4.1 INTRODUCTION

Wetlands are fragile ecosystems and constitute a great potential for economic, cultural and recreation value to human life. They support an appreciable assemblage of rare, vulnerable species or subspecies of plants or animals or have an appreciable number of individuals of any one or more of these species. The wetland plants regulate water quality and provide food and shelter for its inhabitants (Sivaperuman, 2007). Macrophytes are the integral component of wetlands, which are amongst the most productive ecosystem (Nandan et al. 2004). However, aquatic plants are still regarded as a menace and a nuisance because of the unawareness of this great potential and economic value. They are more productive than conventional terrestrial crops. These wetland plants have provided good source of livestock feed, human food, fish food, medicines, organic or biofertilizers, energy fibre and paper. The wetland also supports many birds, amphibians, reptiles and mammals.

Coastal pokkali wetlands of Ernakulam district come under Vembanad Kole, Ramsar site in Kerala. Monsoon and salinity followed by a hot season from March to May highly influence the seasonal variation of macrophytic diversity in pokkali wetland.

To give an idea about the habit forms of the flora of Ernakulam district, they would be tentatively classified as (I) Wetland macrophytes:-Which consist of (a) Free floating hydrophytes (b) Suspended hydrophytes (c) Submerged – anchored
4.2. METHODOLOGY

Studies on the aquatic macrophytes of pokkali wetland, at Kadamakudy, Ernakulam district was carried out during May 2008 - April 2009. The vegetation was mainly herbaceous, soil was clay loamy. Monthly samples were collected from an area of 1x1m$^2$ (Quadrate method, Clements and Weaver, 1971). The plants were identified with the help of reference texts and expert taxonomists. The density, abundance and frequency percentage of each species were also calculated.

4.3. RESULT

A total of one hundred species of plants belonging to fifty two families were recorded from the pokkali wetland area (Appendix: VI). These include wetland macrophytes, mangrove and mangrove associates and terrestrial plants. Dicotyledons, dominate with forty seven families and Monocotyledons with five families. Among dicots, the dominant families were Fabaceae and Mimosaceae and among monocots, the dominant families were Araceae and Poaceae. Four member of Pteridophytes were also noticed in the pokkali wetland. Of the total species (22) was composed of wetland macrophytes, (14) of mangrove and mangrove associates and (64) was composed of terrestrial plants. During the present study one rare (Neptunia prostrata), one endemic (Artocarpus hirsutus. Lam.) and ten species of alien weeds were also recorded from the pokkali wetland area of Kadamakudy.
Among the total one hundred plant species recorded from the study area, only thirteen species of aquatic macrophytes were recorded from the regular sampling sites.

Twenty two species of wetland / marsh macrophytes were recorded from the pokkali wetland area which comprises of one semi aquatic macrophyte, fourteen marsh plants, two introduced alien weeds, one free floating pteridophyte, one free floating alien weed and one anchored submerged alien weed (Appendix: VI). A rare medicinal hydrophyte namely *Neptunia prostrata* was recorded from the wetland area having anchored with floating shoots.

Three true mangroves and ten mangrove associated plants were recorded from the study area (Table: 4.1). Among these *Acrostichum aureum* was a pteridophyte and this habitat was extensively used as a major feeding ground by Grey headed starling (*Sturnus malabaricus*). These birds use these habitats from early morning till late evening for feeding on the insects available here. *Acrostichum aureum*, in the habitat also forms a major shelter/hiding place for Purple moorhen (*Porphyrio porphyrio*). The mangrove associates in pokkali wetland of Kadamakudy include marsh plants, terrestrial plants and introduced /exotic/alien plants. The shoots of mangrove associates like *Echinochloa stagnina* and *Diplachne fusca* form major nest building material for Purple moorhen (*Porphyrio porphyrio*) in the study area.

The respiratory roots of mangroves like *Excoecaria agallocha* formed a major breeding ground for shell fishes/fishes. The closely associated roots of these species served as shelter and nursery for fish/shell fish frys of *Eтроplus suratensis*, *Hyporhamphus limbatus*, *Metapenaeus dobsoni* and *Metapenaeus indicus*. Seventy seven species of terrestrial plants were also recorded from the pokkali wetland area (Appendix: VI). Among these two plants were medicinal climbers, thirteen species were introduced trees, six were terrestrial medicinal weeds, seven were terrestrial medicinal trees, two were medicinal shrubs and one medicinal grass. Two introduced shrubs namely *Ananas comosus* and *Glycosmis pentaphylla* were also recorded from the habitat.
Table: 4.1. List of mangrove/mangrove associates recorded from the pokkali wetland area.

<table>
<thead>
<tr>
<th>SL No</th>
<th>Name of plant species</th>
<th>Type</th>
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<tbody>
<tr>
<td>1</td>
<td><em>Excoecaria agallocha</em></td>
<td>Mangrove</td>
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<td>2</td>
<td><em>Acrostichum aureum</em></td>
<td>Mangrove</td>
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<td>3</td>
<td><em>Gardenia jasminoides</em></td>
<td>Mangrove</td>
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<td>4</td>
<td><em>Terminalia catappa</em></td>
<td>Mangrove associate</td>
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<tr>
<td>5</td>
<td><em>Calophyllum inophyllum</em></td>
<td>Mangrove associate</td>
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<tr>
<td>6</td>
<td><em>Diplachne fusca</em></td>
<td>Mangrove associate</td>
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<tr>
<td>7</td>
<td><em>Cyperus malaccensis</em></td>
<td>Mangrove associate</td>
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<td>8</td>
<td><em>Echinochloa stagnina</em></td>
<td>Mangrove associate</td>
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<td>9</td>
<td><em>Morinda citrifolia</em></td>
<td>Mangrove associate</td>
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<td>10</td>
<td><em>Aniseia martinicensis</em></td>
<td>Mangrove associate</td>
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<td>11</td>
<td><em>Sphaeranthus africanus</em></td>
<td>Mangrove associate</td>
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<td>12</td>
<td><em>Ceratopteris cornuta</em></td>
<td>Mangrove associate</td>
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<td>13</td>
<td><em>Thespesia populnea</em></td>
<td>Mangrove associate</td>
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</table>

