Guide to some invasive plants affecting Lake Tanganyika

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IUCN Invasive Species Initiative

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Table of Contents

Introduction

Lake Tanganyika is one of Africa's Great Lakes. It is the second deepest and the second largest lake in the world by volume. The lake is shared by Zambia, Tanzania, Democratic Republic of Congo and Burundi (the riparian nations) and its management is coordinated by the Lake Tanganyika Authority (LTA), an inter-governmental organization which assists the riparian countries to implement the Lake Tanganyika Convention. The Lake is a source of fresh water, food and minerals for the millions of people around it who also use it for transport and tourism. The Lake holds at least 250 species of endemic cichlid fish and 150 species of non-cichlid fish. It also harbours hundreds of species of crustaceans, molluscs and sponges (many of which are endemic to the lake) as well as both microscopic and macroscopic water plants. However, there is increasing pressure on the Lake's natural resources - thus the need for its protection. In response to this need, the Lake Tanganyika Convention was signed by the four riparian states in 2003 and a Strategic Action Programme (SAP) was formulated to help in the establishment of a regional monitoring system in order to contribute to long-term sustainable management of Lake Tanganyika. This guide to some invasive plants affecting Lake Tanganyika is a product of that SAP through a project supported by UNDP-GEF, managed by UNOPS and implemented by IUCN.

Article 10 of the Lake Tanganyika Convention requires the four riparian states to conserve rare, fragile and representative biodiversity and, as far as possible, to prevent or manage negative impacts from alien species (which may become invasive). This booklet describes some of the plants present in and around Lake Tanganyika that can affect its environment and biodiversity. There are many such plants and there will be more – but this small volume is a starting handbook to invasive plant recognition, understanding and management. It contains a selection of species that can are known to be invasive in other situations and some that have already begun to show that tendency in Lake Tanganyika and/or its catchment.

Each species is described (with minimal technical terms) and illustrated so that it can be recognised and distinguished from other plants. Each species has a small section on its likely impacts on the lake and its contents (often derived from experiences in other lakes and wetlands), its means of spreading (which helps us to control it) and some ways of managing it if the species becomes invasive – or is seen as likely to do so.

What is biological invasion?

Biological invasion occurs when a non-native species is introduced to a new environment (ecosystem or habitat) and spreads causing damage – to native biodiversity or to human livelihoods or developments. This requires that a species not represented in the vegetation or fauna of an area enters from "outside", survives to reproduce, spreads from its point of introduction, becomes naturalised and then spreads further – eventually causing damage.

The initial introduction may, in rare cases, be natural; but most often introduction is associated with people and can be intentional or unintentional (accidental). Most species introductions do not survive to the next stage of establishment. Those that do establish are able to reproduce and may stay where they were introduced – as harmless new arrivals. Some, however, will spread and "naturalise" which means they will establish in the local vegetation or fauna and may, with time, be considered as local species – but do not spread or cause harm. A small proportion of species may spread further and cause damage to the local biodiversity or negatively affect people or their activities: these are the invaders.

This process and its steps from introduction to invasion may take weeks or months, sometimes years or even decades or centuries (as in the case of some trees). This is why we need to take note of new species that arrive and join the flora or fauna – and check if they have a reputation of invasion elsewhere. This process is termed "biological invasion", the species becomes known as an "invasive species" or "invasive alien species" in this context (but not necessarily in other situations). In other words, a species should not be called an invasive species unless it is actually causing problems after going through the stages (above). Before going through those stages or in other places, it does not get the label of "invasive species". This guide has been prepared for a range of species that are already invasive somewhere in Lake Tanganyika and its catchment – or are already showing signs of taking that last step to invasion.

How do invasive species affect the environment and biodiversity?

Invading species – especially invasive plants - can affect the environment in many ways – which are able to have short and long distance impacts on water quality and quantity relevant to the Lake Tanganyika situation. Many invasive plants compete for space, light, water and nutrients with the "less aggressive" plants in their new habitat. In this way they can dominate and replace stable plant communities, sometimes to the extent of local extinction of native species. They are able to dominate because of a range of characteristics that allow them to grow faster and bigger than the local species. To do this, some have more extensive root systems (both deeper and more widespread than local species) which gives them the advantage BUT also affects water supply, the quality of sub-surface waters and the distribution of nutrients in soil and plant litter. All of these changes have impacts on the lake and its waters – whether they are near or far from the lake.

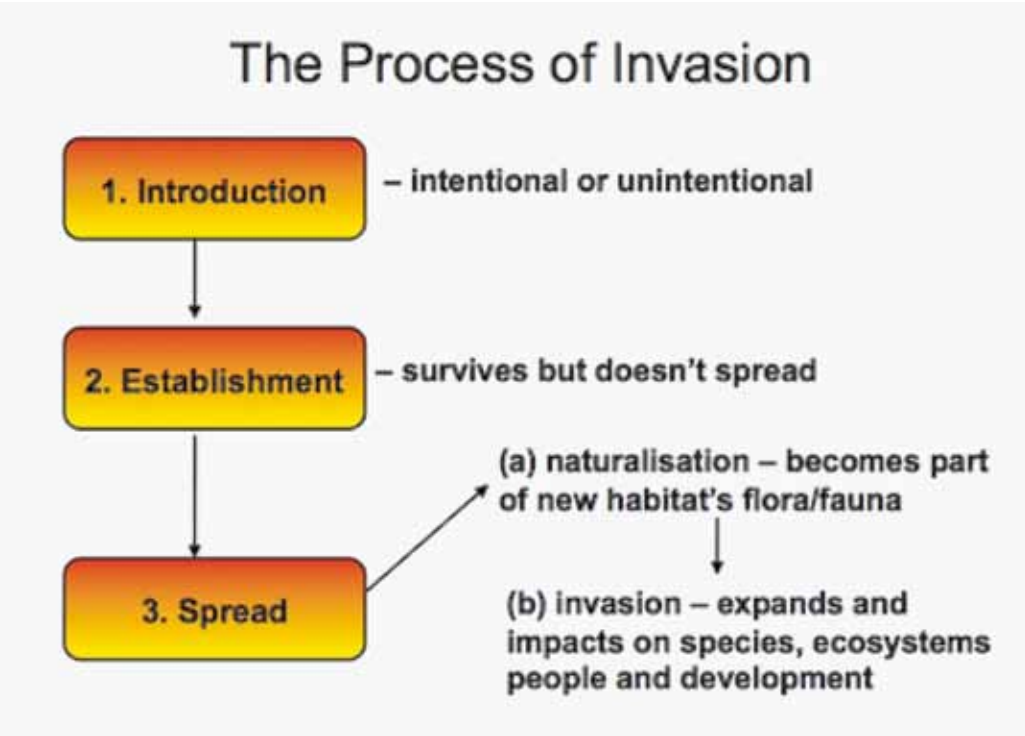


Diagram of the biological invasion process

In addition the greater growth means more dead plant material which has impacts on water quality as it breaks down – changing the amounts of both organic and inorganic breakdown products that reach the lake. Those aquatic plants that become invasive in and under the lakes waters also have impacts as they will change the nature of the use and excretion of nutrients which can have further impacts on other aquatic biodiversity.

Some invasive plants also produce allelopathic substances in their roots or leaves which reduce or stop the germination of native plants and their growth – sometimes hastening the development of a single-species thicket of the invading species. In this way the native floral diversity can be reduced and the plants that people have used for many purposes may disappear from invaded areas. Plant invasions have impacts not only on native plants and their soils and water, but also on animals which may have lessened (or now locally extinct) sources of food, shelter, resting sites, nesting sites and food sources from the natural herbivores of the native plants. The invaders often have more flowers producing more seeds than the local species, further enhancing their advantages and competitive ability. Most often they have come without their "natural enemies" (herbivores, parasites, pathogens, competitors) from their native areas which gives alien species an advantage over native species and adds to the rate of spread and damage of invaders. Finally, it should be mentioned that biological invasions can occur in "productive ecosystems" such as commercial forests and woodlots, agriculture, aquaculture, floriculture and horticulture – with similar impacts of competition, exclusion and allelopathy as affecting wild species and habitats.

What are pathways of introduction and spread?

Pathways are the routes along which alien species move to points of introduction and later the routes and mechanisms that allow established alien species to spread. Both of these mechanisms are important to know because it may be possible to stop (prevent) an introduction or the spread of an incipient invasion by somehow barring the movement of species along a pathway. Natural pathways are rivers and streams, winds and storms, migration routes and other movements of animals that may carry seeds or other propagules[1] (wild and domestic, mammals, birds, fish, crustaceans, etc.), while those related to people include trade, travel, transport and tourism in their many forms. Other pathways are fisheries and sport fishing (boat transport, hull fouling, fishing gears), aquaculture (which always has escapes), and movement of earth-moving, road-making and farm machinery. The same or similar pathways can enable the spread of an invasion; thus spread can also be stopped or lessened by blocking access to such pathways once they are identified for a particular species in a particular area.

1 Propagules are the elements of animals and plants that allow movement and spread of species to initiate or spread a biological invasion; plant propagules include fruits, seeds, spores, bulbs, corms, tubers and plant fragments, animal propagules include eggs, larvae, pupae, adults in aestivation and other immature stages.

How can we control species that have become invasive?

Once an invasion has established, the option for prevention (e.g. along a pathway) has gone; so one should manage the infestation to reduce its vigour, to reduce its impact on native biodiversity, human livelihoods and development - and to restore the former status of the invaded ecosystem or habitat. There are three main types of control for plant invasions: by mechanical or physical means, by chemical means and by the use of biological control. A fourth, integrated control, uses two or three of the previous types together to target specific types and parts of an invasion.

Mechanical control of invasive plants can be done by uprooting, cutting down, mowing, ploughing, bulldozing or burning to reduce or remove the plants from the invaded area. But with most invading plants there will be seeds (or spores) in a seedbank – usually in the soil – which means that the clearance will only be temporarily effective until the next germination. This is equivalent to the weeding of farmed crops which must go on every growing season (often several times a season) year after year – so is not a permanent solution to a plant invasion in most cases.

Chemical control uses herbicides to kill the plants *in situ* through various types of applications and appropriate chemicals. In woody shrubs and trees it is often possible to cut the plants down and then apply a recommended chemical to the stump, standing stem or the roots to ensure that it is killed. The same problem of subsequent germination of the seed bank and regrowth arises because very few (if any) herbicides will kill the seeds in the soil as well as the living plant (unless they are applied specifically for that purpose when they may affect germination and growth of other, non-target (not invasive) plants.

Biological control involves the use of the natural enemies of the invading plant, brought from its original native area. These are selected in the plant's home area, checked for specificity to ensure they do not affect other species of plants, brought to a quarantine facility and reared in large numbers before release at the invasions site. These biological control agents are usually insects specific to the target plant or they can be parasitic fungi or even disease organisms – as long as they are specific to the target plant species and will not affect any other plants. Such biocontrol is intended to weaken the target species so that, for example, it grows more slowly, has less leaves (to enable photosynthesis for energy production), has fewer buds, fewer flowers and so fewer seeds and, perhaps is weakened so that it falls over before growing tall – to reduce its competitive capacity and make it no longer invasive - and so no longer a problem. This type of control is self-sustaining and will continue to work as long as the control organisms are still around.

How can we prevent new invasions?

Using known pathways for introduction and spread of likely invasive plants allows the prevention of new invasions by stopping the species from entering the habitat, ecosystem or even the relevant country or region. This requires the monitoring of pathways of possible introduction of species that may become invasive and preventing their movement across a border or into a new ecosystem. If alien species known to be invasive in similar conditions are recognised, they can be destroyed or sent back to their origins before entry is possible. If there is doubt about their identity or their possible invasiveness, there are methods of Risk Assessment to guide authorities on refusing entry, allowing entry or keeping the species in quarantine for further trials. Many pathways do not cross formal borders or inspection sites and these need to be checked at the edges of susceptible ecosystems or habitats using methods of monitoring specific to the type of possible invader. For example roadsides, pathways and livestock movement routes can be checked for alien species which can then be identified and assessed as to possible invasive history and likelihood of establishment, spread and negative impacts on receptive ecosystems.

Whose responsibility is it to prevent and manage biological invasions?

In the absence of national agencies solely responsible for the prevention and management of biological invasions (sometimes called Biosecurity Departments), invasions become the responsibility of the land (and water) managers, biodiversity managers and human livelihood and welfare organisations. In the case of Lake Tanganyika and its catchment, this is spread across the four riparian countries and is coordinated by the Lake Tanganyika Authority and guided by the Lake Tanganyika Convention – together with relevant government organisations from those four countries. The value of cooperation between states for the management of a shared ecosystem is especially apparent with biological invasions. Many pathways for introduction and the spread of invading species transcend national boundaries and can, for example, stretch from one end of the lake (and even the catchment) to the other. Thus the sharing of information and the synchronisation of preventive or management efforts between countries becomes especially important in the LT ecosystem. This is the origin of the idea to develop a monitoring system for invasive alien species in and around Lake Tanganyika; an initial step to establishment of the system is the opportunity to become familiar with some of the plants that are already (or could soon be) affecting the lake. These have been chosen for all four countries and, most likely, no one country has them all – at present. The following groups of species are described herein:

A. Floating plants

1. *Eichhornia crassipes*
2. *Pistia stratiotes*
3. *Azolla* sp
4. *Lemna* sp
6. *Salvinia molesta*

B. Submerged/sometimes emergent plants

6. *Hydrilla verticillata*
7. *Ceratophyllum demersum*
8. *Potamogeton* sp
9. Filamentous algae and Phytoplankton

C. Riparian plants

10. *Mimosa diplotricha*
11. *Mimosa pigra*
12. *Mimosa pudica*

D. Terrestrial plants

13. *Pennisetum purpureum*
14. *Lantana camara*
15. *Ricinus communis*
16. *Senna alata*
17. *Senna obtusifolia*
18. *Senna occidentalis*
19. *Senna hirsuta*

E. Terrestrial plants distant from the lake

20. *Leucaena leucocephala*
21. *Psidium guajava*
22. *Caesalpinia decapetala*
23. *Acacia mearnsii*
24. *Tithonia diversifolia*

F. Alien trees becoming invasive after many decades

25. *Toona ciliata*
26. *Senna siamea*

G. Native plants that may become invasive

27. *Phragmites australis*
28. *Cyperus papyrus*
29. *Typha domingensis* and *T. capensis*
30. *Aeschynomene elaphroxylon*
31. *Vossia cuspidata*

NOTE: This is not intended to be an exhaustive list of invasive plants around the lake and its catchment; rather it is a collection of species representative of the different types - all of which are from records within the lake and catchment

Flowering water hyacinth invading an edge swamp of Lake Tanganyika.

A. The floating plants: These are water plants (hydrophytes) that are permanently or occasionally free-floating on the surface of still and moving freshwaters. They lack ordinary roots but may become anchored in the substrate at the edge of a water body and persist for a considerable time if the water level drops leaving them "stranded" on drying ground.

