
# AN ECOLOGY RESEARCH STRATEGY FOR WORKING FOR WATER FINAL REPORT

**Produced by:**
Department of Environmental Science
Rhodes University
P.O. Box 94
Grahamstown 6140
South Africa

**Produced for:**
National Working for Water Programme
Private Bag X4390
Cape Town 8000
South Africa

**JULY 2002**

## ABSTRACT

This report emanates from a contract between the Department of Environmental Science at Rhodes University and the Department of Water Affairs and Forestry's Working for Water programme. The purpose was to develop an ecology research strategy based on the identified research gaps and priorities of relevance to the WfW Programme. This report contains a hierarchical list of *research priorities*, with a f*act sheet* for each priority research project.

An annotated database of literature on invasive alien plants, with keywords and searchable fields, and a focus on literature produced in South Africa since 1980 was produced as part of this study and is available on CD, as is an annotated database of *experts* in the field of invasive alien ecology research.

## ACKNOWLEDGEMENTS

We would like to thank all the people listed in Appendices 1 and 3 who provided inputs and made this report possible. Our special appreciation to Environmentek, CSIR for providing the venue for the workshop on 7 February, and to Brian van Wilgen and Dave le Maitre who arranged the venue, and provided valuable support throughout. We would like to thank our student assistants (Nomazibulo Ndikinda, Kelly Scheepers, Jamie Pote and Matthew Gibb) for their able support; we trust they got more than just financial benefits from participating. Several members of Working for Water's ecology research panel provided valuable additional comments, which helped a lot to improve the document. We would like to thank Working for Water for financing this study.

Saskia Fourie, Christo Fabricius and Charlie Shackleton. Grahamstown, July 2002

## TABLE OF CONTENTS

**List of Tables**

**List of Figures**

# SUMMARY


## INTRODUCTION AND TERMS OF REFERENCE:

The Department of Environmental Science at Rhodes University was commissioned to develop an ecology research strategy for the WfW Programme. The Terms of Reference were:

- Review the existing knowledge base with regard to the ecological impacts of alien invading plants (IAPs).
- Develop a research strategy based on the identified gaps of relevance to the WfW Programme.
- Produce a hierarchical list of research priorities.
- Compile the approximate budget requirements and broad research approach for the individual high priority research projects.
- Compile an approximate time schedule for the execution of individual high priority research projects.

## OUTPUTS:

- A hierarchical list of *research priorities*, with a f*act sheet* for each priority research project, containing a) project title; b) project description; c) research objectives; d) broad research approach; e) time line; and f) provisional budget.
- An annotated database of literature on invasive alien plants, with keywords and searchable fields, and a focus on literature produced in South Africa since 1980, but not excluding earlier or relevant international literature. This database has been compiled in Reference Manager and is available on CD.
- An annotated database of *experts* in the field of invasive alien ecology research, with full contact details, on CD. This database (in conjunction with the DWAF service providers database), can be drawn upon to select individuals and organizations who can undertake the research projects listed in this report.

## METHODOLOGY:

The following approaches were used to produce the outputs:

A. A database of relevant literature was compiled.
B. A workshop with experts in the field in invasive ecology was convened.
C. A draft workshop report was produced, and circulated to specialists for review.
D. A report with a full list of research priorities was produced.
E. Top research priorities were selected.

**DATABASE:**

A database was compiled of all relevant literature, drawing on electronic databases, private reference collections, books, journals, reference lists of publications and books, searches for theses and dissertations. The references were compiled in the 'Reference Manager' software package, and consists of 1290 records, with keywords and searchable fields.

An analysis of the database indicates that there is considerable information on fire and clearing/control methods relating to invasive alien plants, and a moderate amount of information on the rate of spread and extent of invasion.

The highest number of entries are on *Acacia*, followed by those on *Pinus*. Entries on the forest biome are most numerous, although this is attributed to the fact that both indigenous and non-indigenous forests were included in the keyword 'forest'. Entries on fynbos are also very numerous.

**WORKSHOP:**

One of the steps in developing the strategy was to convene a workshop with specialists on the ecology of invasive plant species in South Africa. The main purpose of this workshop was to identify gaps in the field of invasive ecology, and to prioritise these to develop the research strategy.

Six main groups of research topics were identified:

- Protocols and guidelines for best practice (including the use of fire and herbicides).
- Rehabilitation, restoration and 'ecosystem repair'.
- Predicting the invasive potential of invader species.
- Local ecological impacts of alien plant invasions (e.g. on soil, water, biodiversity, and fire ecology).
- Regional ecological impacts of alien plant invasions.
- Alternative strategies to cater for human needs.

Research gaps and projects within each of these groups were then identified and a draft report was compiled, which summarized the results of the workshop.

**REVIEW PROCESS:**

The proceedings of the workshop and initial research in the form a draft report was circulated to eighteen other specialists in the field of invasive plant ecology. Their input was incorporated into a report detailing the full list of research priorities.

**PRIORITY PROJECTS:**

Panel members were asked to select and rate in order of importance, 10-15 priority projects from the lists of projects. The six projects with the highest ratings were selected as priority projects, as their ratings clearly separated them from the remainder of the projects, which had substantially lower ratings. These are the following:

1. Determine the criteria by which repair is measured, i.e. clarify what are the aims of repair in different contexts, and when repair can be considered effective.
2. A practical decision support system is required to help with determination of priorities at different scales and management levels.
3. The use and adaptation of international guidelines and research results to predict potential invasive species, to develop a protocol for dealing with the importation of plants into South Africa.
4. Areas for clearing should be prioritised.
5. The direct impacts of aliens on fire severity and behaviour.
6. The extent of invasion, rate and mechanisms of spread, of IAPs.

Preliminary budgets and timeframes were drawn up for the priority projects.

**DISCUSSION:**

A logical sequence has emerged from priority list. Firstly, there is a need for protocols to prevent the entry and further spread of invasive plants, using existing information. Secondly, there is a need for a prioritisation of areas to be cleared at a national level. Thirdly, once the main areas of focus have been decided upon, a decision support system needs to be developed, which informs and assists managers in deciding how to deal with their areas. Fourthly, and rated most highly, is the rehabilitation of cleared areas – this is seen as an essential part of clearing actions. The last two projects are linked to, and will play a role in informing aspects of the first four projects.

**FINAL RECOMMENDATIONS AND WAY FORWARD:**

1. The literature and expert databases should be regularly updated. This should be undertaken by the organisation contracted to provide an advisory service to WfW.
2. DSS systems should be kept up to date and adapted in an iterative manner.
3. This report and database should be circulated to WfW and other managers in relevant departments, research institutions and people working in the field of invasive plants.

4. A system should be put into place to track the implementation of the projects recommended in this report. This should ideally be undertaken by the organisation that acts as an advisory service to WfW.
5. It is envisaged that the research priorities will change with the implementation of the research projects listed in this document, as well as other research implemented in the country. This report should therefore be reviewed every 5 years, when other research priorities may be put forward.
6. To introduce an additional level of flexibility, 10% of the WfW research budget should be set aside for innovative *ad hoc* projects that have not been listed in this report, subject to approval by the WfW panel.
7. WfW should require that the results of any research projects awarded by them be communicated to the public; this should be stipulated in tender documents.

# 1. INTRODUCTION

The Working for Water (WfW) Programme's Research Management Unit is focusing on five themes in support of the Programme achieving its long term goal of managing the spread of alien invading plants. These are:

- Social Development
- Resource Economics
- Hydrology
- Ecology
- Biological control.

The Department of Environmental Science at Rhodes University has been commissioned to develop an ecology research strategy for the WfW Programme. The following form the Terms of Reference for the research strategy:

- Review the existing knowledge base with regard to the ecological impacts of alien invading plants (IAPs).
- Develop a research strategy based on the identified gaps **of relevance** to the WfW Programme.
- Produce a hierarchical list of research priorities.
- Compile the approximate budget requirements and broad research approach for the individual high priority research projects.
- Compile an approximate time schedule for the execution of individual high priority research projects.

The Terms of Reference stated that the following principles must be followed in developing a research strategy:

- The proposed ecological research must result in measurable improvements, in the short- and long-term, in the control of alien invasive plants in South Africa.
- The research must be readily feasible within the WfW budget, and at least some results must be accessible and applied within the short term.
- The research must be conducted in such a way that a strong team of young people is mentored and trained in ecological science.

## 2. OUTPUTS

The following outputs have been produced:

- An annotated database of literature on invasive alien plants, with keywords and searchable fields, and a focus on literature produced in South Africa since 1980, but not excluding earlier or relevant international literature. This database has been compiled in Reference Manager and is available on CD.
- A hierarchical list of *research priorities*, with a f*act sheet* for each priority research project, containing a) project title; b) project description; c) research objectives; d) broad research approach; e) time line; and f) provisional budget.
- An annotated database of *experts* in the field of invasive alien ecology research, with full contact details, on CD. This database (in conjunction with the DWAF service providers database), can be drawn upon to select individuals and Institutions who can undertake the research projects listed in this report.

## 3. METHODOLOGY

The following methods were employed to produce the outputs listed in Section 2.:

A. A database of relevant literature was compiled.
B. A workshop with experts in the field in invasive ecology was convened.
C. A draft workshop report was produced, and circulated to specialists for review.
D. A report with a full list of research priorities was produced.
E. Top research priorities were selected.

These methods will be discussed in Sections 4 to 8.

## 4. SECTION A: DATABASE

### 4.1 METHODS

A database was compiled of all relevant literature, drawing on electronic databases, private reference collections, books, journals, reference lists of publications and books, searches for theses and dissertations. The list of declared weeds and invader species listed in Table 3, Regulation 15, Conservation of Agricultural Resources Act, 1983, Act no. 43, as published in Government Notice No. R. 1048 of 25 May 1984, and amended by Government Notice No. R. 2687 of 6 December 1985 (http://www.nda.agric.za/docs/Act43) was used. All the

invader species listed in this table were used as keywords in searching the databases. Additional keywords that were used included:

- Alien plant
- Invader plant
- Alien invader plant species
- Invasive plants.

