Australian Government

Department of the Environment and Heritage

Supervising Scientist

internal report **492**

Progress and review of the ISP Landscape Program (2002–2004) in the Alligators Rivers Region

ARRTC Key Knowledge Need 5.1 – Landscape scale analysis of impacts

P Bayliss, M Finlayson & R van Dam

October 2004

Progress and review of the ISP Landscape Program (2002–2004) in the Alligators Rivers Region

ARRTC Key Knowledge Need 5.1 – Landscape scale analysis of impacts

P Bayliss, M Finlayson & R van Dam

Environmental Research Institute of the Supervising Scientist
GPO Box 461, Darwin NT 0801

October 2004

Registry File SG2002/0045

Australian Government
Department of the Environment and Heritage
Supervising Scientist

Contents

Progress and review of the ISP Landscape Program (2002–2004) in the Alligators Rivers Region

ARRTC Key Knowledge Need 5.1 – Landscape scale analysis of impacts

P Bayliss, M Finlayson & R van Dam

Background

This report combines all key outputs since inception of the ISP Landscape Program (June 2002), and addresses ARRTC Key Knowledge Need 5.1.

> Establish a landscape scale analysis and monitoring program to differentiate mining related impacts from other causes; and contribute within the broader context to the monitoring of the natural World Heritage values of Kakadu National Park.

Section 1 is a Discussion Paper presented to the 11th ARRTC meeting in February 2003, titled "Ecological Risk Assessment (ERA) and Conceptual Ecosystem Models (Bayliss et al. 2003).

Section 2 is a Discussion Paper presented to the 13th ARRTC meeting in March 2004, titled "Progress report on the ISP Landscape Program (2003-2004) in the Alligator Rivers Region (Bayliss and Finlayson 2004).

Section 3 is the final review Discussion Paper to the 14th ARRTC meeting in September 2004, titled "Review of the ISP Landscape Program (2003-2004) in the Alligator Rivers Region".

Section 4 is a combination of the Power Point presentations given at the Eriss Workplan Day in June 2004 and at the 14th ARRTC meeting in September 2004.

Discussion Paper prepared by Peter Bayliss, Dave Walden, James Boyden, Caroline Camilleri & Alicia Hogan for the 11th Meeting of the Alligator Rivers Region Technical Committee (ARRTC), 17–19 Feb 2003

Ecological risk assessment (ERA) and conceptual ecosystem models

Paper prepared in response to a request from the 10th Meeting of ARRTC (9–10 Sept 2002)

Request 1: How and where will Ecological Risk Assessment (ERA) be used in the future?

Request 2: we would like to see a conceptual model of the ARR ecosystem, with transport pathways clearly shown and best estimates of the loads/fluxes of contaminants shown in this model

1. Ecological models are the backbone of ecological risk assessment and, hence, they need to be discussed together. Risk assessment is about estimating the probability of an adverse event (Caughley & Gunn 1996). A key aspect of risk assessment, therefore, is the assessment of uncertainty. Whilst statistical approaches (Classical or Bayesian) to Ecological Risk Assessments (ERAs) are required in order to embrace and acknowledge the related concepts of variability and uncertainty, Fox (1999) argues that these need to be critically employed to ensure relevance and robustness and this approach will be adopted here.

2. Why Ecological Risk Asssessment? Resource managers in the ARR and elsewhere in northern Australia currently have few quantitative tools to assist them in identifying which of their natural and cultural resource assets are at greatest risk from a diverse range of ecological impacts, and to then choose the best policy option for managing these risks (e.g. due to climate change & sea level rise, invasive species, tourism, infrastructure, mining & agriculture). One noticeable exception is the "Wetlands Risk Assessment" framework develop by van Dam *et al*. (1999), although this approach does not explicitly address socio-economic, cultural and communication issues. The ***eriss*** ERA program will, therefore, focus on enhancing this framework through the development and integration of:

    i. quantitative "whole" ecosystem models;

    ii. socio-economic and cultural models (i.e. their own frameworks);

    iii. adaptive management strategies where appropriate (e.g. for invasive species management). Adaptive management (landscape-scale "experimental" manipulations) of mine site impacts on Kakadu is obviously inappropriate because of the necessity of using the precautionary principle with respect to site-specific impacts within a World Heritage National Park (i.e. BACI design with no “true” statistical controls); and

iv. a strategy which effectively communicates ecological risks to relevant stakeholders (e.g. with respect to RUM, develop a conceptual 3D-landform GIS spatial model with transport pathways clearly shown, using best estimates of the loads/fluxes of mine site contaminants).

3. The development of quantitative ecological models (point i) does not presume the use of a single currency to describe ecosystem processes (e.g. energy or mass), or to fully account for all physical-chemical-biological features and interactions that describe ecosystem function. The models will necessarily be restricted to processes and mechanisms that link specific management actions (water flows, chemical inputs, pest control etc) to specific indicators of ecological performance or “health”. (e.g. plant community structure, biodiversity, abundance of “valued” vertebrate species etc).

4. The ultimate challenge, however, is to realistically link the costs of reduction in “damage” to ecosystem health to perceptions of socio-economic and cultural benefits (see Costanza *et al*. 1997) in order to optimise management investments under budgetary constraints (point ii). At the end of the day decision support tools need to be realistic, pragmatic, defensible and, provide management options that at least balance costs and benefits.

5. A novel approach gaining popularity with ecological risk assessors is to explore both Classical (null hypothesis testing & likelihood estimation) and Bayesian statistical approaches to provide more informative quantitative decision support tools. Bayesian approaches incorporate prior information in model selection (prior probabilities). Hence, new data can be added iteratively to fine-tune management actions if the system allows it (i.e. adaptive management, a selective process of learning by doing; Walters 1997).

6. Despite the attractions of adaptive management as a research and management tool, Walters (1997) has argued that for riparian and coastal ecosystems it has failed to produce useful models for policy comparison or good experimental management plans to resolve key uncertainties. One of the major reasons he cites for failure is that modeling for adaptive management planning has often been supplanted by ongoing modeling exercises. In lieu of adopting “true” experimental management options, many NRM agencies continued to invest heavily in baseline monitoring and complex simulation modeling (ranging from 3-dimensional hydrodynamic models, to individual-based models for population dynamics, to high-resolution landscape models based on GIS information). Walters (1997) suggests that such investments are driven by the assumption that sound management predictions can somehow be found by looking more precisely, in more mechanistic detail, at more variables and factors. This negative view of Walters at the ecosystem level is understandable as there are few successes to tout and, perhaps there really are limits to the “experimental” approach at this scale . However, at the population level at least, there is much scope for success, particularly for invasive species which in the ARR comprise one of the most significant risks to ecosystems.

7. An enhanced Wetlands Risk Assessment framework will hopefully offer a potentially powerful decision support tool for improved management of multiple impacts to minimise adverse ecological effects over scales varying from mine sites, catchments and regions. A secondary objective of the ERA program will be to increase the capacity of NRM agencies to use risk-based assessment methods for management and policy development, and for effectively communicating these risks to relevant stakeholders.

8. As outlined in the ERA project structure (Attachment), and taking note of Walter's (1997) modelling caveat, an ecosystem model of wetlands (& their catchments) of the ARR will be developed for use as a decision support tool for assessing and managing multiple ecological risks at multiple scales. Existing information from previous studies in the ARR and elsewhere will be used to develop four basic submodels of a whole ecosystem model. These are a:

    i. hydrodynamic submodel for space-time variation in water flows;

    ii. hydrochemistry submodel for transport and transformation of key chemical variables such as nutrients and sediments;

    iii. "lower trophic level" submodels for primary (plants), invertebrate, and small "forage" fish production; and

    iv. population dynamics submodel(s) for key or dominant animal indicator species (e.g. predator fish & waterbirds).

9. The most difficult computational problem in combining these submodels has been the cross-scale linkage between physico-chemical processes and ecological processes (Walters 1997). The hydrodynamic and chemical equations are generally solved (simulated) over very short time scales (hours-days) to maintain physical continuity (& further complicated by mixing in whatever medium), compared to ecological time scales (months-years-decades). Walters (1997) suggests "decoupling" simulations in submodel types to allow outputs from one submodel to drive the inputs of another, and this approach will be used here. Once the basic ecological framework has been developed describing key links between ecological character and processes, multiple and multi-scalar impacts can then be modelled and incorporated as additional layers of complexity. For example:

    i. develop a range of ecological risk assessment models for Ranger and Jabiluka mines which integrates all relevant knowledge and information across *eriss* programs (ecotoxicology, biological & chemical monitoring, environmental radiation, hydrogeomorphological & communications), Energy Resources Australia and DBIRD. The "Whole of mine" model developed by Klessa (EWLS) to predict water quality changes downstream of RUM will provide an alternative model to test. Classical and Bayesian "goodness of fit" tests will be used to select between competing models. As mentioned, for communication purposes (& possibly scenario simulation purposes), a conceptual 3D-landform GIS spatial model will be developed which clearly shows transport pathways and uses the best estimates of the loads/fluxes of contaminants (see separate discussion paper on conceptual ecosystem models prepared by Max Finalyson & Peter Bayliss).

ii. develop socio-economic models for management of key invasive species (weeds & ferals) on Kakadu National Park, with potential to expand analysis to agricultural production areas. That is: (a) develop cost-of-control models for key weed (mimosa, paragrass, salvinia & rubber bush) and feral (pigs & buffalo) species; (b) develop biodiversity and production impact models to help quantify benefits of control (damage-abundance relationships); (c) combine (a) and (b) with best available knowledge of species life history and population dynamics; and (d) undertake benefit-cost analysis (with respect to protection of conservation values, provide benefit maximisation & cost-minimisation choices). Finally, incorporate indigenous perspectives of benefits and costs through effective consultation processes.

iii. Socio-economic frameworks and indigenous perspectives can then be integrated into the above ecological risk assessment frameworks to provide powerful decision supports tools. Similar benefit-cost analyses can be undertaken for other ecological impacts such as infrastructure, tourism, and climate change (saltwater intrusion).

References

Caughley, G. and Gunn, A. (1996). Conservation Biology in Theory and Practice. Blackwell Science, Oxford. 459 pp.

Costanza, R. et al. (1997). The Value of the World's Ecosystem Services and Natural Capital. *Nature*, **387**, 253-260.

Fox, D.R. (1999). Setting water quality guidelines – A statistician's perspective. **SETAC News 19 (3)**, 17-18.

Walters, C. (1997). Challenges in adaptive management of riparian and coastal ecosystems. *Conservation Ecology* [online]1(2):1. Available from the Internet. URL: http://www.consecol.org/vol1/iss2/art1

van Dam, R., Finlayson, C.M. & Humphrey, C.L. (1999). Wetland risk assessment: A framework and methods for predicting and assessing change in ecological character. In *Techniques for enhanced wetland inventory, assessment and monitoring.* Edits. CM Finlayson & AG Spiers, *SSR 147*, Supervising Scientist, Canberra, 83-118.

Contact Officer:	Peter Bayliss
Telephone:	08 8920 1170

ATTACHMENT: Ecological Risk Assessment Program

Program Goal
To provide advice on the significance of threats to the biological diversity and functioning of tropical wetlands in the Alligator Rivers Region and elsewhere.

Program Structure
The Ecological Risk Assessment Program has three major projects or outcome areas as broadly defined in the ***eriss*** Strategic Plan (2002-03). These are:

1. Ecotoxicological impacts (with focus in the ARR);

2. Landscape-wide impacts (with focus in the ARR); and

3. Conservation and management of tropical wetlands.

A modified version of the Wetlands Risk Assessment framework developed by van Dam *et al*. (1999), and adopted by the Ramsar Wetlands Bureau (CoP7 1999), underpins all projects and is the unifying concept (see below).

Projects and Outcome Areas
All three project outcome areas overlap to varying degrees. Strategic priority activities or tasks within projects in 2002-03 are outlined below.

Project 1: Ecotoxicological impacts

- Assessment of the aquatic toxicity of Uranium mine toxicants, and the associated derivation of site-specific water quality guidelines.

  - Assess toxicity of Uranium to green algae (*Chlorella sp.)* in Magela Creek (IR & draft Journal article will be completed in Feb. 2003).
  - Assess the toxicity of $MgSO_4$ to local aquatic organisms (part of Clint McCullough's PhD study); complete derivation of site-specific (Magela Creek) TV for Mg using NTU summer students.
  - Annual pre-release testing of Djalkmara Billabong & RP1 using local aquatic biota (Jan. 2003, possibly the last).
  - Commence work on derivation of site-specific (Magela Creek) TV for Manganese (1 range finder & 3 definitive tests).

- Refine and develop ecotoxicological procedures to assess Uranium mine impacts using local aquatic species.

  - Develop a laboratory toxicity test for the freshwater snail (*Amerianna cumingi*) using NTU summer students. Potential to expand site specific (Magela Creek) toxicity data for U and Mg , and provides also an organism that directly relates to ***eriss's*** creekside monitoring program during mine water releases.
  - Initiate study to determine whether or not brood stock holding water (with elevated U & Ca levels) affects the sensitivity of fish fry (black-banded rainbow

fish & possibly purple spotted gudgeons) to Uranium. Potential NTU Honours project.

- Maintain the quality control and quality assurance system of the ***eriss*** ecotoxicology laboratory.

  – Compilation and publication of all toxicity test protocols developed at ***eriss*** (draft completed & under review; SSR will be completed in March 2003).
  – Test for potential chemical differences in Darwin and Magela Creek holding waters (analyses continuing, IR pending).

- Assessment of other ecotoxicological risks or threats to tropical wetlands (e.g. herbicides, mine pollutants in other regions & possibly in future pesticides).

  – In collaboration with OSS, DBIRD (mines) and NTU, investigate the efficacy of diffusive gradients in thin films (DGT) as a monitoring tool for waterways receiving mine run-off.
  – In collaboration with the Centre for Environmental Research (Sussex University), UTS and PAN, investigate the effects of sunscreens as endocrine disruptors in Kakadu swimming holes (continuation of work by van Dam).
  – Continue to seek external funds to assess the ecological risks of two major herbicides (™Starane - fluroxypyr & ™Brush-off - metsulfuron) used to control Mimosa, expanding previous work by van Dam (in press) on Tebuthiuron (™Graslan).
  – In collaboration with NTU, investigate the use of a new laser ablation inductively coupled plasma mass spectrometer system (LA-ICPMS) to ascertain environmental impacts in marine ecosystems.
  – In collaboration with UTS and others, seek external funds to develop a risk-based approach to salinity toxicity for inland aquatic ecosystems (i.e. we derive ecologically sound TVs for tropical wetlands).

Project 2: Landscape-wide impacts

The Independent Science Panel (ISP) recommended that ***eriss*** undertake landscape-wide analysis to help differentiate between mining and non-mining impacts. The development of this Project and accompanying tasks is in response to this recommendation.

- Assessment of World Heritage values of wetlands of Kakadu National Park.

  – Assess World Heritage values of waterbirds in the ARR (with a focus on the Magela wetlands) from a national and global perspective.

  – Assess the ecological risks of major invasive species in the ARR. Weeds: assess risks of three significant weeds on the Magela floodplains (mimosa, salvinia & paragrass) and surrounding catchments. Ferals: determine Traditional owner perceptions of feral animal damage to environmental and cultural values and then assess ecological risks of feral buffalo, pigs, horses & cattle.

- For comparison with the Magela catchment containing mining and infrastructure impacts, assess other key multiple ecological impacts (invasive species – weeds & pigs; potential salt water intrusion; indigenous fire management) at Boggy Plain, South Alligator River, in relation to World Heritage values of Kakadu (particularly waterbirds, customary harvesting & habitat heterogeneity).

- Assess threats to marine and coastal ecosystems in the ARR and NT generally. In collaboration with UNSW (Centre for Remote Sensing & GIS), NTU, NTG, National Oceans Office (NOO) and AIMS, develop spatially explicit ecosystem models to assess climate change impacts for coastline (mangrove) and coastal freshwater wetlands in the ARR.

• Develop an ecosystem model of wetlands (& catchments) of the ARR to be used as a decision support tool for ecological risk assessment and management of multiple impacts at multiple scales.

  - Using information and/or models developed above, and from previous studies in the ARR & elsewhere (i.e. a desktop meta-data analysis), develop four basic submodels with a focus on assessing multiple ecological impacts at multiple scales. These are: (1) a hydrodynamic submodel for space-time variation in water flows; (2) a hydrochemistry submodel for transport and transformation of key chemical variables such as nutrients and sediments; (3) "lower trophic level" submodels for primary (plants), invertebrate, and small "forage" fish production; and (4) population dynamics submodel(s) for key animal indicator species (e.g. fish predators & waterbirds).

  - For predictive purposes, develop a range of ecological risk assessment models for Ranger and Jabiluka mines integrating all relevant knowledge and information across ***eriss*** Programs (ecotoxicology, biological & chemical monitoring, environmental radiation, hydrogeomorphological & communications), ERA (Ranger) and DBIRD. The "Whole of mine" model developed by Klessa to predict water quality changes downstream of RUM will provide another alternative model to test. Bayesian "goodness of fit" tests will be used to select between competing models (i.e. all available prior information will be used). Additionally, for communication purposes, develop a conceptual 3D-landform GIS spatial model with transport pathways clearly shown and using the best estimates of the loads/fluxes of contaminants.

  - Integrate above submodels into a first-cut ecosystem model of the ARR with a focus on the Magela catchment.

• Integrate socio-economic frameworks and indigenous perspectives into ecological risk assessment frameworks to enhance decision supports tools above.

  - Primary focus is to develop bioeconomic models for management of key invasive species on Kakadu National Park, with potential to expand analysis to agricultural production areas. That is: (1) develop cost-of-control models for key weed (mimosa, paragrass, salvinia, rubber bush) and feral (pigs & buffalo) species; (2) develop conservation (e.g. biodiversity) and production impact/damage models to help quantify benefits of control (damage-abundance relationships) for different levels of management; (3) combine economic models with best knowledge of species life history and population dynamics; and (4) undertake benefit-cost analysis (with respect to protection of conservation values – benefit maximisation & cost-minimisation choices). Incorporate indigenous perspectives of benefits and costs through effective consultation processes.

- Similarly, undertake benefit-cost analyses of impacts due to infrastructure, tourism, mining and potential climate change.

Project 3: Conservation and management of tropical wetlands

The knowledge and skills capacity developed in Projects 1 and 2 above will be transferred to Project 3 to address similar environmental protection issues in other regions. Project 3 is best facilitated through the NCTWR and external funds will be continually sought.

- Advise the Ramsar Convention on incorporating indigenous community perspectives in the management of wetlands and methods to assess impacts on the cultural values of water.

  - Contribute to the Millennium Ecosystem Assessment process using ARR as a case study.

- Advise the Ramsar Convention on the impacts of climate change to wetlands and methods of assessing their vulnerability (see projects above).

- Initiate catchment management planning process with indigenous communities in Arnhem land (requires some external funds).

- Develop and implement a Northern Rivers Assessment Program (“out-of-session” funding sought from LWA which could also fund above).

Paper prepared by Peter Bayliss and Max Finlayson for the 13th Meeting of the Alligator Rivers Region Technical Committee (ARRTC), 15–17 March 2004

Progress report on the ISP Landscape program (2003–2004) in the ARR

ARRTC Key Knowledge Need:
Establish a landscape scale analysis and monitoring program to differentiate mining related impacts from other causes; and contribute within the broader context to the monitoring of the natural World Heritage values of Kakadu National Park.

Background

eriss Strategic Workplan 2003-04: Thematic Structure and Priority Activities

A broad thematic research program structure was adopted this year in response to the Alligator Rivers Region Technical Committees' (ARRTC) identification of a number of Key Knowledge Needs. Seven thematic research areas were developed and underpin current research strategy. These themes facilitate a multi-disciplinary approach to ***eriss*** research and monitoring activities. Progress in meeting program activities is summarised in the ***eriss*** Strategic Workplan 2003-2004 and is assessed regularly throughout the year, comprising a large part of our accountability processes that includes progress reports to ARRTC and the Supervising Scientist. This ARRTC paper reports on progress of the Landscape analysis program for July 2003 to February 2004.

Landscape analysis

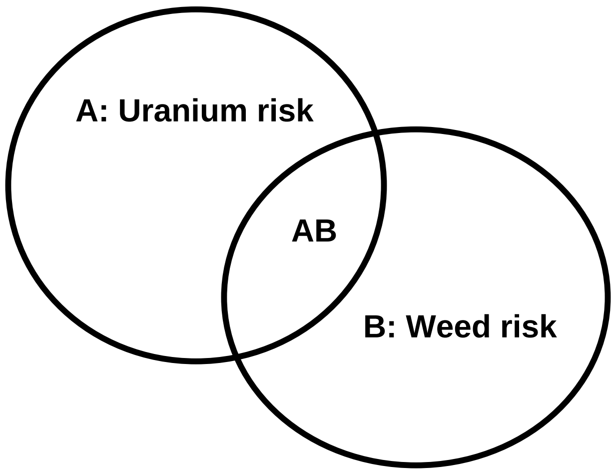
Theme aims: (1) to establish a landscape scale analysis and monitoring program to differentiate mining related impacts from other causes; and (2) contribute within the broader context to the monitoring of the natural World Heritage values of Kakadu National Park. This theme responds to recommendations made by the Independent Science Panel (ISP) in its final report to the World Heritage Committee about mining activity and associated issues in the Alligator Rivers Region (ARR), including the possibility of major changes unrelated to mining, and that there may also be unforeseen problems arising from mining.

Hence, there are two parts to the Landscape analysis theme:

1. The development of a conceptual transport pathways model for on-site management within a risk framework; and
2. Assessment of World Heritage values in the Alligator Rivers Region.

Part 1 is now under the leadership of Rick van Dam and progress will be reported separately to ARRTC in his discussion paper on conceptual models, which at this stage focuses on identification of minor and major pollutants and their pathways. Development of a conceptual statistical model that incorporates spatially explicit multiple risk probabilities (uncertainty) at multiple scales has commenced. A Bayesian approach will be adopted to map ecological risk probabilities across the landscape at different levels of spatial resolution, and ranging in scale from point source risks (e.g. Ranger mining operations, infrastructure) to more extensive landscape-scale risks (e.g. invasive species, climate change). A landscape-level risk framework will initially be developed for the Magela floodplain and incorporate the minesite risk assessment framework being developed in Part 1 of this program and, eventually, information derived from all other ISP-Landscape projects. This framework aims to provide context, coherency and purpose to the innate diversity of our landscape program, and to resolve inevitable tensions between the mining and non-mining faces of ***eriss.***

The spatially explicit Bayesian risk framework will incorporate existing and new knowledge on the effects and exposures of different ecological risks. For example, with respect to weeds, prior knowledge will include habitat preference, life history and population dynamics. And new knowledge will include current distribution and abundance of key weed species and their ecological impacts. Such an approach allows use of isolated and interactive risk probabilities, and/or more informative complex predictive risk models. The latter, for example, may entail statistical predictive models such as multiple regression equations, multivariate components analysis, or consonant ecological models that incorporates knowledge of stochastic processes. Derivation of combined multiple risks, for any particular space within the landscape, can be conceptualised with the following Venn diagram using a hypothetical example.



A 1 km^2 patch of the Magela landscape is covered in Para grass weed that has escaped control efforts. Additionally, there is the constant non-zero risk of uranium concentrations in Magela Creek exceeding the trigger value (5.5 ug/L). What is the combined ecological risk given that the independent ecological risks of A or B = Pr (Exposure A or B) x Pr (Effects A or B). If

A = Ecological risk probability of a uranium exceeding the trigger value (5.5 ug/L) and affecting >1% of species in the Magela ecosystem, or the “isolated” risk probability for uranium.
= 0.0000006 (close to zero)

B = Ecological risk probability of Para grass weed (a reality), or the “isolated” risk probability for Para grass.
= 0.86 (assumed the same as for uncontrolled mimosa weed).

AB = The “interaction” term that defines that proportion of the ecosystem affected by Para grass that cannot be affected by uranium because it is already ecologically affected (or vice versa). This is a conditional probability, the backbone of Bayesian frequentist statistics.
= 0.0000005

Hence, the combined ecological risk probability of uranium and Para grass = A + B – AB = 0.86000008, clearly demonstrating that all of the risk to ecosystem integrity in that particular patch of the landscape is due to Para grass. Hence, this method deals with greater than one risk probability and allows isolated risks to be ranked (e.g. Para grass risk is 1.4 million times greater than uranium risk). Non-additive synergistic and cumulative effects of two or more ecological risks would require much prior knowledge to calculate. Other examples may be the combined risks of two or more weeds, two or more pollutants, two or more weeds and pollutants combined, and so on. Maps of combined Bayesian risk probabilities can be produced in a GIS environment and would be a useful decision support tool for natural and cultural resource managers in the ARR.