Details regarding the seasonality of aquatic macrophytes collected from the regular sampling sites are given below (Table: 4.2). *Nymphaea pubescens* was present in the study area from May to January. *Nymphaea pubescens* was observed maximum during paddy season and minimum during prawn culture season. This may be due to saline water intrusion into the field. Species like *Cyperus compressus*, *Diplachne fusca* and *Echinochloa stagnina* were noticed in the pokkali field from May to November. Harvesting of pokkali rice (*Oryza sativa*) was done during the month of August and the seedling of pokkali rice was noticed after harvesting during
November-December. *Fimbristilis miliacea, Sphenoclea zeylanica, Ludwigia hyssopifolia* and *Eleocharis dulcis* were noticed in the pokkali wetland in the month of July and they disappear during November. *Alternanthera philoxeroides* was noticed in the habitat from July to October.

**Table: 4.2. Seasonality of aquatic macrophytes in pokkali fields of Kadamakudy (May 2008 – April 2009)**

<table>
<thead>
<tr>
<th>SL. No.</th>
<th>Name of plant species</th>
<th>M</th>
<th>J</th>
<th>J</th>
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<th>J</th>
<th>F</th>
<th>M</th>
<th>A</th>
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<tbody>
<tr>
<td>1.</td>
<td><em>Nymphaea pubescens</em></td>
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<td>2.</td>
<td><em>Cyperus compressus</em></td>
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<td>3.</td>
<td><em>Diplachne fusca</em></td>
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<td>4.</td>
<td><em>Echinochloa stagnina</em></td>
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<td>5.</td>
<td><em>Oryza sativa</em></td>
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<td>6.</td>
<td><em>Salvinia molesta</em></td>
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<td>7.</td>
<td><em>Eichhornia crassipes</em></td>
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<td>8.</td>
<td><em>Fimbristylis miliacea</em></td>
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<td>9.</td>
<td><em>Sphenoclea zeylanica</em></td>
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<td>10.</td>
<td><em>Sphaeranthus africanus</em></td>
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<td>11.</td>
<td><em>Ludwigia hyssopifolia</em></td>
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<td>12.</td>
<td><em>Eleocharis dulcis</em></td>
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<tr>
<td>13.</td>
<td><em>Alternanthera philoxeroides</em></td>
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</table>
4.3.1. Monthly fluctuation of aquatic macrophytes

a) Paddy cultivation season (June to October)

Among the thirteen species of aquatic macrophyte noticed during paddy cultivation season, seven species of aquatic macrophytes were recorded during June. *Echinochloa stagnina* and *Diplachne fusca* (26.2, 26.2, 100) showed maximum abundance, density and frequency followed by *Oryza sativa*, *Salvinia molesta*, *Eichhornia crassipes*, *Cyperus compressus* and *Nymphaea pubescens* (Appendix: VII,VIII,IX).

Six additional species were recorded during July and a total of thirteen species were noticed. Of these *Alternanthera philoxeroides* was the most abundant species followed by *Oryza sativa* and *Echinochloa stagnina*. Maximum density was exhibited by *Echinochloa stagnina* (3.7) and *Oryza sativa* (3.7) and low density by *Fimbristylis miliacea* (0.5). Maximum frequency (75) was exhibited by *Nymphaea pubescens*, *Echinochloa stagnina*, *Diplachne fusca*, *Cyperus compressus*, *Oryza sativa* and *Salvinia molesta* and low frequency (25) was exhibited by *Sphaeranthus africanus*, *Eleocharis dulcis* and *Alternanthera philoxeroides* (Appendix: VII,VIII,IX).

During August, *Alternanthera philoxeroides* (6) was noticed as the most abundant aquatic macrophyte and least abundance was exhibited by *Fimbristylis miliacea* (1) and *Ludwigia hyssopifolia* (1). The denser species were *Echinochloa stagnina*, *Oryza sativa* and *Salvinia molesta* (3.7) and least dense were *Fimbristylis miliacea*, *Ludwigia hyssopifolia*, *Sphaeranthus africanus* and *Eleocharis dulcis* (0.5). *Nymphaea pubescens*, *Echinochloa stagnina*, *Diplachne fusca*, *Cyperus compressus*, *Oryza sativa*, *Salvinia molesta* and *Eichhornia crassipes* (75%) were most frequent during this month. *Sphaeranthus africanus*, *Eleocharis dulcis* and *Alternanthera philoxeroides* (25%) were the least frequent species. During August thirteen species of aquatic plants were noticed (Appendix: VII,VIII,IX).

Thirteen species of aquatic macrophyte were noticed during the month of September. The most abundant species during this month was *Alternanthera philoxeroides* (6) and least abundant species were *Cyperus compressus*, *Fimbristylis*...
miliacea and Ludwigia hyssopifolia (1). Maximum density was exhibited by Salvinia molesta and low density by Fimbristylis miliacea, Sphaeranthus africanus, Ludwigia hyssopifolia and Eleocharis dulcis (0.5). Cyperus compressus, Salvinia molesta, Eichhornia crassipes were most frequent during September and Sphaeranthus africanus, Eleocharis dulcis and Alternanthera philoxeroides (25%) were least frequent (Appendix: VII,VIII,IX).