The following databases were searched:

- Ebsco Host
- Sabinet
- Science Direct
- Biological Abstracts
- WaterLit
- SciBase
- PPRI databases in Stellenbosch
- Electronic database at NBI, Kirstenbosch
- Electronic database at CSIR, Stellenbosch

Private collections of Mark Robertson, Timm Hoffman, Dave Richardson and Sue Milton were also searched and relevant literature added to the database.

The reference lists of articles and prominent books (e.g. “The ecology and management of biological invasions in southern Africa” and “The ecology of fynbos”) were searched, and relevant references added to the database. These references were then obtained from various journals (South African Journal of Science, Nature, South African Journal of Botany, Australian.Journal of Botany, Journal of Ecology, Bothalia etc.), and their reference lists were searched and relevant references added to the database.

The references were compiled in a software package called “Reference Manager”, and consists of 1290 entries, with keywords and searchable fields. The database focuses on literature published since 1980, but does not exclude important literature from before this date.

This database was analysed according to species, biomes and subject entries, and the results are presented in Section 4.2.

## 4.2 RESULTS OF DATABASE

The database was analysed to determine the number of entries per species, biome and genus, as percentages of the total number of entries. These are represented in Figures 4.2a-c.

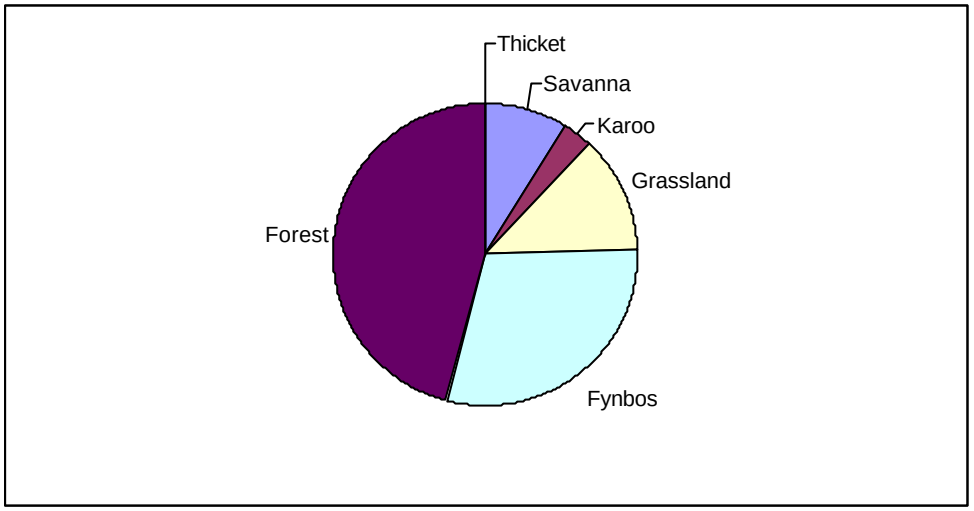


**Figure 4.2a. Proportion of publications in database, by biome**

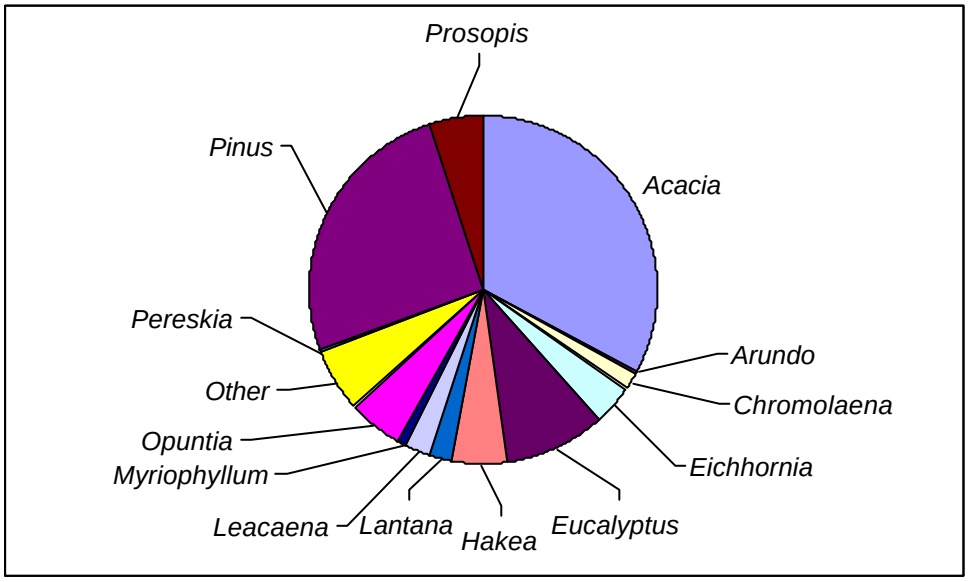


**Figure 4.2b. Proportion of publications in database, by genus**

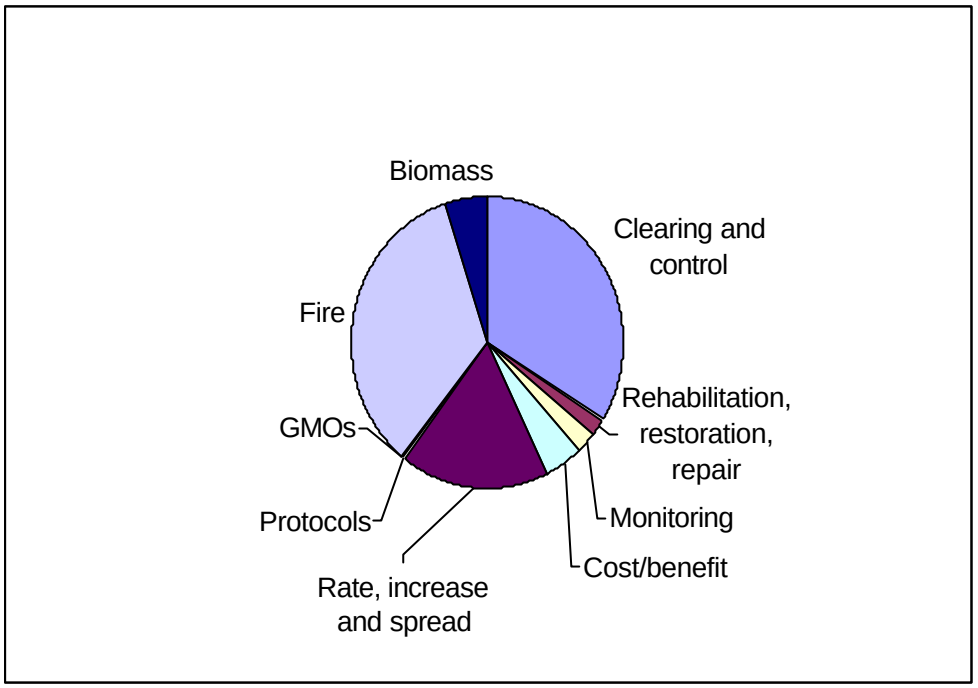


**Figure 4.2c. Proportion of publications in the database, by subject**

The above analysis indicates that there is considerable information on fire and clearing/control methods (see Figure 4.2c), relating to invasive alien plants, and a moderate amount of information on the rate of spread and extent of invasion.

The highest number of entries are on *Acacia*, followed by those on *Pinus*. Publications on genera like *Pereskia* and *Chromolaena* are alarmingly sparse, considering the concern about these species (see Figure 4.2b).

Entries on the forest biome are most numerous, although this may be attributed to the fact that both indigenous and non-indigenous forests were included in the keyword 'forest'. Entries on fynbos are also very numerous. There were no entries on thicket, but this is because it is only a recently recognised biome (see Figure 4.2a).

## 4.3 LIMITATIONS OF THE DATABASE

The following are considered to be limitations of the database:

- For many of the entries only titles of the references were available, and it was therefore not possible to assess the content of the publication.
- Detailed topics did not form part of the original keywords when electronic searches were conducted, e.g. rehabilitation and genetically modified organisms were not included in the

original search criteria when the database was populated. The lack of entries on these subjects in this database might therefore not necessarily reflect a paucity of information on the subject.

- The analysis nevertheless provides an objective view of the main strengths and weaknesses in available information.

## 5. SECTION B: WORKSHOP

One of the steps in developing the strategy was to convene a workshop with specialists on the ecology of invasive plant species in South Africa, to obtain their ideas, benefit from their experience and draw on their theoretical and practical knowledge.

The workshop was held at the CSIR offices in Stellenbosch on 5 February 2002, to deliberate the research priorities on the "ecology" research theme. The main purpose of this workshop was to identify gaps in the field of invasive ecology, and to prioritise these to develop the research strategy.

The following people attended this workshop:

- William Bond (University of Cape Town)
- Carina Cilliers (Plant Protection Research Institute)
- Richard Dean (University of Cape Town)
- Christo Fabricius (Rhodes University, facilitator)
- Saskia Fourie (Rhodes University).
- Pat Holmes (Cape Ecological Services)
- Ahmed Khan (Working for Water)
- David le Maitre (CSIR)
- Ian Macdonald (International Environmental Consultant)
- Christo Marais (Working for Water)
- Sue Milton (University of Stellenbosch)
- Nomhlanhla Mkize (Working for Water)
- Cliff Moran (Independent consultant and member of Working for Water Research panel)
- Roy Siegfried (member of Working for Water Research panel)
- Brian van Wilgen (CSIR)

The above people are hereafter referred to as "the panel". Contact details of the above people are provided in Appendix 1.

