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MINISTRY OF NATURAL RESOURCES AND TOURISM

NGORONGORO CONSERVATION AREA

INVASIVE PLANTS

STRATEGIC MANAGEMENT PLAN

2019

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ABBREVIATIONS AND DEFINITIONS

APO **ANNUAL PLAN OF OPERATIONS**

CBD **CONVENTION ON BIODIVERSITY**

FCZ **FRANKFURT ZOOLOGICAL SOCIETY**

GIS **GEOGRAPHIC INFORMATION SYSTEM**

GPS **GLOBAL POSITIONING SYSTEM**

IAP **INVASIVE ALIEN PLANT**

IPPC **INTERNATIONAL PLANT PROTECTION CONVENTION**

NCA **NGORONGORO CONSERVATION AREA**

NCAA **NGORONGORO CONSERVATION AREA AUTHORITY**

NEPAD **NEW PARTNERSHIP FOR AFRICA'S DEVELOPMENT**

SNP **SERENGETI NATIONAL PARK**

TPC **THRESHOLD OF POTENTIAL CONCERN**

ALIEN SPECIES: A species that is not indigenous or an indigenous species trans-located or intended to be trans-located to a place outside its natural distribution range in nature or has extended its natural distribution range by natural means of migration or dispersal without human intervention.

INDIGENOUS SPECIES: or "native species" means a species that occurs, or has historically occurred, naturally in a free state in nature within the borders of Tanzania and the NCA, but excludes a species that has been introduced in Tanzania as a result of human activity

INVASIVE SPECIES: Any species whose establishment or spread outside its natural range threatens ecosystems, habitats or other species or have demonstrable potential to threaten ecosystems, habitats or other species; and/or may result in economic or environmental harm or harm to human health.

MAINTENANCE LEVEL: The stage reached when the number of alien plants found in late summer is very low and one person can cover two or more hectares a day (<0.5 shift/ha), controlling scattered individuals. Typically, invasive alien plants densities are less than 5%.

NON-SELECTIVE HERBICIDES: Herbicides that affect any plants they contact, often creating bare ground that only encourages further weed invasion.

SELECTIVE HERBICIDES: Herbicides that affect only the target plant or plant group.

SYSTEMIC HERBICIDES: Herbicides that are absorbed by roots or foliage and can move throughout the plant to the growing point which can then be destroyed. They are well adapted to controlling perennial species that have strong root systems and other vegetative storage structures often located underground. They usually require time to penetrate and migrate within the plant so tend to be slow acting.

FOREWORD

Invasion of alien species is globally considered the second greatest threat to biodiversity conservation after habitat fragmentation. It involves introduction of alien organisms, be it plants, or animals into new geographical region followed by rapid multiplication, spread and becoming capable of displacing indigenous species. Due to most of the alien species having the capability of outcompeting and consequently suppressing indigenous organisms; they may directly harm indigenous species, the community structure and/or the ecosystem functions. Many parts of Africa are currently reported to have been invaded by alien species though the magnitude of the problem varies from one country to another and one ecosystem to the other.

Historically, invasive alien species were considered to spread from other continents to Africa through colonialism and exploration, however, today mobility is through tourism and business travel. Further, changes in climate and land use are rendering some habitats more susceptible to biological invasions. In spite of increasing awareness on the impacts of alien species to the environment and human health, and their prevention efforts; invasions have continued to be a great challenge. The concerns about the introductions and the spread of invasive alien plants has however, increased recently as is reflected in the 1993 Convention on Biological Diversity (CBD) and in other national and international treaties.

Recent studies indicate that Tanzania is among the countries that face invasions of alien plants; a problem which is well addressed in the Wildlife Policy of Tanzania 1998; revised in 2007. In NCA, light infestations of alien plants are already evident. Invasive alien plants persist at low numbers for many years, slowly and often insidiously increasing and then suddenly their population literally explodes. Thus, the risk is apparent as those infestations would be more severe with time as alien plant populations in NCA mature and spread, if action is not taken now. This invasive alien plants strategic management plan has therefore been developed in that outlook so that prevention of new infestations and control, if not eradication of the already occurring alien plants alien plants in the area could be contained in order to inhibit further impacts on biodiversity before the population numbers explode.

The plan focuses on the aspects of strengthening the understanding, response and management of invasive alien plants and enhancing monitoring efforts. It also emphasizes the issue of awareness and education to all stakeholders with regard to invasive alien plants‟ factors leading to bio-invasions and their impacts. However, preventing the introductions is considered to be a cornerstone of effective measures for dealing with invasive alien plants and environmentally sound approach as once an invasive plant becomes established; eradication may be impossible and ecologically damaging.

Dr. Freddy Manongi
CONSERVATION COMMISSINER OF NGORONGORO

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EXECUTIVE SUMMARY

The Ngorongoro Conservation Area (NCA) is of vital importance to Tanzania and is of global significance for biodiversity and cultural conservation. Invasive alien plants (IAPs) have been identified as one of the main threats to the ecological and economic future of the NCA and thus need to be well managed to sustain the natural functioning and economic productivity of the area for the benefit of the local communities, the tourism industry, the NCAA and the region and nation as a whole. To a lesser extent, indigenous (native) weeds also threaten the NCA. The Ngorongoro Invasive Plants Strategic Management Plan (2017) is consistent with the Government of Tanzania"s National Five Year Development Plan (2016/17 – 2010/21), the Tanzania Wildlife Policy, the Vision and Mission of the Ministry of Natural Resources and Tourism (MNRT) and the Vision and Mission of the Ngorongoro Conservation Area Authority.

This Strategic Management Plan provides the necessary guidance to effectively manage the problem of IAPs and to also reduce the levels of indigenous weeds encroachment to acceptable levels. The document draws on information contained in the first strategy (2010), what was subsequently done and achieved also what was not done as planned. It also builds on what was learnt and sets revised goals, objectives and targets.

Recommendations and challenges include the imminent and emerging new threats of notorious and extremely impactful invasive alien species, notably *Parthenium hysterophorus* and *Chromolaenaodorata*, which need extreme vigilance and proactive measures to prevent them from becoming established within the NCA.

The reality of resource constraints is recognized but also needs to be addressed responsibly and creatively through a comprehensive and well implemented programme as outlined, which includes preventive measures, monitoring, research, advocacy and awareness raising within and outside the boundaries of NCA. A well planned and managed programme would be well placed to attract donor funding and support from external partners.

The updated strategy includes more information about the rangeland problems which are resulting in increased populations and densities of indigenous weedy plants in the Crater and other rangelands which are very important grazing areas for wildlife and livestock. Mechanical control methods (including mowing), as well as the judicious use of fire are encouraged under closely monitored conditions and supported by evidence from research. Whilst recognizing that the increases in indigenous weeds and concomitant decreases in palatable grasses are symptoms and not the causes or drivers of the root problems to be addressed, we believe that by addressing the problem at that stage, we will be able to control undesirable consequences associated with this. The root causes are either one of a combination of sustained heavy grazing pressure along with

vicissitudes in environmental factors such as rainfall or fire patterns. Increases in indigenous weed distributions and densities are usually an indication that something else has changed and can be a natural response which indicates a rangeland needs time to recover from heavy grazing. Solutions may include introducing incentives or disincentives to pastoralist communities to allow rangelands respite from excessive grazing, otherwise in the long-run the control of the indigenous weeds alone will not result in sustained recovery of the rangeland (grasses).

1. INTRODUCTION

The Ngorongoro Conservation Area (NCA) together with the Serengeti National Park, both of which are UNESCO World Heritage Sites in their own right, and other conservation areas within the same ecosystem form an ecologically and economically very important area. The ecological integrity of this area is of vital importance to Tanzania and indeed, is of global significance for biodiversity and cultural conservation.

Apart from the high diversity of wildlife species and habitats and the exceptional abundance of wild grazing herbivores and associated carnivores that inhabit the ecosystem, the NCA also supports tens of thousands of pastoralists along with their livestock.

Invasive alien plants (IAPs) have been identified as one of the main known biological threats to biodiversity in the area and to the sustainability of the high grazing value of grasslands in the Crater and elsewhere in the NCA. In addition to the problem of IAPs, the grasslands are also becoming increasingly encroached with indigenous pioneer species of plants which impact negatively on grazing quality of the pastures and reduce the visibility and hence game viewing experience of tourists visiting the NCA. The indigenous grasses are essential for the survival of almost all wildlife, as well as livestock, that inhabit the area as they support the entire food chain. Maintaining the grasslands in an ecologically healthy and productive state therefore is essential to sustaining the economic productivity of the NCA for the benefit of the local communities, the tourism industry, the NCAA as well as the region and nation as a whole.

The Ngorongoro Invasive Plants Strategic Management Plan is consistent with the Government of Tanzania"s National Five Year Development Plan (2016/17 – 2010/21), the Tanzania Wildlife Policy, the Vision and Mission of the Ministry of Natural Resources and Tourism (MNRT) and the Vision and Mission of the Ngorongoro Conservation Area Authority.

This Strategic Management Plan provides the necessary guidance to effectively manage the problem of IAPs and reduce the levels of indigenous weed encroachment to acceptable levels. The document discusses the history and current situation with regard to IAPs and indigenous weeds and their management. Based on this and international best practice standards, various goals, objectives and targets have been set and documented. Recommendations and challenges are discussed thereafter.

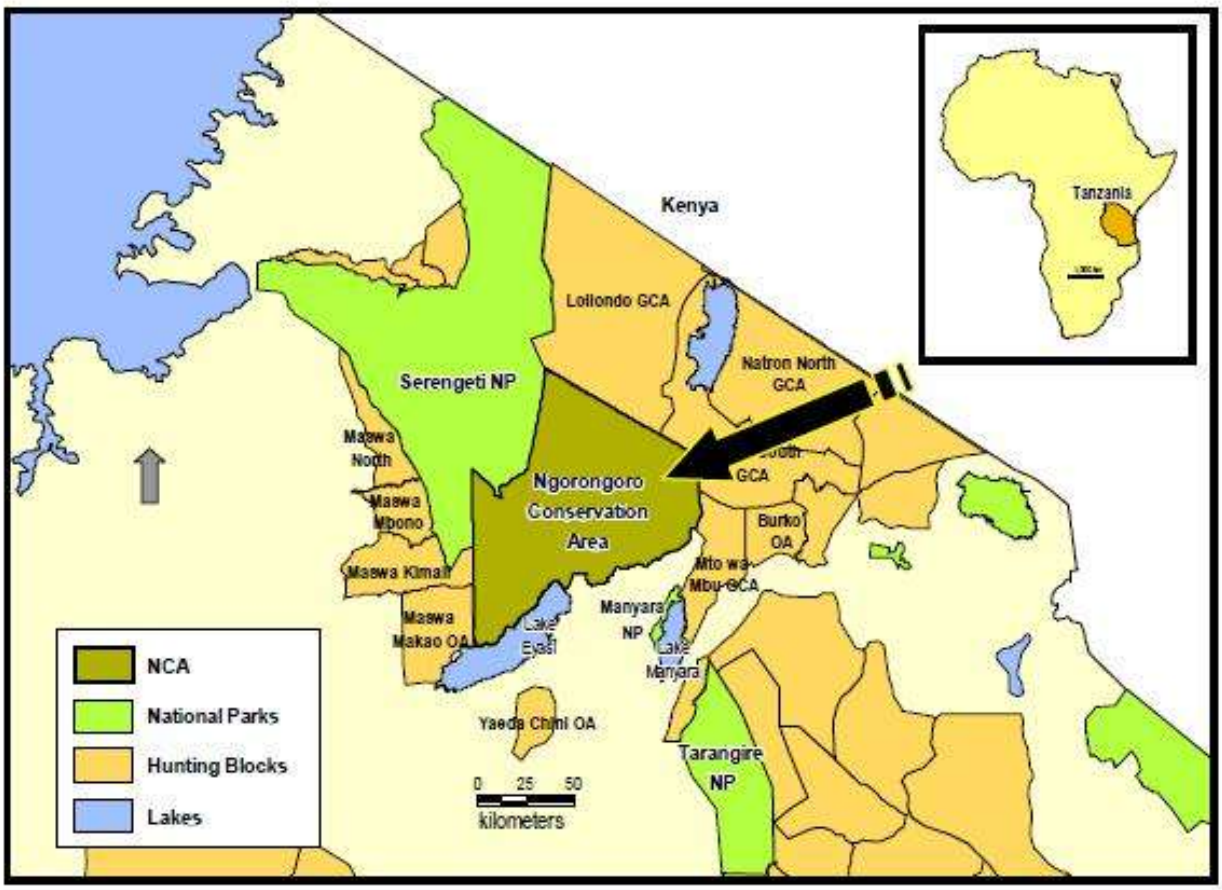


Figure 1. Map of Ngorongoro Conservation Area

2. INVASIVE ALIEN PLANTS

2.1 What is the difference between an indigenous species and invasive alien species?

Indigenous species, be it a plant or an animal, are those species that are native to a particular region. They have evolved and occurred in that region for thousands of years, and were not brought into that area by humans or other agents (Simberloff, 2013). An indigenous species usually has a variety of natural enemies (predators, parasites and diseases) that have developed with it and keep its population numbers under control in relation to the diversity of other species that share its habitat. All indigenous species have natural enemies and occur in a state of dynamic or fairly stable equilibrium with each other. If a species occurs in a region where it is not indigenous, it is referred to as an alien (exotic, foreign, introduced, non-native and non-indigenous) species .Any species that occurs artificially outside its known historical natural range, no matter how long ago it was introduced, is regarded as an alien. Most alien species can only survive in their adopted

country if they are cared for. However, some alien species manage to flourish in their new environments, and reproduce and maintain populations without human assistance. These are termed naturalised species. If naturalised species are also able to spread over considerable distances into new, undisturbed, natural areas and replace the indigenous species, they are regarded as invasive alien species.

The majority of invasive alien species are introduced intentionally. For example, they are brought in as crops, pets or for forestry and as ornamental garden plants. Alien species may also arrive indirectly with fodder, as stowaways on ships (rats) or by adhering to animals, humans or vehicles (plant seeds).

2.2 Impacts of invasive alien species

Invasive alien species are regarded as the second greatest threat to biological diversity globally, after habitat fragmentation and destruction. Their impacts are immense, insidious and usually irreversible and thus pose a real and significant threat to conservation areas in Africa (Cronk and Fuller, 1995). Freed from their natural enemies (most often specialised insects and diseases which occur in their native habitat and inhibit them from growing too prolifically), they have the ability to transform the structure and species composition of eco-systems by replacing or excluding indigenous species by out competing them for resources. Invasive alien species can also change the functioning of ecosystems. For example invasive plants can alter the fire regime, nutrient cycling and hydrology in native ecosystems (Mack *et al.*, 2000). A harsh reality concerning the problem of invasive alien species is that it becomes far more expensive to control invasions the longer they are left, whilst the chances of controlling them effectively diminishes simultaneously over time. There are already numerous cases around the world, such as in New Zealand and the Island of St Helena of Africa, where the infestations of alien species have caused irreversible damage and it is no longer feasible to restore the situation.

3. SITUATION ASSESSMENT OF INVASVIE ALIEN PLANTS IN NCA

In 1998, the NCAA‟s Mr. Henry Sweddy with his knowledge of agricultural weeds noted that *Datura stramonium, Argemone Mexicana* and *Nicandra phaseoloides* were growing sporadically along the roads within the Ngorongoro Crater floor. It had been the end of a drought period and the heavy rains that followed caused the species to spread away from the road into the nearby vegetation and into some of the wetland areas. By 1999 most of the roadsides were covered by *D. stramonium* and approximated 35km$_2$ of open plains areas were invaded (NCAA report - NCAA/D/592/54). It is thought that these species may have been introduced through construction material that was brought in from Karatu area. By 2000, the first control programme began whereby *D. stramonium, Argemone mexicana, Argemone. Ochroleuca* and *Xanthium strumarium*

was uprooted or cut at the base and put in the roads in order to be flattened by vehicles moving along the road. Over 300 hectares was controlled.

In 2002, Lesley Henderson (Plant Protection Research Institute in South Africa) conducted an initial preliminary survey of invasive alien plants, compiled a list of species found within and near to the NCA, and made recommendations for the prevention and control of the most threatening species. This was followed by additional situation assessments with the assistance of external experts, also arranged and hosted by the Frankfurt Zoological Society and NCAA, in 2002. The report by Foxcroft (2003), the summary by Lotter and Foxcroft (2003) in the proceedings from the Black Rhino Workshop held at Serena Lodge, Ngorongoro, and the report by Lotter (2004) contain further pertinent observations and recommendations concerning alien plants in the NCA.

Since then, various short-term control operations have been implemented. These are listed in Table 1.

At a similar time to the first noting of the IAP problem at the NCA by Mr. Sweddy, the rain also facilitated the prolific spread of two indigenous weedy species, namely *Bidens schimperi* and *Erlangia cordifolia* which reportedly covered approximately 75% of the Crater floor drylands (NCAA report - NCAA/D/592/54). In 2001 mowing, later followed by burning was introduced as mechanism to facilitate the removal of *B. schimperi* and *E. cordifolia*. Trial plots were also setup to monitor the effectiveness of these measures. From then onwards a programme was developed in which an area was first mowed and followed up with burning, or vice versa. It was intended that the entire Crater floor would receive such treatment over a period of three years. However, due to budget constraints and the unavailability of a tractor at times smaller areas have been mowed than anticipated. At the time of preparing this revised strategy very large swathes of the Crater floor are covered in dominant stands of *B. schimperi* and *E. cordifolia*. The previous dry season was drier than usual and as a result the grasslands of the Crater floor were denuded more than usual from the heavy grazing pressure that exists in this ecosystem. The good rains which followed this dry period, over the past wet season, resulted in an explosion of weeds which has resulted in substantial concern being expressed by the public and visitors to Ngorongoro during 2017. Although this sudden overabundance of weeds is of some concern, it is part of an unexpected natural cycle whereby indigenous pioneer plant species (especially weedy forbs) dominate the vegetation layer following a major disturbance such as a drought, flood or extremely hot fire, for a period of time. The weeds can provide the more palatable vegetation species such as grasses with some cover and protection from grazing pressure for a period of time(usually a few years if adequate rainfall and respite from disturbance factors persist), where after the grass layer may begin to outcompete and begin to replace the pioneer weed species. Mowing, or a combination of mowing and/or judicious burning can help to speed up this process. *Eleusine jaegeri* is another example of an indigenous weedy and unpalatable species that is dominating the grasslands in some areas.

Should disturbance factors remain, however, such as ongoing drought or continuous overgrazing such as from livestock at unsustainably high numbers, and then the situation can persist and become a permanent problem. The weeds are thus the result of an underlying problem and are not the cause of the problem itself. However, in the case of alien plants invading the grasslands or forests, they are not a part of the local natural cycles and can result in permanent and potentially irreversible lowering of the carrying capacity of the habitat to support wildlife or domesticated animals.

Figure 2. *Gutenbergia cordifolia* in the Ngorongoro Crater

Figure 3. *Bidensschimperi* in the Ngorongoro Crater

Figure 4. *Verbena bonariensis* in the Crater.

Table 1. A summary of invasive alien species and native weeds controlled in various areas in the NCA (P. Mattay per comm.)

