Invasive Species in Eastern Africa: Proceedings of a workshop held at ICIPE, July 5-6, 1999

Edited by
Elizabeth E. Lyons and Scott E. Miller

A regional workshop on "Invasive Species in Eastern Africa" was held at ICIPE to bring together professionals from conservation, agriculture, forestry, research, land management, academia, information technology, and the legal and policy fields, to explore the current status of invasive species in the region (Ethiopia, Kenya, Tanzania and Uganda).

"Alien invasive species are not little green men from outer space, but are even more sinister"

--- Michael Samways

Jackson's Chameleon – threatened in East Africa but an alien pest in Hawaii

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Global Invasive Species Programme
IDRC CANADA
KENYA WILDLIFE SERVICE
Makerere University
National Museums of Kenya
BioNET-INTERNATIONAL GLOBAL NETWORK FOR BIOSYSTEMATICS

Credits: The workshop was funded by UNEP and IDRC, with in-kind contributions by ICIPE, CABI, National Museums of Kenya, and Kenya, Mauritius and South African Airlines. The workshop was coordinated by Elizabeth Lyons and Scott Miller. Metal Sculpture of Jackson's Chameleon by Kioko Mwitiki photographed by Harald Trinkner.

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FOREWORD

A regional workshop on Invasive Species in Eastern Africa was held at the Nairobi headquarters of the International Centre of Insect Physiology and Ecology (ICIPE) on 5-6 July 1999 to bring together professionals from conservation, agriculture, forestry, research, land management, academia, information technology, and the legal and policy fields, to explore the current status of invasive species in the region. The workshop, which focused on four countries (Ethiopia, Kenya, Tanzania and Uganda), was funded by UNEP and IDRC, and co-sponsored by the National Museums of Kenya, World Conservation Union (IUCN), CAB International, Kenya Wildlife Service, EAFRINET (the regional unit of BioNet International), Global Invasive Species Programme and Makerere University (Uganda).

Invasive species, which are usually alien or non indigenous species, are of great interest to agriculture, forestry, environment, and wildlife conservation agencies, as well as academia and the business community. Invasive species can impact the stability of both agricultural and natural habitats, they are one of the greatest threats to long term conservation of biological diversity, they can impact on human health and cultural values, and they can have dramatic economic consequences.

Activities undertaken during the two days included the workshop itself, which was attended by more than 70 people, from 41 different institutions, including participants from Ethiopia, Kenya, Tanzania, and Uganda and speakers from Kenya, Tanzania, Uganda, South Africa, Mauritius, Malawi, and the UK; an Information Fair that provided workshop participants with information and materials related to invasive species from more than a dozen groups; a Public Lecture and Panel Discussion held at the National Museums of Kenya, that provided a forum for increasing public awareness of invasive species issues; and the collection of anecdotal information from participants to produce a Preliminary Survey of Invasive Species in Eastern Africa.

In addition to this printed proceedings, information from the workshop and related activities is also available on Internet at <www.icipe.org/invasive> and in a video tape produced by National Museums of Kenya.

WORKSHOP OVERVIEW

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SUMMARY

A regional workshop on "Invasive Species in Eastern Africa" was held at the Nairobi headquarters of the International Centre of Insect Physiology and Ecology (ICIPE) on 5-6 July 1999 to bring together professionals from conservation, agriculture, forestry, research, land management, academia, information technology, and the legal and policy fields, to explore the current status of invasive species in the region. The workshop, which focused on four countries (Ethiopia, Kenya, Tanzania and Uganda), served as part of ICIPE's community outreach programme, and also part of the ICIPE Biodiversity and Conservation Programme's contribution to conserving biodiversity within the region.

Activities undertaken during the two days included the workshop itself, which was attended by more than 70 people, from 41 different institutions, including participants from Ethiopia, Kenya, Tanzania, and Uganda and speakers from Kenya, Tanzania, Uganda, South Africa, Mauritius, Malawi, and the UK (A participant list is provided in Appendix 1; the workshop program is in Appendix 2); an Information Fair that provided workshop participants with information and/or materials related to invasive species from more than a dozen groups; a Public Lecture/Panel Discussion held at the National Museums of Kenya, attended by 100-120 people, that provided a forum for increasing public awareness of invasive species issues; and the collection of anecdotal information from participants to produce a Preliminary Survey of Invasive Species in Eastern Africa.

BACKGROUND

When ICIPE's Biodiversity and Conservation Programme was started in 1998, the issue of invasive species was identified as an area where ICIPE could make a significant contribution within Eastern Africa. In early 1999 ICIPE staff contacted individuals within the region to gather information on the status of invasive species knowledge and needs in the region, and then began to organize the workshop. A Steering Committee for the workshop was assembled and met several times to provide input on the format and focus of the workshop, as well as on possible participants, speakers, and donors.

ICIPE staff also contacted the Global Invasive Species Programme (GISP), which had just undertaken a programme to increase awareness of the invasive species problem in developing countries. At a GISP/SCOPE meeting in Paris in April 1999, the ICIPE workshop was endorsed by GISP because it fit within GISP's global awareness-raising efforts.

During the organization of the workshop, it was decided that EAFRINET should be invited to participate in order to foster linkages between the systematics community and invasive species professionals. EAFRINET welcomed the chance to bring their expertise to bear on these issues and many EAFRINET members from the region participated, as did individuals from institutions that had served as resources for EAFRINET.

WORKSHOP

Day 1 -- 5 July 1999

On the first day of the workshop, Dr. Hans Herren, Director General of ICIPE, welcomed the participants. Dr. Scott Miller then gave introductory remarks in which he described how different international treaties and conventions were relevant to the control of invasive species and then defined some of the terms used in invasive species work.

The keynote speech was given by Professor Jeff Waage, Head of Biological Pest Management for CAB International Bioscience in the UK and also on the Executive Committee of the Global Invasive Species Programme. Dr. Waage described the global nature of the invasive species problem, the challenges presented by invasive species to national, regional and global ecosystems and political/economic systems, and the role that the GISP might play in controlling invasive species.

Two talks on national invasive species programmes followed. Dr. Wilson Songa of the Kenya Plant Health Inspectorate Service described legal and policy aspects of invasive species, with particular reference to the Kenyan quarantine system. After his talk he invited Dr. Okaasai Opolot, head of the Ugandan Phytosanitary and Quarantine Services to briefly comment on how Uganda quarantine system operated with respect to invasive species and Dr. Opolot kindly obliged. Dr. Christo Marais then described how South Africa, having determined the high cost of water-consuming invasive plants in the dry Cape regions, had started the Working for Water Programme. Because this programme employs thousands of people from poor communities to remove invasive plants, it not only reduces the damage done by invasive species, but it also provides economic and social benefits by helping to alleviate poverty and empower communities.

Two speakers then addressed the economic, legal and policy dimensions of invasive species. Victor Kasulo of York University, UK, and Malawi described economic dimensions of invasive species, touching upon some of the economic and social costs, the types of incentives that can be used to change individual and institutional behavior, and the possible role that donors can play in establishing sustainable invasive species programmes. Vishnu Tezoo (and co-author Yousoof Mungroo) of the Mauritius National Parks and Conservation Service then described how Mauritius, an island with long experience with invasive species, had set up programmes to control invasive species. He described a variety of approaches, including the active removal and continued exclusion invasive species from a set of small reserves on the island.
The afternoon ended with a session moderated by Dr. Richard Bagine of the Kenya Wildlife Service in which country-based working groups discussed the status of invasive species within protected areas in each country, as well as which ecosystems in those countries were most vulnerable to invasive species.

Day 2 -- 6 July 1999

The second day of the workshop started with presentations by the four country-based working groups (their reports are given in Appendices 3-6). These reports showed striking similarities among the countries in pointing out that both in protected areas and elsewhere, there is a need for more information and research on invasive species, for more capacity building at several levels, for better national and regional policy and associated enforcement, and underlying all of the other needs, a need for more funding and government commitment to controlling invasive species.

Four case studies on invasive species in Eastern Africa were then presented:

1) Dr. Timothy Twongo of the Fisheries Research Institute of Uganda spoke on invasive species of the water environment and described the impact and control options for plant and animal invaders in aquatic habitats.
2) Geoffrey Mungai of the National Museums of Kenya (NMK) described how herbarium records, such as those at NMK's East Africa Herbarium, can be used to track both recent and historical movement of invasive plant species.
3) Dr. Waweru Gitonga of the Kenya Agricultural Research Institute described his institution's efforts to control invasive aquatic weeds, including preemptive efforts that include obtaining biological control agents for aquatic weeds that are not yet in Kenya but have been invasive problems elsewhere.
4) Josephine Songa (and co-author William Overholt) of ICIPE described the ecology and dispersal of an agricultural invasive pest, the stem borer, *Chilo patellus*, providing insight into how non-agricultural alien insect pests might invade an area.

Professor Jeff Waage of CABI then gave a brief presentation in which he described the toolkits and associated case studies under preparation by GISP members. One toolkit will provide strategies and a database as part of an early warning system, while the other will provide strategies for developing national policies in the area of invasive species.

During the final session of the workshop, participants turned their attention to shaping future efforts to control invasive species in Eastern Africa. Four working groups were assembled on the basis of participants' interests and a brief report was presented for each of the following working groups (reports in Appendices 7-10):

1) The Role of EAFRINET in the Fight Against Invasive Species
2) Strengthening Research and Research Links on Invasive Species
3) Coordinating Regional Efforts to Control Invasive Species
4) Capacity Building and Implementation in Invasive Species Programmes

Final Discussion: Although the purpose of the workshop was awareness raising and not the creation of specific recommendations, several clear conclusions could be drawn from the final discussion and from the workshop as a whole:

1) There are many invasive species in Eastern Africa, and there now exists in Eastern Africa considerable knowledge about invasive species. However, that knowledge is often not sufficient for management purposes. To effectively control invasive species in the region, much more information is needed about which invasive species are now in the region, where they are, their rate of spread, and the nature and fate of control efforts.
2) There must be better systems of communication about invasive species both within countries as well as among countries. These linkages should bring together land managers and researchers so that the research serves the stakeholders' needs.
3) There now exists in Eastern Africa the capacity to identify and, in some cases, control invasive species. In order to strengthen that capacity, there must be additional attention directed to conducting research on invasive species, to developing systems to monitor invasive species, and to training personnel to control invasive species. All of these require political will and funding. Better estimates of the ecological, social and economic costs of invasive species, as well as the benefits of programmes to control them, may help marshal that political will and subsequent financial support.
4) There is sufficient knowledge, enthusiasm and ideas to carry forward an invasive species initiative within Eastern Africa and the group present at the workshop forms a loose network for supporting such an effort. At the workshop EAFRINET volunteered to serve as a coordinating focal point for any group or groups that want to pursue national and or regional projects on invasive species.

INFORMATION FAIR

On the first evening of the workshop there was a reception at ICIPE in honour of the workshop participants. During the reception there was an Information Fair during which guests examined recent journal articles on invasive species, as well as publications, CD-ROMs, and other material provided by ICIPE Science Press, the Global Invasive Species Programme, the Fisheries Research Institute of Uganda, CAB International, the Lake Naivasha Riparian Association, the US Forest Service and the Kenya Forest Health Unit, BIONET International, the Kenya Agricultural Research Institute, the Government of South Africa, the Kenya Plant Health Inspectorate Service, South Africa's Working for Water Programme, FAO Global Plant and Pest Information System (GPPIS) and The World Conservation Union (IUCN).

PUBLIC LECTURE AND PANEL DISCUSSION

On July 6 at 16:30 hours in the Louis B. Leakey Auditorium at the National Museums of Kenya, Dr. Helida Oyieke, Deputy Director, Biodiversity Centre, NMK, introduced the public speaker, Professor Michael Samways of the University of Natal, South Africa. Dr. Samways, whose talk was entitled "Alien Invasive Species and Ecosystem Agony", spoke on the ecological and societal complexities of the invasive species problem, both within countries as well as around the world. The lecture and subsequent panel was well attended, with 100-120 people in the audience. Dr. Samways' lecture was followed by a panel presentation. Each panelist briefly described appropriate strategies for national, regional or global strategies to stop invasive species. A lively question and answer session followed as the audience peppered the panel with questions. The panelists were: Dr. Helida Oyieke, NMK (moderator); Professor Michael Samways, University of Natal, South Africa; Dr. Bernard Irigia, Kenya Wildlife Service; Dr. Timothy Twongo, Fisheries Research Institute of Uganda; Dr. Okaasai Opolot, Uganda Phytosanitary and Quarantine Services; Dr. Gert Willemse, South African Ministry of Environmental Affairs and Tourism; Dr. Geoffrey Howard, IUCN, East Africa Regional Office; and Professor Jeff Waage, CABI, UK.

PRELIMINARY SURVEY OF INVASIVE SPECIES IN EASTERN AFRICA

Many of the workshop participants returned our survey and shared their perceptions on invasive species in the regions where they work. 38 different invasive species were reported from within the four country region, falling into the following taxa: 21 plants, 5 vertebrates, 9 insects, 1 other invertebrate, and 2 microorganisms.

Several general conclusions can be drawn: there are many invasive species in the region, some new, some old, some under control, some not. Eastern Africa has considerable expertise on invasive species and in some cases the infrastructure necessary to control invasive species is also present, but too often the state of knowledge and the status of research, monitoring, and control efforts are severely lacking. The countries in the region share many invasive species and the shared species may serve as a basis for building local, national and regional cooperation. Finally the survey is quite preliminary but should nonetheless serve to challenge Eastern Africans to expand, confirm and/or modify the information it contains. Even in its current state, the survey may also be valuable in the ongoing efforts to garner political and budget support for initiatives against invasive species.

OUTPUTS OF THE WORKSHOP

In addition to this published proceedings, the proceedings are available on the ICIPE web site (www.icipe.org/invasive) and a video tape of highlights of the talks was prepared by NMK. Copies of the video tape, along with other information, are being distributed to key institutions in each country.

ACCOMPLISHMENTS OF THE WORKSHOP

The workshop succeeded in:

- bringing together a diverse set of regional professionals who deal with invasive species and linking them in a loose network and providing them with contact information for all workshop participants;
- raising participants' awareness of the complexity of invasive species problems by presenting a stimulating set of presentations;
- improving regional and national linkages by giving participants the chance to work in working groups on issues of common concern;
- collecting information for the preliminary survey of invasive species in Eastern Africa;
- linking the EAFRINET community of systematists with people working on invasive species problems. Not only were there discussions of projects that EAFRINET could do to assist the efforts of this community (e.g., a handbook on Invasive Animals of Eastern Africa), but EAFRINET, with its nascent network structure, volunteered to serve in a coordinating role as the group moves forward with new initiatives. (EAFRINET is the eastern African unit of BioNet International).
- focusing attention on the status of invasive species in protected areas in the region;
- identifying specific ecosystems in each country that are likely to be vulnerable to invasive species;
- providing participants with a wide range of material on invasive species from many sources during the Information Fair;
- bringing issues of invasive species to the attention of a large public audience during the Public Lecture and Panel Discussion;
- increasing the ability of the workshop to continue to raise awareness by assembling and

distributing workshop information kits to 3-5 institutions in each country;
- setting up a web page to publish the workshop proceedings, making the proceedings, as well as related material, available to a broad range of stakeholders in the region;
- generating, during the final discussion session of the workshop, several avenues for next steps in organizing national and regional efforts against invasive species.

The purpose of the workshop was an educational one and by almost any standards it succeeded in accomplishing that educational mission. A positive outcome of the workshop is the fact that initiatives stemming from this workshop are likely to move in several directions, with many different partnerships at work. Several local champions emerged at the workshop and it is likely that these individuals will work in their home countries to further the fight against invasive species. Several of the international organizations, such as ICIPE and CABI, have volunteered to help facilitate not only national efforts, but also the linking of those national efforts into a regional effort. ICIPE will also likely contribute to building capacity in this important area by developing courses to help train professional in invasive species identification and management. EAFRINET has volunteered to serve a coordinating role as this effort continues.

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INVASIVE SPECIES IN EASTERN AFRICA: INTRODUCTORY COMMENTS

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INTRODUCTION

The purpose of the workshop is to bring a diverse set of Eastern African stakeholders together to raise awareness to the issues, begin to break down traditional communication barriers, and discuss strategies to deal with current and future invasive species issues. Progress in recognising and mitigating the problems has been held back greatly by traditional thinking in terms of countries, sectors/disciplines and habitats.

- Invasive species do not recognize national boundaries, whether adjacent countries or halfway around the globe.
- Invasive species issues require cooperation amongst agriculture, forestry, environment, and wildlife conservation agencies, as well as academia and the business community. In particular, we hope that we can forge links between management agencies (clients for research) and universities (that often have pools of under utilised students).
- Finally, the same species can, for example, be a pest of agriculture, livestock and conservation, so it is necessary to recognize that Eastern Africa consists of a continuum of habitats -- it is not possible to separate agriculture from conservation.

Because of the potential breadth of issues, we had to focus the meeting and restrict the subjects covered by **excluding**:

- the marine environment, because many other management and research agencies are involved, although there are major issues with organisms spread in ballast water (Carlton and Geller 1993).
- traditional biological control, because it is the subject of its own meetings and organisations.
- genetically modified organisms (GMOs), although they share many issues, they also bring in many additional issues and are the subject of national and international discussions on biosafety. <http://www.biodiv.org/biosafe>

HISTORICAL CONTEXT

Eastern Africa has long been a focus of biological control of invasive species, both for export and import of biological control agents, based around what is now the CABI East Africa office (Greathead 1971; Greathead and Greathead 1992). However, there has been fairly little attention given in Eastern Africa to invasive species in outside of pests of agriculture and forestry, with the exception of water hyacinth and Nile perch in Lake Victoria. Meanwhile in recent years, an increasing number of international conventions, organisations, and meetings have addressed invasive species issues on a global scale. Some of the major events that provide a policy context for this workshop are:

- Convention on Biological Diversity (articles 6 and 8, especially 8h), recommendations of SBSTTA (especially IV/4), and decisions of COP (especially III/9 and IV/1). <http://www.biodiv.org>
- International Plant Protection Convention, dealing with all "plant pests" defined as any animal, plant or disease agent that injures any plant or plant product. <http://www.fao.org/WAICENT/FaoInfo/Agricult/AGP/AGPP/PQ/Default.htm>
- Convention on wetlands of international importance especially waterfowl habitat (RAMSAR), especially at its seventh COP in May 1999. <http://iucn.org/themes/ramsar/>
- Convention on International Trade of Endangered Species of Wild Flora and Fauna (CITES). <http://www.wcmc.org.uk/CITES/english/index.html>
- Convention on the conservation of Migratory Species of wild animals (CMS). <http://www.wcmc.org.uk/cms/>
- Global Biodiversity Assessment (GBA), prepared by UNEP, included a major review of invasive species issues (Heywood 1995).

- Norway/United Nations Conference on Alien Species, Trondheim, Norway, July 1996 (Sandlund *et al*. 1996).
- Global Invasive Species Programme (GISP), now under the umbrella of DIVERSITAS, launched in 1996. <http://jasper.stanford.edu/GISP>

However, management agencies in Eastern Africa are beginning to recognise the importance of invasive species and seek more information and tools to deal with the problems. For example, invasive species are included in the National Environment Plans for Uganda (Uganda Ministry of Natural Resources 1995) and Kenya (draft version in preparation).

WHAT WAS THE ORIGIN OF THIS WORKSHOP?

- Invasive species were identified as an important issue in the January 1997 workshop that created the workplan for the ICIPE Biodiversity and Conservation Programme.
- In the early stages of planning the present workshop, we identified the overlap with GISP, and linked with their activities.

WHY ARE SPECIES INTRODUCED TO NEW HABITATS?

- species introduced accidentally (e.g., passive transport)
- species are imported for specific purpose but then escape (e.g., garden plants and pets)
- species are deliberately introduced (e.g., biological control)

Sometimes it is hard to discern their origins, especially because many species were transported in ancient times, and the native ranges of many species are poorly known. This reminds us of the need for a global taxonomic framework and database tools such as CABI Pest Compendium (CABI 1997) and FAO GPPIS <http://pppis.fao.org>.

But species can also spread naturally, especially if encouraged by climatic change or invasions of associated species. Thus, as defined below, not all alien species are invasive, and not all invasive species are aliens. Our workshop focuses on invasive species, most of which are also aliens.

WHY CARE ABOUT INVASIVE SPECIES?

Here are some of the many reasons, with more documented in recent reviews by U.S. Congress Office of Technology Assessment (1993), Heywood (1995), and Sandlund *et al*. (1996):

- stability of habitats impacts both agriculture and conservation
- invasive species have been considered one of the two major threats to biodiversity, along with habitat loss
- social issues including impacts on cultural uses (e.g., ethnobotany) and aesthetic values
- direct human health issues such as disease vectors opening new pathways for disease (e.g., once an alien vector becomes established, the establishment of the disease is facilitated)
- economic aspects: having them can be expensive, so can eradicating them
- invasive species costing much more than $100 billion in USA alone
- Seychelles: alien ants are disturbing nesting birds that are the sole tourist attraction on one island, thus the alien ants could basically close the island's economy
- Those living in East Africa are familiar with the regular newspaper stories about water hyacinth stopping commerce on Lake Victoria

SOME TERMINOLOGY

Although terminology applied in invasive species is still evolving, the following is a brief guide to vocabulary (see Eldredge and Miller 1995: 4 and Frank and McCoy 1990 for further discussion). In some cases, it is difficult to determine if a species is native (indigenous or endemic) versus alien. These species of unknown origin have been termed *cryptogenic* (Carlton 1996).

alien = *nonindigenous* = *exotic*: occurring outside of natural range and dispersal potential (includes both introduced and immigrant);

introduced: often used for aliens in general, but best restricted to purposefully introduced species (as in biological control introductions);
immigrant = *adventive*: aliens not purposefully introduced (as in accidently transported through commerce);
invasive: a species which is an agent of ecosystem change, especially when threatening biological diversity; usually but not always an alien species;
endemic = *precinctive*: restricted to the region and not found elsewhere (although used in the sense of indigenous by the medical and veterinary community);
indigenous = *autochthonous* = *native*: occurring naturally in the region but not endemic.

BAD OR GOOD DEPENDS ON YOUR POINT OF VIEW

A few examples of the difficult biological, economic and social issues that must be considered in dealing with invasive or alien species issues include:

- Apple snail in Pacific Islands is either a great new crop (escargot) or destroyer of an old crop (taro) (Cowie 1995).
- Many pasture plants are either invasive weeds or valuable food, depending on who eats what (e.g., koa haole in Hawaii see Waage and Greathead 1988).
- Jacksons Chameleon in East Africa is protected under CITES because it is considered threatened by over collecting for the pet trade, while in Hawaii former pets have become an invasive pest (Loope *et al*. 1999).
- Nile Perch in Lake Victoria represents either fisheries improvement or habitat degradation depending on your point of view, although opinions even differ within the fisheries community depending on whether large or small fish are of interest (Balirwa 1995; Goldschmidt 1996).

SPECIAL PROBLEMS OF ISLANDS

For a variety of reasons, island ecosystems are more sensitive to invasive species than continental areas (Simberloff 1995). A striking example is that the present biota of Hawaii is composed of 20% alien species (Eldredge and Miller 1998). In addition to applying to oceanic islands, these problems also apply to habitat islands, such as montane forests in Eastern Africa (Kingdon 1989).

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INVASIVE SPECIES: ECOLOGY AND GLOBAL RESPONSES

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To say that alien invasive species pose an international problem is a truism. Were it not for the movement of species beyond their native range, and particularly between nations, we would not recognise alien invasive problems at all. Semantics aside, however, it must be said that the reaction to alien invasive species has, to date, been profoundly national. My objective in this paper is to show that our approach must become much more international if we are to successfully address this problem. In the process, I will describe some invasive species experiences in other parts of the world and try to show how sharing these experiences and collaborating in development of programmes and methodologies is strongly in our own national interests. In particular, I will address several issues which might also be considered as steps in addressing alien invasive species problems:

- How do we identify and quantify risks from aliens
- How do we prioritise action against established aliens
- How do we manage alien invasive species problems

Finally, I will describe briefly the Global Invasive Species Programme, and what it is trying to do.

ALIEN INVASIVE SPECIES: PUBLIC OPINION, POLITICS, AND THE CHALLENGE TO GOVERNMENTS

Public concern about alien invasive species is relatively recent and growing. While we are concerned here largely with alien invasives as they affect environmental conservation, there are a range of other "alien issues" contributing to public opinion which must be acknowledged, as they will contribute to the broader social and political agenda. Three are particularly important:

- Alien pests of agriculture and health, long a problem for quarantine and trade, are intensifying due to trade liberalisation and their use as trade barriers
- Biotechnology and the concern that the new and perhaps "alien" organisms which it creates are unethical or pose risks to health or the environment.
- Public pre-occupation with alien threats in general, best exemplified by current media fascination with extra-terrestrial invaders.

Overall, there appears to be a general public concern that what we consider natural and healthy is at risk through inadvertent or deliberate introduction of alien species, and that private interests and public institutions have been careless and misguided in allowing this to happen. What this means in a practical sense for scientists is that there is today a political urgency to accurately define and quantify the extent of alien invasive pest problems and management options, and to do this in a way which avoids public misinterpretation and inappropriate political reaction. This, in turn, means broad public engagement at each step of this research. To achieve this, scientists will be challenged to be careful, communicative, and consultative.

