Establishment, Spread and Impact of *Neochetina* spp. on Water Hyacinth in Lake Victoria, Kenya

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Abstract

The Kenya Agricultural Research Institute imported 12,300 curculionid weevils (*Neochetina* spp.) from diverse sources, for biological control of water hyacinth in Lake Victoria, as part of the World Bank-funded Lake Victoria Environmental Management Project in East Africa. In addition to the rearing and quarantine facility at Muguga, a second rearing facility was established in 1996 at Kibos, near Lake Victoria. The Kibos rearing facility and two community rearing facilities at the lakeshores, have produced approximately 100,000 adult weevils and 42,000 weevil eggs over a three-year period. Since January 1997, some 73,500 *Neochetina* weevils have been released at 29 sites and an additional 10,000 redistributed at several sites. Visual observations and regular sampling monitored the establishment and spread and also evaluated the impact of *Neochetina* weevils on water hyacinth. Within two years, weevils were established at 55% of release sites and were being recovered 50 km from release sites. Post-release sampling data from four release sites in Berkeley, Kisumu and Kendu bays, indicated a reduction in leaf length, laminar area and fresh weight of water hyacinth, and a significant increase in number of weevil feeding scars and adult weevils per square metre. Three years after the initial weevil releases, the combined mean number of weevils per plant for Kisumu, Nyakach, Kendu and Homa bays, was estimated to be six, well above the critical threshold of five weevils per plant. *N. bruchi* was the dominant species accounting for 73.3% of the total weevil population. Thus, under Lake Victoria conditions, the critical threshold was attained within 2–3 years of the initial releases.

LAKE Victoria (area ca 69,000 km^2), shared by the three East African countries, Kenya (6%), Uganda (43%) and Tanzania (51%), is the world's second-largest freshwater lake (Figure 1). In 1989, it was invaded by water hyacinth and its presence in the Kenyan part was confirmed in 1992. The origin of the infestation is presumed to be in the River Kagera Basin in Rwanda. At peak infestation in 1997, the area covered by the weed in East Africa was more than 15,000 ha. The tropical aquatic weed of South American origin, has adverse impacts on the health, energy, water and transport sectors (Harley 1990; Harley et al. 1996). The weed presented an enormous challenge for biological control in East Africa.

As early as 1993, the Kenya Agricultural Research Institute (KARI) imported water hyacinth weevils, *Neochetina bruchi* and *N. eichhorniae*, from the Plant Health Management Division of the International Institute for Tropical Agriculture in Benin. These weevils, considered the most important biological control agents against the water hyacinth, have had notable success outside East Africa (Harley 1990; Julien and Griffiths 1998; Julien et al. 1999). However, host-spe-

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cificity tests were ordered in Kenya and Uganda, before releases in Lake Victoria were allowed.

Neochetina weevils were released in Lake Kyoga, Uganda in 1993 (Ogwang and Molo 1997, 1999) and in Lake Victoria in 1996 (James Ogwang, pers. comm.). The first weevil releases in Kenya were in Lake Naivasha, which had water hyacinth since the mid 1980s (Aggrey Mambiri, pers. comm.). *Neochetina* weevils were released in the Kenyan part of Lake Victoria in 1997 (Ochiel et al. 1999; Mailu et al. 1999), while in Tanzania, Mallya (1999) reported the releases of *Neochetina* weevils in the Pangani and Sigi rivers in 1995, and in Lake Victoria in 1996.

This paper presents recent results from a program of classical biological control against water hyacinth in Lake Victoria, implemented by KARI under the Lake Victoria Environmental Management Project.

Materials and Methods

Mass rearing and releases of *Neochetina* spp.

Since 1996, Kenya Plant Health and Inspectorate Services has allowed KARI to import adult *N. bruchi* and *N. eichhorniae* from Uganda, South Africa and Australia for the biological control of water hyacinth in Lake Victoria. KARI established a second weevil rearing facility in December 1996, at the National Fibre Research Centre (NFRC), Kibos, near Lake Victoria. 'Breeding stock' for the Kibos rearing facility was obtained from the quarantined mass-rearing facility at the National Agricultural Research Centre, Muguga, near Nairobi. The breeding material consisted of mature adult *Neochetina* weevils and host plants inoculated with weevil eggs. Later, adult

