

Part B: Terrestrial Environments

Norm McKenzie, Tony Start, Andrew Burbidge, Kevin Kenneally and Neil Burrows

Overview

The Kimberley extends from sub-humid to semi-arid areas and covers a variety of different geological basements. These differences are reflected in the distinctive geomorphologies, soil, landscapes and biotas of the north, central, south and eastern Kimberley, and have determined their different land-use histories and contemporary land condition. In these terms, five biogeographical regions (10 subregions) are recognised in the Kimberley (Thackway and Cresswell 1995, McKenzie *et al.* 2003), that provide a framework for planning and action.

In this section, we review the information base then characterise the bioregions to identify their different contributions to Kimberley diversity (treated here as a mosaic of regional ecosystems). Then we summarise the biodiversity values of Kimberley ecosystems and identify special features, communities, clades and species that should be a particular focus for management because of rarity, special value, vulnerability or imminent risk.

Next, we review the condition and trend of the ecosystems in each bioregion, and provide a schematic model of the soil nutrient, hydrological and inter-species processes that maintain the compositional diversity of savanna because it is the matrix in which all of the Kimberley's other ecosystems and special features are set.

Finally, we identify priority management needs, particularly strategic actions that will mitigate degrading processes throughout the Kimberley and protect or rehabilitate whole suites of ecosystems and species. Healthy country is more productive, both in economic and biodiversity terms (Whitehead *et al.* 2000, Start 2003). The most cost effective conservation strategy is to protect, restore and maintain functional landscapes and systems, rather than trying to preserve small remnants or focussing only on localised, patch-scale remedial actions such as site restoration. A cross-tenure approach needs to be taken in controlling the threatening processes both to maintain the unique values of the Kimberley and to allow sensible development and other activities where appropriate. This process must have a foundation of strong science to inform planning, decision making and, where necessary, restoration.

In terms of its climate, landscapes and biodiversity, the Kimberley is part of northern Australia's tropical savanna biome, so ecological studies and land management lessons from other parts of this savanna bear on its management, especially those from equivalent sub-humid and semi-arid regions in the Northern Territory. Because of uncertainty and knowledge gaps in understanding the processes threatening Kimberley ecosystems, management needs to be implemented in an adaptive management framework, ensuring that best available information is fully utilised and that managers learn by doing (e.g. Williams *et al.* 2002, Burrows 2005).

Information-base

Literature

Attachment 4 (Part B: Terrestrial) lists all references cited herein, and is divided into four sections: overviews, surveys, reserve recommendations and landscape processes. The most recent scientific literature review (Waples 2007) includes 992 entries, including documents on the Kimberley's ecological values, conservation reserve system, wildlife surveys, historic exploration notes, Aboriginal ethnobotany and economic planning. It focuses on literature accessible through formal publications and government reports, but undoubtedly overlooks many less formal articles. For instance, projects undertaken by consultants for industry were often unpublished and can be difficult to identify.

Environmental maps and other spatial data

A total of 240 datasets have been identified that contained information on Kimberley biodiversity (see Handasyde 2006, Waples 2007). They include broadscale datasets that cover a large area beyond the Kimberley such as vegetation mapping of the north end of Australia by the Tropical Savanna CRC, and datasets specific to particular ecosystems such as flora and fauna records from the Kimberley Rainforest Survey (McKenzie *et al.* 1991). A full list of the datasets can be found in Waples (2007).

Environmental maps that provide a first approximation of the regional ecosystem boundaries (the mosaic) and cover the entire Kimberley include the 1:250 000 surficial geology and 1:250 000 vegetation maps (Beard 1979, supplemented by the rainforest classification maps by Kay *et al.* 1991, and by forest cover maps derived from satellite images by Behn 2001). In addition, land-system maps cover large areas of some bioregions (e.g. Speck *et al.* 1960, 1964; Stuart *et al.* 1970). 'Google Earth' provides an aerial view of vegetation-types in the context of topography.