ALIEN INVASIVE PROBLEMS IN THE ENVIRONMENT

The current interest in alien invasive species in the environment owes a great deal to the inclusion of this subject in the Convention on Biological Diversity where, in Article 8h, parties to the Convention agree to "prevent the introduction of, eradicate or control those species which threaten species, habitats or ecosystems" (Convention on Biological Diversity 1992). To be fair, most governments had, at the time the Convention was ratified, insufficient information on this problem to make Article 8h a priority in their biodiversity planning. But subsequent international meetings have raised awareness about invasive species, particularly the 1996 Norway-UN Conference on Alien Species (Sandlund *et al.* 1996) at which representatives from 80 countries met with specialists in invasive species problems and began to work out the international scale and nature of the problem. One of the most lasting conclusions of this Conference was the view that alien invasive species are second only to habitat destruction as a threat to species loss and biodiversity.

The environment community has now moved quickly to take up invasive species issues. For instance, a recent Presidential Decree in the US has identified alien invasive species as a problem for inter-agency co-operation and reallocation of budgets.

As public interest in alien species affecting the environment grows, governments will be challenged to find mechanisms to respond. A first step in this process, as the US government has recognised, is to ensure that there are good links between responsible agencies and effective use of existing institutional frameworks. Existing alien species prevention and management systems include agricultural plant and livestock protection and quarantine services of governments, and similar infrastructures for containment of human diseases nationally and world-wide. Agricultural and health experiences with alien species problems may not provide the answers to new problems with environmental invasives, but they do provide some idea what can be done and how it might be organised.

The agricultural legacy brings three useful elements to the alien invasive species problem:

- National and international systems for identifying the distribution of unwanted aliens and analysing their pathways and movements (including databases like those of FAO and CABI).
- Political and legal systems for preventing the introduction and movement of unwanted aliens, notably the International Plant Protection Convention, and its implementation at the Global (United Nations), Regional (e.g., European Plant Protection Organisation) and national (plant protection and quarantine service) level.
- Some proven approaches to management of introduced aliens, particularly eradication and "classical" biological control.

The fact is, however, that agricultural and environmental interest groups are often very different in any country, and even sometimes in conflict over issues like land use. Ministries of Agriculture and Environment are often seen as providing a counter-balancing system, rather than a system for co-operation. Yet, in many countries faced with alien invasive species problems, the Environment Ministry own much of the problem in its protected or managed areas and the Agriculture Ministry owns much of the solution, in terms of quarantine services for intercepting aliens and pest and disease management specialists for controlling them. The prospect of one ministry duplicating the capability present in another to address an alien weed simply because it has now moved out of cattle pastures into natural grasslands may seem silly, but it happens.

Some of the greatest tragedies associated in recent years with alien invasive species have occurred when the particular problem fell snugly between the remits of different agencies, contributing to political paralysis. A case in point is the rapid spread in the 1980s of the neotropical water hyacinth, *Eichhornia crassipes*, across Africa in the 1980s. Water hyacinth is a floating weed that rapidly covers open water bodies, forming mats which prevent use of boats and dramatically affect water chemistry, fauna and flora beneath them. Affected countries were faced with a problem which had a direct effect on fisheries, trade and water resources, the responsibility variously of transport, environment and military agencies, but which had its immediate solution in agriculture, where national expertise on weed management lay. So, who was responsible? Only where this question was resolved, sometimes through inter-ministerial initiatives, could real progress be made with limited national resources. While this was being realised, the problem spread to every water system of the continent (Charadattan *et al.* 1996). Today, programmes of the Global Environment Facility allocate tens of millions of dollars to African water hyacinth management, but implementation is still constrained by the need for inter-ministerial and inter-governmental co-ordination.

ASSESSING THE RISK OF ALIEN INVASIVE SPECIES IN THE ENVIRONMENT

The invasiveness of species is very difficult to predict. Indeed, one of the "ground truths" of invasive species research is that the vast majority of alien species introductions are not invasive. These include, of course, many crop and horticultural plants. Some exciting research is underway on the prediction of invasiveness, based on the retrospective comparison of related alien species in a particular taxon.

An anecdotal example relates to the water hyacinth story presented, and involves the relative performance of *Eichhornia crassipes* and *E. azurea* around the tropical world. Both plants come from river systems of the Amazon Basin, and both have been introduced into the Old World. But only *crassipes* has become invasive. The two species are very similar floating plants, except that *E. azurea* roots itself in the substrate and *E. crassipes* can be entirely free-floating. While Africa and Asia have many floating plants which grow, rooted, out into water bodies, they have very few free-floating water plants. One explanation, therefore, is that *crassipes* found itself in an environment free of competition, relative to *azurea*, and spread. Interestingly, the other important invasive free-floating weeds in Old World waterways, *Pistia stratiotes* and *Salvinia molesta*, are also of Neotropical origin. These species do compete with *crassipes* for open water in the Old World, so much so that control programmes are advised today to target all three from the outset, even though only one may be abundant at the time. Thus, not only the properties of the alien species, but the existence of empty niches in the area of introduction provide insight into invasiveness.

While questions of invasiveness provide enormous scope for exciting and useful ecological research, the astounding taxonomic diversity of invasive species and the urgency to address invasive problems lead us to an alternative, very pragmatic approach to predicting invasiveness, namely: "look at what is invasive elsewhere". We could all be very well occupied for the next century preventing and managing the problem species we already know about.

As part of the GISP project described below, the IUCN Invasive Species Specialist Group in setting up a database of the Worlds Worst 100 alien invasive species. As a mental exercise, compiling this list is revealing, as it quickly emerges that there are probably less than 100 alien taxa causing most of the perceived problems, and risks around the world today. Mice, rats, cats, dogs, rabbits, deer, trout, Nile perch, brown tree snake, scale insects, lymantriid moths, zebra mussels, avian malarias, weeds like water hyacinth, *Lantana camara*, Japanese Knotweed, *Chromolaena odorata* and its close composite relatives, are just some members of this list with intercontinental notoriety. A regional focus allows even more accuracy – in Europe, for instance, almost all countries will put Japanese Knotweed, Himalayan Balsam and Giant Hogweed near the top of their invasives weed list, purely on the basis of local experience, and yet these plants are far from reaching their potential distribution in Europe.

Given the opportunity to address known alien invasive problems, the priority must be to create public awareness and action through compiling and disseminating information on risky species. Many of these species are still being deliberately introduced around the world, and this should be easiest to stop, relative to other alien invasive species challenges.

PRIORITISING ACTION AGAINST ALIEN INVASIVE SPECIES

As concern and awareness of alien invasive problems grows in a country, the initial action often taken is to survey the presence and severity of alien species problems. This exercise always throws up some interesting questions. How long does a species have to be in a country to lose its "alien" status? How do we consider a species re-established after a long periods, which is particularly relevant to the introduction of European flora and fauna to the glacially impoverished ecosystems of Ireland and Britain? Sometimes, the alien nature of a species is itself in question. This is particularly true for alien marine species, where so much mixing has occurred over centuries of ship movements that by the time a fauna and flora are characterised, they may already include some aliens, which appear to be natives.

It is sensible to argue that the key issue about invasives is their invasiveness, not their native or alien status. However, public opinion, as well as options for particular kinds of management (e.g. the introduction of specialised parasites from the area of origin of the pest) will differ between native and alien invasives. Weed or not, biological control is less likely to be approved for a native than an alien plant.

Surveys of alien invasive species problems inevitably generate a long list of species, leading to the question: What are the priorities? Again, there is a need for ecological research to predict invasiveness, in this case post-introduction rather than pre-introduction. But this challenge is much more tractable. Developing methods to quickly assess the invasiveness and potential biodiversity impact of alien species can draw upon ecological tools for measurement of population spread and growth and community composition. Our limited experience of doing this for alien woody plants in developing countries, where simplicity and cost effectiveness is at a premium, draws upon a number of obvious, but nonetheless, revealing tools (Simon Fowler, pers. comm.):

- Distribution of plants – what does this say about dispersal? Are there key animal dispersers or pollinators?
- Age structure of the population in different sites, does it indicate a growing population in both undisturbed sites and disturbed sites?
- Studies to look at seed banks and recruitment of new plants.
- Comparisons of indigenous species diversity in infested and uninfested habitats.
- Exclusion studies to look at regeneration and competitiveness of native flora
- Manipulated exclusion/inclusions studies to look at factors favouring growth of the alien population

There is always the likelihood that, however targets for management can be prioritised, the problem will require a community rather than a species-specific approach. Because of their taxonomic specialisation, many scientists will focus on the target alien and fail to recognise the importance of other species, often other alien species, in its abundance. Thus, on island ecosystems, introduced vertebrates (pigs, bulbuls) are often important dispersal agents for alien plants, and their management must be part of an overall approach. Similarly, highly degraded natural vegetation, once cleared of an alien weed species, is likely to be invaded by another aggressive alien species if there is no plan to manage all aliens and invest in a process of habitat restoration.

The other factor which will help set priorities for alien species problems is, of course, the prospect of their successful management.

HOW DO WE MANAGE ALIEN INVASIVES?

Only a very small proportion of alien invasive species problems have yet been the subject of management programmes. The great majority of these have been in agricultural areas which provide some good examples of both success and methodology. Particular emphasis has been placed on alien insect pests affecting crops, forest plantations and natural forests, and with alien weeds of cropland, pastures and waterways.

Eradication of potentially serious pests is a highly desirable option, if the risk posed by the invasive species is high, introductions are infrequent and the establishment has not progressed far. However, slow or poorly organised efforts have proven to be expensive failures, such as the campaign against the fire ant, *Solenopsis invicta*, in the USA in the 1970s. Eradications are particularly effective in island situations, but can be done on a continental scale, for instance the stepwise eradication of boll weevil and screwworm fly from North America. While the cost of eradication can be very high, the cost of alternative recurrent control will almost always be higher.

Failing complete eradication of the invasive species, the established species must be managed in perpetuity. This can either involve recurrent control efforts, such as culling, use of poisons (e.g. herbicides, rodenticides or insecticides) or biological control. Biological control seeks to establish specific natural enemies from the area of origin of the alien species that will suppress the pest population to a low, non-damaging level and maintain it there indefinitely through a continuing, predator-prey interaction. Recurrent control efforts have high continuing costs, while biological control has a high one-off cost but then continuing benefits. But not all biological control programmes are successful, because natural enemies may fail to establish or may give insufficient control. The greatest success has been achieved with insects and weeds, and there is one precedent for biological control of mammals, the use of myxomatosis against rabbits.
While this experience of alien species management in agriculture is encouraging, the taxa involved comprise only a very small proportion of the taxa which are invasive in an environmental context. For these taxa, such as virtually all marine invasives, there is almost no history of management. However, one striking success in the environmental sector has been the eradication of vertebrates from small

islands (e.g. rats, cats, goats), leading to the conservation of threatened indigenous vertebrates and plants.

Even where there is a history of management of invasive alien species, as for weeds and insects, the species that are serious environmental invasives may pose different problems than those which have already been managed in agriculture. For instance, in biological control of weeds most agricultural targets have been herbaceous, whereas many environment targets will be trees, which pose, literally, a larger problem. For alien insects, most agricultural targets have been plant pests, whereas important environmental aliens include social insects (ants, wasps, bees), whose social behaviour makes then particularly resistant to biological control.

Environmental invasives often affect much larger, less accessible areas than agricultural invasives, making management a particular problem, while putting a premium on methods which spread themselves (e.g. biological control). Further, the public sector is more likely to get the bill for management of environmental invasives, whereas control of agricultural invasives can expect a substantial private sector contribution from the farming community.

Overall, prospects for management of alien invasives in the environment are poorly known for most taxa, and this will certainly affect how we set priorities for action on invasive species. For the present, for many species, the best management option may be to do nothing, while we put effort into problems which we think we can solve, even if they are lower priorities for other reasons. As we demonstrate the potential to solve these problems, we also build public confidence and support for the required research and effort to address more intractable alien invasive species.

AN INTERLUDE ON A TROPICAL ISLE

Some success stories already exist which are good illustrations of what is possible. I will select two from oceanic islands. Island systems have a rather unique place in the context of alien species, for biological and political reasons. Biologically, they often represent ecosystems of very high endemism where extinction rates are highest. Invasive species are usually the greatest threat to biodiversity conservation and extinction, because habitat destruction on these islands has usually been checked by the creation of parks. As ecological systems, islands are highly invasible. Various explanations for this include their low species diversity and “unfilled niches”, their very wide range of habitats over very small areas, and the poor adaptation of isolated island faunas and floras to competition from aggressive continental species in disturbed habitats. Finally, alien invasive problems (including particular species) are often shared between islands, even quite distant from each other.

On the political side, islands (particularly small island developing states, or SIDS) have limited infrastructure and resources to address these complex problems. At the same time, because of their small size, they may have a better capacity to create inter-agency co-operation. Control options like eradication work particularly well on islands because of their small size.

My first example comes from the UK protectorate of St. Helena in the South Atlantic (Booth *et al.* 1995). Here, the tree flora is highly unusual – and one such species is the gumwood, *Commidendrum robustum*, a tree daisy, represented now by less than 2000 individuals. Less than ten years ago, an alien scale insect, *Orthezia insignis*, appeared on the island and attacked a wide range of plants, including gumwoods. By 1993, 10% of the gumwoods were dead, and the rest dying or likely to be so soon. A programme was mounted to combat this problem, based on the observation that this scale had been controlled biologically in other countries. A specific ladybird predator of this group of scales, *Hyperaspis pantherina*, was introduced and by 1997, the pest and ladybird had declined to very low, but continuing numbers, no longer a threat to the endemic flora.

My other example comes from Mauritius, an island state in the Indian Ocean. Mauritius has long been the focus of work on endangered species, and several successful species recovery programmes have been done, including that for the Mauritius Kestrel and the Pink Pigeon. The island also has a high degree of floral endemism, which is now threatened by many species of invasive weeds. Particularly serious weeds include Asian privet, *Ligustrum robustum*, and strawberry guava, *Psidium cattlianum*, from South America. These plants literally overrun indigenous forest, filling the understory and preventing recruitment of indigenous species. They are spread by fruit feeding birds and monkeys and path making pigs, all of which are also alien. In such a complex system, controlling just one invasive, or vector, is not a solution. Here, therefore, a pilot project to restore natural forest through clearance and exclusion of aliens is underway. Areas of less than one hectare, called Conservation Management Areas, are fenced in to reduce dispersal of seeds by vertebrates, and all alien weeds inside removed. This weeding must be done over time, as recruitment of weeds from seedbanks can be considerable. Eventually the natural forest recovers. Extending this activity to large areas of national park will be very expensive, but it may be possible to create a large number of small Conservation Management Areas to preserve the key species in different habitats. Elsewhere in Mauritius, removal of weeds and mammals from offshore islands, involving many volunteers, and the use of herbicides and rodenticides, respectively, has led to a dramatic recovery of native flora and bird and reptile fauna.

THE GLOBAL INVASIVE SPECIES PROGRAMME

Countries are in very different stages of preparedness to address their alien invasive species problems. Some are doing something, others thinking about it, others still quite unaware of the risk. An initiative has recently been started to help all countries, whatever their present position may be, to become more aware and more capable of dealing with invasive species problems. This is the Global Invasive Species Programme or GISP. GISP arose from discussions at the UN-Norway Conference on Aliens between SCOPE, a scientific research initiative on aliens, and the development community. It is co-ordinated by SCOPE, in conjunction with UNEP, IUCN and CABI and receives initial support from these participating organisations and the Global Environment Facility.

GISP objectives are to assemble and make available best practices for the prevention and management of alien invasive species problems, and to stimulate the development of new tools in science, policy, information and education for addressing these problems. It is organised in a number of elements or projects, each with a co-ordinator who helps to plan activities. Most of these projects are directed at gathering and disseminating information, often through workshops or books. CABI, for instance, is involved particularly in development with IUCN of early warning systems (including the databases on the worst invasive species), and toolkits for governments on how to set up prevention and management programmes. As GISP grows, it hopes to become a valuable source of information and materials. For more information on GISP, please visit its website on http://jasper.stanford.EDU/GISP/.

CONCLUSIONS

Alien invasive species problems in East Africa will be the subject of growing interest in the next few years. Because these problems are international in origin, because they are often shared, and because countries are at different stages in responding to them, there is a value to international co-operation in this area.

At the national level, there is a need to engage all relevant stakeholders and communities – for environmental interest groups this means particularly to be aware and make use of the agricultural tradition in alien species prevention and management.

At the international level, the most useful immediate action is to develop early warning and action systems that prevent the spread of known invasives to new areas and countries. Following this, there is a need to develop nationally, and to share internationally, methods to assess invasiveness, set priorities and implement prevention or management programmes. A new Global Invasive Species Programme has this as part of its objectives.

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CONTROL OF ALIEN INVASIVE SPECIES IN MAURITIUS

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INTRODUCTION

Geographical Location and Background

The State of Mauritius comprises the island of Mauritius, Rodrigues, St Brandon and other offshore islets. Mauritius and Rodrigues, together with Reunion island, form the Mascarene islands. These islands are all of volcanic origin and are notable for the unique flora and fauna that has evolved in relative isolation. Mauritius is located at a latitude 20° South and longitude 58° East, some 800 km from the south east of Madagascar and about 2000 km from the African continent. It has a land area of 1865 km^2 with the highest peak attaining 828 m in altitude with a population of 1.2 million people (1995). It has a tropical to sub-tropical climate influenced by frequent cyclones during the summer months (November to April) and gets a rainfall of between 1000 mm to 5000 mm annually (Padya 1984).

Before its discovery by the Portuguese in 1507, Mauritius supported a very rich biodiversity. During the occupation of the island by the Dutch (1638-1710), the French (1725-1810), and later by the British (1810-1968), together with the increase in human population, the island's forest resources were exploited and forest areas cleared, primarily for agriculture but also for infrastructure, resulting in massive loss of native forests and habitat.

The total forest area is 57,059 ha, out of which 21,867 ha are State forest land and include the National Parks and Nature Reserves (6774 ha), plantations (12,635 ha) and the unplanted or non-productive and to be planted areas (4,647 ha). Privately owned forests constitute of about 34,540 ha and include mountain reserves (3,800 ha) and river reserves (2,740 ha). Private forests including scrub and grazing lands have been estimated at about 28,000 ha.The "Pas Geometriques" constitute 652 ha and include plantations along the sea belts planted with *Casuarina equisitifolia*. Although limited in size, the forests are strategically located mostly in the uplands, constituting about 30 % of the total land area.

THREATS TO NATIVE FORESTS

There are several other factors which have contributed and are contributing to habitat destruction or degradation, resulting in the decline of endemic flora and fauna.

Invasive Alien Species

Invasive alien plant species are as great a threat to biodiversity as introduced animals, probably even greater. The exotic plants which are faster growing than the endemics are a more direct threat to the native plant species. They outcompete the endemics for space, light, nutrients and they colonise any open gap in the forest and form monotypic strands. The two most proliferous alien plant species in the upland forest are Chinese guava (*Psidium cattleianum*) of South American origin and introduced by the French *ca.* 1750 (Grant 1801) and the privet (*Ligustrum robustrum* var. *walkeri*), a native of Asia. The guava is dispersed by monkeys, pigs and deer and has penetrated all the upland forest, in many places it forms thickets so dense that no regeneration of other species occurs. It seems likely that the extraordinarily high fruit production of the guava has helped sustain high populations of pigs and monkeys, forcing them to continue damaging the native flora outside the guava's fruiting season. Both plants can form thickets so dense that they hinder the regeneration of the native plants. Lowland forests are invaded by "liane cerf" (*Hiptage benghalensis*), aloe (*Furcraea foetida*) and wild pepper (*Schinus terebinthifolius*). Many of these alien plants are so perniciously successful only because their new environment lacks their natural diseases and predators.

The forest is invaded to different degrees by aggresive exotics and if nothing is done to halt the invasion of the native forest by the alien species the remaining indigenous flora and fauna will be wiped out resulting in massive loss of biodiversity. The ideal solution to the problems of conservation of the native forest ecosystem would be to completely eradicate all the pests from the forest but this is an impossible task.

CONSERVATION MEASURES

Several actions have been taken to preserve the diverse flora of Mauritius which now consists of about 700 native flowering taxa out of which 311 species are endemic and 186 native pteridophytes of which 15 % are endemic.

Nature Reserves

Sixteen Nature Reserves covering 2.5 % of the island and ranging from the 1.5 ha Perrier Nature Reserve to the 3,611 ha Macchabee-Bel Ombre Nature Reserve have been declared from 1951 to preserve the native ecosystem following the pioneering studies of Vaughan and Wiehe (1937, 1941) on vegetation communities in Mauritius. These reserves are legally protected, but there has been very little or no management. Two Nature Reserves Macchabee-Bel Ombre and Combo now form part of the 6,754 ha Black River Gorges National Park, the first park for Mauritius, proclaimed on 15 June 1994 under the Wildlife and National Parks Act 1993.

Physical Barrier and Manual Weeding in Conservation Management Areas

Intensively managed vegetation plots have been established in representative vegetation communities to conserve plant genetic resources.The first plot was established in the upland forest of Macchabee in the 1930's by Dr Vaughan, the then Conservator of Forests. There are now nine extensively managed plots, Conservation Management Areas (CMAs) as they are called, ranging from 1.5 ha to 19 ha within the National Park. These CMAs are fenced and a low stone wall built to keep deer (*Cervus timorensis*) and pigs (*Sus scrofa*) out and weeds manually uprooted. The fencing and initial weeding of most of the CMAs and the maintenance weeding, four times a year, in all the 9 CMAs, covering an area of 44 ha have been contracted out because of shortage of manual labour within the National Parks and Conservation Service.

The control of the alien invasive plant species in these CMAs has proved to be very promising. Many endangered plants have been found, the endemics are regenerating naturally and they are providing better habitat to the endemic birds. The CMAs are being used by the endemic Pink Pigeon (*Neseonas mayeri*) and the Echo Parakeet (*Psittacula echo*) for nesting and foraging.

Chemical Control

Some chemical control has been tried within the now extended Brise Fer CMA by volunteers from Raleigh International during six weeks in 1993. Chinese guava and privet were cut with rangers knife at about waist height and herbicide was applied to the stump by small brush at a concentration of 10% (one part Garlon to 9 parts water) and a few drops Rhodamine dye were added for identification purposes. But the results have not been promising.

Recent trials with Garlon at the manufacturers concentration on stumps about 20 cm from the ground has proved promising, however Garlon is very expensive and trials with other herbicides are underway.

Biological Control

Successes in biological weed control include control of *Cordia interrupta* by introducing the predatory insects *Schematiza cordia* and *Eurytoma attira* and prickly pear cactus, *Opuntia tuna*, was controlled by a cochineal scale, *Dactylopius* sp., in 1797 and later controlled by the moth *Cactoblastis* sp.

RESTORATION OF HIGHLY DEGRADED AND THREATENED NATIVE FORESTS IN MAURITIUS PROJECT

Previous work undertaken to preserve the biodiversity in-situ has shown that by simply eliminating the invasive exotic weeds and excluding the two ground mammals, deer and pig, native species regeneration has been accelerated. However, the elimination of weeds by uprooting manually and the exclusion of ground mammals by erecting fences are labour intensive and expensive practices and cannot be applied to very large areas. It is imperative to devise some other means of control of the exotics which would be less labour intensive and less expensive and which could be applied to larger forest areas.

The Mauritius Government therefore submitted to the UNDP the project "Restoration of Highly Degraded and Threatened Native Forests in Mauritius" for funding under GEF. The purpose of the project was to halt the degradation of the native forests caused by exotic weeds and animals and to restore to the extent possible the original structure and functions of the forest ecosystem on a larger scale.

The project, which started in June 1996, is being implemented by the Mauritian Wildlife Foundation (MWF), a Non-Governmental Organisation collaborating with Government in the implementation of conservation projects. The assessment of the biodiversity of the area to be restored has been completed. A 6 ha plot within the 25 ha fenced Brise Fer Conservation Management Area has been set aside for the purpose.
A workshop was held in September 1997 with top restoration ecologists and weed control experts to discuss various alternatives for control of exotics and to come up with an efficient method for the control of exotic weeds in the forest ecosystem. The restoration process to be undertaken was also discussed. The recommendations of the workshop, especially the experimentation on the control of the exotics by use of chemicals are now being put into practice. It was generally agreed that the one year remaining for the project, two years having already lapsed, might not be enough to come up with a conclusive result of cost effective method/s of control of the two invasive alien species from the experimentation. It was felt that the project should be extended for another two to three years to complete the experiments- chemical and mechanical methods. An evaluation of the project would have to be carried out and a 2-3 year project extension has to be prepared for submission to GEF through UNDP.

This project is very interesting as it is the smallest project (US $ 200,000) ever undertaken by GEF, excluding the small grant projects programme. It is innovative in that for the first time GEF has undertaken a programme of this nature. It is a project which shows the strong and close collaboration which exists between the main conservation agencies in Mauritius. The technical component has been contracted to MWF. MWF is providing the specialist staff by recruiting relevant consultants for the project. International NGOs such as World Conservation Union (IUCN), Royal Botanical Gardens, Kew, and Wildlife Preservation Trusts International are providing guidance and expert assistance in the implementation of the project.