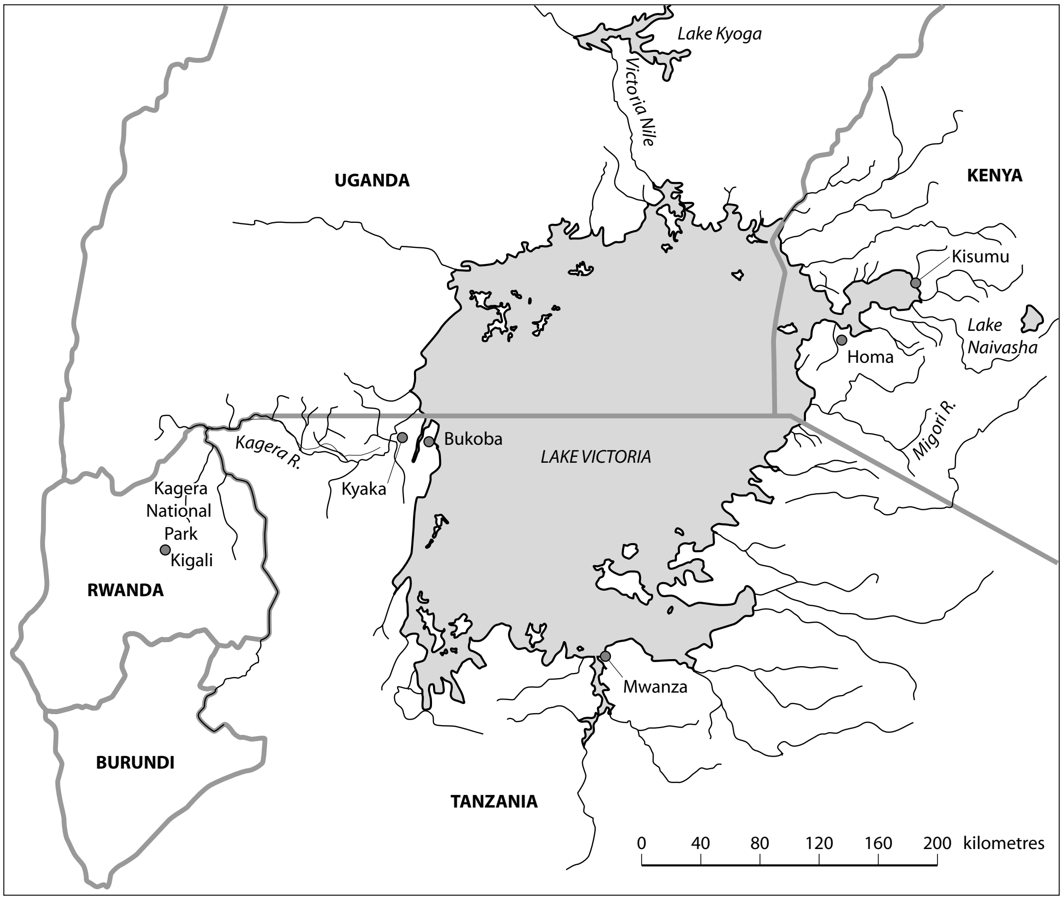

Figure 1. Lake Victoria and surrounds

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Neochetina weevils were imported from Uganda for mass rearing. Julien et al. (1999) describe in detail rearing and harvesting techniques for *Neochetina* weevils from plastic tubs, rearing pools and galvanised corrugated iron sheet tanks, all of which have been in use at the Kibos rearing facility. Additionally, 'Technotank' PVC tanks (120 × 60 cm; 230 L), with sawn-off lids, have been used to rear the weevils at Sango Rota and Nyamware beaches and at Ogenya Primary School (community-based rearing facilities near the lake). Fertiliser NPK 17:17:17 and dried cow-dung were added to the rearing containers once a month to maintain plant vigour.

Weevils were harvested for field releases as described by Julien et al. (1999). *Neochetina* weevils imported from South Africa were released in Lake Victoria in 1997 and further releases were carried out with weevils reared at NFRC Kibos and community rearing facilities. Hyacinth plants infested with weevil life stages and adult weevils were used for releases. Adult weevils were fed on fresh leaves and petioles in plastic jars before transporting them to release sites. Release techniques included planting host plants infested with weevil life stages among hyacinth plants and tipping adult weevils from the plastic containers onto hyacinth plants. Weevils were also released at sites more than 50 m from the shoreline. Canoes were used to release at sites that were inaccessible by motor vehicle or on foot.

