OCEAN LIFE
Volume 3, Number 2, December 2019
Pages: 87-93

E-ISSN: 2580-4529
DOI: 10.13057/oceanlife/o030205

Aquatic macrophyte diversity, distribution, and control in coastal Southern Ghana, with priority on non-native invasive species

ASARE ERNEST, GABRIEL K. AMEKA♥
Department of Botany, University of Ghana. Legon, Greater Accra, Ghana. Tel.: +233-302213850, ♥email: gameka@ug.edu.gh

Manuscript received: 29 September 2019. Revision accepted: 22 December 2019.

Abstract. *Ernest A, Ameka GK. 2019. Aquatic macrophyte diversity, distribution, and control in coastal Southern Ghana, with priority on non-native invasive species. Ocean Life 3: 87-93.* Southern Ghana has been the focus of research into the variety and distribution of aquatic macrophytes, focusing on invasive species. Greater Accra, the Central Region, the Ashanti Region, the Eastern Region, the Volta Region, and the Western Region were all included in the study. Voucher specimens were obtained from 44 locations and submitted to the Ghana Herbarium. Sixty-two species of aquatic macrophytes were found, representing 48 genera and 30 families. All the aquatic macrophytes seen were classified into two groups, those that were invasive and those that were not; these were further divided into their respective families. With nine species, the Cyperaceae family emerged as the contender. IUCN (2004) criteria were used to determine if a species met the definition of an invasive. Because of this, the observed aquatic macrophytes were classified as invasive or noninvasive. Fifty-two aquatic species were found to be noninvasive, whereas eleven were found to be invasive. The aquatic macrophytes' life histories were also analyzed. There were 41 emergent species (67%), 11 free-floating species (17%), eight submerged species (13%), and two floating-leaf species (3%). Eleven types of invasive aquatic plants were found, and distribution maps were made for each. In the southern region of Ghana, *Pistia stratiotes* were found in seven different locations, making it the most widespread invasive aquatic plant in the region. All 62 invasive and noninvasive species were recorded in a database. Among these were the species' scientific and colloquial names and their genus and family, description, reproduction, habitat, distribution, and uses. Each method of control for invasive aquatic macrophytes was reviewed to make advantage of the most effective strategies for their management and eradication.

Keywords: Aquatic macrophytes, distribution, diversity, Ghana

INTRODUCTION

Macroscopic plants found in or near freshwaters are referred to collectively as "aquatic macrophytes," and this group includes some relatively "big plants" (Sculthorpe 1967; Panda et al. 2018). Large trees, shrubs, ferns, mosses, macroalgae, and a variety of vascular plants all fall under the category of aquatic macrophytes since they require either permanently wet soil or a constant supply of standing fresh water (Sculthorpe 1967). In addition, they are essential to the health of aquatic ecosystems because they are native to water bodies, including lakes, rivers, and wetlands (Sculthorpe 1967). These plant species, which are found in different parts of the same bodies of water, are classified as follows: those that grow completely submerged, whether rooted or unrooted in the sediment (e.g., *Ceratophyllum demersum*; *Elodea canadensis*); those that float freely on the surface of the water (e.g., *Eichhornia crassipes*; *Pistia stratiotes*); those that are rooted in the sediment but have at least some portion of the plant extending above the water into the air (e.g., *Typha domingensis*); and those that are rooted in the sediment but have leaves that float freely on the surface of the water (e.g., *Nymphaea lotus*).

Inevitably, the conditions created by freshwater bodies allow for the growth of vegetation (Westlake 1981). Therefore, macrophytes and other types of aquatic plants play a crucial role in the health of any freshwater ecosystem. They share this characteristic with other photosynthetic species, such as planktonic and periphyton algae (Cooper and Knight 1985), and are primary producers. Furthermore, they contribute to ecological processes, including decomposition and energy transfer (McQueen et al. 1986; Dvorak 1996), and may serve as food for other organisms like birds (Batzer et al. 1993) and fish (Crowder and Cooper 1982).

