2. REVIEW OF LITERATURE

2.1. Water Quality Status of Indian Freshwater Systems

Population explosion and rapid pace of industrialization have created an acute problem of disposal of waste materials and the domestic wastes, municipal sewage and industrial effluents by and large are being indiscriminately dumped into the nearby rivers. This has led to pollution hazards to the aquatic environment, leading to the deterioration of the water quality of Indian rivers. Biomonitoring is therefore essential to assess the quality of water of the aquatic system.

Chacko and Sreenivasan (1955) studied the hydro biological characteristics of three major rivers in Madras. Hydrobiology and fisheries of the Ennore river near Madras were investigated by Chacko and Banerjee (1962). Observation on the pollution of Yamuna river at Okhla water works, Delhi were taken by Balani and Sarkar (1965) and it was suggested that the water supplies should be regularly monitored for its free ammonia content which may be useful in fixing the water quality criteria for drinking water supply. George et al. (1966) have pointed out that the wastes of various industries discharged into the river Kali contain a heavy load or organic matter. Ray and David (1966) have studied the effect of industrial wastes and sewage upon the chemical and biological composition and fisheries on the river Ganga at Kanpur. Pollution studies on the river Ganges near Kanpur were also conducted by Saxena et al. (1966) and they found that the
river water was deteriorated due to discharge of industrial effluents and sewage. Sreenivasan and Ray (1967) investigated the effects of certain wastes on water quality and fisheries of river Cauvery and Bhavani. Venkateshwarlu (1969) has studied the status of water quality of the river Moosi in Hyderabad.

A study of the trophic status of Gomti river at Lucknow has been conducted by Arora et al. (1973). In the river Kali near Mansurpur a high load of organic matter was found to influence the oxygen content of the river greatly and changed the water and bottom quality of the river adversely (Verma and Dalela, 1975). Vass et al. (1977) studied the hydro biological features of river Jhelum in Kashmir. Prakash et al. (1978) have carried out biological study of river Jamuna at Agra while Verma et al. (1978) have studied the physicochemical and biological characteristics of Kadarabad drain of Uttar Pradesh. The water quality of sewage drains entering into river Jamuna at Delhi has been studied by Dakshini and Soni (1979) and there were found to influence the water quality. Verma et al. (1980) observed the pollution of Hindon river in relation to fish and fisheries.

Badola and Singh (1981) studied the hydrobiological characteristics of the river Alaknanda of Garhwal Himalaya. The water quality of sewage drains entering the Yamuna at Agra was assessed by Sharma et al. (1981) and it was found that these drains discharged high amount of pollutants in the river causing deterioration of the quality of river water. Agarwal (1982) studied the nutrient level of Chambal river at Kota and Mitra (1982) studied chemical characteristics of a surface water at selected station on the rivers Krishna, Godavari and Tungabhadra. The deterioration of the quality of Chambal river was documented by (Agarwal, 1983). Chandra and Krishna
(1983) studied the impact of tannery waste disposal on the quality of the river Ganges at Kanpur. They have pointed out that quality of water is an immediate hazard for public health. The water quality profile of Vaigai river in Madurai has been determined by Mahadevan and Krishnaswamy (1983). Patil and Patil (1983) have studied the water quality of Ulhas river in Mumbai. Sikander and Tripathi (1983) observed the physicochemical characteristics of Ganga river water at Varanasi. A short term study of pollution status of river Ganga at Kanpur region suggested that the industrial wastes and municipal sewage contribute towards the pollution of the river (Chattopadhya et al., 1984). The water of river Godawari at Named was polluted due to the pouring of sewage and industrial waste (Jagdale et al., 1984). Raina et al. (1984) have found that water in Jhelum requires a continuous monitoring of the river to avoid risk of pollution and to create increased awareness among people so as not to turn the river into open sewer in view of rapid urbanization and increased traffic influx. Potamological studies on lotic environment of river Bhagirathi in Garhwal Himalaya have been carried out by Sharma (1984) while Somashekar (1984) studied the water pollution of the river Cauvery in Karnataka which is being polluted by industrial wastes. Pollution and saprobic status of Eastern Kalinadi was studied by Verma et al. (1984). Ajmal et al. (1985) have also studied the physicochemical aspects of pollution in this river and observed that the same is highly polluted during winter and summer seasons. The environmental impact assessment of the river Ganges at Varanasi suggested that the pouring of untreated city sewage and industrial effluent into the river made it polluted (Chaudhary and Ojha, 1985). Geevarghese and Chandrasekharan (1985) have studied the biological impact of a newsprint factory wastes on Moovattapuzha river ecosystem. Nema and Lal
(1985) have carried out pollutional studies on some river in Madhyapradesh and concluded that this river is polluted in between Chachai and Diyapipal. Sangu and Sharma (1985) studied pollution in Yamuna River at Agra and concluded that the river water has deteriorated over the years.