All ***eriss*** Landscape project activities, whether or not more relevant to Parts 1 or 2, fall under the key outcome areas summarised in Table 1. All activity under this theme will be concluded in 2003-04, and the need for further landscape-scale work will be reviewed.

Table 1 List of ***eriss*** ISP-Landscape projects by key outcome areas, 2003-2004.

Key outcome area	Project
1. Undertake a review of landscape analyses being conducted in the Alligator Rivers Region	• Catalogue of research undertaken in the ARR • Publish a review paper in a journal
2. Catalogue, map, assess and monitor significant habitats and native species in the Alligator Rivers Region	• Changes to significant habitats & native species in the ARR • Gulungul Creek fish project
3. Assess mangrove response to environmental change in the Alligator Rivers Region and surrounding regions (particularly climate change)	• Mangrove response to coastal environmental change
4. Assess landscape-wide ecological risks of threats to wetlands in the Alligator Rivers Region, particularly invasive species and infrastructure impacts	• Landscape mapping of the ARR • Mapping major environmental features of Magela Creek & floodplain • Assessment of multiple impacts on Boggy Plain, South Alligator River • Ecological risk assessment of major weeds on the Magela floodplain • Feral animal management on Kakadu • An assessment of radiation anomalies in the ARR
5. Assess the status of World Heritage waterbird values in the Alligator Rivers Region within regional, national and international frameworks	• Assess World Heritage values for waterbirds in Magela & the ARR
6. Integrate socio-economic frameworks and indigenous perspectives into ecological risk assessment and management frameworks	• LWA Tropical Rivers application, Project 3: provide a framework for analysis of ecosystem services provided by rivers & wetlands of northern Australia (includes ARR) • Millennium Ecosystem Assessment: ARR a sub region • Bioeconomic modelling within invasive species projects • Cultural fire management project within Boggy Plain project • Involvement of Kakadu TOs in waterbird project

1 Undertake a review of landscape analyses being conducted in the Alligator Rivers Region

The review is in two parts. Part 1 aims to catalogue all research undertaken in the ARR, and Part 2 aims to publish a review paper of landscape analysis in the ARR in relation to the management of multiple ecological risks at multiple scales. The framework for the review will encompass the following:

1. Ecological theory, community and population ecology, and ecosystem dynamics.
2. Ecological risk assessment of multiple pressures at multiple scales. The pollution transport pathways model being developed for Ranger uranium mine will be at the centre of the landscape analysis framework.
3. Linking landscape ecology to (1) and (2) above.
4. Uncertainty analysis in data using advanced statistical analyses and ecological modelling methods.

Part 1 of the review is complete and the outputs summarised below. Conceptual modelling for Part 2 will commence in April 2004, and stochastic submodels developed for invasive species by July 2004 after collation and analysis of appropriate spatial data on weed extent and feral pig damage (ground disturbance) on the Magela floodplain.

Title: A catalogue of research undertaken in the Alligator Rivers Region

Aim: To provide as complete as possible a listing of published information on the ARR in the form of an updated, comprehensive database.

Completion: June 2003

Team: J Mount & G Begg

Major findings: Some 2,546 ARR-related references were added to the 4,087 existing references. However, the database is still incomplete and requires further searching as well as updating. Recommendations for geo-referencing and linking articles to a GIS have not been enacted (a suitable model for such an outcome has been provided by the NSW NPWS in a program known as WISE). Access is available through the SSD information platform.

Output: Internal Report 428. J Mount & G Begg 2003. A catalogue of research undertaken in the Alligator Rivers Region describes the status of the database with recommendations for further updating and access. Further updating is the responsibly of OSS staff.

2 Catalogue, map, assess and monitor significant habitats and native species in the ARR

Title: Changes to important & significant habitats and native species in Kakadu National Park

Background / rationale

Potential threats

Stone country habitat in the vicinity of the Jabiluka mine site has the potential to hold endemic and rare plants and animals. The IUCN and ISP recognised that these organisms could be placed at risk from future mining activities including: dewatering of mine voids that could potentially drawdown surface or interstitial waters in adjacent springs and seeps; noise or vibration from explosive blasts that disturbs roosting bats in adjacent cave systems; and/or alteration of fire regimes.

Additional threats to these habitats and associated flora and fauna include: *cane toads* (e.g. predation by birds and mammals; competition from tadpoles with native aquatic fauna in 'simple' freshwater ecosystems on the sandstone plateau); *other feral animals and weeds* (e.g. damage to sensitive habitat; loss of native habitat); *fire* (e.g. loss of habitat and species); *mining.*

It will be important that inventory and monitoring are conducted using a design that enables mining-related changes to be distinguished from those associated with other causes.

World Heritage values

This project is also relevant to the following natural World Heritage values of Kakadu National Park:

> Important and significant habitats where threatened species of plants and animals of outstanding universal value from the point of view of science and conservation still survive, and Plants and animals of outstanding universal value:

- plant and animal species of conservation significance (including iconic species and species of high cultural value);
- high levels of endemism and species diversity.

Components to the study

To map and catalogue important and significant habitats and native species in KNP/ARR

Important and significant habitats and native species in KNP/ARR would be mapped (including geo-referenced) and surveyed. Important and significant species would be identified and, in the case of new species, described.

It is noted that the stone country of Kakadu is particularly rich in "threatened species of plants and animals of outstanding universal value" and warrants priority attention. A significant knowledge gap is the Refugial seeps, springs, streams and cave systems of this part of the Park that are known to harbour important and significant species, including endemics of extremely restricted distributions. While some of these habitats and species have been mapped or catalogued, this task is incomplete.

It is important that the surveys systematically cover the broader ARR in order that the conservation status (species discrimination, distribution and abundance) can be properly assessed.

Monitoring

Locations or exemplary locations holding important and significant habitat and/or species are revisited over time to monitor changes in abundances.

Methods

1. Risk analysis: identify information gaps against possible threats.
    - Collate and synthesise existing information for KNP/ARR on important and significant habitat and/or species.
    - Prioritise habitats and plant/animal communities for which inventories are incomplete and against possible threats.

2. Mapping and surveying

- Priority habitats and native species are mapped (including geo-referenced) and surveyed.
- Native species are identified and, in the case of new species, described.

3. Monitor changes to important and significant habitat and/or species selecting exemplary sites and species where necessary.

4. Nominate endemic species for classification on the IUCN Red List where applicable.

Progress to February 2004

1. Only methods from 2 above have been applied to date.

2. Survey and sampling has focused on water chemistry, aquatic fauna and flora of stone country seeps and springs, though most effort has been directed at aquatic invertebrates. Amongst the invertebrates, particular attention has been paid to sampling of endemic macro-crustacean groups, the isopods (family Amphisopodidae, genus *Eophreatoicus*), prawns and shrimps (families Atyidae and Palaemonidae) and freshwater crabs (*Austrothelphusa* spp).

3. Past (pre-ISP) and current surveys by ***eriss***, Parks Australia and other researchers have discovered a large number of endemic macrocrustaceans in the sandstone escarpment and plateau country of Kakadu and Arnhem Land.

4. Northern locations of KNP from Jabiluka to Namarrgon have been reasonably well (systematically) surveyed, with relevant district PAN staff and aboriginal landowners being involved with the sampling. Central locations around Deaf Adder and southern locations around the upper Katherine, South Alligator and Mary rivers have received less attention.

5. There are currently budgetary constraints associated with additional survey work and the formal identification and descriptions of new species (these latter tasks having to be undertaken by southern private and institutional (Australian Museum) collaborators). In addition to morphological studies, molecular genetics work is also required to distinguish and assess the status of new species; some of this genetics work has been undertaken at no cost (G Wilson, Australian Museum) while additional low-cost collaboration might also be forthcoming (S Bunn, Griffith University). A bid for research funds has been submitted by G Wilson and C Humphrey from ABRS for further taxonomic studies of amphisopodid isopods of the ARR.

6. Continuation of this study would be justified on the basis of completing baseline information needs for (i) any future mining at Jabiluka, or (ii) cane toad invasion.

7. A summary of results and progress to date remains to be summarised in an Internal Report.

Title: Gulungul Creek fish project

Team: Bob Pidgeon & Chris Humphrey

Aims & background

This project was undertaken in 2001 to detect any catchment scale effects of mining on fish communities of Gulungul Creek. Essentially it repeated an earlier study (1978 to 1990) of longitudinal patterns of fish community structure from the headwaters to a point downstream from the mine at the start of the braided stream channel section upstream from Gulungul billabong that is at the confluence with Magela Creek. No mining related changes were detected but adverse effects of increased vegetation following buffalo removal were apparent in several species.

Outputs:

The study has been reported in IR405 and IR406. Further outputs could include publication as an SSR or a journal publication.

Bishop KA & Walden DJ 2003. Fish communities of Gulungul Creek: A landscape analysis. *Phase 1:* 'First-pass' analyses of 1979–2001 Late-Wet–Early-Dry season data (October 2001), Internal Report 405, February, Supervising Scientist, Darwin. Unpublished paper.

Bishop KA & Walden DJ 2003. Fish communities of Gulungul Creek:A landscape analysis. *Phase 2:* 'Second-pass' analyses of 1979–2001 Late-Wet–Early-Dry season data (June 2002), Internal Report 406, February, Supervising Scientist, Darwin. Unpublished paper.

Future:

The authors recommend further studies that involve further monitoring of Gulungul Creek and further data analysis. The latter would involve integration with other fish datasets obtained by ***eriss*** to develop predictive models, involving hydrology as a major variable that could allow sensitivity analysis of their ability to detect mining related changes in fish community structure. This analysis could be programmed as part of the large scale-modelling project for the Magela Creek ecosystem.

3 Assess mangrove response to environmental change in the ARR and surrounding regions (particularly climate change)

Title: Mangrove response to coastal environmental change

Team: Kirrilly Pfitzner

Aims & timeline:

1. To establish, for Kakadu National Park (KNP), past and present baselines of mangrove extent species/community composition, structure and biomass based on, for selected mangroves, a combination of remotely sensed data.
2. To interrogate the resulting datasets to quantify and better understand mangrove response to coastal environmental change.
3. To develop spatial models that predict the future extent and condition of mangroves under scenarios of coastal environmental changes, including those induced by altered climate.
4. To apply the above principles to mangroves in environments other than KNP.

Original task Timeline Start: 1/07/2001 End: 1/12/2003

Expected completion & justification of extension

A complete coverage of mangroves using 1991 aerial photography has been produced for KNP. A detailed study using CASI, AIRSAR and field data has been applied to the West Alligator.

An extension of the mangrove project would allow more collaborative publications to be completed. Any further work would be subject to resources and funding. Note that Richard L is keen to spend some time at **eriss** while on sabbatical. Anthea Mitchell would accompany him. Potential work to complete the original project aims include:

With planned 2004 aerial photo coverage, it is possible to repeat the process undertaken for the 1991 data to better understand any change in mangrove distribution. It is also possible to scale up from the detailed West Alligator studies to other areas in KNP. This would require funding and resources.

An analysis of existing synoptic data for mangroves of KNP (AIRSAR, Radarsat and JERS) has yet to be investigated. Data has been purchased by UNSW. An analysis of newer generation data of KNP for mangrove and wetland mapping has yet to be investigated. This may require funding.

To develop spatial models that predict the future extent and condition of mangroves under scenarios of coastal environmental change (aim 3) is quite involved because it requires inputs of ocean circulation, sea level rise etc., but is an area Richard L is “keen to address next”, and he may do this as part of his sabbatical in 2004.

Applying the principles (4) has been addressed but will be written up in the next three months as Richard L et al. are applying the procedures to Daintree and also to French Guyana for selected sensors (namely SAR). Papers in the next three months are planned.

Anthea Mitchell is working with Richard in the UK from March – May 2004 to write papers, some of which are in collaboration with **eriss**. Christophe Proisy is also in the UK March-April working on modelling mangroves with SAR data. Ake Rosenqvist (JAXA, Japan) is in the UK for three-four days from 8th March talking about potential mangrove mapping from ALOS.

Major research findings to date:

Using the approach outlined by Lucas et al. (2002) for generating baseline datasets of the extent and height of mangroves, a fine (1 m) spatial resolution orthomosaic and accompanying digital elevation model (DEM) for the majority of mangroves in Kakadu National Park has been generated. The orthomosaic, which is based on 66 stereo pairs of colour photographs acquired in 1991, covers an area of approximately 742 km^2 and a coastal distance of 86 km. The DEM has a height resolution of 0.5 m (± 1 m). The mosaic represents a key historical baseline dataset of the extent and height of mangroves within Kakadu National Park against which to observe and quantify changes in response to, for example, sea level rise. The results showed that the extent, height and species zonation differs in the River systems (see IR447 for details).

Expected outputs

Journals: One journal paper has been published (Wetlands Ecology and Management). Others are planned.

Conferences: Four conference papers have been published (3 x Mangroves 2003 and 1 x IGARSS 2003). Papers to “Estuarine and Coastal Sciences Association (ECSA) and Estuarine Research Federation (ERF) International Conference in June 2004” are planned.

IR: IR447 produced. Others planned

Thesis: Anthea Mitchell’s PhD has been submitted.

Articles and Magazines: An article to Position Magazine has been accepted. Research was described in Kakadu Research Newsletter

4 Assess landscape-wide ecological risks of threats to wetlands in the ARR

Title: Landscape mapping of the Alligator Rivers Region

Team: John Lowry & Michael Knox (DBIRD)

Objective:

The overall aim of the project is to collate, compile and integrate datasets in a geographical information system (GIS), which could be used to delineate landscapes within the Alligator Rivers Region at a nominal scale of 1:250 000. This information collected will be used as the base for further detailed analysis and assessment of the impacts of uranium mining activities across the Alligator Rivers Region. However, the specific aim for this year (2003-04) is to complete a report describing the landscape classes, and the methodology used to delineate the landscape classes.

Schedule: Project due to be complete by June 2004. SSR due June 2004.

Progress:

Currently on schedule. SSR due to be sent out to review by end March. Extensions unlikely to be required unless other higher priority projects occur in the intervening period.

Reports & communication

An A1-sized poster describing the landscape types has been published, and 750+ copies distributed. The remaining outputs for this project are anticipated as being a SSR.

Type	Indicative Title	Date
SSR	GEOMORPHIC LANDSCAPES OF THE KAKADU REGION	30/06/2004

The report and remaining poster will be distributed through the normal publication process. Relevant stakeholders and networks will be informed of the availability of the report, poster, and spatial datasets. Staff will be able to access all of the above through SSD explorer.

Title: Mapping major biophysical features of Magela Creek and floodplain

Team: John Lowry, James Boyden & Max Finlayson.

Objective:

The overall goal of this project is to produce updated maps of wetlands, and other biophysical features in areas of the Magela catchment. The specific aims of the 2003-04 year is to produce a base map of the vegetation of the Magela floodplain at a scale of 1:50 000, that will provide a base for further detailed analysis of the biophysical environment, and the assessment of any change due to uranium mining activities; and to produce a report documenting the methods and results of the study.

Schedule:

Vegetation mapping activities of the project to be completed by end June 2004. Erissnote and conference presentation may not occur until 2004-2005 year – the latter depends on finding a suitable venue give presentation at; the former depends on ability of Communications section to produce SSNotes. Mapping of infrastructure to be completed by ~December 04.

Progress:

Currently on schedule for vegetation mapping. SSR due to be sent out to review by end-April. Anticipated that poster will be completed in period between sending SSR out to review and June 04. Looking for relevant conference for paper to be presented in – actual conference unlikely to be before June 04, but (subject to finding relevant conference) anticipate submitting abstract before June 04. erissnote likely to be produced by end June 04 – subject to operational requirements. Infrastructure mapping to be completed by December 04 subject to acquisition of additional high resolution imagery for complete floodplain.

Reports & communication:

Type	Indicative Title	Date
SSR	THE [BIOPHYSICAL ASPECTS] OF THE MAGELA FLOODPLAIN	30/06/2004
POSTER	THE DISTRIBUTION OF VEGETATION COMMUNITIES ON THE MAGELA FLOODPLAIN	30/06/2004
CONF PAPER	MAPPING THE [BIOPHYICAL ASPECTS] OF THE MAGELA FLOODLAIN IN KNP	30/06/2004
POSTER	THE BIOPHYSICAL FEATURES (INCLUDING INFRASTRUCTURE) ON THE MAGELA FLOODPLAIN	31/12/2004
ERISSNOTE	GIS APPLICATIONS IN THE MAGELA FLOODPLAIN	30/04/2004

The project team will provide updates to stakeholders on project progress through erissnotes, meetings, liaison, presentations as required to address stakeholder issues, supply of completed data products to stakeholders (including demonstrations of products if required), and seminars at the conclusion of the project.

Title: Assessment of multiple impacts on Boggy Plain (fire, saltwater intrusion, invasive species), South Alligator River

Team: Peter Bayliss, James Boyden, Rod Kennett (PAN-Kakadu), Kakadu Traditional Land Owners Peter Christopherson, Sandra McGregor and Violet Lawson

Timelines: Start: 1/07/2002 End: 30/06/2004

Completion: **30/12/2004**

Aims:

1. To assess multiple impacts of fire, invasive species (weeds & feral animals) and potential saltwater intrusion on floodplain vegetation communities of Boggy Plain, South Alligator River, Kakadu National Park.
2. To assess the influence of re-introduction of indigenous fire regimes to the abundance and accessibility of key cultural food resources.

Background:

The wetland vegetation-monitoring project at Boggy Plain arose out of concerns expressed by Traditional Land Owners for the maintenance (both access & availability) of natural food resources on Boggy Plain, a key wetland on the park. The project is a partnership venture with the Traditional Land Owners of the South Alligator region and Parks Australia North. It essentially provides technical support to their cultural fire management project, whilst at the same time providing ***eriss*** with a contextual baseline that can be used as a 'non-mining' site for comparison with the Magela Creek floodplain, where mining continues at Ranger uranium mine. Additionally, the study provides an opportunity to develop and validate cost-effective remote sensing methods to monitor and assess wetland vegetation change due to multiple impacts.

Extensive and dense stands of native *Hymenachne* grass restricts Bininj access for hunting (particularly for turtle), reduces the availability of other floodplain plant food resources and, reduces the abundance, diversity and spatial heterogeneity of other wetland vegetation. *Hymenachne* may displace important food plants for magpie geese, such as *Eleocharis* spp sedge and *Oryza* spp (wild rice) unless periodic burning is applied, and this may explain the large reduction in their dry season abundance over time (Bayliss et al., unpublished).

Major Research Findings to Date:

Impact of fire on Hymenachne abundance determined from ground-based vegetation surveys

- *Hymenachne* covered 70% of ground transects before prescribed burning commenced in September 2002, often forming dense, impassable monocultures.
- 6 months after fire (late 2003 wet season), *Hymenachne* cover had decreased by 50% but showed signs of slight recovery.
- An estimate of the recovery rate of *Hymenachne* in the absence of fire will be made with additional data to be collected in the late wet of 2004.

Other observations from vegetation surveys

- At sites where *Eleocharis dulcis* and *Hymenachne* spp coexisted, a strong negative correlation was observed, suggesting interference competition between the two which may have lead to the exclusion of *Eleocharis* spp from many parts of Boggy Plain.
- Hydrological factors were correlated strongly to vegetation structure and composition, and may have varied the disturbance effects of fire and feral pig damage .

High-resolution remote sensing (HRS) mapping & assessment of short-term change

- HRS QuickBird & Hyperspectral imagery are effective products for mapping and monitoring changes in major wetland plant communities at Boggy Plain, in particular the *Hymenachne*, *Eleocharis*, *Oryza*, and *Nelumbo* dominated communities.
- Spectral analysis indicated a marked change in *Hymenachne* dominated communities after fire in contrast to control (unburnt) areas, with a 39% reduction in extent, similar to the absolute reduction estimated from ground-based data.
- Deeper water excluded fire from some *Hymenachne* dominated areas.

Long-term change observed from aerial photo analysis (1950-1991)

- A three-fold increase in the extent of water buffalo “swim channels” occurred from 1950 to 1991.
- A landward expansion of mangroves occurred in the southern-most palaeochannels.

Expected Outcomes/Outputs:

Boggy Plain is probably the most important wetland in Australia for the iconic magpie goose, and no doubt other waterbird species. Bayliss and Yeomans (1989) found that 70-80% of the entire NT goose population used Boggy Plain as a dry season refuge, and this was later confirmed by Saalfeld 10 years later (P&WC NT report). However, magpie geese numbers have been declining and the dry season use of Boggy Plain has reduced considerably causing concern amongst Traditional Owners. Our ecological risk assessments of Boggy Plain will provide a better information base for site-specific management of this World Heritage asset and, additionally, will provide eriss with the information to hopefully tease out some of the confounding effects of landscape-scale impacts from potential mining impacts.

Field work remaining:

- 3 day vegetation survey in May 2003, completing field work.

- Sub meter laser level survey for salt-water intrusion risk analysis (October 2004)

Internal Reports, Publications, & Conferences/Seminars

Indicative Title	Target/Status	Journal/ SSR	Authors
Vegetation Change Analysis on Boggy Plain, South Alligator River using remote sensing: progress report (IR430)	Completed	NA	Boyden, Bayliss, Kennett, Christopherson, Lawson, McGregor, & Begg
Monitoring the response of wetland vegetation to fire and other disturbance regimes at Boggy Plain, South Alligator River Floodplain: Preliminary analysis of ground-based data from September 2002 (IR429)	1/08/2003 / Draft: nearing completion	NA	Bayliss, Boyden, Kennett, Christopherson, Lawson, McGregor
Smoke on the water: Fire management in the wetlands of Kakadu National Park	Presented November 2003	CSIRO seminar	Christopherson, McGregor, Lawson, Kennett, Bayliss & Boyden
Smoke on the water: Fire management in the wetlands of Kakadu National Park	Presented December 2003	3rd International Wildlife Management Conference	Christopherson, McGregor, Lawson, Kennett, Bayliss & Boyden
Imagery assessment of Boggy Plain Using Remote Sensing	June/04 (draft)	J Remote Sensing? (Methodological)	Boyden, Bayliss, Pfitzner
Boggy Plain Fire Project	June/04 (draft)	Video and Picture-book for Binij	Christopherson, Lawson, McGregor, Daniel, Bayliss and Boyden
Imagery assessment of Boggy Plain Using Remote Sensing	June/04 (draft)	J Remote Sensing? (Methodological)	Boyden, Bayliss, Pfitzner
Wetland Vegetation Change Analysis on Boggy Plain	December/04 (submit)	Journal (Ecological)	Bayliss, Begg, Boyden, Kennett, & TOs
Using Fire to Manage Wetlands	December/04 (submit)	Journal (Environmental management?)	Bayliss, Boyden, & TOs

Title: An ecological risk assessment of major weeds on the Magela Creek Floodplain, Kakadu National Park

Outline & aims

Three major weeds that occur on the floodplains of the Magela Creek system will be assessed using the wetlands risk assessment (WRA) framework proposed for wetlands by van Dam et al. (1999). These are *Salvinia molesta* (Salvinia), *Urochloa mutica* (Para grass) and *Mimosa pigra* (Mimosa). The WRA will address four main questions:

1. what areas of the Magela Creek floodplains (macro-habitats) of KNP are at risk of invasion by each of the three weed species? (i.e. current distribution & trend analysis where feasible);
2. what are the likely consequences of these invasions? (i.e. assessment of likely effects & pressures);
3. what management actions are being undertaken, or need to be undertaken, to minimise the risks of further invasions across the Park and region (ARR); and
4. determine how the presence and spread of these species could confound assessment of any mining-related pressures.

Team:

Peter Bayliss - liaison with PAN and other ***eriss*** staff and traditional owners, analysis and reporting, bioeconomic modelling, communications of results.

Dave Walden – project manager, literature review, maintenance of all data bases including GIS, mapping, spatial and temporal analysis, reporting. To coordinate and liaise with John Lowry (GIS) & Kirrilly Pfitzner (remote sensing) on a need to basis.

Max Finlayson – analysis & reporting, plant ecology.

Progress:

All available weed data has been sourced from PAN, DIPE, Knerr (1998) and Cowie & Werner (1987 & 1988). Relevant data has been mapped on existing IKONOS imagery. The resolution of this satellite image is relatively coarse, and this initial step simply provides an overall 'view' of the extent of the major weeds on the floodplain. Literature on the three weeds has been sourced and relevant information has been summarised to scope the first three steps of the wetland risk assessment framework. Data on control effort has been obtained for mimosa in KNP and the nearby Oenpelli floodplain. Modelling of this data has commenced and when completed will provide a valuable management tool for Park managers. All of the above information is presented in IR 439.