1. *Eichhornia crassipes*

Family: Pontederiaceae, Order: Liliales

Common name: Water hyacinth, Jacinthe d'eau

Eichhornia crassipes is an alien free-floating aquatic plant from the Amazon River basin in tropical South America. The dark green leaves have expanded hollow stems (petioles) that enhance the plant's ability to float and can extend to 2 m above the water level. The leaves are produced in basal clusters. The leaf stalks vary from being short, inflated, and spongy to being long and relatively slender (3 - 6 cm long - even up to 2m). The leaf blades (2-25cm long and 2-15cm wide) range from being oval to almost rounded in shape. They are hairless and glossy in appearance due to a waxy coating that keeps them water-proof. Below the water surface, there are root-like structures (rhizoids) which balance the plant and keep its aerial parts upright while taking up water and nutrients.

The showy flowers (4-6 cm long, 3-5.5cm wide) have six "petals" (three petal-like sepals and three petals) and are fused at their bases into a short tube (1-2cm long). They are purple, bluish or mauve in colour with the uppermost petal lobe having a yellow spot surrounded by a darker blue or purplish area. Some 5 to 36 flowers can be found on the upright inflorescence.

The fruits are capsules (10-15mm long) with three compartments and contain up to 300 seeds. The seeds (0.5-1.5mm long) are egg-shaped and ribbed length-wise. When all the flowers on the flower spikes have withered, the stalk gradually bends downwards into the water and after a time the seeds are released from the mature capsules (safe underwater from seed-eating animals). The seeds of Water Hyacinth can germinate quite soon after being "dropped" into the substrate and often do so in response to changing water levels. The seeds, however, do not all germinate at once, and some may germinate every year (or other time period) up to 20 years – which is why mechanical removal (see below) will not remove an infestation of water hyacinth in the long-term unless the plants are prevented from flowering or the removal is carried on for 20 years!

Flowers of *Eichhornia crassipes.*

Water hyacinth can also reproduce vegetatively through the production of lateral shoots that become side stems up to 15 cm long: these are termed "ramets" and each produces a new plant; both the original plant and the new plants can, in turn produce more ramets and so more plants. A single plant under ideal conditions can produce 3000 others in 50 days in this way and cover an area of 600 m^2 in a year.

Water hyacinth grows and spreads rapidly in fresh water. It can withstand extremes of nutrient supply, pH, temperature, and can even grow in toxic water. It grows well in still or slow-moving waters, especially when these are enriched by agricultural chemicals, sediments from catchment erosion, domestic effluents and plant nutrients. It is sometimes called the "World's Worst Water Weed" and is becoming invasive in the Lake Tanganyika basin and on the shores and wetlands of some parts of the lake especially in wetlands and swampy shorelines as well as in quiet lake waters – it does not grow well where there are waves.

Flower stem bent to immerse developing seeds under water.

Impacts

- *Eichhornia crassipes* can form dense floating mats that may cover large areas of water surface – thus excluding light, and air. This then affects animals (including fish) and plants that live and grow below the water surface;
- The floating water hyacinth mats can have serious mechanical impacts on water supply systems, drainage canals, inflows to hydropower turbines, movement of ships and river flows – and can cause flooding by impeding surface drainage;
- Water hyacinth increases evapotranspiration well above that of open water (often over 3 times "open pan" evaporation) thus causing significant water loss to dams, reservoirs and wild waters;
- The crowding of plants at edges of water bodies can prevent people's access to the water for domestic use, fishing and transport, and can, at the same time, make the water unsuitable for human use;
- The mats provide habitats for intermediate hosts of human diseases such as bilharzia-carrying water snails and larvae and pupae of malaria-spreading mosquitoes;
- The floating plants and the mats they produce can also provide habitats for dangerous animals (snakes, crocodiles) and can support other aquatic plants that then form "floating islands" that can block water flows and damage machinery - such as hydropower turbines;
- There is plentiful evidence that water hyacinth can retain disease-causing agents (such as pathogenic bacteria and viruses) especially in its rhizoids, and these can cause human sickness – particularly if the plants are growing in runoff from cities and towns where sewerage is limited;
- The Plants in river deltas and other inflows from erosion can accumulate suspended sediment amongst their rhizoids which later precipitates and can cause significant siltation.

Pathways of spread

- Water hyacinth came to the lake from infestations upstream in the Rusizi River and from "water gardens" where the plant was growing in cities and towns near the lake – where it was kept for its attractive foliage and beautiful flowers.
- Once it is established in a wetland or water body it can spread through wind propulsion of floating plants (or plant fragments), through water currents and on the feathers and feet of the numerous species of local and migratory water birds.
- In other countries in Africa it has been spread by people – as a green cover for dams and other water supplies; and as packaging for fresh fish on their way to markets.
- In areas where it has been introduced, it tends to become invasive where there is some alteration to a water system such as the introduction of nutrients or the modification of flows.
- Water hyacinth can also be spread by natural water flows, by floods, through mud containing seeds (on people's footwear and the feet of animals); in this and other ways it has occupied almost every large water body and river across mainland Africa and also amongst some African oceanic island nations.

Water hyacinth plant showing rhizoids and swollen petioles.

Prevention, Management or Control

- Prevention of introduction of any water plant is difficult unless it is known to be absent from a country and could only enter through commercial channels such as the aquarium trade, garden horticulture or the movement of people and goods from an infested area to a new area: in some cases this can be prevented by quarantine at formal borders and by public awareness of the dangers of plants such as the World's Worst Water Weed.
- Mechanical control can be effective (in the short-term), using manpower and machines. However, this has to be repeated frequently because once the plants flower, seeds accumulate in the substrate and can then germinate from the seed bank – sometimes several times a year for many years.
- Herbicides have been used and can be effective, but there is always concern for effects on non-target aquatic biodiversity and peoples' use of the waters; and poisoning does not affect the seed bank which will replace the poisoned plants within months.
- Biological control is the most effective, affordable and self-sustaining means of management and some very effective agents (insects specific to this plant) have been used effectively in many large and small water bodies across Africa. A number of biological organisms have been used, notably two weevils- *Neochetina bruchi* and *N. eichhorniae*. The moth *Orthogalumna terrebrantis* has also been used as well as host-specific mites that feed on the leaves and pathogenic fungi that cause the plant to rot and sink.
- Integrated control is where two or more of the above methods are combined to manage the plant to reduce its impacts and stop its spread; this method can be effective if properly planned in situations, for example, where biological control can be assisted by strategic use of chemicals or mechanical control.
- Water hyacinth requires some dissolved nutrients in its waters to grow and spread. Thus effective control of water pollution from agricultural run-off, rural and urban drainage and insufficiently treated sewage should be maintained to ensure that if there is a first infestation, it is unable to grow into a significant water hyacinth invasion.

Weevil and mite feeding scars on water hyacinth affected by biological control agents.

Pistia stratiotes close-up showing small flowers.

2. *Pistia stratiotes*

Family: Araceae, Order Arales

Common name: Nile cabbage, Water lettuce, Salade d'eau

This is a free-floating aquatic plant of unknown origin which has been recorded in some African waterways for several hundred years, but is believed to come originally from tropical America. It has a rosette of pale-green leaves and a tuft of relatively long, fibrous roots below the water level. The leaf rosettes occur singly or are connected to others by short stolons. Leaves are often spongy near the base, densely soft, pubescent (hairy) with obvious parallel veins. They are also slightly broader than long and are wider at the apex.

The flowers are inconspicuous, cream coloured and clustered on small fleshy stalks and nearly hidden in leaf axils with the single female flowers below and whorl of male flowers above. Individual plants of *P. stratiotes* can range in size from as small as 2cm up to 30cm in diameter and range in colour from dark green to pale yellow-green depending upon the supply of nutrients in the water.

The roots are numerous and feathery. Fruits arise from female flower as many seeded green berries which produce seeds that lodge in the mud below the plants and may germinate when the water level falls or be moved to other places suitable for germination by animals and people. It also can reproduce by vegetative offshoots formed on short brittle stolons. Plants may be found floating singly or in small groups or large mats on open water or partly stranded on the margins of a water body or wetland.

Pistia can invade ponds, dams, lakes, irrigation canals, rivers and a range of permanent and seasonal wetlands. It often grows and expands in pools and wetlands associated with river systems and then is released into the main river channel when the river rises in its flood season. Water lettuce can be seen floating on deep waters of the Lake Tanganyika (often as single plants) and in accumulations of plants that can form mats on the protected edges of the lake and in associated wetlands.

Impacts

- *Pistia stratiotes* can form thick and extensive mats that block sunlight and air from reaching water surface and so have impacts on aquatic biodiversity and fisheries.
- Nile cabbage can form thick and extensive mats that will crowd out other floating, emergent and even riparian native vegetation.

Pistia stratiotes invading a swamp/lake edge of Lake Tanganyika.

- It can increase loss of water through evapotranspiration and create minor water shortages.
- Water lettuce can accumulate at barriers in flowing water and cause damage or blockage to irrigation canals, drainage lines and inlets to hydropower installations.
- It grows together with water hyacinth and *Salvinia* to worsen the effects of both.
- In shallow waters (such as livestock watering dams), water lettuce can foul the water and make it unpalatable to animals when the older plants rot and release breakdown products.

Whole plants of *Pistia stratiotes* showing rhizoids.

Pathways of spread

- Water lettuce is spread along (and across) water systems by flow and wind and can be moved by aquatic animals (hippos, other marsh mammals, water birds) and human visitors to infested waters.
- *Pistia* is also moved on boats and wheeled vehicles that have come into contact with infested waters – to the extent that some African countries require boats and vehicles moving from one water system to another to be cleaned – sometimes at checkpoints especially for this purpose.
- It is widespread in African water systems at relatively low density but can grow quickly and form mats when the requisite nutrients are available - and in this way become invasive.
- *Pistia* has been grown as an ornamental in ponds, gardens and aquaria to provide cover for fry and small fish.

Management/ control

- Mechanical removal of the plants can be effective but the seed bank from flowering plants may mean that the infestations return quite quickly.
- Chemical control using 2-4D is effective except for the obvious impacts on non-target aquatic plants and animals and upon people and their uses of wetlands and water bodies.
- Biological control using host-specific beetles e.g *Neohydronomous affinis* has been effective in tropical situations. The larvae of the moth-*Spodoptera pectinicornis* has been reported to work elsewhere.
- Where possible, the flow of nutrients from the catchment should be minimized through such measures as processing sewage and minimizing run-off from agricultural lands – both with careful drainage and maintenance of a healthy buffer zone close to the lake – of native riparian vegetation.

Water lettuce plants floating on deep water of Lake Tanganyika

Red-coloured *Azolla filiculoides* in a wetland of Lake Tanganyika

Azolla filiculoides in green phase

3. *Azolla filiculoides*

Family: Azollaceae, Order: Pteropsida

Common name: Red water fern, Azolla

This is a small, free-floating aquatic fern with horizontal stems of up to 3cm. It originates from South America. The leaves (actually fronds, as it is a floating fern) are pale green to red-brown depending upon the nutrients in the water and the amount of sunlight they receive. These small plants can also change colour as a result of changing seasonal ambient temperatures. The adult plant is approximately 25-35mm long with the length of the individual fronds being approximately 1-1.5mm.

Beneath the "leaves" are the unbranched rootlets which dangle down in the water and keep the plant surface upwards.

It has minute fruiting bodies that produce highly dispersible spores, but it mainly propagates vegetatively. It can regenerate from any small fragment as long as it includes a growing point. Under ideal conditions, an infestation can double in area every 4-5days.

Azolla can be found in irrigation systems, ponds and dams, in sheltered parts of reservoirs and lakes and amongst other aquatic plants in slow moving streams, rivers and wetlands. *Azolla filiculoides* can be confused with the native Azollas - *Azolla nilotica* and *A. pinnata*. *A. filiculoides* differs from *A. nilotica* in that the whole plant lies flat on the water surface while *A. nilotica* has some parts branching above the water surface but the differences with *A. pinnata* (subspecies *Africana*) are subtle and need excellent microscopic capacity to distinguish; the genus in Africa is currently being revised and may change these names and species soon. *A. filiculoides* has mostly roots (rootlets) with no side branches; *A. pinnata* may have side branches on its rootlets.

All three *Azolla* species have been recorded in and around Lake Tanganyika in quiet lake waters and associated wetlands – it appears that the alien species *A. filiculoides* has been increasing in density and area in the last decade or so – which is similar to the situation in a number of countries in Eastern and Southern Africa. Azolla as a genus is capable of fixing nitrogen and so has been recommended for introduction to rice paddy to improve yields.

Impacts:

- The infestations can reduce light levels below the Azolla mats and cause die-off of water plants and algae and reduce water oxygenation levels with serious impacts on fish and other fauna.
- The quality of drinking water is reduced by bad odours, colour and turbidity such that some livestock won't drink waters with Azolla - while others become ill if they do.
- Azolla forms mats on the water surface that can block irrigation channels and waterways.
- The blockages can increase water loss.
- The mats interfere with boating and fishing.
- The mats also provide a haven for mosquito larvae and bilharzia carrying snails while preventing light from reaching submerged biodiversity.
- The dense mats that are formed by Azolla invasions also outcompete native aquatic plants.

Dense mat of *Azolla filiculoides* in a wetland of Lake Tanganyika.

Pathways of spread

- Azolla is readily spread by birds and mammals between water systems and irrigation areas.
- It can also be spread unintentionally by people on shoes and vehicles – especially after visiting rice paddy that has been "seeded" with Azolla to increase yields.
- Azolla can be carried by wind and water currents both as spores and as vegetative fragments – in fact even the tiniest fragment can initiate a new plant.
- It has also been spread by the water garden and aquarium trade and can find its way into water bodies through discarded garden or pond waste and flood events.

Management/control

Mechanical removal from the water surface can be used to clear small areas of infestation, but the plants grow back in a very short time. The collected Azolla can then be used as mulch for agricultural crops and vegetable gardens.

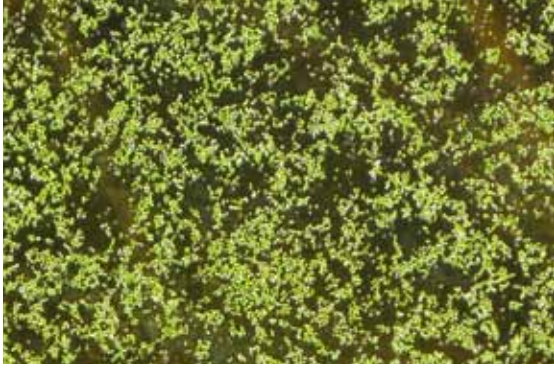
Biological control has been effective in some countries in Africa using leaf-eating insects, a flea beetle (*Pseudolampsis guttata*) and a weevil (*Stenopelmus rufinasus*).

Azolla filiculoides whole plants.