A study of pollution in the Subarnarekha river due to Aluminium factory discharge at Musi in Bihar was conducted by Mishra et al. (1986). Nautiyal et al. (1986) studied the water quality and assessed portability of Alaknanda river water at Srinagar, Garhwal. They concluded that the town sewage is the major source of pollution in the river. The water characteristics of river Tungabhadra at Kumool and Alampur suggested that the river is subjected to paper mill effluent pollution (Ramesh et al., 1986). Rao and Rao (1986) have observed the pollution in Kshipra river at Ujjain due to pilgrim bathers during the Kumbha fair. The impact of distillery effluents on the water quality and ecosystem of river Reh in Doon valley has been assessed by Shankar et al. (1986). Dora and Roy (1987) investigated the water quality of Subarnarekha river in Bihar and found that the river is not yet grossly polluted. Distributory pattern of dissolved oxygen at the selected station in Cooum river at Madras was found to affect the aquatic fauna (Jebanesan et al., 1987). Lakshmanarao and Narayana Rao (1987) studied pollution of selected river and concluded that there are only few success stories of preserving the quality of streams in India. Mishra and Mishra (1987) studied chromate pollution in the river Jhoomar at Ranchi and discussed the hazardous effect of chromium as chromate. Ajmal and Razi – ud – Din (1988) studied pollution of Hindon river and Kalinadi in Uttar Pradesh while the hydrological profile of Hooghly sector (Ballygunge to Bandel) of river Ganga was studied by Datta et al. (1988). The effect of sewage drain water
on the physico chemical and bacteriological characteristics of river Ganga at Patna was studied by Ghose and Sharma (1988). They have noted that raw sewage and sullage cause a serious pollution problem in the river. Water pollution in Nina river in Andhra Pradesh has been studied by Nandkumar et al. (1988). Pollution of Narmada river and measures to control at Hoshangabad have been studied by Palharya and Malviya (1988). The seasonal rhythm in the physicochemical properties of Nana Kosi river in Kumaun region of Uttar Pradesh has been observed by Pande et al. (1988). And it was suggested that siltation process should be checked for environmental equilibrium. Shah (1988) discussed the physico chemical aspects of pollution of river Jhelum at Kashmir and concluded that the water quality has deteriorated from year to year basis. Sunder (1988) has also monitored the water quality in a stretch of this river at Srinagar. Chavadi and Nalawadi (1989) have done the hydro environmental impact assessment of Kali river system in Karnataka. Singh and Singh (1990) have found that urbanization and rapid industrialization have deteriorated the water quality and are the main causes of pollution of river Subamarekha.

Mishra (1990) studied the hydrobiological characteristics of Morar river in relation to plankton and productivity and noticed that river is polluted by domestic sewage, municipal sewage and other discharges along its course in the city Gwalior. The distribution of algal flora in polluted regions of Karwan river at Agra has been studied by Mittal and Sengar (1991) and observed that several species showed interesting pattern of succession in relation to pollution load. Unni et al. (1992) have documented the physicochemical and biological characteristics of river Narmada from Amarkantak to Jabalpur. BOD and COD values indicate that the river is not under heavy
pollution stress. The impact of industrial effluents discharged into the river Tamirabarani, on the fishes have been investigated by Murugesan and Haniffa (1992). Krishnan et al. (1994) have studied the contamination of faecal coliforms in the river Vaigai. Water quality profile of the streams—Seonath, Jonk and Hasdeo, tributaries of Mahanadi has been documented by Mitra (1995).