It is anticipated that higher quality imagery of the Magela floodplain will be obtained in the next few months, thus giving a clearer picture of the extent of the weeds and potentially vulnerable habitat. Researchers at CDU have expressed interest in sharing their knowledge gained on the Mary River system for a trend analysis of Para grass, and assist ***eriss*** in applying this to the Magela. Depending on the time of acquisition of the new imagery, an updated SSR is scheduled for end of June 04, and a draft journal paper on some or all aspects of the project by December 2004.

Future:

The following two new sub-projects have commenced:

1. Analysis of historical patterns of weed colonisation on the Ranger lease and an accompanying ecological risk assessment.
2. Combine Habitat Suitability Index (HSI) models in a GIS environment with a spatial population dynamics & control model of Para grass on the Magela floodplain, in order to undertake spatial risk assessments (a necessary pre-requisite for differentiating the impacts of multiple ecological risks).

Title: Feral animal management on Kakadu National Park

Team:

Peter Bayliss, Dave Walden & James Boyden – in collaboration with Peter Whitehead and Barry Brook from CDU, Key Centre for Tropical Wildlife Management, PAN-Kakadu staff, and Traditional Land Owners from Kakadu National Park.

Objective:

Aims: In general, to develop pest management frameworks and strategies for Kakadu National Park in consultation with Traditional land owners (TOs). Specifically, to:

1. determine how TO's value pigs & buffalo, & the acceptable levels of damage to natural & cultural values;
2. develop conceptual cost-of-control models using a GIS spatial dynamics framework; and
3. determine the current distribution & abundance of feral pigs and buffalo on KNP, using standardised aerial survey methodologies.

Schedule:

Project due to be complete by June 2004. Contract report due March/April 2004. Specific aims (1) and (3) above completed, aim (1) has been reported. The following two draft manuscripts are due end June 2004: (1) The distribution and abundance of feral animals on Kakadu National Park in relation to habitat-specific ground disturbance damage (aim 3); and

(2) Modelling the spatial dynamics of habitat-specific damage and cost-of-control caused by feral pigs on Kakadu National Park (aim 2).

Progress:

Currently behind schedule for the February 2004 contract report, may need to re-negotiate the contract (extension or reduction of modelling services). Collation and analysis of manuscript (1) above on track.

Reports & communication

Whitehead *et al.* (2002). Feral and exotic animal management strategy for Kakadu National Park: Progress report number 1. Unpublished report to Kakadu National Park, Charles Darwin University, Key Centre for Tropical Wildlife Management. Includes sub-contractor contributions.

Bayliss P & Walden D 2003. Developing decision support tools for the management of pigs and buffalo on Kakadu National Park. Internal Report 440, June, Supervising Scientist, Darwin. Unpublished paper.

Bayliss P & Walden D 2003. Managing invasive species impacts – feral animals and weeds. Talk presented to weed and feral animal control rangers at Kakadu National Park (4 April 2003). Internal Report 434, June, Supervising Scientist, Darwin. Unpublished paper.

Bayliss P, Walden D & Boyden J 2003. ***eriss*** landscape projects in the Alligator Rivers Region – seminar presented to the Kakadu Board of Management. Internal Report 433, June, Supervising Scientist, Darwin. Unpublished paper.

Bayliss P, Boyden J, Walden D & Camilleri C 2003. Consultation with Kakadu Research Advisory Committee and invited researchers. Internal Report 432, June, Supervising Scientist, Darwin. Unpublished paper.

Whitehead *et al.* (in prep.). Feral and exotic animal management strategy for Kakadu National Park: Progress report number 2. Unpublished report to Kakadu National Park, Charles Darwin University, Key Centre for Tropical Wildlife Management. Includes sub-contractor contributions.

Title: An assessment of radiation anomalies in the ARR

Team: Kirrilly Pfitzner & Paul Martin.

Original aims & planned end date:

To collate and verify existing information on radiation anomalies in the Alligator Rivers Region using MODAT data, existing airborne gamma spectrometry (AGS) data and historical documents. Acquire new AGS data to verify existing data or fill holes in existing datasets. Ground truthing of AGS data using a portable gamma spectrometer. To produce publications, including maps, which enable people to gain an overall understanding of the presence of radiation anomalies in the region.

Schedule: original task timeline start: 1/01/2003 end: 1/06/2005

Expected completion and justification of extension:

An analysis of MODAT data is complete (Pfitzner K & Martin P 2003. An assessment of radiation anomalies in the Alligator Rivers Region – a review. Internal Report 446, July, Supervising Scientist, Darwin. Unpublished paper).

Existing AGS data has been acquired and show that the data was collected at various times and with differing specifications. The existing AGS data does not include the entire ARR, and in particular, excludes the area of the Ranger/Jabiluka lease. The acquisition of AGS data of the Ranger/Jabiluka lease is therefore proposed. Ground truthing of data is required after the acquisition of AGS data. Existing data, particularly the upper South Alligator River AGS data will be used to design the field methodology and verify the AGS data. The expected completion date is 2006 with the following proposed:

Time	Task
May 2004	Use existing AGS data to identify ground truthing areas
2004-2005	Ground truth existing AGS data. Produce IR.
2004-2005	Collate and review historical documents. Produce IR.
Late dry season 2005	Commission an airborne gamma survey encompassing ~10 km upstream of Ranger (Bowerbird) to Mudginberri
Late dry 2005	Additional ground truthing of new AGS data
2006	Write-up of SSR and journal article

Major research findings to date:

Maps of all known uranium, thorium and potassium sites in the ARR have been mapped as a desktop study. According to this existing information, 164 known uranium locations occur in the ARR. Maps were produced showing the location of uranium mines that have been rehabilitated, historical uranium mines that were mined and abandoned, uranium prospects and uranium anomalies by their size (amount of metal they contain). Apart from radiation anomalies, a number of other metal deposits occurring in the ARR have been mapped (e.g. iron, copper, tin, lead, nickel and gold)

Expected outputs:

Several outputs are expected including IRs, an SSR and a journal article.

5 Assess the status of World Heritage waterbird values in the ARR within national & international frameworks

Title: Assess World Heritage waterbird values of Magela wetlands & for the Alligator Rivers Region. Aims of the project

Objectives: This project aims to collate and assess information on past and current research of waterbirds in the ARR, and to determine the usefulness of such knowledge in protecting the ecological integrity of the coastal and inland wetlands of the region. The specific objectives of the project are to:

- undertake a meta-analysis of existing published & unpublished data to identify knowledge gaps;
- provide a basis for defining parameters needed to monitor the use of the ARR wetlands by waterbirds;
- determine what factors are likely to influence food and nesting resources of waterbirds and, hence, their distribution and abundance;
- develop a conceptual model incorporating basic ecological processes of wetland function and character and waterbird ecology;
- develop predictive waterbird-habitat dynamics models for use as decision support tools in risk management of WH values;
- investigate the potential of remote sensing to cost-effectively monitor & assess the condition of waterbird habitats over large, remote areas;
- provide scientific data to guide management decisions and actions;

- suggest management measures to maintain the WH values of wetlands;
- raise community awareness of the importance of waterbirds and their role in the ARR;
- integrate this regional study with the proposed national and existing international waterbird monitoring programs.

Project benefits

Research carried out on waterbirds in the ARR in the early 1980s mainly focussed on addressing possible impacts of uranium mining activities on the Magela floodplain system. Baseline information was collected on pre-mining levels of several heavy metals in feathers, muscles and livers of 22 species of waterbirds that occur commonly on the Magela creek floodplain. Seasonal patterns of usage of wetlands downstream of major uranium deposits were identified by the early studies by Morton and Brennan (OSS). However, these previous studies were mainly descriptive. Our project aims to enhance these past studies through a detailed, conceptual and quantitative analysis at the level of individual species and at the level of ecological groupings in relation to habitat use. We will focus on individual groups of birds that are likely to respond in similar ways to environmental perturbations. The major outcome will be the structural organisation of baseline information requested by the ISP, on behalf of the World Heritage Committee, on which to develop predictive models, ecological risk assessments and monitoring programs in order to maintain the World Heritage values of waterbirds and their wetland habitats in Kakadu National Park and, the ARR generally.

The project will contribute also to waterbird research at national and international levels, for example the *'National Audit of Waterbirds and Shorebirds in Australia'* and, both the *"East Asian Australasian Flyway"* program and Ramsar Convention.

Schedule:

Project commenced in August 2002 and is, depending on support, expected to finish August 2006 (i.e. two years of meta-analysis of existing data; two years of new research).

Major research outputs to date:

Data management

- Collation of massive waterbird data sets from a diversity of sources. The OSS ARR waterbird data were only available as hard copy (original data sheets), hence much time was expended converting to electronic format.
- Data entry: 20,000 records related to aerial and ground surveys of waterbirds, and approximately 5,000 records related to vegetation surveys, have been entered and stored in an Access database.
- Much effort expended locating custodians of decades-old data collected in the early 1980s, and to negotiate access for analysis and eventual publication.

Meta-analysis of waterbird data

Identification of ecological drivers using conceptual ecological models from individuals to populations to communities. An essential step for protection of WH values embedded in landscapes across the ARR is to identify the processes upon which influence the dynamics of these ecosystems. Waterbirds are an obvious and, hence, key component of tropical wetlands and so has the potential to be used as indicators of ecological condition (e.g. "wetland health"). Understanding the dynamics of wetland habitats, and how they may influence the biodiversity of waterbirds, has been a major challenge for scientists and wetland managers in northern Australia. Despite the valuable knowledge that has accumulated over the years, the levels of understanding is still very low with respect to how such complex ecosystems work (in fact, any natural ecosystem). In order to fill knowledge gaps, conceptual models which incorporate key structural components and system drivers may assist us in how to think about the context and scope of processes that affect the ecological integrity of Kakadu landscapes.

Our first analysis was carried out on the Green Pygmy Goose and results for the population dynamics component of the conceptual model were encouraging (& presented at the 2nd Australasian Ornithological Conference in Canberra – December 2003).

Expected outputs in the future:

Analysis of data and development of conceptual models at the level of individual species will continue with data of sufficient quality.

M Bellio, P Bayliss & P Dostine 2004. Landscape scale analysis of the value of waterbirds in the Alligator Rivers Region, northern Australia. Internal Report 445, March, Supervising Scientist, Darwin. Unpublished paper.

Poster presentation at the International Conference 'Waterbirds around the World' in Edinburgh 3-8 April 2004.

Manuscript for submission to Journal of Animal Ecology by July 2004: Green Pygmy Goose population dynamics in relation to rainfall variability and habitat condition.

***eriss** note* on use of waterbirds as indicators of wetlands health.

Multivariate analysis of all waterbird data will be used to investigate patterns in community structure that are often not apparent from simple exploration of data by univariate statistical methods. We aim to investigate, in better detail, the patterns of habitat use by waterbirds across the different floodplains of the ARR, and to identify similarities at the landscape scale between sites. We will also investigate whether or not ecological groupings of waterbirds into guilds (Jaksic 1981) exhibit the same patterns of distribution across the floodplains. If so, can such similarities strengthen arguments for use of key indicator species to monitor landscape condition. Our ultimate aim is to be able to predict the types of waterbirds birds that are most likely to respond in similar ways to environmental perturbation (e.g. from mining, climate change, modifications of habitat). Multivariate analysis will involve:

- *Discriminating sites*: investigate whether or not there are similar patterns of waterbirds use between floodplains.
- *Representative communities*: can existing patterns of waterbird-habitat use be explained by the full set of biotic variables, or are there a subset of variables which can be used as representative communities and so be used for monitoring and assessment purposes?
- *Linking multivariate biotic patterns to environmental variables:* investigate whether or not community differences associated with different sites can be linked to specific weather events and abiotic site conditions.
- Results obtained from this analysis will be published in IR or SSR, and ***eriss*** notes.

Communications strategy

A comprehensive assessment of the World Heritage values of waterbird and their habitats cannot be undertaken in isolation of the indigenous values of local communities. That is, the ecological values of waterbirds and their habitats cannot be separated from the social and cultural values that they represent. Our communication strategy therefore aims to:

- improve community understanding by reporting results and research outcomes in a timely and appropriate manner;
- recognise aspirations of local communities by engaging in community and interagency consultation;
- recognise existing knowledge, in particular Traditional Ecological Knowledge, by working in collaboration with Traditional Land Owners and other Indigenous people;

- involve local communities in natural and cultural resource management issues relating to waterbirds and their habitats

6 Integrate socio-economic frameworks & indigenous perspectives into ecological risk assessment frameworks

There are no specific ISP projects that encompass this program outcome area. Rather, they are embedded within a handful of key projects that involve close collaboration with major stakeholders in the ARR and elsewhere. For example: bioeconomic modelling of invasive species management is central to those projects; the feral animal project incorporates Traditional Land Owner perceptions and values ascertained after comprehensive consultation spanning a number of years; the driver for the Boggy Plain project is re-introduction of cultural fire management regimes initiated by Kakadu Traditional Land Owners; and indigenous cultural values will be incorporated into the waterbird project in the ARR through consultation and participation.

The flagship project for this outcome area resides in an external Land and Water Australia (LWA) funding application for the Tropical Rivers Program. We are in the final stage of submission (2nd Round Project Application). It is one of three projects likely to be funded and is outlined below.

Project summary:

Sustainable management of Australia's tropical rivers and wetlands requires an integrated information base for assessment of their ecological character (including benchmarking their status) and the development of policy, especially for environmental flows and potential uses of water. An information base will be established for assessing change, undertaking ecological risk assessments of major pressures, supporting local and indigenous management, and strengthening holistic approaches for managing tropical rivers/wetlands.

The information base will be built on consultation, analysis of existing information, and specific investigations to provide further data as a reference for assessing change to the river/wetland habitats and their species, and the ecosystem services they provide. As reference conditions for assessing change and environmental flows cannot be provided for all localities or species, surrogates will be determined and responses to key pressures assessed through structured and quantitative frameworks and linked with the provision of ecosystem services. These analyses will extend analyses being done through other initiatives in tropical Australia.

Project objectives:

The project will provide a basis for determining and applying management priorities and land use practices of relevance to stakeholders, including local and indigenous people, private sectors and governmental agents. Specific objectives are to:

- undertake a multiple-scale inventory of the habitats and biota of the rivers and wetlands of tropical Australia, where necessary developing suitable typologies based on hydrological and landform features
- undertake risk assessments of the major pressures on the habitats and biota of the rivers and wetlands of tropical Australia
- provide a framework for analysis of the ecosystem services (e.g. provision of water for multiple uses), provided by the habitats and biota of the rivers and wetlands of northern Australia

Development of a framework for the analysis of ecosystem services provided by aquatic ecosystems

Duration:12 months (Year 1); student projects based at ***eriss***

Description:

Based on analyses undertaken through the Millennium Ecosystem Assessment and other published sources provide an outline of a framework for evaluating ecosystems services provided by aquatic ecosystems. The framework will entail identification of key services for different habitats (based on the habitat typology) and a description of the methods that can be used for evaluating these at the same scales as used in the analyses given above. The framework development will be led by Dr Dolf de Groot, an expert on evaluation of ecosystem services from the Netherlands, and linked to the UN supported Millennium Ecosystem Assessment (MEA).

Where available data on the value and extent of particular services will be included. The latter is likely to rely on a small number of published analyses of specific habitats and reports from or about industry sectors. Initial consultation will be used to identify the services with further detailed consultation and research being necessary at some stage in the future.

Responsibilities: ***eriss*** will support students from the University of Wageningen, The Netherlands, and linked with various international initiatives.

Outputs: A framework and an initial database for analysing ecosystem services provided by the aquatic ecosystems.

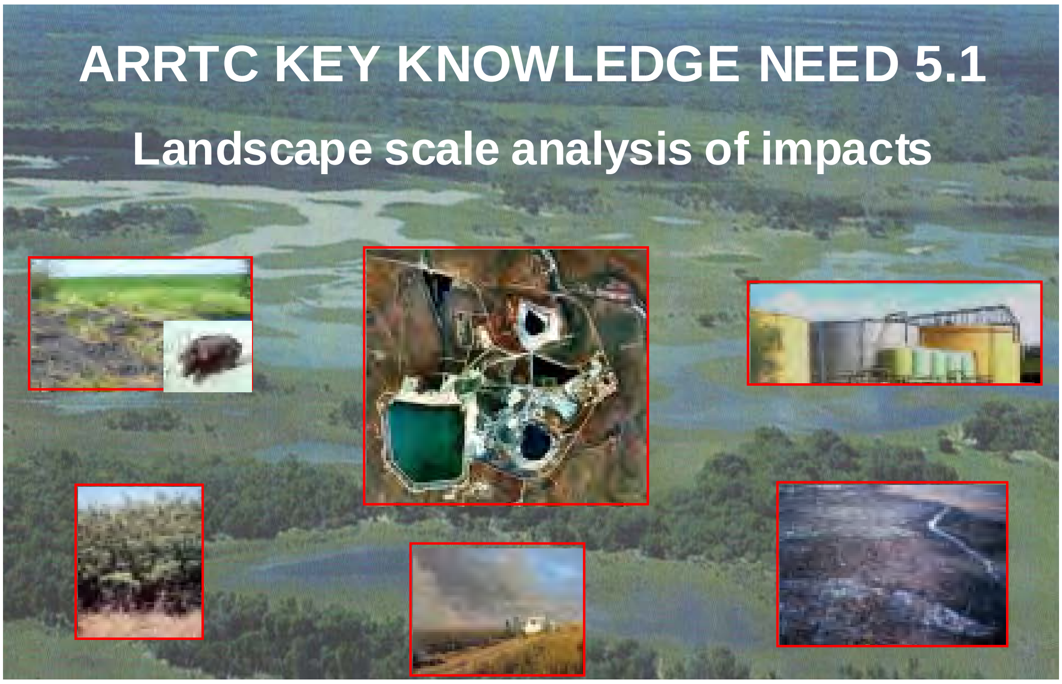
Paper prepared by Peter Bayliss, Max Finlayson and Rick van Dam for the 14th Meeting of the Alligator Rivers Region Technical Committee (ARRTC), 13–15 September 2004

Review of the ISP Landscape Program (2003–2004) in the Alligators River Region

For the 14th Meeting of ARRTC (13-15 September 2004)

ARRTC Key Knowledge Need:

Establish a landscape scale analysis and monitoring program to differentiate mining related impacts from other causes; and contribute within the broader context to the monitoring of the natural World Heritage values of Kakadu National Park.



Key landscape themes: Kakadu National Park; World Heritage and Ramsar values; Ranger uranium mine; invasive species; climate change; and Indigenous fire management.

Summary

The Landscape Analysis Theme was planned as a three-year research program (July 2002 to June 2005) and is in its final year. The development of a conceptual pollution transport pathways model for Ranger uranium mine is almost complete. Similarly, the collation of existing information and acquisition of new information on the condition of, and threats to, World Heritage values in the Magela catchment, particularly the floodplain, is almost complete. Research is now tightly focused on assessing all potential ecological impacts downstream of the mine on the Magela floodplain. For rigor in analysis and reporting a "State of the Environment" (SoE) audit approach is adopted whereby ecological threats to "susceptible" World Heritage assets or values are quantitatively assessed where possible. Development of statistical models (frequentist & Bayesian) that use spatially explicit multiple risk probabilities (uncertainty) at multiple scales have commenced. Hence, risk assessments at any chosen level of spatial resolution can be undertaken to examine multiple threats to multiple assets identified by conceptual models. All risk assessments are scheduled to be completed this Financial Year (FY). Priority tasks for the 2004-05 FY are:

1. Complete by October 2004 the conceptual pollution pathways model as the necessary first step in the process of identifying, and subsequently quantifying, all significant ecological risks from Ranger uranium mine, and to the satisfaction of all stakeholders (including ARRTC).

2. Commence and complete this FY the desktop modelling study by HEP that combines hydrologic, hydraulic and fluvial geomorphic processes in the Magela catchment through the development of a rainfall-discharge hydrology model (using HEC-HMS) (see ARRTC Discussion Paper by Saynor 2004). The model will be used to: (i) assess "worst case scenario" risks associated with extreme events such as flooding; (ii) account for the major surface water pathways of pollutants and/or sediments during the remaining operational and rehabilitation phases of the mine, respectively; and (iii) drive "whole" ecosystem models that allow incorporation of key spatial and temporal uncertainties into cross-sectional characterisations of assets and threats used in risk assessment.

3. After the development of the hydrology model, commence and complete this FY a first-cut "whole" ecosystem model that accounts for key processes and mechanisms that link specific management actions, such as chemical releases from Ranger and invasive species control, to specific indicators of the condition or "health" of the natural World Heritage values on the Magela floodplain. The model will be basically a mass transfer model (water, sediments, nutrients, biomass or species population units) and driven by rainfall-induced flood events on the Magela floodplain. It will have the following four linked submodels: a hydrodynamic submodel for space-time variation in water flows (see point 2); a hydrochemistry submodel for transport and transformation of key chemical variables such as sediments and nutrients; lower trophic level submodels for plants and selected invertebrates; and population dynamics submodels of key animal indicator species (e.g. large fish & waterbirds).

4. Consult a scientist with the right mix of social and biophysical research skills, and community experience, to fully integrate socio-economic frameworks and indigenous values into ecological risk assessment frameworks, particularly with respect to definition of rehabilitation success criteria (see ARRTC Discussion Paper by Bayliss & Pfitzner 2004).

5. Following completion of Priority tasks 1 to 4, the Landscape Analysis Theme should be discontinued as a separate ***eriss*** research program area and embedded across all ARRTC

Key Knowledge Need (KKN) Themes. ERA staff have developed a substantial skills base in quantitative risk assessment, landscape and spatial analysis and population modelling. These skills will remain central to current research and monitoring programs, and future rehabilitation programs. Such skills will provide also significant support to the External projects area that now has a developing focus on catchment-based ecological risk assessments of tropical land and water resources. This recommendation is concordant with current plans to restructure ***eriss*** research programs to focus on priority KKNs.

Background - Landscape Analysis of Impacts Theme

The Landscape Analysis (of impacts) Theme responds to recommendations made by the Independent Science Panel (ISP) in its final report to the World Heritage Committee about mining activity in the Alligator Rivers Region (ARR), including the possibility of major changes occurring that are unrelated to mining, and the fact that there may also be unforeseen problems arising from mining. Broadly, the Landscape Analysis Theme facilitates a multi-disciplinary approach to ***eriss*** KKN research and monitoring activities through use of an ecological risk assessment framework. Landscape ecology forms the backbone of “ecological risk assessment” frameworks and embraces: biophysical patterns and processes over broad spatial scales; spatial heterogeneity encompassing different types of ecosystems and landscape structures (e.g. catchments, habitats, animal & plant communities, species & populations) (Bell *et al*.1997); and cultural landscapes. Landscape ecology is central to natural and cultural resource management, catchment-based land and water management, ecological risk assessments, environmental protection and conservation and rehabilitation or restoration ecology. An additional goal of the Landscape Theme was to integrate socio-economic frameworks and Indigenous values into ecological risk assessment frameworks where appropriate. This paper reviews the Landscape Analysis Theme as requested at the 13th ARRTC meeting, March 2004.

To reiterate, the aims of the Landscape Analysis Theme were to:

1. establish a landscape scale analysis and monitoring program to differentiate mining related impacts from other causes; and
2. contribute within the broader context to the monitoring of the natural World Heritage values of Kakadu National Park.

Hence, there are two parts or Sub-themes that reflect the fact that Ranger uranium mine is embedded within a World Heritage landscape, and these are:

1. development of a conceptual transport pathways model for on-site management within a risk framework; and
2. assessment of natural World Heritage values in the Alligator Rivers Region (ARR) (i.e. assess the condition of natural WH values & threats to these values).