4. *Lemna* spp.(and other *Lemnaceae*)

Family: Lemnaceae, Order Arales

Common name: Duckweed(s)



Small plants of the family *Lemnaceae*

This is a family of very small free-floating aquatic plants that can become invasive when excess nutrients are available. They are all native (or cosmopolitan or pan-tropical) species and so not termed "alien" but even native species can become invasive in a changed environment. These rapidly growing plants grow as simple free-floating thalli on or just beneath the water surface. The plant body is reduced, undifferentiated into stem and leaf. The leaves are broadly ovate to oblong not lobed or divided. The genera concerned are *Lemna*, *Spirodela* and, possibly, *Wolffia*.

The roots are normally solitary and unbranched. They arise from the centre of each leaf or rarely they may be absent. Most are small, not exceeding 5mm in length. *Lemna* thalli have a single root which distinguishes them from related genera *Spirodela* (with several roots per thallus) and *Wolffia* which has no roots (and is even smaller than the other species).

The plants grow mainly by vegetative reproduction: two daughter plants bud off from the adult plant. This form of growth allows for very rapid colonization of new water. Duckweeds are flowering plants and nearly all of them are known to reproduce sexually, flowering and producing seed under appropriate conditions. All species can form mats of tiny floating plants which, in the smaller species, look like scum but are actually living plants. All can become problematic when the nutrient levels in a water body are increased, modified or changed.

Duck weeds have been recorded for the swamps and back-waters of Lake Tanganyika and in ponds and other wetlands in the catchment – often in association with *Pistia* and/or *Azolla*. In some (especially Asian) countries, an edible paste can be made which provides a diet supplement for people.

Many small floating plants of the family *Lemnaceae* in a wetland close to Lake Tanganyika.

Impacts

- The plants can form extensive mats when nutrients are introduced to their water (or when the area of available water shrinks) that hinder access to clean water (for people and animals – including livestock)
- Lemnaceous growths also prevent light from reaching other organisms found below the water surface – including fish
- At high temperatures, decaying Lemna can absorb oxygen and give off carbon dioxide and hydrogen sulphide making both the water and the air unpleasant and even toxic.
- Dense growth of these plants can form a semi-solid mass on the water which can block water supply (irrigation) channels and, more frequently, reduce the efficiency or even the operation of water pumps
- No obvious impacts have been recorded on native species in the L. Tanganyika area – but it is probable that they could affect submerged native aquatics.

Pathways

- Wild and domestic mammals and birds can readily carry either entire plants, plant fragments or seeds of the plants from one water body to another
- Wind can distribute the dried plants containing seeds
- The small plants can attach to the outside structures of boats (e.g. "hull fouling") and fishing gear and so be transported to new localities.

Management/control

- When *Lemna* invades a waterway it can be removed mechanically, by the addition of herbivorous fish or treated with a herbicide.

Pond covered in growth of *Lemna* sp.

Mature and ageing *Salvinia molesta*.

5. *Salvinia molesta*

Family: Salviniaceae, Order Pteropsida

Common name: Water fern, Kariba weed

THIS SPECIES HAS NOT BEEN RECORDED IN OR NEAR LAKE TANGANYIKA DURING THE BASELINE DATA SURVEY – BUT IT IS KNOWN FROM MOST OF THE RIPARIAN COUNTRIES AND IS EASILY TRANSMITTED FROM ONE SOURCE TO ANOTHER

Salvinia molesta is a small, perennial free-floating, aquatic fern with horizontal stems and tightly overlapping leaves. It originates from Brazil and other tropical American countries.

The leaves are green to yellow-green and are covered with course hairs which trap air bubbles and keep the plant afloat. It can easily break apart and can also form dense mats of foliage on the water surface. Younger plants which are mostly light green generally have smaller flat leaves that are more spread apart. As the plants get older, larger leaves are produced that are slightly folded and borne closer along the stems. Eventually the leaves become very folded in nature. The leaves are oval or folded and borne on short stalks.

The surface above the water is unwettable while submerged leaves have hairs resembling roots. These surface hairs (1-3mm long) are arranged in distinct rows and are tipped with distinct "egg-beater-shaped" structures that aid buoyancy. The undersides of the leaves are covered in densely matted brown hairs.

Plants produce slender branching runners (or stems) and form mats of vegetation very quickly. These slender stems (1-2mm thick) are much-branched and grow up to 10cm long before separating to form new plants. The length of the stem between the joints varies depending on the density of the weed. When plant density is low, the internode length is relatively long but as plant density increases, the internode length may become very short.

The roots are brown in colour and highly divided into many filaments (2-50 mm long). *Salvinia* propagates vegetatively and is able to regenerate from any small fragment as long as it includes a growing point. In some places it produces sporophores containing

Young plants of *Salvinia molesta*.

Kariba weed, *Salvinia molesta*.

mostly empty sporangia (stores of spores) and is not known to have such reproduction in Africa. It can be found in the slow-moving edges of rivers and streams in dams, ponds, irrigation channels, lakes and in wetlands such as reed and sedge swamps. It is present in DRC, Tanzania and Zambia, but not (so far) recorded in Lake Tanganyika or its catchment.

Floating mat of *Salvinia molesta*.

Impacts

- *Salvinia molesta* forms mats that can cover water surfaces and expand at an alarming rate (able to double surface area in a few days when conditions are optimum).
- The mats of Salvinia can completely cover a water body so that light and air are unavailable to submerged organisms with consequent damage to fisheries and biodiversity.
- It can prevent people's access to open waters and slow down or prevent water transport and other activities (e.g. fishing, tourism) in occupied static waters like dams and lakes.
- It can cause mechanical blockages to water in channels, irrigation canals and inlets to water supply and hydropower facilities.
- Salvinia can also foul freshwater making it undrinkable by people and animals.

Pathways of spread

- *Salvinia* can be spread by water currents, birds and mammals and almost any fragment can initiate a new plant
- Boats and vehicles that enter infested waters may carry *Salvinia* away to new areas. It can grow from small fragments and so has been spread to most waters systems within Africa-but it only becomes invasive under a range of mostly artificial conditions - including alteration of flows and increases of nutrients as a result of dams, diversions and improper use of agricultural chemicals in a watershed
- It has been widely introduced as an ornamental plant enabling its further spread across Africa.

Control

- Physical control may involve mechanical removal using machines or humans but it grows so fast that this is rarely effective and extreme care would need to be taken to remove all plant fragments from an infestation.
- Herbicides such as 2-4D, Glyphosate and diquat can be used to control *Salvinia* but there is the risk of non-target effects and of missing some plants that may then re-infest the wetland concerned.
- Biological control has been proved effective and sustainable using the host-specific weevil: *Cyrtobagous salviniae.*
- Integrated control combining biocontrol and chemical control or mechanical control is the best form of management.

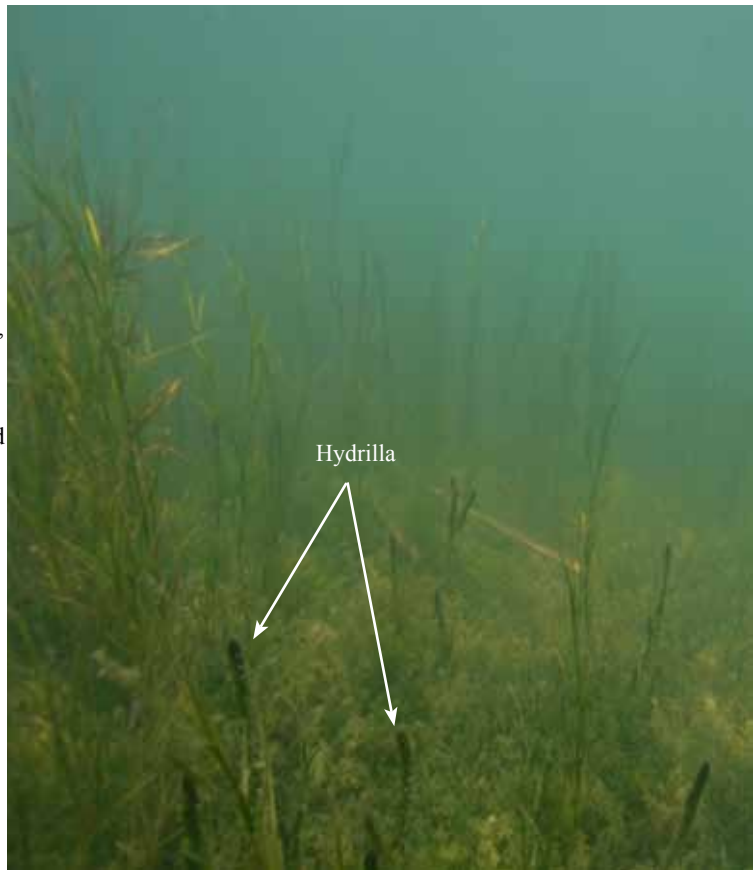
B. Submerged and sometimes emergent plants: The waters of Lake Tanganyika accommodate several completely submerged aquatic plants that most people never see or are aware that they are part of the lake's vegetation. They may grow as deep as 10 m below the surface and some reach almost to the surface when they release their reproductive parts for pollination on the water surface. Others are mostly submerged (usually at a more shallow depth) and may have some parts at, or just below, the water surface. None of these is primarily alien and invasive, but several species that exist within the lake are known to invasive elsewhere (in Africa or abroad) and could become problematic if water and other environmental conditions change. Remnants or fragments of these plants can sometimes be seen washed up on beaches and other visible shorelines of the lake – but that is not a representative sample of what is below the surface – only an indication of the species that come ashore.

6. *Hydrilla verticillata*

Family: Hydrocharitaceae, Order Hydrocharitales

Common name: Hydrilla, Water thyme

The origin of this very variable species is debatable with some authorities believing that it could be native to Lake Tanganyika. If this is so, it is unlikely to become invasive – unless significant changes occur to its native ecosystem, so making it, effectively, alien. This species is regarded as native to tropical Australia and tropical Asia and occurs in parts of tropical America where it is mainly regarded as invasive. It has a variable morphology depending upon depth (and so light), pH (prefers neutral to slightly alkaline), is found mostly to 4 or 5m depth but can survive in less than 1m and down to 10m.



Upright plants in the foreground are *Hydrilla verticillata* 2 m deep in Lake Tanganyika.

The typical plant has leaves that are arranged in whorls of two to eight around the stem, each leaf 5-20mm long and 0.7-2mm broad with serrations or small spines along the leaf margins. Specimens collected in L. Tanganyika so far have had leaves at the smaller end of the range – which is said to be determined by the alkaline conditions there. *Hydrilla* has pale green and slender branching stems up to 8m long, rooting at the lower nodes, sometimes with several stems growing from the same rooted stolons or rhizomes. The leaf midrib is often reddish when fresh. It is normally monoecious (but at times dioecious) with male and female flowers produced separately on a single plant. The flowers are solitary and inconspicuous, are small with three sepals and three petals; pollination occurs when the submerged male flowers rise to the water surface where they dislodge, float around and shed pollen which is attracted to the female flowers which emerge for a short time. Hydrilla reproduces primarily vegetatively by fragmentation and by rhizomes. The flowers are rarely seen.

Remnants of hydrilla can be seen on all four riparian country lake shorelines and samples have been collected by divers in Zambian and Tanzanian waters (for study) from as deep as 5-6 m.

Hydrilla verticillata collected 3 m deep in Lake Tanganyika (Ruler is 30 cm).

Impacts - most of the impacts can be expected if changes occur in the lake waters to turn *Hydrilla verticillata* into an invasive species – especially increased nutrients, change in temperature and pH

- Hydrilla can compete with native plants by growing to the water surface and forming mats that totally can exclude sunlight from other plants, this can in turn reduce aquatic plant and animal biodiversity
- Large populations of *H. verticillata* may affect fish size and population levels where predatory fish cannot hunt effectively within the thick mats
- The dense mats can also affect boat movement, fisheries and recreational activities
- It can slow or clog rivers, irrigation ditches and flood control canals, creating stagnant water that is prime mosquito breeding habitat
- Dense stands alter water quality by decreasing oxygen levels and increasing pH and water temperature.

Pathways of spread

- It is spread by biofouling, when the plant parts stick onto boats, fishing gears and other boating equipment like anchors and oars
- Movement of boats and equipment from one lake to another between fishing competitions and inter-lake tourism
- Movement of plant parts by local and migratory water birds

Management/ control

- Chemical control can be achieved by the application of herbicides (such as diquat and paraquat). Care should be taken on the type of herbicide being used as some may result in herbicide resistance
- Biological control has been tried where it is eaten by grass carp, itself an invasive species in particular areas. Weevils of the genus *Bagous* and the leaf-mining fly have also been used. However the biocontrol effort may not work in a place where the plant is thought to be native.
- Hydrilla can, however, produce tubers that pose a problem to control as they can lay dormant for a number of years – and then spring into life and growth.
- For the proper management of the lake, a watch should be kept on this potentially "invasive" species with relevant agencies prepared to activate some control measures if *Hydrilla verticillata* suddenly starts to expand its distribution – laterally and/or vertically.

Young plant of *Hydrilla verticillata* showing vertical growths from lateral rooted stolon.

7. *Ceratophyllum demersum*

Family: Ceratophyllaceae, Order Nymphaeales

Common name: Hornwort

Close-up of stems and leaves of Ceratophyllum.

This is a submerged free-floating aquatic plant native to North America but nowadays having a cosmopolitan distribution in temperate and tropical regions (pantropical). It grows in still or very slow-moving waters – lakes, swamps, backwaters of rivers.

The stems reach lengths of 3m with numerous side shoots making a single specimen appear as a large, bushy mass when in still water. It lacks roots, having rhizoids, and does not usually attach to any substrate – i.e. it is free-floating in the water.

The leaves are produced in whorls of six to twelve, each leaf 8-40 mm long, simple or forked into two to eight thread-like segments edged with spiny teeth. They are normally curved upwards towards the growing tip. They are also stiff and brittle to the touch although they look as of they should be soft.

C. demersum is monoecious, with separate small male and female flowers produced on the same plant but on different leaf nodes. Pollination occurs in the water (under water) and results in a small, brown "nut" with a spine at one end and a pair of spines at the other. It is dispersed by seed, rhizoids or stem fragments. This plant grows in lakes, ponds and quiet streams with water temperatures of 15-30°C and prefers a rich nutrient status. It is quite common in the shallower waters of Lake Tanganyika, in the wetlands and inflowing streams to the lake.

Mass of Ceratophyllum in shallow water (stems floating on water surface are from *Typha* sp.)

Impacts

- The plant has allelopathic properties and excretes substances that inhibit the growth of phytoplankton and cyanobacteria (blue-green alga).
- Its dense growth can outcompete native underwater vegetation leading to loss of biodiversity and even cause problems with hydroelectric power plants.
- *C. demersum* can form dense monospecific beds that inhibit or prevent boating, fishing, and other activities in dams, ponds and lakes – as well as slow-flowing parts of rivers
- When in high density, the breakdown products of the hornwort can foul water and be toxic to livestock which drink from it
- It can also accumulate suspended sediment in flowing water and then release the silt when flows are reduced – thus contributing to siltation of lake and wetland edges.

Ceratophyllum demersum showing "nuts".