### 5.1 WORKSHOP PROCEDURE

The following step-wise procedure was followed:

1. Participants were asked to write three key **problems**, related to the ecology of biological invasions, on cards.
2. These were pasted onto a wall and sorted into **groups** of related issues. These groups formed the main research topics. Six main groups of research topics were identified:
    - Protocols and guidelines for best practice (including the use of fire and herbicides).
    - Rehabilitation, restoration and 'ecosystem repair'.
    - Predicting the invasive potential of invader species.
    - Local ecological impacts of alien plant invasions (e.g. on soil, water, biodiversity, and fire ecology).
    - Regional ecological impacts of alien plant invasions.
    - Alternative strategies to cater for human needs.
3. For each group of research topics, participants were then asked to define an **acceptable future condition**, related to that topic.
4. The next step was to list the **obstacles** that are preventing that future condition from being realized.
5. **Research gaps** in relation to each topic were then highlighted.
6. The final step was to identify **research projects or programmes** that would assist WfW in overcoming each of the obstacles and fill the gaps.

A report (see Appendix 2) was compiled, which summarized the results of the workshop.

## 6. SECTION C: REVIEW PROCESS

The proceedings of the workshop and initial research in the form a draft report (see Section 5) was circulated to eighteen other specialists (see Appendix 3) in the field of invasive plant ecology (other than panel members), and the following people provided input and comment into the production of the report and databases:

- Mark Anderson (Department of Agriculture, Land Reform, Environment & Conservation)
- Japie Buckle (Department of Water Affairs)
- Richard Cowling (University of Port Elizabeth)
- Jeremy Goodall (PPRI)
- Martin Hill (Rhodes University)

- John Hoffman (University of Cape Town)
- Timm Hoffman (University of Cape Town)
- Klaus Kelner (University of Potchefstroom)
- Peter le Roux (Independent Consultant)
- Stefan Neser (PPRI)
- Terry Olckers (PPRI)
- Elsabe Powell (Directorate Conservation and Environment, Kimberley)
- Dave Richardson (University of Cape Town)
- Alan Urban (PPRI)
- Helmut Zimmerman (PPRI)

Their input was incorporated into a report detailing the full list of research priorities, which is presented in Section 7.

# 7. SECTION D: RESEARCH TOPICS AND PRIORITIES

Research priorities were grouped into six broad categories:

1. Protocols and guidelines for best practice;
2. Methods and approaches to enable cost effective repair;
3. Predicting the invasive potential of invasive plants;
4. The local ecological impact of plant invasions;
5. The regional ecological impacts of biological invasions;
6. Alternative species and strategies to cater for human needs.

These are initially listed in no particular order of importance – prioritisation is reflected in Section 8 of the document.

## 7.1 CATEGORY 1: PROTOCOLS AND GUIDELINES FOR BEST PRACTICE

Protocols should be developed for every stage of the invasive control and treatment process. In particular, early decision protocols, relating to decisions such as whether or not to clear, where to clear, and whether to use mechanical, chemical or biocontrol agents, or a combination of these, should form part of the protocol.

### 7.1.1 Research Projects

a) *Areas for clearing should be prioritised*. A set of priorities for dealing with the alien plant problem in South Africa, based on current and potential future impacts of aliens on the

biophysical environment, should be developed. An analysis of this kind must inform WfW management where they should be concentrating their clearing efforts.

b) *A practical decision support system* is required to help with determining priorities at different scales and management levels. This system should:
    - Integrate existing information;
    - Develop or synthesize existing information on the costs and benefits of the various control options, e.g. chemical, mechanical and biological[1];
    - Offer various suites of options, or permutations of strategies, to optimally control invasive alien plants (IAPs). These options need to be tested in the field;
    - Enable managers[2] to choose optimum methods at each operational scale (e.g. at the local scale taking into account issues such as reducing pollution, erosion and disturbance, etc.; at coarser scales, look at landscape change, and at still coarser scales consider carbon sequestration, catchment management and large-scale dispersal of IAPs).

    - Such a system could take various forms: e.g. a checklist, multi-criteria decision support systems, as appropriate to the scale and management level.
    - A vital requirement is that managers need to participate fully in identifying needs, developing and researching the system and in field-testing to gain their acceptance.
    - A structured capacity building programme must be an integral part of this project and will aim to build skills (including the understanding of the principles of restoration ecology, disturbance, biological control, etc.) to ensure that managers use the system effectively.

c) *The optimal use of herbicides, and their long term ecological impacts* on soil, plant and water resources should be investigated. This includes the effect of especially non-selective herbicides, and the impact of herbicides on biological agents. This project can be viewed as a subset of (b) above.

d) *The optimal use of fire* in the management of IAP's needs to be investigated and incorporated into best practice guidelines.

e) The clearing of one IAP can create a niche for re-invasion by another IAP. Research is needed to predict this, and to find methods of managing this.

### 7.1.2 Research projects overlapping with other themes

The following projects were identified by specialists, but were subsequently regarded as peripheral to the ecological theme. They overlap with other themes such as resource

[1] This project was highly rated by some specialists, while some felt it was not an ecological research priority. It is, however, needed to inform the decision support system, and was therefore kept as part of this section.

[2] "Managers" as referred to in this project is not limited to WfW managers only, but has a wider application, e.g. Municipalities, the relevant personnel in Catchment Management Agencies and Water Services Institutions, Nature Conservation Departments, etc.

economics or biological control, but are also not central to those themes, and might therefore not be listed at all.

a) *The development of sterile strands of commercially important IAPs*, and the development of core competence in plant breeding and genetic manipulation applied to IAPs.
b) *Information on the optimal use of biological control agents* that effectively control IAPs yet retain adult plants for consumptive use (e.g. firewood and construction materials), needs to be made available to managers.
c) *Information about 'reserve populations' of IAPs* that should be maintained, to allow biocontrol organisms to survive and continue their functioning, should be made available or compiled.

### 7.1.3 Priority Ecosystems

All ecosystems were considered equally important. There may be lack of experience and research in some vegetation types or biomes, but these gaps would become clearer once the projects listed in Section 8 have been completed. Possible priority systems could be riparian zones and ecotones, including the repair (see Section 7.2) of these systems to reduce their probability of being re-invaded.

## 7.2 CATEGORY 2: COST EFFECTIVE REPAIR (RESTORATION)

In this report the term "repair" will be used instead of other popular terms such as "rehabilitation" or "restoration", as the latter terms are more limited in their definitions. *Restoration* is defined as the process of returning an ecosystem back to its original condition. In most cases complete restoration is not achievable, and the term *rehabilitation* is used. (Bradshaw, 1984; Westman, 1991). This describes a process of converting an ecosystem to a new, better condition, which is not its original condition. *Repair* as it is used in this report is a broader term, describing the process of re-establishing non-invasive vegetation on a previously invaded system, and creating a new state that is resilient to re-invasion and erosion. Repair could therefore include either restoration or rehabilitation.

A predictive understanding of the implications and consequences of control and management actions on the repair of ecosystems needs to be developed and conveyed to managers.

### 7.2.1 Research projects

a) *Identify the stage or level of infestation of an invaded area when ecosystem repair should be initiated or assisted*, i.e. at what level of infestation is the ecosystem not able to repair itself.

b) *Establish criteria and rules to prioritise* areas for rehabilitation.

c) *Identify the appropriate levels of repair*. Determine the criteria by which the success of restoration can be measured, in relation to the aims of post-repair land use. This will include a monitoring programme to evaluate the success and appropriateness of control actions.

d) *Assess the effect of environmental conditions* on the success of ecosystem repair.

e) *Identify the most appropriate species and strategies to use for repair*, under various environmental conditions at a local scale. Develop tailor-made, context-specific restoration plans that will in many cases require empirical research, including field trials.

f) *Determine the most cost-effective options* for ecosystem repair under various goals and contexts.

g) *Assess the effect of IAP control methods* (including fire and herbicides) on the success of post-control ecosystem repair.

h) *Identify the impact of herbicides*, especially non-selective herbicides, on the re-establishment of natural vegetation.

### 7.2.2 Priority geographic regions, ecosystems and species

**Table 7.2.2: List of priority geographic regions, ecosystems and species for repair** (the priority order of the regions, ecosystems and species will vary according to the specific project being undertaken).

| Priority geographic regions | Priority ecosystems for repair | Priority species |
|---|---|---|
| • Western Cape<br>• Eastern Cape<br>• Drakensberg<br>• South Mpumalanga<br>• KwaZulu Natal<br>• Northern Cape<br>• North West<br>• Gauteng | • Wetlands, riparian zones, ephemeral rivers, ephemeral pans and aquatic systems<br>• Fynbos, especially threatened vegetation types like Sand Plain Fynbos and Renosterveld<br>• Mesic savannas<br>• High altitude sour grassland<br>• Sweet grassland<br>• Forests and thicket | • *A. mearnsii* (black wattle)<br>• *A. dealbata* (silver wattle)<br>• *A. decurrens* (green wattle)<br>• *A. saligna* (Port Jackson willow)<br>• *A. cyclops* (Rooikrans)<br>• *Chromolaena odorata* (triffid weed)<br>• *Eichhornia crassipes* (water hyacinth)<br>• *Lantana camara* (tickberry)<br>• *Pereskia aculeata* (Barbados gooseberry)<br>• *Prosopis* (mesquite)<br>• Any dense alien stand that replaces indigenous vegetation is a priority for repair, including gums, pines and hakeas. |

## 7.3 CATEGORY 3: PREDICTING THE INVASIVE POTENTIAL OF INVADERS, BASED ON PLANT AND ENVIRONMENTAL CHARACTERISTICS

There are two aspects to this:

a) Predicting the rates of spread of recognized alien invasive species.
b) Identifying potentially alien invasive species that are currently not problem plants.