Area	**Year in which control was conducted**	**Species controlled**
Crater floor	2001, 2002, 2003, 2004, 2005, 2006, 2007, 2008, 2009, 2010, 2011, 2012, 2013, 2014, 2015, 2016, 2017	*Datura stramonium, Argemone spp., Verbena spp., Bidens schimperi*, Gutenbergia cordifolia* Erlangia cordifolia** *Tagetes minuta* (since 2014)
Sopa Lodge	2004, 2006, 2011, 2013	*Datura candida* + other exotic ornamental species, NCAA do monthly inspections
Rhino Lodge	2004, 2005, 2007,2008	*Datura candida* + other exotic ornamental species, NCAA do monthly inspections
Maasai Park	Adhoc from 2004 to 2010	*Datura stramonium, Datura candida*
Area between Police Station & Simba campsite	2005,2006, 2015	*Acacia mearnsii*
Conservator Quarters	2005,2006, 2014	*Caesalpinia decapetala*
Near Gibbs Farm	2006, 2012, 2013, 2014, 2015, 2016	*Caesalpinia decapetala*
Endulen	Adhoc from 2003 to 2010, 2011 to 2017 2007, 2009, 2010, 2011 to 2016	*Datura stramonium, Argemone spp,* *Xanthium strumarium* *Lantana camara, Eucalyptus* spp*., Jacaranda mimosifolia* also occur but no control programme in place
Olduvai Gorge	2004 to 2010 & 2011 to 2017	*Datura stramonium,* *Xanthium strumarium*
Alongside the road from Loduare Gate to Golini Gate	2002 to 2009, 2011 to 2017	*Datura stramonium, Argemone* spp*., Verbena* spp*.* improved for these species but *Tagetes minuta* now worse along roadside
Serena Lodge	2005,2006,2007, 2015	*Eucalyptus* spp.& various ornamental species, NCAA do monthly inspections
Wildlife Lodge	2006	Various ornamental species, NCAA do

		monthly inspections
Serena Lodge	2005, 2006, 2007, 2010 to 2016	Various ornamental species, NCAA do monthly inspections & through the Lodge nursery alien species are being replaced with indigenous species
Crater Lodge	2006, 2007, 2010 to 2017	Various ornamental species, NCAA do monthly inspections & through the Lodge nursery alien species are being replaced with indigenous species
SPECIES- LED NCA headquarters &Loduare Gate	2014, 2015	***Parthenium hysterophorus***, highest priority IAP recorded and eradicated (uprooted & removed) upon sight as soon as it is seen anywhere in Ngorongoro.
*Indigenous weedy species		

In 2007 a risk assessment was conducted in the NCA (Runyoro *et al,* 2008) in order to identify and determine the extent of invasive plants and to prioritise the various alien species according to their risk of invasion. One hundred and two alien species have been identified in the NCA. Of these, 23 species are regarded as dormant but with high potential of becoming invasive, 37 species have high potential for becoming invasive and 42 need further evaluation. Climate change will increase the risk of certain species becoming highly invasive.

The majority of alien plant species in the NCA are associated with human settlements and lodges were they have been brought in for ornamental purposes. Outside the NCA, particularly on the southern and south eastern boundary where the NCA is bordered by agricultural communities, agriculturalists have planted *Ceasalpinia decapetala* around their farms to deter marauders from entering into their farms.

The highest risk of all IAP species for the NCA presently is *Parthenium hysterophorus* (Parthenium weed)**,** which is **also known in some countries as Famine weed.** Famine weed is growing and spreading at an alarming rate in and from the Kilimanjaro International Airport and Arusha areas, where it was recorded for the first time ever inTanzania during 2009.In 2014 a few small Parthenium plants germinated just outside the entrance of the Visitors Centre at Ngorongoro headquarters. These plants were immediately uprooted before they set seed and none have been seen since. The seeds were likely brought in on the shoes of someone and were rubbed off in the process of him or her wiping mud off them before entering the building. A year later (in 2015), a small Famine weed plant was seen and uprooted by Mr. Peter C. Nyanswi at Loduare Gate, before it set seed. In both cases these nascent infestations were eradicated thanks to the exemplary vigilance and swift action. However, the infestations outside the NCA are spreading and densifying

at an alarming rate and it is extremely important to remain vigilant, promote awareness of this hugely impactful IAP (impacting on crops, pastures, grasslands, animal health and human health) to both staff and visitors so that any new Parthenium plants seen in the NCA are immediately recorded and removed. Failure to prevent this species from establishing in the NCA will have extremely disastrous and irreversible impacts on the ecology and economy of the NCA.

Another very high risk IAP species that is a major threat to the NCA is *Chromolaenaodorata* (Triffid Weed). Triffid weed, which is another very high impact species, has been introduced to the Grumeti River area of the western Serengeti within the last decade and seeds of it could easily be brought into the NCA by a single traveller entering the area bearing some of the very small seeds of the species from a contaminated site. Both Parthenium and Triffid weed are ranked amongst the world"s top 20 worst invasive alien species. Everything possible must be done to prevent them from becoming established on the NCA, as prevention is far better and much more cost effective than cure.

Based on various previous assessments (Runyoro *et al*, 2008,Henderson 2002, Foxcroft 2003, Lotter 2004, Mattay & Lotter, 2005), the IAP species that were regarded as posing the biggest threat to NCA are:

- *Lantana camara;*
- *Acacia mearnsii;*
- *Azolla filiculoides;*
- *Ceasalpinia decapetala;*
- *Leucaena leucocephala*
- *Lonicera japonica;*
- *Melia azaderach;*
- *Parkinsonian acuelata;*
- *Datura stramonium;*
- *Eucalyptus spp.;* and
- *Jacaranda mimosifolia*.

Photographic illustrations of these species are displayed in Figure 5 below.

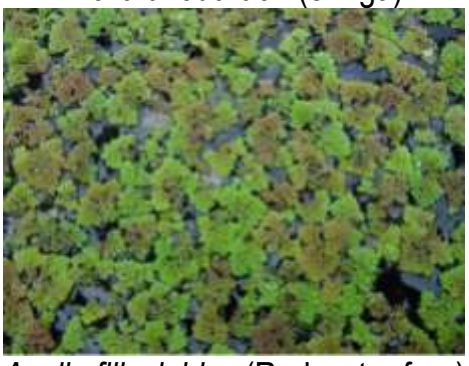
Fortunately, the majority of these invasive/alien plants species are still at relatively low numbers, and have not yet reached a level where control and, in the case of some species, eradication is not possible. However, ongoing control and monitoring of these species is essential as several of these species are known to have had a huge negative biological and economic impact elsewhere in Africa, within a short period of time (10 to 40 years).

*Caesalpinia decapetala (*Mauritius thorn*)*

Lantana camara (Lantana*)*

Melia azedarach (eringa)

Acacia mearnsii (Black Wattle)



Azolla filiculoides (Red water fern)

*Datura stramonium (*Common thorn apple)

*Leucaena leucocephala (*Leucaena0

*Lonicera japonica (*Japanese Honeysuckle)

Parkinsonian aculeate (Jerusalem thorn)

Eucalyptus spp.(Gum tree)

Jacaranda mimosifolia (Jacaranda)

Parthenium hysterophorus
(Parthenium/Famine weed)

Figure 5. Photographs of various invasive plants of NCA

Control of IAPs at the NCA since the compilation of the 2010 Invasive Alien Plants Strategic Management Plan has been carried out on an ongoing basis. In the Gibbs Farm area a team of 10 workers, paid by the NCAA, have been undertaking control work on various IAP species every year since 2010 to remove these plants. At all the lodges within the NCA a team from the Wildlife Development and Range Management Department of the NCAA conducts monthly inspections of the situation. The situation is improved with regard to most of the IAPs at most of the lodges around the Crater. Serena Lodge and Crater Lodge also have their own nurseries where they grow indigenous plant seedlings that are used as replacements for alien species that are removed as part of a long-term programme to phase out the alien species which had been planted many years previously.

In the Ngorongoro headquarters area including around the top management accommodation quarters, *Caesalpinia* was controlled annually until and including 2014 when it ceased. This is due

to be resumed again in 2017. The most significant success has been the rapid detection and removal of a few *Parthenium* (Famine weed) plants from the NCA headquarters and Loduare Gate in 2014 and 2015, respectively! In order to remind people at the gates and lodges about the extreme importance of preventing *Parthenium* from establishing and spreading within the NCA, posters of this highly impactful IAP will be printed and displayed at the gates and other public places.

Sites within the NCA where IAP infestations have not improved in spite of control programmes include: at Endulen and houses along the road to Endulen where *Eucalyptus* and *Lantana* are still being grown at homesteads of residents. The population of *Verbena* has also reportedly worsened inside the Crater in spite of work done to uproot these plants, because the rate of growth and spread of these IAPs has exceeded the rate of control thereof. Increased budget and inputs are thus needed to prevent the situation getting out of control. This need is an especially important priority, considering that the potential impacts of this plant are greater than those of the indigenous weeds in the Crater, i.e. *Gutenbergia* and *Bidens*, should the current infestation not be adequately controlled and prevented from becoming established beyond the currently invaded disturbed areas where it is confined to.

It is important to understand and know the key principles for invasive species management (which are different for alien plants than for native weeds) and the steps to follow to effectively address invasions.

Actions for managing Invasive Alien Plants should be based upon the following principles and steps:

Understanding invasive alien species and what is required for management

There are four key steps that need to be dealt with when managing alien species (Wittenberg and Cock, 2001), namely:

1) prevention;
2) early detection;
3) eradication; and
4) control.

Invasive species very often tend to follow what is referred to as a „"long fuse big bang"" population growth curve. They persist at low numbers for many years, slowly and often insidiously increasing and then suddenly their population literally explodes. Eradication, containment or control should therefore occur before the population numbers explode, as thereafter the impacts on biodiversity are often severe and the cost to clear these species increases exponentially (Figure 6).

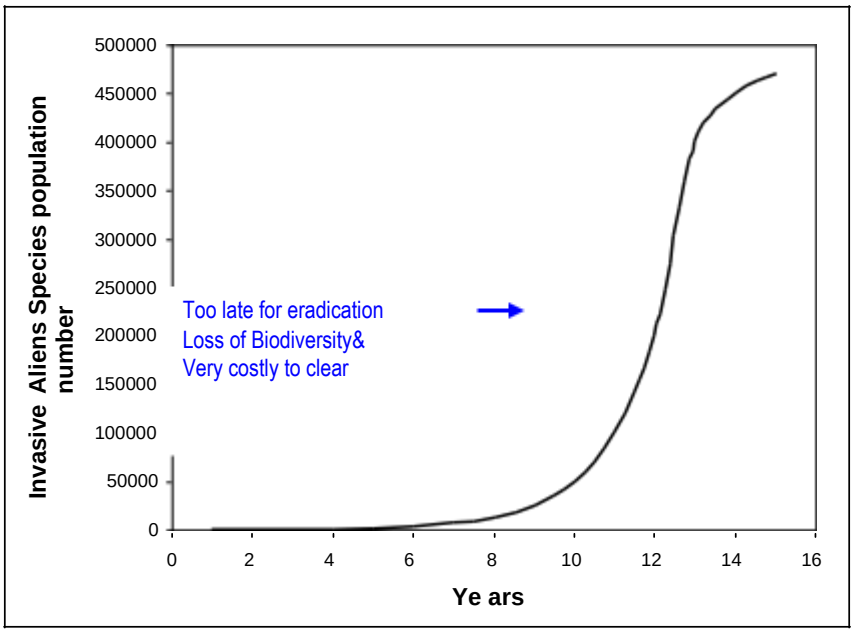


Figure 6. Schematic diagram of an invasive alien species population growth over time since introduction. The graph reflects what is commonly termed „long fuse big bang", that shows it is better to target invasive alien species early, before their population numbers explode.

Prevention of introductions is the first and most cost-effective option. This lesson has been learned the hard way from several cases where highly destructive species have invaded an area and resulted in an enormous loss of native species and money being spent on eradication and control programmes because these species were not intercepted at the outset.

Early detection of a potential invasive species is often crucial in determining whether eradication of the species is feasible. This can be done in the form of species-specific surveys or site-specific surveys.

When prevention has failed, or was not in place at the time of introduction of invasive species, eradication is the preferred course of action. Eradication can be successful and a cost-effective solution in response to an early detection of a non-indigenous species. However, a careful analysis of the costs and likelihood of success must be made, and adequate resources mobilized, before eradication is attempted. Eradication programmes can for example be based on mechanical eradication, chemical eradication, habitat management and hunting.

When eradication is not feasible, control measures need to be put in place. The aim of control is to reduce the density and abundance of an invasive organism to keep it below an acceptable

threshold. Methods for controlling a species are similar to those methods used in eradication programmes.

Fortunately, the NCAA is still in the position whereby the worst and highest risk IAP species threatening the area have not yet established themselves. Consequently, through early detection and eradication of nascent foci (in the cases of *Parthenium* and *Chromolaena*) and containment of small infestations through ongoing and rigorous control programmes with ongoing follow ups (in the cases of *Verbena*, *Lantana camara* and *Caesalpinia*), can prevent Ngorongoro from being severely impacted ecologically and economically from large-scale invasive species infestations.

4. MANAGEMENT OF INVASIVE ALIEN PLANTS AND NATIVE WEEDS

Management of Indigenous Weeds in the Crater and other important grazing areas is based on principles of restoring natural equilibriums.

Control through mowing and burning of the grasslands with high densities of native weeds seems to have had a positive impact. As can be seen in the following photographs, stands that were subjected to mowing, have less herbaceous weeds and more palatable grass, compared to those that have not been mowed.

Figure 7. Photograph showing mechanical mowing to control *Bidens schimperi* .in the Crater

Figure 8. Control plot showing *Bidens schimperi* density higher inside compared with outside

Figure 9. Photograph showing major difference of *Bidens shimperi* densities in different blocks. The foreground has undergone mechanical mowing, while the area in the distance was left untreated

However, evidence from the control plots does not conclusively show what treatments or combination of treatments of mowing and burning are optimal for reducing the weed encroachment in the Crater. Further testing and research is needed to determine the best control options for

Gutenbergia and *Bidens* in the Crater. Preliminary observations do suggest though, that mowing prior to seed setting produces the best results and that the condition of the Crater grasslands would be improved should a larger area of it be mowed. The rate of weed spread and encroachment has exceeded the rate of control treatments applied.

Apart from the situation within the Crater, other important grazing lands for wildlife and livestock are also becoming increasingly encroached by weedy species. Whilst the drought has undoubtedly been a cause of the dramatic relative shift between palatable grass species and unpalatable plant species, the biggest factor which is causing the shift and making it steadily worsen and prevents it from recovering is the constant grazing by livestock. Pastoralists are grazing their herds in areas for longer periods, compared to the more natural situation, in which wildlife would be in an area for a shorter period before moving elsewhere to allow the areas to recover. This continuous and excessive heavy utilization by livestock causes the degradation of the grassland grazing value whereby palatable species are over time replaced with less desirable, unpalatable species. If the underlying causes, particularly overstocking of cattle, sheep and goats, are not addressed the situation can become irreversible. Management programmes that have been implemented by the NCAA whereby the tall and unpalatable *Eleusine jaegeri* (Elephant grass, also known as "Makutiani" locally) grasses are mechanically removed by hired labour teams will not have a long term positive impact if the causal factors of overgrazing are not addressed.

Longer term solutions are required need to be urgently explored. For example, implementing potential ways of encouraging pastoralists to reduce the sizes of their herds. Incentives for villages which have the best quality of grazing in their areas of jurisdiction and/or of herdsman who have the best quality cattle, as adjudged annually through formal assessments, could be possible ways of beginning to encourage positive outcomes for the environment and the communities of Ngorongoro through rewarding good practice.

5. LEGISLATION PERTAINING TO INVASIVE ALIEN SPECIES

In Tanzania, there is currently no legislation that specifically addresses invasive alien species. However, there are several international agreements and declarations pertaining to invasive alien species to which Tanzania is either a signatory of or has agreed to adhere to .A short summary is provided below.

The Convention concerning the Protection of the World Cultural and Natural Heritage

The Ngorongoro Conservation Area (NCA) is a World Heritage Site and has been described as one of the Wonders of the World.

Article 5 of the Convention concerning the Protection of the World Cultural and Natural Heritage states:

"To ensure that effective and active measures are taken for the protection, conservation and presentation of the cultural and natural heritage situated on its territory, each State Party to this Convention shall endeavour, in so far as possible, and as appropriate for each country
(d) to take the appropriate legal, scientific, technical, administrative and financial measures necessary for the identification, protection, conservation, presentation and rehabilitation of this heritage;"

It is therefore vital that the NCAA takes appropriate measures to manage the threat posed by invasive alien plants to the Ngorongoro World Heritage Site

The Convention on Biodiversity (CBD) of 1993

The Convention on Biodiversity commits governments to take appropriate measures to conserve biological diversity, to ensure the sustainable use of biological resources, and to promote the fair and equitable sharing of benefits arising from the utilisation of genetic resources. Under this convention, governments have agreed to prepare national biodiversity strategies and action plans; to identify genomes, species, and ecosystems that are crucial for conservation and sustainable use; to monitor biodiversity and factors that are affecting biological systems; to establish effectively managed systems of protected areas; to rehabilitate degraded ecosystems; to exchange information, to conduct public information programmes; and carry out various other activities for implementing the objectives of the Convention on Biodiversity. Article 8 (h) of the CBD deals specifically with alien species and calls on parties to *prevent the introduction of, control or eradicate those alien species which threaten ecosystem, habitats or species.*

The International Plant Protection Convention (IPPC) of 1952

The purpose of this Convention is "to secure common and effective action to prevent the spread and introduction of pests of plants and plant products and to promote appropriate measures for their control". The implementation of the Convention has been applied mainly to crops, but it also extends to the protection of natural flora. Thus, the scope of the International Plant Protection Convention covers any invasive alien species that may be considered to be a plant pest.

The New Partnership for Africa's Development (NEPAD)

Tanzania is a member of NEPAD, which recognises that invasive alien species have already had major impacts elsewhere in Africa and will affect the degree of success achieved by the programme through their effects on agriculture, biodiversity, trade, tourism, transport and natural resources.

Ramsar

Tanzania is a contracting party to Ramsar Convention on Wetlands whose primary emphasis is on the conservation and wise use of wetlands primarily to provide habitat for water birds. Over the years, however, the Convention has broadened its scope to cover all aspects of wetland conservation and wise use, recognizing wetlands as ecosystems that are extremely important for biodiversity conservation in general and for the well-being of human communities and should not be threatened by invasive alien species.

6. GOALS, OBJECTIVES & TARGETS

The following goals, objectives and targets relating to the management of invasive alien species and indigenous weeds have been set for the NCA. These are in line with the broader conservation objectives set within the General Management Plan of the NCAA.

Goal 1: To reduce the impact of existing invasive alien species to a maintenance level within the NCA and provide a framework for ongoing management of invasive alien species.

Objective 1: To review and update the adaptive strategic plan for invasive alien plant management.

Target – by September 2018

Objective 2: To raise awareness of the various invasive alien species and their associated impacts within and around the NCA, in order to facilitate prevention and support with regard to control programmes.

Proposed Activities:

- *Implement invasive alien species awareness training for all current NCA staff members*
- *Implement invasive alien species awareness education amongst the local communities residing within the NCA at schools and through the Ward Environment and livestock Committees*
- *Implement annual invasive alien species awareness training for management & environmental staff of lodges located within the NCA*
- *Include invasive alien species awareness training for all new NCAA staff and for staff of all lodges operating within and near to the NCA, through the Code of Conduct which should be signed by all new employees (with their job contracts) and included with all letters of employment*

Target – by end of 2019

Objective 3: To develop a simple and effective invasive alien species control programmes for the NCA that can easily be implemented and monitored by NCA. These programmes should be based on priorities and reassessed every two years.

Proposed Activities:

- *Develop a simple and effective invasive alien species control programmes that outlines area for control, type of control method, budget, time frame and follow up treatment requirements*
- Action the control plan

Target - by end of 2018 and revised every 2 years

Objective 4: To keep invasive alien species at all human settlements and lodges at maintenance control level.

Proposed Activities:

- *Maintain ongoing invasive alien species control and monitoring programmes in collaboration with lodges and local residents, where invasive alien plant are systematically removed and where needed replaced with indigenous species. An agreement should be signed to ensure commitment (this will help to ensure the plants are still managed even if there is a change of management)*

Target –already in progress

Objective 5: To further progress towards getting invasive alien species within the entire NCA at a maintenance control level and serve as an example for National Parks, Game Reserves, and other conservation areas in Tanzania.

Proposed Activities

- *Implement an ongoing invasive alien species control and monitoring programme within NCA (where possible collaborate with local communities)*
- *Publish popular and scientific articles that highlight work done to date, successes and challenges.*

Target - by end of 2018

Objective 6: To raise additional funds to facilitate the removal of invasive plants in areas neighbouring NCA.

Proposed Activities

- Compile and submit funding proposals.

Target - by June of 2019

Objective 7: To develop the research, and training capacity required to ensure ongoing cost effective, efficient and sustainable invasive alien plant management.

Proposed Activities

- Where needed, implement research projects to assess effectiveness of control, rate of spread, etc.
- Implement a programme that allows for regular updates on the best mechanisms to control various invasive alien plant species

Target - by end of 2018

Goal 2: To prevent the development of new alien species problems.