Pathways of spread

- *C. demersum* can be dispersed by water flows and by waterbirds when they feed on the nuts and subsequently move away and defecate
- Introduced as an aquarium plant, its bright green leaves provide excellent cover for newly hatched fish.
- Plant fragments can adhere to boats and fishing equipment which may be moved from one water body to another.

Control

- Diquat is commonly used in the control of aquatic weeds but it can become deactivated under turbid conditions and therefore be ineffective. Under these conditions Endothall would be more effective

Like *Hydrilla verticillata*, *Ceratophyllum demersum* causes few if any problems in the general run of things in the lake and its catchment. However this may change with altered temperature and, especially, with increased in-flow of nutrients, so this species should be monitored in case it suddenly becomes troublesome or even invasive.

Ceratophyllum plant (top) out of water (with hydrilla and potamogeton); pen is 15cm long.

8. *Potamogeton spp.*

Family: Potamogetonaceae; Order: Najadales

Common name: Pondweed

This is a group of similar aquatic plants that are both submerged and emergent – or at least floating just beneath the water surface. Most species are perennial and typically produce rhizomes that spread laterally and can produce new plants vegetatively. There are often two types of alternate leaves leaves: thin and translucent leaves that are entirely submerged and floating leaves which tend to be more leathery with a distinct lamina like ordinary leaves. The flowers are composed of four rounded segments borne in a spike that usually stand up from the stems of the floating leaves and so rise above the water. Potamogetons are found throughout the world where there is standing or running freshwater. There are estimated to be around 90 species of Potamogeton. *P. octandrus*, *P. pectinatus* and *P. schweinfurthii* are present in Lake Tanganyika and should be monitored for signs of population expansions indicating a change in status from benign to problematic or invasive. *P. schweinfurthei* is the largest and most obvious species and can be seen floating in ports and around urban areas of the lake where it derives nutrients from urban and agricultural runoff. It can have stems more than 5 m long and so can be rooted in substrate at that depth and still have floating leaves on the surface – such plants can grow very large in total mass and are often found where inflowing rivers bring suspended nutrients before these disperse in the lake waters. *P. pectinatus* is widespread in much shallower water but has been recorded in 5m of water with their flowers and fruiting bodies raised another 10 cm above the water. *P. octandrus* is more of a riverine species which occasionally can be found in the lake.

Potamogeton schweinfurthei above and below the lake surface

Potamogeton pectinatus above and below the lake surface

Flowering *Potamogeton octandrus* in a river flowing into Lake Tanganyika.

Impacts

- Potomogeton species are capable of forming dense mats that inhibit growth of other native species and impede recreational activities such as fishing, diving, swimming and boating
- They can alter natural water flows and block irrigation ditches and drains
- *P. schweinurthei* can form dense beds that can outcompete native aquatic plants – and this may also be true of *P. pectinatus* although some plants in deep water are quite small (less than 0.5m high.

Young plants of *P. pectinatus* from the lake floor, 3 m deep.

Pathways of spread

- As with many flowering water plants, seeds may be spread by water flows and winds (before they sink to the substrate) and fragments of plants can be spread by water birds, boats and fishing equipment such as nets.

Control

- Mechanical clearance involving raking and uprooting is possible and effective in the short-term; but the inevitable seed bank and plant fragments ensure regrowth.
- Diquat, endothall and floridone are effective against these plants – with the usual proviso about the dangers of using herbicides in water used for fisheries and human uses.

As with the two previous species, these species of *Potamogeton* are not alien but native to the water and catchment of Lake Tanganyika. One at least, *P. schweinfurthei*, has been recorded as problematic elsewhere, but none is likely to become dangerously invasive unless there are significant changes in environmental conditions such a temperature and nutrient content of the inflows to the lake. In any case, at least this one species should be monitored in order to be prepared if those changes do occur and infestation begins.

Algae & *Cyperus mundtii*, Kasaba Bay shallows.

9. Filamentous algae and phytoplankton

Filamentous algae are single algae cells that form long visible chains, threads or filaments. These filaments intertwine forming a mat that resembles wet wool. These algae start growing along the bottom in shallow water or attached to structures in the water like rocks, or other aquatic plants. They often float to the surface forming large mats commonly referred to as pond scums. There are many filamentous algae species and often more than one species will be present in a water body. These can include *Spirogyra*, *Anabaena*, *Oscillatoria* and several other genera.

Management/ control

- They can be raked or seined from the water body.
- Chemical control:
    - Fertilization to produce a phytoplankton or algal bloom can prevent the establishment of filamentous algae.
    - Non-toxic dyes or colorants prevent or reduce aquatic plant growth by limiting sunlight penetration.
    - Copper-based compounds have been effective in controlling filamentous algae. So has Sodium Carbonate Peroxyhydrate and Diquat. Sodium Carbonate Peroxyhydrate has hydrogen peroxide as the active ingredient.

Grass carp has been tried and has been observed to feed on filamentous algae after feeding on the rest of the submerged vegetation. Tilapias consume filamentous algae too, as do many species of water snails.

Phytoplankton:

These are the autotrophic components of the plankton community. They are photosynthesizing microscopic organisms that inhabit the upper sunlit layer of almost all oceans and bodies of fresh waters. Most are too small to be individually seen with the naked eye. However, when present in high enough numbers, they may appear as a green discoloration of the water due to the presence of chlorophyll within their cells. Others may vary in colour due to the presence of accessory pigments like phycobiliproteins and xanthophylls. Phytoplanktons serve as the base of the aquatic food web, providing all essential ecological function for all aquatic life. The most important groups of phytoplankton include diatoms, cyanobacteria and dinoflagellates, several other groups of algae are also present. Phytoplanktons account for half of all photosynthetic activity on earth and are thus responsible for much of the oxygen present in the earth's atmosphere. Phytoplanktons could however become invasive if nutrient levels in the water are altered by anthropogenic activities.

Pathways of spread

It is normally introduced and spread by inter-lake movement of ballast water, fishing gear, boats and ships.

Mimosa diplotricha growing at the water's edge.

C. Riparian plants are those that grow in the shallow edge waters of the lake or on damp edges of the land next to the lake. They may also grow in connected wetlands and other damp areas and in areas far from standing water.

10. *Mimosa diplotricha*
Sub-Family: Mimosoidea, Family: Fabaceae, Order Fabales

Common name: Creeping (giant) sensitive plant

Mimosa diplotricha is a prickly erect or prostate spreading shrub or climber that prefers to grow in damp places but can survive in many situations. It originally comes from tropical America and its introduction into Africa is continuing to be felt as it spreads across the continent. It can grow up to up to 2-3m tall with its climbing/scrambling stems up to 5m – aided by its many thorns.

The stems are angled (square-sided) and armed with numerous small, backwards-curved prickles (3-6mm long) that assist the plant to scramble or climb on other plants. These stems become somewhat woody with age, and are much branched from the base of the plant.

M. diplotricha's twice compound leaves are dark green, alternate on the stem and have prickly stalks (petioles) and consist of 4-9 pairs of branchlets, each bearing 12-30 pairs of small leaflets. These leaflets (6-12mm long and about 1.5mm wide) are stalkless (i.e sessile), elongated in shape and have pointed tips.

Its pink or purplish flowers consist mainly of fluffy globular clusters (about 12mm across) of stamens. The flower clusters are borne singly or in small groups on stalks 3.5-16mm long that arise from the leaf forks. The fruit is an elongated and

flattened pod (8-35mm long and 3-10mm wide) containing 3-5 one-seeded segments that break apart when the fruit is mature. The small seed pods are pale green (turning to brown if they dry on the plant) and are found in groups of 5 to 20 at the ends of short stems; both the leaf stems and the pods also have small spines. The seeds (2-3.6mm long and 1.9 -2.7mm wide) are flattened light brown in colour, glossy in appearance and egg-shaped in outline.

The term "sensitive plant" describes the habit of the leaflets to close up if touched (and at night). This mimosa invades wet waste places, disturbed areas, plantations, pastures, cultivated ground and in Burundi it has been seen invading roadsides and city drains. The species may exhibit several different growth forms and can develop into dense thickets.

Impacts

- The plant can grow to at least 5 meters high on shrubs and trees and can weight these down and eventually cause them to fall over – this "behaviour" is easily seen when *M. diplotricha* invades cassava (manioc) fields, climbs upon the plants and all fall to the ground (spoiling the crop).
- It grows very fast and can form impenetrable thickets that prevent access to water, pasture, and fruit trees and can reduce crop yields as a weed on farms and thus livelihoods obtained from fishing, farming and livestock are affected.
- As a weed in cropping areas, it increases the cost and effort required to remove weeds (before and during crop growth) due to the prickles on steps and leaves; its dense growths can also prevent the growth of other plants.
- Thickets of the tangled stems can seriously injure humans and trap animals that may die.

M. diplotricha climbing upon tall manioc (cassava).

Pathways of spread

- The impenetrable thickets that it forms make it attractive for use as a hedge plant meaning that people uproot and replant plants for live fences.
- The plant also produces beautiful pink/ mauve flower balls and people have used it as a garden flower thus enhancing its spread.
- The seed pods are spiny, flattened and can easily stick on to animal fur/coats and people's clothing thus enhancing spread.
- Earth-moving activities like road building and soil dumping have been implicated in its spread as soil containing seeds is moved from one place and dumped in another; seed may also be spread on earth- moving equipment.
- The pods can float on water thus spread to other areas as a result of flooding or heavy rainstorms.

Management / control

- *Mimosa diplotricha* may be controlled physically by slashing, harvesting and burning the plants, but this is hampered by the thorns and the seeds can endure the heat of fire and germinate later (in this case, "later" can mean up to 50 years for seed to remain viable!).
- Chemicals such as paraquat and glyphosate have been used quite effectively but their effects on non-target species makes this risky - especially when dealing with aquatic ecosystems where the poisons may affect water quality, fish, irrigation and peoples' domestic use – and the seeds are not affected by herbicides so the "seed-bank problem" remains.
- The most sustainable and cheapest means of management is biological control using its natural enemies from its homeland. One highly specific sap-sucking psyllid (*Heteropsylla spinulosa*) has been very effective in controlling this mimosa in tropical Australia as it causes the growing tips of the plants to die - thus reducing both growth and flowering to a manageable level.

Mimosa diplotricha was first recognized as an invader in Bujumbura, Burundi in 2007 near the shores of Lake Tanganyika. Since then, it has spread across parts of the city, along roads, city drains and damp areas, as well as more of the lakeshore, irrigation areas and farms. It is now widespread at the Ntahangwa River delta where it is also moving into the reed swamps as well as combining with two other destructive invasive, spiny, related species, the giant sensitive plant, *Mimosa pigra* and the prostrate *M. pudica*. It is also reported from "up-country" Burundi and is growing well amongst the Oil Palm plantations near the lake, south of Bujumbura to Nyanza. It is likely to spread further in Burundi and move to neighbouring (riparian) countries unless checked soonest. *Mimosa diplotricha* is especially destructive because it can thrive across a range of ecosystem types: wetlands, forests, grasslands, wild lands, disturbed areas and roadsides, crop lands and pastures.

Climbing and shrubby *Mimosa diplotricha*.

11. *Mimosa pigra*

Sub-Family: Mimosoidea; Family: Fabaceae; Order: Fabales

Common name: Giant sensitive plant

Mimosa pigra is an upright prickly leguminous shrub or tree that can reach up to 4m in height. It originates from tropical South and Central America but has been in Africa for at least 200 years: as an uncommon riparian plant –which has recently started to spread and become invasive in many parts of wetland and floodplain Africa. There is a possibility that this recent spread and invasiveness is due to the recent arrival of its mycorrhizae or associated soil bacteria that assist it to fix nitrogen - but this is not confirmed.

Its young stems are greenish in colour, rounded, have scattered prickles (5-12mm long) and are covered with short stiff hairs. Older stems become woody and turn greyish to dark red in colour. The leaves are soft, green, finely-bipinnate, are alternately arranged along the stems and are borne on short stalks (petioles). The leaflets (3-12mm long and 0-5.2mm wide) are elongated in shape and are stalkless. They fold inwards when touched and at night (hence the name "sensitive plant").

The flowers are balls of stamens usually pink or mauve, sometimes almost yellow in colour. The fruits are clustered pods, with a furry brown coating of plant hairs, which break up into small sections (with one seed in each) when they mature. Individual flowers have four tiny sepals (0.75-1mm long), four inconspicuous petals (2-3mm long) and eight prominent pinkish stamens that give the flower clusters their fluffy appearance This plant has gradually become invasive in wetlands, lake and river edges and floodplains in many parts of the tropical and sub-tropical world.

Mimosa pigra shrub with flowers and pods (*M. diplotricha* with dark pink flowers below).

Impacts

- *Mimosa pigra* is known to cause extensive damage to local vegetation by displacing native vegetation while forming a single species thicket which can be impenetrable to people and most animals.
- *M. pigra* can diminish grazing/ pastoral lands especially floodplains and reduce habitat diversity for wild animals and plants.
- It can block waterways with impacts on transport and fisheries and can prevent peoples' access to both aquatic and terrestrial habitats.
- Tourism is at times affected when this plant invades protected areas and wildlife can be excluded from their feeding grounds by *Mimosa pigra* invasions.
- *M. pigra* can also affect water flow in natural streams and irrigation canals and is very difficult to remove in the long-term.

Pathways of spread

- The seeds are readily spread be floating on water and being swept away by currents – in streams and floodplains.
- The seedpods adhere to clothing and coats of mammals (including cattle and small stock) and feathers of birds and can thus spread far and wide.
- The seeds and pods can also stick onto vehicle tyres facilitating their spread – by cars, farm vehicles and earth-moving machinery.

Management / control

- Before thickets are established, isolated plants can be managed by mechanical removal through slashing, excavation of roots and burning. The method is very labour-intensive and may stimulate seed germination due to the removal of seed coats.
- Herbicides may be used with subsequent sowing of competitive plants to suppress regeneration from seed; aerial spraying may be needed when the height and density of *Mimosa pigra* hinders access.
- Biological control is the most cost effective and long-term control strategy for *Mimosa pigra* and there is a range of biocontrol agents available which have been used in Asia and Australia including seed feeding beetles (different species feed on both green and ripe seeds), flower bud feeding beetles (weevils), root and seedling feeding beetles and leaf-feeding moths.
- A more integrated plan combining mechanical, chemical and biological control may result in quicker and more effective management results to reduce an invasion and prevent its spread.

Older woody plants of *M. pigra*.

12. *Mimosa pudica*

Sub-Family: Mimosoidea, Family: Fabaceae, Order: Fabales

Common name: Common sensitive plant

Mimosa pudica is a perennial herb that is native to South America and Central America which is weedy in many tropical and sub-tropical countries around the world. It is called the sensitive plant (since it closes its leaflets when touched). It is a prickly, long-lived, herbaceous plant or small prostrate shrub with a creeping or sprawling habit. It usually grows 05-50 cm tall, but can reach up to 1m or more in height when supported by other vegetation and when in competition with other species. The foliage also closes under various other stimuli like darkness, warming, blowing or shaking. It is still expanding its distribution in Africa and is sometimes found in association with *M. pigra* and *M. diplotricha* – as it shares a preference for damp situations but can also grow on roadsides and disturbed areas that are drier.

