Figure 2. Countries where water hyacinth is a weed and where *Neochetina* spp. have been released

2.3 Habitat

Optimum growth of water hyacinth occurs in eutrophic, still or slow-moving fresh water with a pH of 7, a temperature range between 28° and 30°C, and abundant nitrogen, phosphorus and potassium (Chadwick and Obeid 1966; Knipling et al. 1970; Reddy et al. 1989, 1990, 1991). Plants will, however, tolerate a wide range of growth conditions and climatic extremes. Good growth can continue at temperatures ranging from 22° to 35°C and plants will survive frosting (Wright and Purcell 1995). Although prolonged cold weather may kill plants, the seeds remain viable (Ueki and Oki 1979). Plants can infest pristine, relatively low nutrient waterways (Hitchcock et al. 1949) and will survive for several months in low-moisture substrates. They will tolerate acidic waters but cannot survive in salt or brackish water (Penfound and Earle 1948).

2.4 Impact

In its native range water hyacinth is largely restricted to coastal lowlands and along the margins of lagoons and slow-moving waters. It occurs at relatively low densities, only becoming a problem where the hydrological regime of a water body has been altered by human activities, or where the level of nutrients in the water has been increased.

Within its introduced range, however, the species has enormous social, economic and environmental impacts, earning this plant the title 'world's worst aquatic weed' (Holm et al. 1977). Water hyacinth forms dense, impenetrable mats which cover the water surface. Water bodies which are worst affected are still or slow-moving, and include natural water courses, natural and artificial lakes, irrigation and flood mitigation channels, and dams. The presence of water hyacinth limits access to and use of water by man, animals and birds. The weed chokes intake points for water treatment and supply, and for hydroelectric and other industrial requirements. Navigation is obstructed and irrigation systems become blocked (Harley 1990; Harley et al. 1996). Fishing is often limited or prevented, and the germination and establishment of paddy rice seedlings can be affected. The presence of the weed provides suitable breeding sites for vectors of human and animal diseases, increasing the incidence of diseases such as malaria, encephalitis, schistosomiasis, filariasis, river blindness and possibly cholera (Burton 1960; Seabrook 1962; Spira et al. 1981; Gopal 1987; Viswam et al. 1989). The weed mats also create a habitat attractive to venomous snakes.

The presence of water hyacinth has a direct impact on the hydrological balance of a system. Water hyacinth loses water rapidly through its leaves. This can increase dramatically the rate of water loss from a water body, imposing higher operational costs on water supply schemes (Benton et al. 1978) and threatening their viability in arid regions. During floods, water hyacinth can build up against bridges, culverts, fences etc., thereby obstructing water flow and increasing flood levels, and contributing to loss of life and livestock, damage to property and equipment, and serious soil erosion (Harley 1990).

Extensive mats of water hyacinth also change the physical and chemical composition of the water beneath (Ultsch 1973; Reddy et al. 1983; Aneja and Singh 1992). Light penetration is reduced and oxygen levels decline, resulting in anaerobic conditions. This leads to biological changes in the water body that are unfavourable to communities of aquatic vertebrates, invertebrates and plants (Timmer and Weldon 1967; Ultsch 1973; Willoughby et al. 1993).

2.5 Utilisation

The sheer biomass of plant material in water hyacinth infestations has prompted investigation of various schemes for its utilisation (Monsad 1979; Wolverton and McDonald 1979; see papers in Thyagarajan 1984). Schemes suggested include using the weed:

- as an animal fodder, fertiliser, compost or source of fuel;
- in the manufacture of paper, board, handicraft and furniture;
- in the treatment of waste water; and
- in the management of water quality.

Water hyacinth has limited potential for use in any such programs, and its utilisation is never likely to provide a viable method for controlling or managing the weed. With the exception of small-scale specialist or cottage industries, harvesting for commercial use is unlikely to be viable, because of the complications and high costs associated with accessing and harvesting from infested areas, transporting the plants, and drying, processing and marketing the material. Water hyacinth is 95% water (Harley 1990), making collection costs extremely high for only a 5% dry matter return. The possible advantages of utilising water hyacinth are far outweighed by the enormous problems this weed causes throughout its introduced range. Attempts to control the weed should not therefore be compromised by any consideration of its potential use (Julien et al. 1996).