Ram Karan Singh and Anandh (1996) have documented the water quality index of some Indian rivers. Impact of sewage and industrial pollution on physico-chemical characteristics of water in river Betwa at Vidisha, Madhya Pradesh has been observed by Mishra (1996). Singh and Mahaver (1997) have studied the role of heavy metals in river pollution and found that the pollutional load of river Ganga and river Gomti were maximum in respect to Zinc, Arsenic and Chromium, while the physico-chemical characteristics of river Ganga near Patna were observed by Singh (1997). He noticed that most of the stretches of river are the discharge sites of domestic sewage. As a result of which river quality are being deteriorated day by day. Doctor et al. (1998) have studied the physico-chemical and microbial characteristics of dye-contaminated water of river Bhadar. Studies have been conducted by Jain et al. (1998) to assess the effect of waste disposals on the water quality of River Kali. Sivasubramani (1999) have studied the physico-chemical, microbiological, and hydrological characteristics of river Periyar in Tamilnadu. Sujatha et al. (2001) have made an assessment of the microbial pollution in major rivers of Tamil Nadu. Garg (2002) has assessed the seasonal fluctuations of the physical and chemical parameters of river Mandakini, Chitrakoot. Martin and Haniffa (2002) have correlated the quality of water of river Tamirabarani to abundance of phytoplankton population. An
attempt has made by Aditya Tyagi et al. (2003) to study the spatial and
temporal water quality trends of one of the pristine river Kshripa (Madhya
Pradesh) using water quality index. Anil Prasad and Jaswant (2003) have
investigated the effect of paper mill discharge on the water quality of river
Ami. The physicochemical and microbiological analysis of the river Tapi has
been made by Patil et al. (2003). Physico-chemical and biological
parameters have been assessed to study the status of river Umshyrpi at
Shillong (Rajurkar et al. 2003). Ravichandran (2003) has assessed the
hydrological influence on the water quality variables of river Tamiraparani.
Singh and Rai (2003) have investigated on the pollution status of river
Yamuna with reference to their physical, chemical and biological
characteristics. Water quality of river Ambarampalayam has been studied for
physical qualities, along with studying the nutrient content of the river
(Sivakumar et al., 2003). Manvir Singh and Gupta (2004) have assessed the
physicochemical quality of water in river Yamuna at Mathura. Nandan et al.
(2004) have investigated on the water pollution of river Mausam.

2.2. Growth of Water Hyacinth

Increased growth in sewage has been reported in several studies
(Wakefield and Beck, 1962; Center and Balciunas, 1976). Scarsbrook and
Davis (1970) observed good growth in 25 % sewage and it was associated
with uptake of large quantities of nutrients. Haller et al. ((1970) reported that
the critical level of phosphorus for growth is 0.1 ppm though luxury
consumption occurs at higher concentration. Phosphorus concentrations
higher than 40 ppm were toxic to water hyacinth (Haller and Sutton, 1973).
At the higher phosphorus concentrations, the neutralization of phosphoric
acid with sodium hydroxide resulted in solutions with salinities toxic to water
hyacinth (Boyd and Blackburn, 1970). Haller and Sutton (1973) have studied the effects of pH and phosphorus concentrations on growth of water hyacinth and found these parameters to influence water hyacinth growth. Excess of nutrients absorbed from the medium are usually leached out of the stem and roots within six days. Widyanto (1976) has observed a direct correlation between the dry weight and leaf number and phosphorus medium. Tag et al. (1978) has determined the effect of pH on the growth of water hyacinth. Center and Spencer (1981) has worked on the phenology and growth of water hyacinth in a eutrophic lake in North Central Florida. The rate of proliferation and biomass allocation patterns during water hyacinth mat development has been extensively studied by Madsen (1993). Gutierrez et al. (1996) has studied the reproductive biology of aquatic weed, water hyacinth, forming extensive mats in aquatic ecosystems.