### 7.3.1 Research projects

a) Research is needed to *assess and adapt international guidelines* and research results to predict potential invasive species and develop a protocol for dealing with the importation of plants. This project has two subsets:
   - *Determine the invasive potential of genetically modified versions of non-invasive organisms*, and the synthesis of protocols for the importation of GMOs.
   - *Develop early warning systems* to rapidly identify potential IAPs.
b) *Develop a quantitative understanding of the predicted extent of invasion* of IAPs under different scenarios of intervention, e.g. zero control, minimal control and full-scale control respectively, based on an understanding of their mechanisms and rate of spread.
c) *Develop an understanding of the effects of extreme climatic / episodic events* as catalysts for invasion, e.g. extreme rainfall, extreme temperatures, abnormally hot or frequent fires and changes in the frequency of episodic events.
d) *Determine the implications of the current climate change predictions for biological invasions*, to gain a better understanding of which biomes and/or vegetation types would become most vulnerable to invasions as the climate changes.
e) Develop an understanding of the possible synergistic effects between different IAPs. For example, the presence of aliens along riverbanks results in decreased flooding intensity, which prevents the scouring of *Myriophyllum.*

### 7.3.2 Important recognized species which require more research

a) *Chromolaena odorata* (triffid weed)
b) *Arundo donax* (Spanish reed)
c) *Prosopis* (mesquite)
d) *Acacia melanoxylon* (blackwood)
e) *Myriophyllum aquaticum* (parrots feather)
f) Grasses like *Penisetum setaceum* and European C3 grasses
g) *Pereskia aculeata* (Barbados gooseberry)
h) *Cestrum laevigatum* (inkberry)
i) *Solanum mauritianum* (bugweed)
j) *Caesalpinia decapetala* (Mauritius thorn)

k) *Mimosa pigra* (Giant sensitive plant)

l) Although *Acacia* and *Pinus* spp. are regarded as priorities, the work that has been done on these species has to be summarized and collated before new projects are initiated for them.

## 7.4 CATEGORY 4: THE LOCAL ECOLOGICAL IMPACTS OF ALIEN PLANT INVASIONS

This session is concerned with impacts at a local scale, i.e. a single land management unit that usually requires a resolution of 1:50 000 or less to study or record.

### 7.4.1 Research gaps

a) Investigate the *direct impacts of aliens on fire severity and behaviour*.

b) Determine the *role of fire in the increased spread of IAPs*.

c) Assess the *impact of IAPs on soil properties of invaded systems*, especially those with nutrient poor soils.

d) Determine the *impact of IAPs, clearing and alien-fuelled fires on fauna*, notably mammals, birds and freshwater invertebrates.

e) Determine the *impacts of fire on regeneration and management* of ecosystems (e.g. grasses invading Succulent Karoo, where a fire can severely impact the indigenous vegetation).

f) Determine the *rates of stump reduction and decay* of mechanically controlled IAPs.

g) Investigate the *impacts of aquatic weeds on water quality and quantity, water delivery and biodiversity*.

h) Determine the impact of invasions on *biodiversity*.

i) Investigate the *positive ecological effects* of IAPs.

### 7.4.2 Priority ecosystems and species

**Table 7.4.2 List of priority ecosystems and priority species for local ecological impacts of IAPs repair** (the priority order of the regions, ecosystems and species will vary according to the specific project being undertaken).

| Priority ecosystems | Priority species |
|---|---|
| Savannas<br>Grasslands<br>Rivers<br>Road verges and other migration corridors (ecotones)<br>Fynbos<br>Wetlands<br>Coastal forests (in KwaZulu Natal and Wild Coast) | *Prosopis*, and its effects on groundwater and grazing<br>*Eichhornia crassipes* (water Hyacinth)<br>*Chromolaena odorata* (triffid weed)<br>*Pereskia aculeata* (Barbados gooseberry)<br>*Lantana camara* (tickberry)<br>*Cestrum laevigatum* (inkberry)<br>[Although *Acacia* and *Pinus* spp. are regarded as a priority, the work done on these species has to be summarized and collated before new projects are initiated for them]. |

## 7.5: CATEGORY 5: THE REGIONAL ECOLOGICAL IMPACTS OF BIOLOGICAL INVASIONS

This section deals with impacts at a scale coarser than 1:50 000. Research that can feed into larger scale planning is important at this scale. Ecosystems and species of importance were not singled out, as impacts at this level are not limited to certain species and ecosystems.

### 7.5.1 Research gaps

a) Determine the *impacts of IAPs on water quality*.
b) Determine the *impacts of IAPs flood severity*.
c) Determine the *impacts of IAPs on mobile wildlife* (e.g. bird migrations, severing of corridors and landscape linkages).

### 7.5.2 Research projects overlapping with other themes

The following research priorities were identified during the workshop, but were subsequently thought to be overlapping with the resource economics theme; they are therefore peripheral to the ecological theme.

a) *The impacts of IAPs on economically valuable resources* like grazing and the flower trade.
b) *The costs and benefits of eliminating IAPs* in the context of carbon sequestration, including the effect of fire severity on soil organic matter.
c) *The impacts of IAPs on tourism potential*, including adventure tourism (e.g. fly-fishing and rafting) and landscape amenity.

### 7.6 CATEGORY 6: ALTERNATIVE SPECIES AND STRATEGIES TO CATER FOR HUMAN NEEDS

All the research projects in this section were listed during the workshop, but were subsequently classified as overlapping with the social or resource economics theme.

#### 7.6.1 Research projects

a) *Identify appropriate non-invasive replacement species*.
b) *Alternative strategies to minimise or eliminate the invasive potential of economically useful IAPs,* e.g. sterile hybrids, non-invasive choices, biocontrol, planting guidelines.
c) *The development of guidelines and protocols for recommending non-invasive species* to farmers, tree growers and rural communities.
d) *Research into local knowledge* about appropriate alternative species.
e) The effects of clearing on *urban and rural livelihoods*.

#### 7.6.2 Priority species

a) *Acacia mearnsii, A. dealbata and A. saligna*– fuel (especially in colder areas of South Africa) and construction
b) *Eucalyptus* – bee keeping and construction
c) *Prosopis* – fodder, furniture, construction
d) *Psidium guajava* - fruit
e) *Opuntia ficus-indica* – fruit

## 8 SECTION E: PRIORITY PROJECTS

### 8.1 SELECTION OF PRIORITY PROJECTS

Panel members were asked to select and rate in order of importance, 10-15 priority projects from the lists of projects presented in Section 7. The projects that were selected by members of the panel were weighted (e.g. each no. 1 project from each panel member was given a value of 10, each no. 2 project a value of 9, etc., and these values were added to determine the projects with the highest ratings – see Appendix 4). The six projects with the highest ratings were selected as priority projects, as their ratings clearly separated them from the remainder of the projects, which had substantially lower ratings. These projects are presented in Section 8.3.

The research team felt that a limited number of projects should be listed as priorities, as the budget for implementing the recommendations of this report was limited. It is also more

difficult and costly to administer a large number of small projects, and each has less impact in terms of national strategy.

## 8.2 BUDGETS OF PRIORITY PROJECTS

Preliminary budgets were drawn up for the priority projects, and the following assumptions were made in compiling these budgets:

1. The consultancy rates that were used to calculate fees are based on the WfW guidelines. Three levels of rates were used, based on WfW rule of '17.5c for every R 100 earned per annum':
   - Level 1 (Expert): R350/h, based on an annual salary of R 200,000
   - Level 2 (Technical 1): R175/h, based on an annual salary of R 100,000
   - Level 3 (Technical 2): R135/h, based on an annual salary of R 75,000
2. Institutional overheads are built into the salaries.
3. We assume that the maximum distance between project site and the institutional base is 1000 km.
4. The cost of travel was calculated as the largest of R 2.43 / mm, or R 3000 per site visit.
5. External expert reviews will cost three person-days per project.

## 8.3 PRIORITY RESEARCH PROJECTS

The following projects are presented in order of priority rating.

### 8.3.1 Determine the criteria by which repair is measured, i.e. clarify what are the aims of repair in different contexts, and when repair can be considered effective (35[3])

***Objective:*** Evaluate the effectiveness of ecosystem repair after invasive alien control

***Motivation:*** It is vital that productive ecosystems, compatible with the goals of post-clearing land use, should replace alien-dominated ecosystems after control efforts, to prevent ecosystem degradation and alien re-invasion. Research is needed to assess when repair intervention is required, what the goals of repair should be and what criteria should be used against which to measure repair efficiency. This information is required for different ecosystems and disturbance levels, as each vegetation type may differ in terms of their habitats that are most sensitive or important. Different histories of invasion also result in different levels of ecosystem change and require different. Thus these criteria should be compiled by region, in order to direct repair research priorities.

[3] This number behind the priority project refers to the matrix rating that the projects received from the panel members

Repair will be most likely to succeed if the goals of post-clearing land use are clear. Managers need to know how far they are expected to go, and the establishment of suitable criteria is therefore very important. Monitoring programmes should thus be established as part of project, in order to evaluate the success and appropriateness of control actions.

***Broad research approach (Biome and species independent):***

1. Collation of internationally and nationally accepted criteria and measures.
2. Conduct a workshop, attended by 15 people for 2 days.
3. Collate the workshop report.
4. Field testing should take place by WfW managers, and modification of the report and the criteria should be an ongoing process.