Kimberley landscapes support a variety of vegetation including hummock, tussock and bunch grasslands, shrublands, tree steppe, woodlands, riverine forest, mangrove, rainforests and paperbark swamps. While broadscale mapping of mangrove, rainforest, riverine forests and paperbark forests from the satellite images was considered adequate, image analyses did not reliably discriminate savanna vegetation-types (woodlands, tree steppe, shrublands and grasslands) or height classes (Behn 2001). The savanna communities that dominate the Kimberley have not been mapped at a scale with sufficient resolution to adequately inform fire management programs.

Administrative and biogeographic regions

For administrative purposes, the Kimberley is divided into four local government areas: Broome, Derby-West Kimberley, Halls Creek and Wyndham-East Kimberley. For conservation planning purposes it encompasses three biogeographic regions (Northern Kimberley, Central Kimberley and Dampierland) and parts of two others (Victoria-Bonaparte and Ord Victoria Plains) (Fig. 4). The bioregions are characterised in Attachment 1, but more detailed descriptions can be found in May and McKenzie (2003).

Biodiversity data

There has been a long history of botanical and zoological collecting in most parts of the Kimberley with voucher specimens lodged in herbarium and museum collections, particularly the collections of the WA Herbarium and the WA Museum. These records normally include locality data and, except for many invertebrate groups, are available through searches made on-line or by request. Literature searches often reveal the existence and location of early collections of invertebrates as well as vertebrates and plants.

In addition, numerous biodiversity and taxon-specific surveys have been undertaken. Some cover entire ecosystems (mangrove, rainforest, Devonian ranges), while others have focussed on sampling the landscapes of an individual conservation reserve (e.g. Prince Regent, Purnululu) or a particular area or situation (Dampier Peninsula, Edgar Ranges, North Kimberley islands, Mitchell Plateau), or on a particular group of organisms (flora, birds, mammals, frogs, reptiles, fish, land snails or spiders etc) either locally or Kimberley-wide. Many of the relevant studies are listed in Attachment 4. Other surveys have been carried out on Australian Wildlife Conservancy properties, Buccaneer Archipelago, Napier, Oscar and Ningbing Ranges, Victoria-Bonaparte land snails, Fitzroy River fish and lower Ord fish (e.g. Storey 2000).