Time frame & progress

The Landscape Analysis Theme was originally planned as a three-year research program (July 2002 – June 2005). The development of the conceptual transport pathways model for Ranger uranium mine in Part 1 was scheduled to be completed by the end of Year 2 (June 2004), along with collation of existing information and acquisition of new information on the condition and threats to World Heritage values, necessary for analyses in Part 2. All major quantitative ecological risk assessments at the landscape scale are scheduled to commence and finish in Year 3 (June 2004-05). Dynamic ecological modelling of the Magela floodplain was also scheduled to commence and finish in Year 3 (see Bayliss *et al.* 2003: Ecological Risk Assessment and Conceptual Ecosystem Models; Discussion paper for 11th ARRTC meeting). To reiterate, the ecosystem model will be spatially explicit and used to enhance probabilistic ecological risk assessments that rely on cross-sectional time slices of spatial data that describe the condition of natural World Heritage assets and the level of existing threats to them. However, in reality the nature of assets and threats, and the relationships between them, are uncertain because they vary over space and time. Hence, the ecological "process" model will have the following two functions: (i) assess "worst case scenario" risks associated with extreme events such as floods (in the first instance via analysis of surface water pollution pathways); and (ii) account for innate uncertainty in characterisations of asset condition and threat levels by incorporating spatial and temporal (daily, seasonal, annual) variability characteristic of the Magela ecosystem. The ecological model of the Magela floodplain will have two key attributes: (i) restriction to processes and mechanisms that link specific management actions, such as chemical releases from Ranger and invasive species control, to specific indicators of the condition or "health" of World Heritage assets or values; and (ii) basically operate as a mass transfer model (water, sediments, nutrients, biomass or species population units) driven by rainfall-induced flood events in the Magela catchment. Stochastic changes in water level will have a cascading effect throughout all modelled trophic levels and drive simulated changes in the population dynamics of wetland biota (e.g. plants, fish & waterbirds, invertebrates). Hence, there will be four stochastic process submodels of the "whole" ecosystem model (after Walters 1997), and these are the:

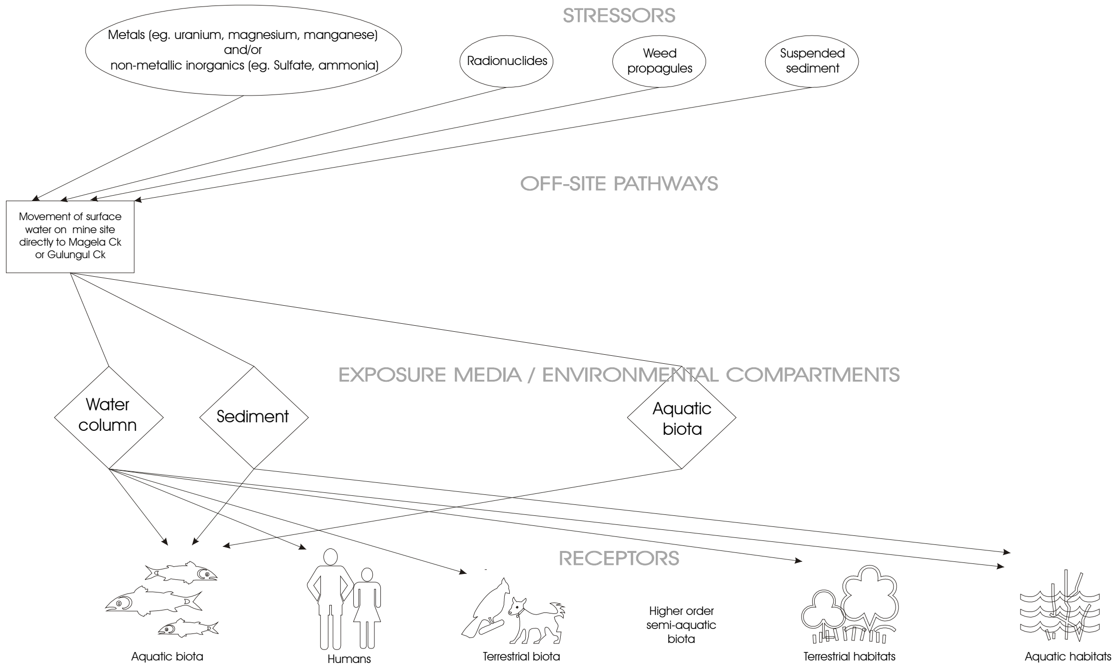
1. hydrodynamic submodel for space-time variation in water flows;
2. hydrochemistry submodel for transport and transformation of key chemical variables such as sediments and nutrients;
3. lower trophic level submodels for plants and select invertebrates; and
4. population dynamics submodels for key or dominant animal indicator species (e.g. large fish & waterbirds).

All of the major risk assessments and the development of ecological submodels are scheduled to be completed by the end of Year 3 (June 2005). Submodels will be used to simulate "what if" scenarios and, hence, model validation will be based more on utility rather than consonance with ecological reality (Hilborn & Mangel 1997, Rykiel 1996). A possible six-month extension into Year 4 (to December 2005) for the modeller may be required in order to undertake more sophisticated risk assessment modelling that incorporates key uncertainties in dynamic and complex ecological processes, and to propagate links from these models to decision models. Currently (September 2004), however, we are mostly on track as outlined below.

Progress for Part 1 has recently been reported in IR 474 (van Dam *et al*. 2004) and at the 13th ARRTC meeting (van Dam 2003). An initial conceptual model has been developed that focuses on clear identification of all minor and major pollutants and their pathways (Finlayson & Bayliss 2003, van Dam *et al.* 2002,; see Fig. 1). The conceptual model now requires expert scrutiny and opinion from all other stakeholders (EWLS, DBIRD & NLC) as to coverage, the relative ranking of risks and possible knowledge gaps. When completed, the conceptual model will provide a useful tool for: operational risk management of environmental contaminants; knowledge management; communications with respect to uncertainty analysis of data, ranking of risks and their interrelationships; and highlighting research gaps and priorities. The next phase of activity, linked to Part 2 outlined below, is to populate the conceptual model with quantitative ecological risk assessments of key environmental stressors (e.g. uranium & $MgSO_4$) through major pathways downstream of Ranger (i.e. the Magela Creek & floodplain systems). Risk assessments will incorporate the best available estimates of the loads/fluxes of contaminants, and account for process uncertainty by using the stochastic rainfall-discharge hydrology submodel introduced above. The risks of pollution from Ranger to the Magela floodplain will be assessed in combination with broader landscape-scale risks associated with invasive species and climate change impacts. Most risk assessments treat stressors in isolation and rarely address the cumulative effects of multiple stressors (Anon 2003). Hence, cumulative ecological risks will be derived from estimates of the isolated and interactive risk probabilities of each stressor (see Bayliss & Finlayson 2004: 13th ARRTC meeting discussion paper).

Progress for Part 2, encompassing a large diversity of project activities, has been reported in the discussion paper presented to the 13th ARRTC meeting (March 2004: P Bayliss & CM Finlayson; Progress Report on the ISP Landscape Program (2003-2004) in the Alligator Rivers Region). Table 1 summarises for each project in each key outcome area, progress status and time to completion, and outputs to date. The Landscape Theme has been revamped for the 2004-05 FY in order to tightly focus on completing all major quantitative risk assessments and the development of a “first-cut” ecosystem model (via the linked submodels outlined above: a 2D rainfall-discharge hydrology submodel simulating flood events; a wetland vegetation-water level dynamics submodel; a fish & macroinvertebrate habitat-dynamic submodels; & keystone waterbird population dynamics submodels). Knowledge obtained in the first two years will be used to provide asset and threat data layers at different levels of spatial resolution (for Kakadu National Park 1km x 1km cells, for the Magela floodplain subset 0.25km x 0.25km cells). Table 2 summarises the 2004-05 Work Plan for the Landscape Analysis Theme and illustrates the new Project-task structure used to facilitate completion (in contrast to expansion). There are now only three key project activities: Project 1 encompasses all risk assessment activity associated with Ranger uranium mine; Project 2 encompasses all activities associated with undertaking landscape-scale ecological risk assessments for the Magela floodplain; and Project 3 encompasses all previous uncompleted projects and mostly entails publication of results. Project 2 is divided into eight tasks to facilitate preparation of discrete spatial data layers describing the condition of assets and levels of threats to the Magela floodplain, development of the hydrologicalsub model and, subsequent quantification of all major risks.

A



B

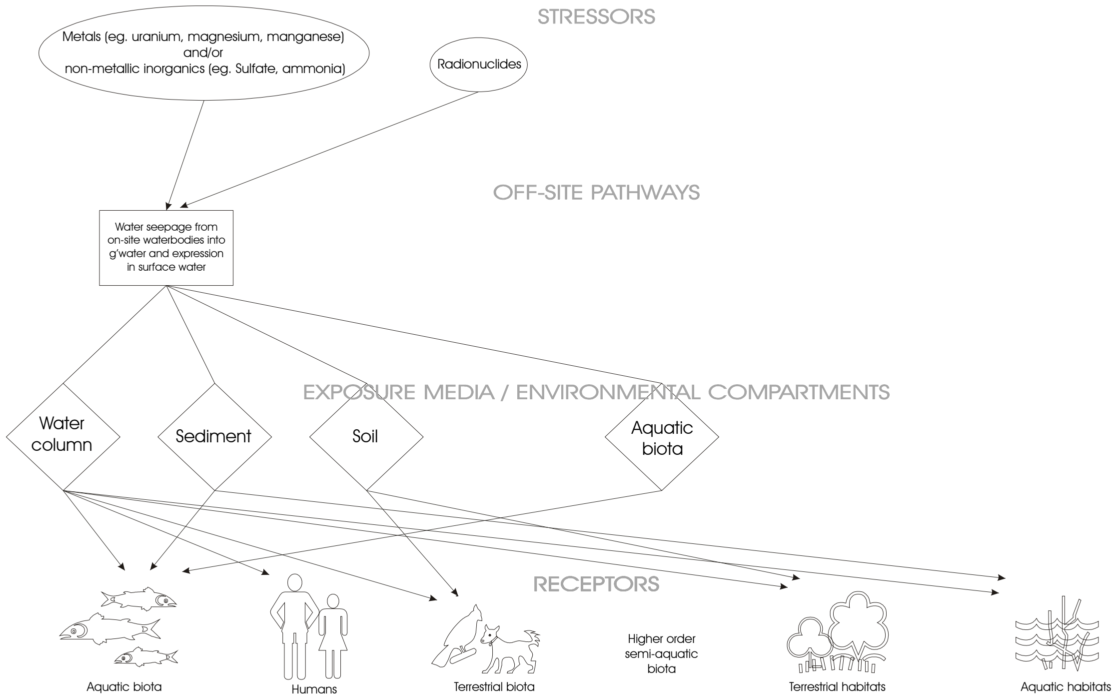
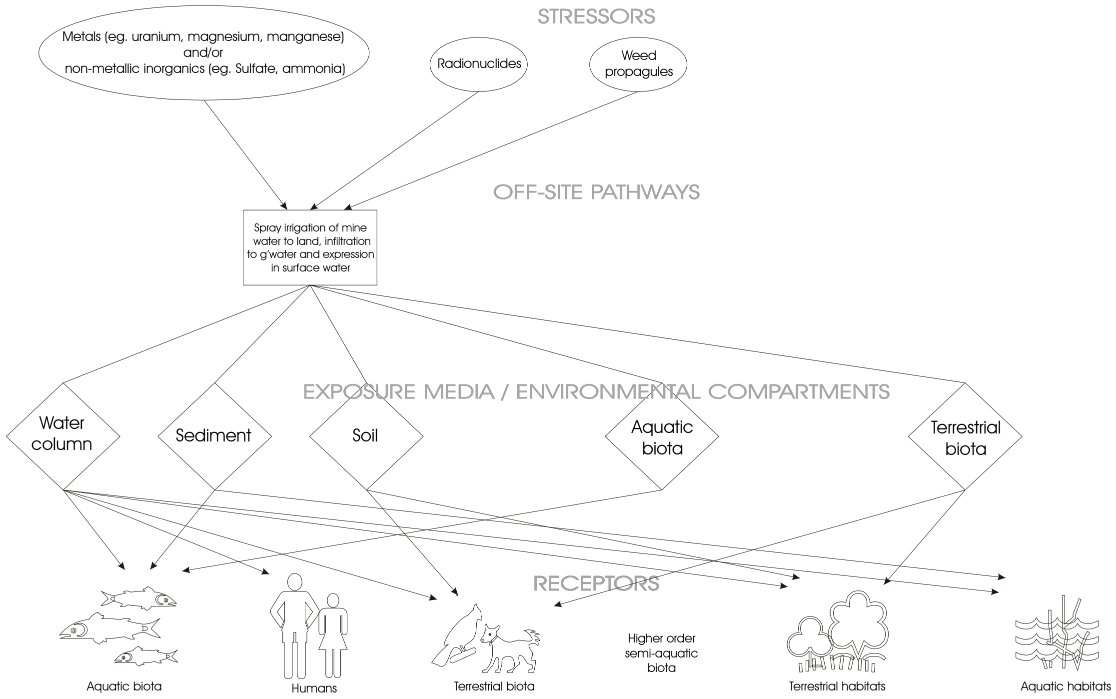


Figure 1 A & B Examples of contaminant pathway sub-models for the Ranger minesite. A: surface water to surface water pathway; B: water seepage pathway

C



D

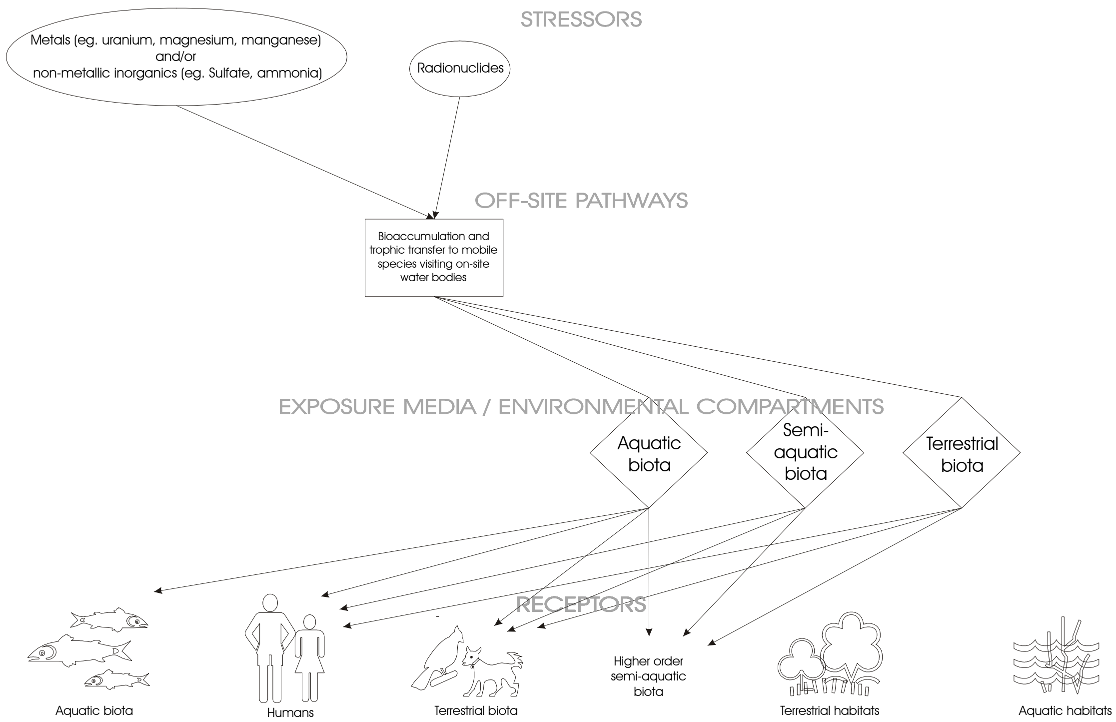


Figure 1 C & D. Examples of contaminant pathway sub-models for the Ranger minesite. C: spray irrigation pathway; D: bioaccumulation and trophic transfer from on-site waterbodies pathway

Table 1 List of ***eriss*** ISP-Landscape projects by key outcome areas, principle investigator, completion status and outputs (2002-2005)

Key outcome area	Project	Investigators	Status	Outputs
1. Undertake a review of landscape analyses being conducted in the Alligator Rivers Region	• Catalogue of research undertaken in the ARR • Publish a review paper in a journal	G Begg/J Mount M Finlayson & P Bayliss	Finished Dec 04	Internal Report 428. J Mount & G Begg 2003. A catalogue of research undertaken in the Alligator Rivers Region. Finlayson M, Bayliss P, Walden D, Lowry J & Bellio M 2003. Multi-scalar landscape analyses and risk assessments of major pressures in the Kakadu region, northern Australia. Paper presented at the IALE World Congress, 13-17 July Darwin, Australia.
2. Catalogue, map, assess and monitor significant habitats and native species in the Alligator Rivers Region	• Changes to significant habitats & native species in the ARR • Gulungul Creek fish project	C Humphrey B Pidgeon	June 05 Finished	Consultancy report to ABRS (Australian museum & ***eriss***): "A species flock of *Eophreatoicus* Nicholls (Crustacea; Isopoda; Phreatoicidea) in the Arnhem Plateau and sandstone outlier regions of the Northern Territory". July 2006. Journal article in prep: "Revision of the Kakaducarididae" (Griffith Uni, Biosciences & ***eriss***): Includes descriptions and molecular studies of new Kakadu shrimp species. May 2005. IRs 405 & 406 Fish projects
3. Assess mangrove response to environmental change in the ARR & surrounding regions (particularly climate change)	• Mangrove response to coastal environmental change	K Pfitzner	Finished	A Mitchell, B Donnelly, R Lucas & K Pfitzner 2003. The extent & height of mangroves in Kakadu National Park - an assessment based on orthorectified stereo colour aerial photography & derived digital elevation models. IR 447. Presentation at International Geoscience and Remote Sensing Symposium "IGARSS04" and Presentations at "Mangroves 04" Conference. PhD Thesis - Anthea Mitchell UNSW
4. Assess landscape-wide ecological risks of threats to wetlands in the ARR particularly invasive species & infrastructure impacts	• Landscape mapping of the ARR • Mapping major environmental features of Magela Creek and floodplain • Assessment of multiple impacts on Boggy Plain, South Alligator River • Ecological risk assessment of major weeds on the Magela floodplain • Feral animal management on Kakadu • Assessment of radiation anomalies in the ARR	J Lowry J Lowry P Bayliss/J Boyden D Walden/P Bayliss D Walden/P Bayliss K Pfitzner – transferred to Radiation Risk Theme	Dec 04 June 05 June 05 June 05 Dec 04 June 05	Finlayson M, Bayliss P, Walden D, Lowry J & Bellio M 2003. Multi-scalar landscape analyses and risk assessments of major pressures in the Kakadu region, northern Australia. Paper presented at the IALE Conference, Darwin NT, July 14–17 2003 Lowry JB & Knox M 2002. Geomorphic landscapes of the Kakadu region, Northern Territory, Australia. Poster, Supervising Scientist, Darwin NT. Lowry J, Finlayson M & Walden D 2004. Mapping the biophysical characteristics of the Magela floodplain, Northern Territory, Australia. Poster presentation at the 7th INTECOL International Wetlands Conference, 26-30 July Utrecht, The Netherlands. Lowry J & Begg G 2001. Thoughts and comments on a landscape-wide monitoring program for KNP. Internal Report 370, Supervising Scientist, Darwin. Unpl paper. Riley J & Lowry J 2002. An initial assessment of changes to Melaleuca distribution on a selected area of the Magela floodplain using aerial photography. IR 394. Finlayson CM, Bayliss P, Bellio MG & Lowry J 2003. Tropical wetlands in Northern Australia – their value and future. Paper presented at 5th International Conference on Environmental Futures, Zurich, Switzerland, 23–27 March 2003, IR 455. Lowry J 2004. **A**ssessing density and distribution change in paperbark trees on the Magela

4. Continue. Assess landscape-wide ecological risks of threats to wetlands in the ARR particularly invasive species & infrastructure impacts				floodplain, Kakadu National Park using Geographic Information Systems (GIS). Supervising Scientist Note 4, Supervising Scientist, Darwin. Riley J, Lowry J & Finlayson M 2002. An initial assessment of changes to Melaleuca distribution on a selected area of the Magela floodplain using aerial photography. Presentation to the 11th Australasian Remote Sensing and Photogrammetry Association Conference, September 2-6 , Brisbane 2002. Santos-Gonzalez C, Lowry JB & Hennecke W 2002. Suitability of NDVI AVHRR for wetland detection. A case study – Kakadu National Park (Australia). In Proceedings of the 11th Australasian Remote Sensing and Photogrammetry Conference, 2–6 September 2002 Brisbane. Australasian Remote Sensing and Photogrammetry Association, CD. Finlayson CM, Lowry J, Humphrey C, Pidgeon R, Bellio M & Bayliss P 2004. Comparative biodiversity of large wetlands: Alligator Rivers and Kakadu National Park, Australia. Boyden J, Bayliss P, Kennett R, Christopherson P, Lawson V, McGregor S, & Begg, G 2003. Vegetation Change Analysis on Boggy Plain, South Alligator River using remote sensing: progress report. IR430. Walden D & Bayliss P D 2003. An ecological risk assessment of major weeds on the Magela Creek floodplain, Kakadu National Park. IR 439. Walden D, van Dam R, Finlayson CM, Storrs M, Lowry J & Kriticos D 2003. A risk assessment of the tropical weed *Mimosa pigra* in Northern Australia – Paper and presentation to the 3rd International Symposium on the Management of *Mimosa Pigra*, Darwin, September 22–28, 2002. IR 420. Whitehead *et al.* (2002). Feral and exotic animal management strategy for Kakadu National Park: Progress report number 1. Unpublished report to Kakadu National Park, Charles Darwin University, Key Centre for Tropical Wildlife Management. Bayliss & Walden (2003). Managing invasive species impacts – feral animals and weeds (talk presented to weed and feral animal control rangers at Kakadu National Park, 4th April 2003). Supervising Scientist Internal Report number 434. Bayliss, P., Walden, D. & Boyden, J. (2003). *Eriss* landscape projects in the Alligator Rivers Region: seminar presented to the Kakadu Board of Management, April 2003. IR 433. Bayliss, P., Boyden, J. & Walden, J. (2003). Consultation with Kakadu Research Advisory Committee and invited speakers. Supervising Scientist IR 432. Whitehead *et al.* (in prep.). Feral and exotic animal management strategy for Kakadu National Park: Progress report number 2. Unpubl report to PAN. Charles Darwin University, KCTWM. Bellio M, Bayliss P & Dostine P. 2004 Landscape scale analysis of the value of waterbirds in the Alligator Rivers Region. IR 445. Supervising Scientist, Darwin. Bellio M, Bayliss P. 2004. Poster presentation at the International Conference ‘Waterbirds around the World’ in Edinburgh 3-8 April 2004. Pfitzner K & Martin P 2003. An assessment of radiation anomalies in the Alligator Rivers

				Region - a review. Internal Report 446, July, Supervising Scientist, Darwin.
5. Integrate socio-economic frameworks and indigenous perspectives into ecological risk assessment/management frameworks	• Tropical Rivers project: analysis framework - ecosystem services • Millennium Ecosystem Assessment: ARR a sub-region • Bioeconomic modelling within invasive species projects • Cultural fire management project within Boggy Plain project	Dutch MSc students M Finlayson P Bayliss/D Walden P Bayliss/J Boyden	Dec 04 Dec 04 June 05 June 05	Finlayson CM, Humphrey C, Pidgeon B, Lowry J & Bayliss P 2003. Components of an ecosystem approach for tropical wetlands – engaging with local communities and a framework for integrated data collection. In National Environment Conference 2003 Proceedings, Brisbane, 18–20 June 2003, Environmental Engineering Society (Queensland chapter), Brisbane, CD. Bayliss, P. & Walden, D. 2003. Developing decision support tools for the management of pigs and buffalo on Kakadu National Park. Supervising Scientist Internal Report number 440. Christopherson P, Lawson V, McGregor S, Bayliss P, Kennett R. 2003. Smoke on the water: Fire management in the wetlands of Kakadu National Park. Seminar to CSIRO Sustainable Ecosystems & the 3rd International Wildlife Management Conference, New Zealand.