The Faculty of Science, University of Mauritius, is playing an important role in capacity building. It is conducting a one-week course on biodiversity conservation. Three courses have already been completed (December 1996, December 1997 and January 1999) as part of a module for undergraduate students taking Biology and Environmental Science, National Parks and Conservation Service technical staff and NGO representatives. Over 120 individuals have benefited from this one week biodiversity training course. The University of Mauritius is also undertaking undergraduate research projects in conservation biology. University students will assess both the exotic and native biodiversity and investigate their interaction. They will also monitor the response of the biodiversity to the control measures adopted.

The National Parks and Conservation Service of the Ministry of Agriculture is the implementing and executing agency for the project. The Director has been designated as the project Director for the project. A Technical Advisory Committee, under the Chairmanship of the Project Director and comprising a representatives of all participating agencies has been established to systematically monitor, evaluate and provide guidance to the project throughout its life.

EXOTIC ANIMALS

Human beings, one of the main agents of extinction, besides having a direct impact on the destruction and degradation of habitats have introduced numerous alien animal species to Mauritius, either accidentally or deliberately. These introduced animals multiplied and spread throughout the island. They could obviously not integrate into the ecosystems without causing any damage.

Historical records bear testimony of the introduction of several terrestrial vertebrates as from the early sixteenth century. We shall not therefore, in this paper, dwell on the introduction of all land vertebrates but shall focus on some of the introductions which have had a negative effect on the native flora and fauna of Mauritius and the measures being undertaken to minimise their impact on the native biodiversity.

Long-tailed Macaque Monkey

The Long-tailed Macaque monkey (*Macaca fascicularis*) is native to South East Asia, including the Philippines, Thailand, Myanmar, Java, Sumatra and Borneo (Sussman & Tatersall 1981) where it is also known as the crab-eating Macaque or Cynomolgus monkey. Monkeys are generally supposed to have been introduced to Mauritius from Java by the Portuguese in the early sixteenth century (La Caille 1763, Pilot 1905). In the absence of mammal competitors or of predators in Mauritius the monkey population has thrived and they are abundant on the island today. The population is estimated between 40,000 and 60,000.

Considerable damage is done by monkeys to agriculture, particularly sugar cane and vegetables. Monkey damage is inflicted on sugar cane at three different stages by digging and destroying the newly planted sections of cane, feeding on the new shoots after harvest and by feeding on ripe sugar cane stems. Cabbages, water melons, maize, potatoes, pumpkins, peppers, tomatoes and pineapples are among the vegetables and fruits which attract the monkeys. Monkeys sample and damage far more food than they actually consume. It is estimated that monkey damage to agriculture is probably costing the island of the order of £ 1-2 m per year (Bertram 1994).

Like other introduced species, monkeys have caused and are still causing major adverse impact on the native wildlife. They are believed to be an important factor in the extinction of forest birds in Mauritius, such as the scops owl (*Scops commersoni*). They are responsible for a significant degree of predation on the nests (eggs and fledgings) and even on adult endangered endemic bird species, such as Pink Pigeon (*Columba mayeri*) (Jones *et al.* 1992) and Mauritius Fody (*Foudia rubra*) (Stafford 1994).

Monkeys live in large groups and are active from dawn till dusk. They effect the native vegetation by preventing regeneration of the native plants as they damage fruits, flowers and tender shoots and branches of native plants and they spread the seeds of alien invasive such as Chinese guava (*Psidium cattleianum*).

No global approach at controlling the monkey population is being tried. However, the cooperation of the two companies exporting monkeys for medical research is available to trap the monkeys in sensitive forest areas where conservation management activities are being carried out in agricultural lands at the request of planters. The monkeys are wary, trap shy, highly intelligent and not easy to control and manage.

Wild Pigs or Wild Boars

The wild pigs or wild boars (*Sus scrofa*) were introduced by the Dutch from Java in 1606 as game. They are now common in the forests where they are detrimental to both the flora and fauna. They prevent regeneration of the native plant species as they consume a large quantity of fruits, seeds and seedlings, uproot seedlings and are an effective agent of dispersal of exotic weeds, especially the Chinese guava. No programme of control has yet been put in place, but pigs have been excluded from restoration areas, the Conservation Management Areas by use of low stone wall at the foot of the fencing which makes it difficult for them to dig under.

Rabbits

Rabbits (*Oryctolagus cuniculus*) were introduced on the mainland of Mauritius in 1639 but failed to establish because of predation. However, they did establish on the predator free islands off Mauritius, especially on Round Island, where for centuries they threatened the biodiversity of the whole island. They were eradicated from Round Island in 1986 by poisoning and as a result there has been a marked increase in the native plant regeneration and the populations of unique reptilian fauna.

Hare

The hare (*Lepus nigricolis*) were introduced in 1639 and contribute to the damage to the vegetation both on the mainland and on some of the islets. However, the extent of the damage is not known as the hare is always associated with other damage causing organisms. Hare has been eradicated as a result of the rat poisoning campaign on the northern offshore islet, Gunner's Quoin, in 1995.

Rodents

Three species of rodent occur in Mauritius, the black rat (*Rattus rattus*), the brown rat (*Rattus norvegicus)* and the house mouse (*Mus musculus)*. Rats are generally assumed to have reached Mauritius from Portuguese ships or shipwrecks in the sixteenth century. They are known to feed on birds, eggs, reptiles, invertebrates, seeds, bark and fruits of plants. The black rat is a good climber and is the largest threat to tree nesting birds, whilst the brown rat will predate on ground nesting birds. Mouse is a predator of smaller native fauna such as reptiles and invertebrates.

Rats have been the main cause of extinction, on the mainland, of the snakes and large endemic lizards that disappeared before the arrival of the Dutch. The extinction of the dove (*Alectroenas rodericana)*, coincided with the appearance of rats, the only predator at that time. It is not therefore surprising that in Mauritius many reptile species still occur only on the rat free Round island (Vinson *et al*. 1969). No regeneration of *Pandanus vandermeerschi*i has been noticed on Gunner's Quoin when brown rats were present because they were feeding on the seeds.

All the northern offshore islets are rodent free. As islets are closed system, eradication of rodents has been possible. Our eradication programme used a grid size of 25 metres to ensure there at least one bait station within the home range of every mouse. The most effective way to achieve total eradication was to lay the poison baits out in as little time as possible. The bait used was a grain based pellet, 20 mm in length and coloured blue/green. This colouring makes the pellet less attractive to birds. Brodifacoum, a second generation anti-coagulant with a strength of 002 %, was the active ingredient. Rats and mice compete for the same food. To achieve the eradication of both species, it was necessary to spread the bait over the entire island five times. At each bait station an area of ground was cleared and a measured portion of bait was laid. Each of these portions weighed 150 gms (approximately 60 pellets). Feral cats died by secondary poisoning by eating sick or dead rats and mice. In spite of our ability to eradicate mammals from relatively small islands the fight against invasive species cannot stop at this point. Continued work is needed to prevent deliberate or accidental reintroduction. Only last year rabbits were introduced to Gunner's Quoin, an offshore islet of conservation importance which had previously been cleared of ground dwelling mammals. Clearly we have to increase the awareness of the impact of alien species on native ecosystems among the public at large if our programmes are going to be successful in the long run.

Brown rats and mice were eradicated from Gunner's Quoin (65 ha) in 1995. Black rats and mice have been eliminated from Flat Island (253 ha). With the removal of black rat on Gabriel Island (42 ha) in 1995, the endemic *Psiadia arguta* is now outcompeting the invasive *Lantana camara.* Mice have also been eradicated from Ile aux Cocos and Ile aux Sables off Rodrigues in 1995. The eradication of rodents on all these islets has been carried out under the Management of Offshore Islets Project with the help and expertise from New Zealand.

On the mainland rodent control is being carried out in specific areas where active conservation management is being practised mainly where captive bred birds are being released. Rodent control and/or eradication has been effected using poisoned pellets or wax block and trapping.

Deer

The Java deer (*Cervus timorensis*) introduced by Van der Stel in 1639 and reared as a game species is an important component of the fauna. The deer provides a very popular meat and is a good source of revenue for private estates during the hunting season. It has a major negative impact on the regeneration of endemic trees because of trampling and browsing of seedlings. They can even kill a tree by ring-barking it with their antlers during rut.

The deer have been excluded from the Conservation Management Areas (about 50 hectares by erecting fences). Action has been initiated to reduce the density of deer within the 6,574 ha Black River Gorges National Park. The deer will be culled by volunteers under the supervision of park staff and the venison will be sold to an approved contractor. Since the proclamation of the National Park in 1994 no more hunting was carried out in those parts of the National Park which were leased for hunting.

The Indian Mynah and the Red-Whiskered Bulbul

The Indian Mynah (*Acriditheres trisis*) and the Red-Whiskered Bulbul (*Pycnonothus jocosus*) also contribute to the degradation of the native forests as they act as seed dispersal agents for the exotic plants. The introduction of the Indian Mynah to Mauritius to control locusts in the sugarcane fields is among one of the first examples of biological control. The Mynah today compete with the endemic echo parakeet for nesting holes and predate on chicks of endemic birds. No control measures are being taken against these two pests.

OTHER PROJECTS

Mauritius has embarked on, submitted proposals or committed itself to the projects below in order to control/eradicate invasive plant species and introduced harmful animals:

(a) We are collaborating with Reunion Island in their project to develop biocontrol methods for elimination of privet (*Ligustrum robustum* var. *walkeri*) and bramble (*Rubus alceifolius*).

(b) Research is being carried on the mongooses in view of controlling/eliminating their negative impact on the Mauritian biodiversity.

(c) Under the National Environment Action Plan II and Environment Investment Programme II, a national pest strategy will be developed.

(d) A project proposal has been submitted to UNDP for future funding and whose main objective is the eradication/control of invasive species on the islets off the north coast of Mauritius.

(e) We have expressed our support to a draft proposal submitted by Fauna and Flora International entitled "Healing Biodiversity loss in the Western Indian Ocean Region through Extensive Control of Invasive Exotic Species and other appropriate measures." The main objectives are to: (i) review the status, origin and uses of those invasive species affecting forestry and conservation sector; (ii) estimate the costs and benefits of these species to the Mauritian economy; and (iii) review the potential economic and ecological effects of controlling these invasives through physical, chemical and biocontrol methods.

CONCLUSION

Several alien invasive animal and plant species are responsible for the degradation of the remaining native forests and constitute a threat to the native biodiversity. Intensive management, involving eradication and/or control of unwanted restoring to the extent possible the original structure and function of the forest. Mauritius has a long tradition of commitment and cooperation with international organisations in the fields of conservation and is taking every opportunity of international expertise to tackle the serious problem of alien invasive species shared by many countries.

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INVASIVE SPECIES AND THE NATIONAL – *WORKING FOR WATER* PROGRAMME: LINKING SUSTAINABLE DEVELOPMENT WITH ECONOMIC EMPOWERMENT IN SOUTH AFRICA

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BACKGROUND

The vision of the South African *Working for Water* (WfW) Programme is to sustainably control invading alien species and optimise the potential use of natural resources, through a process of economic empowerment and transformation. In doing this the programme will leave a legacy of social equity and legislative, institutional and technical capacity.

The objectives of the programme are summarised as follows:

1. To enhance water security.
2. To improve ecological integrity of natural systems.
3. To optimise the social benefits of the programme.
4. To restore the productive potential of land.
5. To promote the sustainable use of natural resources.
6. To develop the economic benefits of the programme through economic empowerment.
7. To protect the economic integrity of the productive potential of the country.

SCIENTIFIC KNOW-HOW

The Process of Invasion

Richardson *et al.* (1992) suggest that most of the Invading Alien Plant (IAP) species in South Africa are adapted to fire. This adaptation accounts for their invasive success. Richardson and Brown (1986) documented the invasion of a Fynbos catchment by *Pinus radiata* in the Jonkershoek valley. The invasion process used in management models for Fynbos catchments today are largely based on the findings of this paper. They found that between 1938 and 1981 *Pinus radiata* invaded an area after aforestation of an adjacent area in 1935. It was found that an increase in the spatial spread and density of invading plants is normally associated with the occurrence of a fire. Fire stimulates the release of large quantities of seed from the serotinous (*Pinus* spp.) cones. It also causes favorable microsites for germination and the establishment of seedlings. The work done by Richardson (1989) has shown that an area that is being burnt will fall within the next higher density class after the fire.

Impacts on Biodiversity

Most invading IAPs in fire prone ecosystems in South Africa are well adapted to fires and produce vast numbers of seeds. In addition most of the IAP have no natural enemies present in South Africa. Normally invaders grow faster than indigenous species. There is extensive evidence confirming the effect of plant invasions on indigenous plant diversity. The Fynbos biome is a good example of this. Macdonald and Richardson (1986) have published strong evidence that dense infestations of IAPs have a negative effect on the number of indigenous vascular plants in Fynbos areas. Richardson (1989) listed a number of cases where mean species richness was compared across invaded and uninvaded sites. On Table Mountain, the mean number of species per 25 m^2 plot in uninvaded Fynbos was 17.6. For areas with dense *Pinus pinaster* invasion it was 15.4. At a site near Kylemore (a Western Cape Town) the average number of species per 4 m^2 quadrat was 17.2 while the average in an adjacent stand of *Acacia melanoxylon* and *Hakea sericea* was only 5.4. At Biesiesvlei in Jonkershoek valley near Stellenbosch the mean species richness in a 0.1 m^2 plot was 8.5, while 35 years after aforestation it was only 1.8.

If only a few IAPs are present in an area there is often little or no significant effect on the species diversity of the area. However, the denser the population of alien plants, the bigger the effect on biodiversity. IAPs can not only displace the canopy (overstory) species but can also suppress sub-canopy (understory) species. When this occurs, plant species diversity is significantly reduced.

Impacts on Ecosystem Function and Services

General Ecosystem Function Changes

Once IAPs have replaced indigenous plants in the system, ecosystem function can change. An ecosystem function that has been neglected in past IAP related research in pollination. Pollination patterns are expected to change because IAPs cause a change in plant species composition. In addition, IAPs can dominate species composition and abundance. In such cases, as in the case of *Acacia* spp. especially, the geochemical cycle changes and the soil becomes enriched as a result of the nitrogen fixing by the invasive *Acacia* spp. (Macdonald and Richardson 1986).

Impacts on Runoff - The most Important Ecosystem Service

The reduction of runoff is the most important ecosystem function change taking place because of the higher biomass of IAP stands in the catchment areas (watersheds) of South Africa (Van Wyk 1987). Reduction in runoff after aforestation with pines can be 30 - 60 %. Runoff reductions are more extreme in summer (during the dry season in Mediterranean areas) than in winter. Low flows in the Jonkershoek catchments (one of the catchments used for long term hydrological research) was reduced by as much as 78% some 16 years after aforestation with species which often invade catchments. It is during the dry season that the conflict between the natural environment and the IAP is peaks. The water needs of the natural environment are highest during the dry season just when the evapotranspiration rate of IAPs also peaks (Van Wyk 1987; Scott and Smith 1997).
The water loss resulting from IAPs can be valued in a number of ways in order to calculate project worth to compare management options. Depending on the objectives of the study, project worth can either be derived from additional water available for use and/or its availability for a number of economic activities, such as agriculture and industry.

Replacement Value of Water

The replacement value of water can be described as the cost per kiloliter (cubic meter) from a water supply scheme which would have to be built to replace the water lost as a result of IAPs. This can be expressed using the unit reference value (URV) as the yardstick. To calculate the URV it is necessary to calculate the Net Present Value (NPV) of the costs and benefits over a specified investment period. These costs include the cost of capital and management and maintenance expenditure over the investment period. In most instances the investment period is assumed to be 45 - 60 years. The annual yield of the scheme is then used to calculate the benefits. The URV is calculated by setting the benefit (yield x URV) equal to the aggregate of the capital, management and maintenance costs related to an existing or proposed water scheme. Both cost and benefit streams are then discounted to calculate the URV of water yielded by the scheme.

Impacts on Yields in Agriculture

The impact of water quality on agricultural yield showed up as a potential source of catchment valuation. The following is not an effort to place a value on water quality as a benefit stream from catchments, but rather to develop a rough approximation of what the value of clean water could be, based on scientific data from a variety of sources. It should also be stressed that this is based on a very high value crop with relatively efficient irrigation systems.

A yield curve supplied by Brummer (personal communication 1997) on the effect of salinity (Total Dissolved Salts (TDS) mg/l) on wine grape yields in the Southern California Coastal Areas was used to get an indication of the effect on grape production. The curve was derived from draft curves supplied for the Southern California Coastal Areas. The curve showed that a TDS increase of 100 mg/l caused a decrease in yield of 0.54 tons/ha. (All figures recalculated from US tons/acre to metric tons/ha). The curve showed a drop in yield from approximately 500 TDS mg/l. These were recalculated to g/m^3 to correlate with the units used for runoff in South African case studies. The aim is therefore to dilute saline water to salinity levels of less than 500 TDS mg/l.

Lastly the dilution value for irrigation purposes was used, calculating the benefit per 1 m^3 of high quality mountain catchment (Fynbos) water. If the Breede River tributaries cited by Moolman (1995) were taken as representative of very poor quality water, the results showed that Fynbos low flow water is worth at least 2.51 South Africa Rand[1]/m^3 (R2.51/m^3) when used to dilute low quality water from tributaries. If the highest value in the Southern California Yield Curves is used, Fynbos low flow water is worth approximately R6.14 /m^3. The dilution value of high quality mountain catchment water increases with a decrease in salinity of the base water.

Economic impacts

Taking into account the economic empowerment and social development objectives of the Working for Water Programme it was decided that participants (beneficiaries in terms of job creation) would be developed in more than just the clearing of IAPs. A market for Environmental Technical Services (ETS) is therefore being developed. This market not only includes the clearing of IAPs as a service but also some other aspects which include fire management services. As many of South Africa's ecosystems are fire prone, the management and control of fires forms an integral part of the management of natural areas. A further component of this market will be the development of basic infrastructure such as roads (jeep tracks) and footpaths to facilitate the wise use of the natural resource through ecotourism. Ecotourism facilitation and management also forms part of the development process to promote non-consumptive use of natural resources.

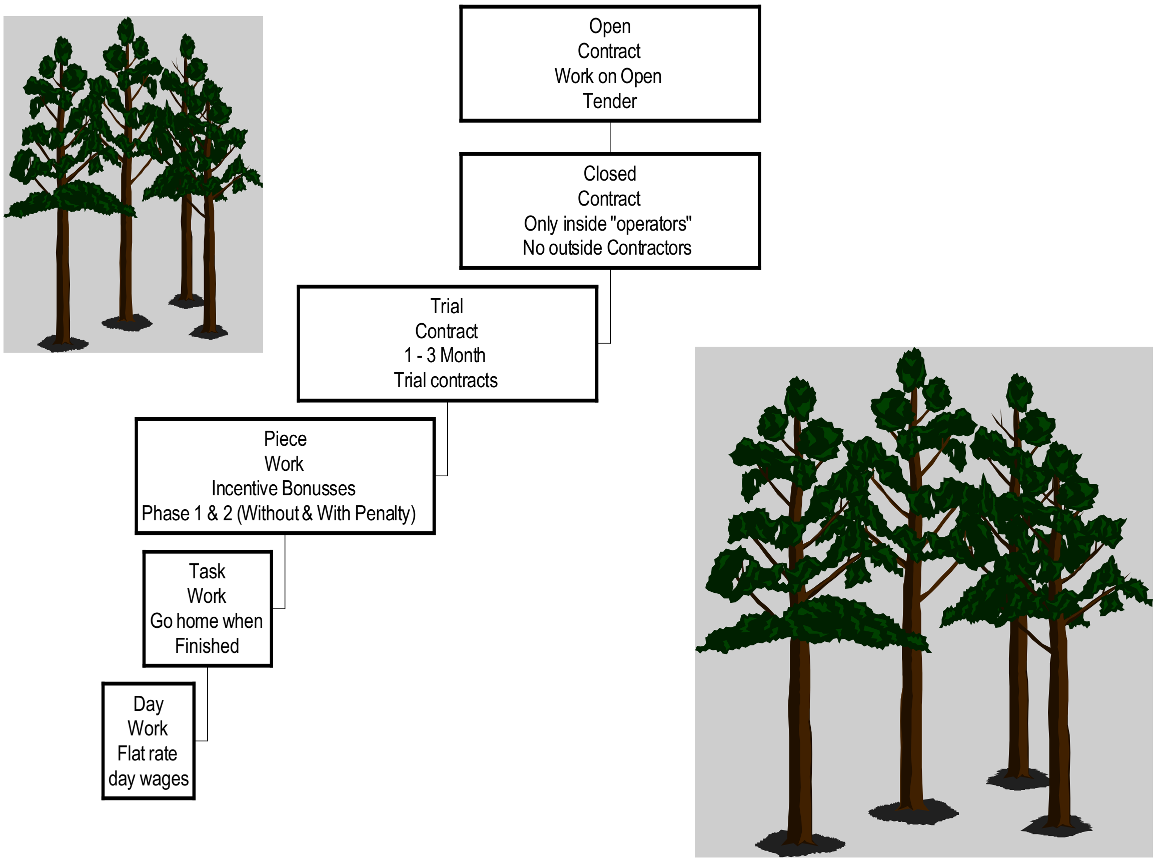
The development of an ethic for the consumptive use of renewable natural resources on a sustainable basis is being promoted in the programme. Participants in WfW are being introduced to a number of activities in environmental management to prepare them for a change in employment opportunities. It is expected that IAPs will be brought under control over the next 15 - 20 years and greater emphasis will be placed on a broader range of ETS.

To spread the benefit of the programme as wide as possible, the development of the service providers takes place at the lowest possible level. For the commercial aspects of the development in WfW to be successful it is necessary to adopt some strategy to supply the participants with financing arrangements, equipment and supplies (Gittinger 1982). To accommodate this, a number of developmental steps were designed for the project.

[1] [Note that at the time of this workshop, the approximate conversion values were US Dollar 1.00 = South Africa Rand 6.00 = Kenya Shillings 70.00.]

Figure 1: Development strategy and steps towards the formalization of the Environmental Technical Services Market.

Figure 1 shows the steps to be followed towards the formalization of the Environmental Technical Services Markets.

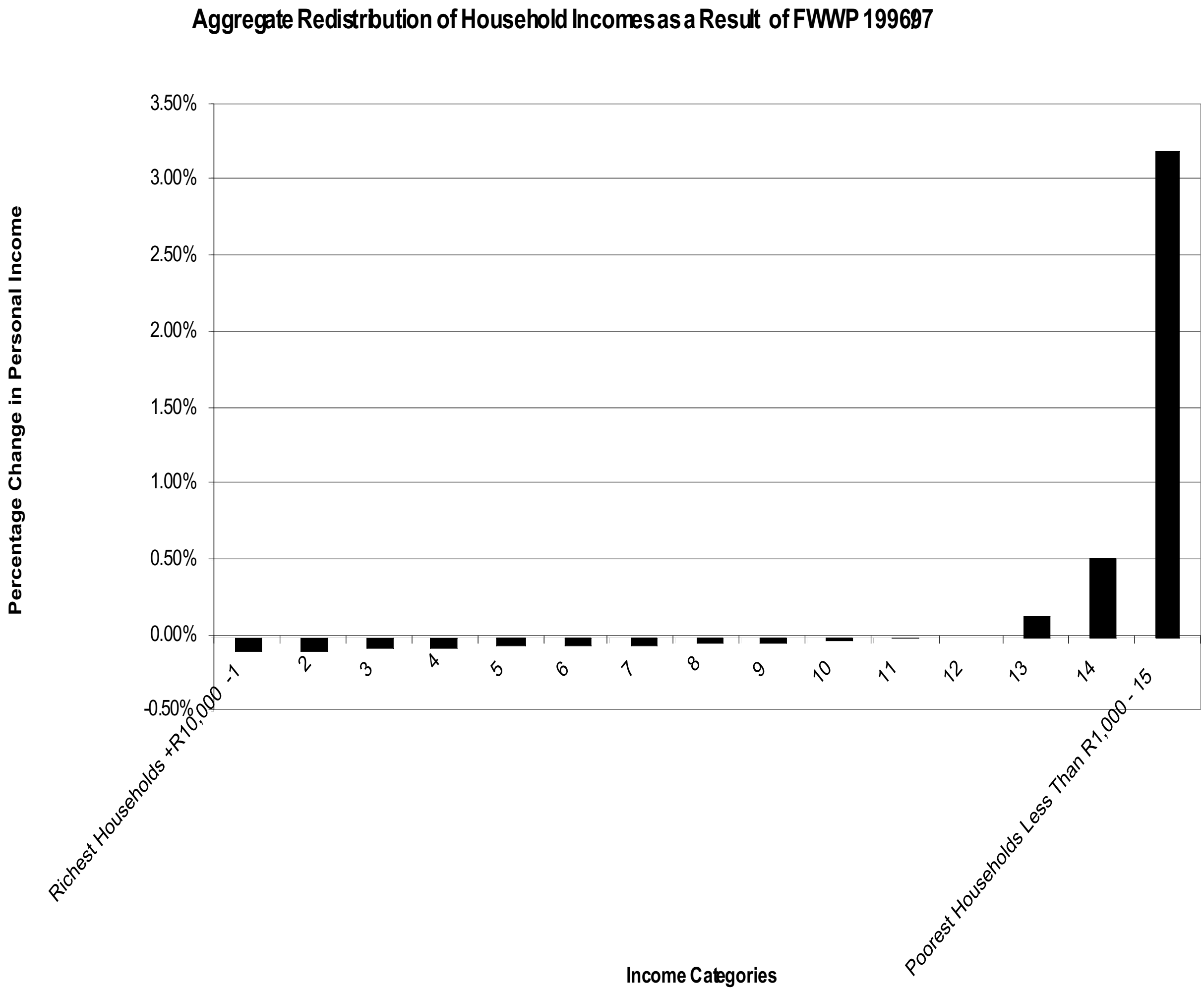


To achieve the above (Figure 1), a number of development and training lines within the project have been identified. Education and training in WfW is aimed at achieving the economic empowerment, social development and transformation objectives of the programme.