Objective 1: To stop and prevent further introductions of invasive alien species by people living in the NCA and activities that have the potential to bring in invasive alien species (e.g. lodges, new building developments, road construction).

Proposed Activities:

- The introduction of known and potentially invasive alien species should be prohibited and existing ones phased out
- Institutionalise invasive alien plant code of conduct
- Where appropriate, such as at lodges and at all developments, the management of invasive alien plants should be included in contractual agreements
- Signs should be placed at all entrance points to the NCA and other strategic areas indicating the problems with invasive alien plants and mentioning that bringing exotic plants into NCA is prohibited.

Target - by July 2019

Objective 2: To ensure early detection of, and rapid action against new invasive alien plant species.

Proposed Activities:

- Coordinate plant identification, reporting and monitoring mechanisms amongst NCA staff and the communities (e.g. rangers and community extension officers trained to identify existing and emerging invasive alien plants and to include all sightings in ranger patrol reports and community extension officer reports)

- Conduct ongoing invasive alien plant surveys by the NCA invasive alien plant unit every year

Target - by December 2018

Goal 3: To reduce the problem of and provide a framework for ongoing management of indigenous weed species of key rangelands in the NCA.

Objective 1: To review and update the NCA plan for indigenous weed management in the Ngorongoro Crater and other key rangelands in the NCA, based on recognition and improved understanding of the underlying causes which result in increased weed abundance.

Proposed Activities

- *Collaborate with Ngorongoro Pastoral Council and other stake holders to Implement an ongoing indigenous weed control and monitoring programmes within the Crater and other identified rangelands and key potential important areas within and outside NCA*
- *Publish popular and scientific articles that highlight work done to date, successes and challenges.*

Target - by March of 2019

Objective 2: To develop the research, and training capacity to ensure ongoing cost effective, efficient and sustainable indigenous weed control and productive rangeland management

Proposed Activities

- Implement research projects to assess effectiveness of control options, rate of changes in weed abundance and rangeland condition, etc.
- Implement a programme that allows for regular updates on the best mechanisms for controlling indigenous weed encroachment problems in the Crater and other important rangelands, including the potential introduction of incentives to livestock owners for improving grazing practices and keeping responsible herd sizes

Target - by June of 2019.

7. RECOMMENDATIONS AND CHALLENGES

7.1. NCA INVASIVE ALIEN SPECIES CODE OF CONDUCT

In order to guide and inform the behaviour and activities within NCA, it is recommended that an invasive alien plant code of conduct should be developed and be instituted by the NCAA. These include an:

1. Invasive alien species code of conduct for all community villages and for all NCA residential areas located within the NCA
2. Invasive alien species code of conduct for other stakeholders (e.g. tourist lodges)

The code of conduct should include but not be limited to the following:

- All previous introduced invasive alien species must be contained, controlled or preferably eradicated (phased out of a period of time). This includes intentionally introduced and accidentally introduced invasive alien species
- The intentional introduction of any invasive alien species into the NCA is prohibited. Only indigenous species should be introduced.
- Any new introduction of an invasive alien species should be reported and disposed of immediately (in a suitable and acceptable manner).
- No alien plants may be dumped beyond the boundaries of the settlement areas or over fences or in any other place other than areas designated for the purpose of disposal and thereafter controlled in a manner to kill the plants and prevent them from establishing and escaping.

7.2 ROLES AND RESPONSIBILITIES

Invasive alien plant and weed management coordinator

In order to ensure the effective management of invasive alien species and indigenous weeds within the NCA, the appropriate roles and responsibilities need to be established. A coordinator should be nominated from the Wildlife Development and Range Management Department to oversee the planning and implementation of the invasive alien plant and the indigenous weed management programmes, respectively. Their role and responsibilities will be to implement the necessary actions to fulfil the goals, objectives and targets set out in this strategy. This will include activities such as:

- Budget planning and management
- Implementing the necessary prevention measures

- Implementing the necessary eradication and control
- Coordinating an advocacy and awareness programme
- Coordinating a programme training
- Coordinating a research programme (if needed)
- Monitoring and reporting
- Implementing a programme that provides incentives for livestock owners to improve grazing practices and keep responsible herd sizes
- Lobbying and writing funding proposals to ensure there is sufficient funds for ongoing invasive alien species and indigenous weed management.

Political and institutional support

For maintenance of the invasive alien plants and native weeds management programme, it is essential that there is understanding and support at senior management level within NCAA and at a political level. Awareness of the potential impact of invasive alien species on biodiversity and rangelands, among appropriate NCAA Board representative, is essential to ensure sufficient political will for the invasive alien species related work. The NCAA Board and its representative also need to help to win support for the introduction of incentives for livestock owners to improve grazing practices and keep responsible herd sizes.

External expertise

Additional technical expertise may be required on an ad hoc basis from external individuals or organisations.

7.3 RESOURCE MANAGEMENT

It is very important to note that once an invasive plant control programme is initiated, it needs to be maintained over the long-term to ensure that areas cleared do not revert back to an invaded state. Thus, regular ongoing control efforts are essential.

The current situation, relating to density and distribution of alien species, is manageable provided reliable and ongoing funding, human and other resources, careful planning and sufficient management capacity remain in place. However, unforeseen events such as large infrequent disturbances (e.g. period of heavy rain, drought) could disrupt this considerably. Other potential risks relate to the sudden invasion of new serious invader species. In both cases, the risk management will relate to rapid response and control actions to prevent further incursions and spread. The budgeting system should therefore need to be flexible enough to be able to cater for unanticipated needs and changes in priority such as those outlined above.

Sound resource management is vital to the success of invasive alien species and indigenous weed management, and the following principles should be borne in mind:

- The greater the level of financial resource inputs that are used in appropriate manner, the sooner the maintenance level will be achieved on the ground and the greater the longer term financial savings will be;
- The lower the level of financial resource inputs and/ or inadequately use thereof, the greater the likelihood of loss of previous investment in managing invasive alien species will be (fruitless expenditure); and
- Overall management costs can be reduced over time through the improvement of control efficiency, the development and refinement of best practices and in some cases through the use of bio-control.

It is also vitally important that sufficient numbers, skill levels and expertise in terms of human resources are developed and retained through an ongoing process of mentoring and training within the NCA.

7.4 AWARENESSCREATION ANDCAPACITY BUILDING

Awareness and capacity building are vital to ensure long term successful invasive alien species management and that the necessary knowledge, skills and behavioural changes are in place. Within the NCA an advocacy and capacity building programme should be implemented primarily to inform and educate staff and other stakeholders on the dangers and consequences of invasive alien species in order to facilitate understanding and support for invasive alien and indigenous weed control programme initiatives, and to ensure the effective management of them. This can be broken down into the following three components:

- Develop and offer a range of activities to convey relevant invasive alien species awareness information;
- Develop training and mentorship opportunities to provide relevant persons with the necessary knowledge to effectively communicate the threats and problems posed by invasive alien species and to management them effectively; and
- Acquire funding to facilitate and maintain the various awareness and capacity building initiatives.

A framework and details of such an advocacy and awareness programme is illustrated in Figure 10.

The following areas should be covered in the training:

- What is an invasive alien plant, and an indigenous weed, and what are their respective impacts
- The NCA invasive alien plant code of conduct

- Identification of highly invasive alien plants known to occur in and around NCA
- Identification of invasive alien plants that are emerging problems in Tanzania, but known to be problematic elsewhere
- What to do when encountering an invasive alien plant or an emerging alien plant species, how to collect, label and preserve suspected invasive species for identification, who to report it to, known control method, etc.).

These should also be incorporated into local environmental education programmes, so that Tanzanian citizens also have a better understanding of the problems associated with invasive alien plants.

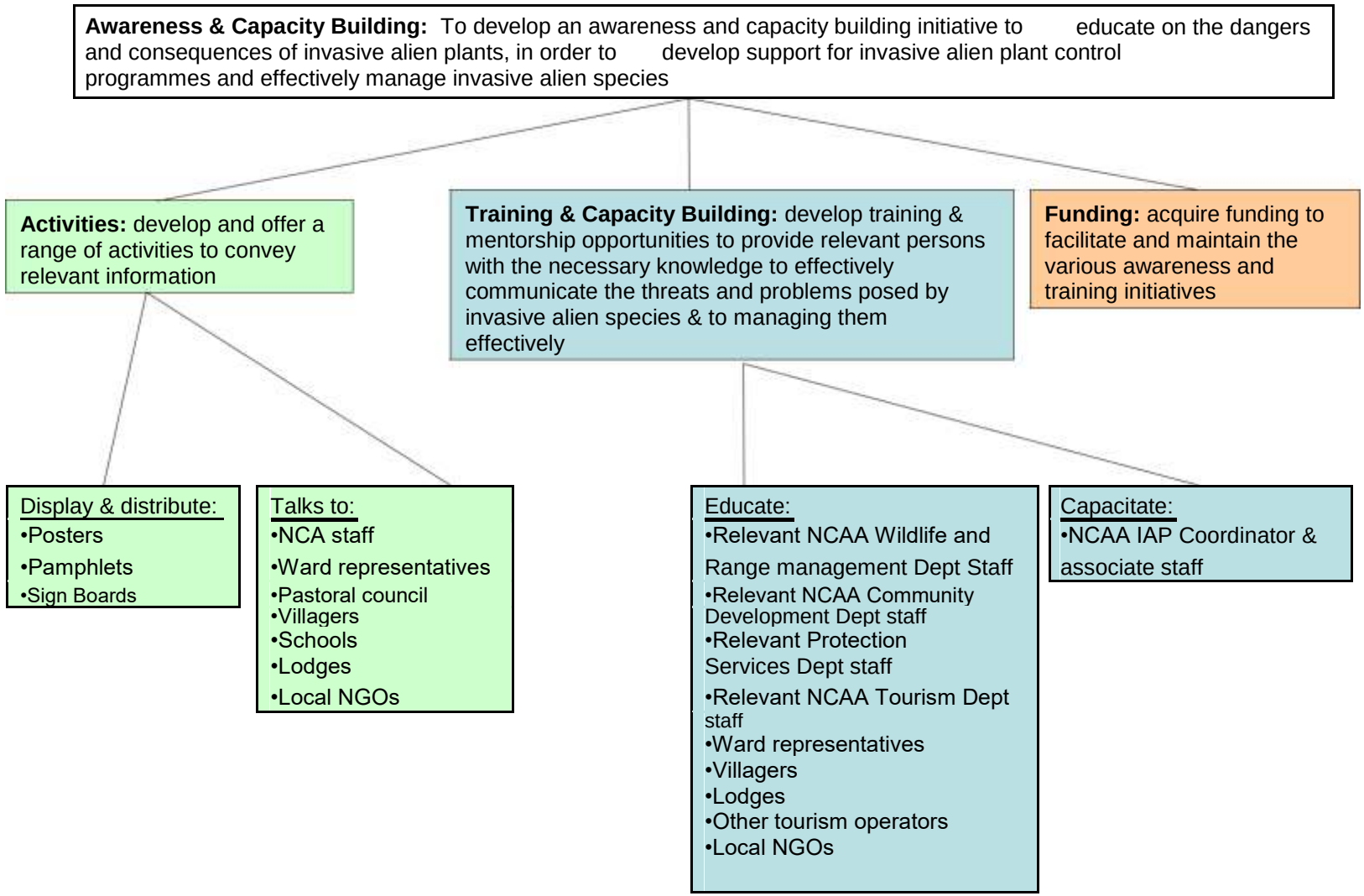


Figure 10. Structure of advocacy and capacity building initiatives, to enable a better understanding of the problem and foster more support for control programmes

7.5 PRIORITY SETTING FOR MANAGEMENT OF ALIEN AND NATIVE INVASIVE PLANTS

Effective prioritisation can mean the difference between success and failure in terms of controlling an invasive alien species invasion or failing to contain it. Unless correct planning; based on sound conservation and alien plant clearing principles are followed; funds can easily be wasted or even result in exacerbating the invasive alien plant species problem. One of the fundamental steps in order to ensure funding is used wisely is judicious priority setting, this will help to ensure the best returns on investments, which in this case is the best returns for money spent on control programmes within the NCA.

The NCA is still at a relatively low level of infestation as far as invasive alien plants are concerned. Most of the invasive alien species occurring within the conservation area are concentrated at human settlement areas (villages, lodges etc.), along roads, at construction sites and along the boundaries. Conversely, indigenous weedy plants have been expanding in cover and density inside the park,, thereby generating more concern from the public and government authorities. The increase in native weeds has been associated with continuous heavy grazing,, climate change, and/or other underlying causes. M

Financial resources are limited and priorities will thus need to be made as to where invasive plant control efforts should be focused. The expiring strategy contained more than 140 invasive plant species or potentially invasive in the NCA. However, following a stakeholder workshop that constituted scientists from various research and academic institutions and staff of Ngorongoro it was agreed that the species should be screened and prioritized for management. The steps followed during screening and prioritization is summerised in Figure 11 but also briefly described here. First, the 140 invasive plants and weeds were reduced to 25. The screening process was done using a combination of expert knowledge, experience as well as nature and context of the NCA landscape. Second, 16 criteria for prioritization of invasive species management were selected by the workshop participants. Third, all 16 criteria were subjected to vote by workshop participants and results are presented in Table 2).Fourth, the 25 invasive plants and weeds were scored against the 16 criteria by NCA staff.The scoring ranged from 1-5 (see Appendix 4).Fifth, analysis of the performance of species against the criteria was performed using Wood Weed decision support tool (http://woodyweeds.org/) and results are presented in Table 3. The species with mean score above 0.75 should be given the highest priority for control followed by those species with mean score between 0.50 and 0.75. Species that scored a mean value below 0.50 are considered to have low impact and therefore should be given less priority but closely monitored.

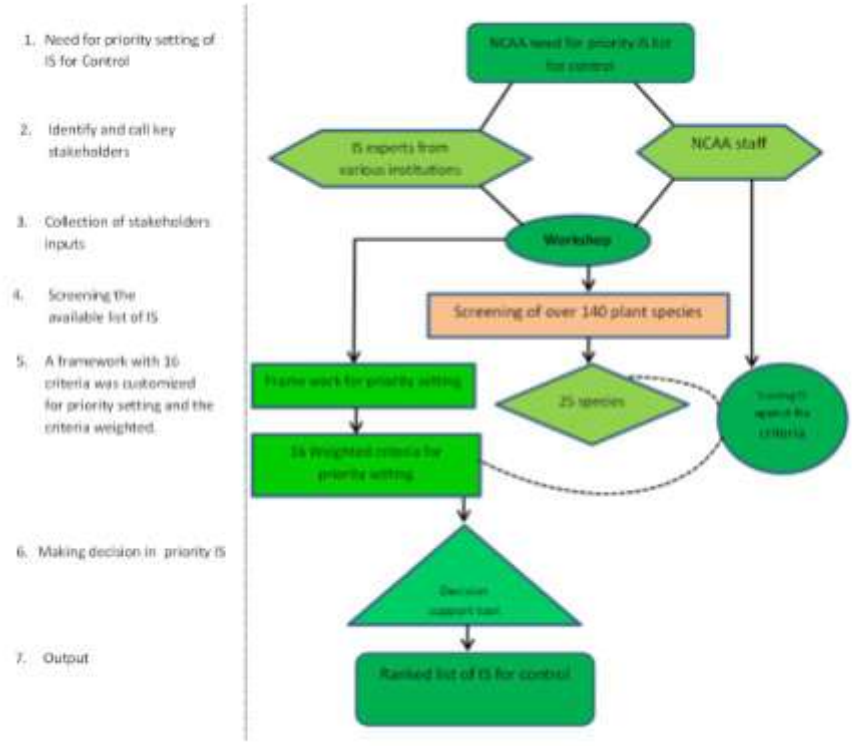


Figure 11. Activities flow chart for setting priority on IAS

Table 2: Ranking of criteria

S-N	Criteria	Category	Number of votes/Importance	Rank
1	High ecological impacts	Ecological	212	1
2	Low Abundance	Ecological	198	2
3	Priority site Reduce Habitat	Ecological	195	3
4	Suitability for wildlife	Ecological	183	4
5	High value of the area being invaded	Ecological	178	5
6	Close to Sensitive Areas	Ecological	177	6
7	Impact human and animal health	Human	173	7
8	Low infestation	Ecological	170	8

9	Easy to manage	Feasibility and coordination	161	9
10	Reduce Aesthetic value	Human	144	10
11	Difficulty of treatment	Feasibility and coordination	141	11
12	Cheap to manage	Feasibility and coordination	135	12
13	Least Palatable by Herbivores	Ecological	133	13
14	Block access to resources	Human	133	14
15	Lack of management techniques	Feasibility and coordination	121	15
16	Close to treatment sites	Feasibility and coordination	116	16

Number of votes = sum of votes by workshop 24 participants (Each criterion was assessed at a scale of 1-10 by all participants)

Table 3 Priority invasive plants for control in NCA

Species	**Mean**	**Rank**
Parthenium hysterophorus (gugu karoti)	0.84	1
Lippia javanica (fever tea or lemon bush)	0.84	2
Amaranthus caudatus (pendat amaranth)	0.83	3
Tagetes minuta (marigold)	0.81	4
Lantana camara (lantana)	0.80	5
Senna didymobotrya (peanut butter cassia)	0.77	6
Gutenbergia cordifolia (gutenbergia)	0.75	7
Eleusine jaegeri (goosegrass or makutiani)	0.75	8
Chromolaena odorata (Siam weed or amachabongo)	0.75	9
Ipomoea hildebrandtii (cairo morning glory or Messina creeper or Kongwa weed)	0.73	10

Clutia abyssinica (lighting bush)	0.70	11
Caesalpinia decapetala (Mauritius or Mysore thorn)	0.69	12
Datura stramonium (thorn apple)	0.69	13
Solanum incanum (bitter-tomato)	0.68	14
Bidens schimperi (beggarticks)	0.67	15
Acacia mearnsii (black wattle)	0.66	16
Heliotropium steudneri (turnsole)	0.64	17
Xanthium strumarium (rough cocklebur)	0.63	18
Azolla filiculoides (water fern)	0.60	19
Ecalyptus sp.	0.58	20
Leucaena leucocephala (wild tamarind)	0.46	21
Jacaranda mimosifolia (Jacaranda)	0.46	22
Argemone mexicana (Mexican poppy)	0.45	23
Melia azaderach (chinaberry tree)	0.43	24
Opuntia sp.	0.43	25

When such decisions need to be made, the following priority setting principles should be considered. These are listed in order of priority:

- Anywhere within the NCA where the top priority threat invasive alien plant species are found to occur, namely *Parthenium hysterophorus* and/or *Chromolaena odorata*, are the first and most important priorities of where to remove these plants, immediately after detection. The objective for these sites and species are complete eradication.
- Areas of high biodiversity importance must be given first priority for control programmes, regardless of the density of the invasive alien species occurring within them.
- Areas that are currently uninvaded with invasive alien species must be kept clean of invasive alien species (keep clean areas clean).
- Control programmes should concentrate on areas with less dense infestation first and only once these areas are under control, should control efforts focus on more dense areas.

- When initiating a control programme, ensure there is a sufficient fund available for a follow-up control treatment. Follow-up control treatments must take preference over implementing control programmes in new areas.
- When controlling a species that disperses by having its seed transported by rivers, ensure that control programmes start at the top of the river catchment and systematically work their way down stream.
- The following areas should be considered of high priority for control programmes:
    - Areas that contain high priority species that is likely to spread to important uninfested areas nearby (eg. *Lantana camara* grows quickly and produces lots of berries that spread by birds versus *Agave sisalana* which spreads slowly through vegetative reproduction);
    - Areas that contain emerging invasive alien species that are likely to spread to important uninfested areas nearby;
    - Areas that contain newly/rapidly expanding infestations of invasive alien plants (e.g. disturbed areas such as road works, floods, drought, fire, often create favourable conditions for local explosions in otherwise clean areas);
    - Strategically located areas that are likely to become infested and become pathways for the invasion of other parts of the NCA;
    - Areas that are likely to be easily maintained over the long term once cleared (e.g. with a controlled fire burning programme);
    - Areas that have significant clean and well maintained areas immediately neighbouring them;
    - Areas that contain infestations/species that are presently easily controlled where they currently occur and/or that do not require rehabilitation work in order to achieve the desired management goal (such as erosion control or replanting); and
    - Areas that have infestations that could significantly exacerbate the potential fire hazard which may result in the risk of damage to property or life.