Table 2 ***Eriss*** Landscape Analysis Theme Work Plan for 2004-2005

Theme: Landscape Analysis of Impacts	
Aim: Establish a landscape scale analysis and monitoring program to differentiate mining related impacts from other causes; and contribute within the broader context to the monitoring of the natural World Heritage values of Kakadu National Park.	
Projects & tasks:	*Lead:*
Project 1. Develop conceptual model of pollution pathways for Ranger, populate with sub-models, and incorporate into an ecological risk assessment for the Magela floodplain (18 p weeks)	
Task 1: Finalise conceptual model showing pollutant/propagule pathways & ecological linkages between uranium mining activities at Ranger & environment of ARR.	**RvD** **PB/MF**
Task 2: Populate conceptual pathways model with sub-models for quantitative ecological risk assessment at minesite & landscape scale.	**RvD** **PB/MF**
Project 2. Commence a multiscale ecological risk assessment of Magela floodplain, linking multiple stressors to multiple World Heritage assets, and quantifying uncertainty in predictions (63 p weeks)	
Task 1: Develop a hydrological model of the Magela floodplain for pollution pathway analysis & as a driver of the Magela ecosystem.	**DM/DW/JB**
Task 2: Map salinity risk profile of Magela floodplain for analysis of potential climate change impacts (eg rising sea levels etc).	**JL/JB/MB**
Task 3: Map infrastructure of the ARR, produce a Magela catchment subset for ERA.	**JL/JB**
Task 4: Produce spatial data layers of native vegetation & weeds on the Magela floodplain for ERA; develop a habitat suitability models for mimosa & para grass for ERA.	**DW/MB/JB**
Task 5: Produce spatial data layers for fish & macroinvertebrate communities on the Magela floodplain for ERA using Habitat Suitability models derived from long-term monitoring data.	**JB/DW/MB/CH /BP**
Task 6: Produce spatial data layers for ERA & food chain analysis of 4 key indicator species of waterbirds using Habitat Suitability models developed for wet season breeding & dry season refuging. Concomitantly assess the condition of World Heritage waterbird values & their wetland habitats.	**MB/JB**
Task 7: Produce spatial data layers for ERA of potential fire impacts on the Magela floodplain, using knowledge & methodologies gained from the Boggy Plain study.	**JB/DW**
Task 8: Undertake quantitative ecological risk assessment using all spatial data layers of assets and risks produced in Tasks 1-6 above.	**PB/MF**
Project 3. Complete projects from 03-04, mostly to publication stage (27 p weeks)	
Task 1: Catalogue & assess significant habitats & species in the Magela Catchment.	**CH**
Task 2: Assess mangrove response to environmental change, especially climate change.	**KP**
Task 3: Map biophysical features of Magela Creek & floodplain.	**JL**
Task 4: Landscape mapping of the Alligators Rivers Region.	**JL**
Task 4: Waterbird publications.	**MB/PB**
Task 5: Boggy Plain publications.	**PB/JB**
Task 6: Magela Weeds (complete & publish spatial risk modelling of para grass & control cost model).	**DW/PB**
Task 7: Feral animals (publish spatial cost-of- control model & maps of pig damage across KNP).	**PB/DW/JB**
Theme Leaders: Peter Bayliss & Max Finlayson. Total staff time: 18 person weeks (transport pathways) plus 90 person weeks (World Heritage values) = 108 person weeks	

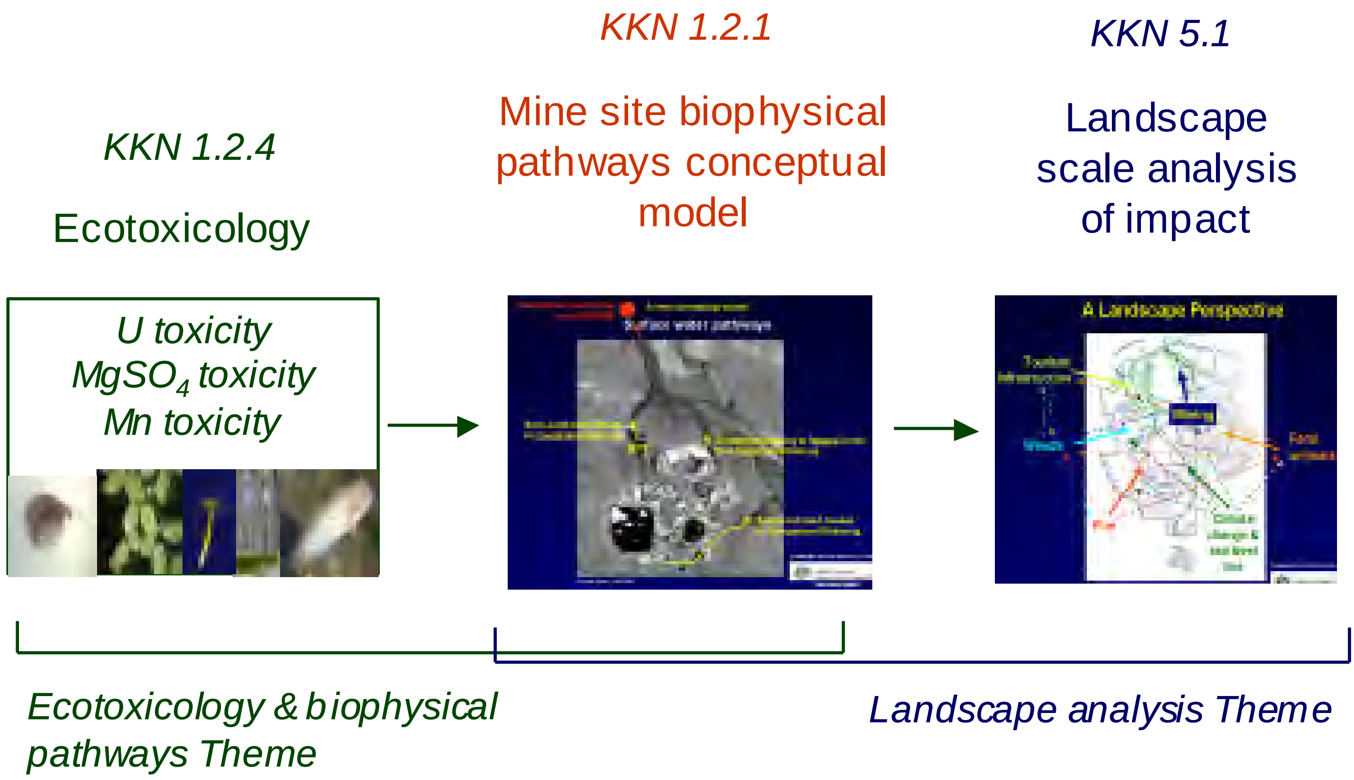


Figure 2 Links between the Ecotoxicology and Biophysical Pathways Theme, and the Landscape Analysis Theme

Landscape study design

The integrated landscape analysis approach to ecological risk assessments of multiple threats to multiple assets on the Magela floodplain overarches all KKN Themes. In particular, the Ecotoxicology (KKN 1.2.4) and Biophysical Pathways (KKN 1.2.1) Theme, and the Landscape Analysis Theme (KKN 5.1), are inextricably linked (Fig. 2). The general design of the Landscape Analysis Theme encompasses two principles illustrated in Figure 3: (a) use of nested, cascading scales of analysis; and (b) comparison of ecological risks on floodplains in catchments with mining and without mining (i.e. the Magela Creek floodplain vs the Boggy Plain floodplain, respectively). Boggy Plain is our non-mining reference site and is located on the South Alligator River, about 70km west of Magela Creek. The ecological risks common to both floodplains are impacts of invasive species and saltwater intrusion due to climate change induced sea level rise (Elliot draft MS: Saline intrusion in the Alligator Rivers Region: Oceanographic Processes). Only the Magela floodplain is at risk from Ranger uranium mine. However, the ecosystems on both floodplains are influenced strongly by Indigenous fire management practices in the dry season (Fig. 4a & b). The “natural” World Heritage and Ramsar values implicitly incorporate Indigenous cultural heritage values and, hence, in the context of risk assessment to these values traditional fire management is not considered a threat but a major driver of cultural and natural landscapes. Additionally, Douglas (1999) suggests strong links between fire management in tropical savannas and streams and riparian zones.

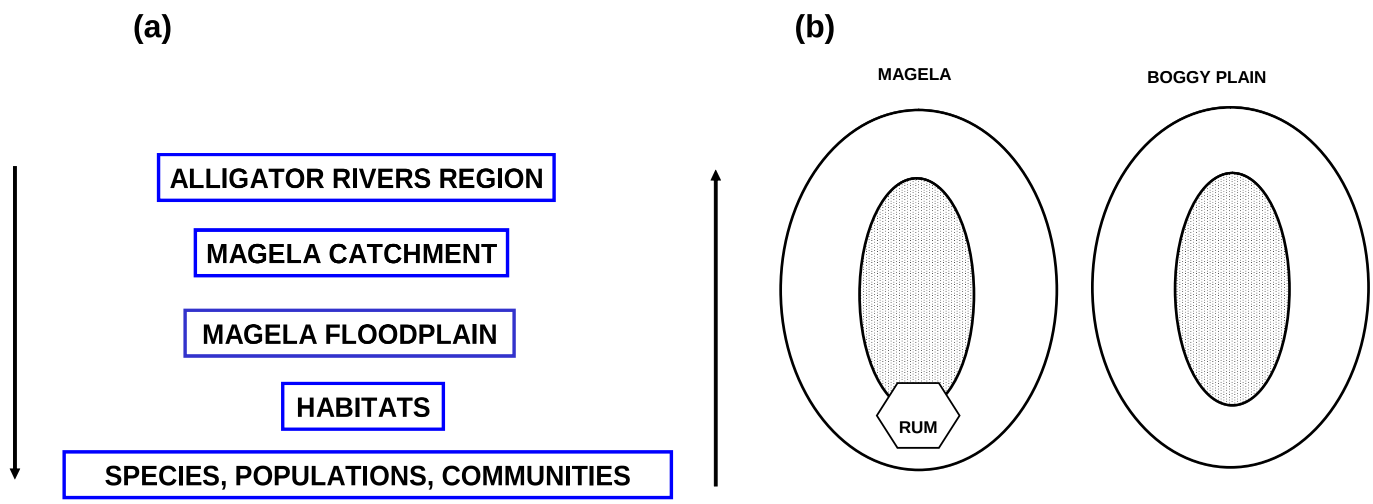


Figure 3 Design of the Landscape Analysis Theme showing (a) the nested cascading scales of analysis used, and (b) comparison of ecological risks in catchments with mining (Magela Creek system) and without mining (Boggy Plain system). The inner and outer ellipses symbolise floodplain and catchments, respectively.

(a)

(b)

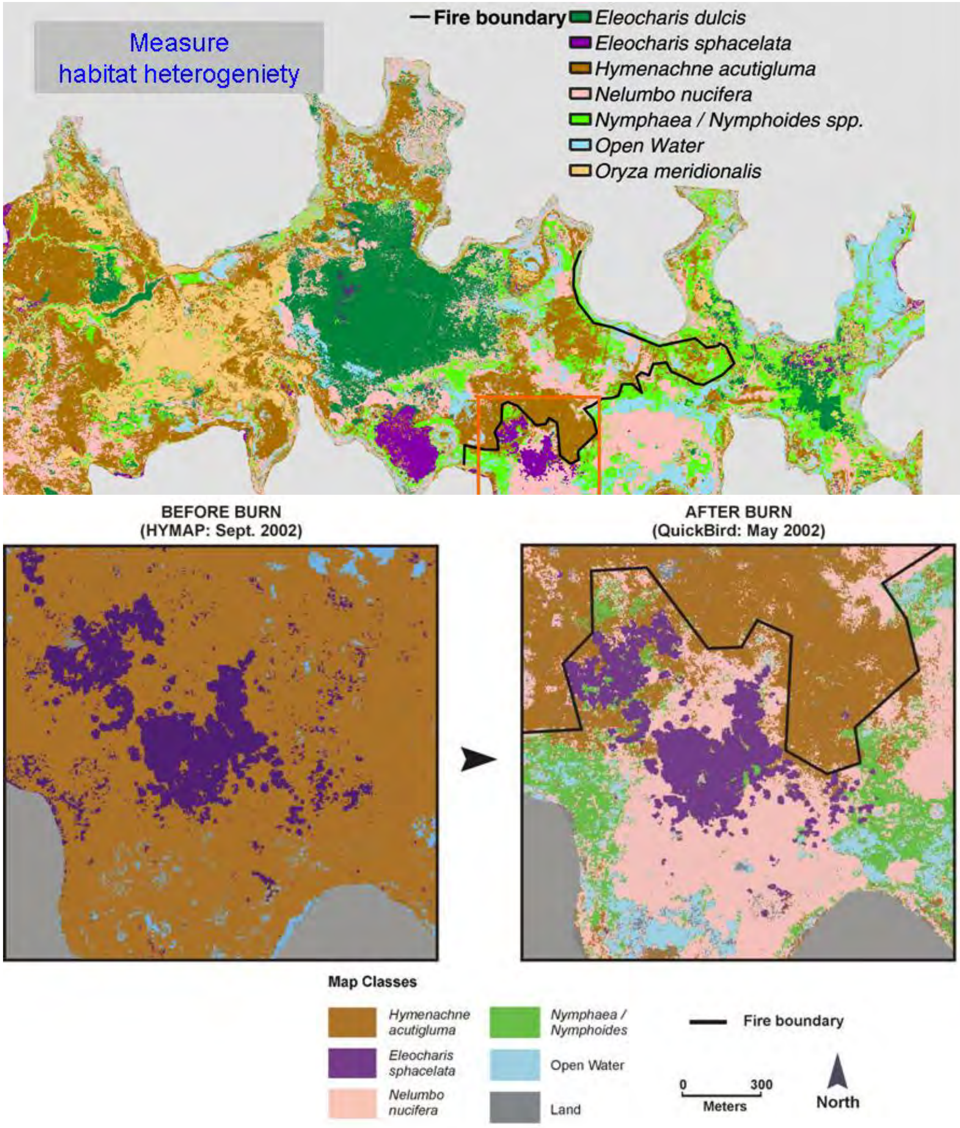


Figure 4 Smoke over water (photo): Indigenous dry season burning on Boggy Plain wetland during October 2002. (a) Floodplain vegetation map derived from a high resolution QuickBird satellite capture in the 2003 wet season. Square inset delineates the ground survey study area; the black line is the fire scar (burnt to the east). (b) Vegetation composition before and after burning in the inset box, derived from Hymap and QB satellite captures in the dry (October 2002) and wet (March 2003) seasons, respectively.

Analysis approach

The Landscape Analysis Theme is now tightly focused on assessing all potential ecological impacts downstream of Ranger uranium mine, particularly on the Magela floodplain (Fig. 5). For rigor in analysis, a “State of the Environment” (SoE) audit approach will be adopted as a first step, whereby ecological threats to “susceptible” World Heritage assets (values) are quantitatively assessed where possible (see Fig. 6 for a Kakadu-scale approach). Development of robust statistical models that incorporate spatially explicit risk probabilities (uncertainty) for use at multiple scales have commenced. Hence, where data allows, risk assessments at any chosen level of spatial resolution will be undertaken to examine multiple threats to multiple conservation assets (Fig. 7) identified in Parts 1 and 2 of this Theme.

Quantification & assessment of ecological risks

The comprehensive risk assessment framework proposed by Burgman (2004 in press) for conservation and management will guide definitions of risk and methods of analysis, interpretation and decision. Additionally, the approach adopted for uncertainty analysis of data in risk assessment outlined by Bayliss *et al*. (2003) will be adopted. Where appropriate data are available, Bayesian and/or frequentist probabilities of the likelihood of exposure to environmental risk, and the effects or consequences of such exposure, will be used in combination to map ecological risk probabilities across the landscape at the required level of spatial resolution.

Risks range in scale from point source risks such as chemical contaminants from Ranger uranium mine, to more extensive landscape-scale risks such as invasive species and saltwater intrusion (see Pearson 2000). A 250m x 250m grid will be superimposed on GIS maps of assets and threats on the Magela floodplain, and cellular text data imported into Excel. Derivation of combined multiple risks in Excel, for any particular space within the landscape, is once again illustrated in Figure 7. Visual Basic programs will be used in conjunction with @Risk software (Anon 2002) for more complex risk analysis, and Netica software (Anon 1997) will be used to create Bayesian Networks to link multiple risks. Lamon and Stow (2004) use a Bayesian classification and regression tree approach to link multiple environmental stressors to biological responses, and to quantify uncertainty in model predictions, and their approach will be tested here for utility.

Para grass example

Para grass weed is most likely the most significant environmental threat facing Magela floodplain today (Douglas *et al*. 1998, Walden & Bayliss 2003) and, hence, is used here as an example of deriving risk probabilities using Bayesian inference. Prior knowledge may include current extent, habitat preference, life history, population dynamics and ecological impacts to natural values. New knowledge may include any likely cumulative and/or synergistic effects with other stressors, and the associated risks can be modeld using isolated and interactive risk probabilities.

Knowledge of the current extent (exposure) of para grass on the Magela floodplain has been updated with recent intensive ground and helicopter surveys, and use of a high resolution QuickBird satellite capture (Fig. 8a & b). A HSI model using Bayesian inference (Ferdinand pers com.) was used to predict the risk of para grass exposure on the Magela floodplain in 1998 (Fig. 9a) and in 2003 (Fig. 9b), both with additional survey data. The maps show the current extent of dense patches of para grass (red areas), areas at risk and areas without para grass. However, more informative and more complex HSI risk models may be derived, such as predictive multiple regression or multivariate components models, or consonant ecological models that incorporate knowledge of stochastic processes and, hence, uncertainty levels. Hence, GLIM models will be developed next to better predict future exposure probabilities of para grass across the floodplain from spatial data layers of water depth and the abundance of native wetland plants (Walden *et al*. in prep.). The ecological effects probabilities will be determined from the literature (e.g. Douglas *et al*. 2001) and combined with exposure probabilities to estimate ecological risk probabilities.

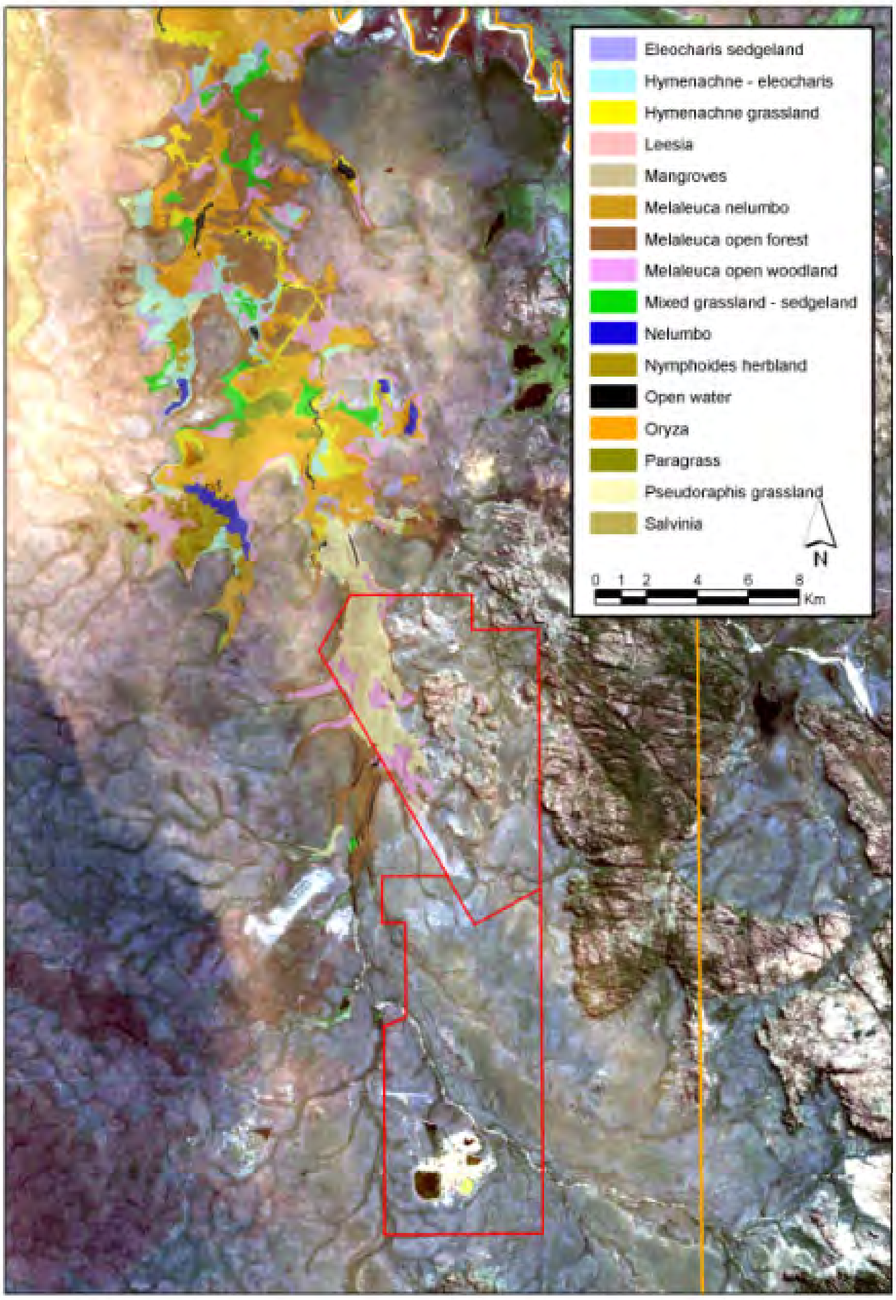
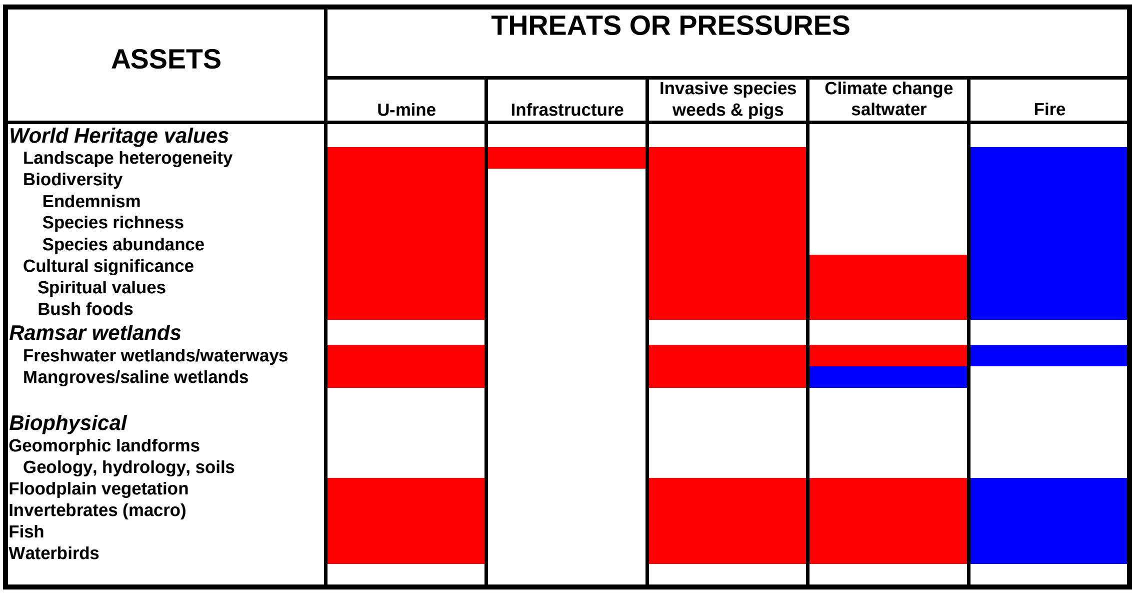


Figure 5 The Magela Creek floodplain system, downstream of Ranger uranium mine.



(a) (b)

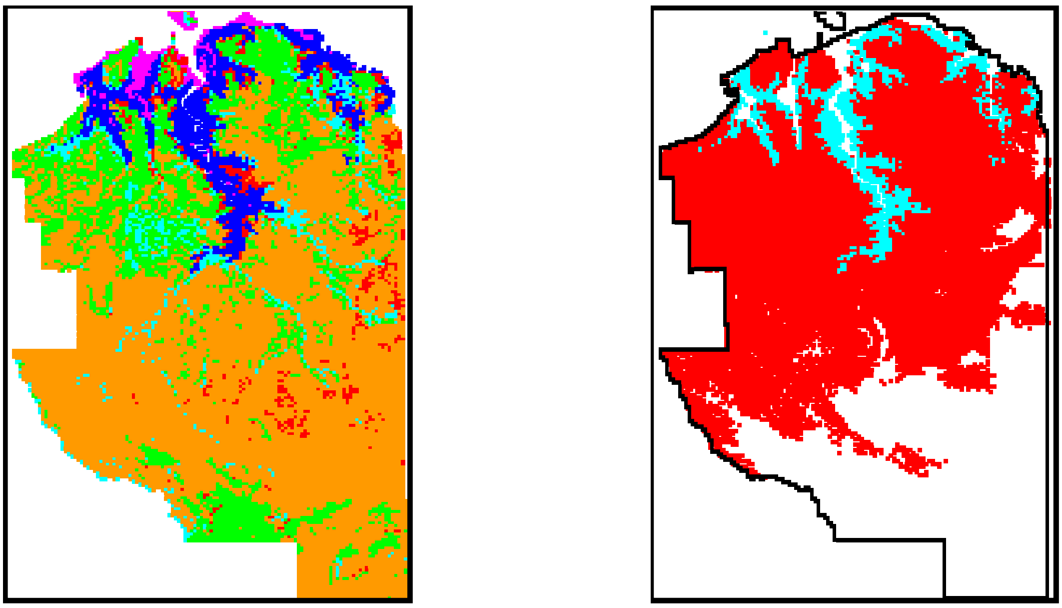


Figure 6 Matrix of key natural assets and threats (above). Fire (blue) is not considered a threat (red) but an ecological driver and part of the cultural landscape. At the scale of Kakadu National Park: (a) distribution of native vegetation (a key “susceptible asset” – blue is floodplain, pink mangrove, red rainforest, orange eucalyptus woodland, green open forest); and (b) distribution of pig damage (key threat to vegetation – pale blue is high damage level as indexed by ground disturbance, red is zero to little damage).