Direct (Tangible) Economic Costs and Benefits

The tangible costs of WfW can be seen as mostly financial. In a very limited number of cases, one of the costs of an IAP clearing programme could be a reduction in the supply of fuel wood over the medium to long term. This can however be addressed by developing a small local industry or source of fuel wood to supply the community through well-managed woodlots. Increased employment in South Africa is seen as a major benefit taking into account that unemployment is most probably the biggest challenge facing the country at present. Employment created by the Wf W programme is a major boost to rural communities. Studies done during 1997 based on the demand created by the projects and the number of people employed in the Western Cape Province showed that over and above the 65 direct jobs per R1million created by the project, 8.93 indirect jobs were created outside the project. 64% of expenditure in the project went to the salaries and wages of workers of which more than 99% were from disadvantaged communities. This had a significant impact on the redistribution of wealth in the Western Cape Province as a whole. If one assumes that the WfW Programme in the province was funded through an increase in taxes, which it was to some extent, the average impact on the richest households in the province was minimal. These families showed an average decrease in household income of 0.09%, while the poorest of the poor showed an average increase in household income of 3.18% (Marais 1998). Figure 2 shows the impacts over the range of household incomes.

The increase in water runoff from catchment areas seems to be the major tangible benefit. Short-term hydrological monitoring experiments commissioned by WfW confirm that the impacts of IAP are comparable with the impacts of aforestation on runoff as shown in long-term hydrological research.



Two experiments done in the Western Cape Province showed runoff increases of $10m^3$ and $12m^3$ per ha per day during the dry season just after clearing (Prinsloo 1996). A similar experiment in the Mpumalanga province showed even more dramatic results (Dye and Poulter 1995).

Van Wilgen *et al*. (1997) showed that clearing of IAPs decreases the unit reference value (replacement value) of runoff in the planned Skuifraam scheme from R0.59 - R0.57/m^3 by maintaining the virgin natural runoff. In the Theewaterskloof catchment across the watershed from the above catchment, the unit reference value of water also decreased as a result of clearing. Here the unit reference value of the runoff was calculated in terms of the clearing costs and did not include the cost of building a new scheme as in the case of the planned Skuifraam scheme. If clearing starts immediately the unit reference value (cost) of water in the Theewaterskloof catchment will be R0.08/m^3. If the programme were delayed by five years the value would increase to R0.09/m^3 and if it is delayed by 10 years it will increase further to R0.10/m^3. This means that the cost to the end user will increase.

A benefit of IAP clearing programmes that has not received much attention to date, is the effect they have on major floods. Although clearing IAPs from the major river systems has not beed carried out within the high lying catchments, expanding the programmes to these areas will have the benefit of flood control. During 1996, the Gauteng Province had major flood damage as a result of the Vaal River bursting its banks. This resulted from a large amount of water that had to be released from the Hartebeespoort dam during the flood. Damage ran into millions of Rands (R6 million). During 1996, WfW started clearing areas below the dam. During early 1997, after a substantial area was cleared below the dam, there was another flood. Exactly the same volume of water was released. The recorded level of the water along the river was seven meters lower than the previous flood and damage to property was minimal (DWAF WfW 1997).

Indirect Benefits

When rivers are used both to convey water to irrigate fields and to drain the landscape, downstream irrigators will again use some of the drainage water (Moolman and Lambrechts 1996). As discussed above, this water will only be available for use if it is of good enough quality. The drainage water will include seepage from irrigated lands, which in most cases go hand in hand with fertilizers and other enrichment agents. To dilute this water, and to keep it in a usable state, it is important to "feed" as much water in the system as possible. This is especially true during the summer period of low flows in the winter rainfall regions of the Western Cape. To ensure the quality of the summer water in the river systems, it is desirable to maximize runoff from the mountain catchments during this period. As already mentioned Van Wyk (1987) showed that low flows after aforestation with *Pinus radiata* in Jonkershoek decreased by as much as 78%. In order to keep salt water content in the Breede River (a major river system in the wine producing Western Cape Province) within acceptable levels, water is released from the Brandvlei Dam during periods when the salinity levels are unacceptably high. Moolman (1995) reports salinity levels of some tributaries of the Breede River as 2157mg/l (Nuy), 1729 mg/l (Vink), 2931mg/l (Poesjesnel) and 2035 mg/l (Kogmans). To dilute these vast amounts of water, 20 - 25% of the total annual release (25 mil. m^3) from Brandvlei has to be released. It is therefore obvious that high quality mountain catchment water could be worth millions of Rands if the dilution value is R2.51 - R6.14 per m^3 as discussed above.

Liebenberg and Uys (1995) quoted the maximum salt concentration which can be tolerated by crops such as maize, potatoes and some types of fruits as 660mg/l. They added that crops that are irrigated with water of this quality do not only have the danger of damage to foliage but also that the soil becomes brackish in due course. Rivers that run through arid parts of South Africa tend to have naturally high salt levels. Some of these rivers drain into the major river systems, so there is a natural source of poor quality water. Add to this the salination effect of fertilizers and reduced runoff from the Table Mountain Sandstone (TMS) catchments as a result of invasions, the loss of the dilution effect that the mountain catchment water has on the major river systems could have significant negative impacts for the agricultural sector. Areas with a TMS substrate are known for the high quality of the natural runoff (Toens personal communication 1997). It is clear that a decrease in runoff from the mountain catchments as a result of IAP could have a dramatic effect on the quality of the agricultural water resources in the Western Cape Province of South Africa.

As a result of the reduction in runoff through the impact of IAP, the yields of water schemes are also being reduced. Thus IAPs are increasing the impacts of droughts, and reducing the ability of water schemes to produce sufficient yields.

A further benefit of the clearing of IAP is the reduction of the negative impacts of fires on soils. Massive soil erosion occurred after fires in an aforested area against Table Mountain (Devils Peak 1990) and Bainskloof pass above Wellington (Versfeld 1995). These erosion incidents can be attributed to water repellency as a result of very high fire intensities in areas with very high plant biomass (fuel) such as pine plantations (Scott and Van Wyk 1992). In river courses where *Acacia mearnsii* is the dominant IAP species, examples of riverbank erosion are common. *Acacia mearnsii* suppresses all vegetation in the understory and the tree itself has a very shallow root system, which washes out during flash floods in the winter (Versfeld 1995). Clearing river banks of IAPs therefore has the added benefit of reducing bank erosion as well as promoting river stability.

Further benefits of the clearing of IAPs could be found in the improvement of the natural beauty of an area. This could have a major effect on the attractiveness of the area for tourists (Higgins *et al*. 1997). Tourists are normally prepared to spend money on visiting pristine areas. The benefit of the improved tourism potential of cleared areas should therefore be taken into account in the economic evaluation of IAP clearing programmes.

The Costs and Benefits to the Conservation of Biodiversity

All the above mentioned direct and indirect costs and benefits are related to the conservation of biodiversity. From the conservationist's point of view, this is certainly an important potential benefit of the IAP clearing programmes. A number of books have been devoted to the topic of biodiversity in the Fynbos biome. In one of these, Macdonald and Richardson (1986) reflect on the effects of IAP species in terrestrial ecosystems of the Fynbos biome, examining the effect of the reduction in diversity on:

- Efficiency of ecosystem function (including water quantity and quality as discussed above)
- The value of the natural resource in terms of the consumptive utilisation (the wild flower industry)
- The value of the natural resource in terms of non-consumptive use (the ecotourism industry)
- The ability of the ecosystem (catchment = MCA) to withstand major natural incidents such as droughts, floods, catastrophic fires (mid summer fires during extreme weather conditions) and human induced incidence such as unsustainable development for example ploughing of virgin land, overgrazing, plantations and housing developments.

In short, what is the effect of IAPs on catchment resilience? We have not quantified it as yet. What we do know however, is that South Africa has an international responsibility for the conservation of the Cape Floral Kingdom. The remarkable features of the Cape Floral Kingdom lead botanists to classify it as one of the six described plant kingdoms of the world (Cowling and Richardson 1995). It is therefore of international importance that the Fynbos catchments be conserved for its contribution to the biological diversity of the world, irrespective of the potential economic value of that diversity.

Biological Control

During the last three decades a number of biological control agents have been tested for IAPs in South Africa. Some of the more successful ones were as follows:

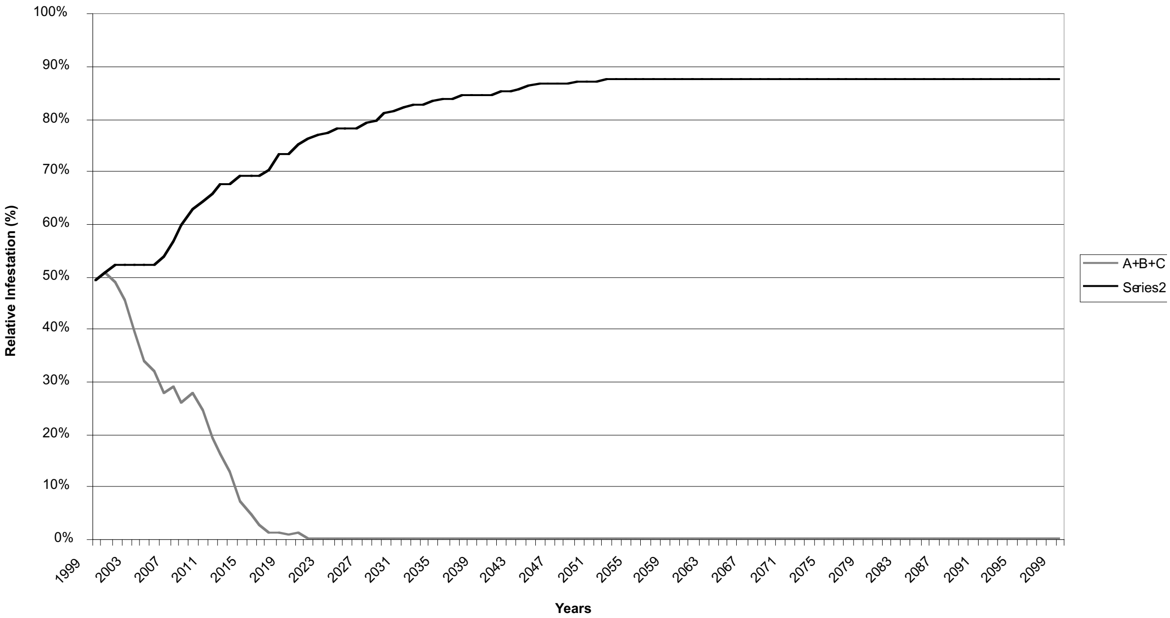
1. The bud-galling wasp *Trichilogaster acacialongifoliae* has been very successful in reducing the seed set of *Acacia longifolia*.
2. The gall rust *Uromycladiun tepperianum* reduced seed production of *Acacia saligna* extensively and large areas of this species died back as a result of the rust (Van Wilgen *et al.* 1992).
3. Other agents that were introduced with a reasonable amount of success were those on *Hakea sericea*. The snout beetle *Erytenna consputa* larvae destroy developing fruits of the Hakea plant. The moth *Carposina autologa* feeds on the mature fruits. The fungus *Colletotrichum gloeosporioides* reduces vigour and causes mortality in certain stands (Van Wilgen *et al.* 1992).

For the IAP species that are being grown for commercial use such as *Pinus pinaster, P. radiata* and *Acacia mearnsii*, no agents have been released as yet. The contribution of biocontrol agents to the clearing programmes is in the form of reducing the rate of infestation as in the case of *Acacia saligna* and *Hakea sericea*. With further development in the field of biocontrol the clearing of IAPs could still become much cheaper. This would make the clearing programmes even more economically viable.

Cost of Clearing

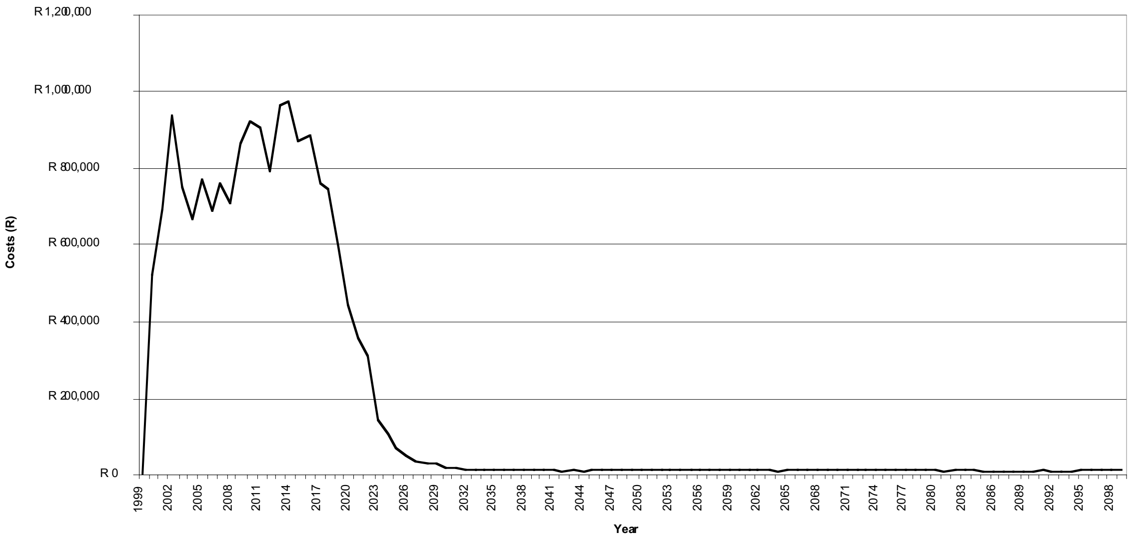
It is accepted that the clearing of IAPs is not a "once off" operation. Based on management data from recent years it is assumed that a 75 - 100% infestation should be treated four to five times over a ten year period to get it to a state where it only needs maintenance. These treatments can take place in a number of ways depending on local circumstances. The first follow up treatment normally takes place within the first year after the initial treatment for resprouting species. The second - fourth/fifth follow ups will then take place at one - two year intervals. On average it is assumed that an area which was 75-100% invaded will be promoted to 25 - 50% after the initial treatment and to 5 - 25% during the next treatment after which it will be promoted to 1 - 5%. Based on these assumptions, management scenarios are being developed for catchments to determine the cost streams for cost benefit analysis of IAP clearing programmes. The impact of a chosen management scenario is seen as the difference in ecosystem services from a no interference scenario (the catchment is allowed to become fully invaded) and the chosen management option. The difference in ecosystem services between the two options is assumed to be the benefit stream.

Figure 3: Predicted Outcome of a Chosen Management Scenario to Clear the Garden Route Catchment vs a No Interference Scenario



Up to the present, water has mostly been used to quantify the benefits of clearing programmes as discussed above. Figure 3 shows an example of the impact of a chosen management scenario on the extent of IAP in a catchment. Based on the costs of initial clearing and the follow up operations, as well as the rate of invasion, the cost stream of the management option is calculated. Figure 4 shows the estimated costs of clearing of the chosen management scenario for the catchment (Figure 3 above). The net benefit is then calculated using the estimated costs and benefits of the clearing programme.

Figure 4: Average Cost per Year Over 10 Year Cycles for the Chosen Management Scenario in Figure 3 to Clear the Garden Route Catchment.



AWARENESS

IAPs have a severe impact on the productive use of land through its impacts on biological diversity, intense fires and floods and erosion. Clearing the land of IAPs gives emerging land-owners a greater ability to optimise the use of the land as well as the available water. The Department of Agriculture & Land Affairs has an awareness campaign similar to the Australian Land Care initiative with the productive potential of land as its main theme. Land Care is an awareness programme addressing sustainable use of natural resources such as water, soil and plant and animal biomass.

Through its objectives, WfW addresses the following Land Care degradation types as defined by the FAO:

- Water erosion: Rehabilitation of over utilized and invaded land.
- Wind erosion: Rehabilitation of over utilized and invaded land.
- Soil fertility decline: Preventing water repellency as a result of very hot fires in invaded areas.
- Lowering of the water table: Lower surface runoff as a result of invading alien plants.
- Forest degradation: Loss of natural riverine forests through invading alien plants and bank erosion as a result of shallow root systems.
- Rangeland degradation: Losing harvestable potential of natural fynbos through invading alien plants.

The National Water Conservation Campaign is aimed at the optimal use of South Africa's water resources. The campaign is aimed at promoting a fair and equitable water management policy for the country as well as optimising the use of its water resources. The components included in the National Water Conservation Campaign are as follows:

1. Assurance of supply.
2. Block rate water tariffs.
3. National water regulations.
4. Retrofitting of household water appliances.
5. Waterwise gardening.
6. Waterwise food production.
7. School water audits and water conservation education.
8. Water loss management.
9. Communication programme.

10. Prepaid water metering.
11. Informative billing.
12. The Working for Water Programme.

LEGISLATION AND POLICY

Since its inception the WfW programme has capitalised on all possible opportunities and, in terms of labour intensive clearing, has grown from strength to strength. Due to the rapid growth of the programme, and a lack of capacity, legislative issues have tended to lag behind.

It is quite clear from experience and from recent surveys, that the problem of invading alien plants is not under control. To a degree, this is due to the lack of understanding of the extent and seriousness of the problem. Both legal and administrative capacity has been lacking. In many instances state land is the most severely invaded and this has hampered the process of acting against landowners not complying with the law, and in many cases there has been a conflict of interest.

In the past few years much has happened that puts WfW in a much better position regarding the IAP problem, especially better information on the extent of the problem and the benefits realized by the WfW programme. The new National Water Act - Catchment Management Authorities and the possibility of charging all water users will enable catchment management agencies to improve catchment management dramatically. The principle legislation pertaining to IAP control is the Agricultural Resources Act.

Revising the Agricultural Resources Act

While making inputs to the Agricultural Resources Act it was recognised that the underlying philosophy had to be consistent with the overall legislative framework as provided by the Constitution and the principles that underlie the new Water Act and other relevant legislation.

The following is a summary of the elements for inclusion in legislation:

- Weeds are everybody's business and responsibility.
- The cost of clearing must be spread equitably amongst all beneficiaries.
- Farmers of alien plants should help share the cost for clearing beyond their own land (the polluter pays principle). Responsibilities must be clearly defined.
- South Africa must learn from the experience gained in other countries.
- Biological control has a key role to play.
- Screening criteria and/or early invading alien plant identification criteria need to be developed.
- Management should ideally be done on a catchment basis.
- Central, provincial and local government must contribute towards the management of catchment areas as custodians of biodiversity in the environment and community welfare, and as landowners where applicable.
- Regional and international/transboundary partnerships and initiatives should be facilitated.
- The potential impact of alien clearing on communities has to be considered.
- Control authorities should be able to work on all land at the landowners expense.
- Recognition that long term follow up and commitment are indispensable.
- Clear guidelines for issuing of permits for cultivation or selling of commercial invading alien plants are needed.
- Heavy fines for contravention or non compliance should be given.
- Additional punitive measures such as withholding licences for the construction of dams and water works and permission to subdivide, rezone or sell land should be implemented.
- Recognition that landowners remain responsible for the management and control of invading alien plants on their land and for restoration actions arising from disturbance activities.
- IAP invasions should be classified as stream flow reduction activities in terms of the new Water Act, 1998 and landowners charged accordingly.
- Transparent and objective methods for prioritisation of areas needing clearing should be demanded.
- Effective systems of control should be developed as a management tool and guidelines for

clearing, biological control, herbicide use and fire as a management tool.

- Where state authorities clear alien plants on private land they must be entitled to claim ownership of any produce and to use income from this to defray costs.
- The extent of alien plant invasions should be systematically surveyed, mapped and monitored and the present status should be "frozen", especially in areas that are considered "clean" or in a maintenance state.
- Administrative/legal management has to be done geographically on a per property basis.

The following are some of the proposals for the revised regulations in the Agricultural Resources Act:

There should be no distinction between weeds and invaders - rather there will be one list with three categories.

- Category 1: Plants that have no or very limited value - no one wants or needs them, e.g., *Solanum* spp.
- Category 2: Plants that are used commercially, e.g., *Pinus* spp. and *Acacia mearnsii*
- Category 3: Plants that have ornamental, cultural or other value, e.g., *Jacaranda*

The principle is that all plants on the list should be treated like weeds, as in the old regulations, except in so called "demarcated" areas. Demarcation will be in terms of the Agricultural Resources Act or as licensed in terms of the Water Act. Conditions can be applied to demarcated areas e.g. not closer than 30 m from river, 100 m from wetland, a certain distance from farm boundary (prevents seed pollution to neighbouring properties) and restrictions can also be placed on the size and the utilisation of invaders in demarcated areas, e.g., woodlots. Demarcation will be at the discretion of the executive officer of the responsible government department. There should be no trade, distribution or new planting of any of the plants listed except for Category 2 Plants in demarcated areas. The list of invaders was expanded and updated to include all the presently known serious problem plants.

The Reconstruction & Development Programme (RDP)

Development in WfW is based on the RDP principles. These were taken from the White Paper on the Reconstruction and Development Programme. The principles of the RDP are:

1. All programmes must strive towards integrated and sustainable development.
2. All programmes must be people driven.
3. The programme and the people-driven process must be closely bound up with peace and security for all.
4. With the establishment of peace and security, all programmes must strive towards nation building.
5. Programmes must strive towards meeting peoples basic needs, open up previously suppressed economic and human potential and integrating growth, development, reconstruction, redistribution and reconciliation.
6. Programmes must strive towards the democratization of society through a process in which affected parties take part in decision-making.
7. All programmes must have goals against which they will be assessed and held accountable.

(Government Gazette No. 16085 9, 23 November 1994; ANC (1994) The Reconstruction and Development Programme)

INSTITUTIONAL COOPERATION

A number of institutions and agencies are involved with WfW. Since its inception the leadership of the programme has strived to make WfW a multi-agency programme with a spectrum of agencies involved with its management and funding. The following departments and agencies are currently involved with the management of the programme:

• WFW acts as Management Agency, with Department of Water Affairs & Forestry (DWAF) as lead agent as well as the major funding agent.

• Department of Labour funds training programmes through their own budget but aimed at WfW.

• Department of Land Affairs funds projects that will enhance or add value to land reform projects.

• Department of Agriculture funds projects that fall within the framework of the Land Care Programme.

• Department of Welfare is involved through its programmes and the poverty indices developed by Welfare are used as one of the major indicators of the socio-economic impacts of WfW projects.

• Department of Finance contributes to the financial management of the programme.

• Department of Health contributes to the AIDS awareness initiative of WfW.

THE FUTURE

WfW has set the following aspects as priorities for the future:

• Legislation & Management to Stop Invading Alien Organisms from Spreading (Not Only Plants)
• Integration of Strategies for the Control of Invading Alien Organisms & Setting up Agencies to Implement
• Development of Import & Exportation Policies
• Collaboration across the African Continent
• Quantification of the Impacts of Invading Alien Organisms
• Education

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POLICY AND LEGAL DIMENSION OF INVASIVE SPECIES

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INTRODUCTION

The threat of invasive species to agriculture and the environment in general has become apparent in the last decade. East Africa has already experienced a number of serious biological invasions, some with severe consequences. The Water Hyacinth and the Larger Grain Borer invasions are among the most well known. The Nile Perch and Louisiana Crayfish in Lake Naivasha are other invasions but with mixed effects.

The importation of any plant material or plant associated micro-organisms is subject to strict specified conditions. The stipulated procedure ensures that enough information on the plant material or the micro-organisms is available to evaluate the pest risk of the potential invasive. Plant quarantine restrictions are based on the pest risk analysis and relies on existing scientific knowledge on the distribution and biology of the plant or micro-organism. Suitable regulations are enforced to facilitate the import and export of plant materials through issuance of import permits and phytosanitary certificates. Legal authority is provided to allow for treatment or destruction of infested/infected plants or plant products. Import and export permits are authorised by the Kenya Standing Technical Committee for Imports and Exports (KSTCIE).

THE KENYA STANDING TECHNICAL COMMITTEE FOR IMPORTS AND EXPORTS (KSTCIE)

The KSTCIE is charged with enforcement or execution of The Plant Protection Act (Cap 324 of The Laws of Kenya). The KSTCIE has membership as follows:

1.	Director of Agriculture, Ministry of Agriculture	-	Chairman
2.	Managing Director - KEPHIS	-	Secretary
3.	Deputy Director of Agriculture (Horticulture)	-	Member
4.	Head Crop Protection Division, Ministry of Agriculture	-	Member
5.	Assistant Director - Plant Protection Services	-	Member
6.	Officer-in-charge Plant Quarantine Station (KEPHIS)	-	Member
7.	Senior Entomologist, NARL, KARI	-	Member
8.	Senior Pathologist, NARL, KARI	-	Member
9.	Senior Entomologist (Bio-Control) NARL, Muguga, KARI	-	Member
10.	Secretary, Pest Control Products Board (PCPB)	-	Member
11.	Director, Kenya Forestry Research Institute (KEFRI)	-	Member
12.	Co-opted Members		

The functions of KSTCIE are as follows:

(i) Acts as an advisory body to the Plant Quarantine Station at Muguga under the Plant Protection Act.