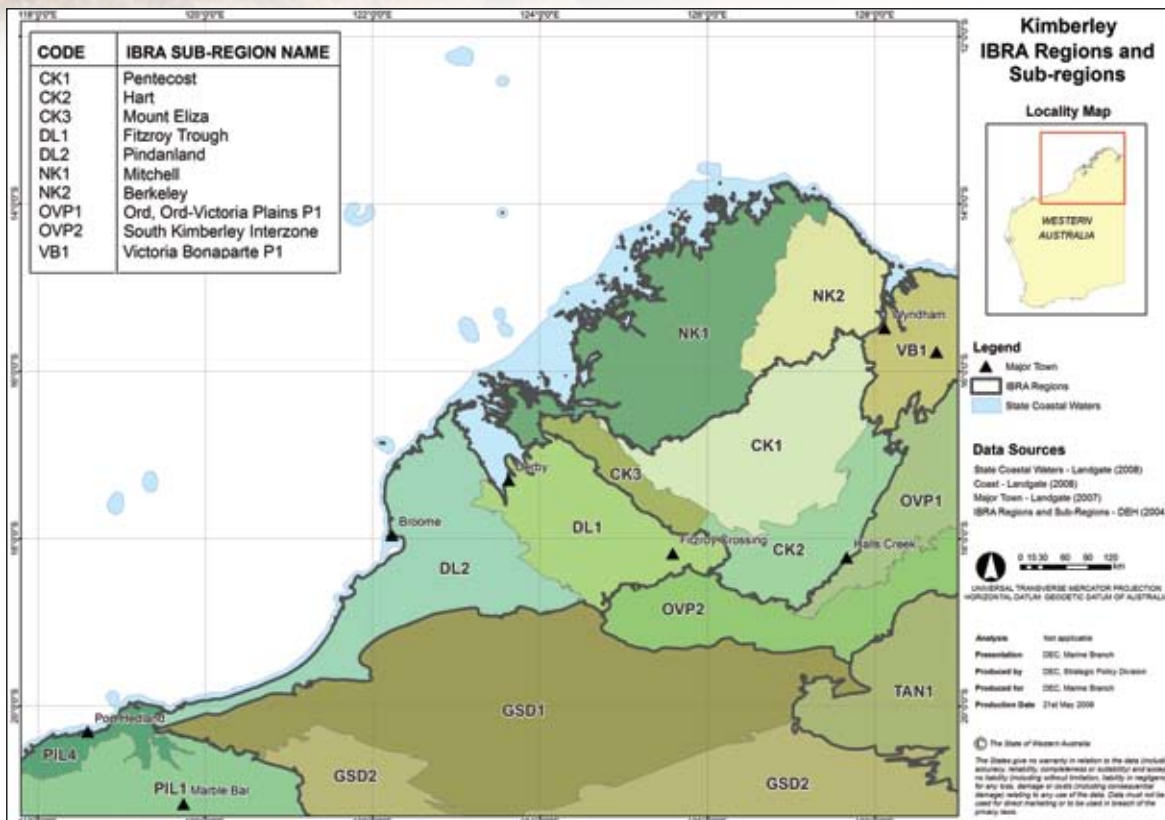


Figure 4: Terrestrial Bioregions and Sub-regions of the Kimberley. NK = North Kimberley, CK = Central Kimberley, DL = Dampierland, VB = Victoria-Bonaparte and OVP = Ord Victoria Plains.

Surveys of fauna in the Kimberley have identified 76 species of native mammal, 295 bird species, 178 species of reptile, and 42 named species of native frogs. Overall species diversity is highest in coastal, high rainfall areas and sandstone ranges (Woinarski 1992). In the Australian Mammal Audit (McKenzie and Burbidge 2002), the Kimberley shows a rich mammal fauna with high endemism and low attrition rates in some areas. Of note, there have been no mammal extinctions in the north Kimberley, though the status and distribution of a number of medium size mammals is of concern (McKenzie and Burbidge 2006). Further, the Kimberley has the highest diversity of frog species in WA. Although work on the invertebrates of the Kimberley is extremely limited (e.g. Solem 1988), many of the 126 species listed as endangered are land snails.

The Kimberley has been listed as a National Biodiversity Hotspot: 230 plant, 16 fish, 10 frog, 31 reptile, 2 bird and 6 mammal species are known to be endemic to the region (e.g. Wheeler 1992), and strongly localised patterns of endemism characterise some invertebrate groups such as the camaenid land snails and earthworms (e.g. Solem and McKenzie 1991). The endemism is not restricted to the sandstone uplands and rainforest patches of the high-rainfall north Kimberley, it is also well documented from limestone ranges in the south-western Kimberley and the Victoria-Bonaparte Bioregion.

In general, the available data are inadequate to assess the real status of many rare or locally distributed species that may warrant gazettal as threatened. There has been no systematic biodiversity survey of an entire Kimberley bioregion or subregion, and no detailed plant or animal surveys of savanna ecosystems on the alluvial plains of the Fitzroy Trough and South Kimberley Interzone Subregions.

General reviews of Kimberley biodiversity, its conservation, condition and trend

Kimberley Regional Planning Study (Burbidge *et al.* 1991)

Biodiversity Audit (May & McKenzie 2003, McKenzie *et al.* 2003, Gordon & McKenzie 2004)

Kimberley Regional Plan (Portlock *et al.* 2001).