Chapter 3
Management of Water Hyacinth

The complete removal of water hyacinth is impossible for most areas. Where 'eradication' of an infestation has occurred the effects are usually short-term. The difficulties in achieving effective eradication stem from the ease with which reinfestation can occur in all but small and isolated water bodies, and the subsequent rapid growth and spread of the weed. Plants and/or seeds are readily transported by currents, boats, fishing nets and possibly animals and birds, and only one or a few plants can result in a new infestation. The seeds are long-lived and germination can continue for up to 20 years (see Section 2.1). The aim of any control program is therefore to manage, rather than eradicate, this weed species. In many situations, management extends only to maintaining open water around critical sites, for example village watering points, navigation channels and intake points for water supply, water treatment or hydroelectricity.

Photo: A. Wright

Removal of water hyacinth by hand near Klong Krea Irrigation Project, Thailand

Photo: M. Julien

Mechanical harvester at Port Bell, Uganda

Control methods fall into three main categories: physical, chemical and biological. The application of these methods is not mutually exclusive and 'best practice' is to formulate a management strategy incorporating some or all of these methods, but with reliance on biological control as the most significant component or the long term objective (Harley et al. 1996; Julien et al. 1996). Integration of control measures is discussed further in Section 8.2.

3.1 Physical

Physical removal is historically the most widely used form of control. For the poorer rural communities to whom water hyacinth is so often a threat, removal by hand pulling is often the only available option; an extremely laborious process. In many areas, mechanical

Photo: C. Cilliers

Aerial spraying with herbicide—South Africa

harvesters have been developed which speed the physical removal of water hyacinth. A few of these have been effective in particular situations, but most have been abandoned as ineffective and/or too expensive to operate. Floating booms and barriers are used to maintain areas free of weed and to reduce the downstream spread of an infestation. Plants accumulate rapidly against the booms and must be removed frequently, either physically or by herbicide spraying. Draining a water body will lead to the death of water hyacinth plants, but seeds usually germinate when water is reintroduced.

Photo: A. Wright

Mechanical harvester operating near Bangkok, Thailand

Photo: C. Cilliers

Removal of water hyacinth by hand near Vaal River, South Africa

The rate of growth and invasion by water hyacinth usually exceeds the rate at which it can be cleared. Reinfestation from plant fragments and/or seeds generally occurs rapidly and the process of removal must be repeated continuously. The material removed from the water should be transported away from the site and disposed of appropriately. Physical removal is useful only on small infestations, in delaying the resurgence of the weed following chemical control, and in situations such as ports, hydroelectricity plants, fish landings etc. where the high labour and/or monetary costs can be justified.

3.2 Chemical

Treatment with herbicides has been effective in controlling small infestations of water hyacinth, and infestations in areas climatically unfavourable to the growth of the weed. The herbicides most commonly used are diquat, glyphosate, amitrole, and the amine and acid formulations of 2,4-D, applied as foliar sprays. The application of these compounds requires skilled operators, strict spray regimes, long-term vigilance and frequent reapplication to provide effective, long-term control over the weed and any regrowth. In most situations, chemical control is unacceptably costly in terms of chemicals, equipment, labour and environmental impact. The problem of chemical sprays is compounded by the use of many water hyacinth-infested sites for obtaining drinking water, for washing and for fishing. The costs associated with herbicide application generally limit the applicability of chemical control to an emergency control measure at critical sites rather than for maintenance control over large infestations.

3.3 Biological

In its native range water hyacinth is attacked by a complex of arthropods. Study of the life history and ecology of some of these began in Argentina in 1961 (Center 1994). Research has shown that some are unable to survive on any plant other than water hyacinth, while others may also survive on some very closely related plant species. The first natural enemies were released as control agents in the USA in the early 1970s (Perkins 1973) and to date seven agents have been released in 33 countries (Julien and Griffiths 1998) (Table 1, Figures 5 and 6).

One or more natural enemies have established in most of the countries in which they have been released, and their impact on water hyacinth has been significant in some areas.

The two *Neochetina* species are the most widely distributed of the water hyacinth biological control agents, and to date are the most successful. This dossier discusses the biology, impact, host range and use of these agents.