***Table 8.3.1 Preliminary budget for repair criteria***

| | **Days** | **Amount** |
|---|---|---|
| **Staffing** | | |
| Expert1 | 55 | R 154,000.00 |
| Technical2 | 15 | R 21,000.00 |
| Technical3 | 0 | R 0.00 |
| | | |
| External review | 3 | R 8,400.00 |
| | | |
| **S&T** | | |
| Subsistence | 40 | R 14,000.00 |
| Travel | R 60,000.00 | R 60,000.00 |
| | | |
| **Office** | | |
| Communication | | R 5,000.00 |
| General | | R 0.00 |
| | | |
| **Capital** | | R 0.00 |
| | | |
| **Subtotal** | | R 262,400.00 |
| | | |
| **Contingency** | 10% | R 26,240.00 |
| | | |
| **TOTAL** | | **R 288,640.00** |
| | | |
| **Time line** | 18 months | |

### 8.3.2 A practical decision support system is required to help with determination of priorities at different scales and management levels (30)

***Objective:*** Develop protocols and guidelines for best practice

***Motivation:*** It is important to use all past and new monitoring and research findings to inform management. Existing information needs to be integrated into a practicable decision support system to aid managers in deciding how an area should be dealt with or cleared. The system will enable managers to choose optimum methods or various suites of options to optimally control IAPs at each operational scale. Part of this process should be to develop or synthesize existing information on the costs and benefits of the various control options, i.e. chemical, mechanical and biological (this overlaps with the resource economic theme).

The development of multi-criteria decision support system (DSS) could take various forms: e.g. a checklist, decision tree, rule-based model, or computer operated expert system as appropriate to the needs at any given scale and level of management. It is important that these products should be developed in a way, and produced in a form, that invites their use by managers.

A structured capacity building programme will be an integral part of this project and will aim to build capacity and skills (including the understanding of the principles of repair ecology, disturbance, biological control, etc.) to ensure that the decision support system is used effectively by managers.

This system should be a tool that accommodates all relevant information, can readily be updated, keeps managers abreast of developments, and highlights important gaps in information requiring further research.

A non-negotiable requirement is that managers need to participate fully in research, in identifying needs, and in field-testing the management systems so that it is accepted and used by them.

***Broad Research Approach (Biome and species independent):***

1. Compile existing information.
2. Consult managers, workers, researchers regarding the current successes and failures. Target 10 projects.
3. Conduct a workshop, with 15 specialists and managers, to develop the first iteration of the DSS system.

4. Reconsult with managers.
5. Provide feedback into DSS system, produce DSS iteration 2.
6. Undertake pilot test period, during which managers run and test the DSS system.
7. Conduct second managers/expert workshop (5 managers, 5 experts).
8. Produce final DSS.
9. Develop products (i.e. checklist, handbook, expert system, etc.).
10. Review.

The project will take approximately 18 months to complete.

***Table 8.3.2 Preliminary budget for DSS system***

| | **Days** | **Amount** |
|---|---|---|
| **Staffing** | | |
| Expert | 95 | R 266,000.00 |
| Technical1 | 95 | R 133,000.00 |
| Technical2 | 25 | R 27,000.00 |
| | | |
| External review[4] | 10 | R 28,000.00 |
| | | |
| **S&T** | | |
| Subsistence | 100 | R 35,000.00 |
| Travel | | R 105,000.00 |
| | | |
| **Office** | | |
| Communication | | R 7,500.00 |
| General | | R 25,000.00 |
| | | |
| **Capital** | | R0.00 |
| | | |
| **Subtotal** | | R 626,500.00 |
| | | |
| **Contingency** | 10% | R62,650.00 |
| | | |
| **TOTAL** | | **R 689,150.00** |
| | | |
| **Time line** | 18 months | |

[4] This is a big project, necessitating input from a large number of people, and 10 external review days were therefore considered necessary.

### 8.3.3 The use and adaptation of international guidelines and research results to predict potential invasive species, to develop a protocol for dealing with the importation of plants into South Africa (27)

***Objective:*** Predicting the invasive potential of invaders.

***Motivation:*** Escape by new invasive species needs to be prevented. An early warning monitoring system is required to rapidly identify potential invasive alien biota. This will be much more efficient than initiating control once they have escaped. WfW's investment in primary research could be reduced by reviewing information on alien biota from other countries with similar bioclimatic regimes. Considerable information is available on this subject, e.g. from the Global Invasive Species Programme, that can be drawn upon in developing such protocols.

The project would incorporate the invasive potential of genetically modified versions of non-invasive organisms, and should produce a synthesis of protocols for the importation of genetically modified organisms (GMOs). The invasive potential of insect-resistant GMOs is poorly understood. They also have the potential to hybridise with closely related indigenous species with unknown consequences for biodiversity conservation and ecosystem processes.

***Broad research approach (Biome and species independent):***

1. Collate existing information, with a focus on international literature.
2. Identify end users and implementers of protocol. These people must have input into the report and review report.
3. Synthesize information and compile report.
4. Review of report.

***Table 8.3.3 Preliminary budget for protocol***

| | Days | Amount |
|---|---|---|
| **Staffing** | | |
| Expert | 20 | R 56,000.00 |
| Technical1 | | R 0.00 |
| Technical2 | 10 | R 10,800.00 |
| | | |
| External review | 3 | R 8,400.00 |
| | | |
| **S&T** | | |
| Subsistence | | R 0.00 |
| Travel | | R 0.00 |
| | | |
| **Office** | | |
| Communication | | R 2,000.00 |
| General | | |
| | | |
| **Capital** | | R0,00 |
| | | |
| **Subtotal** | | R 77,200.00 |
| | | |
| **Contingency** | 10% | R 7,720.00 |
| | | |
| **TOTAL** | | **R 84,920.00** |
| | | |
| **Time line** | 6 months | |

### 8.3.4 Areas for clearing should be prioritised (25)

***Objective:*** Develop protocols and guidelines for best practice.

***Motivation:*** Information is required for effective national strategic planning of alien control programmes, for the selection of priority areas at national and regional levels. A set of priorities for dealing with the alien plant problem in South Africa, based on current and potential future impacts of aliens on water resources, (priority catchment areas), biodiversity, fire management, soil erosion, riverbank stability, and grazing, should be developed. This analysis would of course also look at employment, poverty and other issues, but for funding and administrative purposes, the ecology theme should focus on the biophysical impacts of alien plants[5]. An analysis of this kind would inform WfW management where they should be working and concentrating their clearing efforts.

[5] The budgets of the social and economic theme need to be combined with that of the ecology theme to produce a truly integrated priority system.

***Broad Research Approach (Biome and species independent):***

A Geographical Information System (GIS) will be used as the basis for this project. The GIS layers used will depend on the available national datasets; the budget assumes that a GIS layer of IAP infestation at a national scale already exists, and that it does not have to be generated for this project.

1. Compile a preliminary list of risk criteria /variables.
2. Find data /GIS layers.
3. Assess the suitability of variables and data layers.
4. Conduct a sensitivity analysis.
5. Overlay the map of infested areas, especially of top aggressive IAPs.
6. Isolate and rank priority geographical areas.

This project is scale sensitive, and its resolution depends largely on the scales of the available datasets. It can be executed as a three tier project:

- Level 1: Identify broad risk areas (on a national scale), using the stepwise approach outlined above.
- Level 2: Within these broad risk areas, increase the resolution of the project. Select priority /risky catchments, and identify priority areas within them in more detail.
- Level 3: Conduct a local workshop with a group of specialists to set priorities within the areas identified at level 2.

The budget below was calculated for Level 1 (national scale) resolution only. The time needed to complete this project is approximately 18 months. Longer term field trials and monitoring may be necessary, but are not budgeted for.

***Table 8.3.4 Preliminary budget for priority areas***

| | Days | Amount |
|---|---|---|
| **Staffing** | | |
| Expert1 | 67 | R 187,600.00 |
| Technical2 | 20 | R 28,000.00 |
| Technical3 | 0 | R 0.00 |
| | | |
| External review | 3 | R 8,400.00 |
| | | |
| **S&T** | | |
| Subsistence | 40 | R 14,000.00 |
| Travel | R 60,000.00 | R 60,000.00 |
| | | |
| **Office** | | |
| Communication | | R 10,000.00 |
| General | | R 0.00 |
| | | |
| **Capital** | | R 0.00 |
| | | |
| **Subtotal** | | R 308,000.00 |
| | | |
| **Contingency** | 10% | R 30,800.00 |
| | | |
| | | |
| **TOTAL** | | **R 338,800.00** |
| | | |
| **Time line** | 18 months | |

### 8.3.5 The direct impacts of aliens on fire severity and behaviour (22)

***Objective:*** Assess the local ecological impacts of IAPs

***Motivation:*** Invasions by alien woody plants can cause a marked change in the structure of vegetation, and fuel loads in particular. This is accompanied by changes in fire frequency and intensity. Since fires are important driving factors in the functioning of many of our ecosystems, invaded ecosystems can be radically altered by invasions. The development of a sound understanding of the effect of alien invasions on fire regimes is therefore important.

Fire is also one of the factors in increasing the rate of spread of IAPs, and this therefore forms an important component of this research project.

***Broad Research Approach:***

Fire models already exist for predicting the impact of fuel loads and weather on fire severity. The emphasis here is to look at the change in fire regimes (fire frequency and severity), using biomass accumulation as a variable.

The most important biomes where this project should be implemented are the fire prone biomes, i.e. fynbos, mesic savanna and grasslands. Important genera to target for this study are *Eucalyptus*, *Pinus*, *Acacia* and invasive grasses.

Infested areas at different levels of post-fire successions, and a paired, un-invaded site under similar conditions of the same age need to be selected. As a guideline, 10 paired sites, with four replicates of each site (i.e. 40 paired plots) need to be sampled. The quantity of combustible biomass in these plots has to be measured, and the biomass in invaded and un-invaded plots compared. The fire behaviour model then needs to be exercised with these data, incorporating weather parameters stochastically. The probability of run-away and very severe fires occurring in invaded and un-invaded vegetation can then be calculated by running the model iteratively with randomly generated weather parameters.