- The following areas should be considered of **medium** priority for control programmes:
    - Areas that are important in terms of public awareness and/or tourists (e.g. roadsides, public areas such as picnic sites or viewing points);
    - Areas that are of aesthetic importance.

- The following areas should be considered of **lower** priority for control programmes:
    - Areas that primarily contain weed species for which there are effective bio-control agents available; and
    - Degraded areas (severely disturbed, heavily utilised, eroded, etc) that are prone to invasion and would require rehabilitation to make them less susceptible to re-invasion.

The table below (Table 4) indicates the different weed management zones and order of priority for 2017 based on their ecological importance, current threat from invasive alien plants and level of infestation from indigenous invasive plants, future threat from invasive alien plants, and feasibility of control. The order of priority should be reviewed and updated annually.

Table 4. List of invasive plant management zones and their relative priority (list in order of priority)

Invasive Plant Management Zone	Ecological importance of the area & its nearby surroundings (1 = low, 2= medium, 3 = high)	Current Threat - presence of priority invasive alien plants (0 = none, 1= few, 2 = many)	Future Threat - high risk invasive alien plants are likely to spread to this area (0 = not likely, 1= possible, 2 = likely)	Feasibility of control (1= very difficult to control, 2= control possible, 3 = easy to control)	Overall Priority score
N. Crater floor & slopes	3	2	2	3	10
Lodges on rim	3	2	2	3	10
Lodges on the boundary	2	2	2	3	9
Main and feeder roads	3	1	2	3	9
NCA headquarters & staff quarters	3	1	1	3	8
Schools/institutions	2	1	1	3	7
Temporary bomas in the lowlands and homesteads	2	1	1	3	7
Other lodges and public areas – Ndutu, Olduvai, Endulen, etc.	2	1	1	3	7
Boundary buffer zone – Loduare Gate to Masaai River (internal and external portions)	2	1	1	3	7
Endulen Villages	1	1	1	3	6
Nainokananka villages	1	1	1	3	6
Kakesio villages	1	0	1	3	5
Olbalbal villages	1	1	1	2	5
Boundary buffer zone – Maasai River to OldoinyoKerimasi	2	0	1	2	5
Boundary buffer zone – Lodoare gate to SW corner	2	0	1	2	5
Naiyobi villages	1	0	0	3	4
Boundary buffer zone – NCA / SNP	2	0	0	2	4
Eyasi Villages	1	0	0	2	2
Boundary buffer zone – OldoinyoKerimasi to NW Corner	1	0	1	1	3

7.6 TACTICAL AND OPERATION TOOLS

Annual Plan

In order to guide control programmes within the NCA, annual plans need to be compiled. Annual plans should be drawn up once the budget for the alien plant and indigenous weed control components have been finalised. In addition to the annual plans which are adapted to the NCAA budgets approved for the invasive plant (alien species and indigenous weed) control components, a second annual plan should also be drawn up which reflects actual budget requirements. That is, the alternate annual plan should reflect what it would cost to ensure all the priority needs are fully addressed in the field. This alternate plan and budget requirement projection should show what the needs are to ensure that the rate of weed control exceeds the rate of spread of all priority species and in all the priority zones.

Each NCAA budget year commences in July and ends on the last day of June. The annual plans will be informed by the objectives, priorities, specialist's reports and available budget. The annual plan should be developed by the Head of the Wildlife Development and Range Management Department. The Annual Plan, with records of operations and costs of work done once completed, must all be filed at the Wildlife Development and Range Management Department.

7.7 MANAGEMENT OF DATA RELATED TO INVASVIE ALIEN PLANTS

Effective data management includes the collection, capture and storage of adequate data, as well as the appropriate use thereof and feedback to relevant managers and field staff. A lack of good data/data management inhibits proper planning. It is therefore important to have a system in place that allows for good collection, capture and storage of data relating to alien species and indigenous weeds. Ideally, this information needs to be stored in a central place, and in a format that can easily be understood, accessed by the relevant personnel and backed up regularly.

The Head of the Range Management Section should be responsible for the management of all documents relating to invasive alien species and indigenous weeds. The functions of the document controller include:

- Ensuring that all hard copy and electronic documents/data are filed in an orderly manner;
- Ensuring that regular back-ups are made of all electronic data; and
- Ensuring that when operation or best practice procedure is updated/improved, that the necessary changes have been approved, that all relevant persons receive the updated version and that all previous versions are clearly marked as „"OBSOLETE"".

Within the NCA, the following are examples of the type of invasive alien species and indigenous weed data that will need to be collected and briefly describes how they should be managed:

Annual surveys

The current status of all alien species and of important indigenous weed infestations within and around the NCA ideally needs to be assessed/verified every year (with indigenous weeds only a few infestations in the high priority grazing areas such as in the Crater should be assessed). This should ideally take place in March/April in order to:

- Provide accurate information for the Annual Plan of Operations (APOs);
- Determine budget requirements for the next fiscal year;
- Update the GIS database (if operational);
- Identify thresholds of potential concern (described in Monitoring and Evaluation section).

In order to achieve this, it will be necessary to ensure that the relevant NCA staff members are capacitated to assess identify and map invasive alien plants. The following minimum information should be collected:

- Species
- Size class
- Number of individuals
- GPS co-ordinates
- Locality description.

This information is to be stored at the Wildlife Development and Range Management Department, and if feasible the survey data should be incorporated into the GIS database.

External specialists may be employed from time to time to conduct invasive alien plant surveys in cases where in house capacity is insufficient, or to ensure ongoing capacity building.

Control and Eradication Operations

All information relating control and eradication operations need to be recorded and filed in a systematic manner. This should include:

- Date of work
- Species removed
- Recommended follow-up date
- Associated costs for labour, equipment, etc.

Invasive alien plant sightings from patrol and community development extension work

The patrol datasheets, community development extension work and related reports should include information on invasive alien species sightings. A mechanism also needs to be put in place to ensure this data is collated by the Wildlife Development and Range Management Department.

The following minimum information should be collected:

- Species
- Size class
- Number of individuals, or extent of invasion in Ha
- GPS co-ordinates
- Locality description.

Best Practice Guidelines

Where invasive plant control operations or activities are complex, control measures such as documented best practice procedures or work instructions will need to be put in place. Such best practice procedures or work instructions will also assist in the cases of staff turnover by providing a baseline and guide for new personnel. The Head of the Range Management Section with the assistance of a technical expert (if needed) will be responsible for the development of such procedures. These shall include, but not necessarily be limited to:

- Invasive alien plant control methods best practice guideline (Appendix 2); and
- Involving stakeholders in controlling invasive alien plants best practice guideline (Appendix 3);

7.8 PREVENTION

Preventative measures aim to predict the potential entry of new alien plant species into the NCAA and setup effective methods to prevent such entry. Prevention is the first and least costly line of defence (Wittenberg &Cock, 2001). While the NCA already has a list of well over 100 alien plant species, the potential introduction of new species will continue to lengthen the list. The only form of prevention that will be beneficial is in prohibiting the importation and propagation of alien plant species in the lodges and personnel quarters. The argument that a plant has not escaped from a particular garden and is therefore not invasive does not hold true as the concept of the long lag phase (long fuse big bang theory) explains. Species may take decades or more before becoming invasive in an area. With the reality and well accepted fact that global climate is changing at a relatively rapid rate, it may release certain species that had previously not been able to become invasive due to climatic or other conditions and were thought to be "non-invasive".

A sign/notice should be placed at all entrance points (and possibly camp sites/lodges)to the NCAA indicating the problems with invasive alien plants and that no plants or seeds should be brought into the area. Tourists should also be prepared to have the vehicle checked for any seeds or material if the gate official requires it.

7.9 EARLY DETECTION AND ERADICATION

If invasions are to be detected at an early stage then surveys are needed. These surveys should be carefully designed and targeted to answer specific questions as economically as possible. With the wide range of invasive species present in East Africa and some on the borders of the NCA, it is suggested that an invasive alien plant survey is carried out annually. This will also assist in identification of species that may not have been recognised as invasive in the area and highlight species that may previously have thought to be "non-invasive".

Emerging species

Species that are in an early stage of invasion are commonly known as „emerging" species. Once an emerging species is present within a system, there is a limited period of time before the population may explode. The longer the species goes undetected, the less opportunity there will be to intervene, the fewer options that remain for its control or eradication, and the more expensive any intervention will become. Eradication will rapidly cease to be an option the longer an alien is left to reproduce and disperse (Wittenberg and Cock, 2001).

Not all alien species will necessarily become invasive. Therefore, species that are known to be invasive elsewhere within the region, province and country, should be prioritised for detection and immediate removal once located. The early eradication of a new alien colonizer makes the investment in early detection worthwhile. Two particularly noteworthy emerging species are *Chromolaena odorata* (Triffid Weed), *Parthenium hysterophorus* (Parthenium weed), also known as Famine weed. *Dalia imperialis* Dalia and *Opuntia* spp. Prickly Pear are also noteworthy. All four of these species are shown in Figure 11. One of these has not been observed within the NCA but has been report nearby, namely *C. odorata*. *P. Hysterophorus* was first recorded near Arusha in 2009 and was reported to be rapidly spreading in southern Kenya and northern western Uganda. It has been spreading extremely rapidly in northern Tanzania and has been seen, recorded and rapidly and successfully removed by vigilant officers from the Range Management Section in the NCA on two occasions since 2013. These proactive actions are highly commendable and exemplary because if allowed to establish within the NCA the invasions of *P. hysterophorus* will have hugely costly ecological and economic impacts in time to come.

C. odorata has been observed to north of Serengeti National Park and the Masaai Mara, as well as more recently in Lake Manyara National Park. *D. imperialis* is already present in the NCA but is still much localised. In southern Tanzania, Njombe Region, *Dalia* has spread extensively from the plantations to wetland areas (Figure 12). Similarly, an *Opuntia* sp. has spread extensively in areas of the Serengeti National Park and Grumeti Game Reserve. These two species are present within the NCA. It is recommended that all *D. Imperialis* and *Opuntia* spp. also be removed immediately and all staff be on the lookout for the other emerging species. Any sightings must be reported to the Wildlife Development and Range Management Department immediately to ensure rapid eradication of these species.

Chromolaena odorata (Triffid Weed)

Parthenium hysterophorus (Parthenium weed)

*Dalia imperialis (*Dalia)

Opuntia sp. (Prickly pear)

Figure 2. Photographs of emerging invasive alien plants in the NCA

Figure 3. Photographs showing the aggressiveness of *Dalia imperialis* elsewhere in Tanzania. This photograph was taken in Njombe Region

7.11 CONTROL

The aim of control is to reduce the density and abundance of an invasive organism to keep it below an acceptable threshold or in some cases actually eradicate the species. There are numerous specific methods for controlling invasive species, such as:

- Mechanical eradication – slashing invasive plants, hand pulling invasive plants or hand picking of small invasive fauna;
- Chemical eradication – using herbicides for invasive plants or toxic baits for invertebrates and vertebrates;
- Biological control – the use of host-specific natural enemies to reduce the populations of the invasive plant to an acceptable level
- Habitat management – grazing, or prescribed burning.

Mechanical control is highly specific to the target, but always very labour-intensive. However, in countries where labour is relatively inexpensive these initiatives can often have a dual purpose, in that they will aim to reduce the invasive species but can also assist in job creation/poverty alleviation. Chemical control is often very effective as a rapid and/or short-term solution. The major drawbacks are: that often the necessary herbicides are not yet registered in the country; the high costs and the non-target effects. In comparison with other methods, biological control, when it is successful, is a highly cost-effective, permanent, self-sustaining control method. Integrated management, combining several methods, will often provide the most effective and acceptable control.

The current invasive alien plant infestations within the NCA are still at relatively low numbers, thus at this stage it is still feasible to implement a simple control method such as mechanical control (e.g. uprooting, hand pulling or ring barking). Not only will this mechanical method of control be highly specific but it may also allow for some job creation/poverty alleviation should funds be available for this work. Herbicide may also facilitate control with species such as *Acacia mearnsii, Ceasalpinia decapetala,* and *Eucalyptus* spp.

In the case of certain species, the use of bio-control could be considered. For example if large stands of *Azolla filiculoides*(Red Water Fern) are observed, bio-control should be considered. However, unfortunately in Tanzania appropriate bio-control agents are not yet registered and thus the necessary host-specificity testing would first need to be done and legal permission obtained, which may take several years.

7.12 RESEARCH

It would be useful for a research programme, or parts thereof, to be initiated within the NCA that is driven by important management questions that need to be adequately and objectively informed. Such a research initiative could be done through a partnership with a relevant University/s or other research organisation, with the aim of developing an understanding of the invasion processes and impact in the NCA ecosystems. The three core research areas that would add value to the overall invasive species control programme are:

- *Impacts*- To determine the impact of invasive alien species in NCA and how it affects structure, composition and function of biodiversity.
- *Ecology*- To promote an understanding and predictive capacity of the dynamics of invasive species and integrate short-term practical and strategic long-term research.
- *Efficacy of control*- To enhance the long-term implementation of control programmes through developing an understanding of the associated negative impacts of control and further developing techniques for improved control and rehabilitation.

A schematic framework of the core research areas, which also shows all the key research questions (fields) to be addressed, is included as Figure 13.The research initiative should also ideally seek to address social impacts which are not currently indicated on the framework.

All research needs to be as practical and to be externally funded as far as possible. Funding for research initiatives must not take priority over funding required for control programmes.

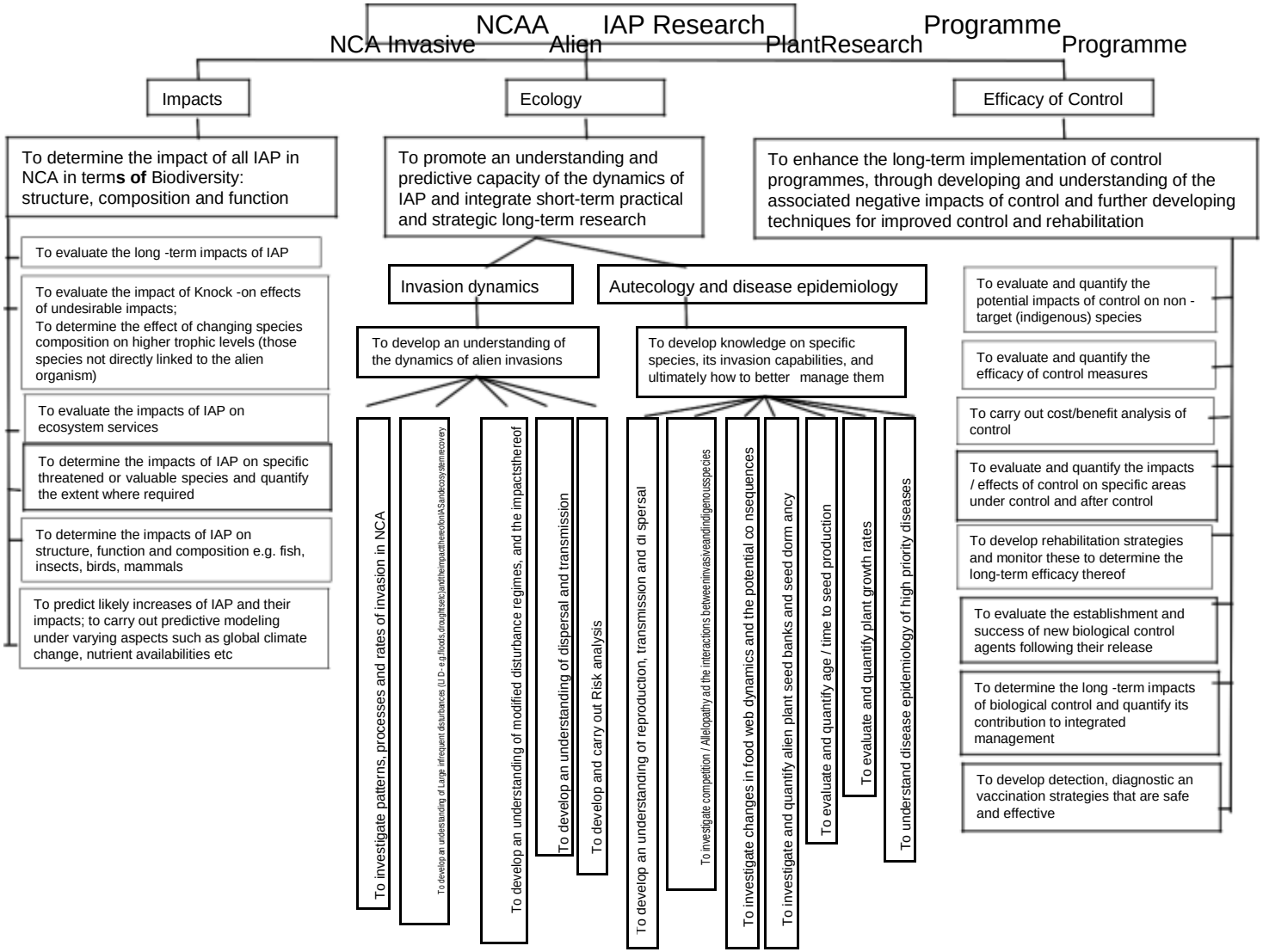


Figure 4. Framework for NCA potential Research Programme

7.13 MONITORING AND EVALUATION

Monitoring

Monitoring represents an ongoing activity such as tracking the spread of emerging and invasive alien species. The monitoring programme for invasive plants within NCA should be largely based on the thresholds of potential concern set for these species/areas. A Threshold of Potential Concern (TPC) is an operational goal to which an aspect of an ecosystem is managed. A TPC is essentially an upper or lower limit along a continuum of change in selected environmental indicators.

When a TPC level is reached, or when it is thought that it is likely to be reached soon, this prompts an assessment to try establish why this environmental indicator has changed. This assessment provides the basis for deciding whether:

1) a management action is needed to moderate the change; or
2) Whether the TPC should be recalibrated in the light of new knowledge and/or understanding.

TPC"s are a form of adaptive management because they are hypotheses of limits of acceptable change in ecosystem structure, function and composition. Therefore, their validity and appropriateness are always open to challenge, and they must be adaptively modified as our understanding and experience of the system increases.

The following TPCs and associated action upon notification of a TPC are recommend for the NCA.

Level 1 TPCs - deal with new invasions of species in the NCA.

When a first ever record of a species is noted in the NCA or is recorded after having been previously regarded as having been eradicated it should be regarded and treated as an immediate threat. When a species is noted close to or on the NCA boundary that is predicted to invade within 12 months it should be framed as an imminent external threat.

In order to detect new invasions EDRR plan should be in place. Upon TPC Level 1 notification, the extent of new or spreading invasions must be determined. If and where appropriate, an immediate contingency plan aimed at eradication will be launched. Data collection for EDRR monitoring activities will be done as indicated in Appendix 5. *The monitoring should continue until it is certain that the species has been satisfactorily eradicated.*

Level 2 TPCs - deal with an increase in distribution of a species in the NCA over a 12 month period.

The TPCs level 2 is when an invasion is noted that it is not contiguous with the previous distribution records or when an existing invasion expands its distribution by more than 5% in a year.

Species that has been established should be controlled using recommended practices. In areas where control have been conducted and is expected to be conducted pre and post monitoring plans and activities should be established in order to determine effectiveness of the control method. Data collection for monitoring control activities will be done as indicated in Appendix 6. *The monitoring should continue until it is certain that the species has been satisfactorily contained.*

In order to evaluate these Thresholds of Potential Concern, the following monitoring programme outlined in Table 3 is recommended.