Two species disappeared from the habitat in October and they were Alternanthera philoxeroides and Oryza sativa. The most abundant species was Salvinia molesta (4.7) and least abundant species were Nymphaea pubescens, Fimbristylis miliacea and Ludwigia hyssopifolia (1). Salvinia molesta (4.7) was the denser species and Nymphaea pubescens, Fimbristylis miliacea, Sphenoclea zeylanica, Sphaeranthus africanus, Ludwigia hyssopifolia and Eleocharis dulcis (0.5) were the least dense species. Eichhornia crassipes and Salvinia molesta (100%) were the most frequent species and Sphenoclea zeylanica, Sphaeranthus africanus, Eleocharis dulcis (25%) were the least frequent plant species (Appendix: VII,VIII,IX).

b) Transient period (November and December)

Eleven species of aquatic macrophytes were recorded during the transient period. During November Salvinia molesta (7) was most abundant and Nymphaea pubescens, Cyperus compressus and Fimbristylis miliacea (1) were least abundant. Maximum density was exhibited by Eichhornia crassipes (2.7) and least density by Nymphaea pubescens, Oryza sativa, Sphenoclea zeylanica and Eleocharis dulcis (0.5). The most frequent species were Salvinia molesta and Eichhornia crassipes (100%) and least frequent were Sphaeranthus africanus, Sphenoclea zeylanica, Ludwigia hyssopifolia, Eleocharis dulcis and Fimbristylis miliacea (25%) (Appendix: VII,VIII,IX).

c) Prawn culture season (January –May)

Five species of aquatic macrophytes were noticed during prawn culture season. The most abundant and frequent species was Salvinia molesta (15) and (100%) during January and least was Nymphaea pubescens (1) and (25%).
Aquatic macrophytes were completely absent during February, March and April months.

In May four species of aquatic plants were recorded. Of these *Echinochloa stagnina* and *Diplachne fusca* were the major weeds of pokkali rice. The abundance, density and frequency of these plants were (26.2, 26.2, 100%) more, followed by that of *Nymphaea pubescens* and *Cyperus compressus* (1, 25, 25%) (Appendix: VII, VIII, IX).

### 4.3.2. Seasonal fluctuation of aquatic macrophytes

Thirteen species of aquatic macrophytes were noticed during paddy cultivation season (June-October), eleven species during transient period (November – December) and five species during prawn culture season. Maximum number (13) and diversity (1.8) of species were noticed during paddy cultivation season. This may be due to rainfall, fresh water intrusion and favourable environmental conditions etc. Minimum number (5) and diversity (0.82) was noticed during prawn culture season and this may be due to the entry of saline water and other environmental factors like rise in atmospheric and water temperature.

![Seasonal diversity of aquatic macrophytes during 2008-2009](image)

Fig. 4.1. Seasonal diversity of aquatic macrophytes during 2008-2009

Among the total one hundred plant species recorded from the study area thirteen species of aquatic macrophytes were recorded from the regular sampling...
sites. The details regarding their abundance, density and frequency in the habitat is given below.

1. *Nymphaea pubescens* (Family: - Nymphaeaceae)

   This is an anchored hydrophyte with floating leaves and observed in the pokkali field from May to January (Fig. 4.1a). The maximum abundance of *Nymphaea pubescens* was noticed during July to September and least abundance during May, June and October. They were denser during July to September and least dense during June, December and January (Fig.4.1a). The maximum frequency of *Nymphaea pubescens* was noticed from July to September and least frequent in May, June, December and January (Fig 4.1b).

   ![Fig.4.2 a)](image_url)

   ![Fig.4.2 b)](image_url)

   **Fig. 4.2a.** Average abundance and density of *Nymphaea pubescens* during 2008-09
   
   **Fig.4.2b.** Average frequency of *Nymphaea pubescens* during 2008-09

2. *Cyperus compressus* (Family: Cyperaceae)

   It is a marsh plant seen in the pokkali field from May to November. The maximum abundance of this species was noticed during July to September and least abundance during May, June, October and November. The maximum density of this species was noticed during July and August and minimum density was recorded during May, June (Fig 4.2 a). Maximum frequency was observed during July to November (Fig 4.2 b).
3 Diplachne fusca (Family: Poaceae)

Diplachne fusca is a marsh and mangrove associate seen in pokkali field. The maximum abundance of this weed was noticed during May and June and least during October and November. The plant was denser in May and June and least during October and November (Fig 4.3a). Maximum frequency was noticed during May, June and minimum during July to November (Fig. 4.3b).

4. Echinochloa stagnina (Family: Poaceae)

This Echinochloa stagnina is a marsh and mangrove associate in pokkali field. Echinochloa stagnina was most abundant and denser in May and June and least abundant and denser in November (Fig. 4.4a). Maximum frequency was noticed during May (Fig. 4.4b).
Chapter IV

Aquatic macrophytes of pokkali wetland and its nearby areas

5 Oryza sativa (Family: Poaceae)

*Oryza sativa* is a marsh plant, most abundant in June and least abundant in November and December. Similar observation was also noticed in the case of density of *Oryza sativa* (Fig. 4.5a). *Oryza sativa*, was most frequent in July to September and least frequent in November and December (Fig. 4.5b).

6 Salvinia molesta (Family: Salviniaceae)

*Salvinia molesta* is a free floating alien weed seen in the pokkali field. *Salvinia molesta* was most abundant and denser in December and least abundant and denser in July and August (Fig. 4.6a). *Salvinia molesta* was most frequent in September to
January and least in June. *Salvinia molesta* was observed in the pokkali field from June to January (Fig. 4.6b).