The following budget reflects the unit cost for researching the impact of one species in one biome. Follow up experiments will be slightly cheaper, as the time allocated to experimental design and modelling will decrease when the project is replicated. Long term field trials may be considered necessary, but are not budgeted for below.

1. Design experiment
2. Find sites
3. Fieldwork (16 days fieldwork per species per system)
4. Process samples
5. Process data
6. Analyse data
7. Modelling
8. Synthesis and write up
9. External review

The project will take approximately 18 months to complete.

***Table 8.3.5 Preliminary budget for the impact of aliens of fire behaviour (for a single species in one biome only)***

| | Days | Amount |
|---|---|---|
| **Staffing** | | |
| Expert1 | 35 | R 98,000.00 |
| Technical2 | 7 | R 9,800.00 |
| Technical3 | 52 | R 56,160.00 |
| | | |
| External review | 3 | R 8,400.00 |
| | | |
| **S&T** | | |
| Subsistence | 36 | R 12,600.00 |
| Travel | | R 26,580.00 |
| | | |
| **Office** | | |
| Communication | | R 3,000.00 |
| General | | R 0.00 |
| | | |
| **Capital (modelling software)** | | R 2,500.00 |
| | | |
| **Subtotal** | | R 217,040.00 |
| | | |
| **Contingency** | 10% | R 21,704.00 |
| | | |
| **TOTAL** | | **R 238,744.00** |
| | | |
| **Time line** | 18 months | |
| | | |

The project above is presented here as the unit costs per species per biome. This should be duplicated for different species in different ecosystems. The total cost of implementing this study in three biomes for the three woody species mentioned in the Broad Research Approach above will thus be R2,148,696.00.

### 8.3.6 The extent of invasion, rate and mechanisms of spread, of IAPs (21)

***Objective:*** Predicting the invasive potential of invaders.

***Motivation:*** Information on the extent of invasion, and rate and mechanisms of spread is needed to predict the future spread of invasive species. This information is vital in order to select undertake national strategic planning of alien control programmes, the prioritisation of IAP species and priority areas at local and regional levels. This research project would therefore feed into the research priority projects on priority areas and decision support systems.

***Broad Research Approach:*** The first step of this project would be to prioritise the species for which this study would need to be undertaken. After this initial step, two separate approaches are outlined in this description; remote sensing (including a ground truthing component) and a field based method, as remote sensing can be used to quantify the distribution of some, but not all species. The plants for which remote sensing would be ineffective include herbaceous species, under storey species and some trees such as wattle, especially under 'wild-growing' conditions. For these species, field based techniques need to be used.

*A. Prioritisation of species:*

1. A literature review on the information available on the existing rates of spread must be undertaken.
2. Relate the rates of spread to plant life histories.
3. Develop models to predict which of the species with unknown rates of spread will have the greatest invasive potential.
4. Validate models, using species with known rates of spread not included in the development of the model.

***Table 8.3.6A Preliminary budget for determining the spread of IAPs (prioritisation of species).***

| | **Days** | **Amount** |
|---|---|---|
| **Staffing** | | |
| Expert1 | 25 | R 70,000.00 |
| Technical2 | 30 | R 42,000.00 |
| Technical 3 | 0 | R0.00 |
| | | |
| External review | 3 | R 8,400.00 |
| | | |
| **S&T** | | |
| Subsistence | | R 0.00 |
| Travel | | R 0.00 |
| | | |
| **Office** | | |
| Communication | | R 5,000.00 |
| Software development and programming | | R 15,000.00 |
| | | |
| **Capital** | | R 0.00 |
| | | |
| **Subtotal** | | R140,400.00 |
| | | |
| **Contingency** | 10% | R 14,040.00 |
| | | |
| **TOTAL** | | **R 154,440.00** |
| | | |
| **Time line** | 6 months | |

*B. Remote sensing:*

1. Select 50 sample sites per species, from a wide range of habitats (at least with a difference in rainfall gradient).
2. Do time series analysis for a minimum of 30 years of the change in the spread and density of each infested stand.
3. Apply current map of known distribution.
4. Calculate and model the rate of spread under different bioclimatic and seed dispersing conditions.

The above approach does not take into account spontaneous eruptions that extend beyond the boundaries of the areas covered by the remotely sensed images or photographs. The recorded rate and extent of spread will therefore be an underestimate of the true rate. To remedy this, some ground truthing will be required to incorporate the effect of random eruptions some distance from the source population.

The ground truthing aspect (mainly for the invasive tree species) of the remote sensing methods will consist of the following:

1. Choose a source population with a known history of invasion and age since first invasion.
2. Record and analyse the ages of spreading plants, at a range of distances from the source.
3. Calculate the probability of encountering trees of different ages at different distances from the source population.
4. Model the population dynamics and extent of spread.

This project should take approximately 18 months to complete, but longer term field trials have not been included.

***Table 8.3.6B Preliminary budget for determining the spread of IAPs (remote sensing)***

| | Days | Amount |
|---|---|---|
| **Staffing** | | |
| Expert1 | 20 | R 56,000.00 |
| Technical2 | 15 | R 21,000.00 |
| Technical3 | 20 | R 21,600.00 |
| | | |
| External review | 3 | R 8,400.00 |
| | | |
| **S&T** | | |
| Subsistence | 50 | R 17,500.00 |
| Travel | R 84,000.00 | R 84,000.00 |
| | | |
| **Office** | | |
| Communication | | R 10,000.00 |
| General | | R 0.00 |
| | | |
| **Capital** | | R 0.00 |
| | | |
| **Subtotal** | | R 218,500.00 |
| | | |
| **Contingency** | 10% | R 21,850.00 |
| | | |
| **TOTAL** | | **R 240,350.00** |
| | | |
| **Time line** | 18 months | |

*C. Field based method:*

This approach will be based on the following techniques:

1. Select sites where WfW is active.
2. Record local knowledge of the history of invasion, and verify this with remotely sensed information.
3. Analyse WfW quarterly records.
4. Record the size distribution of trees and seedlings at distances from the known source (cf. the ground truthing exercise described above).

This project will take approximately 18 months to complete. Longer term field trials have not been included.

***Table 8.3.6C Preliminary budget for determining the spread of IAPs (field based method)***

| | Days | Amount |
|---|---|---|
| **Staffing** | | |
| Expert1 | 30 | R 84,000.00 |
| Technical2 | 20 | R 28,000.00 |
| Technical3 | 30 | R 32,400.00 |
| | | |
| External review | 3 | R 8,400.00 |
| | | |
| **S&T** | | |
| Subsistence | 50 | R 17,500.00 |
| Travel | R 90,000.00 | R 90,000.00 |
| | | |
| **Office** | | |
| Communication | | R 10,000.00 |
| General | | R 0.00 |
| | | |
| **Capital** | | R 0.00 |
| | | |
| **Subtotal** | | R 270,300.00 |
| | | |
| **Contingency** | 10% | R 27,030.00 |
| | | |
| **TOTAL** | | **R 297,330.00** |
| | | |
| **Time line** | 18 months | |

The project above is presented here as the unit costs per species per biome. This should be duplicated for different species in different ecosystems (priority species are listed in Section 7.3.2).

## 9. DISCUSSION

A logical sequence has emerged from priority list. Firstly, there is a need for protocols to prevent the entry and further spread of invasive plants, using existing information. Secondly, there is a need for a prioritisation of areas to be cleared at a national level. Thirdly, once the main areas of focus have been decided upon, a decision support system needs to be developed, which informs and assists managers in deciding how to deal with their areas. Fourthly, and rated most highly, is the rehabilitation of cleared areas – this is seen as an essential part of clearing actions. The last two projects are linked to, and will play a role in informing aspects of the first four projects.

## 10. FINAL RECOMMENDATIONS AND WAY FORWARD

The following are recommendations pertaining the way forward:

1. It is a recommendation that the literature and expert databases that have been produced as part of this project, be updated on a regular basis. This should be undertaken by the organisation that acts as an advisory service to WfW.
2. DSS systems that may be developed as part of the recommended research priority projects should be kept updated.
3. This report and database should be circulated to WfW and other managers in relevant departments, research institutions and people working in the field of invasive plants.
4. A system should be put into place that keeps track of the implementation of any of the projects that have been recommended in this report. This should ideally be undertaken by the organisation that acts as an advisory service to WfW.
5. It is envisaged that the research priorities will change with the implementation of the research projects listed in this document, as well as other research implemented in the country. This report should therefore be reviewed in 5 years time, when other research priorities may be put forward.
6. To introduce an additional level of flexibility, 10% of the WfW research budget should be set aside for innovative *ad hoc* projects that have not been listed in this report, subject to approval by the WfW panel.
7. WfW should require that the results of any research projects awarded by them be communicated to the public; and this should form part of the tender document.

## 11. REFERENCES

Bradshaw, A.D. (1984). Ecological Principles and land reclamation practice. *Landscape Planning* 11, 35-48.

Westman, W.E. (1991). Ecological restoration projects: measuring their performance. *The Environmental Professional,* 13, 207-215.