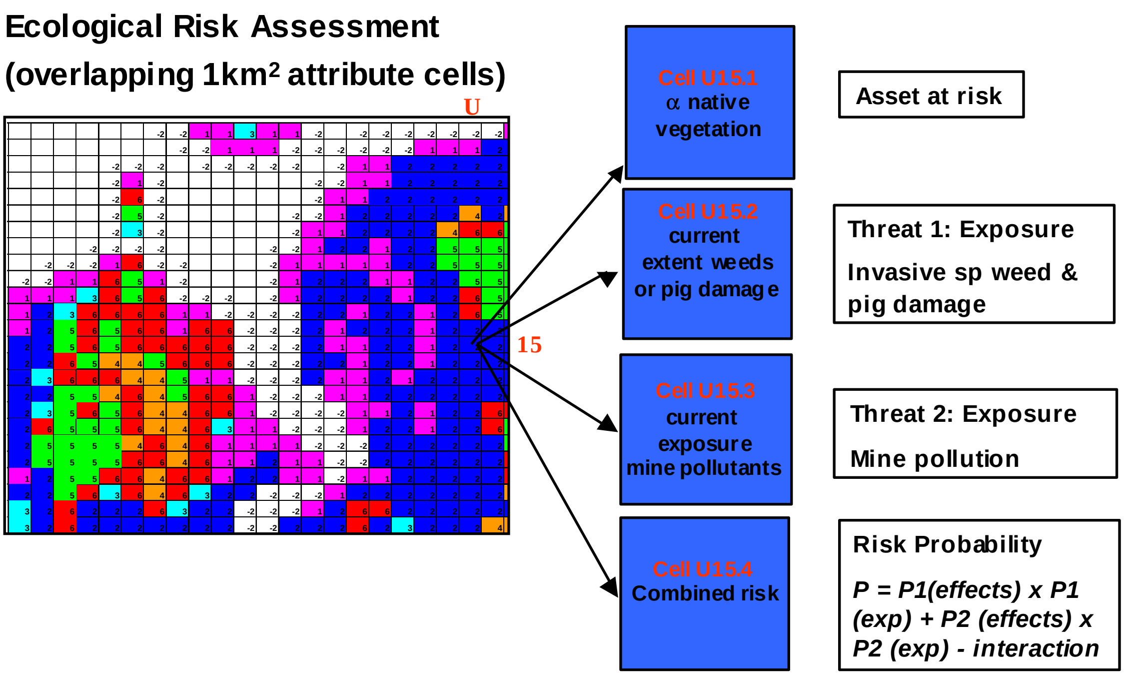


Figure 7 Mouth of the South Alligator River, Kakadu National Park. Combined multiple ecological risk assessment using multiple asset and threat data layers, at 1 km^2 cellular resolution.

(a)

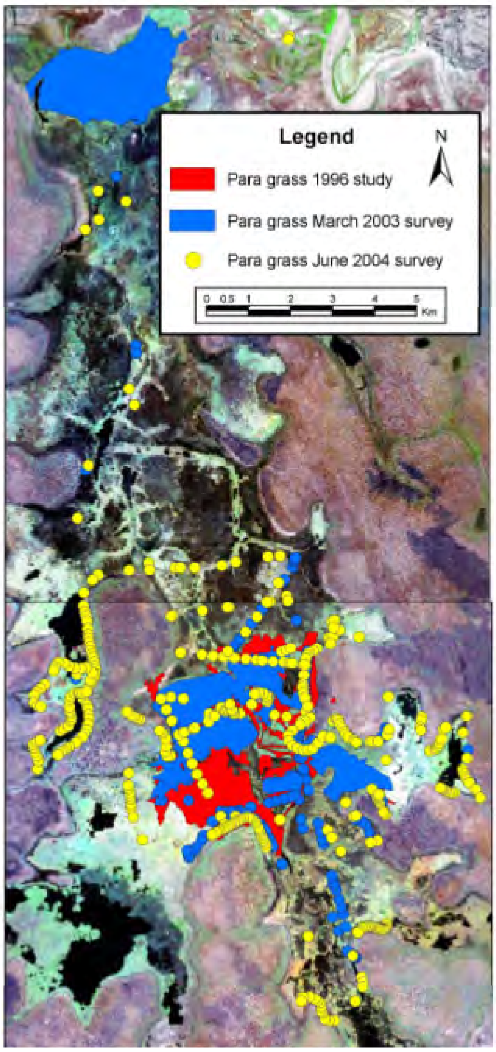


Figure 8a. Updated distribution of para grass on the Magela floodplain mapped on an IKONOS satellite image; photo demonstrates a dense para grass sward that typically extinguishes native wetland vegetation ane, hence, suitable magpie geese nesting habitat.

(b)

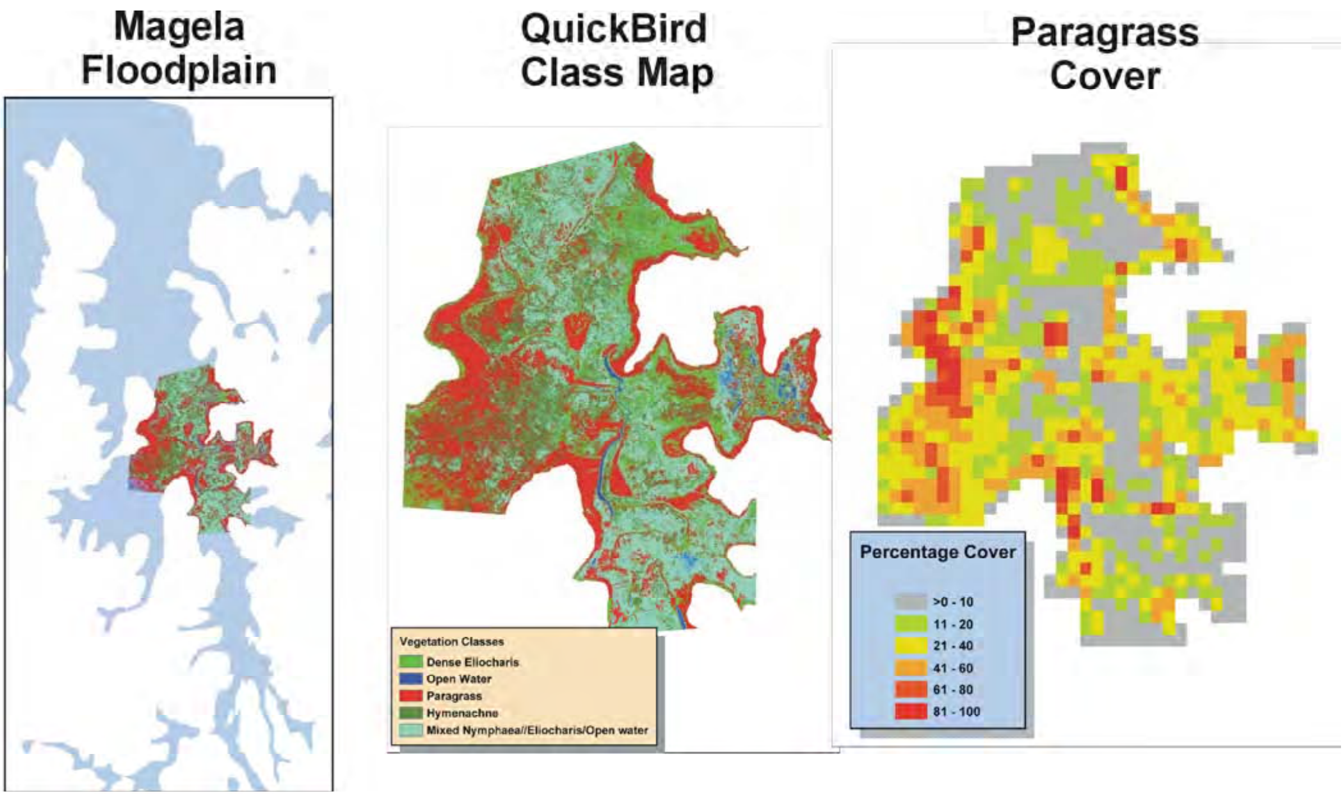


Figure 8b Derivation of current para grass distribution map for the central portion of Magela floodplain using a high resolution QuickBird satellite image (May 2004). The right hand image maps the distribution and abundance (% cover) of para grass in 250m x 250m cells, and will be used as exposure probabilities for quantitative ecological risk assessmnent.

Other HSI models

Waterbirds are a natural World Heritage asset on Kakadu National Park but because many species are highly mobile and range globally, it would be impossible to apportion risk due to *in situ* stressors. Hence, HSI models will be developed also to predict suitable nesting and dry season refuge habitats of waterbirds that occur on the Magela floodplain (see Bayliss & Yeomans 1990 for the iconic magpie goose) and, ecological risk assessments will undertaken on these assets rather than the birds *per se*. This indirect approach is pragmatic and a similar method will be adopted for fish and aquatic macroinvertebrates because of lack of distribution survey data across the entire floodplain.

Decision models

Outputs from all quantitative ecological risk assessments will be used as starting points in decision models to help manage risks to the World Heritage values of Magela floodplain. For example, habitat specific (spatially explicit) cost-of-control bioeconomic models developed for key invasive species (e.g. pigs & wetland weeds) can be used as decision support tools to compare the benefits and costs of various management and/or policy options. Cost-of-control models have been developed for Mimosa pigra and feral pigs on Kakadu National Park. Figure 10 shows results of a simulated pig control operation (initial reduction 80% & annual maintenance control 20%) across the Park, and maps hypothetical reductions in ground disturbance damage and associated control costs. Similar analyses will be undertaken for all other threats to all other assets.

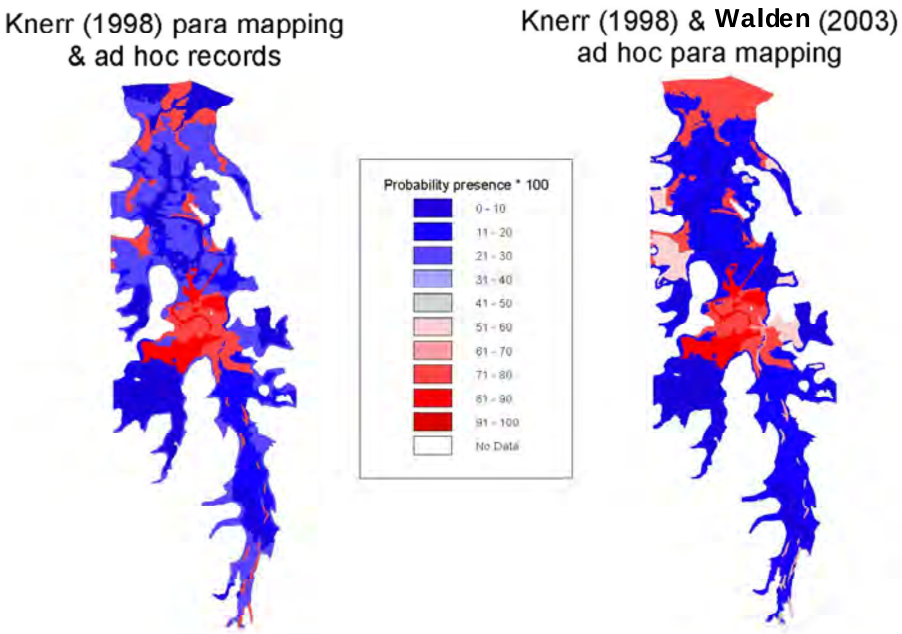


Figure 9. Bayesian risk probabilities of exposure to para grass on the Magela floodplain in 1998 and 2000 using a Habitat Suitability Model developed by Ferdinand (pers comm.), and additional survey data collected in 2003. Dark red is probability of 1.0 representing known occurrences or highly suitable habitat, and dark blue is no known occurrence or unsuitable habitat.

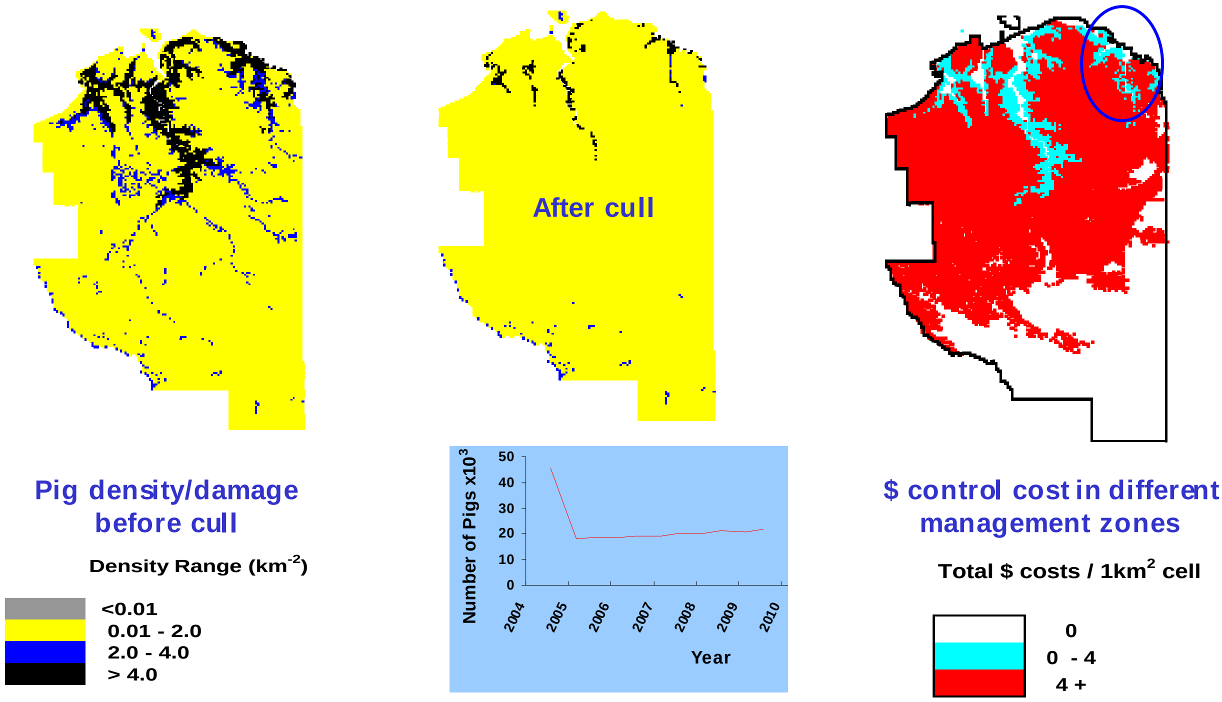


Figure 10 Simulated pig control (middle blue graph) on Kakadu National Park. The left-hand and middle maps show the distribution and extent of feral pig damage before and after culling, respectively. The right-hand map shows the distribution of initial and annual maintenance control costs across the Park. The ellipse encompasses the Magela catchment subset.

The Bayesian approach to risk assessment described above incorporates prior information in model selection and, hence, new data can be added iteratively to fine-tune management actions if the system allows it (Hart *et al.* 2001). This decision making process is basically adaptive management or "learning by doing" (Walters 1997), and appears to be a natural extension of the Bayesian approach to risk assessment. Use of such approaches recognises the partial nature of our knowledge to manage natural systems, and reinforces the need for adequate monitoring and adaptive management programs (Harris 2003).

Integration of values-based frameworks with ERA frameworks

An additional, albiet ambitious, goal of the Landscape Theme was to integrate socio-economic frameworks and Indigenous cultural values into ecological risk assessment frameworks where appropriate. To a limited extent this has been achieved in the invasive species project, and to a greater extent in the Boggy Plain project. As discussed above, bioeconomic models have been developed for the control of damage caused by key wetland weed species and feral pigs, and can be used as decision support tools by Park managers. Whilst Boggy Plain represented our "non- mining" reference site for the Landscape Theme, the influence of Indigenous fire management practices on the composition of wetland vegetation was the key driver for that study. Nevertheless, socio-economic and cultural values implicitly underlie all ecological risk assessments and, hence, more research effort needs to be allocated to integrate these frameworks into Ecological Risk Assessment frameworks. We recommend that a scientist with the right mix of social and biophysical research skills, and community experience, be contracted to close this gap, particularly with respect to incorporation of Indigenous values into rehabilitation success criteria and other facets of the rehabilitation process (See ARRTC discussion paper by Bayliss & Pfitzner 2004).

Recommendations

In terms of preparation of quality data layers to undertake robust and spatially explicit ecological risk assessments of "susceptible" World Heritage values on the Magela floodplain, the Landscape Analysis Theme is currently and mostly on schedule. However, we recommend the following Priority tasks for the 2004-05 FY:

1. Complete by October 2004 the conceptual pollution pathways model as the necessary first step in the process of identifying and subsequently quantifying all significant ecological risks, and to the satisfaction of all stakeholders (including ARRTC).

2. Commence and complete this FY the desktop modelling study by HEP that combines hydrologic, hydraulic and fluvial geomorphic processes through the development of a rainfall-discharge hydrology model (using HEC-HMS) (see ARRTC Discussion Paper by Saynor 2004). The model will: (i) assess "worst case scenario" risks associated with extreme events such as flooding; (ii) account for major surface water pathways of pollutants and/or sediments during the remaining operational and rehabilitation phases of the mine, respectively; and (iii) drive "whole" ecosystem models that allow incorporation of key spatial and temporal uncertainties into cross-sectional characterisations of assets and threats used in risk assessment.

3. After the development of the hydrology model, commence and complete this FY a first-cut "whole" ecosystem model that accounts for key processes and mechanisms that link specific management actions, such as chemical releases from Ranger and invasive species control, to specific indicators of condition or "health" of the natural World Heritage

values of the Magela floodplain. The model will basically be a mass transfer model (water, sediments, nutrients, biomass or species population units) and driven by rainfall and subsequent flood events on the Magela floodplain. It will have the following four linked submodels:

i. a hydrodynamic submodel for space-time variation in water flows;
ii. a hydrochemistry submodel for transport and transformation of key chemical variables such as sediments and nutrients;
iii. lower trophic level submodels for plants and select invertebrates; and
iv. population dynamics submodels for key or dominant animal indicator species (e.g. large fish & waterbirds).

4. Following completion of Priority tasks 1 to 3, the Landscape Analysis Theme should be discontinued as a separate ***eriss*** research program area and embedded across all ARRTC Key Knowledge Need (KKN) Themes. ERA staff have developed a substantial skills base in quantitative risk assessment, landscape and spatial analysis and population modelling. These skills will remain central to current research and monitoring programs, and future rehabilitation programs. Such skills will also provide significant support to the External projects area that now has a developing focus on catchment-based risk assessments to tropical land and water resources (Hart 2004). This recommendation is concordant with current plans to restructure ***eriss*** research programs in order to focus on priority KKNs.

References (other than those summarised in Table 1)

Anon. (2003). Framework for Cumulative Risk Assessment. Risk Assessment Forum, U.S. Environmental Protection Agency, Washington, DC 20460. EPA/630/P-02/001F.

Anon (2002). Guide to using @Risk: Risk Analysis and Simulation Add-In for Microsoft Excel. Version 4.5. Pallisade Corporation, Newfield, NY USA 14867.

Anon (1997). Netica™ Application User's Guide. Norsys Software Corp. Vancouver, BC, Canada.

Bayliss P & Pfitzner K (2004). Progress report on revegetation research for Nabarlek and Ranger mines. Discussion Paper for the 13th Meeting of Alligator Rivers Region Technical Committee, 15-17 March 2004.

Bayliss P & Finlayson CM (2004). Progress Report on the ISP Landscape Program (2003-2004) in the Alligators Rivers Region. Discussion Paper for the 13th Meeting of Alligator Rivers Region Technical Committee, 15-17 March 2004.

Bayliss P, Camilleri C, Hogan A, Walden D, Boyden J & Begg G (2003). Uncertainty analysis of data, linking conceptual models to on-site management and communications. Internal Report 435, June, Supervising Scientist, Darwin.

Bayliss P, Walden D, Boyden J, Camilleri C & Hogan A (2003). Ecological Risk Assessment (ERA) and Conceptual Ecosystem Models. Discussion Paper for the 11th Meeting of Alligator Rivers Region Technical Committee, 17-19 February 2003.

Bayliss P & Yeomans (1990). Seasonal Distribution and Abundance of Magpie Geese, *Anseranas semipalmata* Latham, in the Northern Territory, and Their Relationship to Habitat, 1983-86. *Australian Wildlife Research*, **17**, 15-38.

Bell SS, Fonseca MS & Motten LB (1997). Linking Restoration Ecology and Landscape Ecology. *Restoration Ecology*, **5 (4),** 318-323.

Burgman M (2004 in press). Risks and Decisions for Conservation and Management. School of Botany, University of Melbourne.

Douglas MM, Bunn SE, Pidgeon RJW, Davies PE, Barrow P, O'Connor RA & Winning M (2001). Weed management and the biodiversity and ecological processes of tropical wetlands. Draft final report. National Wetlands R & D Program, Environment Australia, Land & water Australia.

Douglas M (1999). Fire management in tropical savannas: links between streams and riparian zones. LWRRDC's Riparian Lands Management Newsletter. Case Study 4.

Douglas M, Finlayson CM & Storrs MJ (1998). Weed management in tropical wetlands of the Northern Territory, Australia. In: WD Williams - Wetlands in a Dry Land: Understanding for Management, Environment Australia Biodiversity Group, Canberra. pp 239–251.

Elliot M (draft). Saline intrusion in the Alligator Rivers Region: Oceanographic Processes.

Finlayson CM & Bayliss P (2003). Conceptual model of ecosystem processes and pathways for pollutant/propagule transport in the environment of the Alligator Rivers Region. Discussion Paper for the 11th Meeting of Alligator Rivers Region Technical Committee, 17-15 February 2003.

Harris G (2003?). Inadmissible Evidence: Knowledge and Prediction in Aquatic Systems. Where?

Hart BT, Grace MR, Breen P, Cottingham P, Feehan P & Burgman MA. (2001).

Application of ecological risk assessment in river management. *Proc. Third Australian* Stream Management Conference - Value of Healthy Streams. I. Rutherfurd, F. Sheldon, G. Brierley and C. Kenyon. Melbourne, CRC for Catchment Hydrolog**y:** 289-295.

Hart B (2004). Environmental Risks Associated With New Irrigation Schemes in Northern Australia. *Ecological Management & Restoration*, **Vol 5 (2)**, 107-111.

Hilborn R & Mangel M (1997). *The ecological detective: confronting models with data.* Monographs in Population Biology 28. Princeton University Press, Princeton, New 21 Jersey. 22

Lamon, EC & Stow, CA (2004). Bayesian methods for regional-scale eutrophication models. *Water Research*, **38**, 2764-2774.

Pearson D (2000). Investigating the impacts of human activity on northern Australian landscapes by analysis of spatial structure. 4th International Conference of Integrating GIS and Environmental Modelling (GIS/EM4): Problems, Prospects and Research Needs. Banff, Alberta, Canada, September 2-8, 2000.

Rykiel EJ (1996). Testing ecological models: the meaning of validation. *Ecological Modelling*, **90**, 229-244.

Saynor M (2004). Extreme events in the Alligator Rivers Region. Discussion Paper for the 14th Meeting of Alligator Rivers Region Technical Committee, 13-15 September 2004.

van Dam R, Finlayson CM & Bayliss P (2004). Progress on the development of a conceptual model of contaminant pathways from Ranger uranium mine. Supervising Scientist Division, IR 474.

Van Dam R (2004). Progress Report on the development of a conceptual model of contaminant pathways for uranium mining activities in the Alligator Rivers Region. Discussion Paper for the 13th Meeting of Alligator Rivers Region Technical Committee, 15-17 March 2004.

van Dam RA, Humphrey CL & Martin P (2002). Mining in the Alligator Rivers Region, northern Australia: Assessing potential and actual effects on ecosystem and human health. *Toxicology* **181-182**, 505-515.

Walden D & Bayliss P D (2003). An ecological risk assessment of major weeds on the Magela Creek floodplain, Kakadu National Park. Supervising Scientist IR 439.