Studies have been conducted on assessing the population dynamics of water hyacinth by modeling water hyacinth biomass (Wilson et al., 2001). *E. crassipes* and *P. stratiotes* showed low relative growth rates when cultured in lower concentration of nitrogen and phosphorus that probably limited the growth of these species (Henry-Silva et al., 2002). A comparison of the effects of nutrient concentrations on the growth of water hyacinth, water lettuce and water fern has been made by Henry-Silva et al. (2002). Comparison of *E. crassipes* traits between vegetation communities has shown that this species is likely to be responding to varying environmental and plant interaction conditions by showing plasticity in its leaf morphology (Milne et al., 2002). Morphological variations in *Eichhornia azurea* and *Eichhornia crassipes* has been extensively worked into (Milne et al., 2002). Alves et al. (2003) have evaluated the effect of excessive nutrient levels on
the physiology and biochemical characteristics of water hyacinth. Rinku Verma et al. (2003) have assessed the growth and water hyacinth coverage in relation to nutrients in aquatic systems in Bangalore city.

2.3. Biological Control of Water Hyacinth across the world

Biological control of water hyacinth is destined to become one of the landmark examples of successful control of an exotic weed by reassociation with its natural enemies. Water hyacinth is attacked by arthropods including insects and mite and fungi. In all biocontrol programmes decrease in size and density of water hyacinth closely followed build up of weevil population (Del Fosse, 1978). According to Wright (1979) high levels of control have been achieved using biocontrol agents at many infestations in tropical regions. Center (1980) has worked on the biological control and its effects on production and survival of water hyacinth leaves. Wright (1983) reported that reduction in the nutrient input in the water system reduces the nutrient content of the water hyacinth and this in turn reduces the populations of *N. eichhorniae*. Observations on the effect of the weevils *Neochetina eichhorniae* Warner and *Neochetina bruchi* Hustache on the growth of water hyacinth has been made by Bashir *et al.* (1984). It was reported that *N. eichhorniae* affected reduction in water hyacinth height, density and biomass at test sites and was a major factor contributing to reduction in water hyacinth coverage in Louisiana (Cofrancesco *et al.*, 1985). Center (1985) has worked out the leaf life tables for assessing sublethal effects of herbivory on water hyacinth stress. Charudattan (1986) has peered into the integrated control of water hyacinth with a pathogen, insects and herbicides and found to be an effective strategy. Many researchers and aquatic plant managers view use of the biocontrol agent *N. eichhorniae* as an effective...
alternative to more traditional methods of water hyacinth management including chemical applications (Grodowitz and Freedman, 1989). Room (1990) stated that a positive implication for biological control is natural enemy populations, which may proliferate because of higher quality host plants. Harley (1990) reported that higher level of control of water hyacinth has been achieved in the USA and Sudan where both species of Neochetina weevils have been established, than in countries where only one species is established.