Because of their ability to assimilate nutrients, aquatic macrophytes can affect water quality and provide a biological indicator of a body of water's nutrient status simply by virtue of their presence, absence, and abundance (Uotila 1971; Wang et al. 2012). In addition, they may manage the quality of the water supply by secreting a wide range of organic and mineral compounds into the body of water. Additionally, they absorb metals from the water they live in (Devlin 1967; Moyo et al. 2013; Ammar et al. 2014; Matindi et al. 2014; Wanyonyi et al. 2014; Puspha et al. 2016; Feng et al. 2017; Arenas et al. 2018; Krupnova et al. 2018; Ting et al. 2018). Furthermore, they help keep sediments stable in water bodies by providing habitats for other creatures (Chung 1974).

As a result of their interactions with the other species in their natural environment, they have natural enemies that help to keep their numbers in control, preventing them from becoming a nuisance. However, when introduced to new ecosystems, invasive aquatic macrophytes generally outcompete native flora. They cause a decline in biodiversity due to their rapid population growth, high dispersal rate, and short generation period.

The International Union for Conservation of Nature (IUCN 2004) defines invasive species as "animals, plants, or other organisms brought by man into regions out of their normal distribution range, where they get established and disperse, having a negative impact on the local ecosystem and species." When individuals or propagules are transported to areas outside of a taxon's native range, invasion can be considered to have begun (Mooney and Cleland 2001). There are four distinct phases of an invasion: introduction (the act of moving an organism to a new area), establishment (the process of establishing a new population in a new location), naturalization (the process of allowing the population to maintain itself), and invasion (Mooney and Cleland 2001). A worldwide problem, invasive species seriously threaten terrestrial, marine, and freshwater ecosystems (Mooney and Cleland 2001). Ballast water, hull fouling, aquaculture escapes, and accidental or planned introductions spread aquatic invasive species (MEA 2005). The most significant risks to global biodiversity come from the introduction and spread of invasive species, climate change, and habitat degradation (MEA 2005). Because of the compounding effects of these variables, the rate at which biodiversity is being lost in a given area may increase dramatically, and efforts to curb the spread of invasive species may be rendered futile.

The purpose of this research is to catalog the types, distributions, and management strategies for aquatic macrophytes, focusing on invasive species in southern Ghana. The goals of this study are to (i) identify invasive and noninvasive macrophytes in freshwater bodies in southern Ghana; (ii) map the distribution of invasive aquatic macrophytes encountered during the research; and (iii) examine the ecology of and potential solutions for, invasive aquatic plant populations.

MATERIALS AND METHODS

Study area

Six different regions of Southern Ghana were included in the research, i.e., the Western, Eastern, Central, Ashanti, Greater Accra, and Volta regions (Figure 1). Accessibility by vehicle and boat, the effect of the presence of the aquatic macrophytes, and the use that the bordering communities made of the aquatic macrophytes all played a role in the selection of sampling sites.

The southeast coast of Southern Ghana is warm and relatively dry, while the southwest coast is hot and humid. Humidity is another defining feature of the climate. It is especially true at night when the humidity could reach 100%. South Ghana experiences two distinct wet times of the year. It includes the months of April, May, and July, as well as September and October. The GPS coordinates of the sampling sites in southwestern Ghana are shown in Table 1.

Survey of aquatic plants

It was decided to survey the aquatic macrophyte vegetation in Southern Ghana. All locations in the study region were divided into smaller sections, and samples of aquatic macrophytes were taken randomly from each section. A GPS Magellan Smart 5390 was used to record the precise location of the place. All those kinds of aquatic macrophytes found were then given unique identification codes, and images of those plants were taken for inclusion in a database. As most of the aquatic plants observed were fruiting specimens, they were collected and dried in a herbarium press. Herbarium press specimens of plants were checked frequently to ensure rapid drying. The specimens were dried and placed on mounting sheets at the Ghana herbarium. On-site identification of all invasive aquatic macrophytes was validated at the Ghana Herbarium, Department of Botany, University of Ghana, Legon. The following data were provided for each species observed in the wild. Locals were surveyed to get the following information about the macrophyte: its scientific name, synonym, common name, family, description, reproduction, place of collection, and uses.