Table 4. Monitoring programme for the NCA

	Indicator of	Sample intensity	Sampling sites	Sampling technique	Sampling performed by	Response to TPC
MONITORING						
1) Alien species survey in NCA	New invasive species in NCA or change in distribution of alien species	Ongoing	Entire NCA and nearby surrounding areas with special attention to source sites (villages, lodges, campsites, trade centres, roads& construction sites)	• A specific invasive alien plant survey is conducted annually. • During patrols, community development extension work etc, all invasive alien species sightings are reported and regularly compared with previously reports from that area. • If feasible observations should be stored in a GIS database	• Wildlife Development & Range Management Dept staff • Protection Dept staff • Community Development Dept staff • Tourism Services Dept staff	Level 1: Eradicate or monitor Level 2: Eradicate or contain

	Indicator of	Sample intensity	Sampling sites	Sampling technique	Sampling performed by	Response to TPC
2)Surveys of indigenous weeds in impacted grazing lands	Worsening or improving rangeland condition, due to e.g. a change in rainfall, livestock numbers or grazing pressure, etc.	Ongoing	Crater floor, Crater rim and other important rangelands for wildlife & livestock	• A specific rangeland condition survey including assessment of weed densities is conducted annually. • Before and after photographs are taken of rangelands after control activities are conducted (mowing, burning, and uprooting) and compared with untreated stands of important rangelands. • Observations from monitoring, and any relevant studies done,	• Wildlife Development & Range Management Dept staff • Protection Dept staff	Level 1: Monitor Level 2: Contain

	Indicator of	Sample intensity	Sampling sites	Sampling technique	Sampling performed by	Response to TPC
				should be stored in a GIS database.		
3) Ad hoc or opportunistic emerging species surveys	New invasive species or increase in distribution of emerging species	As opportunity arises	NCA and surrounding areas	All emerging species noted and GPS points recorded	• Wildlife Development & Range Management Dept staff • Protection Dept staff • Community Development Dept staff • Outsourced specialist	Level 1: Eradicate or monitor Level 2: Eradicate or contain
4) Aquatic weeds species survey	Change in distribution or abundance of aquatic species	Ongoing	Water bodies adjacent and within NCA	• A specific invasive alien plant survey is conducted annually. • During patrols, community development extension work etc, all invasive alien species sightings	• Wildlife Development & Range Management Dept staff • Protection Dept staff • Community Development Dept staff	Level 1: Eradicate or monitor Level 2: Eradicate or contain

	Indicator of	Sample intensity	Sampling sites	Sampling technique	Sampling performed by	Response to TPC
				are reported and regularly compared with previously reports from that area. • If feasible observation should be stored in a GIS database		
5) Ad hoc or opportunistic invasive alien species surveys in tourist lodges, campsites, trade centres, villages & roadsides	New invasive species or increase in distribution of emerging species	As required &opportunities arise	Tourist lodges	All emerging species noted and GPS points recorded	• Wildlife Development & Range Management Dept staff • Tourism Services Dept Staff	Level 1: Eradicate or monitor Level 2: Eradicate or contain

	Indicator of	Sample intensity	Sampling sites	Sampling technique	Sampling performed by	Response to TPC
6) Bio-control sites (if in place)	Establishment and/or efficacy of bio-control agents	At least annually	Release sites	As per International Guidelines	• Wildlife Development & Range Management Dept staff • Outsourced specialist	NA

Evaluation

Evaluation represents a systematic and objective assessment of ongoing or completed programmes in terms of their design, implementation and results. Within the NCA the control programmes of the alien plants, indigenous weeds in top priority sites and of livestock numbers, will need to be evaluated as will compliance to the invasive alien plant policy need to be assessed.

Details of the alien plant and priority indigenous weed infestation evaluations are outlined in Table 4 below. A livestock population and grazing control programme has not yet been developed, hence the evaluation of livestock numbers and condition is not included in this Table.

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Table 5. Invasive Plants Evaluation programme for the NCA

	Indicator of	Assessment intensity	Assessment sites	Assessment technique	Assessment performed by	Output
EVALUATION						
1) Evaluate invasive alien plant control programme (initial treatment)	Adequacy of invasive alien plant control programme (initial treatment)	After control programme	All areas that have undergone control	All areas that have undergone control are systematically checked, to ensure that all invasive alien species have been removed or treated and that control methods have been correctly applied. Any inconsistencies are recorded	• Head of Range Management Section, Wildlife Development & Range Management Dept.	• Report back Wildlife Development & Range Management Dept. • If no corrective action required, payment is issued to clearing team (where funding is available and applicable)

	Indicator of	Assessment intensity	Assessment sites	Assessment technique	Assessment performed by	Output
2) Evaluate indigenous weed control programme	Adequacy of indigenous weed control treatments	After control programme	All areas that have undergone treatment actions and adjacent sites to benchmark against	All areas that have undergone control are systematically checked, to ensure that the control treatments have been correctly applied& the weed and grasses responses to them recorded. Any inconsistencies and all results are measured, photographed &recorded	• Head of Range Management Section	• Report back to Wildlife Development & Range Management Dept. • Control programme is adapted according to which treatments and combinations yield the best results

	Indicator of	Assessment intensity	Assessment sites	Assessment technique	Assessment performed by	Output
3) Evaluate invasive alien plant control programme (follow-up treatment)	Adequacy of invasive alien plant control programme (follow-up treatment)	After control programme	All areas that have undergone control	All areas that have undergone control are systematically checked, to ensure that all invasive alien species have been removed or treated and that control methods have been correctly applied. Any inconsistencies are recorded	• Head of Range Management Section	• Report back to Wildlife Development & Range Management Dept. • If no corrective action required, payment is issued to clearing team (where funding is available and applicable)
4) Evaluate compliance to control programmes agreed to at lodges& campsites	Compliance to invasive alien plant control programmes agreed to at lodges	Annually	All areas that have undergone control programmes in which an agreement to further manage invasive alien species was signed.	All areas are systematically checked, to ensure that all invasive alien species have been removed or controlled. Any inconsistencies are recorded	• Head of Range Management Section	• Report back to Wildlife Development & Range Management Dept.

	Indicator of	Assessment intensity	Assessment sites	Assessment technique	Assessment performed by	Output
5) Evaluate compliance to invasive alien plant code of conduct	Compliance to invasive alien plant code of conduct	Annually	• All villages within the NCA • All tourist lodges& campsites within the NCA	All areas are systematically checked, to ensure that all invasive alien species have been removed or controlled. Any inconsistencies are recorded	• Head of Range Management Section	• Report back to Wildlife Development & Range Management Dept.

7.14. REVIEW AND REPORTING

Review

Results and recommendations of invasive alien plants and indigenous weeds management should be presented at a formal Management Review to the Conservator and other key NCA staff. This will help to ensure that invasive alien species remain understood and recognized as a priority threat, and will facilitate continual improvement and adaptive management.

Table 6.The minimum information that should be discussed and reviewed:

AGENDA ITEM	INFORMATION REQUIRED	ITEMS TO BE HIGHLIGHTED OR MOTIVATED	ACTION REQUIRED
Control Programmes	• Summary report on which areas have been controlled • Report on expenditure for the period under review	• Achievements or deficiencies • Proposed changes to control programmes	• Note performance • Consider and approve changes
Objective and Targets	• Objective and Targets for period under review • Proposed Objectives and Targets for the forthcoming year	• Achievements or deficiencies • Proposed objective and targets in perspective of long term goals	• Note performance • Approval of Objectives and Targets for the forthcoming year
NCA IAS code of conduct	• NCA IAS code of conduct	• Compliance within NCA • Proposed changes	• Endorse status quo or recommended changes
Structure, Responsibility and Resources	• Summary of current structure, roles and resources (human, technology, equipment etc.) • Status of donor funding (if applicable)	• Suggested changes to structure, roles and responsibilities • Additional resources & budget required for forthcoming year (human, technology,	• Consider and approve

AGENDA ITEM	INFORMATION REQUIRED	ITEMS TO BE HIGHLIGHTED OR MOTIVATED	ACTION REQUIRED
		equipment etc.). • Requirements for further donor funding	
Training	• Summary report on training and awareness programmes for period under review	• Progress and shortfalls for period under review • Training plans & budget requirements for the forthcoming year	• Note progress and shortfalls • Consider and approve training plans & budget requirements for the forthcoming year
Communication with stakeholders	• Summary report of internal and external interactions with stakeholders	• Significant interactions with stakeholders	• Endorse Communications approach, or review if necessary
Monitoring and Measurement	• Summary of results from the various monitoring programmes	• Status of monitoring databases • Trends shown and interpretation thereof • Recommended changes to monitoring programme	• Endorse status quo or recommended changes
Evaluations and non-conformities	• Summary of evaluations and non-conformities over the period of review • Summary of corrective and preventive actions	• Issues and trends arising from incidents and non-conformities • Suggested improvements relating to corrective and preventive action	• Endorse status quo or recommended changes

Reporting

The results of the evaluations and the Management Review should be included in an Annual Report.

8. CONCLUSION

To ensure the adequate management of invasive alien plants and of indigenous weeds within vitally important rangelands in the NCA, it is essential that all necessary nuts and bolts outlined in this document are addressed and implemented. The invasive alien plants problem within the NCA is still at a manageable level and the troublesome indigenous weed problems in rangelands is reversible should the causal grazing management challenges be addressed, and thus with sufficient financial resources and support and commitment they can be easily controlled to ensure they do not threaten the ecological integrity (and ultimately the sustainability) of the area.

This Strategic Management Plan should be seen as working document and should be revised at least every 3 years.

APPENDIX 1:LIST OF ALIEN SPECIES OBSERVED WITHIN THE NCA AND ITS SURROUNDS.

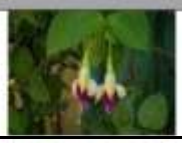
Serial Number	Scientific Name	Common English Name	Maasai Name	Photo
	Acacia mearnsii	Black wattle		
	Acalyphawikesiana			
	Achyranthes aspera	Chaff flower		
	Acrocarpus fraxinifolius			
	Agapanthus africanus/praecox	Agapanthus		
	Agave americana	American Agave		
	Agave sisalana	Sisal		
	Ageratum conyzoides	Invading ageratum		
	Aglaonema commutatum			
	Alternanthera pungens	Paperthorn		
	Annona montana			
	Anthurium sp.			

Serial Number	Scientific Name	Common English Name	Maasai Name	Photo
	Araucaria heterophylla			
	Argemone mexicana	Yellow flowered Mexican poppy		
	Argemone ochroleuca	White-flowered Mexican poppy		
	Artocarpus heterophyllus			
	Azolla filiculoides	Red water fern		
	Bauhinia variegata			
	Begonia hybrids			
	Bidens pilosa	Blackjack		
	Bougainvillea hybrids			
	Bougainvillea spectabilis			
	Bryophyllum delagoense			
	Caesalpinia decapetala	Mauritius or Mysore thorn		
	Caesalpinia pulcherima			
	Calissiarepens			

Serial Number	Scientific Name	Common English Name	Maasai Name	Photo
	Callistemon lanceolatus			
	Canabis sativa	Common Hemp		
	Canna indica	Garden canna		
	Canna generalis	Garden canna		
	Capscum frutecens			
	Capsellaburs apastoris	Shepherd‟s purse		
	Cassia didymobotrya			
	Casuarina equisetifolia			
	Catharanthus roseus			
	Cereus jamacaru			
	Cestrum aurantiacum			
	Cestrum elegans			
	Chlorophytum spp.	Hen-and-chicken		
	Chrysanthemum spp.	Common Chrysanthemum		

Serial Number	Scientific Name	Common English Name	Maasai Name	Photo
	Citrus lemon	Common Lemon Tree		
	Citrus sinensis	Common Orange Tree		
	Coffea arabica	Common coffee		
	Colocasia escualenta	Elephant's ear		
	Conyza spp.	Fleabane spp.		
	Cupressus lucitanica	Cypress tree		
	Cupressus pyramidalis	Cypress tree		
	Curcuma zedoaria			
	Cyphomandra betacea			
	Dahlia imperialis	Dahlia		
	Datura candida (= Brugmansia candida)	Angel trumpet White trumpet		
	Datura erecta			
	Datura stramonium	Common thorn apple		
	Delonix regia	Flamboyant		

Serial Number	Scientific Name	Common English Name	Maasai Name	Photo
	Dovyalis caffra			
	Dypsis leptocheilos			
	Epipremnum aureum			
	Epipremnum pinnatum			
	Erigeron karvinskianus			
	Eriobotrya japonica			
	Eucalyptus camaldulensis	Eucalypts, gum trees		
	Eucalyptus globulus	Eucalypts, gum trees		
	Eucalyptus saligna	Eucalypts, gum trees		
	Euphorbia pulcherina			
	Euryops chrysanthemoides	Daisy bush		
	Ficus benjamnima			
	Ficus elastica			
	Ficus hybrids			

Serial Number	Scientific Name	Common English Name	Maasai Name	Photo
	Fuchsia spp			
	Galinsoga parviflora	Small flowered quick weed, gallant soldier		
	Grevillea robusta	Australian silky oak		
	Gynandropsis gynandra (= Cleome gynandra)	Spider-wisp		
	Hedera spp.	Ivy creeper		
	Helianthus annuus			
	Helicona caribaea			
	Helicona rostrata			
	Huracrepitans			
	Hydrangia macrophylla	Christmas rose		
	Hyposestes phyllostachya			
	Iresine diffusa			

Serial Number	Scientific Name	Common English Name	Maasai Name	Photo
	Jacaranda mimosifolia	Jacaranda		
	Jatrophacurcus	Jatropha		
	Lantana camara	Lantana		
	Leucaena leucocephala	Leucaena		
	Lonicera japonica var. Halliana	Japanese or Hall"s honeysuckle		
	Ludwigia stolonifera			
	Malus domesticus			
	Mangifera indica	Mango tree		
	Markamia lutea			
	Melia azedarach			
	Monstera diliciosa	Delicious monster		
	Morus alba			
	Musa paradisciaca	Banana tree		
	Nephrolepus exaltata			

Serial Number	Scientific Name	Common English Name	Maasai Name	Photo
	Nerium oleander			
	Nicandra physalodes	Apple of peru		
	Nicotiana rustica/glauca			
	Nicotiana tabacum			
	Opuntia exaltata or cylindrica	Long spine cactus		
	Opuntia inermis			
	Opuntia vulgaris			
	Parkinsonia aculeata			
	Parthenium hysterophorus	Famine weed / Parthenium		
	Passiflora edulis	Passion plant		
	Pelargonium domesticum			
	Pennisetum purpureum	Napier fodder Elephant grass		
	Persea americana	Avocardo		
	Phaseolus vulgaris	Common Bean		

Serial Number	Scientific Name	Common English Name	Maasai Name	Photo
	Podranea sp.	Port St John‟s or Zimbabwe creeper		
	Polyalthia longifolia			
	Prunus persica			
	Psidium guajava			
	Raphanus raphanistrum	Wild radish		
	Ricinus communis	Castor-oil plant		
	Rosa sinensis			
	Rosemarinus officinalis			
	Salvia leucantha			
	Sanchezia parvibracteata			
	Schinusmolle	Pepper tree		
	Senna siamea			
	Senna spectabilis			
	Solanum tuberlosum			
	Sonchusoleraceus	Milk thistle		

Serial Number	Scientific Name	Common English Name	Maasai Name	Photo
	Spathadea companulata			
	Syngonium podophyllum	Goosefoot		
	Syzgium cuminii			
	Tagetes minuta	Mexican marigold, Khaki weed		
	Tecoma ricasoliana			
	Tecoma stans			
	Terminalia mantaly			
	Terminalia superba			
	Thevetia peruvianna	Yellow oleandar		
	Tithonia diversifolia			
	Tradescantia zebrina	Wandering jew		
	Tropaeolum majus	Garden nasturtium		
	Tulbaghia violacea			
	Verbena bonariensis	Wild verbena, Purple top		

Serial Number	Scientific Name	Common English Name	Maasai Name	Photo
	Verbena officinalis	Slender verbena, European verbena		
	Vinca major	Large blue periwinkle		
	Widdringtonia nodiflora			
	Withanias omnifera			
	Xanthium strumarium			
	Zea mays	Maize		
	Zingiber neglectum			

APPENDIX 2: INVASIVE ALIEN PLANT CONTROL METHODS BEST PRACTICE GUIDELINE

There are five basic methods of controlling invasive alien plants. These include:

- **Mechanical control:** This involves removing the invasive plants or damaging them severely by physical actions such as uprooting, hand pulling, slashing, rings barking, strip-barking or mowing. This is done either by hand, or with appropriate tools, instruments or machines.
- **Biological control:** This entails the use of host-specific natural enemies to reduce the populations of the invasive plant to an acceptable level.
- **Chemical control:** This involves the application of registered herbicides to the invasive plants or to the soil surrounding them, with the aim of killing or suppressing the plants. The choice of herbicides, the correct application method, dosage, time of application and follow-up actions are very important.
- **Fire**: This entails putting in a management burn to reduce invasive alien plant biomass.
- **Integrated weed management:** This involves a combination of methods described above.

Each of these control methods is briefly described below. A list of recommended control methods for all invasive species occurring within NCA is displayed in Addendum 1, and a more detailed control method description is outlined for each of the priority invasive alien species occurring in NCA in Addendum 2.

MECHANICAL CONTROL

MECHANICAL CONTROL TECHNIQUES
Mechanical techniques such as uprooting, hand-pulling, slashing, ring barking and strip barking may be used to control some invasive plants, particularly if the plant population is relatively small. These techniques can be extremely specific, minimizing damage to desirable plants, but they are generally labour and time intensive. Treatments must typically be administered several times to prevent the weed from re-establishing, and in the process, labourers may severely trample vegetation and disturb soil, providing prime conditions for re-invasion by the same or other invasive species.
Common mechanical control techniques are described below.

Uprooting

Uprooting involves pulling out or digging out a plant with various tools such as picks or winches. It is commonly used for seedlings or small trees and shrubs. Detached root fragments of some species can resprout while others do not. Similarly, some species once uprooted may be able to survive if left in contact with the soil. As with all methods of control, it is very important to carry out simple tests to see how each species in a particular area or habitat responds to control techniques. Soil disturbance can be minimized by replacing the soil to disturbed areas.

Hand pulling

Grip the young plant low down and pull out by hand (using gloves).This is best done after rain, when the soil is soft and roots are more pliable. It can be effective against some shrubs, tree saplings, and herbaceous and floating weeds. Annuals and tap-rooted plants are particularly susceptible to control by hand-pulling. However, it is not as effective against many perennial weeds with deep underground stems and roots that are often left behind to re-sprout.
Hand pulling is easy to plan and implement, and is often the best way to control small infestations, such as when a weed is first detected in an area. The key to effective hand pulling is to remove as much of the root as possible while minimizing soil disturbance. For many species, any root fragments left behind have the potential to re-sprout, and pulling is not effective on plants with deep and/or easily broken roots.

Soil disturbance can be minimized by pulling out weeds slowly and carefully, and replacing the soil to disturbed areas where possible. Trampled and disturbed areas can provide optimal germination sites for many weeds. Minimize trampling by limiting the number of people in the site and the amount of time spent there. Whenever a manual technique is used, it is wise to wear gloves, a long-sleeved shirt, and long pants. Some plants can cause moderate to severe skin irritation, especially when their stems and leaves are crushed and broken. Even the flimsiest weeds can leave hands raw and bleeding after several hours of pulling.

The advantages of pulling include its small ecological impact, minimal damage to neighbouring plants, and low (or no) cost for equipment or supplies. Pulling is extremely labour intensive, however, and is effective only for relatively small areas.

Slashing or mowing

Slashing or mowing can reduce seed production and restrict weed growth, especially in the case of annuals that are cut before they flower and set seed. Some species however, re-sprout vigorously when cut, replacing one or a few stems with many that can quickly flower and set seed.

Slashing or mowing are often used as primary treatments to remove aboveground biomass, in combination with prescribed burning or herbicide treatments.

Ring barking

Ring barking is often used to control trees or shrubs that have a single trunk. It involves cutting away a strip of bark several centimetres wide all the way around the trunk. The removed strip must be cut deep enough into the trunk to remove the vascular cambium, or inner bark, the thin layer of living tissue that moves sugars and other carbohydrates between areas of production (leaves), storage (roots), and growing points. This inner cambium layer also produces all new wood and bark.

To ring bark a tree, cut parallel lines approximately three inches or more apart around the circumference of the tree. The cuts can be made using a knife, axe, or saw, and should be slightly deeper than the cambium. Strike the trunk sharply between the cuts using the back of an axe or other blunt object. The bark should come off in large pieces and prevent the tree from any further growth. It is important not to cut too deeply into the trunk because this could cause the tree to snap and fall in high winds. To determine the depth of the cambium, make two short test cuts and strike the bark between the cuts. After several strikes the bark should come off intact, exposing the cambium and wood (xylem) below.