Studies had been initiated on the biological control of water hyacinth using Neochetina eichhorniae in South Africa and the weevil showed effect on the water hyacinth populations (Cilliers, 1991). Grodowitz et al. (1991) have assessed population dynamics of water hyacinth and the biocontrol agent N. eichhorniae at a South East Texas location. Center and Dray (1992) have investigated the associations between water hyacinth weevils and water hyacinth and concluded that weevils affected the phenological stages of Eichhornia crassipes in Florida. The problem of water hyacinth in Nigeria and its control strategies have been reported by Epelle and Farri (1993). Center (1994) has reviewed on the biological control of weeds, especially water hyacinth and water lettuce. Gutierrez et al. (1996) have compared the various control strategies for the management of water hyacinth and found biological control to be the most efficient and long term one. Bartodzief and Leslie (1998) have assessed efficiency of the water hyacinth weevils, and have documented them to be potential agents for biological control of water hyacinth in Florida. Center et al. (1999) have made a comparison between herbicidal and biological control of water hyacinth and concluded that an integrated strategy could be the better option. Ding et al.
(1999) has worked on the integrated management of water hyacinth with *Neochetina eichhorniae* and herbicide. Various authors have suggested biological control to be an important strategy for weed and pest management (Cory and Myers, 2000; Follett and Duan, 2000; Messing, 2000). Center *et al.* (2001) has worked on the use of competitive experiments to evaluate the efficiency of new water hyacinth biocontrol agents and compared their efficiency with arthropodan agents. A holistic approach of weed management employing the chemical, mechanical and biological means have been carried out to manage water hyacinth in Zimbabwe and control has been achieved (Chikwenhere, 2001). Ding *et al.* (2001a and 2001b) has investigated the efficiency of *Neochetina eichhorniae* in control of water hyacinth in China and found reduction in the density of water hyacinth by 50 % of coverage of the water surface. Fayad *et al.* (2001) have documented the use of arthropodan agents for combating the problem of water hyacinth in Egypt. Successful bio-control of water hyacinth in South Africa has occurred when the weevils became established and reduced the weed mat cover to less than 10% of weed coverage. The remaining plants in the dam were also very small (Hill and Olckers, 2001). Julien (2001) has made a review of various arthropods employed for biological control of water hyacinth and suggested that biological control was the apt tool to tackle water hyacinth problem. Rwanda has implemented efforts to rear and release the two Neochetina weevil species as biological control agents (Moorhouse *et al.*, 2001). Establishment and spread of *Neochetina* population and their impact on the water hyacinth plants in lake Victoria, Kenya have been observed by Ochiel *et al.* (2001). Spread of weevil after resurgence of water hyacinth in Lake Victoria was observed by Ogwang (2001). He reported that the weevil established immediately after the weed
emerged once again. Lewis (2002) has reviewed the spread of water hyacinth in Thailand and the measures undertaken to combat their proliferation. The comparative cost of water hyacinth control strategies on South Africa have been worked out by Van Wyk and Van Wilgen (2002) and found to be very cheaper when compared with others. Mwiinga et al. (2002) has studied the impact of *N. eichhorniae, N. bruchi* and *O. terebrantis* in lake Kariba in Africa. A pioneering study was made on the socioeconomic impact of water hyacinth and its biocontrol (De Groote et al., 2003). They stated that water hyacinth caused economic and social problems and biocontrol proved to be cheaper. Mc Fayden et al. (2003) have worked the cost of biological control of water hyacinth. Reports have been documented on the invasion of the noxious aquatic weed, water hyacinth and management of the weed in Portugal (Monteiro et al., 2003). Rachel and McFadyen (2004) have assessed the post – release impact of biocontrol agents and found that biocontrol agents greatly affected plants and reduced their proliferation.

2.4. Biological Control of Water Hyacinth in India

In India a study had been carried out to survey the natural enemies of the aquatic weed *Eichhornia crassipes* and to determine if these natural enemies could be suitable candidates for biological control (Kaiser Jamil et al., 1982). Jayanth (1987) reported that *N. eichhorniae* was a suitable candidate for suppressing the growth of water hyacinth. Reports show that *N. bruchi* is an effective biological control agent of water hyacinth and has the potential to suppress the weed through out India (Jayanth, 1988). Mishra et al. (1992) reported that the exotic weevils, *Neochetina eichhorniae* and *N. bruchi* have eliminated the weed in a reservoir in North India. A biological control trial was conducted in Nacharam tank in Hyderabad, where adult
weevils and all the developing stages of the weevils were released. Both the species of *Neochetina* severely stressed water hyacinth and caused the plants to die keeping the tank free of this weed (Meera Gupta *et al.*, 1993). Jayanth (2000) reported that control of water hyacinth by release of weevils has brought about a permanent solution to weed problem in Manipur. The compatibility among the two water hyacinth weevil species and the mite and its implication in biological control of water hyacinth has been investigated by Ganga Visalakshy (2001). Murugesan *et al.* (2002d) have made a review of the biocontrol agents of water hyacinth and suggested biological control to be an ideal strategy to combat the weed problem. A preliminary attempt has been made by Praveena *et al.* (2002) to study the integrated effect of fungi and mite in the management of water hyacinth and found them to be effective. The potentiality of *Alternaria alternata* as a biocontrol agent to control water hyacinth and other aquatic weeds have been studied by Mohan Babu *et al.* (2003). Naseema *et al.* (2004) have documented that *Fusarium pallidoroseum*, a wilt-inducing pathogen isolated from water hyacinth could resist the multiplication and cause reduction in the proliferation of the weed.

