatic species which Amissah (2010) considered as invasives which in (IUCN 2004) were non-invasives. The increasing number of invasive aquatic macrophytes in Ghanaian water bodies could cause local flooding, reduced available fish habitat and impede boats navigation and recreation (Boyd, 1971). This can also interfere with hydropower generations in the Kpong headpond and reduce fish catches (Charudattan, 2001). This would eventually affect the economy.

The non-invasive aquatic macrophytes encountered were 51 and belonged to 26 families. The dominant family of the non-invasives was Cyperaceae with 8 aquatic species belonging to this family. Amissah (2010) recorded 33 non-invasive aquatic plants belonging to 19 families in the Kpong headpond. A total of 10 aquatic macrophytes were recorded by Amissah (2010) belonging to the family Cyperaceae. This number of non-invasive species belonging to Cyperaceae is almost the same to other research works carried out by deGraft-Johnson, 1991.

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5.2 Distribution of aquatic macrophytes encountered

Aquatic macrophytes like most water organisms are more widely distributed throughout the world than terrestrial plants. This is because factors or conditions required by aquatic plants are uniform in general than those to which land plants must adapt to. The aquatic invasive that was widely distributed in this study was *Pistia stratiotes.* This was widely distributed within southern Ghana with a total of 7 distribution spots (Fig.4.22). *Pistia stratiotes* was also recorded by (deGraft-Johnson, 1996) in both the Kpong headpond and Lower Volta. Also *Eichhornia crassipes* was present in both the kpong headpond and the Lower Volta in this study. It was in 1990 found in the Abby-Ehy-Tano-Nveye River and Lagoon complex in the Western Region and then in 1998 in the Oti River Arm of Lake Volta and during 2003 in Kpong Headpond (deGraft-johnson, 1991). At Ada, *Eichhornia crassipes* was also encountered during the study. This was found at the bridge at Bedeku which led to Ada Main Township. *Vossia cuspidata* and *Ceratophyllum demersum* were present in both the Lower Volta and the Kpong headpond. Amissah (2010) also recorded both *Vossia cuspidata* and *Ceratophyllum demersum* in the Kpong headpond.

5.3 Uses of aquatic macrophytes

The uses of aquatic macrophytes have opened a new research area for study. As shown in chapter 4.2 and 4.3, the uses of the aquatic macrophytes encountered were basically for fodder, compost and their medicinal values. Boyd, 1974 indicated that *Salvinia molesta* was a good material for composting or mulching and in Kariba Lake it was mixed with the dung of animals for manuring farm lands. Investigations done by Mitchell (1976) in Lake Kariba demonstrate that *Salvinia* mats play an important role as habitat for young fish and their prey. They may also provide food for other organisms like birds (Batzer *et al*., 1993)

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and fish (Crowder & Cooper, 1982). At Adutor in the Volta Region, personal observations were made. A lot of the fishermen harvested *Ipomoea aquatica* which was used in stew and soup preparations. Other areas which aquatic macrophytes could be employed are biogas energy. As new areas are been explored to provide energy to meet the global industralisation, invasive aquatic macrophytes could be studied for use in biofuel generation. This energy that would be generated can be used in the automobile industry. Aquatic macrophytes can also be used to control water quality. Aquatic macrophytes are able to use nutrients and thus influence water quality and also reflect the nutrient status of their immediate habitat by their presence/absence and abundance which can be used as a biological indicator in any available water body (Suominen, 1968; Uotila, 1971). They may also control water quality by exuding various organic and mineral components into the water body.

5.4 Problems created by invasive aquatic plants

Aquatic plants are considered nuisance when excessive growth interferes with desired water uses in a number of ways (Adeniji, 1979). The presence of invasive aquatic macrophytes in water bodies create problems for organisms in the water body and humans whose livelihood depends on these water bodies. To be able to control these invasive aquatic macrophytes, it was important to identify the various pathways through which these aquatic macrophytes were introduced into the various freshwater bodies. The pathway of spread of invasive aquatic plants were of much importance as this unique information tells one of the processes or means by which these plants were transported from one place to the other. The pathways of spread for the 11 invasive aquatic macrophytes encountered were almost the same. They were spread through wind

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propulsion of floating plants or plant segment and seed through water currents. The seeds were also attached to the feathers and feet of the numerous species of local and migratory water birds. In this and other ways invasive aquatic macrophytes have been able to occupy almost every large water body and river across mainland Africa and also among some African oceanic island nations. Sometimes the seeds were also carried with the mud sticking to the feet of birds, man and agricultural implements.