M. pudica's stem is slender, branching and sparsely prickly and often growing horizontally. The leaves are alternate, with a relatively long (prickly) petiole bearing 4 groups of pinnae at the distal end. There are 10-26 pairs of leaflets which are 6-15mm long and 1.2-3mm wide.

The flower heads are globose, pale pink or purple and arise from the leaf axils. They are held in ovoid, stalked heads of 1-1.3 long and 0.6-1 cm wide. A cluster of 1-5 flower heads is borne on the leaf axil. The plant flowers all year round each plant producing many seeds per year. Seeds remain viable for many years making eradication or permanent clearing difficult.

The pods are 1.8cm long and 3-5mmwide, densely bristly, clustered and have prickles along their margins. They are pollinated by wind and insects. The fruit consists of clusters of two to eight pods from 1-2cm long each which are prickly on the margins containing seeds are pale-brown when ripe.

Mimosa pudica showing the stemmed leaves with four pinnae at their ends and flowers.

M. pudica in prostrate form.

Impacts

- The species can be a troublesome weed in tropical crops particularly when fields are hand cultivated. It tends to affect maize, coconuts, tomatoes, coffee, cotton, bananas, sugar cane, soy beans and papaya.
- When some varieties are fed on by livestock (when used a forage plant) they can be poisonous/ toxic.
- *M. pudica* is able to form dense ground cover preventing growth and reproduction of native plants by competition for light and space; when it grows with the other two species of Mimosa, the two or three together can completely obliterate any other native vegetation – especially in damp and riparian situations.

M. pudica in dense almost-bushy growth.

Pathways of spread

- *M. pudica* has been planted as a favourite ground cover and is grown as an ornamental plant because of its pink flowers and its ability to move the leaflets.
- The pods can attach to fur of mammals, to bird feathers and to human clothes and vehicles (including farm and road-making equipment) thus transferring this species from place to place.
- Pods are also spread by floating on water.
- Seeds may be spread by grazing animals.
- It is also spread when soil is moved from place to place during road construction.

Control

- Mechanical control may involve uprooting/ digging out and burning. Hand-weeding of older plants is difficult because the plant's prickles can break off and irritate the skin.
- Many herbicides may be used to control the plant including pycloram, glyphosate, triclopyr and tebuthiuron.
- *Mimosa pudica* is susceptible to a number of biological control agents and it has been noted that it is severely damaged by the fungus *Fusarium pallidoroseumi* and larvae of the Brazilian moth *Psigida walkeri* severely defoliates it (this agent will also have a destructive impact on *M. diplotricha*).

D. Terrestrial plants that do not depend on (or tolerate) standing water for any length of time. Their significance for Lake Tanganyika is their presence in buffer zones near the lake and its wetlands and in drainage areas of the lake ecosystem - which they can influence (as invasive species) by changing water quality and quantity that drains into the lake.

13. *Pennisetum purpureum*

Family: Poaceae, Order Poales

Common name: Uganda grass, elephant grass

This is a species of grass native to the tropical grasslands of Africa. It is a tall perennial plant growing to 2-4.5m high rarely up to 7.5m.

The flowering stems are upright, at least initially and relatively robust (up to 3cm thick). They are branched, particularly towards the top and are somewhat hairy. Older stems often produce roots from their lowermost joints and sometimes these long stems fall over and produce similar roots where they come into contact with the ground.

The alternately arranged leaves consist of a leaf sheath that partially encloses the stem and a spreading leaf blade. The leaf sheaths are hairless to stiffly hairy and are often particularly hairy near where they join the stem. The narrow leaf blades (30-120cm long and 1-5cm broad) are generally much less hairy. The large leaf blades have a prominent whitish central vein, a pointed tip and rough margins. Where the leaf sheath meets the leaf blade there is a dense fringe of hairs 1.5-5mm long.

The seed head is a dense cylindrical spike to 30cm long, usually brownish-yellow, with spikelets 4-7mm long. It is very bristly and is actually made up of a hairy main stalk with numerous very short branches each of which have a few (1-5) flower spikelets only one of which is normally fertile. These flower spikelets are surrounded by numerous bristles (8-16mm long) in several rows, the outer ones being shorter that the inner ones. Each of the flower spikelets have three yellow stems and a feathery two branched stigma that is purplish in colour.

When the seeds are mature the entire flower spikelet (including the bristles and the other sterile spikelets) turns brownish in colour and falls from the seed-head as a whole. The oval or egg shaped seeds (1.8-2.2mm long) remains concealed inside the remains of the fertile flower spikelet.

P. purpureum spreads by stolons and seeds. It has high productivity as a biofuel crop. However, it is a weed of waterways, wetlands, floodplains, open woodlands, forest margins, pastures, plantation crops, roadsides, disturbed sites, and waste areas. It favours moist conditions or high rainfall.

Impacts

- Studies have shown that it has suppressive effects on neighbouring plants of different species, through allelopathic interactions. Its above-ground tissue debris can reduce the fresh weight of some crops including maize.
- Its tall growth is capable of crowding out other species (of grasses and other plants) and obscuring vision on roads.

Pennisetum purpureum at lake edge.

Pathways of spread

- The seeds can stick onto animal fur or coats and human clothes facilitating movement from place to place.
- The seeds are light enough to be blown by wind.
- *P. purpureum* is sometimes introduced as a wind break and a pasture grass – as well as an attractive garden plant.
- The seeds may also be spread as contaminants of agricultural produce.
- The seeds can spread by floating on water beside roads and in drains.

Management/ control

Not withstanding its value for forage, napier grass has become one of the worst weeds in the tropics because of the difficulty of controlling it in croplands and fallow areas.

- Cultivation alone is not sufficient to control it in croplands and frequent mowing will help in its replacement by other grasses.
- The herbicide glyphosate provides acceptable control in aquatic sites.
- Sometimes, it should be burnt off and any regrowth sprayed with 2,2-DPA products e.g. Shirpon or Dowpon.

Pennisetum purpureum at a roadside benefitting from moisture run-off.

14. *Lantana camara*

Family: Verbenaceae, Order: Lamiales

Common name: Lantana, Tick berry

This frequently flowering plant is considered to be an invasive species in many tropical and subtropical areas. The native range includes Mexico, Central America, Bahamas, Colombia and Venezuela. It has become naturalized in tropical, subtropical and even warm temperate regions of the world. It is a heavily branched shrub that can grow as compact clumps, dense thickets and as scrambling and climbing vines. It usually grows to 2-4m tall as a shrub, but can "climb" a tree up to 15 m or more.

The stems are green and square with small recurved prickles – although some plants are without the prickles (this is a very variable species or species complex). As they mature the stems become rounded and turn grey or brown in colour. The leaves have a characteristic pungent odor and are bright green - about 6cm long with rounded edges and grow opposite one another along the stem (i.e. in pairs). They are simple and have leaf stalks that are 5-30mm long and a toothed margin. The leaf blades are mostly egg shaped in outline with broad end at the base and are 2-12cm long and 1.5-7cm wide. The texture of the leaf is quite rough, the underside can be softly hairy.

Lantana's dense flower clusters consist of numerous small tubular flowers (9-14mm long and 4-10mm across). These flower clusters are borne on stalks originating in the leaf forks (axils). The flowers can be a wide variety of colours, from pale cream to yellow, white, pink, orange, red, lilac, and purple are about 2.5cm in diameter and made up of three circles of florets, each usually of a different colour. This results in over 100 different combinations of flower colour in wild varieties.

Fruits are 3-6mm in diameter, glossy, rounded, green when young and then fleshy and purplish black when ripe and contain 1-2 seeds. The plant flowers and fruits all through the year with a peak during the first two months of the rainy season.

Lantana grows in a wide variety of habitats from exposed dry hillsides, to wet heavily shaded gullies. The plant is listed in Category 1 "Invasive Toxic Species" or "Noxious Weeds" in countries where it is problematic. Its leaves are rich in alkaloids and so are almost immune to herbivory (apart from the special insects from its homelands which are immune to the chemicals). *L. camara* is found in many protected areas in Africa with warm climates as well as inhabiting roadsides, along foot paths, deserted fields, and farms – and even urban areas.

Impacts

- The pentacyclic triterpenoids contained in its foliage cause hypertoxicity and photosensitivity in grazing animals such as sheep, goats, bovines and horses.
- *L. camara* prevents the regeneration (and germination) of any other plants that come in contact with its fallen leaves due to their containing allelopthic properties including important and rare native species of plants and food items for many African animals

- Lantana forms dense, impenetrable thickets that take over native bushland and pastures
- It competes for resources and reduces the productivity of pasture and forestry plantations
- It adds fuel to fires and is especially problematic in forests (production and conservation types) where fires can "run up the ladder" provided by lantana's climbing stems: this allows ground fires to reach the forest canopy and kill the trees from the top
- *Lantana camara* is a problem in gardens because it can cross-pollinate with cultivated varieties to create new, more resilient forms.

Pathways of spread

- Lantana can colonize new areas when its seeds are dispersed by birds which eat the fruits, but sometimes, by sheep, goats, cattle, monkeys and rodents. It also reproduces and disperses by vegetative means from broken plant parts and from stumps or batons left in the ground
- Efforts to eradicate it have been thwarted by its ability to spread quickly, ability to coppice so well and resistance to fire.
- It was mostly spread as an ornamental for gardens and hedges – from which it readily escapes or is transported by birds (and even children who eat the sweet-tasting fruits).

Management/ control

Before choosing which control methods to use, it is important to know the site, density, and geographic location of infestations.
A combined approach of different control methods including mechanical, chemical, fire and biological – compliant with land management practices - is most effective.

- Mechanical control may be difficult because stems are prickly and the plant often covers extensive areas. Isolated plants can be dug out. Physical removal or burning can be effective provided that desirable trees are introduced to shade out regrowing lantana plants; but the seed bank problem remains and the seeds remain viable for years
- Effective herbicides include 2,4-D, MCPA, dicamba, trichlopyr, glyphosate and picloram
- Many biocontrol organisms have been used in Lantana control, these include *Teleonemia scrupulosa*, *Octotoma scabripennis*, *Calcomyza lantanae* and *Ophiomyia lantanae*. These are effective in reducing the vigour of the plants and their flowering and fruit/seed production.

15. *Ricinus communis*

Family: Euphorbiaceae, Order: Euphorbiales

Common name: Castor oil plant

Castor oil plant inflorescence and leaves.

This is a flowering plant indigenous to the South Eastern Mediterranean basin, North-Eastern Africa and India and is now widespread throughout tropical regions. It is a fast growing, suckering perennial shrub which can reach the size of a small tree.

The glossy leaves are 15-45cm long, long-stalked, alternate and palmate with 5-12 deep lobes with coarsely toothed segments. In some varieties they start off dark-reddish purple or bronze when young gradually changing to dark green sometimes with a reddish tinge as they mature. The leaves of some other varieties are practically green from the start whereas in others a pigment masks the green colour of all the chlorophyll-bearing parts, leaves, stems and young fruits so that they remain a dramatic purple or reddish brown throughout the life of the plant.

The flowers are borne in terminal panicle-like inflorescences of green or in some varieties shades of red monoecious flowers without petals. The male flowers are yellowish green with prominent green stamens and are carried in ovoid spikes up to 15cm long. The female flowers are borne at the tips (tops) of the spikes and have prominent red stigmas.

The fruit is a spiny greenish to reddish-purple capsule containing large, oval, shiny, bean-like highly poisonous seeds with variable brownish mottling. Castor seeds have a warty appendage called the caruncle which promotes its dispersal by ants. Its seed is the **castor bean** which is the source of **castor oil**. The seed also contains ricin, a toxin which is also present in lower concentrations throughout the plant.

Impacts

- *Ricinus communis* is capable of displacing native plant species in riparian areas and drainages. Its seeds are amongst the first to germinate after a fire giving it a "head start" in competition with local species.
- Plants colonize disturbed areas, as they grow rapidly, shading out native species seeds and seedlings and producing monospecific stands in areas with previously healthy native vegetation.
- It causes symptoms such as stomach irritation, diarrhoea, abdominal pain, increased heart rate, profuse sweating, collapse, and convulsions when ingested by humans. Broken seeds can cause skin irritations. Seeds that are ingested but not chewed will likely pass through the body harmlessly. Humans and horses are vulnerable to the seeds if they are chewed.
- This plant is also toxic to most insects.

Castor oil plant establishing in a reedy buffer zone

Pathways of spread

- *Ricinus* is widely grown as an ornamental plant and as a source of castor oil.
- The seeds may be spread by road-building machinery/ earth-moving equipment.
- The seeds are often dispersed by floodwaters and animals like rodents and birds.
- Humans also spread the seeds in dumped garden waste, mud, soil and on vehicles.

Management/ control

- *Ricinus* can be controlled by digging it out and removing it from the site of concern.
- The herbicide Glyphosate can be applied on cut stumps to ensure plants die.
- 2,4-D has been known to be effective on young plants.
- When it becomes weedy in neglected cropland, and pasture, it is a matter of controlling through cultivation and mowing.

Dense growth of *Ricinus communis*.

16. *Senna alata*

Subfamily: Papilionoidea, Family: Fabaceae, Order: Fabales

Common name: Candle bush, Candelabra bush

Senna alata is native to Mexico and can be found in diverse habitats. In the tropics it grows up to an altitude of 1200m. It is an invasive species in many countries.

Senna alata is a large shrub with very large once-compound leaves consisting of 8-14 pairs of leaflets. The very large leaflets (5-17cm long and 2-5cm wide) have margins and rounded tips. The leaves are alternately arranged along the stems and can be very large (30-80cm long and 12-25cm wide). They are borne on stalks 2-4cm long and have 8-14 pairs of leaflets. The individual leaflets (5-17cm long and 2-5.5cm wide) are oblong or oval in outline and have entire margins.

Its golden yellow flowers are borne in dense elongated clusters (30-60cm long) near the tips of the branches or in the upper leaf forks. The inflorescence looks like a yellow candle. These clusters are borne on hairy stalks 15-30cm long and contain numerous (20-40) densely crowded flowers. The individual flowers (2-3cm across) are borne on short stalks 5-8mm long. They are initially held within dark yellow or orange coloured bracts but these fall off as the flowers open. Each flower has five sepals (9-15mm long and 8mm wide), five bright yellow petals (up to 20mm long and 12mm wide) and two stamens with relatively large elongated anthers (11-12mm long). There are also eight small filaments (2-4mm long) that do not have any anthers or only have rudimentary anthers.

Senna alata has large and elongated pods (12-25cm long and 8-20mm wide) that are somewhat four-angled and have papery wings – the reason for the species name. They turn dark brown to black in colour as they mature and contain numerous (about 50) dark-coloured seeds. These pods are somewhat four-angled in cross-section and have papery wings (about 6mm wide) along these angles.

