CHAPTER I

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Aquaculture is one of the important means of food production to meet the needs of the ever increasing population. The world population, which was 3.9 billion in 1973, has grown to 4.6 billion in 1981 and is predicted to rise to 6.4 billion by 2,000 AD and 8.2 billion by 2,050 AD (Coale, 1974). With a requirement of 8.3 MJ energy and 65 g protein per day per average person (Wheaton, 1977), the world is heading towards a food crisis.

Production of food is mainly from agriculture and fisheries. Though the total potential arable land of the world is estimated to be 7.36 billion hectares, it would not be possible to bring more than 2.5 billion hectares of land under agriculture, the constraints being lack of irrigation, uncultivable months and various socio-economic problems (Revelle, 1974). Animal husbandry also contributes considerably towards food production. As the livestock production is land-based and closely associated with crop production, the problems faced are also akin to that of
agriculture. The increase of human population brings pressure on land availability which renders the fodder cultivation and livestock-farm maintenance more and more difficult, thereby restricting the animal production.

Fisheries, of which the capture fishery is most important, has also its limitation. The world capture fisheries production level of 70 million tonnes per year during 1970-75 could be increased only to 100 million tonnes per year, with all the scientific management of the available resources (Wheaton, 1977). On the contrary, the present total world aquacultural production level of 5 million tonnes per year (Pillay, 1972) could be increased many folds by exploiting the 108 million hectares of potential area available for aquaculture. At present, only 1 million hectares are being utilized for the purpose (Pillay, 1973). Through advanced culture techniques, the unit area production could be further increased. Thus, aquaculture holds the key for more food production to supplement the land-based crop and livestock production and the capture fisheries.

For an Indian pisciculturist, control of excessive growth of aquatic vegetation is one of the crucial problems that confront him in aquaculture, as it drastically reduces the productivity of the cultivable waters by absorbing large quantities of nutrients and restricting the plankton production. 'Aquatic weeds', as they are called, upset the equilibrium and lead to eutrophication of the water bodies in due course. They
also inhabit rivers and traditional fishing grounds, impeding man's access to fish.

Of all the aquatic weeds, the two free-floating macrophytes namely water hyacinth (*Eichhornia* sp.) and water fern (*Salvinia* sp.) are the most troublesome ones. They have an ubiquitous distribution in the tropical and some sub-tropical countries.

The origin of both the weeds were traced to Central or South America, commonly known as Neotropics (Bose, 1945; Evans, 1963; Mitchell, 1979; Gopal and Sharma, 1981; Forno, 1983). Attracted by their fascinating appearance, they were introduced into India as ornamental plants and they lost no time in spreading all over the country (Varshney and Singh, 1973). The first appearance of water hyacinth in the country appears to be in the Bengal region and the time of introduction, somewhere between 1888 and 1896 (McLean, 1922). Today, it is present throughout India, choking all the accessible water bodies.

*Salvinia* appears to have a recent entry into the country. Thomas (1962) has reported the first appearance of the aquatic fern as a weed in Kerala, as late as 1956 and his later report (1977) showed its dominance in many suitable habitats of India. Though wild growths of *Salvinia* have not been reported from northern India (Gopal, 1973), its growth and spread has been alarming in southern India, especially in Kerala.

In Kerala, a small state in India, *Salvinia* (known in vernacular as 'African payal') and water hyacinth have invaded the rivers, canals, open water bodies, back waters, impounded waters like lakes, reservoirs and ponds and even paddy fields (Cook and Gut, 1971; Joshi, 1973; Thomas, 1973; Unni, 1973; Thomas, 1979; 1981) causing considerable problems to fish culture, paddy cultivation, water transport, irrigation, hydroelectric power generation and public health.
Kerala has fairly large inland aquatic resources, with 11 back water bodies arranged all along the length, 40 rivers and about 10,000 hectares of water impoundments (Plate - I) and there is hardly any of these aquatic habitats left untouched by these two weeds.

With two periods of rainfall (South-west monsoon from June to August and North-east monsoon from September to November), Kerala has a typical monsoon climate. The temperature varies from 18°C during the mild winter months of December and January, to 35°C during the humid summer months of March to May. The South-west monsoon produces higher precipitation and the mean annual rainfall is ca. 3,000 mm.