(ii) Review plant quarantine regulations to conform with new technical information.

(iii) Approves import of restricted and new materials into the country (GMOs, Biocontrol agents).

(iv) Ensures pre-clearance and inspection of sources of materials during growing period.

(v) Ensures inspection of open quarantine stations.

(vi) Provides advice on pre-treatment of products before shipment in compliance with import permits.

PLANT IMPORT PERMITS (PIP) AND PHYTOSANITARY CERTIFICATE

All intending importers wishing to bring plant materials into Kenya must obtain a plant import permit prior to shipments of such plants from origin regardless of whether they are duty free, gifts or for commercial purposes. The permit specifies the requirements for plant health indicating prohibitions, restricted quarantine importation and additional declaration with regard to pre-shipment treatments. The original permit must therefore, reach the plant health authorities in the country of origin for strict adherence to our permit requirements. All plant consignments arriving in Kenya should therefore be accompanied by a copy of our permit and additional plant health certificate (Phytosanitary certificate International model or its equivalent) in full compliance to the specifications set out in our permit.

Plant materials arriving without authority and correct accompanying documents may not be allowed entry and may be destroyed or reshipped at the owners cost. All plant materials must be declared on arrival. Any person who contravenes or fails to comply with the Plant Protection Act, shall be guilty of an offence and shall be liable to a fine or imprisonment or both.

Plant Import Permit Commodity classes

1.	Plant	- Gramineae (export seed) - PIP required - Phytosanitary certificate required
2.	Bulb/tubers	- PIP required - Phytosanitary certificate required
3.	Seeds	- PIP required for seeds - Phytosanitary certificate required
4.	Fruits/Vegetable	- PIP required for export - Phytosanitary certificate required
5.	Cut flowers/ornamental	- PIP required - Phytosanitary certificate required
6.	Packing material	- PIP required - Phytosanitary certificate required
7.	Soil	- Strictly prohibited
8.	Grains/Other	- PIP required - Phytosanitary certificate required
9.	Endangered or rare species	- Approval by the Government and in accordance with the Convention on International Trade on Endangered Species (CITES) - Phytosanitary certificate required
10.	Bio-Control Agents	- Importers of beneficial bio-control organisms apply for permit at least 30 days before expected shipment. The application is considered by KSTCIE before permit is issued with conditions.

11. Genetically modified organisms (GMOs)

    Permission to import GMOs is given by National Biosafety Committee (NBC) after approval by the Institutional Biosafety Committee (IBC). The applicant applies for permit from KSTCIE after approval by the NBC.

Regional Harmonization of Plant Quarantine Services

An effective policy and funding framework to control invasive species requires the integration of economic and legal concerns at local, national and international levels. An outcome of the Uruguay round of the General Agreement on Tariffs and Trade (GATT) was the Agreement on the Application of Sanitary and Phytosanitary (SPS) measures. This requires signatories to base all the SPS measures on scientific principles, to publish their regulations, to use the principle of equivalence, and to apply measures without arbitrary discrimination between members of GATT now the World Trade Organisation (WTO).

The SPS agreement states that a key component in the implementation of these requirements is pest risk analysis (PRA). The agreement defines PRA as the evaluation of the likelihood of entry, establishment or spread of a pest or disease within the territory of an importing member, and the associated potential of the biological and economic consequences.
At the moment lack of information and practical methods for conducting PRA leads to quarantine officers having to make arbitrary decisions on SPS measures. Apart from being contrary to the GATT/WTO agreement, this increases the risk of exotic pests being unintentionally imported, and inhibits trade.

The CABI Africa Regional Centre and Kenya Plant Health Inspectorate Service (KEPHIS) convened a workshop, in Nairobi for quarantine officers from East Africa to discuss the constraints they face, and to identify their immediate needs.

The Objectives of the Workshop were:

(i) To review PRA activities in East Africa, and identify problems and constraints.

(ii) To define what needs to be done to overcome the problems.

The Permanent Tripartite Commission for East Africa has also stressed the importance for harmonization and strengthening phytosanitary services, inspection and certification. The Commission recommends:

(i) Harmonization of phytosanitary measures based on international standards, guidelines or recommendations where they exist.

(ii) Trade within member states to minimize introduction of pests and diseases.

(iii) A regional technical committee be formed to oversee sanitary and phytosanitary (SPS) measures.

THE ECONOMICS OF INVASIVE SPECIES: COSTS, INCENTIVES, RISK ANALYSIS AND THE ROLE OF DONORS

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INTRODUCTION

This paper is concerned with the economics of an invading species that becomes a pest. An invading species becomes a pest if it is associated with negative economic effects once established (Knowler and Barbier 1999). Although invaders appear to have a small probability of becoming pests, the economic impact of such pests are likely to be large. This is demonstrated by the case of water hyacinth, *Eichhonia crassipes*.

The paper further explores the issue of incentives and how they can be applied to change peoples' behavior relative to invasive species. It also analyses the economics of applying risk analysis instead of crisis management, as recommended by the precautionary principle. Finally the paper looks at how the involvement of donors, particularly in donor-driven economies, might influence peoples' behavior towards invasive species.

ECONOMIC IMPACT OF INVASIVE SPECIES

Although it is possible for an invading species to yield economic benefits once established (Kasulo 1999; Pitcher and Hart 1995), the focus of this paper is on the more common occurrence where the invader becomes a pest. Williamson's (1996) 'tens' rule of thumb of biological invasions suggests that only 10 percent of introduced species will become established in a host environment and that only 10 percent of the established invaders will become pests. However, available evidence shows that the economic damage caused by invasive pests is extremely large. So, although potential invaders appear to have a small probability of becoming pests, the economic impacts of such pests are likely to be large.

The economic costs imposed by an invading pest can be obtained by using contingency valuation methods. The economic costs associated with the invasive pest can be defined by the willingness of the affected parties to pay to avoid detrimental effects. The benefits of a control programme can be defined by the willingness of the affected parties to pay for the programme to gain its positive effects.

Although attempts are often made to use the contingency valuation method, most empirical studies use simple methods that estimate the direct benefit and cost of control (Joffe and Cooke 1997). In this case benefits of control comprise the values of damage avoided.

There are a number of studies that evaluate the damage caused by invasive species. One example is that of the infestation of water hyacinth, *Eichhonia crassipes*, in East Africa. In Uganda for instance, Bikangaga *et al*. (1998) tried to quantify in monetary terms how much various sectors have lost or benefited due to the presence of the weed. In a different valuation analysis, the World Bank/GEF Lake Victoria Environmental Management project estimated annual losses of US$ 0.2 million in local fisheries, US$ 0.35 million in beaches and water supply for domestic, livestock and agricultural purposes, and US$ 1.5 million in urban water supply due to blocked intakes (Joffe and Cooke 1997). These estimates represent the direct benefits of control.

The cost of controlling water hyacinth depends on the method of control. Alimi and Akinyemiju (1990) compared the direct cost of manual, mechanical and chemical control methods for some sites in Nigeria. Costs to clear one square kilometer of hyacinth were US$ 9,500 for manual control (most of the cost being labour charges), US$ 8,000 for mechanical control (the main costs being machine purchase and mechanical repairs), and US$ 4,400 for chemical control (mostly chemical and application costs). Although this analysis appeared to support chemical control, no mention was made of its environmental effects on non-target species. Nor was it stated that these costs would be recurring indefinitely, and there was no comparison with the costs of biological control methods. One estimate of the cost of biological control found that a total cost of US$ 60,000 could completely control water hyacinth over areas very much larger than one square kilometer (Thompson 1991), but there is no estimate of the direct costs of biological control per square kilometer.

In Uganda mechanical operations around Owen Falls dam required the purchase of three harvesters at a total cost of US$ 2.5 million. Variable costs were estimated at US$ 19,000 per month. For chemical control, the use of a boat was estimated at US$ 246 per hectare for glyphosate and US$ 118 per hectare for 2,4-D. Spraying by aircraft would cost US$ 187 per hectare for glyphosate and US$ 59 per hectare for 2,4-D. For biological control, it was estimated that US$ 95,000 would be spent annually mainly for monitoring. In most cases manual, mechanical and chemical control options have high recurrent cost implications. Manual and mechanical operations may be required continuously while chemical spray would need to be repeated periodically (Joffe and Cooke 1997).

Examples from different countries and water bodies show that control of water hyacinth can be quite costly. In Nigeria a defensive expenditure approach has been used to generate a preliminary estimate of US$ 50 million annual economic costs associated with water hyacinth infestation of the Niger River system. For Lake Victoria the World Bank/GEF Lake Victoria Environmental Management Project allocated US$ 8.31 million to water hyacinth control to defend against estimated direct costs of US$ 6 - 10 million per annum in the absence of control (Joffe and Cooke 1997). In Uganda the government allocated US$ 3.09 million for the control of water hyacinth in Lake Victoria between 1991/92 and 1997/98 (Muramira 1998), in addition to US$ 4.5 million from a variety of donors. Additional costs for a medium term programme covering other main affected lakes and waterways are estimated at US$ 19.5 million. In Egypt manual and mechanical control expenditures are running at around US$ 7 million per annum. In Malawi the total project costs for a three-year biological control programme in the Lower Shire Valley are US$ 400,000. Zimbabwe has spent US$ 215,000 on physical and chemical control of water hyacinth on Lake Chivero (Joffe and Cooke 1997). Table 1 gives a summary of the estimated annual expenditures associated with the control of water hyacinth in the different countries and water bodies. These figures are rough estimates and provide a very incomplete perspective on the problem. But they support the conclusion that invasive species, in general, are associated with significant economic costs for the affected African countries.

Table 1: Economic Costs and Control Expenditures (Per Annum) Associated with Water Hyacinth. Data from Joffe and Cooke (1997).

Country/Water Body	Amount (Thousands of US $)
Nigeria	50,000
Lake Victoria	9,660
Uganda	4,560
Egypt	7,000
Malawi	133
Zimbabwe	43
Total	**71,396**

THE USE OF INCENTIVES

The control of invasive species is often hindered by the open-access nature of the affected resources. The open-access characteristic of the affected resources can be considered as a question of externalities. By definition, an externality is a cost or benefit that is imposed on others as a result of a particular activity. External costs and benefits imposed on a large number of people are called social costs and benefits (Clark 1990). The wide social benefits stemming from the control of invasive species may not translate directly into strong individual motivation for control. On the other hand since invasive species affect different sectors differently, there might be perverse incentives against control in sectors benefiting from or engaged in an activity that promotes the introduction and establishment of invasive species. Changing this behavior requires comprehensive packages of incentives that can motivate the control of invasive species at the local level.

A number of direct and indirect incentives and disincentives can be considered for this purpose. Direct incentives include tax breaks, subsidies, grants, compensation for damage, and easy access to loans. Indirect incentives take the application of fiscal, service, social, natural resource and other policies to specific control problems. Disincentives may take the form of penalties, punishment and other forms of law enforcement accompanied by public information (Barbier 1995).

A popular argument for open-access resources is the establishment of secure property rights, where applicable, and the recognition and strengthening of community based organisations in areas affected by invasive species. It is argued that where they have sound economic incentives and access to relevant services, individuals and communities that have the right to manage and maintain resources are likely to provide an important pillar of long term control strategy (Joffe and Cooke 1997).

ECONOMICS OF RISK ANALYSIS

Environmentalists often argue that where the costs of current activities are uncertain, but are potentially both very high and irreversible, society should take action before the uncertainty is resolved, since the cost of not taking action may well be greater than the cost of preventative or anticipatory action taken now. The policy of taking action before uncertainty about possible environmental damages is resolved has been referred to as the precautionary principle (Heywood 1995). The adoption of the precautionary principle has meant a general shift from crisis management to risk analysis and prevention. A distinction is often made between risk and uncertainty. Risk is said to exist where the set of all possible outcomes of an action and the probability distribution of those outcomes is known. On the other hand uncertainty exists where the set of all possible outcomes of that action and/or the probability distribution of the outcomes of the action is unknown (Heywood 1995). Although economic analysis deals more with risk than uncertainty, risk analysis in this paper embraces uncertainty since the effects of invasive pests are more associated with uncertainty than risk.

The dominant approach to the analysis of risk in economics is the expected utility approach by which individuals are assumed to evaluate a risky prospect in terms of mathematical expectation of the value or utility to them of the prospect. The von Neumann-Morgenstern (1944) utility function is often used. It assumes that preferences between prospects are transitive, continuous and independent, which makes it simple to characterize individual attitudes toward risk. If individuals are averse to risk, for example, their von Neumann-Morgenstern utility function is concave. The concavity, linearity, and convexity of the von Neumann-Morgenstern utility function is used to describe risk aversion, risk neutrality and risk loving, respectively.

This approach to risk analysis has, however, been disputed. The empirical evidence suggests that many of the fundamental assumptions of the approach do not reflect reality. There is evidence, for example, that individual attitudes to risk are highly sensitive to income, and hence that attitudes to risk are not nearly as consistent as is assumed in the expected utility approach. It has been observed that people tend to be risk averse at low levels of income and risk loving at high levels of income (Heywood 1995). In terms of risk associated with invasive species, this observation suggests that poor people value risk reduction more highly than do the wealthy.

Risk can be reduced through mitigation (self-protection) and adaptation (self-insurance). Mitigation actions take effect when people change the pattern of species distribution, and thereby reduce the odds that bad events happen. Adaptation occurs when people make adjustments in practices, processes or structures of systems, thereby reducing the consequences when a bad event does occur. For invasive species, mitigation methods take the form of quarantines, and trade, transport and other regulations that reduce the risk of introductions. Some national and international conventions can also be considered as part of the mitigation process (Shogren 1999). An example is Article 8(h) of the 1992 Convention on Biological Diversity that calls for the prevention, control or eradication of alien species that threaten ecosystems, habitats or species (UNEP 1994). Adaptation activities include changing the choice of crop, seedling or fish species that reduce the severity of a pest invasion (Shogren 1999). In Malawi, for instance, the culture of carp fish in ponds was stopped to avoid its transfer to the lakes and rivers (DREA 1994).

The risk of undesirable invasive species is both an economic and biological problem. The fact that people can mitigate and adapt to risk implies that observed risks are functions of both biological and a state's self-protection decisions. Invasive species hazards need to be considered as being influenced by human activities that create risk and human reactions to that risk. It follows that attempts to assess risk levels solely in terms of natural science may be highly misleading. The fact that human activities create and reduce risk implies that researchers must explicitly address the simultaneous nature of how economic decisions affect observed risk and how natural science features affect economic decisions. This calls for an integrated, holistic risk assessment and management framework (Shogren 1999). It must be emphasized that much as adaptation and mitigation activities reduce risk, failure to take these actions would increase risk. And as already explained, these risk reduction strategies will succeed if economic incentives are taken into account.

THE ROLE OF DONORS

The involvement of donors, particularly in African countries that rely heavily on donor assistance, may influence peoples' behavior towards invasive species. National governments should ensure that the involvement of donors provides incentives and motivation for the control of invasive species, and that it does not facilitate the introduction and establishment of invasive species. For example, donors can influence people's behavior towards invasive species, through the provision of incremental cost finance, and adoption of the precautionary approach to natural resource management.

The introduction and establishment of invasive species is a local as well as a global problem. Invasive species do not only generate externalities at the national level but also at the international level. The social benefits arising from the control of invasive species by one nation may spillover to neighboring countries and the international community as a whole. However, a country may not bear all the costs of control for the benefit of other countries unless it is assisted by donors and other international financial aid agencies. This is particularly true for most African countries due to their heavy reliance on foreign aid.

The idea of providing additional financial assistance for activities having global benefits is not new. It is in line with the principle of incremental cost financing endorsed by the Convention on Biological Diversity and pioneered by the Global Environmental Facility (GEF). Under the terms of the Convention, developed country signatories have an obligation to provide new and additional financial resources to developing countries to help them meet any portion of the costs that the latter may incur in implementing globally beneficial conservation activities over and above the national benefits of conservation (Barbier *et al*. 1995). The GEF's mandate is to finance conservation activities that would provide cost-effective benefits to the global environment, but would not have been undertaken by individual country because the measurable benefits to the national economy were too low to justify investment by that country on its own (Munasinghe 1992). The control of invasive species also falls within the GEF's mandate.

The incremental cost financing principle, therefore, acts as an incentive for national governments to carry out invasive pest control measures. However, the incremental cost financing principle alone would not be adequate in influencing people's behavior towards invasives. This is because issues associated with invasive species are multi-sectoral in nature, affecting different sectors of the economy. In general, it would be advisable for both donors and recipient countries to employ a precautionary approach to natural resource management especially to changes in social, economic and natural conditions that would facilitate the introduction, spread and establishment of invasive pests. For example, the World Bank uses environmental assessment as a principle screening mechanism for all its lending operations. The Bank assists borrowers to identify and tackle major environmental concerns through environmental action plans. It also provides support for the control of invasive species under its pest management programme (Joffe and Cook 1997).

CONCLUSION

This paper has shown that although the probability of invaders becoming pests is small, the economic impacts of such pests are likely to be enormous. The example of water hyacinth in Africa shows that large amounts of money are being spent to control the weed. It has also been shown that applying appropriate incentives and risk reduction strategies matters more for the control of invasive species and that, at least for Africa, the involvement of donors can play a significant role in changing peoples' behavior towards invasive species.

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WEED INVASIONS TRACKED WITH HERBARIUM RECORDS

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No transcript was submitted, but the talk was based on the following previously published article:

Stadler, J., G. Mungai, and R. Brandl. 1998. Weed invasion in East Africa: insights from herbarium records. *African Journal of Ecology* 36: 15-22.

Abstract: The invasion process was documented from data on the labels of specimens stored in the East African Herbarium at the National Museums of Kenya. We analysed data from seven abundant alien plant species: *Ageratum conyzoides* L. (Asteraceae), *Capsella bursa-pastoris* (L.) Med. (Brassicaceae), *Datura stramonium* L. (Solanaceae), *Galinsoga parviflora* Cav. (Asteraceae). *Tagetes minuta* L. (Asteraceae), *Spergula arvensis* L. (Caryophyllaceae) and *Stellaria media* (L.) Vill. (Caryophyllaceae) and compared these data with the spread of two native weeds: *Cynoglossum coeruleum* A.DC. (Boraginaceae) and *Senecio discifolius* Oliv. (Asteraceae). Although all investigated species had been already recorded before the Second World War, most specimens were collected between 1960 and 1980. This regional spread is correlated with a change in the agricultural systems of Kenya. The early records of alien weeds were restricted to higher altitudes. With the increasing human population and the associated increase of agricultural activities (e.g., irrigation in arid areas) the weed species from South America were able to spread to lower altitudes.

INVASIVE SPECIES IN THE WATER ENVIRONMENT IN EAST AFRICA

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AQUATIC INVASIVES - WHAT ARE THEY?

Definition - organisms, often alien but sometimes native, which:

- Threaten native biodiversity
- Impair socio-economic integrity of water resources

Characteristics:

- Highly prolific
- Build huge populations or biomass
- Impair ecosystem health
- Impact through complex ecological interactions

MAJOR AQUATIC INVASIVES OF EAST AFRICA

Plants:

- Algae - e.g., blue greens
- Ferns - e.g., water fern (*Salvinia*)
- Flowering plants - e.g., water hyacinth

Animals:

- Invertebrates - e.g., Louisiana crayfish
- Fishes - e.g., Nile perch, Nile tilapia

IMPACTS OF AQUATIC INVASIVES

Ecological impacts

Impact	Affected service/process/attribute	Agent invasive
Physical damage by moving biomass	Damage to native water plants, spawning nursery, feeding grounds of fish and other animals	Water hyacinth, Water fern, Native weeds
Physical obstruction by weed biomass	Spawning, nursery and feeding grounds smothered; no fish under large shoreline mats	Water hyacinth, Water fern Native 'weeds'
Nutrients load from decaying weed biomass	Nutrient addition/enrichment	Water hyacinth, Water fern
Increased shelter at edge Of weed mats	Increased diversity abundance of aquatic animal life	Water hyacinth, Water fern, Water lettuce

Ecological impacts (cont'd)

Impact	Affected service/process/attribute	Agent invasive
Oxygen depletion, noxious gases under weed mats	Reduced primary production; low oxygen content; decline in biodiversity	Algal blooms Water hyacinth Water fern Native 'weeds'
Impeded light penetrations & gaseous exchange	Reduced primary production; low oxygen content; decline in biodiversity; native plants smothered	Water hyacinth, Water fern
Predation, competition for food and space	Declining biodiversity disrupted food chains/webs	Crayfish Nile perch Nile tilapia
Enhanced evapotranspiration	Water loss	Water hyacinth

Socio-economic Impacts

Impact	Affected service/process/attribute	Agent invasive
Blocked access	Landing sites, transport routes, fishing grounds, watering sites	Water hyacinth Water fern Native 'weeds'
Impeded water flow	Water flow in stream, irrigation canals and wetlands; water flow through hydropower turbines	Water hyacinth, Water fern Native 'weeds'
Fouled water	Impair cooling systems of hydropower generation, water filtration; escalated cost of water treatment; contaminated water	Water hyacinth Algal blooms
Siltation biomass, death decay, filthy environment	Loss of aesthetic value, potential health hazards due to poor water quality	Water hyacinth Algae blooms Water fern
Increased incidence of bilharzia and malaria vector organisms; and snakes	Increased potential for infection with bilharzia and malaria; higher probability of snake bites	Water hyacinth

CONTROL OPTIONS - PLANTS

Physical - manual

- Community participation (mobilisation and sensitisation essential)
- Vital temporary relief
- Unsustainable for large infestations

Physical - mechanical

- Massive capital outlay:
  - equipment: collector pushboats, booms, harvesters; transit boats/vehicles
  - operational and maintenance costs
- Unsustainable

Chemical

- Herbicides available, but option is controversial
  - one view - environmentally unfriendly and/or harmful to human health
  - others insist it is absolutely safe!

- Unsustainable
  - repeated application essential
  - expensive

Biological

- Some natural enemies available
- Mostly slow but often sure
- Environmentally friendly
- Minimum cost hence sustainable

CONTROL OPTIONS - PLANTS AND ANIMALS

Strict quarantine and surveillance

- Secure the borders
- Mobilise & sensitise communities

Catchment management

- The real challenge
  - highly complex
  - diverse players
- Effective and preventive if attained
- Long term option

CONSTRAINTS TO EFFECTIVE MANAGEMENT

- Lack of awareness, sensitisation of communities, authorities
- No unifying policy framework for inter-sectoral approach
- Inadequate border controls and quarantine safeguards
- Lack of inadequate transboundary and regional mechanisms for joint action
- Slow information flow nationally and internationally
- Inadequate research information on weed problem: magnitude, dynamics impacts, cost of impacts, and effectiveness of control options
- Insufficient funding

THE SPREAD AND ECOLOGICAL CONSEQUENCES OF THE INVASION OF *CHILO PARTELLUS* (SWINHOE) (LEPIDOPTERA: CRAMBIDAE) IN AFRICA

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INTRODUCTION

The arrival and establishment of alien species in a new geographical area is probably best documented when the invasive organism becomes a pest in its new environment, or is intentionally introduced as a biological control agent (usually of an introduced pest). Alien introductions which cause no readily apparent consequences to economic endeavours may largely go unnoticed. However, the types of ecological impacts of invasive species may be very similar, regardless of whether the organism is considered to be economically important or not. Thus, well documented case histories of the invasion of pest species may serve as a general model for the ecological consequences of invasive species in general.

DISTRIBUTION

Chilo partellus (Swinhoe) (Lepidoptera: Crambidae) is a native Asian stemborer which feeds on several species of wild and cultivated grasses (Bleszynski 1970). In its native home, *C. partellus* is considered to be an important pest of maize and sorghum. Its distribution remained restricted to Asia until around 1930 when it was first recorded in Africa in Malawi (Tams 1932). As Malawi is a land-locked country, and air transport in Africa was uncommon in the early 1900s, it seems most likely that *C. partellus* arrived by ship at one of the seaports on the East African coast, perhaps Dar-Es-Salaam or Mombasa. Since arriving, the distribution of *C. partellus* has expanded and now includes Ethiopia, Sudan, Somalia, Kenya, Tanzania, Uganda, Mozambique, South Africa, Swaziland, Lesotho, Zimbabwe, Zambia, Malawi, and Botswana (Nye 1960; Ingram 1983; Harris 1990). There are also records from Cameroon and Togo (IAPSC 1985), but as *C. partellus* has not been found in recent surveys in several countries in West Africa (Moyal and Tran 1988; Bosque-Perez and Mareck 1990; Schulthess *et al*. 1991; Shanower *et al*. 1991; Gounou *et al*. 1993), it seems likely that the original records were based on misidentifications (Overholt *et al*. 1994a).