### 2.5. Biocontrol agents

#### 2.5.1. Water Hyacinth Weevils

Perkins (1974) stated that adult feeding at the junction of petiole and leaf blade kills the blade and eliminates the leaf completely. De Loach and Cordo (1976) have made a comparison of the biology of *N. bruchi* and *N. eichhorniae*, stating that the two weevil species differ slightly in their ecological niche. *N. eichhorniae* seems not to exceed the carrying capacity
of its resource and maintains a fairly stable, persistent population (Center, 1980). The effects of *N. eichhorniae* on the growth of water hyacinth have been studied by Forno (1981). He reported that *N. eichhorniae* reduced the growth rate and reproduction of water hyacinth. Wright and Center (1982) reported a direct relationship between number of feeding scars on water hyacinth leaves and the adult weevil population size. Higher feeding intensity was observed with low weevil stocking rates. The efficiency of *N. bruchi* in checking the growth of the plant has been investigated by Bashir *et al.* (1984). He reported that *N. bruchi* is more efficient in checking the growth of water hyacinth. Buckingham and Pasova (1985) have studied the flight muscle and egg development in water hyacinth weevils. Cofrancesco *et al.* (1985) have studied the feeding behaviour of the water hyacinth weevils and found that larvae feed on meristematic tissue in the plant crown. The larvae and adult injury patterns of the weevils have been explored by Center (1985). The effect of insect damage on leaf death and production of smaller leaves have been studied by Center (1987). Laboratory studies have been carried out to study the fecundity and longevity of *Neochetina eichhorniae* and *N. bruchi* and found that *N. bruchi* produced more eggs than *N. eichhorniae* (Jayanth, 1987). The host specificity of *Orthogalumna terebrantis* Wallwork has been tested under quarantine and it was found that only water hyacinth was attacked, as evidenced by gallery formation on leaves (Jayanth and Nagarkatti, 1988). Studies on drought tolerance in water hyacinth weevils have been carried by Jayanth and Visalakshy (1990). They stated that adult *N. eichhorniae* and *N. bruchi* could survive for up to 24 – 48 days. Bartodzej and Leslie (1998) have worked on the correlation of weevil population and feeding damage on water hyacinth plants. The effects of chemical herbicides on *N. eichhorniae* have been investigated by Ding *et al.*
(1998). Ding et al. (2002) have studied the biology and host range of *Neochetina* and found the weevil safe for release. Wang and Ding (2002) have studied the effect of water hyacinth leaf age on *Neochetina bruchi*. The feeding of water hyacinth weevils in relation to size, plant biomass and biochemical factors have been assessed by Moran (2003).