Kimberley Regional nature conservation strategy (DEC 2008, unpublished draft)

Kimberley Biodiversity Review (Waples 2007)

Tropical Savanna CRC's Ord-Bonaparte project (e.g. Sandercock 2004, Wolanski *et al.* 2001)

Handasyde (2006) inventoried publications and available biodiversity data-sets on the terrestrial environment for the Kimberley, with the main focus on the mainland and on issues relevant to fire management (e.g. Craig 1997, 1999).

AusRivas project (Halse *et al.* 2001).

WA State of Environment Report (EPA 2007).

Biodiversity values

Tropical savanna ecosystems

These ecosystems vary in their vegetation structure and species composition according to factors such as substrate, rainfall, biogeographic history and disturbance history (e.g. Williams *et al.* 2007), and form the matrix in which the Kimberley's other ecosystems and special features are set. An array of savanna ecosystems are recognised in the Kimberley, each characterised by specific tree and grass communities (perennial hummock and tussock grasslands, annual cane grasslands etc), shrublands, tree steppes and woodlands on:

- the various soil surface types found in each bioregion (eluvial, alluvial, aeolian; silt, clay, sand), and
- each of the geomorphic units expressed by the stratigraphy (rock formations recognised) in each bioregion (various sandstones, volcanics, granites, limestones, mudstones, siltstones etc) (e.g. Gellatly and Sofoulis 1973).

Riverine and freshwater swamp ecosystems

Wetlands, including water courses and their riparian zones, are an important resource for waterbirds and provide refugia during the dry season for many savanna species, as well as containing a vast array of aquatic species that are often poorly documented (e.g. Halse 2000, Loh *et al.* 2001). The riverine wetlands also provide one of the Kimberley's few forests, a discrete vegetation community with a paperbark and rivergum canopy and a characteristic vertebrate fauna. Four wetlands are recognised for their significance at a global level and are listed under the Ramsar Convention. Only one of the four Ramsar-listed wetlands in the Kimberley is within a nature reserve although nature reserves and marine parks recommended in Burbidge *et al.* (1991) and Wilson (1994) would cover all, or portions, of the remaining three sites. A further 21 sites are considered nationally important wetlands. DEC's Wetlands Database Project 2005 provides online information on the location, tenure, hydrology, geomorphology, flora and fauna of significant wetlands in the Kimberley. The Australian Wetlands Database contains information on the wetlands of international (Ramsar Convention) and national importance (Environment Australia 2001), their physical and ecological features, threatened flora and fauna, migratory fauna, social and cultural values, threats and management activities.

Coastal ecosystems

The Kimberley coast provides habitat for important vertebrates such as estuarine crocodiles, mangrove birds and mammals, migratory shorebirds, seabirds and marine turtles, although more detail on their ecological and community requirements and interactions is needed to optimise management programs. While there are considerable data on the birds and bats of the mangrove communities (e.g. Johnstone 1990, McKenzie and Rolfe 1986), the composition of arboreal mammals and reptiles that use the mangal is still poorly understood.

Some of the largest patches of mangrove in Australia occur along the Kimberley coast. They have a total area of 140 000 hectares, are rich in species, and considered to be among the most pristine mangals in the world as they have not been open to logging or fragmented by coastal infrastructure. Stands comprise up to 18 tree species and their fauna is both rich and distinctive. Relevant publications include Pedretti and Paling (2001), Semeniuk *et al.* (1978), Wells (1982), Hutchings (1995), Hanley (1998), Johnstone (1990), Bridgewater and Cresswell (1999), Saenger (1998), Wells and Bryce (1996), Semeniuk (1980, 1982, 1985), Messel *et al.* (1987), McKenzie and Rolfe (1986) and Thom *et al.* (1975). Mangals provide coastal protection by reducing the shoreward effects of storm surges associated with cyclones, and also create an interface between marine and fresh waters that reduces the effects of nutrient runoff, roles on which adjacent corals and seagrass ecosystems are thought to depend (see Part A above and Bridgewater and Cresswell 1999). They also provide nursery and breeding habitats for important fisheries along this coast (Pedretti and Paling 2001), and habitat for saltwater crocodiles. Given the apparent resilience of this ecosystem, there are no major perceived immediate threats (although see Wolanski *et al.* 2001 re Cambridge Gulf), but their arboreal mammal and reptile faunas need detailed study, and the potential effect of feral pigs needs to be investigated.