![Graph 1](image1.png)  
Fig. 4.7 a)  
**Fig. 4.7 a.** Average abundance and density of *Salvinia molesta* during 2008-09  
**Fig. 4.7 b.** Average frequency of *Salvinia molesta* during 2008-09

7. *Eichhornia crassipes* (Family: Pontederiaceae)

*Eichhornia crassipes* is a free floating alien weed observed in the pokkali field from June to December. *Eichhornia crassipes* was most abundant in July and August and least abundant in June and December. *Eichhornia crassipes* was most denser in September to November and least denser in June (Fig. 4.7a). The maximum frequency of *Eichhornia crassipes* was noticed during August to December and low frequency in May (Fig. 4.7b).

![Graph 2](image2.png)  
Fig. 4.7 a)  
**Fig. 4.7 a.** Average abundance and density of *Eichhornia crassipes* during 2008-09  
**Fig. 4.7 b.** Average frequency of *Eichhornia crassipes* during 2008-09

![Graph 3](image3.png)  
Fig. 4.8 a)  
**Fig. 4.8 a.** Average abundance and density of *Eichhornia crassipes* during 2008-09  
**Fig. 4.8 b.** Average frequency of *Eichhornia crassipes* during 2008-09
8. *Fimbristylis miliacea* (Family: Cyperaceae)

*Fimbristylis miliacea* is a marsh plant noticed in the pokkali field from July to November. *Fimbristylis miliacea* was most abundant in July to November. This plant was denser in July to September and least dense in October and November months (Fig. 4.8a). Maximum frequency of *Fimbristylis miliacea* was noticed from August to October and minimum in November (Fig. 4.8b).

![Fig. 4.9 a) Average abundance and density of Fimbristylis miliacea dueing 2008-09](image1)

![Fig. 4.9 b) Average frequency of Fimbristylis miliaacea during 2008-09](image2)

9. *Sphenoclea zeylanica* (Family: Campanulaceae)

*Sphenoclea zeylanica* is a marsh plant noticed in the pokkali field from July to November. This plant was maximum abundant in October and November and least abundant from July to September. This species was denser in July to September and least dense in October and November months (Fig. 4.9a). The high frequency of *Sphenoclea zeylanica* was observed in July to September and low frequency in October and November (Fig. 4.9b).

![Fig. 4.10 a) Average abundance and density of Sphenoclea zeylanica during 2008-09](image3)

![Fig. 4.10 b) Average frequency of Sphenoclea zeylanica during 2008-09](image4)
10. *Sphaeranthus africanus* (Family: Asteraceae)

*Sphaeranthus africanus* is a mangrove associate and observed in pokkali field from July to December. Maximum abundance, density and frequency of *Sphaeranthus africanus* was noticed from July to December (Fig. 4.10 a and 4.10 b).

![Graph showing average abundance and density of Sphaeranthus africanus](image1)

**Fig. 4.10 a)**

**Fig. 4.10 b)**

Fig. 4.11 a. Average abundance and density of *Sphaeranthus africanus* during 2008-09

4.11 b. Average frequency of *Sphaeranthus africanus* during 2008-09

11. *Ludwigia hyssopifolia* (Family: Onagraceae)

*Ludwigia hyssopifolia* is a marsh plant noticed in the pokkali field from July to November. *Ludwigia hyssopifolia* was most abundant, denser and frequent from July to November (Fig 4.11a and 4.11b).

![Graph showing average abundance and density of Ludwigia hyssopifolia](image2)

**Fig.4.11 a)**

**Fig.4.11 b)**

Fig. 4.12a. Average abundance and density of *Ludwigia hyssopifolia* during 2008-09

4.12 b. Average frequency of *Ludwigia hyssopifolia* during 2008-09
12. Eleocharis dulcis (Family: Cyperaceae)

Eleocharis dulcis is a marsh, anchored emergent plant noticed in the pokkali field from July to November. Eleocharis dulcis was most abundant from July to October and least abundant in November. Eleocharis dulcis was denser from July to October and most frequent from July to November (Fig 4.12a and 12b).

Fig. 4.13 a) Average abundance and density of Eleocharis dulcis during 2008-09
Fig. 4.13 b) Average frequency of Eleocharis dulcis during 2008-09

13. Alternanthera philoxeroides (Family: Amaranthaceae)

Alternanthera philoxeroides is a marsh, alien weed with floating shoot and noticed in the pokkali field from July to September. The maximum abundance, density and frequency of Alternanthera philoxeroides was noticed from July to September (Fig 4.13a and 13b).

Fig. 4.14 a) Average abundance and density of Alternanthera philoxeroides during 2008-09
Fig. 4.14 b) Average frequency of Alternanthera philoxeroides during 2008-09
The birds like Baya weaver, Munia and Purple moorhen were closely associated with aquatic macrophytes like *Sphaeranthus africanus*, *Sphenoclea zeylanica* and *Diplachne fusca*. These bird depend on these plants mostly for food (insect available on these plants), shelter, as their breeding ground and in providing nest building material.

Plants like *Fimbristylis miliacea* \( (r=0.744, p<0.01) \) *Ludwigia hyssopifolia* \( (r=0.768, p<0.01) \), *Sphenoclea zeylanica* \( (r=0.741, p<0.01) \), *Sphaeranthus africanus* \( (r=0.774, p<0.01) \) and *Cyperus compressus* \( (r=0.780, p<0.01) \) showed positive significant correlation with humidity. *Diplachne fusca* \( (r=0.823, p<0.01) \) and *Sphenoclea zeylanica* \( (r=0.786, p<0.01) \) showed positive correlation with temperature and *Nymphaea pubescens* \( (r=0.630, p<0.01) \) showed significant positive correlation with rainfall.