Ring barking is effective against species such as pines and gums. It typically requires less labour than cutting and removal, is inexpensive, and kills only the targeted plant. It also leaves no residue except the standing trunks. In addition, a dead standing tree (snag) can provide valuable wildlife habitat, and if left to decay, allows the nutrients of the tree to be returned to the system, rather than being removed and deposited elsewhere. Ring barking is useful for leaving large trees for raptor nests.

Strip barking

Bark stripping is similar to ring barking but requires the bark to be removed all the way down to ground level from any chosen height above knee height (about 50 cm).

Felling

Felling involves cutting down the tree. This method is useful where standing plants are displeasing to the eye, but is not useful where access is needed and logs are left to rot (decomposition may take many years). Felled trees can be used for firewood or charcoal, however the felling, cutting up and removal of the wood does cause disturbances to the nearby area.

MECHANICAL CONTROL CONSIDERATIONS

Unfortunately, mechanical control is often not enough to control many problem species. It is not suited to:

- Species with extensive root stocks (such as *Rubus cuneifolius);* as recolonisation is exacerbated by the removal of cover and further disturbance.
- Species favouring steep slopes or areas susceptible to erosion (riverine zones and where water quality is imperative).
- Large rapidly expanding infestations

Mechanical control is also very time-consuming and therefore costly. It is in reality practically applied only on small-scale areas where labour intensive methods are required.

ADVANTAGES OF MECHANICAL CONTROL

- Little training or supervision needed, except in the case of felling
- Simple tools required and only target species treated, except in the case of felling
- When implemented with care the environment is unharmed (except in the case of felling) e.g. disturbed areas from uproots plants can be refilled with soil, soil compacted and covered with grass or leaf litter.

DISADVANTAGES OF MECHANICAL CONTROL

- Physically demanding
- Slow and costly for large area or dense infestations where it is seldom completely successful and requires repeat follow-up operations
- Any soil disturbances can promote germination of undesired weed seeds

- In dense infestations indigenous/desirable species may be mistakenly destroyed
- In the case of felling, thorough training is required to prevent harm to property, injury or death.

BIOLOGICAL CONTROL

Biological weed control involves the use of natural enemies to reduce the vigour or reproductive potential of an invasive alien plant. The principle is that plants often become invasive when they are introduced to a new region without any of the natural enemies of the plant. The alien plants therefore gain a competitive advantage over the indigenous vegetation, because all indigenous plants have their own natural enemies that feed on them or cause them to develop diseases. Biological control is an attempt to introduce the alien plant's natural enemies to its new habitat, with the assumption that these natural enemies will remove the plant's competitive advantage until its vigour is reduced to a level comparable to that of the natural vegetation. Natural enemies that are used for biological control are called bio-control agents.

Most frequently used agents are insects, mites and pathogens (disease-causing organisms such as fungi). Bio-control agents attack specific plant organs of specific plant species, such as the vegetative parts of the target plant (its leaves, stems or roots) or the reproductive parts (flowers, fruits or seeds). The following are examples that attack the leave and stems of the weed:

- The herring bone leaf mining fly, *Ophiomyiacamara* for *Lantana camara*
- *The leaf defoliating moth, Parachaetesinsulata* for *Chromolaenaodorata*

Other bio-control agents do not kill plants or reduce the infestations but prevent further spread by attacking the reproductive sections of the plant like the flowering buds, flowers and seeds. For example:

- The seed feeding weevil, *Rhyssomatusmarginatus* which feeds on *Sesbania punicea*
- the flower feeding weevil, *Trichapionlativentre* which feeds on *Sesbania punicea*

If the invasive alien plant is useful in certain circumstances but becomes a pest when uncontrolled, then a „conflict of interest‟ may arise. In these cases, it is not wise to use bio-control agent that kill the invasive alien plant, but to rather suppress the dispersal of the invasive alien plants. In these cases a seed reducing agent may be most suitable. For example in the case of *Acacia mearnsii*, this is used for timber and tannins but is also highly invasive. A seed feeding weevil, such as *Melanterius maculatus,* which attacks mature seeds and not the tree it self could be used.

IS BIOLOGICAL CONTROL SAFE?

The introduction of living organisms from one country to another is always extremely hazardous, and numerous cases are known where alien organisms (whether introduced on purpose or inadvertently) have wreaked havoc and driven numerous indigenous plants or animals to extinction. Therefore, biological control of invasive alien plants has developed into a science that is practised with the utmost care. Every conceivable precaution is taken to prevent the introduction and release of alien organisms that could become harmful. The introduction and release of weed biocontrol agents may be undertaken only by scientists who have the necessary knowledge and experience of insects, mites and/or fungi and their interaction with plants, who have access to approved quarantine facilities in which the introduced organisms can be studied and reared without the danger of escape, and who are subject to the safety regulations imposed by their own government as well as regular scrutiny and discussion of their projects by fellow scientists from other countries.

The potential risk posed by a candidate bio-control agent is determined by bio-control researchers through extensive host range studies (specificity tests) that are carried out in a quarantine facility. These trials determine the range of plants that a potential bio-control agent is able to use as host plants throughout its life cycle, as well as its host plant preferences. Permission to release a bio-control agent will be sought only if the host-specificity tests prove without doubt that the potential agent is sufficiently host-specific for release in this country. To be regarded as sufficiently host-specific, the candidate agent must be either monophagous (i.e. the insect feeds on only one plant species, the target weed in this case) or it could have a slightly wider host range, provided that none of the additional host plants occur in Tanzania or surrounding countries, either as indigenous or introduced crop plants. These tests are very stringent and can take up to 5 years to complete satisfactory. Only once these have been evaluated can they be acquired and released.

HOW EFFECTIVE IS BIOLOGICAL CONTROL?

Probably without exception, bio-control agents do not completely exterminate populations of their host plants. At best, they can be expected to reduce the weed density to an acceptable level or to reduce the vigour and/or reproductive potential of individual plants. The fact that a few host plants always survive, in spite of the attack by a bio-control agent, actually ensures that the agent does not die out as a result of a lack of food. The small population of bio-control agents that persists will disperse onto any regrowth or newly-emerged seedlings of the weed. For this reason, bio-control can be regarded as a sustainable control method.

A biological control project is considered complete successes if no other control measures are required to keep the weed under control. A few examples of complete successes in South Africa are the biological control of red water fern (*Azolla filiculoides*), water lettuce (*Pistia stratiotes*), Port Jackson acacia (*Acacia saligna*), red sesbania (*Sesbaniapunicea*) and Australian pest pear (*Opuntia stricta*). The degree of control is regarded as significant if methods other than biological control are still needed to reduce the weed to acceptable levels, but less effort is required. This could mean that fewer herbicide applications are needed per year or that less herbicide is needed per unit area because the bio-control agents have reduced the size or density of the weed infestation. It could also mean that less follow-up is

necessary because the bio-control agents have reduced the weed's ability to regrow mechanical or chemical clearing actions. Examples of such projects are the biological control of jointed cactus (*Opuntia aurantiaca*), prickly pear (*O. ficus-indica*), parrot's feather (*Myriophyllum aquaticum*), water hyacinth (*Eichhorniacrassipes*) and silky hakea (*Hakea sericea*) in South Africa.

Biological control works relatively slowly. Considering the number of years it has taken invasive plants to reach their present population levels, it is unrealistic to expect an insect species to increase in numbers within one or two years to a level at which it can already significantly reduce the invasive plants. On average, at least five years should be allowed for a bio-control agent to establish itself successfully enough before starting to cause significant damage to its host plant species.

Unfortunately, biological control is not necessarily effective or possible against every problem species. It could happen that effective bio-control agents do exist, but cannot be released in Tanzania because they are not sufficiently host-specific. Alternatively, the invasive plant might be a man-made hybrid between two or more species, and is no longer an acceptable host to the natural enemies of either of the parent plants. It could also happen that the natural enemies of some plants are not adapted to all the climatic regions in which the plant is a problem in Tanzania, or that the habitat already contains predators or parasitoids that attack the bio-control agents. In such cases, biological control will have to be replaced or supplemented by chemical or other control measures.

ADVANTAGES OF BIOLOGICAL CONTROL

- It is environmentally friendly because it causes no pollution and affects only the target (invasive) plant
- It is self-perpetuating or self-sustaining and therefore permanent
- It is cost-effective (once all the testing has been completed
- It does not disturb the soil or create large empty areas where other invaders could establish, because it does not kill all the target plants at once. Instead, it allows the natural vegetation of the area to recover gradually in the shelter of the dying weeds.

DISADVANTAGES OF BIOLOGICAL CONTROL

- It is slow and expensive to develop. Years of research need to be undertaken by experts in strict quarantine facilities before a bio-control agent can be introduced into a country. Thereafter, mass rearing also often needs to take place before the agent can be released in adequate numbers, both of which are costly.
- It is slow to achieve results. It may take several years to suppress an invasive alien plant population versus a few weeks or months when using other control methods.
- It will not totally eradicate the invasive alien plant population.

- It is often unpredictable in the sense that, even once established infield it usually takes years to ascertain what extent of impact the bio-control agent will have on the target plant and whether or not it will be adequate.

CHEMICAL CONTROL

This involves the application of registered herbicides to the invasive alien plants or to the soil surrounding them, with the aim of killing or suppressing the plants. The choice of herbicides, the correct application method, dosage, time of application and follow-up actions are very important.

HERBICIDE SELECTION

Selection of appropriate herbicides for chemical control depends chiefly on, the target species to be controlled within the local area, the registered herbicides and their cost-effectiveness. Other factors are multi-species applicability, the residual effect of particular herbicides, and their selectivity. Rather than using a wide range of herbicides for different species, it is best to limit the use to a few herbicides. This makes for less error in storage, application and mixing.
When selecting a herbicide it is important to consider the following (WESSA-KZN, 2008):

The active ingredient

- The key for selecting a herbicide is the chemical compound called the active ingredient. Different herbicides can have the same active ingredient (e.g. glyphosate) but are sold under different trade names and at different prices. The concentration of the active ingredient can also be different (e.g. glyphosate 360g ae/l or 450, 500 g ae/l) more or less is then needed to achieve the same result. Thus, although two products may have different brand names, if they contain the same active ingredient and concentration they will be similarly effective.

- Always store your herbicides in the original labelled container and out of reach of children and animals.

- Some herbicides contain a dye. Dyes can also be bought and are useful to show where the herbicide has been applied.

- Some herbicides require the use of a „wetter" to be effective.

- Water or diesel is used as a „carrier". Diesel is expensive and can affect the environment. Whenever appropriate, use water. Diesel is never used for foliar spraying.

Selective herbicides

- These are herbicides that affect only the target plant or plant group, e.g. selective, broadleaf herbicides will kill broadleaf plants but not grasses.

- Most selective herbicides will lose their selectivity at high enough doses.

Non-selective herbicides

- Those herbicides that affect any plant they contact, often creating bare ground that only encourages further weed invasion.

Systemic herbicides

- Systemic herbicides move within the plant from the point of contact towards the growing points that will then be destroyed. They are well adapted to controlling perennial species that have strong root systems. They usually require time to penetrate and migrate within the plant so tend to be slow acting.

Contact herbicides

- Contact herbicides are translocated throughout the plant from the area initially treated. Thorough coverage and wetting of the plant is necessary for effective control. They work well on annual species and are adapted to remove the vegetation prior to planting especially in tropical environments. They are usually fast acting and rain-fast. Many plants become tolerant of such chemical as they mature but seedlings are typically very sensitive to these herbicides. Roots usually remain intact thus allowing good erosion prevention. Remember that perennial plants can resprout and re-grow from the remaining root system and are often able to recover.

Residual effect or non-residual effect

- As some herbicides can remain active in the soil for a considerable amount of time, the residual effect needs to be seriously considered before rehabilitation of a treated area is attempted.

Table 7: Common herbicides and associated information on each

Commercial Names	Target Plants	Active Ingredients	Effect on plants	How it works	Residual effects	Carrier
Access Browser	Broadleaf	Picloram 240g/l SL	Selective	Systemic	Moderate	Water
Brush-off Climax	Broadleaf	Metsulfuronmethyl 600g/kg WG	Selective	Systemic	Low	Water
Chopper Hatchet	All	Imazapyr 100g/l SL	Non-selective	Systemic	Moderate	Water
Garlon Tricolon	Broadleaf	Triclopyr 480g/l EC	Selective	Systemic	Nil	Water/ Diesel
Midstream	Water weeds	Diquat 200g/l	Non-	Contact	Nil	Water

Commercial Names	Target Plants	Active Ingredients	Effect on plants	How it works	Residual effects	Carrier
		EC	selective			
MSMA SL	Succulents/grasses	MSMA 720 SL	Selective	Contact/ Systemic	Nil	Water
Round Up Mamba Springbok Senator Xtra	All	Glyphosate 360g.a.e/l SL	Non-selective	Systemic	Nil	Water

Herbicide concentration

Herbicide prescriptions must be followed. Too weak a dose is costly in time, money and resources and is a waste of effort. Conversely, too strong a dose than is recommended may not only lead to an unnecessary waste of expensive herbicide but may also lead to herbicide resistance in the target species. Too high a dose can also cause die-back of the treated part without killing the plant or result in the die off of non-target plants.

The Table below will help assist to ensure the correct concentration of herbicide is used. **Table 8:** Amount of herbicide to be used in different sized containers

Container Capacity (ml)	Recommended Concentration of Herbicide						
	0.5%	1.0%	1.5%	2.0%	3.0%	5.0%	10%
50	0.25ml	0.5ml	0.75ml	1.0ml	1.5ml	2.5ml	5ml
100	0.5ml	1.0ml	1.50ml	2.0ml	3.0ml	5.0ml	10ml
200	1.0ml	2.0ml	3.00ml	4.0ml	6.0ml	10.0ml	20ml
500	2.0ml	4.0ml	6.00ml	8.0ml	12.0ml	20.0ml	40ml
400	2.5ml	5.0ml	7.50ml	10.0ml	15.0ml	25.0ml	50ml
1000 (1l)	5.0ml	10.0ml	15.00ml	20.0ml	30.0ml	50.0ml	100ml
2000 (2l)	10.0ml	20.0ml	30.00ml	40.0ml	60.0ml	100.0ml	200ml
5000 (5l)	25.0ml	50.0ml	75.0ml	100.0ml	150.0ml	250.0ml	500ml
7500 (7.5l)	37.5ml	75.0ml	112.5ml	150.0ml	225.0ml	375.0ml	750ml
10 000 (10l)	50.0ml	100.0ml	150ml	200ml	300ml	500ml	1000ml

PRECAUTIONS AND TIPS

- Develop safety protocols for storing, mixing, transporting, handling spills and disposing of unused herbicides and containers before obtaining herbicides

- Take precautions to avoid getting herbicide on your skin
- Avoid breathing the vapour
- Wear overalls, rubber gloves and face masks
- If spraying, stay upwind of the target plants
- Do not spray in windy weather or if it looks like it is going to rain
- Apply herbicide when plant is actively growing
- If leaf colour has started change as a result of the onset of winter, it is too late
- Do not use herbicides on drought stressed or diseased plants or in extremely hot or cold conditions (the wilting temperature is 27 degrees Celsius)
- Spray before seed is produced i.e. between flowering and fruit set
- Be aware that there are restrictions on using herbicides near wetlands and waterways
- Stage the weed removal where appropriate. Large areas of exposed soil are an open invitation to weed invasion and to erosion.

HERBICIDE APPLICATION TECHNIQUES
The various techniques of herbicide application are described below:

Foliar application
Foliar spray

Use a foliar application with great care, especially in windy conditions, because of the potential damage to surrounding environment. This method should be considered for large areas of invasive growth where risk to non target species is minimal.
The correct mixed herbicide is sprayed on to the rapidly growing leaves and stems (foliage) of the target plant, usually to the „point of runoff" i.e. when the herbicide mix is about to run off the leaves. Some herbicides require the use of a „sticking agent" or „wetter" to ensure efficient results. Ideally, enough foliage must be present so that the plant „catches" sufficient herbicide to kill it. When spraying plant previously cut down the re-growth or coppice should generally have reached a height of between 50 to 100cm for effective control, but labels may specify requirements. A dye can be added to indicate sprayed areas.
Do not use river water as it has a high soil content and blocks sprays etc. Uptake of herbicides is hampered by poor water quality. E.g. water with a high PH or containing dissolved solids.

Advantage of foliar spray

- An easy and versatile technique
- Can be used on small or large areas where conditions are rough or where there are small obstacles
- Ideal for follow-up work

Disadvantages of foliar spray

- Plants often require preparation making it a two part operation
- Application rates are unlikely to be accurate as they are influenced by terrain, plant density, the weather (e.g. drift) and the operator (e.g. fatigue)
- Environmental conditions (e.g. rain) and the state of the plant (e.g. stressed due to heat or drought, dusty, eaten by insects etc.) affect herbicide efficacy
- Frequently refilling of apparatus slows rate of work (about 2 man days per hectare)
- Non-target plants can be „caught in the spray".

Stem applications

Basal stem

For plants with thin bark or stems up to 25 cm in diameter. Most invasive alien plants are perennials and have the ability to regrow after being damaged or cut down, so apply mixture of herbicide and water or diesel to all bark with a paint brush or sprayer from ground level to 0.25m. Spraying uses 3 x more mixture but is less tiring and faster than painting. All bark pieces left in crevices after strip barking should be killed by thorough spraying/painting. In multi-stemmed plants, each stem must be treated separately, avoid sand on stump or bark when painting on herbicides.

Total Frill

Frilling is used for treating shrubs or tree greater than 10 cm in diameter at the base or when you want them to die in place. Often used instead of ring barking as it takes less time. A ring of linked downward cuts is made in the bark of the tree, as low as possible and deep enough to include the cambium, using a blunt hand axe (cuts are too deep if the axe is sharp). Herbicide,

mixed as per the label, is applied to the frill with a suitable applicator, e.g. syringe or hand-held sprayer. Large cuts (5 cm long) hold and 1 ml initially if cut is level. Care is needed with cutting and application, so work is slow.

Stem injection

Recommended mainly for succulent and woody weeds where you want them to die in place. There are purpose-built stem injection devices but a hammer and chisel or a cordless drill can be used. Make an angled cut or hole down into the sapwood just below the bark and apply herbicide into the cut immediately. Don"t drill too deeply or get into the heart wood which does not take up herbicide. About 2ml of water soluble herbicide solution it put in each hole. (approximately 4 holes for a plant small than 2 m and maximum of 12 holes for large plants)

Advantage of stem applications

- A simple, target specific method which requires little preparation or training
- Ideal for tall trees that can be left to remain standing
- Usually not dependant on weather conditions. If diesel is the carrier, it is water repellent and work can continue in light rain although possibly less effectively. Work can still take place when plant is stressed.

Disadvantage of stem applications

- If diesel is the carrier it is expensive and usually more toxic to humans than the herbicide
- Open containers used in paintbrush method often fall over, causing wastage and soil contamination
- Frill and stem injection are slow techniques.

Stump applications

Cut stump

Cut the plant as close to the ground level as possible with a horizontal cut. Use a tool that will give a clean cut e.g. loppers for diameters up to 50mm and a saw for diameters greater than 50 mm. The ideal stump is short, with a level cut-surface, none of the bark is torn away from the wood and there are no exposed roots. Remember sharp, angled cuts make the stumps hazardous. For cut stump, mix herbicide according to label and apply as soon as possible to

the outer ring of the freshly cut surfaced just inside the bark. If you are too slow, air is sucked into the sap vessels, preventing uptake of the herbicide. For multiple, small stumps with diameter less than 50 mm treat all cut surfaces.

Total stump

Mix herbicide according to label and apply to cut surface, the sides of the stump (all exposed bark) and any exposed roots.

Advantage of stump application

- The most effective method which could be considered whenever practical
- Good in sensitive areas, because the herbicide is placed into the target plants
- Only a small amount of herbicide is used per plant
- A one-pass operation, there is usually no need to return to the same plants.

Disadvantages of stump applications

- Cutting down is tiring work
- Progress is slow because falling branches need to be avoided and cleared to one side
- Removal and disposal of large amounts may be difficult
- If diesel is used as a carrier for the herbicide it makes it expensive
- Removal of the canopy will stimulate many seeds to germinate
- Some herbicides are long-acting (or have residual action) and may be absorbed by non-target species planted later.