5.5 Control methods for the invasive species encountered

Control methods for the 11 invasive species encountered were a necessity. This was done to help make available control methods that were necessary for controlling aquatic invasives. The control methods for the eleven species were grouped into three main parts. These were the physical or mechanical, biological and chemical control methods.

The physical methods of control for the 11 invasive aquatic species were as follows. The use of combine harvester in harvesting the invasive macrophytes was the easiest way of physically controlling invasive macrophytes. Also in some instances, to prevent further spread of these aquatic macrophytes, lines were attached to poles to prevent the spread to new areas where the infestation has not yet taken place and this method works peferctly. Another way to control aquatic macrophytes physically was by raking or hand picking from the infested water bodies. Aquatic macrophytes could also be controlled physically by cutting and then burning it.

The next control method was by chemical means. There were three most commonly used aquatic herbicides: 2, 4-D (2, 4-dichlorophenoxy), Diquat (6, 7-dihydrodipyridol pyrazinediumion) and Glyphosate (Isopropilamine salt of N-phosphonomethyl glycine).

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For their use, the approval of Plant Protection Agencies was necessary, and must be applied strictly by trained technicians. These chemicals mentioned could be used to control the 11 invasive aquatic macrophytes except *Vallisneria aethiopica* which no chemical was advised to be used in controlling it. Also, *Salvinia* was effectively controlled by spraying with paraquat at a concentration of 2.1kg active ingredient per litre at the rate of 1125 litres per hectare (Dias, 1966).

The last control method was by biological means. Biological control is the use of host-specific natural enemies to reduce the population density of a pest (Howard and Harley, 1998). Classical biological control involving the importation, colonization and establishment of exotic natural enemies (predators, parasites and pathogens) to reduce exotic pest populations and maintain them at, economically insignificant densities was the predominant approach to biological weed control (McFadyen, 1998). With this method of control for the 11 invasive aquatic macrophytes, all the 11 invasive aquatic macrophytes have host specific organisms that were used in their control except *Limnocharis flava* which had no biological control agent yet available. For *Eichhornia crassipes*, research into the use of biological agents for water hyacinth control includes arthropods and pathogens. In the case of arthropods, only a few insects were found to reduce the growth of water hyacinth significantly of these, only the following species were considered worthy of introduction to other countries:

- the mite *Orthogalumna terebrantis* Wallwork (Bennet, 1981);
- the moth *Acigona infusella* Walker (Deloach *et al.*, 1983) and *Sameodes albiguttalis* (Warren) (Deloach and Cordo, 1976);

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- the miridae *Eccritotarsus catarinensis* Carvalho (Hill *et al.*, 1999*)* the weevils *Neochetina eichhorniae* Warner and *Neochetina bruchi* Hustache (Deloach and Cordo, 1976 a, b; Center *et al.*, 1986).

The Chinese grass carp was the biological control agent for *Ceratophyllum demersum* and for *Vossia,* biological control was done by using grazing animals on the area where the control was to be undertaking. The *curculionid Cyrtobagous salviniae* was considered to provide cost-effective environmentally-sound and apparently permanent biological control for *Salvinia molesta*. For biological control of *Mimosa,* stem-boring moth *Neurostrota gunniella* and a fungal plant pathogen *Phloeospora mimosae-pigrae* were introduced to the *Mimosa* plant (Cullen, 2004). This could be introduced one at a time or both species could be introduced. Biological control was seen as the only viable long-term control option for this weed (Hill, 1999). The biocontrol of *Azolla filiculoides* has been effective (e.g. in South Africa) using leaf-eating insects: a flea beetle (*Pseudolampsis guttata*) and a weevil (*Stenopelmus rufinasus*) (Henderson, 2001). For *Typha domingensis*, Muskrats could decimate *Typha* spp. in temperate areas (Kadlec *et al.,* 2007), and could effectively control populations of *Typha*. *Vallisneria aethiopica* was controlled mainly by bio- control means. Some fish species feed from this submerged aquatic macrophyte to control their population.

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CHAPTER SIX

6.0 Summary and Recommendation

6.1 Summary

1) The study of aquatic macrophytes within southern Ghana was done from February 2013 to January 2015.

2) The study covered six Regions in Ghana namely Greater Accra, Volta, Central, Eastern, Western and Ashanti, with a total of 44 sampling sites.

3) A total of sixty-two aquatic macrophytes were encountered within the water bodies in southern Ghana. Out of this number, 11 of the species were invasives and the remaining 51 were non-invasives. The aquatic macrophytes encountered belonged to 48 genera in 30 families with Cyperaceae being the most dominant.