Monitoring the establishment and spread of *Neochetina* weevils

We recorded petiole damage by weevil larvae, fresh adult feeding scars and the number of adult weevils on water hyacinth at release sites with resident mats of water hyacinth and at non-release sites. These visible signs are indicators of an establishing or established weevil population at a given site. Weevil recovery at non-release sites indicated weevil spread on water hyacinth.

Evaluation of the impact of *Neochetina* spp. weevils on water hyacinth

Using a modified sampling protocol developed at the Commonwealth Scientific and Industrial Research Organization (CSIRO), Australia, we evaluated the impact of *Neochetina* spp. on water hyacinth. The objectives of the sampling were to: (1) evaluate water hyacinth growth parameters; (2) quantify weevil feeding damage; and (3) estimate weevil populations. A half-metre^2 quadrat was thrown randomly on mats of hyacinth plants. The number of plants per quadrat was recorded. For each of 10 or 30 plants from the quadrat or nearby, the following parameters were recorded: fresh weight; leaf laminar area; leaf length; number of feeding scars; number of weevils per plant; and number of adult weevils per square metre (mean number of weevils per plant × number of plants per quadrat). Rapid assessment of weevil populations was done by counting the number of weevils from each of 10 or 20 randomly selected plants at selected sites.

Results

Importation of *Neochetina* weevils

Between 1996 and 1998, KARI imported 12,300 *Neochetina* weevils from Australia, South Africa and Uganda, for mass rearing and releases on water hyacinth in Lake Victoria (Table 1).

Table 1. Importations into Kenya of *Neochetina* weevils for biological control of water hyacinth in Lake Victoria

Species	Year imported	Number	Purpose	Source
Neochetina bruchi	1996	1300	Mass rearing	Uganda
	1997	2000	Mass rearing/releases	Australia
	1998	1000[a]	Releases	South Africa
Neochetina eichhorniae	1997	5000	Mass rearing/releases	South Africa
	1997	2000	Mass rearing/releases	Australia
	1998	1000	Releases	South Africa
Total		12,300		

[a]Batch did not survive

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From December 1996 to December 1999, the Kibos rearing facility and community rearing facilities produced approximately 100,000 adult weevils, of which 25,000 were for 'breeding stock' and for releases in Lake Naivasha and Nairobi Dam.

Between January 1997 and December 1999, approximately 73,200 adult weevils were released at 29 sites in Kisumu, Nyando, Rachuonyo, Bondo, Homa Bay, Migori, Suba and Busia districts (Table 2). An additional 10,000 weevils were redistributed from the Homa Bay Pier and Police Pier release sites to other sites within the Kisumu District.

Monitoring the establishment and spread of *Neochetina* weevils

Monitoring in January 1999 confirmed that the weevils were firmly established at 16 sites in 7 districts along the Lake Victoria shoreline (equivalent to 55% of the sites). Weevil recoveries were also made at distances ranging from 5–50 km from the nearest release sites.

Evaluation of the impact of *Neochetina* spp. weevils on water hyacinth

In general, post-release sampling data collected (November 1997 to May 1998) at four selected release sites in Berkeley, Kisumu and Kendu Bays, indicated a suppression of plant growth parameters (fresh weight, leaf laminar area and leaf length) and substantial increases in number of feeding scars and adult weevils per plant (Table 3). Fresh weight reduction was noted at a single site, Bukoma Beach. Leaf length reduction was noted at two sites, while leaf laminar area reduction was evident at Sio Port and Bukoma. The number of feeding scars and adult weevils per plant increased at all sites.

Estimations of weevil populations

Post-release sampling of water hyacinth at six selected sites in three bays (May–December 1999), gave a combined mean number of 6.0 *Neochetina* weevils per plant, with actual number of weevils per plant ranging from 0 to 32 (Table 4). Table 4 also shows that *N. bruchi* was the dominant of the two weevil species, accounting for 73.3% of the total weevil population.