Scrape and paint

Suitable for large vines and scrambling plants with a wood stem. Using a knife and starting from the base scrape 20 to 100 mm of the stem to expose the sapwood just below the bark. Try to scrape all the main stems. Within 20 seconds apply herbicide to the scraped sections. Do not scrape right around the stem, do only one third of the diameter. Stems over 1 cm in diameter can be scraped on 2 sides. Leave the vines to die in place to prevent damaging the plant/s they are growing on.

FIRE

The most effective fires for controlling invasive plant species are typically those administered just before flower or seed set, or at the young seedling/sapling stage. Sometimes prescribed burns that were not originally designed to suppress an invasive species have that positive side effect. But in some cases, prescribed burns can unexpectedly promote an invasive, such as when their seeds are specially adapted to fire, or when they resprout vigorously. These prescriptions must be modified or other management actions taken to undo or reverse the promotion of the invader (Tu *et al.* 2001).

Most successful weed control efforts that result from burning are due to the restoration of historical (natural) fire regimes, which had been disrupted by land use changes, urban development, fire breaks, or fire suppression practices. Many prescribed burn programs are, in fact, designed to reduce the abundance of certain native woody species that spread into unburned savannas and grasslands. Repeated burns are sometimes necessary to effectively control weedy plants, and herbicide treatments may be required to kill the flush of seedlings that germinate following a burn (Tu *et al.* 2001). If used judiciously, fire can be an important and cost effective tool for controlling invasive alien as well as weedy indigenous plant infestations if it is used with other methods of control.

INTEGRATED WEED MANAGEMENT

Integrated control can be described as "The integration of any number of control methods or techniques, in any possible way, to achieve the most favourable outcome in terms of predictable economic, sociological and ecological consequences."Thus, it involves any combination of two or more of the methods described above.
When using integrated weed management, control methods and techniques must be compatible and complementary so that their combined effect results in (Lotter, 2007):

- greater weed mortality
- increased versatility in mixed weed infestations
- minimal use of herbicides
- improvement in cost-efficiency of control
- reduction in physical disturbances during clearing operations

REDUCTION IN SOIL EROSION OR NON-TARGET DAMAGE CAUSED BY CLEARING OPERATIONS - LONGER LASTING RESULTS.DEALING WITH PROBLEMATIC INDIGENOUS WEED SPECIES IN THE NGORONGORO CRATER

The indigenous species *Bidens schimperi* and *Gutenbergia cordiolia* have a weedy tendency and have become problematic on the Crater floor and elsewhere. As far back as 1962, *G. Cordifolia* was recorded to be dominant over a large part of the Crater floor. *B. schimperi* appears to have undergone an explosion of growth and spread in more recent years. The

proliferation of these species may be a result of sustained grazing pressure on the Crater (and other areas surrounding the Crater), variable rainfall or changes in fire regime. This is also combined with other environmental factors such as climate, rainfall, soils and burning. Although indigenous, these species present a problem in terms of reducing available forage and clearly is avoided by many animals. Various range management techniques need to be investigated in order to reduce the density and distribution of these species to acceptable levels. Management will have to be adaptive and utilise best available knowledge on the problems and develop an understanding of the plants dynamics in response to control measures. Some control measures have been started, such as mowing and burning. Efforts should be made to study the species in order to gain an understanding of these plants biology and ecology. This will help in developing a predictive response to management. Permanent plots under a range of different management actions and in open unmanaged areas (control plots) will provide insight into many of these aspects. As both species are indigenous and should be in the system, acceptable thresholds should be determined, according to which the plants are managed. For example, cutting will only be done when more than 30% of the Crater floor is invaded at a density greater than 50%. These thresholds can then be developed and evaluated annually and if due to natural circumstances, the plants do not reach these levels no management intervention is needed. Aerial photography and fixed-point photography from viewing platforms on the Crater rim may be useful tools in assessing and managing these problems. Accurate records should be maintained of exactly where and when each mowing was done in order to evaluate the long-term effects. Herbicides are not recommended as the system is closed and the effects of bioaccumulation not known. Although herbicides can be carefully selected to be as environmentally friendly as possible and break down rapidly, these should only be investigated if it is shown that the current method is not successful (Foxcroft, 2003).

APPENDIX 3: INVASIVE ALIEN PLANT STAKEHOLDER INVOLVEMENT BEST PRACTICE GUIDELINE

INTRODUCTION

The majority of alien plant species in the NCA are associated with human settlements such as villages, tourist lodges and even schools, where they are primarily planted for ornamental purposes. In order to facilitate the removal of these invasive alien plants and prevent them from spreading into the surrounding areas a proactive approach is needed, where the NCAA and stakeholders work together to systematically remove these species and prevent further introductions. The following steps are recommended:

VILLAGES & SCHOOLS

Step 1: Identify all alien species present at the village and school

Step 2: Develop appropriate awareness posters

Step 3: Meet with village government and school head teacher

- Explain the term „Invasive Alien Species"
- Explain the impacts and consequences of invasive alien species
- Explain to village government which alien species need to be removed and what method must be used to remove these
- Explain that the removal process
  - **Must occur in two stages!** First an initial removal operation must take place and then approximately 6 months later a second removal operation must be conducted. The follow up operation is to remove any species that may have been missed and any re-growth that is evident
  - NCA will assist the village to remove these species by
    - Providing replacement seeds, seedlings, exercise books and/or other suitable forms of incentives for their positive cooperation.
    - Paying a small fee to facilitate the supervision by village leaders and head teacher, for successfully overseeing the two removal operations
  - Progress on clearing operations must be reported to NCAA on a regular basis
  - After the second clearing operation, NCAA is to conduct a final inspection and if the work is satisfactory, the replacement seeds, seedlings or exercise books can be delivered
- Discuss how the village, with the help of the NCAA, will create village Bylaws in which they agree to manage the invasive alien species problem on an ongoing basis and in which they prohibit the planting of alien species
- Hand out awareness posters

Step 4: Meet with village assembly and school teachers& school children

- Discuss the outcomes of the meeting described above

Step 5: Village & School to determine plan for removal and monitoring/supervision

Step 6: Village & School to conduct initial plant removal and monitoring/supervision

- Ensure everybody is clear as to which species need to be removed
- Ensure regular communication between village and NCAA

Step 7: Village & School to conduct 2nd plant removal and monitoring (6 months later)

- Ensure everybody is clear as to which species need to be removed
- Ensure regular communication between village and NCAA

Step 8: NCAA to conduct an inspection at each village and school

Step 9: Distribution of seeds, seedlings, exercise books, etc.

- In the case of seeds and seedlings ensure this takes place at an appropriate time of year, to ensure maximum germination of seeds and survival of seedlings

Step 10: NCA to facilitate the creation of invasive alien species village & school Bylaw

Step 11: NCA to monitor enforcement of the By law

Note: the above can also be done in the form of a competition, whereby the village or school that shows good performance with regard to removal, awareness and creation of Bylaws is rewarded.

LODGES AND CAMPS

Step 1: Letters to be sent to the owners or management of all operational lodges and camps in or bordering NCA

- Examples of potentially suitable content for letters that could be used for this purpose are included with this guideline as Addendum A and B.

Step 2: Relevant NCAA staff member to meet with the various lodges and camp managers

- Identify all alien species
- Discuss and agree on eradication programme that systematically removes alien species and replaces them with indigenous species. Where applicable NCAA to provide assistance

Step 3: NCAA to draft a Contract between NCAA and lodge or camp

- The contract is to include
    - details and timeframe of the eradication programme
    - the lodge agrees to manage the invasive alien species problem on an ongoing basis and agrees to prohibit the planting of alien species
    -

Step 4: NCAA to monitor eradication programme and enforcement of the signed contract

APPENDIX 4: PRIOTIZATION FRAMEWORK FOR CONTROL OF INVASIVE PLANT SPECIES IN THE NCA

Date:		
Location:		
Observer:		
GPS Coordinates:		
Category	**Ecological Criteria**	**Value**
1	Low Abundance	
	Very low abundant	*5points*
	Low	*4points*
	Moderate	*3points*
	Abundant	*2points*
	Very abundant	*1 points*
2	Least Palatable by Herbivores	
	least palatable	*5points*
	less palatable	*4points*
	moderately palatable	*3points*
	more palatable	*2points*
	most palatable	*1 points*
3	Low infestation	
	less than 1%	*5points*
	1-9%	*4points*
	29 to 10 %	*3points*
	50 to 30 %	*2points*
	greater than 50%	*1 points*
4	***Priority site***	
	Crater	*5points*
	utility (settlements, services, investiments, pasture land, infrastructure, temporal bomas, campsites, lodges, etc.)	*4points*
	water bodies and water ways	*3points*
	Roadside	*2points*
	Corridor (wildlife)	*1 points*
5	What‟s the value of the area being invaded?	
	Pasture land	*5points*
	Habitat	*4points*
	Tourism	*3points*
	Water catchment area	*2points*
	Cultural/archaeological	*1 points*
6	**High ecologcal impact.**	

Date:		
	decline of forage	*5points*
	habitat and biodiversity loss	*4 points*
	reduced water quality and quantity	*3points*
	reduced aesthetic value	*2points*
	Increased human-wildlife conflicts	*1 points*
7	***Reduce Habitat Suitability for Wildlife***	
	Very severe	*5points*
	Severe –	*4points*
	Moderate –	*3points*
	Minimal	*2points*
	Very minimal	*1 points*
8	***Close to Sensitive Areas*** – How close is the species to the nearest sensitive area (Breeding sites, corridors, pasturelands)	
	located within < 1km	*5points*
	located between 1 - 2 km	*4points*
	Located between 2- 5 km	*3points*
	Located between 5 - 10 km	*2points*
	Located > 10 km	*1 points*
	HUMAN VALUES CRITERIA	***Value***
9	***Reduce Aesthetic value –*** What is the severity of the aesthetic impacts of the invasive infestation?	
	Very severe	*5points*
	Severe –	*4points*
	Moderate –	*3points*
	Minimal	*2points*
	Very minimal	*1 points*
10	***block access to***	
	Grazing	*5points*
	Water	*4points*
	animals viewing	*3points*
	photographing	*2points*
	Recreational facilities	*1 points*
11	**Impact human and animal health –**	
	Very severe	*5points*
	Severe	*4points*
	Moderate	*3points*
	Low	*2points*
	Very low	*1 points*
	FEASIBILITY & CORDINATION OF TREATMENT CRITERIA	***Value***

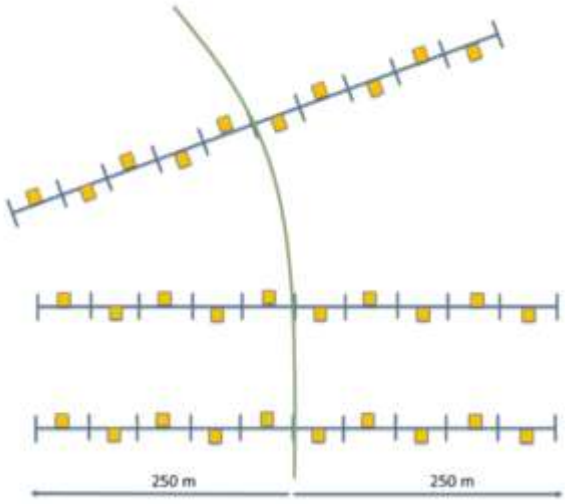
Date:		
12	Easy to manage	
	NCAA	*5points*
	Village	*4points*
	government (offices, hospitals, schools)	*3points*
	Community organisation (churches, play grounds)	*2points*
	Individuals	*1 points*
13	***Close to Treatment Sites***	
	Very far	*5points*
	Far	*4points*
	Moderate	*3points*
	Near	*2points*
	Very Near	*1 points*
14	***Difficulty of Treatment*** – How difficult would treatment be at this location?	
	Very difficult	*5points*
	Difficult	*4points*
	Moderate	*3points*
	Simple	*2points*
	Very Simple	*1 points*
15	Effective management techniques.	
	Very scarce	*5points*
	Scarce	*4points*
	Moderate	*3points*
	Available	*2points*
	Readily available	*1 points*
16	**Cheap to manage**	
	Very expensive	*5points*
	Expensive	*4points*
	Moderate	*3points*
	Cheap	*2points*
	Very Cheap	*1 points*

APPENDIX 5: INVASIVE PLANT MONITORING FORM FOR EARLY DETECTION AND RAPID RESPONSE (EDRR)

1. Group leader				
2. Date (y/m/d)		**3. Site/Priority site**		**4. Location**
5. Transect No.		**6. Plot No.**		**7. Site description**
8. Action taken		**9. Date action taken**		
11. Supplementary field data		**11. Costs/duration**		**10. Degree of disturbance**
13. Plant name	**14. No in 10m square plots**	**15. % Cover**	**16. Dominant plant species**	**17. Any comments**

NB. Description of items to be recorded in appendix 5

1. Group Leader: name of person in charge of the sampling.
2. Date: the date when monitoring is done
3. Site/Priority Site: the name of area or site given priority within the NCA (e.g. catchments, grazing land, tourist facilities (hotels/campsites) etc.
4. Location: the GPS location of where the sampling is being done
5. Transect No: The number of transect established. Transects should be established in cardinal directions (North, East, South and West) from a point that is arbitrary chosen almost at the Centre of a priority site.
6. Plot No: The number representing the Plot being sampled. The figure below represents the plot lay out along transects as shown in Figure below. The proposed transect length is 1 km long, depending on terrain. The size of plots will be 10 sq. m for trees and shrubs and 1 sq. m for grasses and herbs and can be placed at intervals of 50 m, in an alternating pattern between left and right (see Figure below).



invaded uninvaded

Figure 1. Set up of transects for EDRR practices; at time 0, 250m of the transect should be within the invaded range, while 250m should be outside the invaded range. The invasion front may not be as clearly distinguishable as in the figure.

7. Site description: Simple description of the area being sampled (vegetation type and landscape)
8. Action taken: state the action implemented (uprooting, burning, mowing or none). In this case future monitoring and data collection can inform the effectiveness of the method used.
9. Date action taken: Record the Date when the action was taken.
10. Disturbance comments: (1-Livestock; 2-Fire; 3- flooding; 4-Recreation; 5-Visitor use; 6-Trail; 7-Outfitter; 8-Off-road vehicle use; 9-Utility construction; 10-Maintenance (road/others); 11 Habitat improvement project)
11. Levels of disturbance: (1-No disturbance apparent; 2 Light to moderate disturbance; 3-Site heavily disturbed)
12. Supplementary field data: In case identify of species cannot be determined in the field, then plant samples and pictures should be taken.
13. 12 Costs/duration: The total cost or time spent to take the action in no. 8.
14. IP name: List names (local or botanical names) of all the Priority Invasive plants seen in plots.
15. No. of IP in 10m square plots: Record the frequency of each Priority Invasive Plants in plots.
16. % cover of IP: Estimate of the percentage cover of IP within 100 sq m.
17. Dominant Plant Species: Record one or two species that are dominant in the areas (they can be IP or native species), Do not record more than three species.
18. Any comments: provide any comments that may be useful to describe scenarios that are important and may not have been captured before.

APPENDIX 6: PRE- AND POST-TREATMENT DATA COLLECTION FORM

INVASIVE PLANT CONTROL MONITORING DATA SHEET											
NAME:			**DATE:**		**LOCATION:**			**TREATMENT (MOWING/UPROOTING/BURNING):**			
PLOT NAME	NAME OF INSECT/PHOTO	NO. OF INSECT	NAMEOF ANIMAL/PHOTO	NO. OF ANIMAL	NAME OF PLANT SPP / PHOTO	IS% GROUND COVER	OVERALL % GROUND COVER	% DISTURBANCE	GREENNESS SCORE	RAINFALL	REMARKS

NB: no. of insect/ animal = number of insect/ animals per 1m2/ 25m2/100m2, plot name= area where monitoring will be conducted, IS % ground cover = estimated % ground cover by respective iinvasive species per 1m2/ 25m2/100m2, overall % ground cover = estimated ground cover by all species per 1m2/ 25m2/100m2, % disturbance = estimated % disturbance per 1m2/ 25m2/100m2, greeness score = 1 (deep green), 2 (pale green), 3 (brown)

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ADDENDUM A – RECOMMENDED CONTROL METHODS FOR NCA INVASIVE SPECIES

Table A: List of invasive alien species and indigenous weedy species occurring in NCA and the recommend control methods (* = species indigenous to NCA)

Species	Control Method									
	Mechanical							Chemical		Biocontrol
	uproot	uproot & burn	hand pulling	slashing or mowing	ring barking	strip barking	Felling	foliar spray	cut stump	
Acacia mearnsii					x	x	x		x	
Acalyphawikesiana	x									
Achyranthes aspera			x							
Acrocarpus fraxinifolius	x				x	x	x			
Agapanthus africanus/praecox			x							
Agave Americana		x							x	
Agave sisalana		x							x	
Ageratum conyzoides			x							
Aglaonema commutatum			x							
Alternanthera pungens			x							
Annona montana	x									
Anthurium sp.	x									
Araucaria heterophylla	x				x	x	x			
Argemone mexicana		x						x		
Argemone ochroleuca		x						x		
Artocarpus heterophyllus	x				x	x	x			
Azolla filiculoides										X
Bauhinia variegate	x								x	
Begonia hybrids			x							
Bidens pilosa			x							

Species	Control Method									
	Mechanical							Chemical		Biocontrol
	uproot	uproot & burn	hand pulling	slashing or mowing	ring barking	strip barking	Felling	foliar spray	cut stump	
*Bidens schimperi**				x						
Bougainvillea hybrids	x									
Bougainvillea spectabilis	x									
Bryophyllum delagoense		x								
Caesalpinia decapetala		x						x	x	
Caesalpinia pulcherima	x									
Calissiarepens			x							
Callistemon lanceolatus	x									
Canabis sativa			x							
Canna indica		x								
Canna x generalis		x								
Capscumfrutecens			x							
Capsellaburs apastoris			x							
Cassia didymobotrya	x									
Casurina equisetifolia					x	x	x		x	
Catharanthus roseus			x							
Cereus jamacaru		x							x	
Cestrum aurantiacum	x				x	x			x	
Cestrum elegans	x				x	x			x	
Chlorophytum spp.			x							
Chrysanthemum spp.			x							
Citrus lemon	x									
Citrus sinensis	x									

Species	Control Method									
	Mechanical							Chemical		Biocontrol
	uproot	uproot & burn	hand pulling	slashing or mowing	ring barking	strip barking	Felling	foliar spray	cut stump	
Coffea arabica	x									
Colocasia escualenta	x									
Conyza spp.			x							
Cupressus lucitanica					x	x	x		x	
Cupressus pyramidalis					x	x	x		x	
Curcuma zedoaria					x	x				
Cyphomandra betacea	x									
Dahlia imperialis		x								
Datura candida (= Brugmansia candida)		x							x	
Datura erecta		x								
Datura stramonium		x								
Delonix regia					x	x	x			
Dovyalis caffra	x				x	x				
Dypsis leptocheilos	x									
Epipremnumaureum			x							
Epipremnum pinnatum			x							
Erigeron karvinskianus			x							
Eriobotrya japonica					x	x				
Eucalyptus camaldulensis					x	x	x		x	
Eucalyptus globulus					x	x	x		x	
Eucalyptus saligna					x	x	x		x	

Species	Control Method									
	Mechanical							Chemical		Biocontrol
	uproot	uproot & burn	hand pulling	slashing or mowing	ring barking	strip barking	Felling	foliar spray	cut stump	
Euphorbia pulcherina	x	x								
Euryopschrys anthemoides			x							
Ficus benjamnima					x	x				
Ficus elastic					x	x				
Ficus hybrids					x	x				
Fuchsia spp	x		x							
Galinsoga parviflora			x							
Grevellea robusta					x	x	x			
*Gutenbergia cordifolia**				x						
Gynandropsisgynandra (= Cleome gynandra)			x							
Hedera spp.			x							
Helianthus annuus			x							
Helicona caribaea	x									
Helicona rostrate	x									
Hura crepitans	x									
Hydrangia macrophylla	x									
Hyposestes phyllostachya	x									
Iresine diffusa			x							
Jacaranda mimosifolia					x	x	x			
Jatropha	x									
Lantana camara		x								
Leucaena leucocephala	x									
Lonicera japonica	x									
Ludwigia stolonifera			x							