The eventual distribution of *C. partellus* in Africa can be predicted based on the locations where it is known to occur, and then extrapolating to other locations which have similar characteristics. Using a GIS tool (Almanac Characterization Tool) (Corbett et *al.* 1999), we mapped the known distribution of *C. partellus* from our own sampling data in Kenya and Uganda, and then calculated the mean values for maximum temperature, evapotranspiration, precipitation and elevation at the sites. Upper and lower thresholds for each parameter were calculated as the mean of each parameter ± 2 standard deviations. Using this methodology, the predicted distribution of *C. partellus* in Kenya is shown in figure 1.

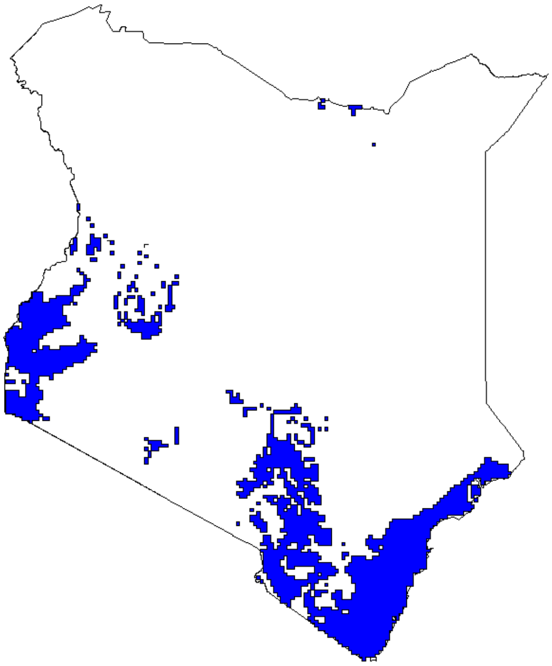

Figure 1. Predicted distribution of *C. partellus* in Kenya

As maize growing regions of Kenya have been extensively sampled in recent years, we know that the predicted distribution is a quite accurate. Using the same methods, we extrapolated outside of the borders of Kenya to the rest of Africa using another GIS programme, the Spatial Characterization Tool (Corbett and O'Brien 1997). Figure 2 shows the predicted distribution based on the sampling data from Kenya, Uganda, Mozambique and Zambia. In figure 3, we expanded the data set to include points from Ethiopia, Somalia, Mozambique, Zambia, Lesotho and South Africa. As can readily be seen, the distribution predicted in figure 3 is more extensive than the one in figure 2. We know from sampling records that neither distribution is entirely correct. Colleagues in South Africa have told us that the distribution predicted in figure 2 is incorrect as *C. partellus* occurs in a wider area than predicted (R. Kfir personal communication). The distribution in figure 3 is also not entirely accurate in several countries. For example, in Zimbabwe *C. partellus* is predicted to occur everywhere, whereas we know from sampling data that it does not occur in the higher elevation areas.

One likely explanation for the discrepancy between the two Africa-wide predictions is that different *C. partellus* populations have become locally adapted to various abiotic and biotic conditions encountered in Africa. For example, the South African population is probably adapted to colder temperatures than populations occurring near the equator. Availability of host plants, and competition from native stemborers (see below) may also vary from location to location. Regardless, the distribution predicted in figure 3 may represent locations where *C. partellus* could eventually become established, taking into account the intraspecific diversity. As can be seen, Namibia and Angola will probably be invaded (if *C. partellus* does not already occur in those countries). Additionally, parts of Nigeria, Cameroon, Togo, Benin, Ghana and Ivory Coast may also be conducive to the establishment of *C. partellus*.

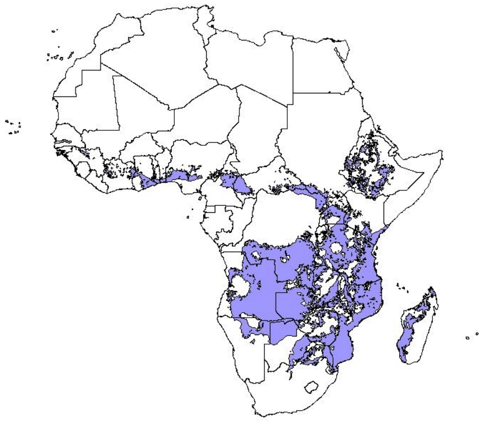

Figure 2. Predicted distribution of *C. partellus* based on sampling data from Kenya, Uganda, Zambia and Mozambique.

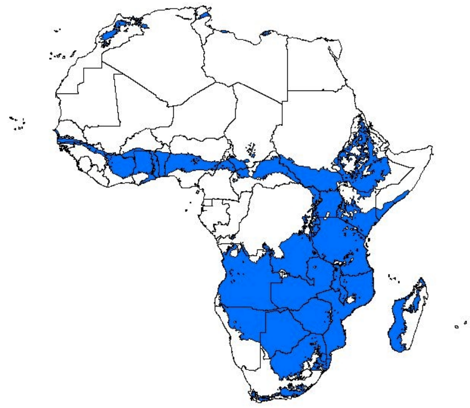

Figure 3. Predicted distribution of *C. partellus* based on data from Kenya, Uganda, Ethiopia, Somalia, Mozambique, Zambia, Lesotho and South Africa.

DISPLACEMENT OF NATIVE SPECIES

Probably the most dramatic ecological consequence of the introduction of *C. partellus* into Africa has been the partial displacement of native stemborers. In the coastal area of Kenya, the first detailed study on stemborers in maize was conducted from 1965 to 1969 (Mathez 1972). The native species, *Chilo orichalcociliellus* Strand, was found to be dominant, accounting for approximately 60% of the borers collected. *Chilo partellus* was the second most common species, accounting for about 30% of the borers, and another native species, *Sesamia calamistis* Hampson (Lepidoptera: Noctuidae) was lowest in abundance. In the period 1978-81, Warui and Kuria (1983) found that *C. orichalcociliellus* and *C. partellus* were nearly equally abundant in maize and sorghum, and that *S. calamistis* was much less common. However, in 1991-92 in the same area, *C. partellus* accounted for > 80% of the stemborers, with both *C. orichalcocliellus* and *S. calamistis* being of minor importance (Overholt *et al*. 1994b). The average numbers of stemborers per plant found in the three studies were approximately the same. In Mathez's (1972) study there were 0.8 to 2.3 stemborers per plant, Warui and Kuria (1983) found 0.7 to 1.4, and Overholt *et al*. (1994b) found 0.2 to 1.8. Thus, while the density of stemborers in the southern coastal area of Kenya does not appear to have increased since the invasion of *C. partellus*, the exotic species has become relatively more abundant, at the expense of a native species. Whether the displacement of *C. orichalcociliellus* will proceed toward complete extirpation from the southern coastal area of Kenya, is unknown. However, sampling conducted from 1991 to present (Overholt, unpublished) suggests that *C. orichalcociliellus* will continue to exist. Recent investigations have found that *C. orichalcociliellus* is able to complete development in two native grasses, in which *C. partellus* cannot develop (Ofomata *et al*. 2000). This difference in niche breadths of the two species may account for the continued occurrence of the native species.

In addition to the work in the coastal area of Kenya, there is evidence of displacement of native stemborers in two other areas in Africa. In the Eastern Province of Kenya, Seshu Reddy (1983) found that *C. partellus* was present, but less abundant than *Busseola fusca* (Fuller) (Lepiodoptera: Noctuidae). However, in the same area in the period 1996-1998, *B. fusca* was rare and *C. partellus* was dominant (Songa 1999). Similarly, Kfir (1997) found that *C. partellus* had partially displaced *B. fusca* in the eastern Highveld region of South Africa over a period of 5-7 years. The displacement was most evident in grain sorghum where the proportion of *C. partellus* in the total stemborer population increased from about 3% in 1986 to 91% in 1992.

MECHANISMS OF DISPLACEMENT

Several factors have been investigated which may be responsible for the competitive superiority of *C. partellus* over some native stemborers. Studies by Kioko *et al*. (1995) in artificial diet, Mbapila (1997) in maize, and Ofomata *et al*. 2000) in maize, sorghum and three wild grasses have shown that *C. partellus* completes a generation in less time than *C. orichalcociliellus*. As fecundities of both species are similar (Delobel 1975), the shorter generation time will result in higher population growth, which possibly gives the alien species a numerical advantage. A more rapid diapause termination compared to both *C. orichalcociliellus* (Ofomata *et al*. 1999a) and *B. fusca* (Kfir 1997) has also been shown, which may allow *C. partellus* females to colonise host plants before the two native species. Kfir (1997) speculated that *B. fusca* avoids plants already infested by *C. partellus*, using odours associated with host plant feeding. Ofomata (1997) showed that when equal numbers of *C. partellus* and *C. orichalcociliellus* infest the same maize, sorghum or wild sorghum plant, more *C. partellus* successfully completed development, suggesting superiority during direct competition. However, in napier grass, more *C. orichalcociliellus* survived, again indicating niche differences which may allow coexistence of the native and alien borers. Finally, Ofomata (1997) demonstrated that more neonate *C. partellus* larvae disperse from the plant where they were oviposited, and disperse greater distances, than *C. orichalcociliellus*, which may allow *C. partellus* to colonise more plants than the native borer. All of these factors, along with others as yet unidentified, may play a role in the competitive superiority of *C. partellus* over the native species.

INCREASED PLANT DAMAGE?

The three studies conducted in the coastal area of Kenya cited above, indicate that although *C. partellus* is displacing *C. orichalcociliellus*, total stemborer numbers have not changed much. The mean number of stemborers per plant appears to have remained at about one. This raises an interesting question of whether damage to plants, both economically important cereals and wild host grasses, has changed since the invasion of *C. partellus*. In the laboratory, Ofomata *et al*. (2000) fed *C. partellus* and *C. orichalcociliellus* on maize and sorghum, and found that *C. partellus* consumed greater quantitites of both plants on a daily basis, and in a lifetime, suggesting that even though stemborer numbers may not have increased since the invasion of *C. partellus*, damage to plants may be greater.

NEW RESOURCE FOR THE THIRD TROPHIC LEVEL?

Native predators and parasitoids of stemborers have expanded their ranges to include *C. partellus*. In a review of the literature, Bonhof *et al*. (1998) lists 31 native parasitoids recorded from *C. partellus* in East Africa, and several predators. Kfir (1992) mentions 11 native parasitoids attacking *C. partellus* in South Africa. This is not surprising since *C. partellus* is ecologically equivalent to native borers, exhibiting nearly identical behaviour and occupying the same habitats (Ofomata 1999b). Thus, native parasitoids encounter and attack *C. partellus* while searching for native hosts. Physiologically, *C. partellus* appears to be equally suitable for the development of the most common native larval stemborer parasitoid, *Cotesia sesamiae* (Cameron) (Hymenoptera: Braconidae), as some, but not all, native hosts (Ngi-Song *et al*. 1995). The ecological implications of the new host/parasitoid associations that have formed since the arrival of *C. partellus*, are complex, and little work has been done in this area. Over time, native parasitoids have probably become increasingly better adapted to searching for, attacking, and successfully developing in the alien stemborer, which may eventually result in a decreased density of *C. partellus* in Africa (alternatively, natural selection may drive *C. partellus* to better avoid parasitism).

CONCLUSIONS

Chilo partellus is an alien species which has been in Africa for at least 70 years, and possibly longer. As an important pest of cereal crops, its spread, and the ecological implications of its arrival on the continent, have been fairly well documented, and thus may serve as a model for other alien species which have lower direct economic consequences to man. The distribution of *C. partellus* has clearly increased dramatically since arriving on the continent, and is probably still increasing. This paper presents evidence that different populations may be locally adapted to prevailing conditions. The invasive borer is competitively superior to some native homologues, and there is clear evidence of partial competitive displacement at some locations. Various factors which may give *C. partellus* a competitive advantage over native borers include a higher growth rate, a more rapid diapause termination, and a higher rate of dispersal. Native parasitoids have expanded their ranges to include the exotic borer, but the ecological implications of this are not well understood.

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IS *MAESOPSIS EMINII* A PROBLEM IN EAST USAMBARA FORESTS?

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[Note: This paper was prepared for the workshop on 'Invasive Species in Eastern Africa' but the authors were unable to present it in person.]

ABSTRACT

Maesopsis eminii, a tree species with origins primarily in West Africa, is a widely planted species in East Africa, where it has become invasive in some locations. Because in some areas this species has been intentionally introduced to ease timber shortages, any management actions must also consider the benefits derived from this species in a particular time and place. In some areas of the East Usambara forests, the species has had a significant negative ecological impact on the natural vegetation. However, the invasive impact of *M. eminii* in forest reserves may be declining as forest cutting and disturbance has greatly decreased, thereby greatly reducing the opportunity for this pioneer species to invade. We conclude that the factors that determine whether *M. eminii* constitutes a management problem for particular areas of the East Usambara forests of Tanzania are site-specific and depend on economic resource issues as well as on how this species responds to disturbance. More research is needed to examine *M. eminii's* long-term pattern of recruitment and subsequent long-term ecological impact in relatively undisturbed East Usambara forests.

INTRODUCTION

Several tree/shrub species are known to invade various ecosystems in the world. Among such documented species are: Salal - *Gautheria shallon* Parsh (Weetman *et al.* 1989; Messier and Kimmis, 1991), Mountain maple - *Acer spicatum* Lamb. (Archambault *et al.* 1998), Lantana camara L. (Thakur *et al.* 1992), *Prosopis* species (Harding and Bate 1991) and *Maesopsis eminii* Engl. (Rhamnaceae) (Binggeli 1989). Where they become invasive, these species can create serious problems by replacing natural vegetation and/or by rendering land useless for farming. *Maesopsis* was introduced in Amani/Kwamkoro forest reserve in Tanzania's East Usambara Mountains 85 years ago and today some patches of that forest are totally dominated by the species.

Maesopsis is a large tree averaging 15-27 m in height, with rare trees attaining a height of up to 43 m. It is valued as a forest product because the straight, slightly buttressed bole reaches 10-30 m in height, with a diameter breast height (dbh) of up to 0.9 m (Eggeling and Dale 1940; Dale and Greenway 1961; Street 1962). The species is used for firewood, timber (furniture and light construction), poles, veneer/plywood, fodder, shade (coffee, banana and tea) and as an ornamental (Mugasha 1981; Mbuya *et al*. 1994).

Maesopsis is regarded as a typical Guineo-Congolian species, since its range corresponding quite closely to the African lowland rain forest zone (Hall 1995). It is among the most widely distributed of African lowland forest tree species occurring from West Africa in Togo and Nigeria, to Congo and southern Sudan. In East Africa it occurs naturally from West and Southern Uganda to Lake Victoria Islands and north-western regions of Tanzania (Mugasha, 1981; Mbuya *et al*. 1994). In Kenya, the species is known to grow naturally in the Kakamega forest. The species grows best on deep fertile sandy loams, well drained soils (Mugasha, 1981). Its altitudinal range is from 500 m a.s.l. (in Kabinda, Congo) to 1500 m (in the Lake Victoria basin). In general the species grows in wet tropical and wet montane climates (Mbuya *et al*. 1994) with mean rainfall ranges of 800-2000 mm per year and mean annual temperature ranges from 20-23^{o}C (Hall 1995).

Maesopsis eminii, like other invasive tree species, possesses several characteristics which enable it to successfully invade areas beyond where it is planted. These characteristics include:
- No dependence on a specific pollinator,
- Large seed crops and long periods of seed dispersal,
- Widespread availability of dispersal agents (hornbills),

- Very high growth rate in its juvenile stages,
- Shade-tolerant seedlings that can survive up to six months in heavy shade,
- Ability to become established in a range of gap and soil surface conditions,
- Ability to coppice from cut or fallen stumps, and
- Long lifespan.

THE SILVICULTURE OF *MAESOPSIS EMINII*

Phenology

Maesopsis eminii has a large annual seed crop. A kilogramme of its seeds can contain 500 - 880 seeds with outer flesh removed (Watkins 1960; Mbuya *et al.* 1994); this high variation in seed mass is probably due to variation in the age and vigor of seed trees, and the moisture content of seeds (Mugasha 1981). Under natural conditions the tree starts flowering and fruiting between ages 4 -10 years (Hall 1995). Flowering can take place in both rainy (at Lushoto; Mugasha 1981) and dry seasons (at Amani; Binggeli 1989), but it is unclear if there are normally two separate fruiting seasons or a single long fruiting period. Fruits take three or four months to develop after pollination. Seeds are dispersed over a long period each year because of the extended fruiting period (Hall 1995). At Amani, the main agents for seed dispersal are hornbills (Mugasha 1981).

Seed biology

Mature seed of *M. eminii* can be collected from the forest floor. Fresh seed (with high moisture content) loses viability in 3 – 5 months. Wide variation exists in time of seed germination, i.e., 90 – 200 days (Yap and Wong 1983; Mugasha and Msanga 1987; Binggeli, 1989). This seed dormancy, in combination with the long period each year over which fruits ripen, means that even with large early loss of seeds, populations can still recruit from seed over much of the year (Hall 1995).

Natural regeneration

Although most seeds lose viability shortly after they drop to the forest floor, the species often regenerates itself freely in nature, from seeds and/or from coppice. Under and near mature *Maesopsis* stands typical of forest edges and old gaps, seed rain can be heavy, with seedling density of greater than 800 per m^2 (Binggeli 1989). In intact natural forests heavy seedling production occurs but most seedlings soon succumb to shading. Seedlings establish themselves very easily in gaps created by natural tree fall or in areas cleared soon after seed fall (Mugasha 1981; Hall 1995). Similar observations from Bukoba indicate that seedlings tend to establish only where banana and coffee shade is light. This suggests that *M. eminii* is a pioneer species with a light-demanding nature that makes it difficult to reach the sapling stage under the dense overgrowth (Mugasha 1981).

Maesopsis is also known to have high coppicing ability. At Amani 80-90% of all cut stumps produce coppice regrowth within one year. Stump size was unrelated to the vigor and time period for regrowth to start. Stumps remain viable for at least a year and shooting increases during the dry season.

Artificial regeneration

Direct seeding normally results in poor germination and low survival, but 6 – 9 month old potted seedlings can be planted out, growing best where there is direct overhead light. *Maesopsis* has been used as a nurse tree for some indigenous tree species. Because the species is very sensitive to competition, weed slashing and thinning are essential in young plantations.

Growth and yield

Maesopsis eminii can achieve a height growth of over 2 m per year during the first 5 years and 1 m per year over the 40-year rotation. Trees may grow to a dbh of over 4 cm per year over the first 5 years and 2 cm per year over the rotation. The tree basal area is normally 1 m^2 per ha per year and wood volume production can reach 200 m^3.

INVASION OF *MAESOPSIS EMINII* IN EAST USAMBARAS

Description of the area

The East Usambaras (4° 48' S to 5° 13'S ; 38° 48' E) are a range of low mountains close to the coast of northeast corner of Tanzania. The mean annual rainfall ranges from 1500 mm to 2100 mm and the mean monthly temperature in the highlands is below 18°C. Rainfall is greatest at the higher altitudes and to the southeast. The topography of the area is moderate to steep with soils that fall in the humid ferralsol category of FAO soil classification scheme. The vegetation of East Usambara is dominated by sub-montane forests in the highlands and lowland coastal forests in the low elevations (Moreau 1935). The dominant tree species in sub-montane forests are *Newtonia buchananii* and *Allanblachia stuhlmannii* (Lovett 1991; Zahabu & Malimbwi 1998).

Importance of East Usambara Forests

The forests of East Usambara are famous among biologists as an area of high endemism, with many rare animals and plants, some found nowhere else in the world (Rodgers & Homewood 1982). More than a quarter of some 30 species of amphibians and reptiles in East Usambara are found nowhere else in the world. Among plants, the submontane forests are especially rich in endemic species: 50 tree species are found only in East Usambaras or a few other locations in eastern Tanzania, Kenya and Mozambique. There are also many threatened species of birds, insects and other animals and plants.

Time and Purpose of Introduction of *Maesopsis* in East Usambara

In the early 1900's high demand for forest products led to a planting preference for faster-growing non-native tree species over the species native to East Usambara. *Maesopsis eminii* was selected because it has a 40-year rotation age that is considerably shorter than the 80-year rotation age for most native species (Mwasha 1988). *Maesopsis eminii* was first introduced in Amani in 1913 for plantation and growth monitoring plots (Tanzania Forest Research Institute Experiments 285 and 385). Among the well known points of introduction were below the Amani rest house and at Kwamkoro. Other high-elevation areas where *Maesopsis* was planted include the Mtai forest (where the species was used for enrichment near the Mamba enclave) and as an agroforestry trial species at the top of the botanic garden. There were also lowland plantings - in Longuza forest reserve and at Manga. Later *M. eminii* was used experimentally as a nurse tree for valuable native tree species such as *Cephalosphaera usambarensis*, *N. buchananii* and *Berchemedia kweo*; long-term observations indicate that this nursing experiment was a failure (Mugasha 1982).

From the silvicultural point of view the widespread logging operations at Amani in the 1960's and 1970's opened the canopy in numerous places. This disturbance, together with favorable climatic conditions, enabled *M. eminii* to spread easily. It spread extensively in both forests reserves and public lands, creating a monoculture with attendant negative ecological consequences (see below).

Current forest status in East Usambaras

The East Usambara mountains cover an area of 1300 km^2. However, since the mid 1960's much of the forest area has been exploited by the expansion of peasant agriculture and large scale logging operations. Only a few forest patches remain in a reasonably natural state (Hamilton 1989). Due to the importance of these remaining forests, the Amani Nature Reserve, comprising all of the Amani forests, was established in 1998. Although *Maesopsis* was planted in some of these areas, the exact extent of planting versus subsequent spread is uncertain.

ECOLOGICAL CONSEQUENCES OF THE SPECIES

When *Maesopsis* becomes abundant in submontane forests the following can happen to the soils:
- the upper organic soil horizons normally present disappear;
- the dense superficial root-mat disappears;
- the litter becomes thinner;
- the pH is raised;

- the soil fauna changes in its species composition and becomes more uniform;
- the rate of soil erosion can increase.

Some scientists have argued that *M. eminii* is displacing desirable species and so should be eliminated from the East Usambara forests (Mwasha 1988; Binggeli 1989; Hamilton 1989). Hall (1995) reported that its spontaneous spread, usually attributed to efficient dispersal by hornbills, had affected most areas of the forest above the escarpment and south of Bulwa in East Usambara. In these areas, many of the endemic and near-endemic trees and understory plants are absent and other more widespread species become common.

Binggeli' s (1989) review of the *Maesopsis* situation, which predicted dire consequences if the species was left unchecked, greatly increased the drive for management action to reduce the impact of the invader. Suggested eradication measures included:

- isolation of seed sources well inside the forest by removal of the scattered trees in the forest,
- mechanized logging or pit-sawing that is timed to occur when there is little or no fruiting and is accompanied by manual uprooting of regeneration saplings,
- mechanized logging or pit-sawing that is accompanied by re-seeding of the disturbed area with indigenous pioneer species, and
- use of draught animals to extract logs from both plantation and spontaneously developed stands (Binggeli 1989; Seymour 1993).

Although the species is still widespread in East Usambara, there are recent findings that suggest the spread of *Maesopsis* within the forest has declined since logging ended in 1986 (Hall 1995). Under such undisturbed conditions, *M. eminii* could experience a much lower (even negative) population growth rate and have a much reduced ecological impact. Additional data is therefore needed on:

- the degree of persistence and dominance upon release for seedlings/saplings growing under high and moderate shade,
- the rate of change in population size over period of long-term forest stability, and
- the degree to which *M. eminii* suppresses the regeneration of indigenous pioneer or later successional species, particularly for uncommon or rare endemic species, in relatively undisturbed forests.

CONCLUDING REMARKS

Maesopsis eminii, a pioneer tree species widely introduced into East Africa for its silvicultural characteristics, has invaded large areas of disturbed forest in the East Usambara Mountains.
In some areas of the East Usambara forests, the species has had a significant negative ecological impact on the natural vegetation. However, the invasive impact of *M. eminii* may be declining as forest cutting and disturbance has greatly decreased, thereby greatly reducing the opportunity for this pioneer species to invade. More research is needed to examine the long-term patterns of recruitment and subsequent ecological impact of this species in relatively undisturbed East Usambara forests.

Because this species has been intentionally introduced to ease timber shortages, any determination of the species' invasive threat must also consider its contribution to local welfare. In those areas where timber is scarce, the value of this tree may be perceived as far greater than its threat. Conversely, in areas where timber is not scarce, *M. eminii* is unlikely to be planted because doing so has little value. The magnitude of threat posed by this invasive species is therefore very site-specific, and depends on any local benefits derived from its introduction, and on any ecological impacts in a particular forest setting.

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PRELIMINARY SURVEY OF INVASIVE SPECIES IN EASTERN AFRICA

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As part of the workshop on "Invasive Species in Eastern Africa", participants were asked to provide information about their perceptions of invasive species that posed a threat in the areas where they worked. We have compiled these surveys and comment on the results here.

CAVEATS

The information in this survey must be considered strictly anecdotal. We asked participants for their perceptions and did not require them to gather any precise estimates for the figures requested. Furthermore, the sample of individuals polled has likely influenced the information provided in several ways:

1) Some of the participants have had little experience with invasive species, but because they are responsible for managing areas vulnerable to invasive species, came to the workshop in order to learn more about them. These participants may be more likely to identify the commonly known invasive species, such as water hyacinth, even if that particular species did not pose the greatest threat in their area.