The Kimberley includes many estuaries and tidal mudflats. OzEstuaries online database includes data on the condition of 80 estuarine sites in the Kimberley as pristine, with four considered to be largely unmodified and one (Ord River estuary) modified. Extensive tidal mudflats characterise Kimberley coastlines, particularly its estuaries, inlets and bays. Geomorphological studies of mudflats in Cambridge Gulf have been undertaken (Wright *et al.* 1972, 1973, 1975, Thom 1975, Wolanski *et al.* 2001) and Semeniuk (1980, 1981, 1985) has described sediments of the tidal flats of King Sound. Roebuck Bay has received a great deal of attention (see Part A above) and there is ongoing collaborative research on the invertebrate fauna and relationship with sea, shore and migratory birds (de Goeij *et al.* 2003, Rogers *et al.* 2003, Piersma *et al.* 2006). While Roebuck Bay studies have identified a high invertebrate and shorebird biomass and diversity, this research has not been repeated at other similar sites and it is not known whether this level of biodiversity and productivity is unique to Roebuck Bay or more widespread across the Kimberley. Sites such as Eighty Mile Beach and Roebuck Bay are considered of international significance given the numbers and diversity of birds that feed in these areas seasonally, and are listed Ramsar sites. There is a reasonable amount of published literature on sea and shorebirds in the Kimberley (e.g. Storr 1980, Johnstone 1990, Woinarski 1992, Watkins 1993, Tulp and DeGoeij 1994, Collins 1995, Barrett *et al.* 2003, Hickey *et al.* 2003). Long-term research programs have been active through Birds Australia (the Broome Bird Observatory) and the Australian Wader Study Group, and limited surveys of seabird breeding islands have been conducted (e.g. Burbidge and McKenzie 1978, Burbidge *et al.* 1978). However, there is a need to maintain a monitoring program for these islands. The north-west of Australia is a first stopping point for many of these bird species on their migratory route from southeast Asia. The islands of the Kimberley and the regions intertidal coastal environment and wetlands, contain a number of important areas, not all of which have been identified, where these species congregate, feed and rest.

Short steep beaches can be found between rocky headlands on the many coastal islands of the Kimberley. These beaches comprise coarse terrigenous material, sometimes including pebble beaches in areas where there are basalt or dolerite outcrops. Consolidated beach dunes behind the beaches are usually well vegetated with beach spinifex and, further back, with hummock grasslands stands of *Pandanus* and patches of semi-deciduous monsoon vine thicket. They are rich in vertebrates such as mosaic-tailed rats, black whip-snakes and skinks, and the fore-dunes are known nesting sites for marine turtles.

A high proportion of the Kimberley shoreline is rocky. Although surveys record a variety of vertebrate species foraging in this environment, including water rats, northern quoll, mangrove kingfishers, oystercatchers and other wading birds, olive pythons, and various lizards, there have been no specific studies of rocky shore communities and their relationship to adjacent communities such as the mangrove, sandstone and volcanic country. There are also spectacular boulder bars presumed to have been generated by tsunamis (e.g. on Darcy Island), that may provide an understanding of tsunami threats to the Kimberley coastline.