S. alata is a weed of waterways, floodplains, wetlands, drainage channels, native bushland, disturbed sites, waste areas, roadsides, and overgrazed pastures in wetter tropical and subtropical environments – and can easily turn from a weed to an invasive plant.

Impacts

- Seedlings establish an extensive root system in the first year and compete for space and nutrients with other plants.
- *S. alata* can be a significant agricultural weed.
- It is capable of impeding water ways and disturbing drainage and certainly changing the nature of any occupied natural drainage lines into the lake.
- It is suspected of being poisonous to livestock.

Pathways of spread

- *Senna alata*'s seeds are distributed by water aided by the ability of the seed to float considerable distances.
- It is also intentionally spread as an ornamental flowering plant and an attractive hedge species.
- It's seeds can become attached to mud sticking onto vehicles, machinery and animals.

Management / control

- Seedlings can be pulled out or dug out, roots must be removed.
- Larger stands are slashed close to the ground and cut surfaces treated with 2,4-D plus picloram or triclopyr.

17. *Senna obtusifolia*

Subfamily: Papilionoidea, Family: Fabaceae, Order: Fabales

Common name: Sicklepod or Chinese Senna

This species of *Senna* is native to tropical America and grows wild in North, South and Central America, Asia, Africa and Oceania and is considered a particularly serious weed in many places. *Senna obtusifolia* is a short-lived (annual and biennial) shrub growing up to 2.5m tall, but usually less than 2m in height.

The lower stems often sprawl along the ground in open areas. Plants produce numerous, branched, sprawling stems that are 1.5-2m long. These stems are usually softly hairy when young, but become mostly hairless with age.

The foliage has a slight odor. The compound leaves are alternately arranged along the stems and are borne on relatively short stalks 15-20mm long. They have two or three pairs of leaflets (17-65mm long and 10-40mm wide) with those further from the leaf stalk usually being larger. The leaflets are egg-shaped in outline with the narrower end attached to the stalk and have rounded tips (obtuse apices). Their surfaces may either be hairless or sparsely hairy and the entire margins are usually edged with tiny hairs. There is a small elongated structure (gland) 1-3mm long located on the main leaf axis between the lowest pair of leaflets (occasionally also between the second pair of leaflets as well).

The yellow flowers (10-15mm across) are borne on stalks (pedicels) 7-28mm long. These flowers usually occur in pairs in the leaf forks and are mostly located near the tips of the branches. They have five green sepals (5.5-9.5 mm long) and five yellow or pale yellow petals (8-15mm long). Each flower also has seven fertile stamens with anthers (3-5mm long) that have short narrow projections on one end.

The fruit is a slender, strongly curved downwards sickle-shaped pod (6-18cm long and 2-6mm wide) that is almost round in cross-section, containing 25-30 seeds each, sometimes slightly flattened or four-angled. The pods turn brownish-green as they mature and are slightly indented between each of the numerous seeds. The seeds (3-6mm long) are brown in colour, shiny in appearance and either diamond-shaped or irregular in shape. The plant is a prolific seed producer and seeds may remain viable in the soil for several years.

S. obtusifolia is invasive in disturbed sites, waste areas, roadsides, riparian zones, flood plains, drainage canals, open woodlands, fallow land, crops and pastures in wetter tropical and subtropical environments.

Characteristic leaflets of *Senna obtusifolia*.

Impacts

- *Senna obtusifolia* can grow as a pasture weed thus diminishing pasture land and affecting pasture productivity and dependent livestock productivity.
- It is a significant agricultural weed that also invades natural plant communities – competing with similar-sized plants.
- It grows in dense thickets, competing for light, water, nutrients and displacing native vegetation.

Pathways of spread

- Seeds are dispersed by water and animals that eat the pods (e.g. cattle, wild herbivores).
- They may also be spread as a contaminant of agricultural produce (fodder and pasture seeds).
- The seeds may stick in mud that is then carried around by animals, on footwear, machinery and vehicles.
- It is introduced for use as a green manure, for poles, hedges and firewood and so can disperse seeds in this way
- It is introduced in some places as an ornamental.

Management / control

- *Senna obtusifolia* is very difficult to control with cultivation which usually results in spreading rather than controlling this weed
- Hand pulling is difficult because of its long curved taproot.
- Slashing reduces vigour and if combined with other management measures such as restricted grazing and soil fertility augmentation, can bring this plant under control.
- A variety of herbicides can be used to control it. Their success depends upon environmental conditions – especially if the plants are near water.
- A number of biological control organisms have been used in its control and some micro-organisms have even been formulated into mycoherbicides to give greater than 96% control.

Sparse shrubs of *Senna obtusifolia* showing sickle-shaped pods.

18. *Senna occidentalis*

Sub-Family: Caesalpinioidea, Family: Fabaceae, Order: Fabales

Common name: Coffee senna, Stinking weed

Senna occidentalis is a pantropical plant species native to tropical America which was formerly placed in the genus *Cassia*. It usually flowers and fruits as a shrub up to 2.5m tall with distinctly pinnate leaves and yellow flowers.

Leaflet blades are about 40-70 x 15-25mm, the terminal pair being the largest. A conspicuous raised gland is present on the upper surface of the compound leaf petiole shortly above its junction with the twig. The alternately arranged, compound (pinnate) leaves are borne on reddish stalks 3-5cm long. They have three to five pairs of oppositely arranged leaflets (3-10cm long and 2-3cm wide) that are oval in shape with acute apices.

The yellow petals are about 13mm long. Stamens are 10 in number, six fertile (two large and four smaller) plus four staminoides. The ovary is curved and clothed in white prostrate hairs while the stigma is green and recurved.

Pods are slightly inflated, about 10-12 x 0.8-1.1cm long, septate and bent upwards. Seeds measure about 5 x 4mm, olive green in colour, transverse in the pod and slightly sickle-shaped or almost straight pod. Each pod contains 20-35 seeds. The upright stems are sparsely branched, smooth or sparsely hairy. They are reddish-purple in colour or somewhat four-angled or grooved when young, but turn greenish –brown in colour and become rounded as they mature. The species gives off a foul odor especially when the leaves are crushed or otherwise damaged. It is a weed of roadsides, waste areas, disturbed sites, pastures, grasslands, open woodlands, coastal environs and crops in tropical, subtropical and semi-arid regions. It is, however, used as a medicinal plant by some who believe that it prevents malarial infections; it is also used as a substitute for coffee in some parts of the tropics.

Leaves and pointed leaflets of *Senna occidentalis* with flowers.

Impacts

- *Senna occidentalis* is reported to be poisonous to cattle. Leaves contain anthraquinones while the roots contain emodin and the seeds contain chrysarobin.
- *S. occidentalis* displaces native and pasture vegetation by forming monocultures in areas invaded and then spreading wherever sufficient moisture is available – in roadside drains, small streams and wetland edges – and near the edges of Lake Tanganyika.

Characteristic pods of *Senna occidentalis* showing septate arrangement and upright curved shape.

Pathways of spread

- The seeds are dispersed by water or in mud sticking to animals, humans, machinery and vehicles.
- They may also be spread as a contaminant of agricultural produce.
- It is introduced in some places as an ornamental and tended carefully in other places resulting in heavy seed production and consequent dispersal.
- It has become invasive in forests where it was introduced as boundary markers.

Management / control

- Mechanical removal of plants is quite effective – but, of course, a seed bank remains to germinate and grow again
- In fields these plants are not usually problematic because of the usual farming practices – but in inactive fields, they can spread and form monocultures to the detriment of native plants. However, in some situations there is local objection to the removal of *S. occidentalis* because of its reported medicinal value.

Dense growth of *Senna occidentalis*.

19. *Senna hirsuta*

Sub-Family: Papilionoidea, Family: Fabaceae, Order: Fabales

Common name: Hairy senna, Wooly senna

Senna hirsuta is an erect herb or shrub, up to 2.5m tall, becoming soft woody with age. It is native to Southern USA, Mexico, Central America, the Caribbean, and tropical and subtropical South America. It is recorded as invasive in tropical Australia, parts of Asia and in eastern/southern Africa. *S. hirsuta* is found invading many areas such as roadsides, degraded lands and fallow fields – but it specializes in riparian areas – near lakes and streams – where it grows near (but not in) the waters.

The stems, leaves and pods are covered with long-greyish white hairs (hence its common name) and the stem is usually ridged lengthwise (longitudinally).

Its compound leaves (10-25cm long) are simply paripinnate (meaning the leaflets are even, in pairs) usually have 3-6 pairs of large leaflets (40-105mm long and 20-40mm wide) with those further from the leaf stalk usually being noticeably larger with pointed tips – and sometimes with a terminal or unpaired leaflet. There is a small finger-like projection near the base of the leaf stalk.

The bright yellow flowers are borne in small unbranched clusters at the tips of the branches or in the upper leaf forks. These clusters usually contain only 2-8 flowers, each flower being borne on a stalk 10-25mm long. The flowers have five petals (8-16mm long) which may become conspicuously brown-veined as they mature. They also have five sepals (6-8mm long) and six or seven fertile stamens with anthers 3-8mm long.

Senna hirsuta's fruit is a very slender, flattened pod (10-18cm long) that is usually curved slightly downwards (sickle-shaped). The pods are densely covered in long whitish hairs. They turn brown as they mature and are slightly indented between each of the seeds. The seeds are dark-brown in colour, dull in appearance and rounded in shape. It is fast growing and coppices well when cut near its base.

Throughout its native and naturalized range, *S. hirsuta* inhabits waste locations, roadsides, railway embarkments, dry ditches, disturbed sites, waste areas, plantation crops and fallow lands, open woodlands, pastures, grasslands and secondary forests. It can also be found in gardens and fields as a weed.

Senna hirsuta showing leaves, leaflets and flowers.

Senna hirsuta invading a woodland: note curved pods.

Impacts

- *S. hirsuta* is capable of displacing native vegetation – especially in riverine and wetland conditions where it spreads fast.
- Its preference for stream-sides results in altered water flows, changes in water content and loss of other native riparian plants which would, otherwise, have a role in water purification and sediment removal.
- It can be a significant weed of crops, especially in wetter areas, thus increasing the effort and cost of crop production.
- Some references report that *S. hirsuta* is poisonous – but with no details.

Pathways of spread

- *S. hirsuta*'s abundant seeds are the main agents of spread and are dispersed by water and animals that eat the pods
- They may also be spread as a contaminant of agricultural produce and the results of weeding fallow and cropping areas
- The seeds may be carried in mud sticking to animals, footwear, machinery and vehicles.

Management / control

There is no particular or special control mechanism for *Senna hirsuta*, so the best advice is to remove new plants from affected areas when they are young, best to do so before they flower or produce pods (and so seeds and a seed-bank) – especially in riparian areas and areas of conservation importance and water management. Plants need to be completely removed from their growing site as they have the capacity to re-grow from fragments of roots remaining in the soil.

E. Terrestrial plants distant from the lake that are able to influence water systems through alteration of quality and quantity of surface and sub-surface waters.

20. *Leucaena leucocephala*

Sub-Family: Mimosoidea, Family: Fabaceae, Order: Fabales

Common name: Leucaena, Lead tree, white popinac

This is a small variably shrubby and highly branched to medium-sized tree, native to tropical America but is now naturalized throughout the tropics – often as a result of introduction as an agroforestry species – because of its growth rate, nitrogen-fixing capacity and use of the foliage as livestock fodder.

The bark on young branches gives them a smooth surface and grey brown colour while this is an evergreen tree with relatively deep roots. It often has a combination of flowers, immature and mature pods all present on the tree at the same time – demonstrating that is potentially high-yielding where seed production is concerned – a factor contributing to its ability to invade.

Leucaena's leaves have 6-9 pairs of pinnate leaflets which are 9-16mm long. The leaflets fold up with heat, cold or lack of water. Flower heads are white or very pale cream in colour (hence its scientific name), 12-21mm in diameter with 100-180 flowers per head in groups of 2-6 in leaf axils, arising on actively growing young shoots. The pods are quite large, 9-19cm long and 15-21mm wide, and can be very many in number and stand out with their size and bright brown colour against the pale green of the foliage.

Seeds are dark brown with a hard shining testa (seed coat), 6.7-9.6 mm long, 4-6.3mm wide and aligned transversely in the pods. *L. leucocephala* tolerates fast fires and can regrow after being burned to the crown by slower fires.

It is an aggressive colonizer of modified lands and secondary or disturbed vegetation in many places: this is attributed to its precocious year round flowering and fruiting, abundant seed production, self-fertility, hard seed coat and ability to resprout after fire or cutting. It is now naturalized and weedy (often invasive) in many areas such as open (often coastal) habitats, semi-natural, disturbed, degraded habitats and occasionally agricultural land where it has been planted as an agroforestry tree. It is also promoted as a "miracle tree", mostly introduced for use as fibre, firewood, construction poles, sand-binding and livestock fodder. The tree is known to be highly invasive in various parts of the world where it grows quickly and forms dense thickets which crowd out any native vegetation. It grows very fast in suitable areas, coppicing to form dense, homogenous thickets that are difficult to control once established.

Leucaena leucocephala trees within 100 m of Lake Tanganyika.

Impacts

- Areas invaded by leucaena become unusable and inaccessible with most other vegetation replaced – with consequences on downstream waters and wetlands.
- It constitutes a threat to native biodiversity since once it establishes itself it displaces local plant species with subsequent impacts on native animals.
- It can promote conditions for the establishment of even more aggressive invaders.
- The toxic substance mimosin in the leaves of leucaena can cause hair loss, infertility and stomach problems in livestock especially those that are not ruminants.

Pathways of spread

- *L. leucocephala* is frequently promoted for afforestation or agroforestry due to its fast growing nature – and continues to be planted widely, even though its invasive characteristics in tropical Africa are well-known.
- It can be dispersed by small animals (rodents and birds) and livestock.
- The light pods may also be spread short distances by wind and water and can float on water.

Leucaena leucocephala bearing many seed pods.

Management / control

- Grazing by goats has been used as an effective management technique in controlled situations.
- Cutting and uprooting can work for younger plants at a localized scale but older plants are likely to re-sprout after such interventions. Cutting must be followed by herbicide application to the cut stump to prevent coppicing.
- A biocontrol agent (a psyllid sap-sucking insect *Heteropsylla cubana*) defoliates *Leucaena leucocephala* resulting in severely reduced fodder as well as wood but does not kill the plants.
- There are also insect seed predators that affect the seed production and viability but do not seem to stem its spread. *Acanthescelides macropthalmus*, a seed-feeding bruchid beetle is being released for Leucaena's control in some places.

Young trees of *Leucaena leucocephala* producing pods.

21. *Psidium guajava*

Family: Myrtaceae, Order Myrtales

Common name: Guava, Edible guava

Psidium guajava is an evergreen shrub or small tree generally 3-10m high with many branches. It originates from tropical America but has been spread around the tropical and warm temperate world as a fruit-tree which produces two main types of fruit familiar to most people – with the yellow-cream flesh and the pink flesh. It has rather recently escaped from domestication (and orchards) and become troublesome – see below.