2) The workshop participants represented an uneven sampling of expertise in the full range of taxa in which invasive species are found. For example, there was an ornithologist from Kenya who identified three invasive birds found in his country. On the other hand, there was no ornithologist from Uganda or Ethiopia present and no invasive birds reported from those countries; the absence in our survey of invasive birds from those countries could reflect the real situation or could be a function of how the information was gathered. A similar situation occurred for ants, with one individual reporting three invasive ants from Tanzania, with no other invasive ants reported for any other country.

3) The number of participants varied from country to country, so the identification of more invasives from one country may be a function of the number of participants rather than of the true distribution of invasive species.

RESULTS

27 survey forms were returned from all four countries in the region and 4 additional survey forms were also returned by participants from Malawi, South Africa and Mauritius.

For the Eastern Africa Region, 38 different invasive species were identified, falling into the following taxa: Plants: 21, Vertebrates: 5, Insects: 9, Other Invertebrates: 1, Microorganisms: 2. The list of the species, the countries from which they were reported, as well as some additional information on impact and control efforts are reported in Table 1.

OBSERVATIONS

- Most reported invasive species are vertebrates, plants, or insect pests of crop plants. Invasive insect pests on non-crop systems were not common in our sample, nor were microorganisms. This suggests that outside of agricultural areas larger species may be more likely to be identified, at least in the early stages of monitoring for invasive species.
- Knowledge about when a species was introduced, its rate of spread and its current range was in most cases quite limited.

- While qualitative information about the impact of invasive species on human welfare was often available, neither in the surveys nor during the workshop did any of the East African participants have quantitative information on the economic or social costs of invasive species.
- As far as the participants knew, there were little or no control efforts being undertaken for many of the invasive species.
- There were, however, successful control efforts reported for several species.
- There is broad overlap between several countries for invasive species in several habitats. For example, the aquatic weeds in our survey were all found in more than one country. Also, invasive insects on crop plants also tended to be reported from more than one country. This could reflect the fact that trade in crop species has spread invasives widely in the region, and/or that agricultural pests are better known than invasive pests on non-agricultural species.
- Some invasive species are shared not by neighboring countries, but rather by countries that share ecological conditions. For example, the islands of Zanzibar and Mauritius both reported problems with rats. Ethiopia and the Cape of South Africa, both quite arid regions, both reported Mesquite species as problem invasives.
- Some of invasive species reported were intentionally introduced, e.g., Nile Perch, Eucalyptus trees, and the tree *Maesopsis emenii.* The fact that these are reported as invasive species could indicate that they have become invasive beyond the purpose for which they were imported. More likely, however, this reflects a conflict between the aims of those who introduced the species (e.g., for economic gain from fisheries or forestry) and the aims of those who manage areas for other uses such as biodiversity conservation. Such inter-sectoral conflicts are commonly associated with invasive species around the world and Eastern Africa could consider how such conflicts have been mediated elsewhere.
- Some of the invasive species are serious and widespread problems in Eastern and Southern Africa - e.g., *Lantana camara* and Acacia trees. These species might form the basis of initial cooperative efforts between Eastern and Southern Africa.
- There are several genera that tend to have multiple invasive species within them. For example, there are several species of Acacia that are problem invasives in South Africa, with different Acacia species being reported as invasives in different parts of Uganda and Tanzania. Not only do these invasive species present an opportunity for sharing expertise among different countries, but they also highlight the need for a list of potential invasives. Such a list, drawn from experience with invasive species from around the world, would be an important part of any early warning and monitoring system for Eastern Africa.
- A number of species are reported only once from one area. There is a tendency to pay less attention to such examples and more attention to more widespread invasive species. However, it is possible that reports of species with currently small distributions do not reflect a low potential of those invasive species to spread, but rather that they have just recently arrived! This survey could therefore contain information that might serve as an early warning, however, without more information and follow up, it is not possible to use our survey in this way.

CONCLUSIONS

The anecdotal information provided by our survey serves to reinforce several of the workshop's general conclusions.

- There is a wide diversity of invasive species present in Eastern Africa with many taxa in many habitats. Some of the invaders are recent, while others have been here a long time. Some are coming under control, while others are likely to be on their way out of control.

- There now exists in Eastern Africa considerable knowledge about invasive species. However, that knowledge is quite limited. To effectively control invasive species in the region, much more information is needed about which invasive species are now in the region, where they are, their rate of spread, and the nature and fate of control efforts.

- There now exists in Eastern Africa the capacity to identify and, in some cases, control invasive species. In order to strengthen that capacity, there must be additional attention directed to conducting research on invasive species, to developing systems to monitor invasive species, and to training personnel to control invasive species. All of these require political will and funding.

- There are common invasive species shared by many countries in Eastern African and in Sub-

Saharan Africa. These already identified species can serve as the basis for initial cooperative efforts on several regional scales.

Although our data are anecdotal in nature and incomplete, this survey has served as a first step in compiling a list of the invasive species of the region. It has identified a wide range of invasive species already known from different habitats within the region. We hope that this preliminary survey serves at least two purposes: 1) to challenge others to expand, confirm or modify the information in this status report and 2) to make it easier to make the case to politicians, scientists, land managers and others that much more information and action is needed in order to protect Eastern Africa from invasive species.

Preliminary Survey of Invasive Species in Eastern Africa

LEGEND	PLANTS													
Species	**Water hyacinth (*Eichhornia crassipes*)**	**Water fern (*Salvinia molesta*)**	**Wild rice (*Oryza sp.)***	**Prickly pear (*Opuntia spp.*)**	**Sensitive plant (*Mimosa pigra*)**	**Mexican marygold (*Tagetis minuta*)**	**Paper mulberry (*Broussonetia papyrifera*)**	**Mexican weeping pine (*Pinus patula*)**	**Acacia (*Acacia* species)**	**Castor oil plant (*Ricinus communis*)**	**Bermuda grass (*Cynodon dactylon*)**	**Macdonaldi (*Galinsoga parviflora*)**	**Swordgrass (*Imperata cylindrica*)**	**Lantana (*Lantana camara*)**
Country	**KE, TZ, UG, ET**	**KE, UG**	**TZ (Zanzibar)**	**KE, UG**	**ET**	**KE**	**UG**	**TZ**	**TZ, UG**	**TZ**	**UG**	**UG**	**UG**	**TZ, UG, KE**
Range	large and small waterways throughout region	Lakes Naivasha, Victoria	Zanzibar	Nairobi National Park, Queen Elizabeth National Park in Uganda	Americas, SE Asia & Australia	widespread, E & S Africa	In Uganda, in a small area, but spreading	plantation tree	SW Uganda, southern highlands of TZ	lowlands and highlands	worldwide	East Africa	worldwide	worldwide
Year of arrival	1950s	1957	unknown	1940-50's		unknown	1953		1950's - 60's	long ago	long ago	long ago	long ago	1950's
Rate of spread	reduced	reduced		slow		unknown	slow	unknown	slow	unknown	very rapid	very rapid	very rapid	slow
Habitat	lakes, ponds, creeks	lakes, ponds, creeks	wetlands		river banks, lake edges & floodplains			adjacent to industrial forest plantations	rangelands	in fallow fields and valleys	roadsides, disturbed areas	croplands, abandoned areas	abandoned areas	waste places, scrublands, grazing lands
Impact on native plants and animals and ecosystems	Biological Oxygen Demand increased, prevents mixing of water, shades algae and submerged vegetation, has enhanced population recovery of some cichlids	prevents mixing of water, shades algae and submerged vegetation, leads to buildup of sludge under mats	competes with native vegetation	outcompetes native plants, precludes browsing or grazing near it	covers other vegetation	minimal	displaces native plant species. primates like its leaves and fruit	suppresses natural regeneration on pasturelands, its high water use reduces stream flow	displaced native species that are more palatable to wildlife, changes soil fauna, e.g. earthworms	suppresses indigenous fallow plants	replaces native plants, retards plant succession	replaces native plants	reduces growth of native plants	chokes out other vegetation
Impact on humans	Harms transportation, fisheries and irrigation, facilitates some transfer of parasites (e.g. malaria and bilharzia)	damages fishing and irrigation	outcompetes native rice, increased labor required for weeding	harmful to eyes, poisonous, spines dangerous	prevents human movement (nasty spines)		leaves are irritating to humans	reduces grazing and available water	thorns can injure livestock, reduces grazing area	high cost of land preparation and weeding	reservoir for mosquitos	reduces crop production, reservoir for mosquitos	retards transport, difficult to weed	poisonous to livestock, good habitat for tsetse flies
Current status	decreased in open lakes, but still in creeks and bays			slowly spreading	not currently a pest but has potential to expand	unknown					widespread	widespread	widespread	widespread
Agencies addressing it, approaches	KE: KARI, with Lake Victoria Management Programme, using biocontrol, with local communities using mechanical removal; UG: NARO, MAAIF, MUK, NEMA; ET: EWSS	KARI		KWS started to remove but too expensive		KWS has ongoing removal via physical uprooting by casual labor force	none		sometimes cut and burnt, but this is not very effective; no control measures in TZ	no control measures	none	none	none	

Data compiled/combined from reports on perceptions of participants in ICIPE's workshop on "Invasive Species in Eastern Africa" July 5-6 1999

Preliminary Survey of Invasive Species in Eastern Africa

LEGEND	PLANTS								VERTEBRATES				
Species	***Senna spectabalis* (Cassia)**	***Parthinium hysterophorus***	**Mesquite (*Prosopis juliflora*)**	***Leucaena leucocephala***	***Maesopsis eminii***	**Morning glories (*Ipomoea spp .*)**	**Eucalyptus trees**	**Blue-green algae**	**Nile perch (*Lates niloticus*)**	**House sparrow (*Passer domesticus*)**	**Hybrids of yellow-collared and Fischer's lovebirds (*Agapornis* spp.)**	**Indian House Crow (*Corvus splendens*)**	**Rat (*Rattus rattus*)**
Country	**UG**	**ET**	**ET**	**TZ**	**TZ**	**KE**	**KE**	**UG**	**KE**	**KE**	**KE**	**KE, TZ (Zanzibar)**	**TZ (Zanzibar)**
Range	very small area	most of Ethiopia, also Kenya	Mid-upper Awash Valley, E part of Halange	throughout TZ	Mostly in humid lowland forests of Eastern Usambara Mts.	disturbed areas	Nairobi National Park		Lake Victoria	from Coast to Nairobi along railway	Nairobi, Naivasha, Nakuru, Athi River	Coast	widespread on island
Year of arrival	unknown	mid-70's	mid-1980's	1989 in west Usambara mts on farmlands	1950's - intentional introduction as nurse tree	1960's	1939-1945	1970's became invasive	intentionally introduced in1960's	early 1900's	19th century	1947 in Kenya, 1890's in Zanzibar	unknown
Rate of spread		very fast	very fast	fast	rapid	ongoing	unknown		spread throughout lake	unknown		unknown, though it has spread along most of EA coast	
Habitat		rangelands, agricultural lands, wastelands	rangelands, river banks, agriculture	agricultural lands	forests		forested areas	lakes, ponds	lakes			coast, forest, agriculture and urban areas	
Impact on native plants and animals and ecosystems	excludes other plant species	allelopathic, so prevents other plants from growing	allelopathic effect, so deters recruitment of other plants	outcompetes native plants	hinders regeneration of native trees of climax forest	colonizes large areas, grows over and outcompetes other plants, reduces forage for wildlife	minimal, though some evidence that it retards recruitment of native plants	declining diversity and anoxia in partsof the lake ecosystem	has greatly reduced abundance of native cichlids, probably driving some to extinction	displacing local sparrows	competing for nest holes with native species	displacing native crow species, destroys nest and young of other birds, kills fruit bats, geckos and native invertebrates	damages eggs and young of birds, reptiles, damages seeds of many plants
Impact on humans	none	reduces grazing area, health hazard, sours milks and honey, casues irritation; reducing biodiversity in national parks	reduces carrying capacity of rangeland, overgrown roads & national parks	reduces abundance of native fallow species, and some other fodder plants	perhaps loss of medicinal plants, forest animals exposed to more hunting pressure	reduces pasture for domestic grazers	none	undocumented	economic boost to fisherman, but has reduced catch of popular smaller fish	noisy, messing buildings with nests	pests, especially on cereals	urban pest, damages crops and livestock, is noisy, interrupts electrical supply, hazard at airport, contaminate water	losses due to crop damage, contamination of food stuff
Current status		widespread							well-established			well-established	
Agencies addressing it, approaches	none	Surveyed, with pilot project to start soon	surveyed, EWSS creating awareness. EARO looking at it	Some studies done to identify alternative indigenous species for alley cropping	Many - including IUCN East Usambara catchment forest project and Amani Botanical Garden - doing research into control practices	ASAL land use programme, Elangate Wuas Ecosystem Management Programme	KWS has recently started to control it	FIRI is beginning to incorporate into environmental management strategies	FIRI in Uganda		Lake Naivasha lovebird project, since 1985 monitoring its impact on other species	KE: 1980's- Mombasa authorities, with Min. of Tourism and Wildlife, started control programme. Zanzibar: Dept. of Env. traps, poisons, pays rewards for killing crows	Plant Protection Division and others carrying out eradication programme on Zanzibar island

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Preliminary Survey of Invasive Species in Eastern Africa

LEGEND	ARTHROPODS										MICROBES
Species	**Louisiana crayfish (*Procambarus clarkii*)**	**Larger Grain Borer (*Prostephalus truncatus*)**	**Mosquitoes (*Anopheles spp* ., *Culex spp* .)**	**Cassava green mite (*Mononchellus tanajoa*)**	**Cypress aphid (*Cinara cupressus*)**	**Cassava mealybug (*Phenacoccus manihoti*)**	**Citrus wooly aphids (*Aleurothrixus sp* .)**	**Long-legged ant (*Anoplolepis longipes*)**	**Custodian ant (*Anoplolepis custodiens*)**	**Big-headed ant (*Pheidole megacephela*)**	**Cassava Mosaic Virus**
Country	**KE**	**KE, TZ**	**TZ (Zanzibar)**	**TZ**	**TZ**	**TZ**	**TZ**	**TZ**	**TZ**	**TZ**	**TZ**
Range	Lake Naivasha	Kenya's border with TZ, TZ		TZ's cassava growing areas	Eastern and Central Africa	all cassava growing areas in TZ	Tango, Morogoro	unknown	unknown	unknown	Kogera region of TZ
Year of arrival	1970	late 70's - early 80's	unknown	1972	1986	1982	1991/92	unknown	unknown	unknown	unknown
Rate of spread		more than 10,000 sq km per year			very rapid			unknown	unknown	unknown	
Habitat	lake	agricultural areas		agricultural lands	all areas where cypress grows, approx 10,000 sq km	agricultural lands	unknown	many areas with loose soil	many areas with loose soil	widely distributed in many habitats	
Impact on native plants and animals and ecosystems	greatly reduced some parts of local fauna and flora (e.g. leeches, waterlilies), harmed vegetation, led to loss of birds species, increased turbidity	little impact on non-agricultural systems	not documented	little impact on non-agricultural systems	Cupressus species almost eradicated in TZ	little impact on non-agricultural systems	little impact on non-agricultural systems	outcompetes native ants and changes insect fauna	outcompetes native ants and changes insect fauna	outcompetes native ants and changes insect fauna	little impact on non-agricultural systems
Impact on humans	harvested by fisherman	maize yields reduced, storage infected, food shortage	vectors of human disease	crop losses and food shortages	severe economic hardship in Iringa & Mbeya, where economy depended on cypress	destroys up to 20% of cassava on some farms; food shortage	losses of citrus crops	increases pest load on fruit crops	increases pest load on fruit crops	increases pest load on fruit crops	reduces cassava yield, food shortages
Current status	widespread	In TZ - 800,000 sq km	widely distributed								
Agencies addressing it, approaches	no group	KE: KARI Biocontrol and trapping; TZ: GTZ, IITA, TPRI, and universities are developing control strategies; UG: NARO, MUK, MAAIF	Ministry of Health insecticides control programme	TZ govt/IITA working on biological control agents	TAFORI testing biocontrol agents since 1989; CABI and ICIPE also working on biocontrol	Ministry of Agriculture has worked on since 1989, introduced parasitic wasp, has given some control	TZ govt./GTZ working with biocontrol with parasitoids	Plant Protection Division and National Coconut Dev. Programme - doing ecological studies and chemical control	Plant Protection Division and National Coconut Dev. Programme doing ecological studies and chemical control	Plant Protection Division and National Coconut Dev. Programme - doing ecological studies and chemical control	TZ Plant protection and Extension Staff and Domestic Quarantine working on it

Data compiled/combined from reports on perceptions of participants in ICIPE's workshop on "Invasive Species in Eastern Africa" July 5-6 1999

APPENDIX 1
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Appendix 2

PROGRAMME
WORKSHOP ON 'INVASIVE SPECIES IN EASTERN AFRICA'
JULY 5-6, 1999 ICIPE CAMPUS, NAIROBI

Monday July 5

8:30-10:00 Registration and Welcoming Remarks
Dr. Hans Herren (Director General, ICIPE)
Dr. Scott Miller (Leader, Biodiversity and Conservation Progamme, ICIPE)

NATIONAL, REGIONAL AND GLOBAL PROGRAMMES TO FIGHT INVASIVES

10-10:45 Jeff Waage, CAB International, UK, and Global Invasive Species Programme Executive Committee. "Alien Invasive Species: Ecology and Global Response"

10:45-11:00 Break

11:00- 11:40 Vishnu Tezoo and Yousoof Mungroo, Mauritius National Parks & Conservation Service, "The National Strategy to Fight Invasive Species in Mauritius"

11:40-12:20 Christo Marais, Tyl Willems and Karoline Hanks, Working for Water Programme, South Africa "Invasive Species and the National Working for Water Programme: Linking Sustainable Development with Economic Empowerment in South Africa"

12:20-12:45 Discussion

12:45-2:00 Lunch

ECONOMIC, LEGAL AND POLICY DIMENSIONS OF INVASIVE SPECIES

2:00-2:40 Wilson Songa and Chagema Kedera, Kenya, Kenya Plant Health Inspectorate Service (KEPHIS), "Policy and Legal Dimensions of Invasive Species"

2:40-3:20 Victor Kasulo, Malawi & York University, "The Economics of Invasive Species: Costs, Incentives, Risk Analysis and the Role of Donors"

3:20-3:40 Discussion

3:40-4:00 Break

INVASIVE SPECIES AND VULNERABLE ECOSYSTEMS

4:00-5:30 Discussions in country working groups.
Moderated by Richard Bagine, Kenya Wildlife Service
1) Invasive species in protected areas; 2) Ecosystems most vulnerable to invasives

5:30-7:00 Reception and INFORMATION FAIR

Tuesday July 6

9:00- 10:00 Presentations of Country Working Group Reports
Ethiopia
Tanzania
Uganda
Kenya

10:00- 11:30 **CASE STUDIES**
"Aquatic invasive plants in Kenya", Waweru Gitonga, Kenya Agricultural Research Institute (KARI)
"Weeds Invasions Tracked with Herbarium Records", Geoffrey Mungai, Kenya, National Museums of Kenya (NMK)
"Invasive species of the water environment", Timothy Twongo, Fisheries Research Institute (FIRI), Uganda
"Spread and ecological consequences of the invasion of the stem borer, *Chilo patellus*, into Africa", W. Overholt, J. Songa, V. Ofomata and R. Jeske, ICIPE
Discussion

LOOKING FORWARD IN EAST AFRICA

11:30-12:00 Jeff Waage, CAB International, UK, and Global Invasive Species Programme Executive Committee, "An Introduction to the Global Invasive Species Programme (GISP) Tool Kits"

12:00-2:00 WORKING GROUP DISCUSSIONS (Working lunch provided)
The Role of EAFRINET in the Fight Against Invasive Species
Strengthening Research and Research Links on Invasive Species
Coordinating Regional Efforts to Control Invasive Species
Capacity Building and Implementation in Invasive Species Programmes

2:00-3:30 Working groups reports, wrap-up discussion

3:30 Leave for Museum
4:30 Public Lecture and Panel Discussion at Louis B. Leakey Auditorium, National Museums of Kenya

PUBLIC LECTURE: Professor Michael Samways, University of Natal, South Africa, "Alien Invasive Species and Ecosystem Agony"

PANEL DISCUSSION: "National, Regional and Global Strategies for Fighting Invasive Species". Moderator: Dr. Helida Oyieke, NMK. Panelists: Dr. Bernard Irigia, KWS, Dr. Timothy Twongo, FIRI, Dr. S. Okaasai Opolot, Ugandan Phytosanitary and Quarantine Services, Dr. Geoff Howard, IUCN, Dr. Gert Willemse, South African Ministry of Environmental Affairs and Tourism, Dr. Jeff Waage, CAB International.

INFORMATION FAIR
Exhibitors who displayed books, videos, CD-ROMs etc. :

ICIPE Science Press	CABI	KEPHIS
IUCN	USDA Forest Service	EAFRINET/BIONET
Working for Water Programme, South Africa		Government of South Africa

Appendix 3

COUNTRY WORKING GROUP DISCUSSION: INVASIVE SPECIES AND VULNERABLE ECOSYSTEMS IN KENYA

1. Protected areas in Kenya

Forest Reserves
National Parks
Marine Parks
National Monuments (e.g., Kaya Forests)

2. Status of Protected Areas

A. Status of knowledge

1. Lack of catalogue and identification in:
   - Marine and coastal
   - Montane/Alpine
2. More information is available for:
   - Inland waters
   - Forests
   - ASALS

B. Some Invasive species well known to our group:

1. Plants	14
2. Insects	2+
3. Other invertebrates	1
4. Birds	4

	21

C. Many other invasive species exist but not yet identified by studies

D. Non-protected areas suffer many of the same problems

3. Management of Protected Areas and potential partners

INSTITUTIONS	*PARTNERS*
1. KWS	1. KARI
2. Forest Department	2. Dept of Remote Sensing
3. NMK	3. Universities
	4. NGOs & CBOs

4. Capacity to monitor invasive species. In theory the following institutions should all have some capacity, though for all it is currently inadequate:

1. KEPHIS
2. KWS
3. NMK
4. Other research institutions

5. Control Activities

A. Quarantine systems in place
B. Attempts to manually remove
C. Attempts to use herbicides
D. Attempts to use biological control

6. Awareness by leaders

Some are aware
Most are not aware

7. Vectors for movement of invasive species

A. Human activities (intentional and unintentional)
B. Migratory animals
C. Wind
D. Water

8. Obstacles to effectively controlling invasive species

A. Lack of appropriate policy
B. Lack of awareness
C. Lack of funds
D. Poor collaboration
E. Lack of mechanisms for capacity building/training

9. What the participants in this workshop can do

A. Promote the following:

i. Soil and water management activities
ii. Education/awareness raising
iii. Collaboration/Networking
iv. Research/monitoring
v. Mapping/remote sensing
vi. Community mobilisation/sensitisation
vii. Inventorying/regional hand book

B. Recommendations to carry out

i. Develop a policy framework on invasive species
ii. Widen scope/capacity of KEPHIS and others
iii. Intensify monitoring
iv. Create awareness and training
v. Collaborative network
vi. Catalogue and publish regional handbook on invasives
vii. Initiate and intensify research

Appendix 4

COUNTRY WORKING GROUP DISCUSSION: INVASIVE SPECIES AND VULNERABLE ECOSYSTEMS IN TANZANIA

1. Status of invasive species in protected areas.

   a) There are 5 categories of protected areas (PAs) in Tanzania:
      1. National Parks (NPs)
      2. Game Reserves (GRs)
      3. Ngorongoro Conservation Area (NCA) [multiple use area]
      4. Game Controlled Areas (GCAs)
      5. Forest Reserves (FRs)

   b) These protected areas are managed as follows:-
      1. NPs- by a parastatal organization, the Tanzania National Parks (TANAPA).
      2. GRs - by Wildlife Department in the Ministry of Natural Resources & Tourism.
      3. NCA - by Ngorongoro Conservation Area Authority (NCAA)
      4. GCAs - by Wildlife Department, Ministry of Natural Resources & Tourism.
      5. FRs - by the Forestry & Beekeeping Division, Ministry of Natural Resources and Tourism.