4) The species were grouped into four life forms namely, emergent, free-floating, submerged and floating-leaved. The number of species that were emergent were 41, floating-leaved two, submerged 8 and free-floating 11.

5) *Pistia stratiotes, Vossia cuspidata, Ceratophyllum demersum* and *Typha domingensis* were the most widely distributed within southern Ghana with a total of seven distribution spots for *Pistia stratiotes* and then six distribution spots for the remaining three.

6) A database was created for all the 62 aquatic macrophytes encountered with their classification, synonyms, common name, uses, habitat and their mode of reproduction. Photos of the aquatic plants that were encountered were also provided.

7) The Volta River System contained most of the invasive aquatic plants that were encountered during the study.

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6.2 RECOMMENDATION

1) Further studies should be conducted to determine the nutrient richness of the various water bodies within southern Ghana to be able to determine how nutrients present in the various water bodies can affect the process of invasion of aquatic macrophytes.

2) A further study should also be conducted in northern Ghana to have a complete database of all the aquatic macrophytes within Ghana and how to control those that are invasives.

3) There is also the need for all inhabitants of Ghana to be well educated and advised on what to do should anyone comes across any aquatic plant in or around any water body in Ghana.

4) An Invasive Species Management team or IAS Coordinating Body is also to be formed with experts in the field of invasive species, Environmental Management, and Water Resource Management to help moniter and tackle any issue of aquatic invasives.

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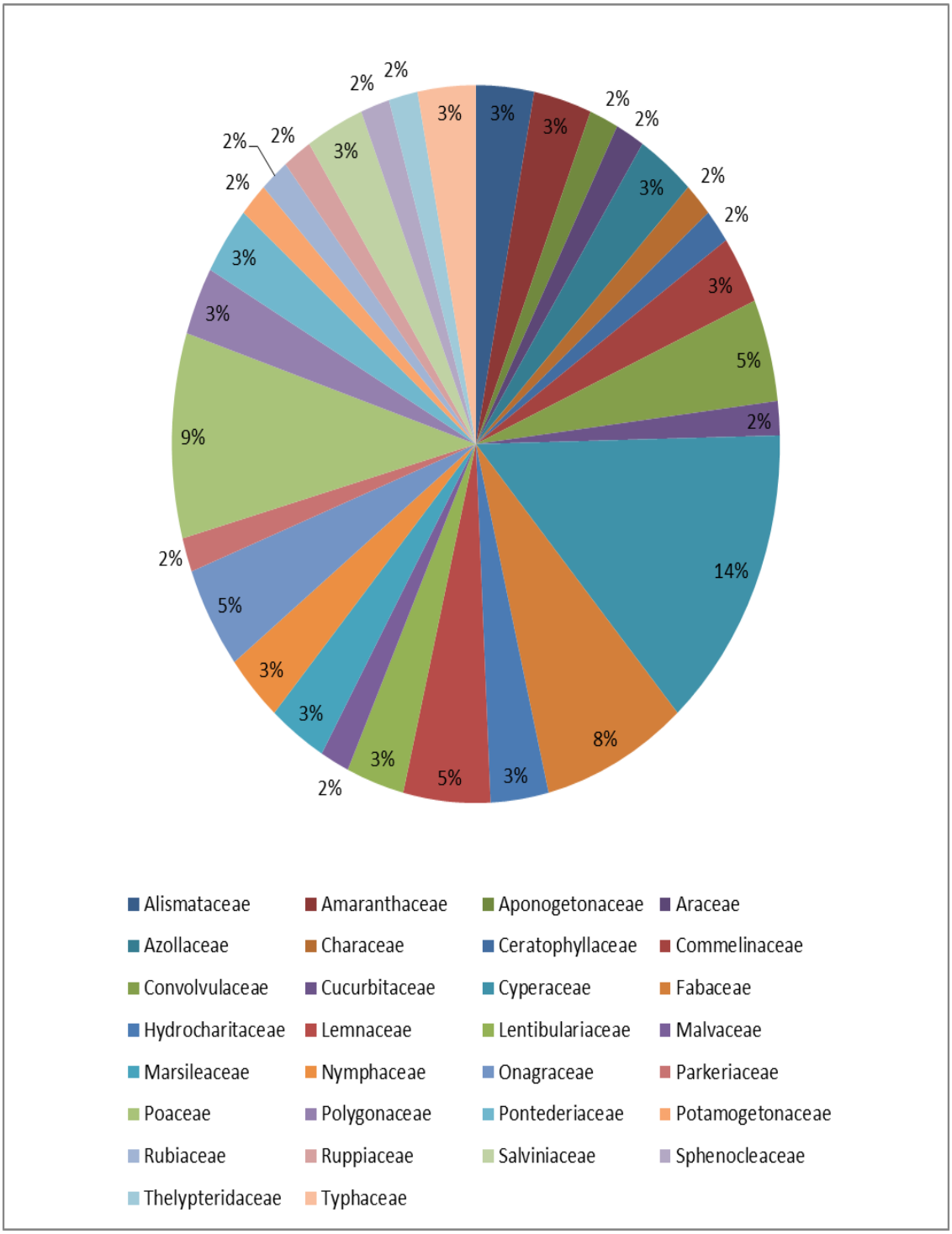
APPENDICES