Discussion

Importation of additional biological control agents, the moth *Niphograpta albiguttalis*, the mite *Orthogalumna terebrantis* and the hemipteran bug *Eccritotarsus catarinensis*, to augment biological control efforts by *Neochetina* weevils, is recommended. Rearing pools, which are easier to manage and have a larger capacity, are preferred over both plastic basins and tanks and galvanised iron sheet tanks. Tub rearing was found to be labour-intensive and time-consuming. Tubs may, however, be used for 'demonstration mass rearing units' in schools and community-based rearing facilities near the lake.

Releases on floating mats assisted in the redistribution and spread to non-release sites. Wind and water currents were responsible for the spread of weevils on floating mats of water hyacinth. Under the environmental conditions of Lake Victoria, weevils established quite rapidly.

At a regional level, monitoring the water hyacinth infestation pattern using aerial reconnaissance photography, ground truthing and satellite imagery has been proposed. At a national level, monitoring and evaluation of the impact of weevils on water hyacinth, redistribution to areas with low weevil populations and scouting for new infestations should continue.

Weevil damage has been held primarily responsible for the reduction of the weed cover by up to 80%, from the peak infestation of 6000 ha in 1998 (Synoptics, Integrated Remote Sensing and GIS Applications, The Netherlands). By late 1999, water hyacinth in the Kenyan part of the lake was no longer capable of flowering and producing ramets (daughter plants). This has been attributed to weevil damage and opportunistic fungi. The El Niño flooding of 1997 may have physically destroyed plants by washing them ashore.

Ecological succession of water hyacinth by emergent plant species, mainly papyrus (*Cyperus papyrus)* and hippograss (*Vossia cuspidata)*, has been noted (Ochiel, personal observations). This phenomenon has also been observed in Lake Kyoga, Uganda, following the successful biological control of water hyacinth by *Neochetina* weevils. However, this is short-lived and the secondary vegetation will disappear after the degraded hyacinth substratum supporting it eventually sinks.

The long-term approach to water hyacinth management and indeed other floating or submerged aquatic weeds, should focus on curbing the discharge of effluents into Lake Victoria from surrounding urban settlements, agricultural and industrial activities.

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Table 2. Releases of *Neochetina* at sites in Lake Victoria, Kenya, January 1997 to September 1999.

Site–Grid Reference	Release dates	Life stage	
		Eggs	Adults
Police Pier 0°5.5'S;34°44.3'E	23.1.97–18.2.98	13 850	5 553
Fisheries Pond 0°5.4'S;34°44.0'E	23.1.97–15.4.97	3 680	1 000
Golf Club 0°5.4'S;34°43'E	23.1.97–18.5.97	600	500
Yacht Club 0°8.5'S; 34° 45.5'E	22.1.97–3.6.98	3 500	6 705
Usoma Beach 0°06'S;34°38'E	21.2.97–14.7.98	10 695	5 967
Karamadhan 0°07'S;34°38'E	27.2.97–15.4.98	6 250	750
Otonglo Beach 0°04S;34°39.5'E	21.7.97–7.6.99	3 100	3 071
Dunga Beach 0°09'S;34°46.5'E	23.5.98–6.8.98	3 680	2 042
Kaloka Beach 0°9.5'S;34°32.5'E	17.5.98–28.5.98		2 075
Sango-Rota Beach 0°16.5'S, 34°47.5'E	7.6.97–25.3.98		2 153
	30.7.99–30.9.99		10 000
Kusa Beach 0°18.5'S,34°51'E	17.11.98		1 066
Nduru Beach 0°15.5'S;34°51.5'E	21.5.98		979
Kendu Bay Pier 0°20'S;34°39'E	7.6.97–10.8.98		2 150
K'Owuor Pier 0°21'S;34°28'E	30.1.98		740
Homa Bay Pier 0°31'S;34°28'E	21.11.97		509
Ombogo Beach 0°28.5'S;34°30'E	29.1.98		430
Tagache Beach 0°58'S,34°6.5'E	28.1.98		100
Sori-Karungu Beach 0°50'S,34°10'E	29.1.98		300
Luanda Nyamasare Beach 0°27'S,34°17'E	21.4.98		508
Aram Beach 0°18'S,34°16'E	12.11.97–11.3.98		1 250
Usenge 0°03'S,34°05'E	12.11.97–16.5.98		1 250
Usigu (Uharia) Beach 0°04'S,34°9.5'E	3.2.98–16.5.98		1 750
Obenge Beach 0°13'S,34°12.5'E	16.5.98		540
Luanda Kotieno 0°18'S,34°16'E	11.3.98		250
Sio Port 0°14'N,34°02'E	12.9.97–13.1.99		1 200
Bukoma Beach 0°12'N,33°58.5'E	29.9.97–2.2.98		1 046
Nyamware Beach 0°16'S, 34°42'E	13.8.98		950
	12.7.99–30.9.99		15 000
Ogenya Beach 0°15.5'S,34°52'E	20.5.99–22.5.99		471
Total		41 975	73 225