Table 1. Biological control agents released against water hyacinth worldwide

Agent	Type of damage	Countries where released
Insects		
Coleoptera		
Curculionidae		
Neochetina bruchi Hustache	Adults feed on foliage and petioles, larvae tunnel in petioles and crown	see Figure 5
Neochetina eichhorniae Warner	Adults feed on foliage and petioles, larvae tunnel in petioles and crown	see Figure 6
Lepidoptera		
Pyralidae		
Niphograpta albiguttalis Warren (=*Sameodes albiguttalis* (Warren)	Larvae tunnel in petioles and buds	Australia Benin Ghana Malawi Malaysia Panama Papua New Guinea R. South Africa Sudan Thailand USA Zambia Zimbabwe
Pyralidae		
Xubida infusella (Walker) (=*Acigona infusella* Walker)	Larvae tunnel in petioles and buds	Australia Thailand Papua New Guinea
Hemiptera		
Miridae		
Eccritotarsus catarinensis (Carvalho)	Adults and nymphs suck cellular or intercellular fluid from leaves	Malawi R. South Africa Zambia
Mites		
Acarina		
Galumnidae		
Orthogalumna terebrantis Wallwork	Immatures tunnel in laminae	India Malawi R. South Africa Zambia
Fungi		
Hyphomycetes		
Cercospora rodmanii Conway	Punctate spotting and chlorosis of laminae and petioles; necrosis of laminae	R. South Africa

References: Julien and Griffiths (1998), M. Hill, pers. comm.

Chapter 4
The Water Hyacinth Weevils

The genus *Neochetina* is considered to have six species, all of South American origin and all restricted in their feeding to the family Pontederiaceae. The two *Neochetina* species in use as biological control agents are *N. bruchi*, the chevroned water hyacinth weevil, and *N. eichhorniae*, the water hyacinth weevil. A generalised life-cycle of the weevils is shown in Figure 3. The development durations of the different life stages and average fecundities are detailed in Table 2. The following descriptions of the biology and life histories of the weevils are summarised from DeLoach and Cordo (1976), Center (1982, 1994), Jayanth (1987), Harley (1990), and Ogwang and Molo (1997).

4.1 *Neochetina bruchi*

Egg: Eggs are whitish, ovoid and measure 0.8 mm × 0.6 mm. They are laid singly or in groups of up to 25, usually deposited in the 2nd or 3rd layer of aerenchymatous cells in the middle third of the petiole, particularly on older leaves. Eggs are often laid in holes chewed by the female or in small necrotic spots. Eggs fail to hatch below 15°C.

Larva: Larvae are uniformly white with a light-brown head capsule. There are three larval instars. Newly hatched larvae tunnel towards the bases of petioles and into the crowns where they excavate small pockets. From this location larvae often feed on developing axillary buds. Larvae usually occur singly, but occasionally their tunnels become joined and 2 or 3 larvae occur together. As the plant grows, leaves containing feeding larvae are displaced towards the outer edge of the rosette. Consequently, older instar larvae often occur in the older leaves from where they sometimes migrate back into the younger leaves. The impact of feeding on these youngest leaves is particularly severe.

Pupa: Fully grown larvae exit the crown and move down to the roots to pupate under water. They construct a dark, circular cocoon about 2 mm diameter using excised root hairs and attach this to one of the larger roots. A period of dormancy has been reported from South Africa where fully-formed adults remain within the pupal cocoon for several months (M. Hill, pers. comm.).

Photo: A. White

Leaf feeding scars caused by *Neochetina* adults

Figure 3. Generalised life cycle of the *Neochetina* weevils and durations of developmental stages