The heavy monsoonic rains falling in the Western Ghats (elevation 1,500 - 2,700 m) situated along the eastern border of the state, flow down westward to the coastal plains before opening into Arabian Sea. This process flushes out the free-floating aquatic weeds from the lotic habitats like rivers into larger water bodies and lentic environments, during monsoons. The periodic opening of the coastal lagoons and estuaries into the sea empties the weeds into the sea as well. With the increase of salinity, the weeds would perish and sink to the bottom (Chandrika et al., 1980). The movement of water helps to distribute the weeds, but the intensity of weed population is drastically reduced in the lotic habitat (Thomas, 1979) and salinity retards their growth in the brackish environments (Divakaran, 1980 a). In the lentic water bodies like ponds...
lakes and reservoirs, they grow unhindered, forming floating masses, accumulating debris, encouraging secondary plant colonizers and ultimately leading to eutrophication, if left unattended.

Different methods have been tried throughout the world to check or eradicate the two most obnoxious aquatic weeds. Ranging from the time consuming, labour intensive manual control measures, to the most safe and effective biological control methods, control of *Salvinia* and water hyacinth has been the focus of attention to many environmentalists and ecologists. Mechanical removal, though cheaper and quicker than the laborious manual control, is invariably incomplete and weeds may quickly replenish. Velu (1973) has described a weed control machine which can clear, squeeze and dump ashore both the floating and submerged weeds, covering at the rate of 1.0 to 1.5 hectare per day. Druijff (1973) has described a chain scythe which could be used as a simple tool for controlling aquatic weeds in irrigation canal.

Successful chemical control methods have been reported using herbicide AF 100 (Julian, 1983), foliar spray of aquous ammonia (Ramachandran and Ramaprabhu, 1973), gramoxone and cheap mineral oils (George, 1973) for the suppression of *Salvinia*. Use of 2,4-dichlorophenoxy acetic acid was reported to be very effective in the control of water hyacinth (Joshi, 1973; Jamil et al., 1983 b; Patnaik and Das, 1983; Ramaprabhu et al., 1983).
Cost of operation, residual toxicity of some chemicals and risks in their handling are some of the discouraging aspects of the chemical control measures. Single application of chemicals is seldom long-lasting. Long-term repeated treatments for the total eradication of aquatic weeds are highly expensive. Therefore, biological control method, which is self-sustaining and long-lasting, has been recommended as the safe and economic alternative (Bennett, 1972; Irving, 1972; Bennett, 1983; Wright and Center, 1983). Many bio-control agents like the duck (Anas platyrhynchos) variety 'Khaki Campbell', semi-aquatic grasshopper (Samara multiplicalis) and the common snail (Pila globosa) were tried against Salvinia (Thomas, 1979). Gopal and Sharma (1981) have enumerated the attempts carried out the world over, on the control of water hyacinth using bio-agents like snail (Maria cornuarietes), turtle (Pseudemys floridana peninsularis), manatee (Trichechus manatus), insects (Acigona infusella, Epipagis albiguttalis, Thrypticus sp. and Gesonula functifrons) and many phytopathogens. A successful allelopathic method using Ottelia was reported by Indra and Krishnamurthy (1983), for the suppression of water hyacinth. Of all the bio-control agents tried for the suppression of the two exotic aquatic weeds, use of the beetle, Cryptobagous singularis against Salvinia (Room et al., 1981) and the weevils Neochetina bruchi and N. eichhorniae against water hyacinth (De Loach, 1976; De Loach and Cordo, 1976; Galbraith, 1983; Anonimous, 1985) only, appears to be the most effective ones.
Total and complete eradication is still a far cry, though its eradication is the ultimate aim, because the valuable water bodies cannot be left unused. But, until such time when a suitable strategy is evolved for its complete control, it is advisable to exploit the weed biomass for any suitable purposes.

While efforts are on for the control of the weed menace, attempts are also made side by side to put the abundantly available weed biomass to as many uses as possible, in view of the global awareness that these efficient converters of solar energy should not be left unutilized. Little (1979) has reviewed the world wide work on the aquatic weed utilization.