Aquatic macrophytes function in the aquatic environment in several ways. The wetland plants regulate water quality and provide food and shelter for its inhabitants. Kumar *et al.* (1991) noticed that chemical status of water appears to be the vital factor significantly influencing the general distribution of aquatic plants but abiotic factors like bottom soil and fluctuation of water greatly affect the distribution of plants within range of chemical tolerance. Janil (1991) observed that aquatic plants could change the quality of water by lowering temperature and dissolved oxygen content. According to Korschgen and Green (1988) aquatic plants like *Vallisneria spiralis* was noticed to be more sensitive to turbidity and water depth.

Wetland plants are at the base of the food chain. Through the photosynthetic process, wetland plants link the inorganic environment with the biotic one. The primary productivity of wetland plant communities varies, but some herbaceous wetlands have extremely high levels of productivity, rivaling those of tropical rainforest. And unlike many terrestrial ecosystems, much of the organic matter produced is not used directly by herbivorous but instead is transferred to the detrital food chain (Gopal, 1995).

A series of studies on the aquatic macrophytes were carried out at one of the major Ramsar sites, Keoladeo National Park, Bharatpur, Rajasthan. The flora of the
park consists of 377 species of angiosperms belonging to 254 genera and 81 families. Of these 96 species were wetland plants coming under 66 genera and 36 families. It was reported that the dominant emergent species in the park were *Paspalum distichum* and *Ipomoea aquatica*. *Hydrilla verticillata* and *Najas* species were the dominant submerged species. Among the rooted floating plants, *Nymphoides cristata*, *Nymphoides indica* and *Nymphaea* species were seasonally abundant. The wetland area of the park provided habitat for one of the endangered Cranes of the world, Siberian cranes. This is the only place in India where the Siberian cranes regularly winter (Vijayan, 1991).

Seventy two wetland plants including 14 species of submerged plants and twelve seaweed species have been reported from Chilika lake (Rout and Durani, 1993). They reported that this large-scale diversity has a key role in the food chain of this lake ecosystem. The dominant hydrophytes of the lagoon were *Potamogeton pectinatus*, *Najas minor*, *Hydrilla verticillata*, *Vallisneria spiralis*, *Nymphoides cristata*, *Nymphaea nauchali* and *Halophila ovalis*. Out of this *Potamogeton pectinatus* was found in all the sectors of the lagoon (Bhatta and Pattnaik, 1998). The two dominant submerged plants in Chilika lake were *Potamogeton pectinatus* and *Najas indica*. The estimated weed cover of the above two species were 78 % and 14 % respectively (Patnaik, 1973).

Seshavathram (1990) studied the aquatic macrophytes and their standing biomass in Kolleru lake, Andrapradesh. The *Ipomoea aquatica*, *Ottelia alismoides* and *Nymphoides hydrophylla* were the most dominant species noticed in this lake. Kolleru lake supports the vulnerable bird species, Grey Pelican (*Pelecanus philippinensis*). The lake harbours a variety of resident and migratory birds like Flamingos, Mallards and Grey Pelicans etc.

Species composition of aquatic macrophyte, their succession and phytosociological status in four wetlands of Barak valley, Assam was conducted by Kar and Barbhuiya (2000). Twenty seven aquatic macrophytes were recorded from the wetland, which include five free floating, six rooted floating and three submerged and 13 emergent species. Six aquatic macrophytes species have been found to occur throughout the year.
Biodiversity of wetlands of Darbhanga district, Bihar was studied by Ahmad et al. (2006) and reported 86 species of angiosperms. They observed that on the basis of physicochemical parameters of water and species diversity of angiosperms the wetland was more or less unpolluted.

The wetlands of Kerala are rich in floristic diversity. Despite their fundamental importance to aquatic ecosystems, relatively little research has been directed towards aquatic and wetland plants, especially in riverine environments.

A general survey of the flora of Alapuzha district, Kerala was carried out by Sunil (2000). One thousand one hundred and eleven species of flowering plants belonging to 619 genera and 139 families were recorded from the district. Analysis of the flora showed that 64 species were endemic and about 145 species were rare. A total of 88 wild relatives of cultivated crop plants and 128 important medicinal plants have also been collected from the district.

The only comprehensive aquatic flora survey available in Kerala was conducted by Joseph (2002). The study mainly concentrated on the inland wetlands of Malabar region and described only 241 species of angiosperms belonging to 42 families. Based on the study three groups of aquatic macrophytes were noticed in Kerala. The first group plants growing in running water, second group growing in stagnant water and third group growing in marshy areas.

Sanil and John (2002) studied the aquatic macrophytes of Muriyad wetland, Trichur, Kerala, to assess the ecological effects and role of macrophytes in relation to rice cultivation and fishing. They identified 50 major plants from the study area. Drosera burmanii Linn. was a threatened species reported from this area. Plants like Ipomoea carnea, Salvinia sp. Limnocharis flava, Nymphaea, Nelumbo sp. and Ipomoea aquatica were some of the major weeds noticed in this wetland.

Wetlands support a wide array of flora and fauna and deliver many ecological, climatic and social functions. CED (2003) collected 530 species of higher plants from the major wetlands of Kerala. A total of 725 vascular plants which include 8 pteridophytes and 717 angiosperms coming under 81 families were
recorded from the wetland area. Many wading birds and waterfowl like Egrets, Herons and Cranes nest in wetlands.

Seasonal variation in the biomass of aquatic macrophyte of the aquatic area at Salim Ali Bird sanctuary Thattekad, Kerala was carried out by Seema (2004) and recorded 91 species of plants belonging to 35 families (including shrubs and herbs). Three major plant groups were recorded from the study area. They were free floating macrophyte like \textit{Salvinia} and \textit{Eichhornia}, submerged macrophyte and marshy vegetation. Four floating macrophytes, 9 submerged macrophytes and 42 marshy species were reported from the study area. Family Poaceae was represented with maximum number of species followed by Cyperaceae. Out of the 30 species recorded from the regular sampling station the natural habitat supported 24 species. The dominant species noticed was \textit{Leersia hexandra}. 27 species were recorded from the fragile wetland habitats. \textit{Eleocharis dulcis}, \textit{Leersia hexandra} and \textit{Sacciolepis interrupta} were dominant species recorded from the fragile wetland habitat. The study also shows that submerged macrophytes provides shelter and protection to the water organism. These macrophytes play an important role in increasing the dissolved oxygen content of water (Seema, 2004).