Invasive aquatic macrophytes

Each aquatic macrophyte that was found had its invasiveness or noninvasiveness evaluated. These species were classified as invasive based on the following criteria (IUCN 2004): lack predators, infections, and diseases that would keep population numbers in check; generate copious amounts of seed with high viability of that seed; employ successful dispersal techniques; very opportunistic; fast-growing, allowing them to displace slower-growing plants;

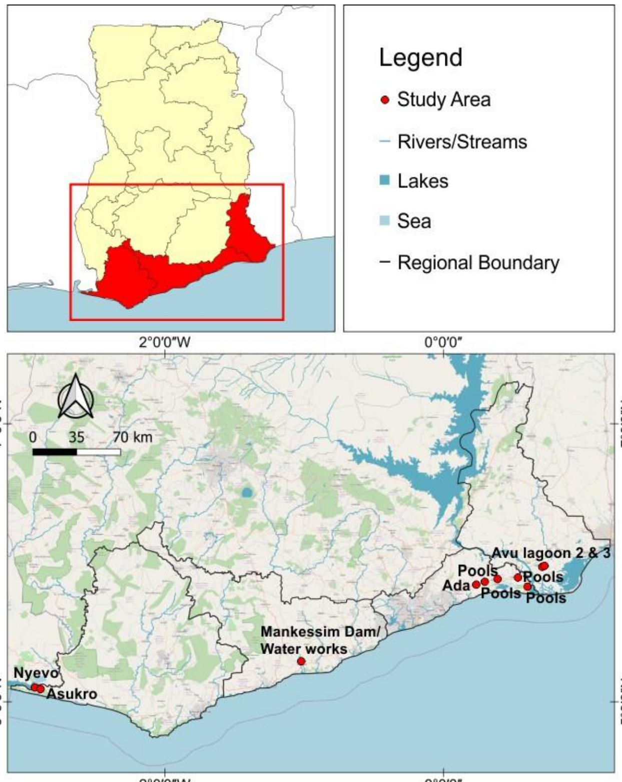

Figure 1. The major sampling sites of water bodies within Southern Ghana

release compounds that impede the growth of other plants nearby; have longer photosynthetic periods; alter soil and habitat conditions where they grow to suit their survival and expansion better; habitat modification. In addition, they may grow in various conditions, are difficult to eradicate, spread rapidly (typically via wind, water, or animals), and remain dormant for long periods.

Distribution of aquatic macrophytes

Each aquatic macrophyte found during the sample visits was included in a comprehensive distribution list.

Table 1. Localities and sampling sites

Locality	Site	Longitude/ latitude
Ada	Dawa	05˚50.726N, 0˚14.533E
Ada	Dawa	05˚52.055N, 0˚18.188E
Ada	Sege	05˚52.792N, 0˚23.792E
Ada	Bedeku	05˚53.672N, 0˚32.562E
Ada	Big Ada road	05˚49.436N, 0˚36.690E
Mankesim	Water works	05°17.425N, 1°00.982W
Avu lagoon	Entrance of channel	05˚58.150N, 0˚42.845E
Avu lagoon	Middle of channel	05˚58.538N, 0˚43.517E
Avu lagoon	Main lagoon	05˚68.660N, 0˚44.051E
Jewi wharf	Nveye	05°06.437N, 2°55.864W
Jewi wharf	Asukro	05°05.651N, 2°53.552W
Kpong headpond	Main dam	06°14.100N, 0°30.841E
Kpong headpond	Main dam	06°07.185N, 0°06.139E
Kpong headpond	Main dam	06°06.444N, 0°06.188E
Weija	Edge of dam	05°34.108N, 0°20.389W
Lower Volta River	Entrance of river	05°59.425N, 0°35.062E
Lower Volta River	Along the bridge	05°59.425N, 0°35.097E
River Ayensu	Channel of River	05°35.376N, 0°37.102W
River Ayensu	Main river	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 Univ.	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