The stems of this guava are often crooked, the bark is usually light to reddish brown, thin, smooth and continuously flaking. The rooting system is generally superficial and very extensive, frequently extending well beyond the canopy.

Guava leaves are arranged opposite each other on the stem, simple with margins that are entire somewhat thick and leathery dull grey to yellow-green above, slightly downy below with prominent veins. The inflorescence (flowering area) is usually axillary and 1-3 flowered. The calyx is usually splitting irregularly into 2-4 lobes, whitish and sparsely hairy within, petals are 4-5 and white in colour. The white flowers measure 3-4cm in diameter and grow solitary or in clusters in the axils of leaves and become yellow at maturity.

The fruit is an ovoid or pear shaped berry 4-12 cm long weighing up to 500g. The skin turns yellow when ripe, sometimes flushed with red, the pulp is juicy, creamy white or creamy yellow to pink red, mesocarp is thick, edible and the seeds are kidney shaped or flattened. The exterior of the fruit is fleshy and the centre consists of a seedy pulp. It is readily pollinated by insects seeking nectar.

This species of guava is widely cultivated in the tropical and subtropical regions of the world. When cultivated from seed, guavas are notable for an extremely slow growth rate for several months before a very rapid acceleration in growth takes over. Guavas are highly adaptable and have become invasive in various tropical regions. *Psidium guajava* appears to have started to spread in relatively open areas such as savannah / shrub vegetation types or in frequently disturbed areas where it is a strong competitor in early secondary growth. It is considered a noxious weed in many tropical pasture lands. The guava is a very hardy tree that adapts to a wide range of growing conditions and can stand a wide range of temperatures.

Impacts

- *Psidium guajava* is capable of spreading and forming dense thickets that displace native species in woodland and open forest areas where they impede regeneration of native species.
- The tree grows quickly in forest gaps and can overrun fields and pastures.
- Interactions with other invasive species may lead to further invasions for example, it serves as a host of fruitflies.

Pathways of spread

- The tree is cultivated as an ornamental tree in gardens from which it can escape.
- Guava is also widely planted in orchards for its fruits – another source of escape.
- It is widely spread by fruit-eating bats and birds as well as other animals (e.g. rats, baboons and monkeys that raid plantations).

Management / control

- Extensive stands of young trees may be controlled by burning; but cutting usually results in regrowth with multiple stems.
- Regeneration from underground parts by suckering limits the effectiveness of manual control.
- Guava is sensitive to foliar spray by triclopyr, dicamba and 2,4-D.
- Goats and sheep can be used for control as they browse on the leaves and strip the bark.
- Seedlings and saplings may be pulled or dug out, roots must be removed.
- Larger trees can be cut and the stumps treated with herbicide.

Flowers and leaves of *Psidium guajava*.

Dense growth of wild (invasive) *Psidium guajava*.

22. *Caesalpinia decapetala*

Subfamily Caesalpinioideae, Family: Fabaceae, Order: Fabales

Common name: Mauritius thorn, Mysore thorn

This is a tropical prickly, climbing or scandent shrub or tree originating in tropical west Asia. The name "Mauritius thorn" implies that it might come from the Western Indian Ocean, but this is not so – and the reason for that name is lost in history.

C. decapetala's young branches are densely covered with tiny brownish or golden coloured hairs and have numerous sharp prickles. Older stems are thicker, greyish brown in colour and have larger thorns. The leaves (up to 30cm long) are twice compound, alternately arranged, dark green and have a pair of small leafy structures at their base. These structures (4-20mm long) are egg shaped in outline but taper to a point. The leaves are borne on stalks (petioles) that measure 3-8cm long. The extension of this stalk is slightly hairy, prickly and bears 4-10 pairs of branchlets. Each of these branchlets has 8-12 pairs of leaflets. The leaflets (7-20mm long and 2-8mm wide) are oblong in outline and somewhat hairy on both sides. The lower surface of these leaflets is significantly paler than the upper surface.

The flowers are usually pale yellow or yellow in colour (occasionally white) with five petals (10-15mm long), five sepals (9-10mm long), ten stamens (10-16mm long) and a style (15 to 20mm long) topped with a cup-shaped stigma. Four of the petals are almost circular in shape but the upper petal is smaller and narrower than the others. The flowers are borne on stalks 15-25mm long and arranged in upright, elongated clusters (10-40cm long) at the tips of the branches.

The fruits are flattened, oblong pods with a small projection at one end. These woody pods (6-10cm long and about 25mm wide) are hairy and turn from green to brown as they mature. When they are fully mature, they split open to release 4-9 rounded seeds. These seeds may be dispersed by rodents and granivorous birds and running water.

Caesalpinia decapetala has become a seriously invasive species in many locations. It can invade agricultural areas, natural forests, planted forests, grasslands, riparian zones, disturbed areas, shrublands, water-courses, bushy hillsides, along streams, forest margins and on roadsides.

C. decapetala pods.

Impacts

- Caesalpinia is capable of forming impenetrable thickets due to its dense growth and strong, sharp spines.
- It has a thorny smothering habit which can reduce flora and fauna habitat through forming dense monocultures.
- The thorns hinder access to livestock and other animals.
- Infestations alter light penetration thus affecting the growth of other plants and seedlings.
- The dense thickets near water courses reduce access to water.
- It out-shades and can smother native vegetation causing trees to collapse.
- It restricts access to forest, roadside and riparian areas, reducing aesthetic value and potentially seriously injuring people and may thus impact on tourism assets.
- It has adverse effects on pastoralism when it closes off pastures to animals. When it grows in forests, it then impedes forest pathways.

C.decapetala climbing a tree.

Pathways of spread

- *C. decapetala* is often planted as a hedge as it forms impenetrable thickets which keep out intruders – both people and wildlife including baboons, browsers and even elephants.
- It may be spread down water courses as floating vegetation or debris.
- It is available through the plant nursery trade in some places and introduced for ornamental purposes – from which it easily escapes.
- Through translocation of machinery/equipment the large seeds can be carried down streams to start new infestations.
- The seeds may be spread by animals (especially rodents and birds).

Management / control

- Foliar spray using Metsulfuron methyl based herbicides may be the best way to treat plants due to the numerous thorns and thicket-like structure that would make basal bark or cut stump treatments difficult. The herbicide should be applied when the plants are actively growing (before flowering). Triclopyr and glyphosate may also be used for the foliar spray.
- Since it is a prickly tree, extreme caution needs to be exercised when attempting to cut down or dig out the trees.
- Several species of insects have been evaluated for biological control, the seed-eating weevil, *Sulcobruchus subsuturalis* has been tested in the field, but it failed to establish and continued releases are being tried using improved strategies.

Caesalpinia decapetala inflorescence.

23. *Acacia mearnsii*

Subfamily: Mimosoideae, Family: Fabaceae, Order: Fabales

Common name: Black wattle

Acacia mearnsii is a small to medium-sized tree, reaching to 15 m at its highest, which originates from sub-tropical and warm temperate parts of southern Australia where it is most often found as a component of *Eucalyptus* woodlands. It is one of the Australian acacias that maintain pinnate leaves throughout life – unlike the majority of species which develop phyllodes. *A. mearnsii* was brought to and planted in many areas of Africa as a source of tannic acid (from the bark of the adult trees) for use in the tanning of hides.

Black wattle is an evergreen tree with grey-green bipinnate leaves (with 9 – 20 pairs of pinnae, each with 20 – 60 pairs of small leaflets) which have nectar glands along the main axis of the leaf. The flowers are pale yellow and showy, in large, sweet-smelling sprays which can almost completely cover the foliage when in full-flower. The fruits are dark-brown pods, 6 – 15 cm in length, which have noticeable constrictions between each seed – giving them a "lumpy" appearance. The numerous pods can remain on the tree for long periods of time and will, eventually, shed many seeds (if these are not eaten on the tree by small mammals or birds).

Acacia mearnsii is now widespread in eastern and southern Africa with densest invasions in South Africa and some remaining (tannin) plantations in other countries.

A. mearnsii tree in flower.

Impacts

- Black wattle has become invasive in many parts of eastern and southern Africa as a result of its fast growth, high yield of seeds, large seed bank and difficulty to control. It is able to spread from plantations or from single trees – and form thickets or incipient forests which dominate other plant life.
- This species has been recorded as one of the culprits that reduced stream flows in various parts of South Africa through excessive uptake of soil and surface waters – which became the origin of the Working for Water invasive species management programme.
- *Acacia mearnsii* can establish in woodlands, forests, edges of streams and wetlands as well as in commercial forest plantations and, in all cases, may replace native or planted vegetation.
- This species has a very efficient nitrogen-fixing capacity and can increase soil fertility for its own growth and for other invasive species.

A. mearnsii flowers.

Pathways of spread

- This tree produces masses of seeds when the pods split and drop them from the tree where they can be spread by wind and water.
- The seeds can also be spread by animals eating the pods – such as rodents and birds – and then dispersing them.
- Plantations of *A. mearnsii* have been sources of spread by the means above as well as through logging and bark collection traffic.
- The seed bank can be dense (reported as up to 20,000 seeds per m^2) and seeds can remain viable for over 50 years.

Management / control

- Mechanical means are quite effective in managing *A. mearnsii*, but caution requires that most roots should be excavated as they are able to shoot from any reasonable-sized root; this species is also capable of quick and prodigious coppicing – so tree trunks must be cut at or below ground level.
- Fire is quite an effective control agent – but, unfortunately, fire stimulates the germination as well as basal sprouting – which requires a follow-up to complete control.
- Chemical control of younger trees can be effective with glyphosate; mature trees can be killed using 2,4,5-T.
- Biological control agents are being investigated – especially seed-eating beetles; a recent success has been achieved using a flower-galling fly which can result in the plant producing only deformed flower buds which cannot produce fertile flowers (and so seeds).

A. mearnsii, pods.

Roadside infested with *Acacia mearnsii*.

24. *Tithonia diversifolia*

Family: Asteraceae, Order: Asterales

Common name: Mexican sunflower, Tree marigold

Tithonia diversifolia is native to tropical America but has a nearly pantropical distribution as an introduced and naturalized species. This tall herb can be either annual (dying back or dying out in the dry season and then germinating from seed the next rainy season), or perennial, meaning "remaining alive for several years with fresh growth each rainy season" This depends upon the regularity of rains, the general dryness of the area and the aspect of the plants. Both types can occur in the same country in eastern and southern Africa.

The mature leaves usually have five sharp lobes, that is, there are four quite deep divisions in the leaf and five points on the lobes. Occasionally, particularly in juvenile plants, there may be only three lobes visible. The alternately arranged leaves are borne on stalks (petioles) 2-10cm long. The leaf blades (6-33cm long and 5-22cm wide) have tapered bases and 3-7 pointed lobes with scalloped or toothed margins. The leaves are finely hairy.

T. diversifolia can grow to 2m (or even up to 5m) in height with upright hollow stems which sometimes develop secondary thickening (woodiness) when the plants are more than a year old. Only limited branching (even of tall stems) occurs except at the growing tips where flowers form. The bright yellow-flowers open with a "neat" set of petals which quickly become somewhat "ragged" petals which give the flowers an "unruly" appearance. The flower-heads are borne in small groups at the ends of the leafy branches, on stalks 7-30cm long. These flower-heads (5-15cm wide) look like sunflowers, but have yellow centres (3-5cm across). They have 7-15 bright yellow petals that are 4-7cm long and 9-16mm wide, each with three small teeth at their tips. There are also numerous (80-120) tiny yellow flowers (tubular florets) in the centre of the flower heads and they are surrounded by several rows of green bracts. Flowering mainly occurs during the rainy seasons, but there are often some flowers present year long.

The seeds are 4-8mm long and topped with a ring of scales and are covered in close-lying hairs, blackish in colour and are somewhat four-angled. *T. diversifolia* is a prolific seeder which retains its thousands of seeds per flower head until the plant dries in the dry season.

T. diversifolia flower & leaves.

This species can grow into thick stands with remarkably stout stems – some of which can be 3.5 cm in diameter. *Tithonia diversifolia* is capable of invading roadsides, cleared areas, abandoned farms, wild areas and fields. It is spreading rapidly in habitats such as grasslands, disturbed land and riparian zones especially banks of water courses leading into the lake.

Impacts

- *Tithonia diversifolia* exhibits allelopathic properties which prevent other plants from growing or germinating beneath or near it. It has been known to negatively affect the germination, growth and chlorophyll content of important crops.
- *T. diversifolia* can quickly colonize croplands thus affecting agricultural production systems.
- It can also form dense infestations in areas of native vegetation, spreading above and within wild growths of plants and seriously disturbing biodiversity.

Pathways of spread

- In some cases, *T. diversifolia* was imported as an ornamental plant which has then spread; they are also cultivated as green mulch and have been used as a cover crop for fallow fields.
- It may be promoted for use in agroforestry species since it has special properties related to accumulation of phosphorus.
- It is also spread when used as a live fence (or hedge) from which it can escape.
- When the seeds disperse, they are spread by wind, water and the movement of people, livestock and vehicles.
- People may spread it when using it as a fodder crop for livestock.

Management / control

- *Tithonia diversifolia* can be dug out when numbers are low. Slashing can result in resprouting from uncut stumps.
- Suitable herbicides can be applied as foliar spray or as spot spray
- Research into biological control options for this plant is being undertaken in various parts of the world as it spreads further and becomes a more widely acknowledged invasive species.

NOTE: Another introduced species of *Tithonia*, *T. rotundifolia* (red sunflower) can be confused with *Tithonia diversifolia* especially before it flowers. *T. rotundifolia* can grow to a similar height in similar habitats but has leaves without lobes or a maximum of three lobes and its stems branch much closer to the ground. The flowers are similar in shape, slightly smaller and bright orange or red in colour. Most recently, a third species of the genus, *Tithonia tubiformis,* has been identified invading maize fields in one of the L.T. riparian countries; this one is even taller than the others and overshadows crops and wild vegetation.

Dry season *Tithonia diversifolia*, 5m high.

F. Alien trees becoming invasive after many decades.

25. *Toona ciliata*

Family: Meliaceae, Order: Sapindales

Common name: Toon tree, Toona tree, Australian red cedar

Toona ciliata originates from tropical Asia (and Australia) and grows in a variety of sites such as well-drained woodlands, farming areas, river banks, lake edges and is used as a common shade tree and street tree as well as a decorative species.

This is a large (10 to 35 m in height with wide-spread branches) semi-deciduous tree which is fast-growing and with a wide and rounded crown and drooping foliage. The leaves are dark green, quite long (to 2m) and pinnate with 8-13 pairs of leaflets – and occasionally with a terminal leaflet. The trunk of the mature tree dark grey or reddish brown and smooth for the first years of maturity but then become rough with vertical cracks. The trunk at breast height can grow to a girth of 3 m in situations where the plant has no competition for light and space (i.e. "in the open").

The fragrant honey-scented flowers are small (around 5 mm long) white or cream in colour and borne in hanging inflorescences. Toona's fruits are woody capsules, 2 cm long which split open to release winged seeds which are blown significant distances by even faint winds.