Walters C (1997). Challenges in adaptive management of riparian and coastal ecosystems. *Conservation Ecology* [online], **1(2):1**. URL:http://www.consecol,org/vol1/iss2/art1

ARRTC KEY KNOWLEDGE NEED 5.1

Landscape scale analysis of impacts

Landscapers

Eriss

Maria Bellio
James Boyden
Dave Walden
Chris Humphrey
Bob Pidgeon
Kirrilly Pfitzner
John Lowry
Dene Moliere
Peter Bayliss
Max Finlayson

Others

Violet Lawson (TO)
Sandra McGregor (TO)
Peter Christopherson (TO)
Rod Kennett (PAN)
Anne Fergusson (PAN)

Links between KKN Themes

KKN 1.2.4

Ecotoxicology

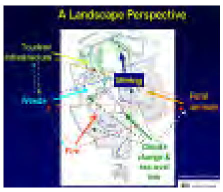
U toxicity
$MgSO_4$ toxicity
Mn toxicity

KKN 1.2.1

Mine site biophysical pathways conceptual model

KKN 5.1

Landscape scale analysis of impact



Ecotoxicology & biophysical pathways Theme

Landscape analysis Theme

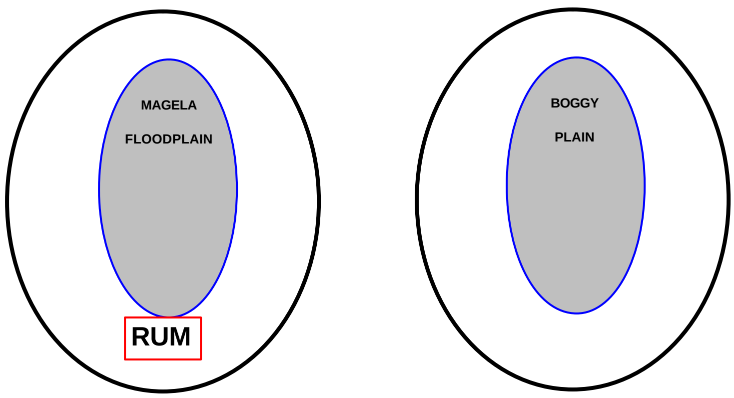
Landscape ecology

- Patterns & processes over broad spatial scales
- Embraces spatial heterogeneity encompasing different types of ecosystems & landscape structures
- e.g. Catchments, habitats, communities & species populations
- Central to natural resource management, sustainable development, land & water management, environmental protection & rehabilitation/restoration ecology
- Includes cultural landscapes

Ecological Risk Assessment Framework

= integrated landscape framework

Comparative approach: floodplains within two catchments



Mine within a landscape

Reference site – no mine

Nested scales of analysis

ALLIGATOR RIVERS REGION

MAGELA CATCHMENT

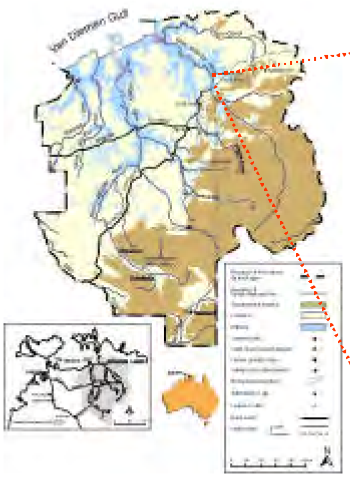
MAGELA FLOODPLAIN

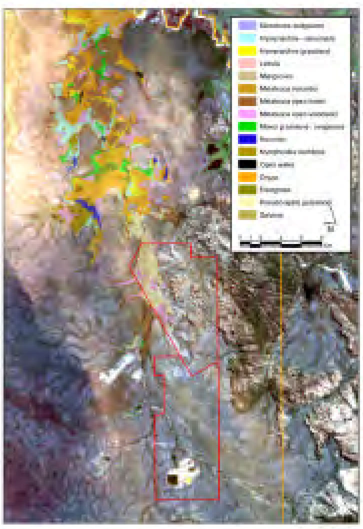
HABITATS

SPECIES, POPULATIONS, COMMUNITIES

LANDSCAPE FRAMEWORK

Ranger - Magela subset





Regional scale - ARR

Australian Government
Department of the Environment and Heritage

AIMS

- Establish a landscape scale analysis & monitoring program to differentiate mining related impacts from other causes
- Contribute to monitoring of the natural World Heritage values of Kakadu National Park

Landscape analysis Supervising Scientist Division *eriss*

Australian Government
Department of the Environment and Heritage

LANDSCAPE THEME

Aims achieved through two sub-Themes

- Develop pollution transport pathways model for RUM, within an ecological (landscape-scale) risk assessment framework
- Assess “condition” of natural World Heritage values on Kakadu National Park

Landscape analysis Supervising Scientist Division *eriss*

Work Plan Landscape Theme 04-05

Theme: Landscape Analysis of Impacts	
Aim: Establish a landscape scale analysis and monitoring program to differentiate mining related impacts from other causes; and contribute within the broader context to the monitoring of the natural World Heritage values of Kakadu National Park.	
Projects & tasks:	*Lead:*
Project 1. Develop conceptual model of pollution pathways for Ranger, populate with sub-models, and incorporate into an ecological risk assessment for the Magela floodplain (18 p weeks)	
Task 1: Finalise conceptual model showing pollutant/propagule pathways & ecological linkages between uranium mining activities at Ranger & environment of ARR.	**RvD** **PB/MF**
Task 2: Populate conceptual pathways model with sub-models for quantitative ecological risk assessment at minesite & landscape scale.	**RvD** **PB/MF**

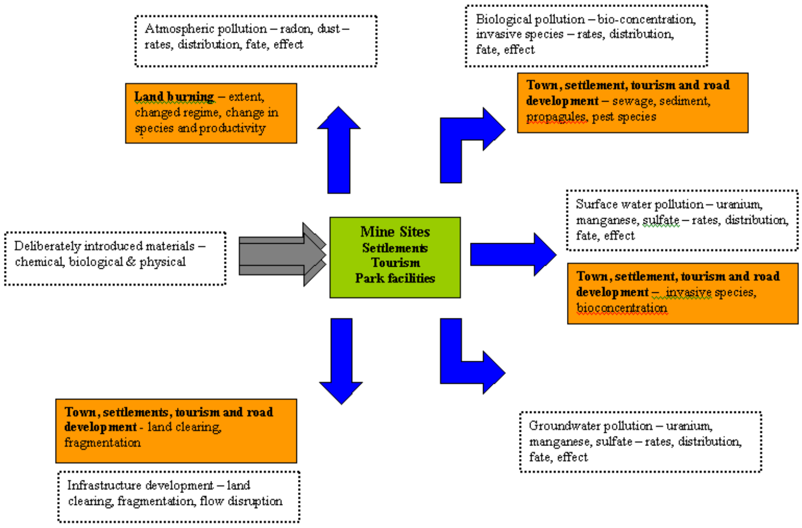
Work Plan Landscape Theme 04-05

Theme: Landscape Analysis of Impacts	
Aim: Establish a landscape scale analysis and monitoring program to differentiate mining related impacts from other causes; and contribute within the broader context to the monitoring of the natural World Heritage values of Kakadu National Park.	
Projects & tasks:	*Lead:*
Project 2. Commence a multiscale ecological risk assessment of Magela floodplain, linking multiple stressors to multiple World Heritage assets, and quantifying uncertainty in predictions (63 p weeks)	
Task 1: Develop a hydrological model of the Magela floodplain for pollution pathway analysis & as a driver of the Magela ecosystem.	**DM/DW/JB**
Task 2: Map salinity risk profile of Magela floodplain for analysis of potential climate change impacts (eg rising sea levels etc).	**JL/JB/MB**
Task 3: Map infrastructure of the ARR, produce a Magela catchment subset for ERA.	**JL/JB**
Task 4: Produce spatial data layers of native vegetation & weeds on the Magela floodplain for ERA; develop a habitat suitability models for mimosa & para grass for ERA.	**DW/MB/JB**
Task 5: Produce spatial data layers for fish & macroinvertebrate communities on the Magela floodplain for ERA using Habitat Suitability models derived from long-term monitoring data.	**JB/DW/MB/CH /BP**
Task 6: Produce spatial data layers for ERA & food chain analysis of 4 key indicator species of waterbirds using Habitat Suitability models developed for wet season breeding & dry season refuging. Concomitantly assess the condition of World Heritage waterbird values & their wetland habitats.	**MB/JB**
Task 7: Produce spatial data layers for ERA of potential fire impacts on the Magela floodplain, using knowledge & methodologies gained from the Boggy Plain study.	**JB/DW**
Task 8: Undertake quantitative ecological risk assessment using all spatial data layers of assets and risks produced in Tasks 1-6 above.	**PB/MF**

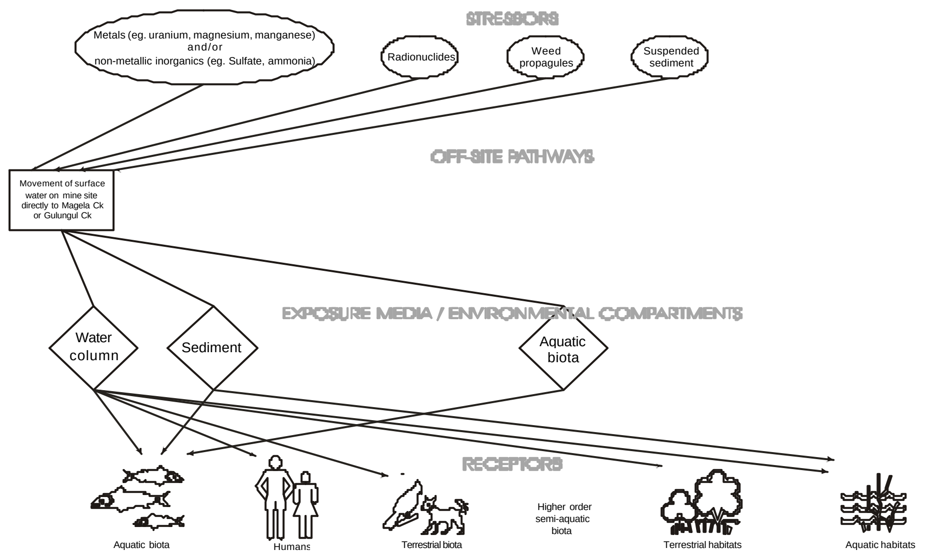
Work Plan Landscape Theme 04-05

Theme: Landscape Analysis of Impacts	
Aim: Establish a landscape scale analysis and monitoring program to differentiate mining related impacts from other causes; and contribute within the broader context to the monitoring of the natural World Heritage values of Kakadu National Park.	
Projects & tasks:	*Lead:*
Project 3. Complete projects from 03-04, mostly to publication stage (27 p weeks)	
Task 1: Catalogue & assess significant habitats & species in the Magela Catchment.	**CH**
Task 2: Assess mangrove response to environmental change, especially climate change.	**KP**
Task 3: Map biophysical features of Magela Creek & floodplain.	**JL**
Task 4: Landscape mapping of the Alligators Rivers Region.	**JL**
Task 4: Waterbird publications.	**MB/PB**
Task 5: Boggy Plain publications.	**PB/JB**
Task 6: Magela Weeds (complete & publish spatial risk modelling of para grass & control cost model).	**DW/PB**
Task 7: Feral animals (publish spatial cost-of- control model & maps of pig damage across KNP).	**PB/DW/JB**
Theme Leaders: Peter Bayliss & Max Finlayson. Total staff time: 18 person weeks (transport pathways) plus 90 person weeks (World Heritage values) = 108 person weeks	

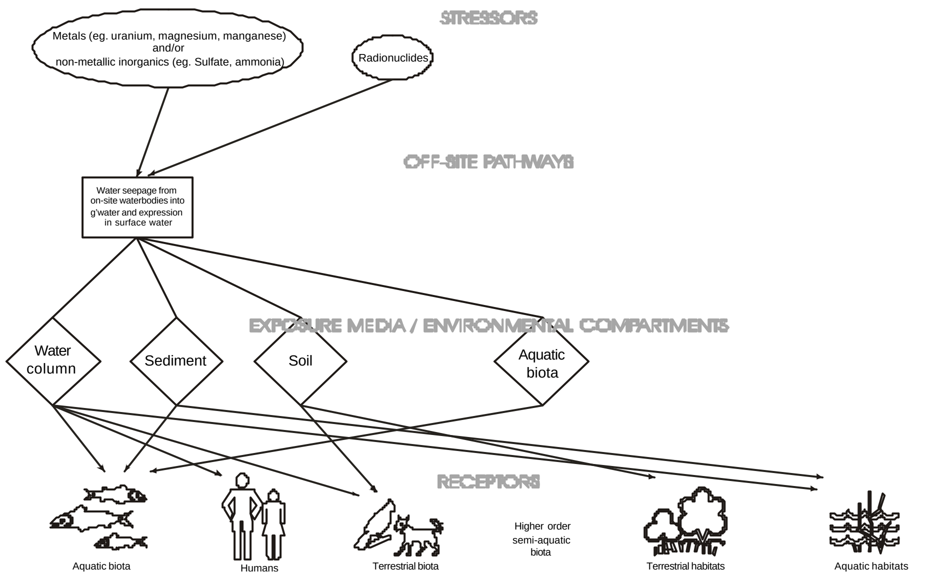
Old conceptual model (Finlayson & Bayliss 2003)



Conceptual model A: surface water to surface water pathway

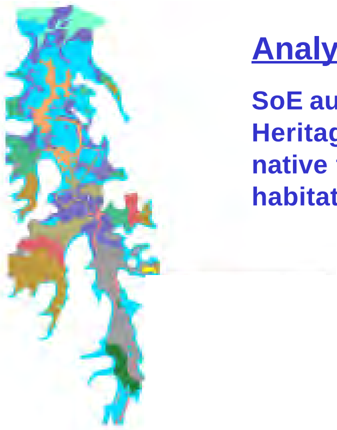


Conceptual model B: water seepage pathway



Magela Floodplain

Primary interest area for potential mine impacts



Analysis approach

SoE audit reporting – assess condition of World Heritage assets & level of threats. e.g. threat to native floodplain vegetation & waterbird nesting habitats from spread of para grass weed

Ranger

LANDSCAPE ANALYSIS APPROACH

- Derive spatial data layers of "susceptible" assets & risk probability of key threats
- At any appropriate level of spatial resolution
  - Kakadu: 1.0 km^2 resolution
  - Magela: 250 m^2 resolution
- Monitoring data – provides temporal & spatial variability, & limits to spatial resolution
- Incorporate hydrological model as key "ecological driver" of biological layers & major pollution pathway

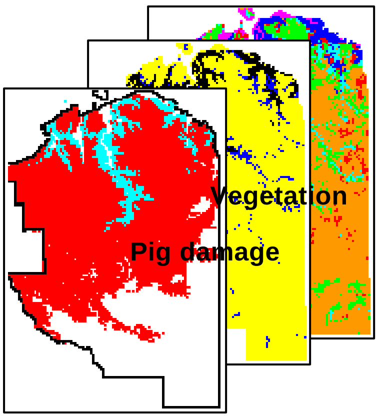
LANDSCAPE ANALYSIS FRAMEWORK

Matrix of assets & threats

ASSETS	THREATS OR PRESSURES: U-mine	Infrastructure	Invasive species weeds & pigs	Climate change saltwater	Fire
World Heritage values					
Landscape heterogeneity					
Biodiversity					
Endemnism					
Species richness					
Species abundance					
Cultural significance					
Spiritual values					
Bush foods					
Ramsar wetlands					
Freshwater wetlands/waterways					
Mangroves/saline wetlands					
Biophysical					
Geomorphic landforms					
Geology, hydrology, soils					
Floodplain vegetation					
Invertebrates (macro)					
Fish					
Waterbirds					

LANDSCAPE ANALYSIS FRAMEWORK

Spatial layers – 1km^2 resolution – SoE audit



Ecological risk

Susceptible Assets

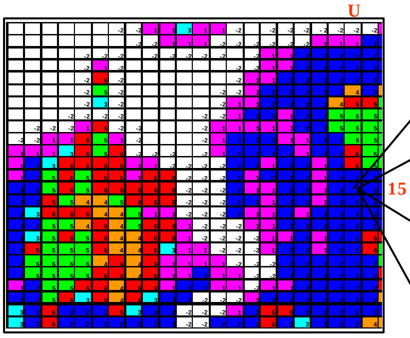
- Vegetation
- Waterbirds
- Fish
- Aquatic macros
- Biodiversity
- Habitat heterogeneity
- World Heritage values
- Ramsar values
- Indigenous cultural values

Threats or Pressures

- Ranger mine pollution
- Invasive species
- Climate change – salt
- Infrastructure

LANDSCAPE ANALYSIS FRAMEWORK

Ecological Risk Assessment
(overlapping 1km^2 attribute cells)



Cell U15.1
a native vegetation

Asset at risk

Cell U15.2
current extent weeds or pig damage

Threat 1: Exposure
Invasive sp weed & pig damage

Cell U15.3
current exposure mine pollutants

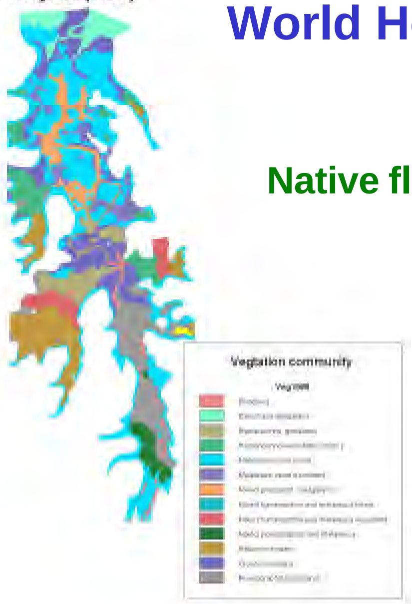
Threat 2: Exposure
Mine pollution

Cell U15.4
Combined risk

Risk Probability
P = P1(effects) x P1 (exp) + P2 (effects) x P2 (exp) - interaction

Assets: Ramsar listed wetlands

Magela Creek vegetation
Finlayson (1989)

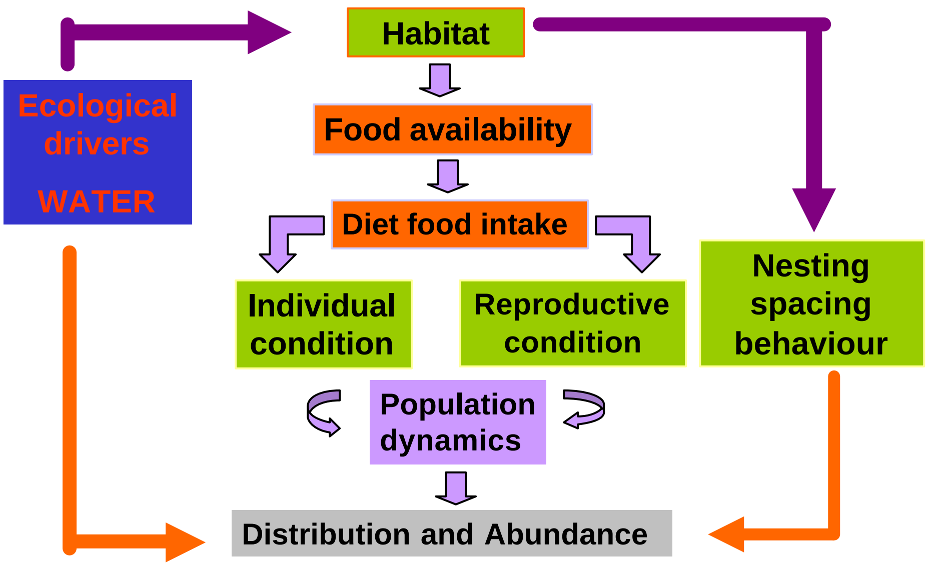


World Heritage assets or values

Native floodplain vegetation

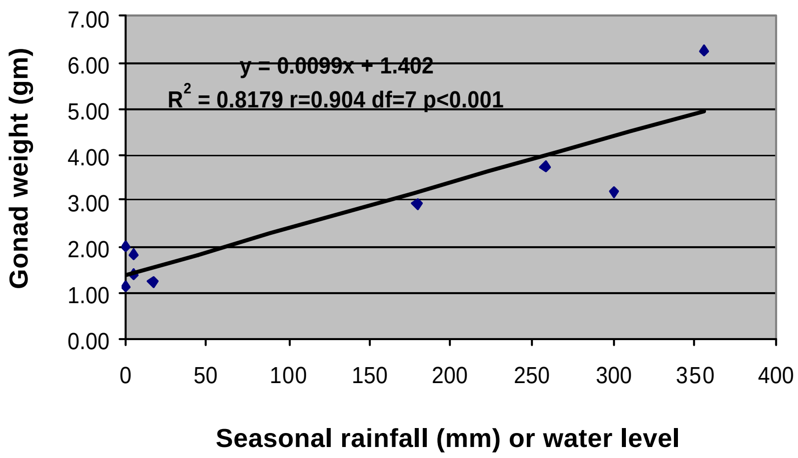
WH asset: Waterbirds

Conceptual waterbird habitat- population dynamics model

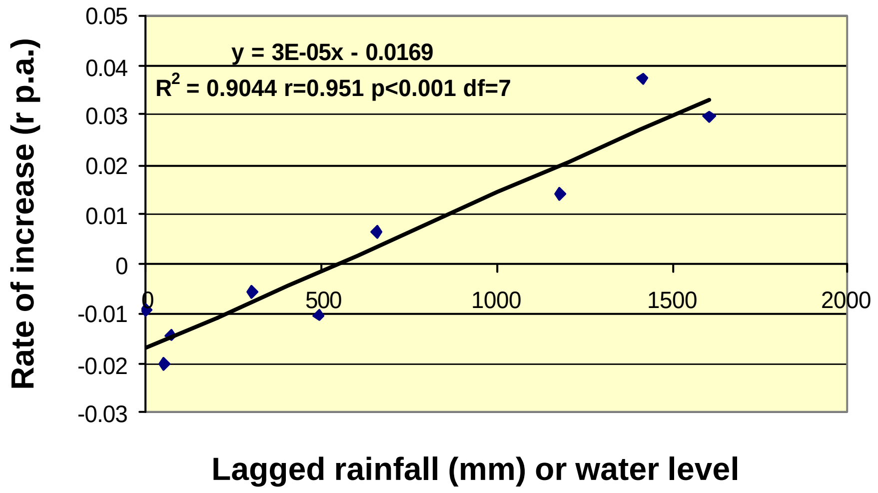


Reproductive condition Green Pygmy Goose

Correlation of female gonad condition with rainfall



Rate of increase and lagged rainfall

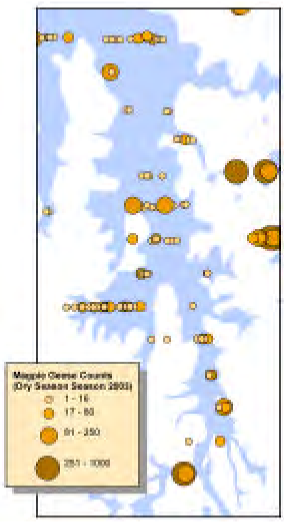


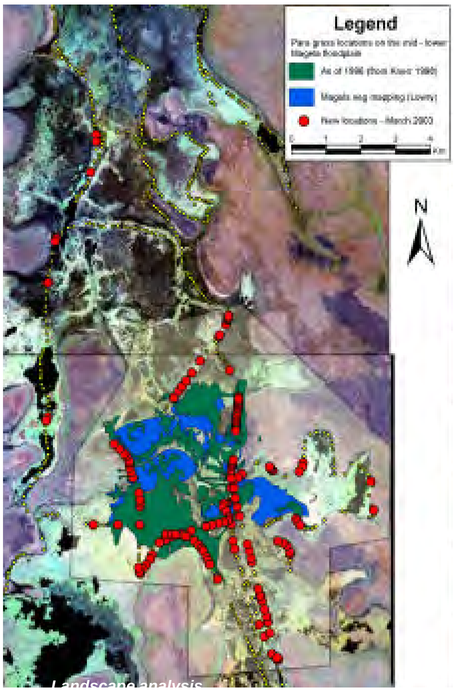
Exists similar relationship for magpie geese (Bayliss 1989)

Seasonal distribution & abundance of magpie geese on the Magela floodplain ascertained by aerial survey