Water hyacinth was found useful in the following areas:

(i) biogass production (Deshpande et al., 1979; Abbasi and Nipaney, 1983; Guha et al., 1983; Murty and Thyagarajan, 1983; Omar and Farooq, 1983; Pathe et al., 1983; Pillai et al., 1983; Polisetty et al., 1983 b; Sankies, 1983; Sarkar et al., 1983; Sarma and Rao, 1983; Srivastava et al., 1983).

(ii) compost and manure making (Saha et al., 1951; Dhar and Gupta, 1961; Eva Mitra and Banerjee, 1973; Khandelwal, 1980; Kondap et al., 1981; Haider et al., 1983 b; Venkataraman et al., 1983),
(iii) carbon preparation (Ahmed et al., 1983),

(iv) root extraction as growth promoters
(Chakraverty, 1983),

(v) paint making (Sumathi Vedanayagam et al., 1983),

(vi) mulching for horticultural crops (Abdulla and Hafeez, 1969; Kamal and Little, 1970),

(vii) paper and board making (Ghosh et al., 1983; Majumdar et al., 1983),

(viii) pathogen cleansing of sewage waters (Gilman et al., 1983),

(ix) pollution abatement and effluent treatment
(Rogers and Davis, 1972; Haque and Sharma, 1980; Haider et al., 1983c; John, 1983; Mosse and Chagas, 1983; Nath et al., 1983; Prasad et al., 1983; Reddy and Sutton, 1983),

(x) protein extraction (Dutta et al., 1966; Pirie, 1966; Taylor and Robbins, 1968; Matai, 1973),

(xi) as green fodder for poultry, ducks, pigs and cattle (Brown, 1951; Hora, 1951; Little, 1965b; 1968; Mahmud, 1968; Smetana, 1968; Easley and Shirley, 1974),
cattle feed formulation and as feed supplement (Boyd, 1968; Hentges et al., 1972; Frank, 1973; Bagnall et al., 1974 b; Anonimous, 1981 b; El-Serafy et al., 1981; Reza and Khan, 1981; Kashem et al., 1983; Mudgal and Singh 1983) and

as egg collectors in common carp breeding (Sharma and Rathi, 1974).

However, Salvinia has been found to be useful only in restricted areas: as nutrient absorbent (Awad et al., 1979), mulch for coconut palm (Cocos mucifera), in paper board making (Thomas, 1979) and as biogas supplement (Abbasi and Nipaney, 1983).

These weeds could also be recycled for aquaculture through compost, detritus and formulated feeds for fish. The use of the weeds as fish feed becomes more significant in the light of the fact that the supplementary feed has become an important and necessary input in intensive aquaculture and the formulated fish feed and food organisms have become costlier and difficult to procure or produce.

So, the present study has been undertaken to find out the feasibility of using the two dominant aquatic weeds of Kerala as a supplementary feed in aquaculture. The two weeds, being high in moisture, are not readily consumed directly by the fish. Edwards (1983) had found that fresh water hyacinth was not consumed by fish directly. Same is the case with
Salvinia, which has not been so far tried as feed or feed supplement in any form. So, the weeds had to be bioconverted into an acceptable source of feed, through a simple partial anaerobic process. The optimum inclusion levels of this source material, namely the weed silage, into fish diets, were then estimated through feeding trials.

The biomass production and chemical composition of the weeds had to be estimated, as information on these aspects was also essential before designating the weeds as suitable source of supplementary feed in aquaculture.

The studies have been done from four angles namely (a) the studies on the biomass availability in unpolluted lentic waters, (b) the chemical composition of the two weeds, (c) suitability of a bioconversion process to convert the weed material as a fish feed source material, and (d) the diet formulation and evaluation of such weed diets through feeding trials.

The numerous small ponds, a large lake and a network of backwaters in Kayangulam, situated in Southern Kerala (9°10'N latitude and 72°30'E longitude) (see also map - Plate I), provided an ideal lentic habitat to carry out the investigations on biomass production of the two aquatic weeds.