This species was widely planted in colonial times as a shade tree in towns, especially around government offices, and sometimes as an "avenue" leading to important building. It is mentioned here because over the last 20 years or so, it has begun to spread from these locations and establish its own new colonies of fast-growing, sun-loving trees. This can lead to invasion and is a classic case of a "lag phase" in that this species did not begin to spread in the first half century or so of its establishment in Africa.

Young trees of *T. ciliata* beginning to invade a pine forest.

Impacts

- *Toona ciliata* is now regarded as an invasive species because it can spread both close to a "mother tree" or disperse widely and establish in disturbed forests, woodlands, river valleys and where there is sufficient light.
- It can enter, establish and then compete with trees in both young and mature production forests.
- Toona can form thickets that grow fast and dominate native vegetation and reduce biodiversity.

Pathways of spread

- Toona's pathways of spread start with the falling of seeds around a "mother tree" and then further dispersal by wind and/or water
- This species is favoured for agroforestry and so spread by organisations promoting its uses as a shade and timber tree, for tannin and, in some cases, the leaves are used for animal fodder.

Management / control

The authors are unaware of any established protocols for the management of *Toona ciliata* invasions but it is likely that young saplings or small trees could be uprooted and older trees treated with herbicides – especially treatment of stumps after the trees have been felled.

Senna siamea dominating village trees.

26. *Senna siamea*

Subfamily: Caesalpinioideae, Family: Fabaceae, Order: Fabales

Common name: Blackwood cassia, Iron wood

Senna (formerly *Cassia*) *siamea* is native to South-East Asia but, is widely-planted around the tropical and warm temperate world as a street tree and garden ornamental on account of its bright yellow flowers which, in some places, are present all year round. It is an evergreen tree of up to 15 m (rarely, in crowded conditions it may reach 20 m) with a widely-spreading crown (when grown in the open) and with smooth, pale grey-brown bark which is slightly fissured longitudinally.

The pinnate leaves which are dark green and composed of 7 – 10 pairs of oblong leaflets which are rounded at both ends; the whole leaf being up to 30 cm long – including the petiole. The notable flowers are bright yellow and found in dense heads on long stems (up to 30 cm long). The fruits are long flat pods (15-25 cm) with indentations between the seeds – yellow-brown and smooth when young, but turning grey, even black, when mature.

S. siamea is widely planted as an agroforestry species for its shade, small timber, poles, firewood, charcoal, livestock fodder, bee-forage, mulch, windbreaks and erosion control. This tree was mostly not invasive for the first many decades of its use in Africa, but has recently ended its "lag-phase" and is beginning to spread.

Impacts

- This species can produce seedlings ("wildlings") around its base and area of influence and when this happens in a plantation within natural woodland, the resulting spread of senna can result in a monoculture – eventually excluding all other species.
- *S. siamea* is increasingly forming thickets of young plants which slowly spread and dominate (and exclude) native vegetation.

Pathways of spread

- It spreads naturally through the seeds which can be dispersed by wind and water and the movements of animals.
- *Senna siamea* is a favoured agroforestry tree which continues to be spread and planted for that purpose and for the restoration of degraded and eroded lands.
- The pods and seeds can be eaten by ruminants (but are poisonous to non-ruminants) and then spread when the animals disperse.

Management / control

Senna siamea is most often seen as a beneficial tree and so there are few protocols for its control. Management in thickets would be by uprooting – preferably before any flowering begins - to ensure that no seed bank is established beneath the thicket. As with other trees that can coppice, removal of well-grown trees would require herbicide application to the stumps of cleared trees or complete removal of the larger roots – which can be quite widespread.

Senna siamea, young trees forming a thicket.

Senna siamea, at the lake edge.

G. Indigenous species that may be potential invasives: Many other species of organisms that are not alien may cause problems with water movement and wetland biodiversity and have local impact on people's uses of wetlands. They are often local species that respond to some changing circumstance that makes them more obvious when they increase their densities from what was considered "normal".

Tall specimens of *Phragmites australis* reeds in 1 m depth of water.

27. *Phragmites australis*

Family: Poaceae, Order: Poales

Common name: Common reed

This is a large perennial reed found in wetlands, lakes and rivers throughout temperate and tropical regions of the world. *Phragmites* is usually regarded as a monospecific genus with just one species *Phragmites australis* and probably several sub-species originating in different parts of the world which have now been mixed because of introductions over centuries. In tropical Africa, *Phragmites* lives, grows and flowers all year round – while in temperate climates it stops altogether in the winter.

Phragmites commonly forms extensive stands known as reed beds which may be as much as 1 square kilometre or more in extent. Where conditions are suitable it can extend to 5m high and a longer distance laterally as a result of horizontal runners which put down roots at regular intervals. The result is that in a phragmites reed bed, it is difficult to isolate a single plant. The Common Reed can grow in damp ground or standing water up to (around) 2m deep or even as a floating mat. The erect stems grow to 2-5m tall with the tallest plants in areas with fertile growing conditions of soil and/or water nutrients.

The leaves are long for a grass, 20-50cm and 2-3cm broad. They are smooth in texture. The leaf sheaths are loose and overlap. There is an appendage at the junction of the leaf sheath and the leaf blade which consists of a rim of hairs with a tuft of longer hairs at the leaf margins.

The flowers are produced in a dense dark purple panicle about 20-50cm long. Later the numerous long, narrow, sharp-pointed spikelets appear greyer due to the growth of long silky hairs; but BEWARE because the various parts of the phragmites stem and leaves are prickly to the touch and can pierce one's skin.

Common reed is suppressed where it is grazed by livestock. Under these conditions it either grows as small shoots within the grasslands or it disappears altogether. *Phragmites* is a problem when and where stands appear to be spreading while other species typical of the community are diminishing.

The risk of invasion would come about if there was a significant change in ambient and water temperature and nutrient content in the substrate and water. Small changes like this have been detected and the common reed is regarded as a weed in some places. Its capacity to form floating mats (sometimes called "sudd") can become problematic when it combines with other water plants also susceptible to increases in nutrients and then "floating islands" develop. But, to date, this has not been reported for Lake Tanganyika – but may have been seen in the larger in-flowing rivers.

Impacts

- When phragmites becomes weedy, it can threaten fisheries, water traffic, native biodiversity and general access of people to the freshwater environment.
- The invasions may threaten wildlife as it alters the structure and function of wetlands, lakes and rivers by dominating and degrading habitats of wildlife.
- The monitoring and control of mosquito breeding is nearly impossible in dense stands – which provide habitat for the vectors of malaria and the vector snails which carry bilharzia.
- Large floating mats and floating islands can affect the outflows of the lake and its rivers and create new environments for other weeds and pests (in other situations they can cause problems with hydropower stations and irrigation off-takes).

Management / control

- Control may involve spraying with herbicides like dalapon, amitrole and glyphosate – always bearing in mind that herbicides have non-target impacts, especially in water.
- Mechanical control may be effective through: Mowing and bulldozing in unflooded areas (drier areas), cutting stems above water with specialized machinery or even manual removal.
- Crushing repeatedly with rollers may contribute significantly to *Phragmites* control.
- Dredging is effective in some situations but has potential effects on water bodies by changing depths, bringing substrates to the surface and generally changing the nature of the aquatic environment.
- Burning and grazing can also be effective.

An aerial view of a lake edge dominated by common reeds.

Cyperus papyrus lining a river near its entrance to Lake Tanganyika.

28. *Cyperus papyrus*

Family: Cyperaceae, Order: Cyperales

Common name: Papyrus, Paper reed

This is a herbaceous perennial native to tropical Africa which forms tall stands of reed-like swamp vegetation in shallow water. Papyrus sedge have a long history of use by humans notably by the ancient Egyptians as the source of papyrus paper; in addition the highly buoyant stems can be made into boats. Papyrus is now cultivated as an ornamental plant.

It is a tall robust leafless aquatic plant which can grow 4-5m high. It forms a grass-like clump of triangular green stems that rise up from thick woody rhizomes. Each stem is topped by a dense cluster of thin bright green thread like stems around 10-30cm in length resembling a feather duster when the plant is young.

Young papyrus plants emerging from a swamp of *Vossia cuspidata* (See No. 31).

A dense growth of papyrus (fringed by *Aeschynomene elaphroxylon* No. 30) at lake edge.

Greenish brown flower clusters eventually appear at the end of these rays giving way to brown nut-like fruits. The younger parts of the rhizome are covered by red-brown papery, triangular scales which also cover the base of the culms. Botanically these represent reduced leaves. Though native to Africa, it has naturalized and escaped to cause invasions in other parts of the world. Papyrus forms vast stands in swamps, shallow lakes, and along stream banks throughout the wetter parts of Africa. Pollination is by wind and the mature fruits after release are distributed by water. It has a prodigious growth rate. It is regarded as a minor environmental weed or potential environmental weed since it has escaped cultivation and invaded the margins of permanent water bodies.

Impacts

- It is a rapidly growing species that can spread to cover areas of open water, preventing other aquatic natives from growing and reducing light levels to submerged plants.

  The spread and management of papyrus are similar to phragmites and it is often a component of floating islands. However, unlike the common reed, it is not spiny so is safe to handle and use for handicrafts, rafts and even boats.

29. *Typha capensis* and *T. domingensis*

Family: Typhaceae, Order: Poales

Common name: Bulrush, Reed-mace, Cattail

These are two species of tall emergent reeds (up to 5m above water level) with long thin flat leaves and a characteristic flower spike on a stout tubular stem. This stem has many tightly packed brown female flowers and cream male flowers above. It inhabits freshwater wetlands of all types, river and lake edges and shallow dams and ponds as well as irrigation canals and roadside ditches. *Typha* can grow in slightly saline or sodic waters and is able to colonize temporary and new wetland situations. The two species are widespread in Africa and the tropics elsewhere. They are native to Africa but can become significant weeds when they spread. Typha has the ability to quickly outcompete other native wetland vegetation as a colonizer if conditions change to its advantage. These reeds are one of the first species to take advantage of any changes (usually man-made) to a water body – such as increased nutrients, changing salinity, altered water flows and increases in water temperature; such changes can allow the reeds to become invasive because their original ecosystem has changed around them – in a sense, making them alien without moving.

Typha spp. can be used as fibre for weaving and craft production, roofing, building and fencing material, fuel and fodder for both domestic and wild animals.

Bulrushes on the edge of Lake Tanganyika.

A reed swamp of *Typha* species

Impacts

- *Typha* species have a wide tolerance of water conditions and are able to colonize new wetland areas and altered water bodies especially where there is increasing salinity, increasing nutrients or altered water flows. In this way it dominates and replaces other wetland vegetation
- Mechanical damage can be caused by blocking irrigation and drainage canals and water supply systems.

Management / control

- In managed water bodies, *Typha* can be controlled by increasing water depth (beyond 2m).
- In wild wetlands, cutting stems under water can control *Typha* – which then "drowns".
- Chemicals like 2, 4-D have been used-but their management is difficult.

Aeschynomene elaphroxylon leaves, stems and flowers.

30. *Aeschynomene elaphroxylon*

Subfamily Papilionoideae, Family: Fabaceae, Order: Fabales

Common name: Ambatch, Pith tree, Balsa wood tree

This is a common large shrub to small tree that can grow up to 9m high with spiny stems and pairs of substantial thorns under the base of the leaves. It is indigenous to parts of tropical Africa.

It has a swollen, pithy, often conical stem. Branches have sticky glandular hairs and are armed with short sharp spines. It has a dense mat of adventitious roots. The outer bark is green and smooth.

Leaves are pinnate with 20-40 oblong leaflets, mostly hairless above, blue green and pubescent below particularly on the margin and mid-vein. Petiole and rachis are covered with bristly hairs and often with minute spines.

Flowers are found in 1-4 flowered axillary inflorescences and are yellow to orange. Flowers have 10 stamens fused into a sheath and split into two groups of 5.

Seeds are purplish brown, kidney shaped and up to 8mm in diameter. Pods are spirally contorted, 10-14 cm long, 6-17 jointed and densely covered in bristly glandular hairs. The seeds have been known to stay viable after being buried for a few years in the waterlogged banks where it grows well. The seeds are contained in pods that grow in flattened, erect spirals on the tree.

Aeschynomene elaphroxylon has not been recorded as a weed or as invasive, but it needs to be monitored in case of change in density and consequent impact on other species.

A large shrub/small tree of *Aeschynomene elaphroxylon* near the edge of Lake Tanganyika.

31. *Vossia cuspidata*

Family: Poaceae, Order Poales

Common name: Hippo grass

Vossia cuspidata is a perennial grass which grows rooted in the edges of streams, lakes and dams. It has floating stems that can grow laterally up to 10 or 20m onto open water. It is also a dominant grass on many African floodplains which grows with rising waters, spreads along the water surface and then subsides with a receding flood to leave large areas covered with grass. Hippo grass can grow tall as well as laterally and some plants can reach 3m in height. It can also form floating mats and grass islands and is capable of growing over other floating aquatic plants such as water hyacinth to from dense, floating associations of wetland plants (such as Phragmites and Water Hyacinth). *Vossia* is found along rivers and creeks in slow-flowing waters and on the edges of lakes, reservoirs and dams. It has a reputation of being a "water weed" but, at the same time is a shelter for many aquatic species – including fish when spawning – and a source of food – both when in the water and when floods recede and it becomes pasture for livestock and wild herbivores on floodplains.

Vossia cuspidata in shallow water at the edge of Lake Tanganyika.

V. cuspidata has leaves which are slightly grey-green in contrast to other aquatic grasses and reeds which are darker green. It has a flower not unlike that of phragmites, but much smaller and less obvious.

Impacts

- Overgrowths of *Vossia* may alter water flows, impede transport and dominate other wetland plants and their associated biodiversity.
- When it grows on top of invasive species such as water hyacinth and *Salvinia*, it can form impenetrable mats which become much more difficult to control than any of the original invaders and can often develop a sudd or permanent floating wetland vegetation complex where none occurred before.

Management / control

- Mechanical (using manual efforts and aquatic harvesters) clearance of blockages and use of grazing animals can reduce heavy growths.
- Herbicides commonly used to control grasses can be used - but with utmost caution.
- This species should be monitored to detect any increases in density that suggest invasion.

Hippo grass spread across the water surface several meters from a river bank near Lake Tanganyika.

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Helpful websites

A database and datasheets of details of more than a thousand invasive species on the CABI Invasive Species Compendium: www.cabi.org/isc

Biology and Control of Aquatic Plants: A Best Management Practices Handbook and other linkss– which can be found on the Aquatic Ecosystem Restoration Foundation's website: www.Aquatics.org

Global Invasive Species Database – on the website of the Invasive Species Specialist Group of IUCN: www.issg.org/

Many different lists (by country and theme) as well as other data on the Global Invasive Species Information Network: www.gisin.org

lta.iwlearn.org

www.bioone.org

www.csiro.au

www.hear.org

www.invasions.si.edu

www.invasivespeciesinfo.gov

www.keyserver.lucidcentral.org

www.nobanis.org

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