## APPENDIX 1: CONTACT DETAILS OF WORKSHOP PARTICIPANTS

| Surname | Name | Organisation | Address | Telephone | Fax | E- mail |
|---|---|---|---|---|---|---|
| Bond | William | Botany Department University of Cape Town | University of Cape Town, Rondebosch, 7701 | 021 6502439 | 021 6504041 | bond@botzoo.uct.ac.za |
| Cilliers | Carina | ARC, Plant Protection Research Institute | P/Bag X134 Pretoria, 0001 | 012 3293269 | 012 3293278 | rietcjc@plant2.agric.za |
| Dean | Richard | University of Cape Town | University of Cape Town, Rondebosch, 7701 | 023 541 1828 | 023 541 1828 | lycium@mweb.co.za |
| Fabricius | Christo | Rhodes University | P.O. Box 94 Grahamstown, 6140 | O46 6038614 | 046 6226242 | c.fabricius@ru.ac.za |
| Fourie | Saskia | Rhodes University | P.O. Box 94 Grahamstown, 6140 | 046 6038616 | 046 6225524 | saskia.fourie@ru.ac.za |
| Holmes | Pat | Cape Ecological Services | 23 Dreyersdal Road Bergvliet, 7945 | 021 7127816 | 021 7127816 | prebelo@mweb.co.za |
| Khan | Ahmed | Working for Water | P/Bag X4390 Cape Town, 8000 | 021 4052200 | 021 4257880 | ahmed@dwaf-wcp.wcape.gov.za |
| Le Maitre | David | CSIR | P.O. Box 320 Stellenbosch, 7599 | 021 8882610 | 021 8882693 | dlemaitre@csir.co.za |
| Macdonald | Ian | Environmental Consultant | P.O. Box 12236 Die Boord, 7136 | 021 8528077 | 021 8529055 | macdonfam@kingsley.co.za |
| Marais | Christo | Working for Water | P/Bag X4390 Cape Town, 8000 | 021 4052200 | 021 4257880 | chris@mweb.co.za |
| Milton | Sue | University of Stellenbosch | P/Bag X1 Matieland, 7602 | 021 8083304 | 021 8083304 | sjm@sun.ac.za |
| Mkize | Nomhlanhla | Working for Water | P/Bag X4390 Cape Town, 8000 | 021 4052200 | 021 4257880 | mkizen@dwaf-wcp.wcape.gov.za |
| Moran | Cliff | Consultant/WFW Research Panel | 19 Walker Bay Crescent Hermanus Heights, 7200 | 028 3130567 | 028 3130566 | vcmoran@iafrica.com |
| Siegfried | Roy | WFW Research Panel | P.O. Box 395 Constantia, 7848 | 021 7947026 | 021 7947026 | |
| van Wilgen | Brian | CSIR | P.O. Box 320 Stellenbosch, 7599 | 021 8882479 | 021 8882693 | bvwilgen@csir.co.za |

## APPENDIX 2: WORKSHOP REPORT

# WORKSHOP TO CONTRIBUTE TO AN ECOLOGY RESEARCH STRATEGY FOR WORKING FOR WATER

# WORKSHOP REPORT

Environmental Science
Rhodes University
Grahamstown
6140

**Produced for:**
National Working for Water Programme
Private Bag X4390
Cape Town
8000

**MARCH 2002**

## ACKNOWLEDGEMENTS

We would like to thank the CSIR for providing the venue for this workshop and MJ Services for the catering. We would like to thank the participants (listed in Appendix A) for providing their time and knowledge, which made this workshop and report possible, and Working for Water who financed this study.

# TABLE OF CONTENTS

# 1. INTRODUCTION

The Working for Water Programme's Research Management Unit (RMU) is focusing on five themes in support of the Programme achieving its long term goal of managing the spread of alien invading plants. These are the following:

- Social Development
- Resource Economics
- Hydrology
- Ecology
- Biological control.

Environmental Science at Rhodes University has been commissioned to develop an ecology research strategy for the WfW Programme. The following objectives are being addressed:

- Review of the existing knowledge base with regard to the ecological impacts of alien invading plants.
- Developing a strategy based on the identified gaps of relevance to the WfW Programme.
- Assess the potential research capacity in the country in the relevant fields, and the process and resources necessary to build capacity within this field.
- A compilation of the approximate budget requirements of the individual high priority research project concepts.
- A compilation of an approximate time schedule for the execution of individual high priority research projects.

One of the steps in developing the strategy was to convene a workshop with the best available specialists in South Africa, to obtain their ideas, benefit from their experience and draw on their theoretical and practical knowledge.

A workshop was held at the CSIR offices in Stellenbosch on 5 February 2002, to deliberate the research priorities on the "ecology" research theme. The main purpose of this workshop was to identify gaps in the field of invasive ecology, and to prioritise these, in order to develop the research strategy.

The following people attended this workshop:

- Christo Marais (Working for Water)
- Ahmed Khan (Working for Water)
- Nomhlanhla Mkize (Working for Water)
- Brian van Wilgen (CSIR)
- David le Maitre (CSIR)
- Pat Holmes (Cape Ecological Services)
- Sue Milton (University of Stellenbosch)
- Cliff Moran (Independent consultant and member of Working for Water Research panel)
- Ian Macdonald (International Environmental Consultant)
- Roy Siegfried (member of Working for Water Research panel)
- William Bond (University of Cape Town)
- Carina Cilliers (PPRI, Pretoria)
- Christo Fabricius (Rhodes University, facilitator)
- Saskia Fourie (Rhodes University)

Contact details of the above people are included in Appendix 1.

### 1.1 WORKSHOP PROCEDURE

The following step-wise procedure was followed:

1. Participants were asked to write three key **problems**, related to the ecology of biological invasions, on cards.
2. These were pasted onto a wall and sorted into **groups** of related issues.
3. For each group of research topics, participants where then asked to define an **acceptable future condition**, related to that topic.
4. The next step was to list the **obstacles** that are preventing that future condition from being realized.
5. **Research gaps** in relation to each topic were also highlighted.
6. The final step was to identify **research projects or programmes** that would assist Working for Water in overcoming each of the obstacles.

### 1.2 RESEARCH TOPICS

Six main groups of research topics were identified:

1. Protocols and guidelines for best practice;
2. Rehabilitation, restoration and 'ecosystem repair';
3. Predicting the invasive potential of invaders species;
4. Local ecological impacts of biological invasions (e.g. on soil, water, biodiversity, and fire ecology);
5. Regional ecological impacts of biological invasions;
6. Alternative strategies to cater for human needs.

## 2. RESEARCH TOPICS AND PRIORITIES

### 2.1 PROTOCOLS AND GUIDELINES FOR BEST PRACTICE

Protocols should be developed for every stage of the invasive control and treatment process. In particular, early decision protocols, relating to decisions such as whether or not to clear, and whether to use mechanical, chemical or biocontrol agents, will form part of the protocol.

#### 2.1.1 Priority Ecosystems

All ecosystems were considered equally important.

#### 2.1.2 Information Gaps

a) Existing information needs to be integrated into a practicable decision support system; e.g. a checklist needs to be compiled to aid managers in deciding how an area should be dealt with or cleared. Multicriteria decision support systems need to be developed in such a way that managers use them.
b) A predictive understanding of the implications and consequences of management actions on the repair of ecosystems needs to be developed and conveyed to managers.
c) Information on the types of herbicides that have been tested, and the results of these tests, should be summarized.
d) Information on the optimal use of biocontrol agents, to effectively control IAPs yet retain adult plants for consumptive use (e.g. fire wood and construction materials) needs to be made available to managers.
e) Information about the reserves of IAPs that should be maintained, in order for biocontrol organisms to survive and continue their functioning, should be made available.
f) Various suites of options, or permutations of strategies, to optimally control IAPs need to be tested in the field and made accessible to managers.
g) To improve their acceptance of these protocols, managers need to be involved in research, in identifying needs, and in testing the management systems.

## 2.2 COST EFFECTIVE RESTORATION (REPAIR)

### 2.2.1 Priority ecosystems for repair

a) Wetlands, riparian zones and aquatic systems.
b) Fynbos.
c) Mesic savannas.
d) High altitude sourveld.
e) Sweet grassland.

### 2.2.2 Priority geographic regions

a) Western Cape.
b) Eastern Cape.
c) Drakensberg.
d) South Mpumalanga.
e) Kwa-Zulu Natal.

### 2.2.3 Species of concern

a) *A. mearnsii* (black wattle)
b) *A. dealbata* (silver wattle)
c) *A. decurrens* (green wattle)
d) *A. saligna* (Port Jackson willow)
e) *Chromolaena odorata* (triffid weed)
f) *Eichhornia crassipes* (water hyacinth)

### 2.2.4 Research gaps

a) Identify the appropriate levels of repair/restoration/rehabilitation. Determine the criteria by which restoration is measured, i.e. what the aims of restoration are and when restoration is sufficient.
b) The stage of infestation when ecosystem repair should be initiated.
c) The effect of environmental conditions on the success of ecosystem repair.
d) The most appropriate species and strategies to use for rehabilitation and restoration, under various environmental conditions.
e) The effect of IAP control methods on the success of post-control ecosystem repair.

## 2.3 PREDICTING THE INVASIVE POTENTIAL OF INVADERS, BASED ON PLANT AND ENVIRONMENTAL CHARACTERISTICS

There are two aspects to this:
a) spreading of recognized alien invasive species.
b) potentially invasive species that are currently not problem plants.

### 2.3.1 Important recognized species which require more research

a) *Chromolaena odorata* (triffid weed)
b) *Arundo donax* (Spanish reed)
c) *Prosopis* (mesquite)
d) *Acacia melanoxylon* (blackwood)
e) *Myriophyllum aquaticum* (parrots feather)
f) Grasses like *Penisetum setaceum* and European C3 grasses

### 2.3.2 Research gaps (the first 4 research gaps have been rated of highest priority)

a) The extent of invasion, and rate of spread, of IAPs under different scenarios of intervention, e.g. zero control, minimal control and full-scale control respectively.
b) The use and adaptation of international guidelines and research results to predict potential invasive species and develop a protocol for dealing with the importation of plants into South Africa.

c) The effects of extreme climatic / episodic events as catalysts for invasion, e.g. elevated CO2, extreme rainfall, extreme temperatures, and changes in the frequency of episodic events).
d) The synergistic affects between different IAPs. An example of this is the prevention of scouring of *Myriophyllum* because of the presence of other aliens along the riverbanks, which results in decreased flooding.
e) The invasive potential of genetically modified versions of non-invasive organisms, and the development of protocols for the importation of GMOs.
f) The development of sterile strands of commercially important IAPs, and the development of core competence in plant breeding and genetic manipulation applied to IAPs.
g) The development of an early warning monitoring systems to track potential IAPs.