Sunil (2004) studied the flora of Ernakulam district and recorded 253 species of plants coming under 127 genera and 50 families. Monocotyledons dominate with 134 species. Seventeen species were endemic to peninsular India which form 7% of the total plants recorded. 24 species were rare, 22 species were alien weeds, and 19 species were medicinal plants.

Invasive aquatic weeds of the canals, rivers, and slow flowing ecosystems of Kuttanad, Kerala, in relation to paddy fields were reported by Sylas \textit{et al.} (2004). They recorded 29 species of aquatic weeds from Kuttanad wetland ecosystem. The most dominant and widely distributed weeds noticed were \textit{Salvinia molesta}, \textit{Cyperus compressus}, \textit{Eichhornia crassipes}, \textit{Alternanthera philoxeroides} and \textit{Nymphaea pubescens}. These plants were also noticed in the pokkali wetland as dominant vegetation.
An ecological study of the macrophytic vegetation of Pallom region in Kuttanad was conducted by Bindhu et al. (2004) and reported 25 species of aquatic macrophytes. Among these *Nymphaea pubescens*, *Echinochloa stagnina*, *Cyperus compressus*, *Fimbristylis miliacea*, *Salvinia molesta*, *Eichhornia crassipes*, *Alternanthera philoxeroides*, *Ludwigia hyssopifolia* were also noticed in the pokkali field habitat.

Sivaperuman and Sujana (2005) studied the flora of Kole wetlands of Thrissur and recorded thirteen species of aquatic macrophytes in Kole lands. It was noticed that besides all floating vegetation, grasses and sedges acted as microhabitat for fauna of Kole wetland. It was also noticed that the faunal diversity was greater in Kole wetland.

Aquatic macrophyte diversity of Kuttanad wetland ecosystem, Kerala was carried out by Sylas et al. (2006) and reported 129 macrophyte species among which 6 species were pteridophytes belonging 6 genera of 5 families and the rest were angiosperms belonging to 71 genera of 38 families.

Useful macrophytes of the Vembanad Kole Ramsar site, Kerala were reported by Sujana and Sivaperuman (2007). Eighty species of economically important macrophytes including 34 medicinal plant species were reported from the area. All these species were found to be useful for wildlife. The study also indicate that the floral diversity of the wetlands need to be conserved since extreme changes in climatic factors and natural disasters like spate coupled with anthropogenic disturbances tend to affect the biodiversity of the area.

Floristic study in Vembanad ecosystem, Kerala was conducted by Unnikrishnan (2008) and reported 243 hydrophytes and wetland dependent plants under 56 families. There were 23 hydrophytes, 8 mangroves, 12 mangrove associates and 200 wetland dependent plants. Cyperaceae and Poaceae were reported as the most dominant families.

Floristic studies in Ambalamedu – an industrial belt of Ernakulam district, Kerala was carried out by Reshmi et al. (2010) and reported 349 plant species including shrubs, herbs and trees along with 11 endemic and rare species.
noticed that the undisturbed belt of vegetation is a boom to this industrial area not only in contributing to the scenic beauty but also in nurturing a fresh environment. The site selected is a good example of the sustainable development where both nature and technology are merged in order to ensure a healthy environment.

Biodiversity studies in wetland ecosystem of Anachal, North Paravoor, Kerala was conducted by Aiswarya et al. (2010) and reported 32 taxa of plant species belonging to angiosperms and pteridophytes. The study inferred that the area represents unique yet fragile vegetation in the coastal ecosystem of Kerala. This is the abode of multitude of living organisms each with its ecological adaptability.

Riverine flora of Pamba river basin, Kerala was conducted by Joby and George (2010). They reported 410 angiosperms, 3 gymnosperms and 20 pteridophytes from the river basin. Dominant family recorded from the river basin was Poaceae.

Aquatic and semi-aquatic weeds occur in the pokkali fields is plenty during crop season. They get dried and decayed in the off-season, ie during March to May. Fourteen species of aquatic weeds were recorded from the pokkali field by Tomy et al. (1984). The important weeds were *Panicum crusgalli*, *Fimbristylis miliacea*, *Monochoria vaginalis*, *Vallisneria spiralis*, *Nymphaea* species, *Marsilea quadrifoliata*, *Asteracantha longifolia*, *Sphenoclea zeylanica*, *Cyperus difformis*, *Ludwigia octovalvis*, *Salvinia auriculata* and *Eichhornia crassipes* etc.

During the present study 100 species of plants belonging to 52 families were noticed in the pokkali wetland of Ernakulam district. Dicotyledons dominate with 47 families and monocotyledons with five families. Among dicots the dominant families were Fabaceae and Mimosaceae and among monocots dominant families were Araceae and Poaceae. Four members of pteridophytes were also noticed in the pokkali wetland area. Among the total species recorded 22% was composed of wetland macrophytes, 14% of mangrove and associates and 64% was composed of terrestrial plants.

The present study result conducted in pokkali wetland area showed that 25% of flora of the Ernakulam district is represented in the pokkali wetland area. One
rare, one endemic and seven species of alien weeds were represented in the flora of pokkali wetland.