Rainforest ecosystems

Between 1987 and 1989 a broad scale ecological survey was undertaken of the Kimberley rainforests. Data were collected on compositional patterns of biota, disturbance and physical characteristics of the environment. The results of this survey provide information on soil and landform, invertebrate and vertebrate fauna, floristics, vegetation structure and spatial distribution of rainforest patches (McKenzie *et al.* 1991). About 1 500 patches are scattered across 170 000 square kilometres of the Kimberley. They have a distinct structure, are rich in species not found in the surrounding savanna, and occur as small, isolated patches on hillsides and scree slopes, in gorges and gullies, in swamps, along rivers and on coastal sand dunes. The average patch has an area of three hectares and few exceed 20 hectares; most are in the rugged high rainfall north-west. They are characterised by high levels of invertebrate endemism, and numerous plants and vertebrates depend on the archipelago of patches for their persistence in the region. Nearly 25% of the 2 000 species that comprise the Kimberley flora were recorded in the rainforests, and about a third of these are confined to them.

Unlike savanna communities, a high proportion of rainforest plants produce succulent fruits that are an essential food resource for many of the region's fauna. A total of 141 bird species was recorded in Kimberley rainforests (45% of the Kimberley terrestrial bird fauna), and some of the most colourful of Western Australia's birds rely on them (figbirds, yellow oriole, spangled drongo, rainbow pitta, orange-footed scrubfowl, emerald dove and rose-crowned pigeon). The patches are part of a great corridor of monsoon forests extending through South-east Asia and into Australia that is important for the seasonal migration of birds such as koels and channel-billed cuckoos. Many of the small immobile species endemic to the Kimberley have only been recorded in rainforest patches. This includes 90% of the earthworms and 48% of the land snails.

Troglobitic and stygofauna ecosystems

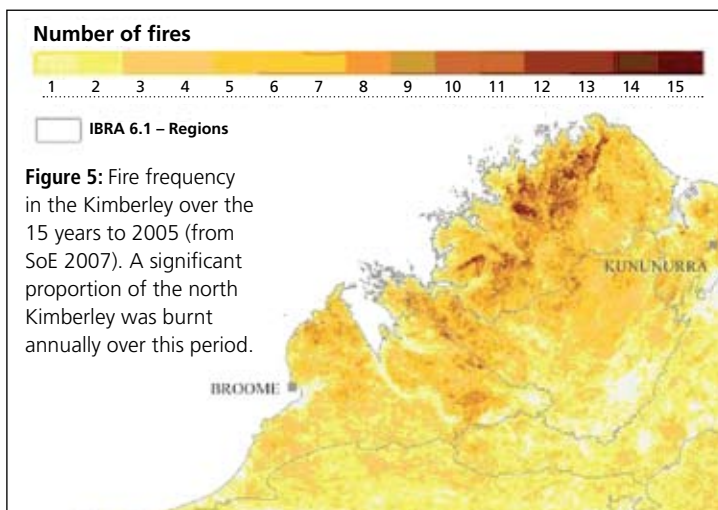
There is a significant subterranean fauna in the Kimberley containing both troglobitic and stygobitic elements. This poorly studied group is known from limestone ranges of the east and west Kimberley, alluvial aquifers of Ord River Irrigation Area (Humphreys 1995, 1999) and Argyle Diamond Mine (Humphreys 2003), sandstones and offshore islands (Wilson and Keable 1999). The fauna is typically locally endemic and some elements represent globally significant basal and/or relictual phylogenetic lineages (Cho *et al.*, 2005, Wilson and Keable 1999, Wilson and Ponder 1992).