2.5.2. Water Hyacinth Mite

The oviposition of mite with effect to release of a kairomone from water hyacinth tissue has been investigated by Del Fosse and Perkins (1977). He stated that *Neochetina* oviposit more in the presence of mite. Del Fosse (1978) has studied the combined effect of *Neochetina eichhorniae* and *Orthogalumna terebrantis* on water hyacinth and found that the mite increases the fecundity of weevils. Harley (1990) reported that extensive wounding of plants by mite might render them vulnerable to infection by pathogens. Ganga Visalakshy and Jayanth (1991) have studied the life history of *Orthogalumna terebrantis*. Cordo (1996) suggests that *O. terebrantis* is a promising agent for management of water hyacinth. Julien and Griffiths consider the mite to be a potential biocontrol agent for water hyacinth. Cordo (2001) documents the efficiency of *O. terebrantis* as a potential agent for integrated control of water hyacinth. Hag and Sumangala (2003) have compared the efficiency of acarine mites, *O. terebrantis* and *O. biharensis* in damaging water hyacinth. Integration of *O. terebrantis* along with *N. bruchi* and *N. eichhorniae* has brought promising results in Kenya. The species has established well and brought damage to plants in parts of water body (Kusewa, 2004).
2.5.3. Snail

Snails have been studied in connection with control of aquatic weeds (Blackburn and Andres, 1968; Blackburn et al., 1971). A survey has been conducted on the molluscs associated with water hyacinth (Sabitha Akhtar, 1978). *Pomacea canaliculata* has been suggested as a possible agent for general aquatic weed control in its native Argentina (Cazzaniga, 1981). Ampullarid snails such as *Marisa cornuarietis* have been used or suggested for control of aquatic weeds (Home et al., 1992). *Pomacea glauca* has been used in the Caribbean for control of some aquatic weeds (Perara and Walls, 1996). *Pomacea canaliculata* has been suggested as a possible agent for biological control in Japan, where it is introduced (Okuma et al., 1994; Wada, 1997). Cowie (2001) has made a review on the effectiveness of snails as biocontrol agents.

2.5.4. Grass carp

Several phytophagous fish species have been considered as bio-control agents for aquatic weeds. In practice, however only one species, the grass carp, (*Ctenopharyngodon idella*) is used on a large scale as a biocontrol agent. Almost all states in India have the problem of aquatic weeds. Alikunhi and Sukumaran (1964) studied the importance of fishes in controlling aquatic weeds in India. In Eastern Europe the potential for aquatic weed control played a role in encouraging the culture of grasscarp (Krupauer, 1971; Nikolskiy and Aliyev, 1974; Yefimova and Nikanorov, 1977; Opuszynski, 1979; Negonovskaya, 1980; Charyev, 1984). The introduction of grass carp into the west was mainly for weed control purposes (Leventer, 1981; Markman, 1984; Fowler, 1985). In Africa grasscarp were introduced
both for the production of food and the control of aquatic weeds (Pieterse, 1979; Dubbers et al., 1981; George, 1982; Schoonbee et al., 1985; Abdusamadov, 1986). Many studies have focused on grass carp for controlling submerged weeds and water hyacinth and trials have been carried out in almost all Asian countries (Ahmad, 1968; Pheang and Muchsin, 1975; Van Zon, 1981). Reichert and Trede (1977) have conducted preliminary experiments on the utilization of water hyacinth by grass carp. Chinese grass carp has been tested for the control of various species of floating, submerged and emergent weeds in various parts of Japan and found to be very effective (Okuma et al., 1984). Catarino et al. (1997) have studied the preferences of grass carp for macrophytes, especially water hyacinth and parrot feather in the Iberian drainage channels. Pipalova (2003) has investigated on the efficiency of Ctenopharyngodon idella in controlling duckweed proliferation. Wellset al. (2003) documents the control of macrophytes by grass carp.

2.5.5. Grasshopper

In the United States, the grasshopper Paroxya clavuliger (Serville) (Acrididae) occasionally causes severe defoliation of water hyacinth (Gordon and Coulson, 1971). The grasshopper genus Cornops (Acrididae) includes a number of species specifically associated with Eichhornia sp. The damage caused by Cornops species to water hyacinth is easy to recognize (Perkins, 1974). Work has been carried out on the water hyacinth grasshopper, Cornops aquaticum to determine if it is sufficiently host specific for introduction as a control agent against water hyacinth (Guido and Perkins, 1975). Current studies have identified a number of species within the group, one or more apparently specific to water hyacinth (Cordo, 1999).