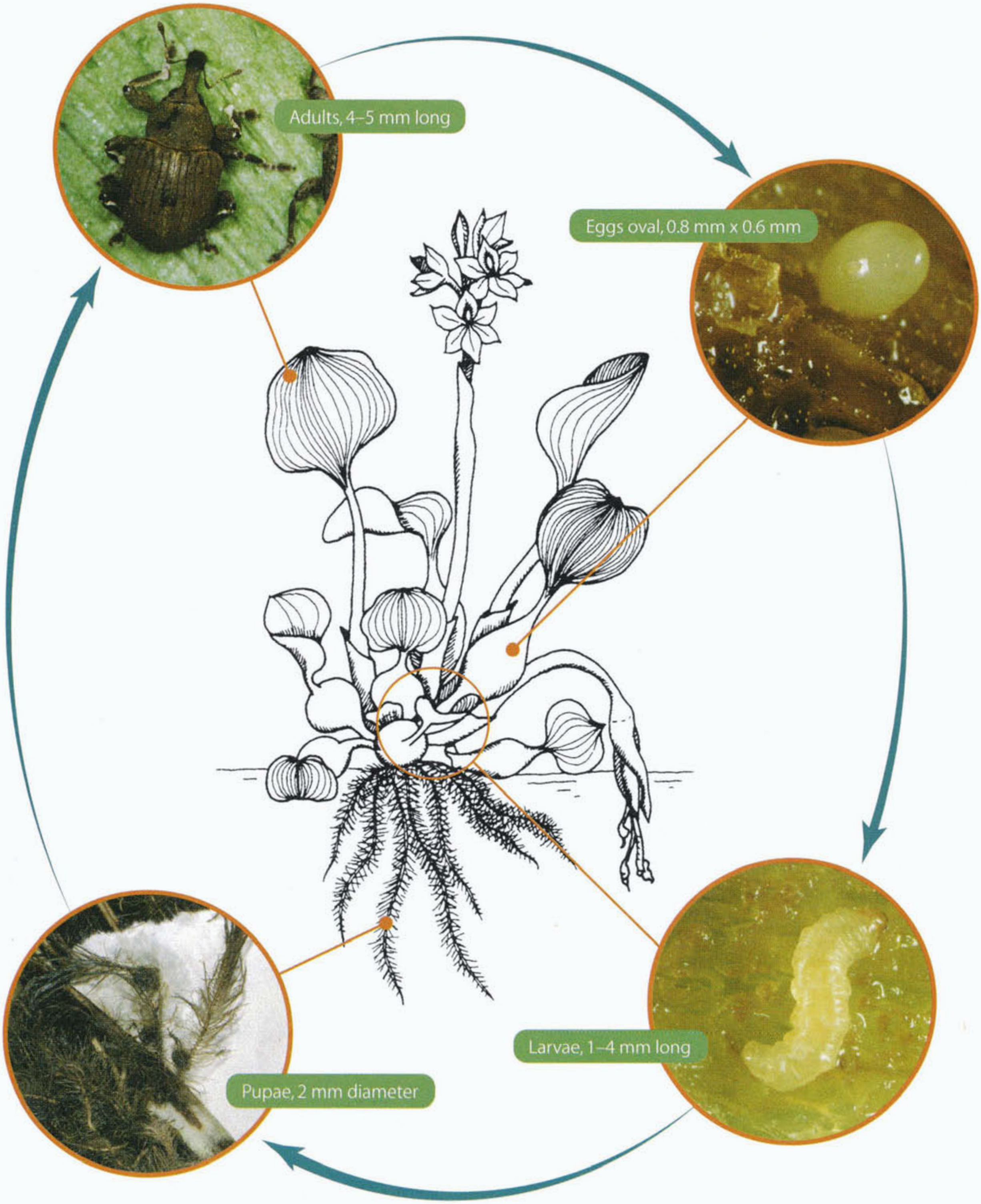

Table 2. Development durations for each life-cycle stage and fecundities for both *Neochetina* species

		Approximate duration (days)					
		N. bruchi			*N. eichhorniae*		
		Argentina[1]	Uganda[2]	India[3]	Argentina[1,4]	Uganda[2]	India[3]
Development stage							
Egg		7.6	7		7–14	10	
Larva							
	I instar	10					
	II instar	14					
	III instar	6					
	Total	32	35		75–90	58	
Prepupa		7	10				
Pupa		23	23				
Prepupa + pupa		30			14–20	28	
Generation time		96	72		120	96	
Adult longevity							
	Average	89		134			142
	Max.				309 (field)		
Fecundity							
Total		293		682			891
Average				4.5			
Daily max.		8.5		26	5–7		

References: [1]DeLoach and Cordo (1976), [2]Ogwang and Molo (1997), [3]Jayanth (1987), [4]Harley (1990)

Adult: Adult beetles are 4–5 mm long and brownish to grey. They are nocturnal and during the day lie concealed near the plant crown. Adults commence feeding within 24 hours of emergence. They feed externally by scraping the epidermal layer and some of the underlying cells to form small, characteristic subcircular scars, which usually do not penetrate through to the other side of the leaf. Adults feed preferentially on the narrow upper third of the petiole and on the upper surface of the lamina, particularly of the first or second youngest leaf. Some feeding may occur during daylight when adults are largely stationary and concealed. Females commence oviposition between 3 and 7 days after emergence. Oviposition peaks during the second week and close to 90% of eggs are laid by the fifth week. The optimal temperature for feeding and oviposition is approximately 30°C. Adults are susceptible to heat and low relative humidity, and exposure to high temperatures may result in a decrease in egg production and death of adults.