Species	Control Method									
	Mechanical							Chemical		Biocontrol
	uproot	uproot & burn	hand pulling	slashing or mowing	ring barking	strip barking	Felling	foliar spray	cut stump	
Malus domesticus	x									
Mangifera indica					x	x	x			
Markamia lutea	x									
Melia azedarach					x	x				
Monstera diliciosa	x									
Morus alba					x	x				
Musa paradisciaca	x									
Nephrolepus exaltata		x								
Nerium oleander	x									
Nicandra physalodes	x									
Nicotiana rustica/glauca	x									
Nicotiana tabacum	x									
Opuntia ?exaltata or cylindrica		x							x	
Opuntia inermis		x							x	
Opuntia vulgaris		x							x	
Parkinsonia aculeate	x									
Parthenium hysterophorus		x								
Passiflora edulis	x									
Pelargonium domesticum			x							
Pennisetum purpureum	x									
Persea Americana					x	x				
Phaseolus vulgaris			x							
Podronea sp.	x									
Polyalthia longifolia					x	x				

Species	Control Method									
	Mechanical							Chemical		Biocontrol
	uproot	uproot & burn	hand pulling	slashing or mowing	ring barking	strip barking	Felling	foliar spray	cut stump	
Prunus persica	x				x	x				
Psidium guajava	x				x	x				
Raphanus raphanistrum			x							
Ricinus communis	x									
Rosa sinensis	x									
Rosemarinus officinalis	x									
Salvia leucantha	x									
Sanchezia parvibracteata	x									
Schinusmolle	x				x	x				
Senna didymobotrya	x									
Senna siamea	x				x	x				
Senna spectabilis	x				x	x				
*Solanum incanum**	x									
Solanum tuberlosum	x									
Sonchus oleraceus			x							
Spathadea companulata	x				x	x				
Syngonium podophyllum			x							
Syzgiumcuminii	x				x	x				
Tagetesminuta			x							
Tecomaricasoliana	x									
Tecoma stans	x									
Terminalia mantaly	x				x	x				
Terminalia superba	x				x	x				
Thevetia	x				x	x				

Species	Control Method									
	Mechanical							Chemical		Biocontrol
	uproot	uproot & burn	hand pulling	slashing or mowing	ring barking	strip barking	Felling	foliar spray	cut stump	
peruvianna										
Tithonia diversifolia	x									
Tradescantia zebrine			x							
Tropaeolum majus			x							
Tulbaghia violacea			x							
Ulceus roseas			x							
Verbena bonariensis			x							
Verbena officinalis			x							
Vinca major			x							
Widdringtonia nodiflora	x				x	x				
Withania somnifera	x									
Xanthium strumerium	x									
Zea mays	x									
Zingiber neglectum	x									

ADDENDUM B – CONTROL METHODS FOR KEY INVASIVE ALIEN SPECIES OCCURRING IN & AROUND NCA

Based on various assessments and previous plans (Runyoro *et al*, 2008,Henderson 2002, Foxcroft 2003, Lotter 2004, Mattay& Lotter, 2005), it has been suggested that the plant species that pose the biggest threat to NCA are:

- *Acacia mearnsii;*
- *Azolla filiculoides;*
- *Caesalpinia decapetala;*
- *Datura stramonium;*
- *Lantana camara;*
- *Leucaena leucocephala*
- *Lonicera japonica;*
- *Melia azaderach;*
- *Parkinsonian acuelata;*
- *Parthenium hysterophorus;*
- *Eucalyptus* spp.*;* and
- *Jacaranda mimosifolia*

A detailed description of the best control methods for each of these species, as well as for *Verbena bonariensis* which is spreading along roadsides in the Ngorongoro Crater is described below:

ACACIA MEARNSII

Chemical

The mature Black wattle trees are cut at ankle height above the ground and treated with a registered herbicide. The regrowth is sprayed with a foliar application of a registered herbicide.

Stems less than 10cm in diameter:

Mix herbicide in diesel. Use 1% Tordon super (Picloram 120g/l and Triclopyr 240g/l) (100ml Tordon super in 9.9 litres of diesel) or use 2% Garlon 4 (Triclopyr) (200ml Garlon4 in 9.8 litres diesel). Apply herbicide to basal portions of stems- paint on with a paintbrush. The diesel carries the herbicide through the bark to the sapwood.

Stems greater than 10cm in diameter and with crevices and / or exposed roots:

Bark is stripped away from tree from waist height to soil level using a slasher. Apply herbicide (same mixes as above) to areas where bark could not be removed. Do not apply herbicide to the white exposed wood. Repeat application of the herbicide mix to any portions of bark that show signs of recovery/re-growth.

Biological

Is the use of natural enemies to suppress the growth of the alien plants thereby making other control options viable. Two bio-control agents have been used in South Africa; the first is a mycoherbicide that is used the same way as a herbicide. The second is *Melanterius*

maculatus, a seed feeder. Adult feeding is seen on both mature and immature seedpods as small holes above the middle of the seed. The appearances of the trees are not affected. Any reduction in seed viability will reduce the rate of spread of the weed and its ability to regrow in cleared areas.

AZOLLA FILICULOIDES

CONTROL OPTIONS FOR *AZOLLA FILICULOIDES* ARE LIMITED. DUE TO A SURFACE-AREA DOUBLING TIME OF 7-10 DAYS, MECHANICAL CONTROL IS IMPRACTICAL. MANUAL, MECHANICAL AND HERBICIDAL CONTROL IS UNDESIRABLE AND ONLY SMALL INFESTATIONS OF AZOLLA CAN BE REMOVED MANUALLY USING FINE MESHED NETS. IN SOUTH AFRICA A SUCCESSFUL BIOLOGICAL CONTROL AGENT WAS USED. IT IS A FROND-FEEDING WEEVIL *STENOPELMUSRUFINASUS* AND HAS HELPED CLEAR UP MANY DAMS AND WATER RESERVOIRS THAT WERE COVERED BY AZOLLA. HUSSNER, A. (2006).*CEASALPINIA DECAPETALA*

Mechanical & Chemical

Caesalpinia decapetala is usually controlled using chemical methods. Chemical control of *C. Decapetala* relies on foliar spraying of a registered herbicide on seedlings and young plants, as well as coppice regrowth. A triclopyr formulation is preferred as it is selective to woody plants and thus pioneer grass species are protected.

In South Africa, registered herbicides for control of this plant are:

Active ingredient /Formulation	Dosage	Time of Application	Remarks
Glyphosate; SL; 360 g/l	1.5l/100l water	Summer	Apply overall foliage spray to seedlings Apply by means of a knapsack sprayer. Spray plants up to 1m tall
Glyphosate trimesium; SL; 720g/l	1l/100l water	Summer	Apply overall foliage spray to seedlings
Triclopyr; EC; 480 g/l	0.5l/100l water	-	Foliar application on young actively growing plants. Plants too high for a good cover spray should be slashed and regrowth sprayed ±500mm high

In situations where chemical control is not advisable e.g. near a river, *C. decapetala* can be controlled by mechanical means. However the plants coppices when cut, so the entire rootstock should be dug out if herbicide is not applied. Some references suggest burning the weed during the dry season, or ring barking or removing all the bark from the base of the stems where they are accessible so the plant dies from the roots upwards within a few months. Seedlings and saplings should be uprooted by hand pulling when the soil is moist.

Biological

Sulcobruchusbakeri (Bruchidae) has been released in South Africa on *C. decapetala*. It is a seed feeder and only attacks the seeds of *C. decapetala*. However, only limited success has been achieved.

DATURA STRAMONIUM

Mechanical

Plants should either be slashed or uprooted before they set seed as which is currently been done in the NCA.

LANTANA CAMARA

Lantana camara is difficult to control as it is a perennial plant that will regrow to form denser thickets if it is simply slashed and left. A combination of mechanical and chemical control is most successful. Single plants and small, isolated patches should be tackled first to prevent their spread and densification, while large thicket should just be contained until other areas have been brought under control. All forms of control should be followed by revegetation, indigenous groundcovers to prevent seedlings from forming new thickets. It is also essential that ongoing follow-up work, involving hand pulling of seedlings and spot spraying of regrowth, is conducted at least annually.

Mechanical & Chemical

Seedlings and isolated small plants up to a metre tall should be uprooted by hand pulling, either when the soil is moist or after first loosing dry earth with a hoe, pick, mattock or fork. For larger plants and dense thickets, top growth should first be cut away and pangas to expose the base of the plant. The plant should then be felled close to the ground, and the stump treated with a registered herbicide. Small plants can be treated with a foliar spray of a registered herbicide.

Large, dense bushes cannot be treated with a foliar spray as it is expensive and not very successful, since the maximum height that can be reached using a backpack sprayer is 1.5 - 2m. Taller plants and dense thickets should rather be slashed near the ground level and left to regrow. The regrowth is then sprayed when 0.5-1m tall. However, if plants are to be cut anyway, cut stump treatment should be considered as the preferred method as it is likely to be cheaper and less labour intensive.

In South Africa, registered herbicides for control of this plant are:

Active ingredient /Formulation	Dosage	Time of Application	Remarks
Glyphosate; SL;360 g/l	3-4l/100l water or 300ml/10l water	Summer and Autumn	Foliar application. Use the higher dosage rate if applied by

	and dye		a mist blower
Glpyhosatetrimesium; SL;720g/l	2l/100l water	Summer	Spray to actively growing plants. Slash large bushes in winter if necessary
Imazapyr;SL;100 g/l	0.2l/10l water	-	Seedlings and coppice: Apply as full cover spray to the foliage. Coppice should be 0.5-1m high. Cut stump treatment: Apply 10ml per 100mm of stump diameter to sapwood region of freshly cut surfaces

Biological

Biological control has not been substantially successful at controlling the plant, but reportedly has made other control methods easier in some geographical areas. Many insects have been used to control the plant, as it is a serious agricultural pest in many countries. The following are examples of some of the most successful insect bio-control agents on this species:

- *Teleonemiascrupulosa* (Hemiptera) has been used in Australia and Fiji, but attacked non-target plants in Uganda and appears to be effective only in dry conditions.
- *Octotomascabripennis* (Coleoptera), *Uroplatagirardi* (Coleoptera) and *Ophiomyialantanae* (Diptera) have been partially successful at controlling the shrub.
- *Calcomyzalantanae* (Diptera) has been successfully introduced in Australia and South Africa, although populations of the insect have been declining in Australia.
- *Cremastobombycialantanella* (Lepidoptera) is providing partial control in dry areas of Hawaii.
- *Hypenastrigata* (Lepidoptera), *Ophiomyialantanae* (Diptera) and *Teleonemiascrupulosa* (Hemiptera) are among the most effective biocontrol agents used in Hawaii.
- *Falconia intermedia* (Hemiptera) has been released in Australia, but is only effective at controlling some varieties of *L. camara*.

Use of fungi for biological control is being trialled and seems to be a promising method of control. The pathogenic fungi *Prospodiumtuberculatum, Puccinia lantanae* and *Ceratobasidiumlantanae-camarae* are being considered for use as biological control agents.

LEUCAENA LEUCOCEPHALA

Mechanical& chemical

Once established, *Leucaena leucocephala* is difficult to eradicate. Small individual plants may be manually removed taking care to remove the roots. Cut stumps need to be treated with diesel or other chemicals, as It resprouts vigorously after cutting. Furthermore, the soil seed bank can remain viable for at least 10-20 years after seed dispersal.

In Australia, registered herbicides for control of this plant are:

Active ingredient/Formulation	Dosage	Time of Application	Remarks
triclopyr (240 g/L) + picloram (120 g/L) e.g. Access®	1 L per 60 L diesel (for plants with stem diameter <5 cm)	Summer	Apply on basal bark
triclopyr (240 g/L) + picloram (120 g/L)	1 L per 60 L diesel	Summer	Cut stump treatment
triclopyr (300 g/L) and picloram (120 g/L) e.g. Grazon DS®	350 mL per 100 L water	-	Foliar application on young actively growing plants.

Biological

A bruchid beetle seed predator, *Acanthoscelidesmacrophthalmus* has been used in South Africa as a biocontrol agent.

LONICERA JAPONICA

Mechanical

Plants should be pulled out of the ground and roots dug out (uprooted). Follow-up will be required to ensure that the entire plant was removed and that not regrowth is occurring. Small seedlings and re-growth will also need to be uprooted.

MELIA AZADERACH

Mechanical & Chemical

M. azedarach has the ability to send root and stem suckers from underground storage organs. Mechanical methods of control may therefore be ineffective in controlling the spread and extent of *M. azedarach* infestations.

The best control method for large trees is a basal bark herbicide application. Trees that have a diameter of less that 30cm (breast height) should be felled and the stumps treated within 5 minutes of cutting. Ideally control should take place before fruiting.

Seedlings can be foliar sprayed with a registered herbicide.

In South Africa, registered herbicides for control of this plant are:

Active ingredient /Formulation	Dosage	Time of Application	Remarks
Triclopyr; 240g/l; EC	400ml/10l diesel		Basal stem application for plants with a stem diameter of up 100mm. Ensure wetting of the root crown, exposed roots and stem up to a height of 250mm
Imazapyr; 100g/l; SL	300ml/ 10 l water		Cut stump treatment

Biological
No successful agents have been found.

PARKINSONIAN ACUELATA

Mechanical
Small seedlings and juveniles can be hand pulled, taking care not to injure oneself on the thorns. Adults will need to be uprooted.

Fire
Fire can also be used to kill smaller seedlings, however adult plants will usually survive

Chemical
Foliar (overall) spray: A very effective control method for seedlings up to 1.5 m tall. Spray leaf and stems to point of runoff. A wetting agent (2ml/L of spray mixture) must be used. Trade name of herbicide is Grazon DS. Active chemicals are picloram & triclopyr. Suggested rate of application is .35L/100L water. For foliar spray using Grazon DS, use a rate of dilution of 1:50 in distillate

Basal bark: Effective for stems up to 15 cm diameter, carefully spray completely around base of plant to a height of 30 cm above ground level. Larger trees may be controlled by spraying to a greater height, up to 100 cm above ground level. Plants should be actively growing and preferably flowering. Field experience has shown that good soil moisture is essential for effective control. In areas that are subject to flooding care is needed to ensure that mud and flood debris does not prevent spray penetration. The trunk may be needed to be cleared before application. Trade name of herbicide is Garlon 600. Active chemical is triclopyr. Suggested rate of application is 1L/60L diesel. Also suggested for stems up to 5 cm is a herbicide with the trade name Access. Active chemicals are Triclopyr & picloram. Suggested rate of application is 1L/60L diesel. For basal bark treatment using Garlon 600, the suggested rate of dilution of 1:60 in distillate.
Cut stump: May be performed any time of year. Cut stems horizontally as close to the ground as possible. Immediately (within 15 seconds) swab cut surface with herbicide mixture. Trade name of suggested herbicide is Access. Active chemicals are triclopyr & picloram. Suggested rate of application is 1L/60 L diesel.

Biological
In Australia, three biological organisms have been introduced to try to reduce the invasion of Jerusalem thorn, two seed beetles (*Penthobruchusgermaini* and *Mimosestesulkei*) which attack the mature seeds, and one leaf bug (*Rhinacloacallicrates*) which feeds on the leaves and shoots. While all three insects have established at release sites, *Penthobruchusgermaini* is currently the most effective at establishing and attacking seeds of *Parkinsonia aculeata.*

PARTHENIUM HYSTEROPHORUS

Mechanical

Hand pull or dig out seedlings before they flower and burn them at a safe spot to destroy any potential seeds.

Chemical

Chemical control is not recommended for this species in the Ngorongoro Conservation Area (NCA) at present. The current objective for *Parthenium* in the NCA is eradication and not control.

Biological

No biological control agents are recommended at present.

EUCALYPTUS SPP

Mechanical

Plants can either be killed standing or felled and a cut-stump treatment applied. Should equipment such as a chainsaw not be available and also considering the danger element in felling large trees (specialised skills are required to fell large trees) it may be easier to consider a standing-kill method such as frilling.

Chemical

Use Chopper (Imazapyr) and cut a frill around the stem of the plant at approximately 50cm to 1 meter from the ground. Mix with water at 12, 5% (1250ml chopper to 1 litre water).

JACARANDA MIMOSIFOLIA

Mechanical

Hand pull or dig out seedlings and young trees.

Chemical

Limited information is available, however it has been suggested that cut stump with a glyphosate can be used to kill adult trees.

Biological

No suitable seed-feeding insects have been found.

VERBENA BONARIENSIS

Mechanical

Hand pull or dig out.

ADDENDUM A: EXAMPLE OF DRAFT LETTERS TO BE SENT TO LODGES AND CAMPS OPERATING IN NCA

To: The Manager

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RE: INVASIVE ALIEN PLANTS AND THE NGORONGORO CONSERVATION AREA

It is widely accepted in the international conservation community that invasive alien species are the single greatest threat to biodiversity within protected areas, worldwide. In Africa too, documented examples already exist of where alien plant invasions directly resulted in the extinction of native species, and in some individual southern African game reserves millions of dollars are being spent annually on attempts to control them.

Alien plant invasions in the Ngorongoro Conservation Area (NCA) are fortunately still at an early stage of incursion. However, literature confirms that plant introductions inevitably lead to increased weed problems after a time lag typically of 50 years. Therefore, dramatic increases in the populations of various species can soon be expected at Ngorongoro if appropriate management interventions are not implemented.

As you are well aware the NCA is a World Heritage Site and has been described as one of the Wonders of the World. Article 5 (d) of the Convention concerning the Protection of the World Cultural and Natural Heritage states:

"To ensure that effective and active measures are taken for the protection, conservation and presentation of the cultural and natural heritage situated on its territory, each State Party to this Convention shall endeavour, in so far as possible, and as appropriate for each country –

(d) to take the appropriate legal, scientific, technical, administrative and financial measures necessary for the identification, protection, conservation, presentation and rehabilitation of this heritage;"

It is therefore vital that the NCA Authority (NCAA) takes appropriate measures to manage the threat posed by invasive alien plants to the Ngorongoro World Heritage Site.

Over 100 alien plant species are known to occur in or on the boundaries of NCA. Several of which are known to be highly invasive and various steps have been initiated to control these species. This includes the process of replacing alien species with indigenous species around all residential areas and tourist lodges. [Wildlife / Serena / Sopa / CCA Crater/ Rhino] Lodge

were involved in the initial eradication programme, however due to changes in lodge management and staff, the NCAA will again be initiating this eradication programme.

Staff from the Wildlife Development and Range Management Department of the NCAA, will contact you soon to arrange a mutually convenient date and time to visit your lodge to discuss a suitable phased programme to eradicate the inappropriate species from your terrain. Staff from the Wildlife Development and Range Management Department will also be responsible for overseeing the implementation of this programme.

We thank you sincerely for your co-operation thus far with regard to this important matter and look forward to working with you to address the problem, for the long-term good of our unique World Heritage Site.

Yours,
CONSERVATION COMMISSINER OF NGORONGORO

ADDENDUM B: EXAMPLE OF DRAFT LETTERS TO BE SENT TO LODGES BORDERING NCA

To: The Manager

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RE: INVASIVE ALIEN PLANTS AND THE NGORONGORO CONSERVATION AREA

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Over 100 alien plant species are known to occur in or on the boundaries of NCA. Several of which are known to be highly invasive and various steps have been initiated to control these species. This includes the process of replacing alien species with indigenous species around all residential areas and tourist lodges. Although your lodge and farm is not within the NCA it would be greatly appreciated if you would eradicate, or at least control, the potentially invasive alien species that are not of important use to you.

Staff from the Wildlife Development and Range Management Department of the NCAA, will contact you soon to arrange a mutually convenient date and time to visit your lodge to discuss a suitable phased programme to eradicate the inappropriate species from your terrain. Staff

from the Wildlife Development and Range Management Department will also be responsible for overseeing the implementation of this programme.

We thank you sincerely for your co-operation thus far with regard to this important matter and look forward to working with you to address the problem, for the long-term good of our unique World Heritage Site.

Yours,
CONSERVATION COMMISSINER OF NGORONGORO