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Table 3. Post-release sampling data to evaluate the impact of *Neochetina* weevils on water hyacinth at four sites in Lake Victoria, Kenya

Site	Sampling date	Fresh weight (g) ± SE	Leaf length (cm) ± SE	Laminar area[a] (cm^2) ± SE	Feeding scars ± SE	Weevils/plant ± SE
Sio Port ($40\ m^2$)	19.11.97	1685±958	137.2 ± 14.9	195.4±9.7	2.5 ± 1.9	0.4 ± 1.4
	10.3.98	3550±1755	77.8 ± 23.0	110.2±12.5	100.3 ± 9.6	1.8 ± 2.6
Bukoma Beach ($15\ m^2$)	20.11.97	2270±935	162.9 ± 16.5	178.6±0.7	2.5 ± 2.1	0.2 ± 0.6
	10.3.98	925±528	75.5 ± 19.9	126.8±13.0	107.4 ± 28.2	2.2 ± 1.9
Police Pier ($1500\ m^2$)	28.11.97	251±128	19.9 ± 4.8	49.0±5.0	19.4 ± 6.9	0.4 ± 0.5
	20.5.98[b]	482±271	31.3 ± 15.8	74.6±12.8	138.8 ± 28.3	4.5 ± 3.9
Kendu Bay Pier ($400\ m^2$)	21.11.97	1950±797	78.8 ±19.3	146.8±5.6	2.9 ± 2.3	0.1 ± 0.3
	12.3.98	2510±127	100.3 ±33.1	124.8±13.1	268.3 ± 52.4	6.0 ± 3.0

[a]Second youngest petiole sampled
[b]n = 30. At all other sites n = 10.

Table 4. *Neochetina* weevil populations on water hyacinth estimated from six sites in Lake Victoria, Kenya, May–December 1999.

Site	Sampling date	Mean no. of weevils/plant[a] ± SE	Mean no. of weevils by species[b] ± SE		Range
			Nb	Ne	
Kisumu Bay					
Police Pier	6.5.99	2.5 ± 2.3	1.8 ± 0.9	0.7 ± 0.3	1–4
	14.12.99	6.3 ± 4.5	5.1 ± 3.3	1.2 ± 0.6	0–6
Karamadhan	6.5.99	1.8 ± 2.1	1.1 ± 1.7	0.7 ± 0.9	0–6
	4.12.99	3.7 ± 2.8	2.9 ± 2.3	0.8 ± 0.9	0–7
Nyakach Bay					
Kusa	7.5.99	14.0 ± 6.7	14.0 ± 6.7	0.0 ± 0.0	2–22
	14.12.99	3.2 ± 3.9	3.2 ± 3.9	0.0 ± 0.0	0–11
Sango Rota	7.5.99	5.4 ± 4.4	3.7 ± 2.9	1.7 ± 2.3	1–13
	15.12.99	2.9 ± 1.6	1.5 ± 1.9	1.4 ± 1.6	0–8
Kendu Bay					
Kendu Bay	7.5.99	2.4 ± 2.3	2.0 ± 1.7	0.4 ± 0.7	0–6
Pier	16.12.99	2.0 ± 1.7	1.5 ± 1.6	0.5 ± 0.9	0–4
Homa Bay					
Homa Bay	18.9.99	18.1 ± 15.3	15.4 ± 7.2	2.7 ± 2.3	0–32
Pier	15.12.99	9.2 ± 8.6	6.5 ± 5.9	2.7 ± 3.0	0–32
Grand mean		6.0 ± 5.3	4.4 ± 3.1	1.6 ± 0.9	
Percentage			73.3	26.7	

[a]Mean of 10 plants per site, except for Homa Bay 18.9.99, where n=20
[b]Nb = *Neochetina bruchi*. Ne = *N. eichhorniae*.

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