## 2.4 THE LOCAL ECOLOGICAL IMPACTS OF BIOLOGICAL INVASIONS

### 2.4.1 Ecosystems of importance

a) Savannas
b) Grasslands
c) Road verges and other migration corridors
d) Fynbos
e) Wetlands

### 2.4.2 Species of importance

a) *Prosopis*, and its effects on groundwater and grazing
b) Acacias
c) Conifers
d) *Eichhornia crassipes* (water Hyacinth)

### 2.4.3 Research gaps (the first 4 research gaps have been rated of highest priority)

a) The direct impacts of aliens on fire severity and behaviour.
b) The impact of IAPs on soil properties of invaded systems, especially those with nutrient poor soils.
c) The impact of invasions on biodiversity.
d) The impact of alien-fuelled fires on flora and fauna.
e) Rates of stump reduction and decay of mechanically controlled IAPs.
f) The effect of fire severity on soil organic matter, in the context of Carbon sequestration.
g) The impacts of IAPs on economically valuable resources like grazing and the flower trade.
h) The impacts of aquatic weeds on water quality and quantity, water delivery and biodiversity.
i) The impacts of fire on alien spread, regeneration and management (e.g. grasses invading succulent Karoo, where a fire can wipe out the indigenous vegetation).
j) The positive ecological effects of IAPs.
k) The impact of IAPs and clearing on freshwater invertebrates.

## 2.5: THE REGIONAL ECOLOGICAL IMPACTS OF BIOLOGICAL INVASIONS

Ecological impacts need to translate into economic impacts which need to translate into planning actions.

### 2.5.1 Research gaps

a) The positive and negative impacts of IAPs on livelihood activities, e.g. grazing, agriculture, silviculture, and bee-keeping.
b) The costs and benefits of eliminating IAPs in the context of Carbon sequestration.
c) The impacts of IAPs on water quality.
d) The impacts of IAPs on tourism potential, landscape amenity, and adventure tourism (e.g. flyfishing and rafting).
e) The impact IAPs have on flood severity.

## 2.6 ALTERNATIVE SPECIES AND STRATEGIES TO CATER FOR HUMAN NEEDS

### 2.6.1 Priority species

a) *Eucalyptus* – bee keeping.
b) *Acacia saligna* – fuel.
c) *Prosopis* – fodder, furniture, construction.
d) Guava, prickly pear – fruit.

### 2.6.2 Research gaps

a) Identification of appropriate non-invasive replacement species.
b) Identification of indigenous replacement species.
c) Alternative strategies to curb, rather than eliminate, economically useful IAPs e.g. sterile hybrids, non-invasive choices, biocontrol.
d) The development of guidelines and protocols for recommending non-invasive species to farmers, tree growers and rural communities.
e) Research into local knowledge about appropriate alternative species.
f) What are the effects of clearing on indigenous service provider systems?

# 3. CONCLUSION AND THE WAY FORWARD

This report will be circulated to various specialists in the field of invasive plant ecology for comment and input. Their input will be incorporated into the document, which will be sent to the participants of the workshop for a final review, after which the final Ecology Research strategy report will be produced and submitted to Working for Water.

## APPENDIX 3: SPECIALISTS CONSULTED DURING THE REVIEW PROCESS

1. Mark Anderson (Department of Agriculture, Land Reform, Environment & Conservation)
2. George Bredenkamp (University of Pretoria)
3. Japie Buckle (Department of Water Affairs)
4. Richard Cowling (University of Port Elizabeth)
5. Jeremy Goodall (PPRI)
6. Lesley Henderson (SA Sugar Cane Association)
7. Martin Hill (Rhodes University)
8. John Hoffman (University of Cape Town)
9. Timm Hoffman (University of Cape Town)
10. Klaus Kelner (University of Potchefstroom)
11. Fred Kruger (Independent Consultant)
12. Peter le Roux (Independent Consultant)
13. Stefan Neser (PPRI)
14. Terry Olckers (PPRI)
15. Elsabe Powell (Directorate Conservation and Environment, Kimberley)
16. Dave Richardson (University of Cape Town)
17. Alan Urban (PPRI)
18. Albert van Jaarsveld (University of Pretoria)
19. Ben-Erik van Wyk (Rand se Afrikaanse Univeristeit)
20. Helmut Zimmerman (PPRI)

# APPENDIX 4: DATA MATRIX RANKING OF PRIORITY PROJECTS

The projects that appear in the table below were rated by panel members as top priority projects. Projects that were considered to be priority 1 projects, were given a rating of 10, priority 2 projects were given a rating of 9, etc., while priority 10 projects were given a rating of 1. This inverse weighting was necessary since some people only rated three projects, and others twenty.

| Project number* | Brian van Wilgen | David le Maitre | Sue Milton | Pat Holmes | Ian Macdonald | Cliff Moran | Totals | Ranking |
|---|---|---|---|---|---|---|---|---|
| 2.1a | | | | | 7 | 2 | 9 | 11 |
| 2.1b | 10 | | | | 6 | 9 | 25 | **4** |
| 2.1c | | 10 | 5 | 5 | 9 | 1 | 30 | **2** |
| 2.1d | | | | | | 10 | 10 | 10 |
| 2.1e | | | 9 | 3 | | | 12 | 8 |
| 2.2a | 9 | 9 | | 9 | 8 | | 35 | **1** |
| 2.2d | | | 4 | 7 | | | 11 | 9 |
| 2.2e | | | | 6 | | | 6 | 14 |
| 2.2g | | | | 8 | | | 8 | 12 |
| 2.3a | | 8 | | 10 | | 3 | 21 | **6** |
| 2.3b | | 7 | 10 | 2 | | 8 | 27 | **3** |
| 2.3c | | 6 | | | | | 6 | 14 |
| 2.3e | | 2 | 2 | | | | 4 | 17 |
| 2.3g | | | | 1 | | | 1 | 19 |
| 2.4a | 8 | | | 7 | | 7 | 22 | **5** |
| 2.4b | | | | | | 6 | 6 | 14 |
| 2.4c | | | 8 | | | 5 | 13 | 7 |
| 2.4d | | | | | | 4 | 4 | 17 |
| 2.4i | | | 7 | | | | 7 | 13 |

* The project numbers refer to the projects as listed in the draft research strategy report that was sent to the panel for comment and rating of priority projects. These are the following:

**Category: Protocols and guidelines for best practice**

2.1a) A predictive understanding of the implications and consequences of control and management actions on ecosystems and the repair of ecosystems needs to be developed and conveyed to managers.

2.1b) Areas for clearing should be prioritised.

2.1c) Existing information needs to be integrated into a practicable decision support system; e.g. a checklist needs to be compiled to aid managers in deciding how an area should be dealt with or cleared. Various suites of options, or permutations of strategies, to optimally control IAPs need to be tested in the field and made accessible to managers. Managers should be able to choose optimum methods specific to a local area to reduce pollution, erosion and disturbance etc. Multicriteria decision support systems need to be developed in such a way that managers use them.

2.1d) Develop or synthesize existing information on cost/benefit analyses of the various control options, i.e. chemical, mechanical and biological.

2.1e) The fate and long term ecological impacts (on soil, plant and water resources) of herbicides, especially non-selective herbicides, should be investigated. This includes the impact on the re-establishment of natural vegetation and the effect of these herbicides on biological agents.

**Category: Cost effective repair**

2.2a) Identify the appropriate levels of repair/restoration/rehabilitation, including the assessment of the level of disturbance/degradation. Determine the criteria by which restoration is measured, i.e. what the aims of restoration are and when restoration is sufficient (this will include a monitoring programme to evaluate the success and appropriateness of control actions).

2.2d) The most appropriate species and strategies to use for rehabilitation and restoration, under various environmental conditions on more local scales, i.e. refined and tailor-made restoration plans.

2.2e) The effect of IAP control methods (including fire and herbicides) on the success of post-control ecosystem repair.

2.2g) Establish criteria for prioritising areas that should be rehabilitated.

**Category: Predicting the invasive potential of invaders**

2.3a)The extent of invasion, rate and mechanisms of spread, of IAPs under different scenarios of intervention, e.g. zero control, minimal control and full-scale control respectively.

2.3b) The use and adaptation of international guidelines and research results to predict potential invasive species and develop a protocol for dealing with the importation of plants into South Africa.

2.3c)The effects of extreme climatic / episodic events as catalysts for invasion, e.g. elevated $CO_2$, extreme rainfall, extreme temperatures, fire and changes in the frequency of episodic events).

2.3e) The invasive potential of genetically modified versions of non-invasive organisms, and the development of protocols for the importation of GMOs.

2.3g) The development of an early warning monitoring systems to track potential IAPs.

**Category: The local ecological impacts of alien invasions**

2.4a) The direct impacts of aliens on fire severity and behaviour.

2.4b) The impact of IAPs on soil properties of invaded systems, especially those with nutrient poor soils.

2.4c) The impact of invasions on biodiversity.

2.4d) The impact of alien-fuelled fires on flora and fauna.

2.4i) The impacts of fire on alien spread, regeneration and management (e.g. grasses invading succulent Karoo, where a fire can wipe out the indigenous vegetation).