Mangroves are specialized ecosystems developed along seacoast and river mouths in tropical and subtropical regions of the world, mainly in the intertidal zone. Hence the ecosystem and its biological components are under the influence of both marine and fresh water conditions and has developed a set of physiological adaptations to overcome problems of anoxia, salinity and frequent tidal inundations. Mohanan (1997) combined remote sensing data and field observations and reported that the extent of mangrove ecosystem in Kerala is about 4,200 hectare. About 18 species of typical mangrove species belonging to 36 families have already been recorded from Kerala and ten species of true mangrove species were recorded from Kochi area. With regard to fauna in the mangroves Radhakrishnan et al. (2006) studied the fauna of mangroves and recorded 489 species including 122 species of fishes and 196 species of birds.

Studies related to mangrove wetlands are also available. Garrett (2006) noticed that mangroves provide nursery habitat for many wildlife species including fish, crustaceans, molluscs and birds. Jevannel (2010) reported 29 species of birds from the mangrove habitats of South Florida. It was noticed that the floating / diving birds feed on fishes, plant materials and invertebrates. Osprey, Pond Heron and Brahminy Kite feed extensively on the fishes that occur in mangrove. The bird species also roost and nest within the mangrove canopy. The study also suggests that mangrove avian species are part of our ecosystem that needs to be preserved and protected.

Importance of mangrove ecosystem in aquaculture was stressed by Krishnamoorthy and Jayaseelan (1961 and 1984). They suggested that the mangroves provide feeding, breeding ground and shelter for fishes and mangroves act as critical habitats for several marine species of fin fishes and crustaceans during their early growth and when they return to sea for spawning. Vijayakumar et al. (2006) studied the dynamics of mangrove ecosystems and avian migrants at Panangadu estuary, Kadalundy, Kerala and reported 6 species of mangroves in their study site. *Avicennia officinalis* and *Acanthus ilicifolius* were the dominating
mangrove species. It was noticed that mangrove species provide an important meandering ground for a variety of faunal species including transnational migratory birds.

Ten species of true mangroves were reported from Valanthakkadu mangrove ecosystem, Kochin (Aneesh et al. 2008). The true mangroves and mangrove associates serve as feeding, roosting, and breeding grounds for several migratory birds. Similar observations were also noticed in Mangalavanam bird sanctuary, Kochi by Jayson and Sivaperuman (2001).

Thirteen species of mangroves and associates were recorded from the pokkali wetland area during the present study. The shallow waters and exposed mudflats of the mangroves make this habitat ideal for probing by shore line birds. Wading birds also utilized these habitats and deeper waters along the mangroves for different activities. Birds like Herons and Egrets visited mangroves in search of food and habitat.

Hundred species of plants were recorded from the pokkali wetland area during the present study. Among these, thirteen species were observed in the regular sampling sites. Thirteen species were noticed during paddy cultivation period, eleven in transient period and five during prawn culture period. It was noticed that salinity and rainfall were the major factors that control the seasonality of the aquatic vegetation in the pokkali field of Kadamakudy. During the paddy cultivation period (June-October) the availability of freshwater was mostly responsible for the thick growth of aquatic macrophytes. Pokkali fields are allowed to have free exchange of water during transient period (November-December) and as a result saline water enter into the field, which result in the decomposition of aquatic vegetation. During the prawn culture season the paddy field become more saline and this resulted in the reduction of aquatic vegetation.

During the paddy cultivation period (June-October) rainfall and the fresh water intrusion result in the thick growth of aquatic vegetation. Salinity, biochemical factors, rainfall etc were the major factors responsible for the seasonality of aquatic macrophytes in pokkali wetland area. The average soil pH during this period 5.4,
water pH 6.3, dissolved oxygen 2.6 mg/L, salinity 0.4 ppt and water temperature 29°C.

After rice cultivation, pokkali field is allowed to have free exchange of water which resulted in the entry of saline water into the field. Due to the entry of saline water the aquatic vegetation decompose which resulted in change in the physicochemical characteristics of the habitat. The average soil pH was 6.4, water pH was 6.7, dissolved oxygen was 3.6, water temperature was 30°C and salinity was 21ppt. This physiochemical condition of the habitat was favourable for the growth and development of shellfishes.

Thomson (2001) noticed that oxygen values are normally higher during high saline period and decreases during low saline period in Kochin backwaters and dissolved oxygen usually ranged from (0.8 – 5 ml/L). A similar trend was noticed in the present study also.

Kemp et al. (2004) conducted studies of habitat requirements for submerged aquatic vegetation in Chesapeake Bay and pointed out that submerged aquatic vegetation improves water quality by filtering nutrients and contaminants from the water, stabilizing sediments and damping wave action. It also provides food and shelter for waterfowl, fish and shellfish.

Prasad et al. (1989) pointed out that the decay of plant matter led to the considerable change in the water quality of the wetland area of Keoladeo National park, Bharatpur. It was also noticed that the pH, alkalinity and hardness of water changed substantially.

The disintegrating paddy stubbles, internationally left during rice harvest, release nutrients to the system invigorating photosynthetic activity, periphyton production and live feed generation. The live feed thus generated forms the basis of perpetual renewable bio-energetic resources for the alternate production of rice/prawn in pokkali fields (Purushan, 2002).

In the pokkali field it was also noticed that the decaying straw, aquatic vegetation and other products from paddy cultivation makes the land nutritive for prawn culture. Pokkali rice harvesting take place by October end. Only the panicles are cut and the rest of the stalks are left to decay in the water, which in time become feed for the prawns that start arriving in November – December from the sea and the...
backwaters after the rice harvest. Aquatic plants and mangroves in the pokkali provide suitable shelter and breeding place for fishes and aquatic invertebrates.