RESULTS AND DISCUSSION

Diversity of aquatic macrophytes

Sixty-two species of aquatic macrophytes representing 48 genera and 30 families were found throughout the research. These are detailed in Table 2. Lakes, lagoons, ponds, river systems, head ponds, and seasonal pools were suitable for the aquatic macrophytes. Cyperaceae was the most common family found. As many as nine distinct species could be found within this family. The Poaceae family was the second most numerous, with six members, followed by the Fabaceae family, with five members. *Cyperus*, represented by four species, was the most numerous genus in the analysis. Then came *Ipomoea* and *Ludwigia*, both of which had three flowers.

In addition, aquatic macrophytes were classified into the different forms of life-based on their location in the bodies of water they were found in; 41 of the species were found to be emergent, 11 were found to be free-floating, and eight were found to be submerged; however, only two of the aquatic plants found were floating-leaved.

Systematics, diversity, morphology, and distribution of aquatic macrophytes

There were 62 different types of aquatic macrophytes found, 11 of which were considered invasive. The eleven plants represented 11 families of invasive aquatic plants. The *E. crassipes* were placed in the Pontederiaceae family, and *Cyperus papyrus* was placed in the Cyperaceae family. Those of the Poaceae family for *Vossia cuspidata*, the Azollaceae family for *Azolla filiculoides*, and the Fabaceae for *Mimosa pigra*. There is the Salviniaceae for *Salvinia molesta*, the Ceratophyllaceae family for *C. demersum*, the Typhaceae for *T. domingensis*, the Hydrocharitaceae family for *Vallisneria aethiopica*, the Araceae family for *P. stratiotes*, and the Alismataceae family for *Limnocharis flava*.

Several types of invasive macrophytes in water were also classified. There were six adrift, four emergings, and one buried. The southern region of Ghana was home to seven distribution points for *P. stratiotes*. Next in line with 6 locations were *V. cuspidata* and *C. demersum*. The next two species, with five occurrences each, were *A. filiculoides* and *L. flava*. While, *M. pigra* and *V. aethiopica* each had two distribution points, *E. crassipes* had three. Finally, the Jewi wharf and the Kpong head pond were the only places where *S. molesta* and *C. papyrus* could be found.

There were two categories of macrophytes in the water: aquatic and semi-aquatic. It was determined by their degree of reliance on the specific body of water in which they were discovered. Plants that can't survive without water to conduct their life cycle are known as aquatic plants. A lack of water leads to their demise. The semi-aquatic plants might complete their life cycles in dry conditions. However, they are flourishing as terrestrial plants due to evolution and adaptation. There were 62 different kinds of aquatic macrophytes, 25 of which were true aquatic plants and the other 37 semi-aquatic.

Table 2. 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
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
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

The Lentibulariaceae member *Utricularia reflexa*, and the Parkeriaceae member *Ceratopteris cornuta*, were two of the most notable. It is important to note that the only known homes for these species are the Avu lagoon in the Volta Region and the Mankesim swamp in the Central Region.

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

Voucher specimens were collected from each sampling site and sent to the Ghana Herbarium for preservation. In Western Region, for instance, one may find aquatic and semiaquatic plant species near the Nveye entrance, a part of the Tano lagoon complex. The sudd neighborhood, mostly made up of Vossia-Oxycarium, was plain to discern. Plant species ranged in structure and geography across the Tano lagoon system. *E. crassipes* was another easily recognized invasive aquatic plant. It was kept under control via a biological management program that is still active today. It was possible to see the biological control agent, *Neochetina bruchi*, on and under the water hyacinth leaf.