Wet season nests 2000

Dry season 2003

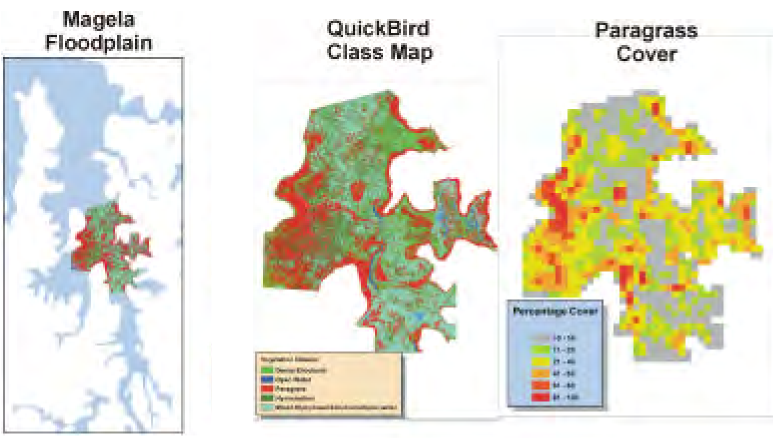




THREAT: WEEDS

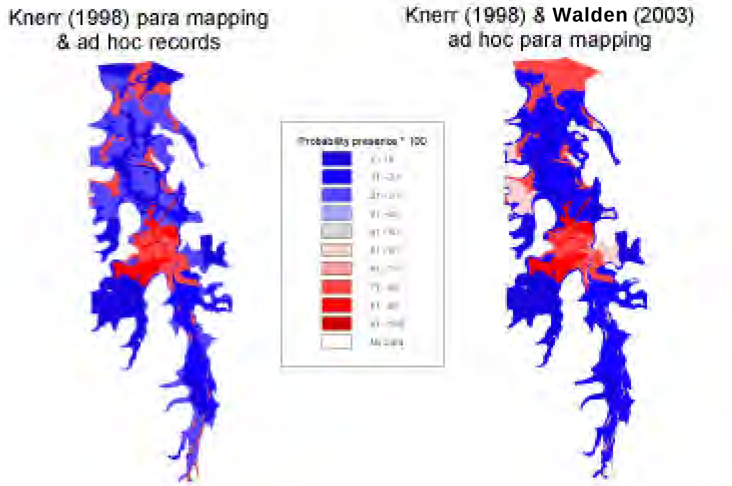
Updated distribution of para grass on the Magela floodplain using recent (2003-04) & historical observations mapped on an IKONIS satellite image

Current para grass distribution map for central Magela floodplain derived from high resolution QuickBird satellite image (May 2004)



RH image maps % cover of para grass in 250m x 250m cells = exposure probabilities for quantitative ERA

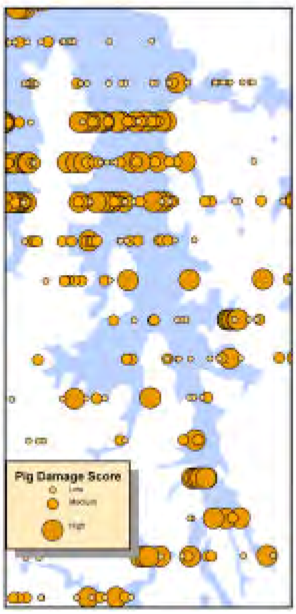
Bayesian risk probabilities of para grass exposure on the Magela floodplain in 1998 & 2000 using a HSI model & ad hoc records (Ferdinands)



New HSI model will use water depth & distance to nearest large patch

Additional submodels will include spread rates & control costs

THREAT: FERAL PIGS

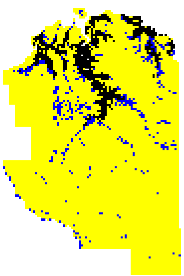


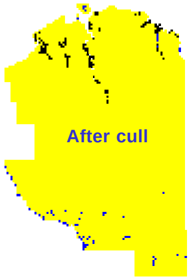
Magela floodplain & riparian zone

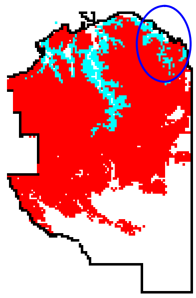
Distribution of pig damage levels in the 2003 dry season

THREAT: FERAL PIGS KNP

(+ decision model: control cost)



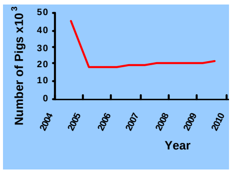




Pig density/damage before cull

Density Range (km^{-2})

<0.01
0.01 - 2.0
2.0 - 4.0
> 4.0

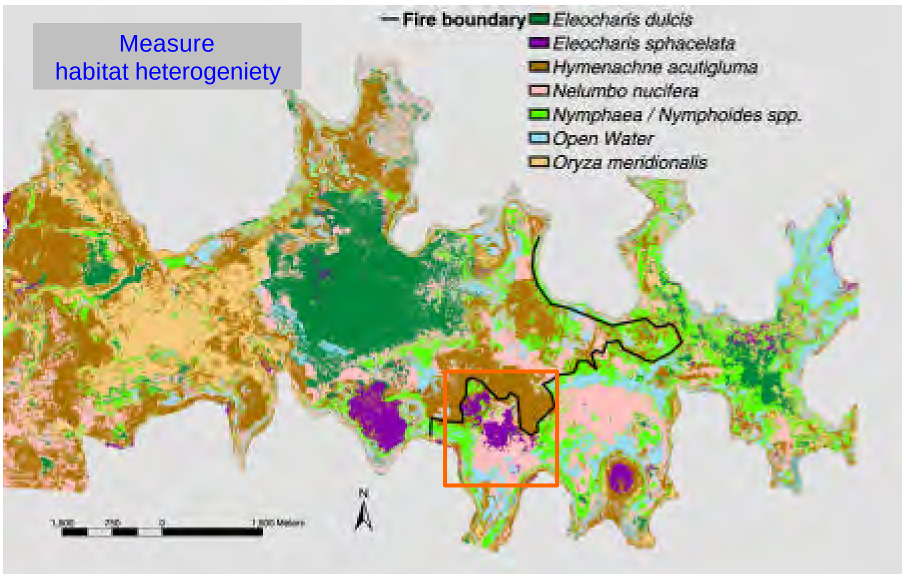


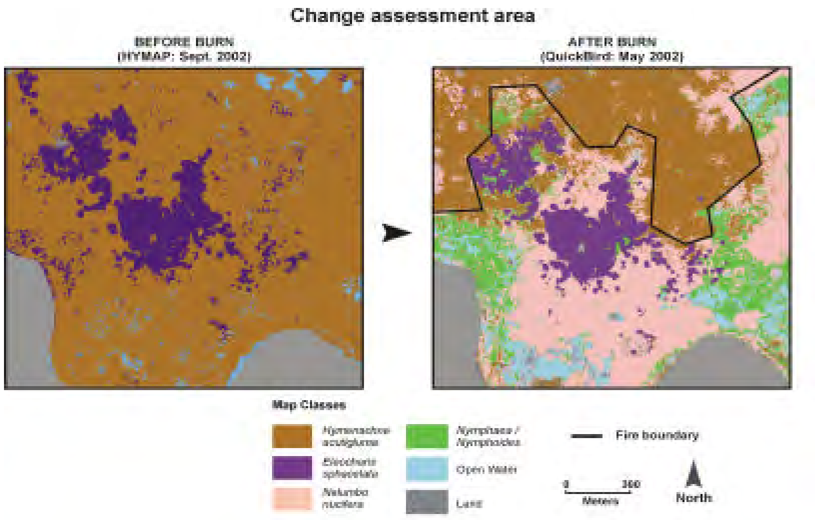
$ control cost in different management zones

Total $ costs / 1km^2 cell

0
0 - 4
4 +

Increased access to floodplain bushtucker





Remote sensing results matched ground survey results: no change in *Eleocharis sphacelata*; increase in open water & lillies; & a 75% reduction in *Hymenachne.*

Boggy Plain project

- **Salinity risk profile (DEM) mapped this year.**
- **Multiple ecological risk assessment (saltwater intrusion, weeds & feral pigs) to cultural & natural resources has commenced.**
- ***eriss* resources now directed to Magela.**
- **Good news story – project continues - a new partnership formed with Kakadu Traditional Owners, CSIRO SE, CRC Bush Fires, PAN (funding ~ $200K p.a. cash & IK x 3 years) & *eriss* .**

Ecosystem model

- Hydrodynamic submodel for space-time variation in water flows (HEC – HMS)
- Hydrochemistry submodel for transport and transformation of key chemical variables such as sediments and nutrients
- Lower trophic level submodels for plants and select invertebrates
- Population dynamics submodels for key or dominant animal indicator species (eg large fish & waterbirds)

Ecosystem model

- Used to enhance probabilistic risk assessments by incorporating spatial & temporal variability of threats & assets where data allows.
- Stochastic process submodels may account for key process uncertainties.
- 2D hydrological rainfall-discharge model used for “worse case scenario” analysis at Ranger, & to model major surface water pollution pathway.
- But need good DEM of Magela catchment.
- Model outputs will extend to decision models.

Progress: Landscape Analysis Theme

- 3 year research program (2002 – 2005)
- Conceptual pollution pathways model for Ranger almost complete
- Collation old data & acquistion new data of key assets & key threats on Magela floodplain almost complete
- Spatially explicit ERA of multiple threats to multiple World Heritage assets commenced
- Draft MSs for publications underway

Landscape Analysis of Impacts Theme

Work Plan 2004-05

- Complete spatial data layers for quantitative ERA of key WH assets and their threats
- Develop a "first-cut" ecosystem model with linked stochastic process submodels
- Use a rainfall-discharge hydrological model to simulate "worst-case" scenarios associated with extreme flood events, & to drive the "whole" ecosystem model
- Complete quantitative ERAs
- Explore range of statistical methods to assess multiple threats to multiple assets (Bayesian classification & regression trees, causal mapping & Bayesian networks, Path analysis etc)

Review of Landscape Analysis Theme

Future recommendations

- Discontinue ISP Landscape program in the 2005-06 FY; continue with more complex ERA modelling & commence decision modelling.
- Embed ERA & Landscape analysis frameworks & skills base into all research projects that address KKNs.
- New Project? Broaden the ERA framework developed for Magela floodplain to the Magela catchment; then scale up to ARR?

A landscape-scale monitoring program for the ARR ?

Future recommendations (continue)

In collaboration with PAN & others, develop a landscape-scale monitoring program for the ARR using a combination of Landsat^{TM} & QB satellite captures & ground data to assess changes in natural assets (e.g. wetlands & waterways, mangroves) in relation to climate change & other impacts.

Qualitative Risk Assessment

Likelihood exposure	Consequences exposure		
	Little	Serious	Catastrophe
Low			
Medium			
High			

But what are behind the ratings?

Quantitative Ecological Risk Assessment

- Quantitative risk assessment is estimating the probability of an adverse event
- Two components of risk
  - Effects consequences of adverse event
  - Exposure likelihood of exposure to adverse event

Pr (Risk) = Pr (effects) x Pr (exposure)

Australian Government
Department of the Environment and Heritage

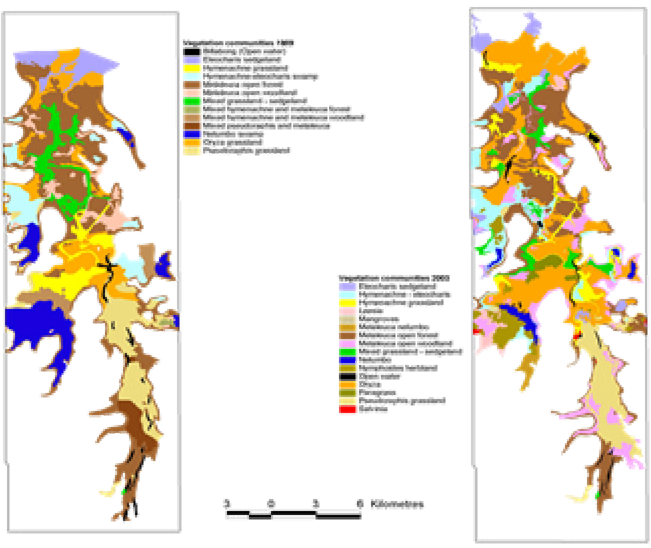
Mapping the biophysical features of the Magela floodplain

Aim:

- To collate and integrate data on the biophysical characteristics of the Magela floodplain that could be used to determine the impact of mining / non-mining activities

Landscape analysis

Australian Government
Department of the Environment and Heritage



Landscape analysis

Issues:

•Data integration – different scales, sources, methods, projection etc

•Data completeness

Where to in 2004-05 ?

- Complete SSR (infrastructure mapping)
- Honours project with CDU, quantifying changes in *Melaleuca* community extent noted by Riley & Lowry (2002)

Landscape analysis

Australian Government
Department of the Environment and Heritage

Radiation anomalies in the ARR

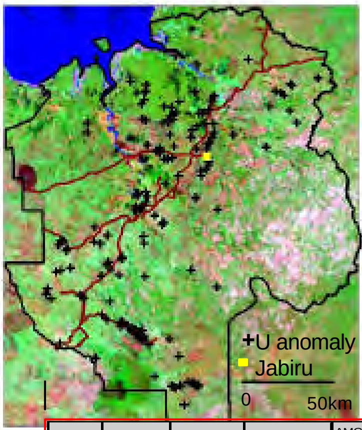
AIM: To provide relative radiation baseline data in the Region and to develop techniques for calibrating airborne and ground based gamma data for assessment of uranium mine rehabilitation.

1. Collate and verify existing information (NTGS MODAT √ & analysis of existing AGS data √). Ground truthing.

2. Produce publications including maps √

3. Commission airborne survey over Ranger and Magela. Ground truth.

RESULTS 2003-04

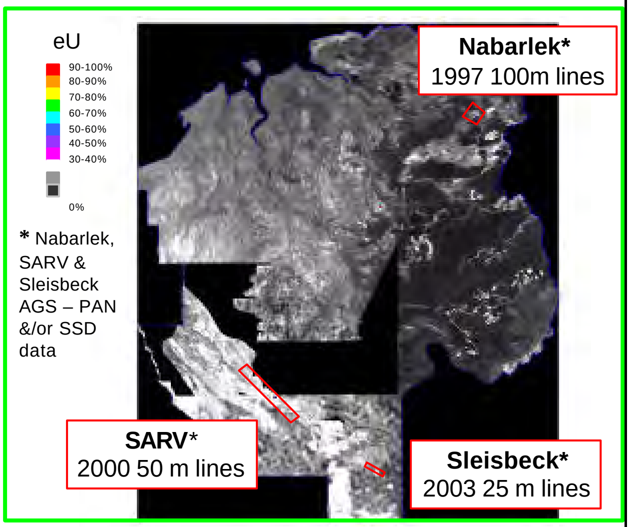


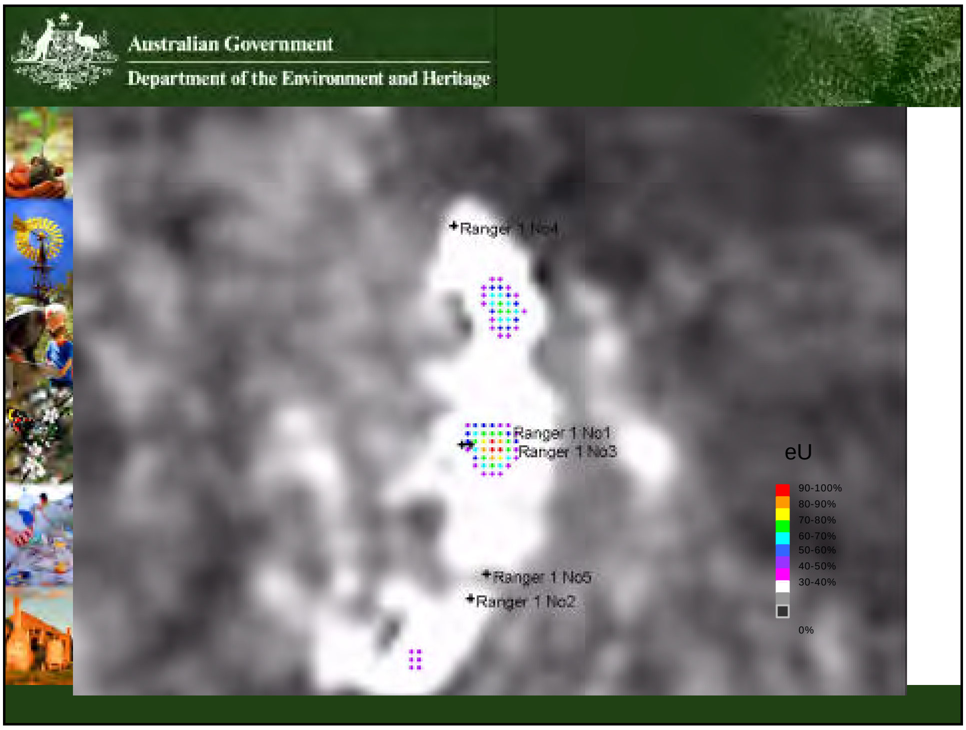
- Existing information (NTGS MODAT) collated.
- 163 U anomalies id. from MODAT & mapped to size (tonnes) & status (eg occurrence, rehabilitated, prospect).
- IR446 - An assessment of radiation anomalies in the ARR – a review

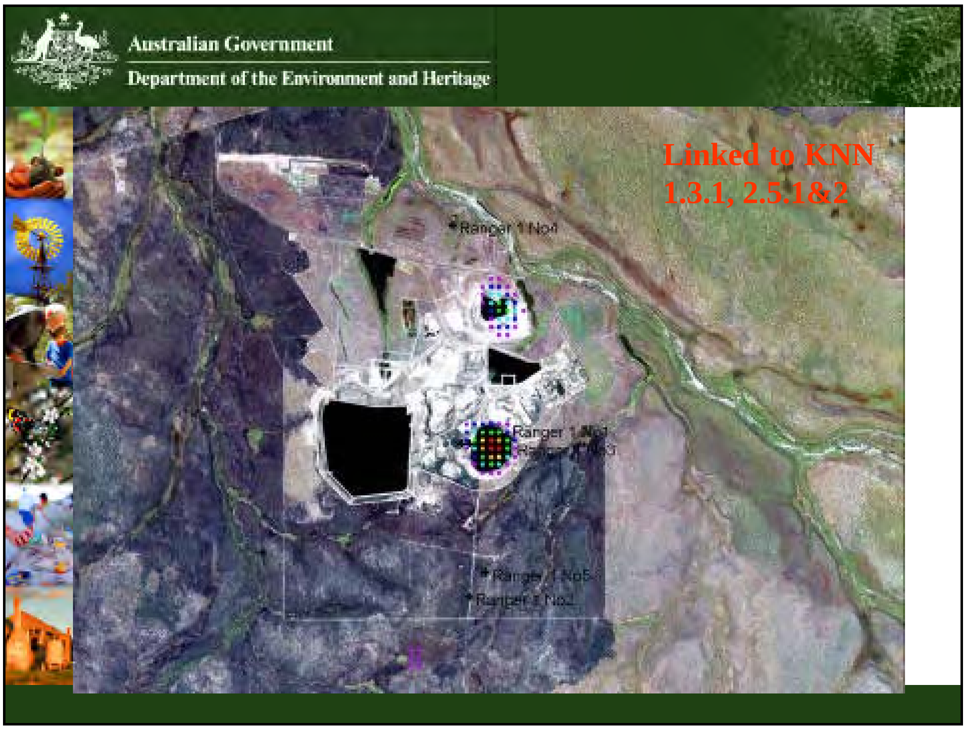
Site_Id	Name	Status	100K_Map	AMG_E AGD66	AMG_N AGD66	Latitude AGD66	Longitude AGD66	Size	Orebody Shape
5	Tadpole	Occurrence	Oenpelli	294500	8651800	-12.189244	133.11123	Occurrence	Sheet
52	Ranger 50	Occurrence	East Alligator	234000	8633700	-12.348409	132.55398	Occurrence	Unknown
360	Palette	Abandoned	Stow	236100	8502300	-13.535718	132.56176	Medium	Pipe-like
1435	Scinto 1	Prospect	Stow	235500	8502000	-13.538374	132.55619	Occurrence	Tabular

Australian Government
Department of the Environment and Heritage

NTGS AGS data
Top 70% of maximum eU values corresponded to South Alligator River Tailings area, Nabarlek and Ranger mine sites.




Australian Government
Department of the Environment and Heritage
Ranger 1 No4
Ranger 1 No1
Ranger 1 No3
eU
90-100%
80-90%
70-80%
60-70%
50-60%
40-50%
30-40%
0%
Ranger 1 No5
Ranger 1 No2


Australian Government
Department of the Environment and Heritage
Linked to KNN
1.3.1, 2.5.1&2
Ranger 1 No4
Ranger 1 No1
Ranger 1 No3
Ranger 1 No5
Ranger 1 No2

Australian Government
Department of the Environment and Heritage

FUTURE

- Commission AGS survey Ranger and Magela (Late dry season 2005?)
- Develop AGS ground truthing methodology – South Alligator River valley (Dry season 2005)
- Ground truthing of Ranger AGS (close to overpass time).

Anomalies paper delayed.

Australian Government
Department of the Environment and Heritage

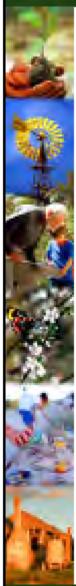
Mangroves response to coastal environmental change

AIM:

To develop methods to monitor changes in the extent, community composition, structure and biomass of mangroves on KNP using a variety of remote sensing data.

Landscape analysis

Australian Government
Department of the Environment and Heritage

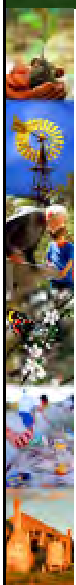


Results

- Techniques developed to monitor mangroves and baseline established
- IR447 –Extent and height of mangroves in KNP
- Conference presentations – “IGARSS” and “Mangroves 04”
- PhD Thesis – Anthea Mitchell UNSW

Landscape analysis

Australian Government
Department of the Environment and Heritage



Applications

(a) Monitor changes in mangroves on KNP
(b) Mangroves in other regions
(c) Other vegetation communities (riparian & FW wetlands)
(d) Climate change modelling (saline intrusion, freshwater boundary change)

Future 04/05

- **Publications with Lucas and Mitchell**

Landscape analysis

Australian Government
Department of the Environment and Heritage

Landscape scale analysis of impact

Significant species, populations and communities

Rationale and aims

- Broader WH value from original, specific ISP/IUCN request to examine ecological assets (/potential threats to) of seeps and springs around Jabiluka, especially endemic macro-crustaceans
- Some urgency given to sampling with imminent cane toad invasion

Progress to date

- Sampling of various stone country locations undertaken to complement existing survey data, with effort to date in the north of KNP (esp. around Jabiluka)
- Collections not exhaustive of all aquatic communities but likely to capture true endemics
- Degree of endemism and conservation significance of fauna: Initial molecular genetics work on two species of isopod reported (SS Annual Report)
- Awaiting outcomes of bid for ABRS funds to continue isopod taxonomic work
- Water chemistry and biological community data currently being compiled

Landscape analysis

Australian Government
Department of the Environment and Heritage

Landscape scale analysis of impact

Significant species, populations and communities

Proposed program for 2004-05

- Report water chemistry and biological community data for existing collections
- Degree of endemism and conservation significance of fauna
  - Provide modest funds to three interstate collaborators – taxonomists and molecular geneticists – to determine degree of genetic differentiation of macro-crustaceans from key sites, including Jabiluka.
  - Formal description of one endemic palaemonid shrimp species
  - Limited additional surveys proposed where sampling of key sites incomplete
- Flora and fauna associated with various habitats
  - Provide ERA group with species-level information on particular biological communities associated with specific habitats in KNP

Landscape analysis

03-04 Evaluation

Summary of outputs 03- 04

TYPE	On Track	Actual	By Dec 04
IRs	7	4	11
SSRs	3	1	4
Draft Journal MS	5	1	6
Published Journal MS	0	0	0
Referenced in book	0	1	1
ErissNote or other	1	1	2
Conference/workshop	2	6	8
Promotional material	2	3	5
PostGrad (Hons, MSc, PhD)	1	2	3

LANDSCAPE ANALYSIS THEME

Future Work (Challenges) rest 03-04 & 04 – 05

- Publish all papers
- Finalise outstanding field tasks (map para grass on Magela, map salinity risk profiles on Magela & Boggy)
- Assess “condition” of key World Heritage assets on Magela
- Quantitative ERA Magela of multiple threats to multiple assets (combine Ranger mine site & landscape risk assessments)
- Integrate several modelling approaches – Bayesian statistics & networks, habitat suitability models, ecosystem dynamics models (hydrology, populations, communities)
- Undertake benefit-cost analyses to assess alternative risk management scenarios
- Commence development of decision support tools for risk management of Magela floodplain

LANDSCAPE ANALYSIS THEME

FUTURE OPTIONS

Option 1

- Keep name, focus on ERA KKNs at landscape scale, strong link to Rehabilitation Theme

Option 2

- Replace with "Ecological Risk Assessment Theme" focused on Ranger mine in Magela catchment – and in addition:
- Establish new Tropical Knowledge Theme (mix internal/external funds) with sub-Themes reflecting future strategic research
  - Tropical Rivers
  - Commercial assessments – eg East Timor, Mt Todd Ecotox
  - Climate change & mangroves
  - Socioeconomic analyses
  - Waterbirds – regional, national & international

Other Options Explore as part of SSD Strategic Review