Marsh plants in the pokkali wetland provide resting site, roosting ground, nest building material to the birds of pokkali wetland. Tubers of *Nymphaea pubescens* formed the main food of Purple Moorhen. Grains and seedlings of *Oryza sativa* was extensively used as food by Purple Moorhen. Alien weeds like *Eichhornia crassipes* and *Salvinia molesta* act as a floating island and this formed a major habitat of Pond Heron and Sand Piper during the transient period. It was also noticed that during the flowering stages and decaying stages of *Eichhornia crassipes* many insects were attracted which resulted in an increase in the number of insectivorous birds in the habitat.

Fredrickson and Reid (1988) pointed out that vegetation is important to waterfowl for providing seeds, tubers and browse providing nest sites and serving as substrate for animal food. The emergent marsh stage with the greatest number and diversity of birds has been called the “hemi marsh” in Columbia.

An interaction has been noticed between waterfowl and aquatic vegetation in Chilika lake (Balachandran and Rahmani, 2005). Birds like Northern Pintail, Northern Shoveler, Eurasian Wigeon, Common Pochard, Red-crested Pochard, Garganey, Common Teal, Spot-billed Duck, Grey Goose, Common Shelduck mostly feed on sealilly species, *Potamogeton pectinatus*. *Cyperus* species was one of the food item of Northern Pintail, Eurasian Wigeon, Common Teal and Spot-billed Ducks and *Hydrilla verticillata* formed the major food item of Cotton Teal, Eurasian Wigeon, Garganey, and Cotton Teal preferred *Nymphaea* species (Balachandran and Rahmani, 2005).

In the present study it was noticed that *Nymphaea* species, seedlings of aquatic plants like *Echinochloa stagnina*, *Diplachne fusca* and pokkali rice were noticed as the main food item of Purple Moorhen (*Porphyrio porphyrio*) during paddy cultivation season in the pokkali wetland.

Wetlands are also important resting sites for migratory birds. Aquatic vegetation is a valuable source of food, especially for waterfowl. In winter, migratory waterfowl search the sediment for nutritious seeds, roots and tubers. Resident waterfowl may feed on different species of aquatic vegetation around (Gopal, 1995).

Sivaperuman and Jayson (2005) noticed that the Kole wetland, at Thrissur, act as a feeding, roosting and breeding ground for many species of migratory and resident birds. It was noticed that aquatic macrophytes acts as indicators of water quality, reduce pollution by acting as nutrient pumps, provide suitable breeding and sheltered place for varied aquatic fauna and support large quantities of epiphytic algae and periphyton. The aquatic macrophytes also function as a source of food in the trophic relationship of wetland ecosystem.

In the present study also it was noticed that pokkali wetland act as a feeding, roosting and breeding ground for resident and migratory birds especially during the prawn culture season. Pokkali wetland supports 119 species of birds including 35 species of migratory ones. Terrestrial plants in the pokkali wetland area provide nest building site, fruits, resting site and roosting area for birds. *Cocos nucifera* in the wetland area was an important nest building site of Baya Weaver bird. Mangroves and associates of pokkali wetland area provided feeding, roosting, resting ground for the birds in the pokkali wetland. Habitat with *Acrostichum aureum* plant was used as a better feeding ground for Grey headed Starling. Twigs of plants like *Diplachne fusca*, *Sphenoclea zeylanica*, *Echinochloa stagnina* were extensively used as nest building material by Purple Moorhen. *Acrostitcum aureum* was used for roosting by Purple Moorhen and Pond Heron in the pokkali wetland. The insect associated with this plant was the main attraction of these birds.
Vijayan et al. (1989) recorded 24 species of aquatic macrophytes from regular sampling stations in Keoladeo national park, Rajasthan with a maximum of only 15 were recorded in a month either in March or November. Monthly variation in the species diversity of aquatic macrophytes occurred both inside and outside the park. The association among plant species was worked out from the biomass data and reported that maximum abundance of aquatic macrophytes was noticed in November 1987 (inside the park) and in September 1988 (outside the park).

During the present study, thirteen species of aquatic macrophytes were recorded from the regular sampling sites. Average diversity of aquatic macrophytes was maximum (1.8) during prawn culture season (January-May) and minimum (1.2) during paddy cultivation season (June-October). It was also noticed that among the various aquatic macrophytes which were noticed regularly in the pokkali habitat seven of them showed significant positive correlation with biochemical parameters. The aquatic plants like *Sphaeranthus africanus* \((r= -0.600, p<0.01)\), *Ludwigia hyssopifolia* \((r= -0.577, p<0.01)\), *Sphenoclea zeylanica* \((r= -0.642, p<0.01)\), *Fimbristylis miliacea* \((r= -0.634, p<0.01)\), *Eleocharis dulcis* \((r= -0.418, p<0.01)\), *Cyperus compressus* \((r= -0.800, p<0.01)\) etc showed close association in the pokkali wetland. All of these species showed a negative significant correlation with salinity.

In the present study it was noticed that shell fish like *Metapenaeus dobsoni* showed association with aquatic plants like *Eichhornia crassipes*, fishes like *Gambusia affinis* with *Salvinia molesta*, *Puntius vittatus* with *Diplachne fusca* and *Echinochloa stagnina*. These shell fishes /fishes were associated with these plants for shelter, feeding and breeding.

Various species of grasses and sedges form the floristic spectrum of pokkali wetland area and have great value of ecological, economical and medicinal importance. Two medicinal climbers, six medicinal weeds, seven terrestrial medicinal trees, two medicinal shrubs and one medicinal grass were also recorded from the habitat (Appendix: VI).
Sustainable development and conservation are important for the survival of the pokkali wetlands and for the maintenance of the delicate balance of life that exists within the special ecosystem. During the study, it was noted that a large number of introduced exotic species become aggressive colonizers and they threaten the habitat of the native species.