The southern part of the Kpong Head pond was home to various aquatic and semiaquatic plants. There were emergent, free-floating, floating-leaved, and submerged types of life to be seen at the Head pond's deep water edge. Coves, shallow waterways, deep seas, sudds, and the peripheries of islands provided ideal habitats for various plant life in Head pond. However, primarily *T. domingensis, C. demersum, N. lotus,* and *L. hexandra* thrived in the water.

Several species of aquatic and semiaquatic plants were identified in the Avu lagoon in Adutor, particularly along the channel leading to the main water body. Likewise, some aquatic organisms seemed freely floating, while others were clustered at the channel's boundaries. The tiny blooms of *Utricularia imflexa* and *A. filiculoides* predominated along the canal. Several types of aquatic plants were found in the main body of water, with *C. demersum* being the most numerous and largest. *C. demersum* looks like an island from afar.

Most Ada sampling locations were temporary pools used only during certain times of the year. The *N. lotus* was the most common water plant in these temporary pools. In addition, a small quantity of *E. crassipes* was discovered in the water body beneath the Bedeku Bridge.

The reddish-blooming *A. filiculoides* were the most numerous and dominant species in the pool where the samples were taken in Mankesim. Sedges such as *C. articulatus* and *E. complanata* were spotted both in and around the pool. The Mankesim location was also near some rice plantations. Some farmers claim that harvesting and dumping *A. filiculoides* onto their rice farms could increase crop yields by using *Azolla* species' nitrogen-rich soil.

Typha domingensis was the preeminent plant at Weija; it occurred in the central body of water and periphery. The Weija sampling location also has abundant *C. demersum* and *V. cuspidata*.

Classification of encountered aquatic plants into their families

Of the aquatic macrophytes identified, nine belonged to the Cyperaceae family, six to the Poaceae family, five to the Fabaceae family, and three each to the Convolvulaceae, Lemnaceae, and Onagraceae families. In addition, two members of the families Amaranthaceae, Azollaceae, Commelinaceae, Pontederiaceae, Marsileaceae, Nymphaceae, Polygonaceae, Salvinaiceae, Lentibulariaceae, Alismataceae, and Hydrocharitaceae; one member each of the families Parkeriaceae, Ceratophyllaceae, Thelypteridaceae, and Cucurbitaceae.

Discussion

Systematics of aquatic macrophytes present in the study

There were 62 species of aquatic macrophytes found, representing 48 different genera. Eleven of them were found to be invasive. There were 11 distinct families represented among the invading species. In his research on the macrophytes of the Kpong head pond, Amissah (2010) found 50 species representing 26 different families. Also, Amissah (2010) found 17 non-native species in the Kpong head pond. Amissah (2010) identified six aquatic species that IUCN (2004) classified as noninvasive but which Amissah (2010) classified as invasive. Accumulating invasive aquatic macrophytes in Ghana's waterways raises the risk of floods, reduces fish habitat, and makes boating and other water-based activities more difficult (Boyd 1971). The Kpong headpond's hydropower generation could be disrupted, and fish populations could plummet (Charudattan 2001). Their economic sector would feel the effects of this in the long run.

Fifty-one different noninvasive aquatic macrophytes were found, spread over twenty-six different families. Eight of the noninvasive plant species were members of the family Cyperaceae. For the Kpong head pond, Amissah (2010) found a total of 33 noninvasive aquatic plants from 19 different families. Amissah (2010) documented ten species of the Cyperaceae family of aquatic macrophytes. Cyperaceae contains nearly the same amount of noninvasive species as other studies conducted by deGraft-Johnson (1991).