APPENDIX 1

Families of aquatic plants of southern Ghana



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Appendix 2

Life forms and their frequencies

Emergent	41
Floating-leaved	2
Free floating	11
Submerged	8

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Appendix 3

List of aquatic plants encountered and their invasive status

Aeschynomene elaphroxylon	Non- invasive
Alternanthera sessilis (L) DC	Non -invasive
Aponogeton pectinatus L.	Non- invasive
Azolla africana Desv.	Non- invasive
Azolla filiculoides Lam.	Invasive
Celosia pseudovirgata Schinz	Non -invasive
Ceratophyllum demersum L.	Invasive
Ceratopteris cornuta (P. Beauv.) Lepr.	Non- invasive
Chara canescens J.L.A. Loiseleur Deslongschamps	Non -invasive
Commelina diffusa Burm.f.	Non- invasive
Commelina nudiflora Linn.	Non -invasive
Cyclosorus striatus (Schum.) Ching	Non -invasive
Cyperus articulatus Linn.	Non -invasive
Cyperus distans Linn. f.	Non -invasive
Cyperus nudicaulis Poir	Non- invasive
Cyperus papyrus L.	Invasive
Echinochloa stagnina (Retz.) P.Beauvois	Non- invasive
Eichhornia crassipes (Mart.) Solms-Layb.	Invasive
Eichnochloa pyramidalis Lam. Hitchc.& Chase	Non -invasive
Eleocharis complanata Boeck.	Non- invasive
Fureina umbellata Rottb	Non- invasive
Ipomoea aquatica Forsk.	Non- invasive
Ipomoea asarifolia (Desr.)Roem. &Schult.	Non- invasive
Ipomoea carnea Jacq.	Non- invasive
Leersia hexandra Sw.	Non- invasive
Lemna paucicostata var.membrabacea Hegelm.	Non -invasive
Linmocharis flava (L.) Buchenau	Invasive
Linmophyton obtusifolium L.	Non- invasive
Ludwigia erecta (L.) H.Hara	Non- invasive
Ludwigia hyssopifolia (G Don) Exell	Non- invasive
Ludwigia stolonifera Guill. &Perr. Raven	Non- invasive
Luffa aegyptica Mill.	Non- invasive
Mariscus alternifolius Vahl	Non- invasive
Marsilea minuta L.(*M. diffusa* leprieur ex. A. Braun)	Non- invasive
Marsilea polycarpa Hook. & Grev.	Non- invasive
Mimosa pigra L.	Invasive
Najas pectinata (Parl.)	Non- invasive
Nauclea latifolia Sm.	Non- invasive
Neptunia oleraceae Lour.	Non- invasive
Nymphaea lotus Linn	Non -invasive
Nymphaea maculata Schumacher & Thonning	Non -invasive
Oxycarium cubense (Poepp. &kunth)Lye	Non- invasive

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Panicum maximum Jacq.	Non- invasive
Phragmites karka (Retz.) Trin.	Non- invasive
Pistia stratiotes Linn.	Invasive
Polygonum lanigarum R.Br	Non -invasive
Polygonum senegalense Meins.	Non -invasive
Potamogeton octandrus Poir.	Non- invasive
Rhynchospora corymbosa (Linn.) Britt.	Non -invasive
Ruppia maritima L.	Non- invasive
Salvinia molesta D.S Mitchell	invasive
Salvinia nymphellula Desv.	Non -invasive
Sesbania sesban (L.) Merr.	Non -invasive
Sida acuta Burm. f.	Non- invasive
Sphenoclea zeylanica Gaertner	Non- invasive
Spirodella polyrrhiza Linn	Non- invasive
Typha domingensis Pers.	invasive
Utricularia imflexa L.	Non- invasive
Utricularie reflexa L.	Non- invasive
Vallisneria aethiopica Fenzl.	invasive
Vossia cuspidata (Roxb.) Griff	invasive
Wolfia arrhiza Benth.	Non -invasive