      Note: Management of Protected Areas in Tanzania is done with close collaboration and participation of the local communities.

   c) Invasive Alien Species are a problem in the Protected Area System of Tanzania. Mechanical, chemical and biological control has been attempted in protected areas with mixed success. Invasive species found in Tanzania Protected Area System include (but are not limited to):

      PLANTS:
      1. *Cassia spectabilis* - in Mahale Mountain National Park
      2. *Maesopsis eminii* - in East Usambara Forest Reserve
      3. *Opuntia* species - in Serengeti National Park
      4. *Agemone mexicana* – in Lake Manyara National Park

      ANIMALS:

      1. Rats
      2. Indian house crow (especially on coast)
      3. Rinderpest
      4. *Cinara cupressi* (aphid)

2. Tanzania Ecosystems Vulnerability to Invasive Species

   a) Six ecosystems were thought to be particularly vulnerable, due to a combination of biological, geographical and human effects:
      1. Agricultural ecosystems
      2. Wetlands
      3. Mountain ecosystems
      4. Forest ecosystems
      5. Grassland Savanna ecosystems
      6. Island ecosystems

   b) Examples of Invasive Species in Tanzanian Ecosystems

PLANTS:
1. Water hyacinth - Wetlands
2. Water fern (*Salvinia molesta*) - Wetlands
3. Water lettuce (*Pistia stratiotes*) - Wetlands
4. *Striga asiatica* - Agricultural lands
5. *Leucaena leucocephala* - Agricultural lands
6. *Maesopsis eminii* - Mountain ecosystems
7. *Agemone mexicana* - grasslands & savannas

ANIMALS:
1. Indian House Crow - Island ecosystems, coastal areas
2. Larger grain borer (*Prostephanus truncatus*) - Forestry & agricultural Ecosystems
3. Cassava mealybug (*Phenacoccus manihoti*) - Agricultural
4. Sugarcane scale (*Aulacaspis tegalensis*) - Agricultural
5. Cassava green mite (*Mononychellus tanajua*) - Agricultural
6. Citrus Woolly white fly (*Aleurothrixus floccosus*) - Agricultural
7. Cypress aphid - Forestry

c) Awareness is still low among leaders and inter-sectoral cooperation in invasive species issues is low.

d) Transport mechanisms for these invasive aliens includes:
   1) air/wind
   2) water
   3) animals, birds
   4) human activities, e.g., trade and tourism

e) A major obstacle to protecting protected areas is lack of capacity to identify invasive species, including lack of identification manuals and taxonomists

f) Of all these Tanzanian Ecosystems, the group identifies the following ecosystems as the most susceptible to invasive species:
   a. Agricultural
   b. Wetlands

g) The capacity for monitoring the invasives in the country is low due to the lack of appropriate infrastructure (trained personnel, facilities) and the lack of general awareness of the potential dangers of invasive species.

h) At the present level of awareness, the country is undertaking various measures to contain the problem of invasives. They include quarantine and inspectorate service (Pre-entry mechanisms); and control and eradication of invasives in the country (Post-entry) through mechanical removal, use of bio-control agents, and chemical application (herbicides & insecticides etc)

3. Conclusions

The Tanzanian group concluded that the major obstacles in the management of invasive aliens can be solved by both national and international efforts. Members of this Workshop, in particular, can help by:

a. Sharing experiences and collaborating on ideas for the development of programmes and methodologies in the control, prevention, monitoring and the management of invasive species

b. Developing recommendations on how best we can nationally and regionally manage the invasive and alien species

Appendix 5

COUNTRY WORKING GROUP DISCUSSION: INVASIVE SPECIES AND VULNERABLE ECOSYSTEMS IN ETHIOPIA

Caveat:

1. Our group could not compile a comprehensive list of all the invasive species in Ethiopia since none of us is expert in the field of invasive species.

2. Very little research has been done on invasive species in Ethiopia, except for a few assessments in some parts of the country.

Based on our group's knowledge, the following is a list of invasive species that are likely to be of economic importance or impact:

1. Congress weed - *Parthenium hysterophanus* - This weed was introduced to Ethiopia with aid packages of wheat. It is becoming very common in areas along the Assab - Addis Ababa highway and it is widespread in eastern, central and northeastern parts of the country.

2. *Prosopis juliflora* – It is said that this species was introduced to Ethiopia by a foreigner who visited areas along the Awash river, especially in Afar region, to explore its potential for plantations of cotton and citrus. When he found there were no green plants during the dry period in the area, he brought a single pod to the area. Now this tree is encroaching in many areas on the grazing area of the Afar people.

   Note: These two species above have the potential to spread to several National Parks and Wildlife Reserve.

3. Water hyacinth - *Eichhornia crassipes* - As noted earlier in the workshop, water hyacinth is a problem in many African countries. In Ethiopia it causes serious problems in dams, which are sources of hydroelectric power and lakes (e.g., Koka dam, Aba Samuel dam; Abaya & Zewai Lakes in the Rift Valley).
4. *Lantana camara* - This species is common in the eastern part of the country, the Somali region. Some people also grow it as an ornamental plant and use it for fencing in southern Ethiopia.

5. *Eucalyptus* spp. – These species are common in some priority forest areas (e.g., Menagesha-Suba Forest). Its potential to replace the indigenous species of an area is high. (People also want to grow trees like *Podocarpus juniperus* since it is a fast growing tree as compared to the indigenous trees.)

6. *Agemone mexicana* - This weed is also common in the arable lands of the Rift Valley, in areas along the Assab - Addis Ababa Highway.

7. *Opuntia* sp. - People use this plant for fencing purposes. It has the potential to spread to Bale Mountain National Park and Senkelle Swayner Hartebeest Sanctuary.

8. "The slug" (mollusc) spreading in cities, but status not known.

9. Nile perch - needs study.

1. a. MANAGEMENT OF PROTECTED AREAS

In the past, all of the protected wildlife and forest areas were managed by the Federal government (Ministry of Agriculture - MOAS). Starting in 1996, for political reasons, the Federal government handed over most protected areas to their respective Regional agricultural offices, except those which fall in two or more regions and so are difficult to manage. The MOAS-Ethiopian Wildlife Conservation Organisation (EWCO) & the Forestry Department are responsible for the management of these protected areas.

b. The capacity for monitoring for invasive species by the Federal and Regional governments in Ethiopia is negligible in protected areas since we do not have expertise to look at the issue of invasive species.

c. Invasive species are a considerable problem now in Ethiopia, and weeds such as *Parthenium* and *Prosopis* in terrestrial ecosystems and water hyacinth in wetland ecosystems have the potential to spread and invade many areas.

d. The current activities to control invasive species in Ethiopia are:
1) Creating awareness among policy makes about the potential for species like *Prosopis, Parthenium* and water hyacinth to spread.

2) The Institute for Biodiversity Research and Conservation (IBRC) is beginning to establish a structure to control the import and export of species.

3) MOA and Ethiopian Agricultural Research Organisation (EARO) have a Quarantine Service to control the import & export of species.

e. The leaders of EARO, IBRC, MOA, EWCO, Enivornmental Protection Agency (EPA), Addis Ababa University (AAU), Alemaya University of Agriculture, Awasa Agricultural College are aware of invasive species as a potential problem. A preliminary survey on *Prosopis* and *Parthenium* has been carried out by a colleague from EARO, and some studies on water hyacinth have been conducted by botanists at AAU.

f. The major vectors of the aforementioned invasive species brought to Ethiopia are:
- Aid packages - shipping
- Human beings
- Wind
- Irrigation
- Animals - sheep, goat, cattle, birds

g. The biggest obstacles to protect protected areas against invasive species are:
- Lack of awareness on the types and damages of invasives
- Lack of research activities to identify the risks of invasives in ecosystems
- Lack of regional networking among East African countries
- Lack of trained manpower in the field of invasive species
- Lack of funds for capacity building
- The government's low priority for environment issues.

h. To over-come the aforementioned obstacles, the people at this workshop will help in:
- sharing their experiences and fill the gap of knowledge on invasive species in Ethiopia
- Developing regional net-working to know the type of invasive species and their controlling mechanisms
- Approaching funding organisations for capacity building

2.a. In our discussion, we also identified the following ecosystems which might be most vulnerable to invasive species:

1. Small-leaved deciduous woodland. These environments are changing rapidly, due to high levels of human impact. Over-exploitation of natural resources, sometimes beyond carrying capacity (e.g., over-grazing), could provide favourable conditions for the growth and spread of invasive species. These ecosystems are particularly vulnerable because the two invasive species *Prosopis* and *Parthenium* are spreading in these areas.

2. Wetlands. Dams and lakes are particularly vulnerable because of the potential for water hyacinth to spread.

3. Mountainous ecosystems, such as the Afroalpine. The biodiversity of the tropical dry and moist forest ecosystems as well as of the mountain grasslands are vulnerable to invasive species. Because these ecosystems are fragile by nature and because they are areas of heavy agricultural practice (which disturbs the natural ecosystem and introduces many potential vectors for invasives), they are at considerable risk from invasive species. Risk for invasive species increases with increased human activity.

b. The vectors for bringing invasive species into these ecosystems are aid packages, human beings, birds, sheep and goats, and natural elements.

c. The capacity for monitoring invasive species in these ecosystems is not great at this point in time, however, IBRC is trying to build a structure so that they can monitor the invasive species in these ecosystems.

d. The people at this workshop can help to protect such vulnerable ecosystems by:
   1) Sharing their workshop experience.
   2) Taking the conclusions of the workshop home to strengthen efforts to guard protected areas against invasive species. Those efforts will involve:
      a) Increased research on invasive species
      b) Capacity building for monitoring and controlling invasive species.

Appendix 6

COUNTRY WORKING GROUP DISCUSSION: INVASIVE SPECIES AND VULNERABLE ECOSYSTEMS IN UGANDA

1.1 *Protected Areas in Uganda*

Protected Areas in Uganda	*Area*
• National Parks	11,155 sq. km.
• Forest Reserves	
• Tropical high forest	417,000 ha
• Woodlands	720,000 ha
• Conifers	12,000 ha
• Eucalyptus	18,600 ha
• Biosphere Reserve	1,978 sq. km.
• Wildlife Reserves	8,764 sq. km.
• Community Wildlife Areas	27,605 sq. km.
• Wetlands	30,100 sq. km.

[Source: State of the Environment Report for Uganda, 1996]

1.2 *Responsible Authorities*

- National Parks - Uganda Wildlife Authority (UWA) in Ministry of Tourism
- Forest Reserves - Department of Forestry
- Wetlands - Ministry of Environment and Water Resources
- Wildlife Reserves - UWA
- Community Wildlife Areas - UWA
- Wild Heritage - UWA

1.3 *Invasive species in different areas*

• Water hyacinth	Wetlands
• Water lettuce	Wetlands
• Pepper mulberry	Forest Reserves
• *Lantana camara*	Miscellaneous lands and degraded rangelands
• *Oxalis latifolia*	Farmland/Agrosystems
• *Opuntia vulgaris*	National Parks
• *Digitarium* sp.	Agroecosystems
• Nile perch	Wetlands/Lakes/Rivers
• *Tilapia* sp.	Wetlands/Lakes/Rivers
• *Vossia* sp.	Wetlands/Lakes/Rivers
• *Striga asiatica*	Agroecosystems
• *Acacia* spp.	Degraded rangelands
• *Prostephanus truncatus*	Agroecosystems/Forests

1.4 *Monitoring on Invasive species*

- UWA monitors research and collects data in game parks, wild heritage sites, etc.
- Forest Department monitors invasive species in forests but no quantification is done
- Fisheries Research Institute and Department of Fisheries monitor wetlands
- Department of Crop Protection monitors agricultural land and agroecosystems

1.5 *Limitations*

- Analysis of Social and Economic Impacts of invasive species is not yet carried out in Uganda
- Conflict of Interests
- Difficulty in eradication/containment of invasive species especially in aquatic environments, e.g., Nile perch
- Limited availability and flow of information

1.6 *Policy/Legislation on Invasive Species*

Available in

- NEMA statute
- Plant Protection Act

Note: Implementation of statute/Act is limited

1.7 *The Way Forward for Uganda*

- Produce a report on the workshop
- Produce a documentary on invasive species, spearheaded by NEMA
- Write newsletter and articles
- Form an interdisciplinary committee on invasive species
- Propose and organize a national workshop on invasive species
- Identify research topics
- Network in the region (Africa) and subregion (Eastern Africa)
- Identify the Politician/Minister to spearhead an invasives crusade

1.8 *The Way Forward for Eastern Africa*

- Form a regional committee to work out the way forward for Eastern Africa
- Strengthen networking with EAFRINET playing a leading role

2. *Ecosystems Most Vulnerable to Invasive Species*

- Waterbodies and wetlands (aquatic systems)
- Agricultural lands and rangelands
- Urban centres
- Highway and railway sides
- Ecotones

Appendix 7

Working Group Report: The Role of EAFRINET in the Fight Against Invasive Species

Background: EAFRINET is a unit of BioNET INTERNATIONAL, a worldwide network of systematists. EAFRINET is a recently formed network of East African systematists and hopes to become more closely associated with ASARECA, the Association for Strengthening Agricultural Research in Eastern and Central Africa. However, the work of EAFRINET members is not limited to working on organisms in agricultural settings. Because EAFRINET is just getting started, participation in the meeting is one its first activities.

The working group affirmed that EAFRINET is keen on supporting efforts to control invasive species by, among other things, providing services in biosystematics (on a reciprocal basis). The following are ways that EAFRINET and its members might be able to assist in the invasive species effort:

1) Helping to identify suspected or confirmed invasive species, as well in some cases, as their possible control agents.
2) Helping to assemble and maintain regional databases that might help track and identify invasive species.
3) Gearing activities in research and training to assist the efforts of national, regional and global (e.g., Global Invasive Species Programme) invasive species programmes.
4) Contributing to the production of information booklets (e.g., A Handbook on Invasive Animals of East Africa).

Appendix 8

Working Group Report: Strengthening Research and Research Links on Invasive Species

There are needs for research in many broad areas relevant to invasive species. The group concentrated on which research issues are most urgent, how to build linkages to strengthen research, and the status of funding for such research projects.

1) Research issues that need to be addressed:

The status and distribution of different invasive species in the region
A checklist of invasive species
The mechanisms by which invasive species move (vectors)
The ecology and biology of invasive species
The ecological, economic and social impact of invasive species
Methods of control of invasive species, particularly biological control agents
Utilization of invasive species

2) The kinds of linkages that need to built and/or strengthened, to improve invasive species research:

A. Linkages between universities and research institutions.
B. Linkages between these institutions and stakeholders, users (e.g., farmers and management agencies)
C. Linkages between groups within the region, such as regional research institutions, including regional governmental institutions that can help influence national and regional policy.

3) Increasing or leveraging funding will require:

A. Sensitizing national governments about the need for more research on invasive species.
B. Building partnerships that bring together university students looking for a project on invasive species with land management agencies that have research questions and the invasive species to manage, but are often short on personnel.

4) Other suggestions:

A) Those involved in research on invasive species should also help develop a curricular materials that provide better training on issues related to invasive species.
B) The efforts to control invasive species would benefit greatly from a Research Institute on Invasive Species, which could serve as a focal point for research and service, helping to coordinate efforts across species and countries.

Appendix 9

Working Group Report: Coordinating Regional Efforts to Control Invasive Species

This group considered ways to foster effective coordination and communication on relevant invasive species issues within the region.

The group suggested a structure with the following components:

1) A Regional Steering Committee made up of one or two members from each country in the region (Ethiopia, Kenya, Tanzania and Uganda).
2) One (or two) institution(s) from each country that is responsible for leading the effort to fight invasive species. The Steering Committee members are likely to be drawn from these lead institutions. The group suggested the following institutions:
    a) Ethiopia – Environmental Protection Authority and the Institute for Biodiversity and Conservation Research
    b) Kenya – the National Museums of Kenya and the National Environment Secretariat.
    c) Tanzania – the National Environment Management Council.
    d) Uganda – the national Environment Management Authority.
3) Relevant national institutions (e.g., government departments, NGO's, CBO's) that work with the lead agency to implement the national strategy.

The group also suggested some mechanisms to help coordinate future activities:

1) Regular newsletters, with organizational efforts spearheaded by EAFRINET.
2) Regional Steering Committee meetings every two years, with the first to be held sometime around February 2000, in order to prepare for the GISP meeting in South Africa in September 2000.
3) Continuous communication and linkages via email.

Appendix 10

Working Group Report: Capacity Building and Implementation in Invasive Species Programmes

The group first addressed whether Eastern Africa had the capacity to control invasive species. The conclusion was that the capacity was present, but was as yet untapped.

The capacity has several dimensions, all of which require work: infrastructure, human resource capacity and financial capacity. The group focused on the last two of these.

Human resource capacity:
- is not necessarily lacking.
- must include many kinds of people who should not be overlooked. If capacity building aims very high, it misses the chance to involve many local people in the control efforts.
- should include people who can help identify invasive species, such as parataxonomists, who, with small amounts of training, can serve in rural areas as an early warning system.
- can be more efficient if a few key people are first trained who can then do secondary training at a local level.
- can be developed to undertake a range of management methods – e.g., physical, biological, chemical.

Financial capacity:
- needs to take into account both the costs of control/removal, as well as the benefits
- varies over the time course of an invasion. The financial needs can be significant early in the growth phase of an invasive, especially if communities are to be mobilised. However, such early investments end up saving large amounts if the invasive can be stopped before it reaches crisis proportions.
- can be increased by soliciting support from donors, but that support should be structured from the beginning so that it is phased out over time.
- must also be used in a way that increases equity across many parts of the region affected. This has the added benefit that it helps make the community better prepared and more willing to participate.
- must build in incentives to foster long-term participation by communities. For example, if the community plants trees that then belong to a forester, there is little incentive for the people to care for the trees. If the trees belong to the community, the community will be more likely to protect the trees.
- can be increased by looking for appropriate partnerships, with communities, businesses, donors, government management agencies, NGOs.
- can be increased if ways are found to utilize invasive species (e.g., making furniture from water hyacinth). However, it should be realized that such jobs are not permanent.

The group then considered some of the constraints that hinder efficient implementation of an invasive species programme.

Some bottlenecks in implementation of invasive programmes include:
- Different ministries that are responsible for management of invasives often have different attitudes, depending on their missions. For example, a forestry department might not be unhappy with an invasive tree that grows rapidly and provides firewood, but an environment ministry might be very unhappy with the same species if it outgrows and kills native trees and degrades the biodiversity of an area.
- Different institutions that might be committed to the same goal of fighting an invasive species often have different expertise, approaches, and capacities. The strategies and programmes of such institutions need to be harmonized.
- Controlling an invasive species must be seen as part of a longer-term effort to manage an area. For example, if an invasive plant is removed from an area, the job is not complete. If nothing else is planted, another invasive is likely to move in. Instead, control and/or removal of an invasive should be followed by a programme that plants native plants of value.

Appendix 11

SELECTED BIBLIOGRAPHIES ON INVASIVE SPECIES

We provide two working bibliographies on the biology and impact of invasive species. These should only be considered as starting points and make no claim to comprehensive coverage. They emphasize insects and other invertebrates, but include some coverage of all organisms. One bibliography focuses on Africa, while the other includes references from around the world (especially North America and the Pacific islands) as well as papers on theory and policy. These bibliographies were compiled by Scott Miller as byproducts of work for ICIPE funded by the government of Norway and the Hawaii Biological Survey funded by the John D. and Catherine T. MacArthur Foundation.

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Appendix 12

LINKS RELATED TO INVASIVE SPECIES

Because the Internet is constantly evolving, these addresses are subject to change, but were correct as of April 2000.

SPONSORS OF OUR WORKSHOP

CAB International <www.cabi.org>
Global Invasive Species Programme <http://jasper.Stanford.edu/GISP>
International Centre of Insect Physiology and Ecology <www.icipe.org>
International Development Research Centre <www.idrc.ca>
Kenya Wildlife Service <www.kenya-wildlife-service.org>
Makerere University <www.muk.ac.ug>
National Museums of Kenya <www.museums.or.ke>
United Nations Environment Programme <www.unep.org>
World Conservation Union (IUCN) <www.iucn.org>

OTHER ORGANISATIONS

Food and Agriculture Organization of the United Nations (FAO) <www.fao.org>
Invasive Species Specialist Group of IUCN <www.issg.org>

INTERNATIONAL CONVENTIONS

Biosafety Protocol <http://www.biodiv.org/biosafe>
CBD: Convention on Biological Diversity <http://www.biodiv.org>
CITES: Convention on International Trade of Endangered Species
<http://www.wcmc.org.uk/CITES/english/index.html>
CMS: Convention on the Conservation of Migratory Species <http://www.wcmc.org.uk/cms/>
IPPC: International Plant Protection Convention
<http://www.fao.org/WAICENT/FaoInfo/Agricult/AGP/AGPP/PQ/Default.htm>
RAMSAR: Convention on wetlands of international importance <http://iucn.org/themes/ramsar/>

INFORMATION RESOURCES

African biodiversity links (ICIPE) <http://www.icipe.org/environment/biolist.html>
AGRICOLA (U.S. National Agriculture Library citations database) <www.nal.usda.gov/ag98/ag98.html>
AGRIS (FAO literature citations database) <www.fao.org/agris>
Aquatic weeds (University of Florida) <http://aquat1.ifas.ufl.edu/welcome.html>
BIOCAT (CABI database of introductions and releases of insect natural enemies for controlling insect pests)
<www.bdt.org.br/bdt/irro/biocat>
BiologyBridge to Entomology (combined citations database from CABI, BIOSIS and Zoological Record)
<www.biologybridge.org>
Biological collections and biodiversity <http://www.keil.ukans.edu>
Bugwood network (agroforestry, pest management and related) <www.afae.org>
Ecoport (ecological database) <www.ecoport.org>
Global Plant and Pest Information System (FAO) <http://pppis.fao.org>
Hawaii Biological Survey (invasive species on Pacific islands) <www.hbs.bishopmuseum.org>
ICIPE bibliography on African entomology <http://www.icipe.org/icipedata/biodiversity/Africasearch.cfm>
ICIPE library <http://www.icipe.org/icipeLibrary/icipeLibrarySearch.html>
Introductions of aquatic species (FAO database)
<http://www.fao.org/waicent/faoinfo/fishery/statist/fisoft/dias/index.htm>
Invasive woody plants of the tropics research group <www.safs.bangor.ac.uk/iwpt/invasive1.html>
Library of Congress African literature citations <http://www.icipe.org/locnairobi>
MEDLINE (U.S. National Library of Medicine citations database) <www.nlm.nih.gov/locatorplus/>
Web sites related to biodiversity policy and law <www.bionet-us.org/website.html>

APPENDIX 13

ABBREVIATIONS AND ACRONYMS

AAU	Addis Ababa University, Ethiopia
ANC	African National Congress, South Africa
ASALS	Arid and Semi-Arid Lands
ASARECA	Association for Strengthening Agricultural Research in Eastern and Central Africa
CABI	CAB International
CBO	Community Based Organisation
CITES	Convention on Trade in Endangered Species
CMA	Conservation Management Area, Mauritius
CMS	Convention on Migratory Species
DIVERSITAS	An international umbrella programme coordinating biodiversity science activities
DREA	Department of Research and Environmental Affairs, Malawi
DWAF	Department of Water Affairs and Forestry, South Africa
EAFRINET	The Eastern African unit of BioNet International
EARO	Ethiopian Agricultural Research Organisation
EPA	Environmental Protection Agency, Ethiopia
ETS	Environmental Technical Services
EWCO	Ethiopian Wildlife Conservation Organisation
EWSS	Ethiopian Weed Science Society
FAO	Food and Agriculture Organisation of the United Nations
FIRI	Fisheries Research Institute, Uganda
FR	Forest Reserve, Tanzania
FRD	Foundation for Research Development, South Africa
GATT	General Agreement on Tariffs and Trade
GBA	Global Biodiversity Assessment (book)
GCA	Game Controlled Area, Tanzania
GEF	Global Environment Facility of the World Bank
GIS	Geographic Information System
GISP	Global Invasive Species Programme
GMO	Genetically Modified Organism
GPPIS	Global Plant Pest Information System of the FAO
GR	Game Reserve, Tanzania
GTZ	German Technical Agency
ha	hectare
IAP	Invading Alien Plant
IBC	Institutional Biosafety Committee, Kenya
IBRC	Institute for Biodiversity Research and Conservation, Ethiopia
ICIPE	International Centre of Insect Physiology and Ecology
IDRC	International Development Research Centre, Canada
IITA	International Institute of Tropical Agriculture
IPPC	International Plant Protection Convention
IUCN	World Conservation Union
KARI	Kenya Agriculture Research Institute
KEPHIS	Kenya Plant Health Inspectorate Service
KSTCIE	Kenya Standing Technical Committee for Imports and Exports
KWS	Kenya Wildlife Service
MAAIF	Ministry of Agriculture, Animal Industry and Fisheries, Uganda
MOA	Ministry of Agriculture, Ethiopia
MUK	Makerere University, Kampala, Uganda
MWF	Mauritian Wildlife Foundation
NARL	National Agriculture Research Laboratory, Kenya
NARO	National Agricultural Research Organization, Uganda

NBC	National Biosafety Committee, Kenya
NCA	Ngorongoro Conservation Area, Tanzania
NCAA	Ngorongoro Conservation Area Authority, Tanzania
NEMA	National Environmental Management Authority
NGO	Non Governmental Organisation
NIS	Non Indigenous Species
NMK	National Museums of Kenya
NP	National Park, Tanzania
NPV	Net Present Value
PA	Protected Area, Tanzania
PCPB	Pest Control Products Board, Kenya
PIP	Plant Import Permit
PRA	Pest Risk Analysis
RAMSAR	Convention on Wetlands of International Importance
R	Rand, South Africa
RDP	Reconstruction and Development Programme, South Africa
SBSTTA	Subsidiary Body on Scientific, Technical and Technological Advice, Convention on Biological Diversity
SCOPE	Scientific Committee on Problems of the Environment
SIDS	Small Island Developing States
SPS	Sanitary and Phytosanity
TANAPA	Tanzania National Parks
TDS	Total Dissolved Salts
TMS	Table Mountain Sandstone
TPRI	Tropical Pesticides Research Institute
UK	United Kingdom
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
URV	Unit Reference Value
USA	United States of America
UWA	Uganda Wildlife Authority
WfW	Working for Water Programme, South Africa
WTO	World Trade Organisation