Distribution of aquatic macrophytes encountered

Like other aquatic organisms, water macrophytes have a greater global distribution than terrestrial plants. It is because the components or conditions needed by aquatic plants are more standardized than those needed by terrestrial plants. In this research, *P. stratiotes* was the most pervasive aquatic invasive species. There were seven locations in Southern Ghana where this was disseminated (Figure 1). Additionally, *P. stratiotes* was found in both the Kpong head pond and Lower Volta (deGraft-Johnson 1996). In addition, the researchers found *E. crassipes* in both the Kpong head pond and the Lower Volta. It first appeared in 1990 in the Western Region's Abby-Ehy-Tano-Nveye River and Lagoon complex, then in 1998 in Lake Volta's Oti River Arm, and finally in 2003 in Kpong Head pond (deGraft-johnson 1991). The researchers also came across *E. crassipes* at Ada. It was located on the Bedeku Bridge that connected to Ada Main Township. *V. cuspidata* and *C. demersum* can be found in the Kpong head pond and the Lower Volta. *V. cuspidata* and *C. demersum* were also found in the Kpong head pond, according to the research of Amissah (2010).

Uses of aquatic macrophytes

Aquatic macrophytes have provided researchers with a new field to explore. Aquatic macrophytes found were mostly utilized for food, compost, and medicinal purposes, as demonstrated in sections 4.2 and 4.3. According to Boyd (1974), *S. molesta* is a valuable addition to compost piles and mulch beds. It is used in this capacity around Kariba Lake, where it is combined with animal manure to fertilize crops. Mitchell's (1974) research in Lake Kariba shows that Salvinia mats serve as critical habitats for juvenile fish and their food. In addition, it has been suggested that they serve as a source of nutrition for other species, including birds (Batzer et al. 1993) and fish (Crowder and Cooper 1982). Personal observations were taken in the Volta Region at a place called Adutor. Many fishermen gathered Ipomoea aquatica as a vegetable in soups and stews. Aquatic macrophytes may also be useful for producing biogas in other contexts. For example, invasive aquatic macrophytes could be researched for biofuel generation as new regions are investigated to generate energy to fulfill global industrialization. The energy produced could be put to use in the automotive sector. In addition to filtering out pollutants, aquatic macrophytes can be employed to improve water quality. Because of their ability to assimilate nutrients, aquatic macrophytes can affect water quality and serve as a biological indicator of a body of water's nutrient status simply by virtue of their presence, absence, or abundance (Uotila 1971). They may also regulate water quality by secreting different organic and mineral components into the water body.

Problems created by invasive aquatic plants

When an aquatic plant grows to the point where it disrupts other activities that use water, it is called a nuisance (Adeniji 1979). Invasive aquatic macrophytes threaten both native aquatic life and the human communities that rely on healthy aquatic ecosystems for subsistence. The only method to stop the spread of harmful aquatic macrophytes was to figure out how they got there in the first place. Invasive aquatic plants' transmission routes were crucial because they revealed the specific processes and vectors by which these plants were disseminated. It was found that the 11 invasive aquatic macrophytes almost all followed the same transmission routes. Water currents carried the seeds and segments of plants that the wind had propelled. Many local and migratory aquatic birds also carried the seeds on their feet and feathers. Because of this and other factors, invasive aquatic macrophytes have spread to virtually every major body of water and river across mainland Africa and even to several African ocean island nations. In addition, the mud attached to the feet of birds, people, and agricultural tools would sometimes transport the seeds.

Control methods for the invasive species encountered

Eleven different invasive species were found, all of which required some management strategy. This action was taken to facilitate the availability of control methods vital to eradicating aquatic invasive species. Three basic categories were created to organize those eleven species' control strategies. Mechanical, biological, and chemical means of regulation were described.

The following physical approaches managed the 11 aquatic invasive species. When it comes to the physical management of invasive macrophytes, employing a combine harvester for their harvesting was the simplest and most effective method. In certain cases, lines were strung between poles to restrict the spread of these aquatic macrophytes to uninfested areas, which proved to be highly effective. In addition, aquatic macrophytes could be physically managed by raking or hand plucking from affected water bodies. Finally, it is possible to physically manage aquatic macrophytes by chopping them down and setting them on fire.

Chemical methods of regulation came next. 2, 4-D (2, 4-dichlorophenoxy), Diquat (6, 7-dihydrodipyridyl pyrazinediumion), and Glyphosate (Isopropilamine salt of N-phosphonomethyl glycine) were the three most widely used aquatic herbicides. Plant Protection Agencies had to approve them before being used, and only qualified technicians could apply. Nevertheless, eleven invasive aquatic macrophytes could be managed with the pesticides indicated above, except for *V. aethiopica*, for which no chemicals were recommended. Paraquat was also efficient in suppressing *Salvinia* (Dias and Santos 1966).

Biological methods had previously been used as a form of management. One method of reducing pest populations is employing natural enemies particular to that insect's host (Howard and Harley 1998). Historically, the most common method of biological weed control involved the introduction of exotic natural enemies (predators, parasites, and viruses) to an area to lower exotic pest populations and keep them at economically negligible densities (McFadyen 1998). Although no biological control agent was available for *L. flava* at the time this strategy was developed, all other 11 invasive aquatic macrophytes were successfully eradicated using host-specific organisms. Studies have been conducted on the effectiveness of arthropods and diseases in controlling *E. crassipes*. Few arthropods, such as mites, moths, and weevils, were shown to diminish water hyacinth development considerably; nonetheless, the following species were deemed worthy of introduction to other countries: the mite *Orthogalumna terebrantis* (Bennet 1981); the moth *Acigona infusella* (Deloach and Cordo 1983 and *Sameodes albiguttalis* (Deloach and Cordo 1976); the Miridae *Eccritotarsus catarinensis* (Hill et al. 1999); the weevils *Neochetina eichhorniae* and *N. bruchi* (Deloach 1976; Deloach and Cordo 1976; Center and Durden 1986).

Ceratophyllum demersum was controlled using the Chinese grass carp as a biological agent, while *Vossia* was managed by utilizing grazing animals in the affected region. *S. molesta* had been thought to have a permanent biological control in the form of the curculionid *Cyrtobagous salviniae*, which would be both cost-effective and environmentally friendly. For biological control, the stem-boring moth *Neurostrota gunniella* and the fungal plant pathogen *Phloeospora mimosae-pigrae* were introduced to the *Mimosa* plant (Cullen et al. 2004). Either species could be released at once or separately. Biological control was considered our only hope when considering how to eradicate this weed permanently (Hill 1999). Insects that feed on *A. filiculoides* leaves, such as the flea beetle *Pseudolampsis guttata* and the weevil *Stenopelmus rufinusus*, have proven effective in their role as biocontrol agents (e.g., in South Africa) (Henderson 2001). Muskrats can potentially eradicate *Typha* spp. in temperate regions (Kadlec et al. 2007), reducing the invasive plant population. Most efforts to manage *V. aethiopica* relied on biological methods of pest management. Several fish species use this submerged aquatic macrophyte as a food source and population regulator.

From February 2013 to January 2015, researchers in southern Ghana studied aquatic macrophytes at 44 sites throughout six regions: Greater Accra, Volta, Central, Eastern, Western, and Ashanti. Sixty-two different types of aquatic macrophytes were found in southern Ghana waters. Of these, only 11 were invasive species, while the rest 51 were noninvasive. Forty-eight genera and 30 families were represented among the aquatic macrophytes found, with the Cyperaceae family being the most common. The various species were classified into the following four lifestyle categories: emergent, free-floating, submerged, and floating-leaved. There were 41 emergent species, two floating-leaved species, eight submerged species, and 11 free-floating species; the most widely distributed species in southern Ghana were *P. stratiotes*, *V. cuspidata*, *C. demersum*, and *T. domingensis*, with *P. stratiotes* having seven distribution sites and the other three having six each. In addition, the researchers compiled information on the 62 different types of aquatic macrophytes we found, including their scientific names, common names, uses, habitat, and reproduction strategy. The study also included photographs of the aquatic plants found; the majority of the invasive aquatic plants found in the study were located in the Volta River System.

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