Special landscapes, ecosystems and species values (see Attachment 2 for details)

- A largely intact flora and fauna in the north west margin of the Mitchell Subregion, including many endemics as well as mammals that are extinct elsewhere in Australia. Its sandstone communities show high species endemism and ecosystem diversity.
- A submerged coastline with extensive coastal archipelagos that form virtually weed and feral animal free microcosms of the adjacent mainland and an opportunity to protect intact, healthy ecosystems.
- Napier, Oscar and Ningbing Ranges, the stranded remnants of Devonian barrier reef system. Rivers traversing the ranges have created spectacular gorges. There are many species and genera endemic to these ranges and extensive cave systems with troglofauna.
- Rainforest patches have endemic invertebrates and act as seasonal refugia.
- Mound springs and swamp rainforest.
- Wetlands such as the Camballin Floodplain.
- Grasslands associated with black soils in Dampierland (Roebuck Plains – *Sorghum*), Kimberley Interzone (Mitchell Grass) and Victoria-Bonaparte (Rice Grass & *Sorghum*).
- Extensive coastal mudflats which support numerous migratory birds (e.g. Roebuck Bay and Eighty Mile Beach)
- Tropical laterite flora on Mitchell Plateau, with a palm-dominated landscape, is unique in WA. The Cape Bougainville rainforest on laterite and volcanic surfaces is the largest single rainforest patch in the Kimberley.
- Many island and mainland beaches are turtle breeding sites.

Ongoing degradation of regional ecosystems and special features

Attachment 3 provides an overview of condition and trend in the landscape biodiversity of the five Kimberley bioregions. Pastoral influences and changed fire regimes are a ubiquitous theme. Below we discuss Kimberley ecosystems and special features that have strategic, cross-tenure priority for on-ground management action.



Above left Degraded pindan shrubland severely impacted by too frequent burning is a common feature of the Dampierland Bioregion.

Savanna and riverine ecosystems

Fire is a natural environmental factor that has shaped tropical savanna ecosystems over millennia. As well as lightning-caused fires, Aboriginal people lit fires extensively to hunt game, to regenerate food and medicinal plants, or to “clean up country”. Since European settlement there has been a reduction in traditional Aboriginal use of fire because in many areas people are not ‘on country’ as they were in the past and land use and tenure have changed. The fire regime has changed from one dominated by mild, patchy fires mostly lit early in the dry season, to mostly intense, large fires later in the dry season (Russell-Smith *et al.* 2002 and 2003, EPA 2005, Radford and Anderson 2006). In most places, fires are also more frequent than they once were (see Fig. 5). The fire situation in the Kimberley is of such concern that in 2005 the then Minister for the Environment requested that the Environmental Protection Authority (EPA) review environmental aspects of fire in the Kimberley and interior of the State (EPA 2005).

The compositional complexity, vegetation structure and soil structure of tropical savanna ecosystems have changed, and continue to change, under the current regime of extensive, frequent, intense, late-dry season fires and grazing by feral herbivores (e.g. Roth 2004). As well as large scale degradation of the structural and floristic integrity of vegetation and fauna habitats, these changes affect landscape productivity through nutrient erosion and hydrological change, particularly infiltration/runoff coefficients (e.g. Braithwaite and Muller 1997; Ludwig *et al.* 1999, 2005; Russell-Smith 2006), and are ubiquitous. They are particularly severe in the semi-arid Ord and Fitzroy Trough Subregions because their fertile alluvial plains offer fewer natural barriers to fire and stock. Pastoral development in the rugged northern Kimberley is both more recent and more localised, but the soils of its landscapes are shallow, skeletal and more sloping on average, and rainfall events are more frequent and heavier. In the northern Kimberley cattle have emigrated from pastoral leases using riparian and other corridors into conservation reserves, Aboriginal land and unallocated Crown land. Changes include simplified vegetation structures dominated by annual grasslands and with fewer perennial trees, shrubs and grasses and loss of obligate seeders (e.g. Russell-Smith *et al.* 2002, 2001, Dyer 2001, Woinarski *et al.* 2004), increased soil erosion including the loss of leaf litter, organic-A and mineral-A soil horizons, greater runoff volumes and velocities, with increased alluvial deposition on footslopes, floodplains and in estuaries, and as bedload in rivers, and more severe flood events in drainage lines with high flow velocities that strip riparian zone vegetation and enhance weed invasion (Fig. 6).

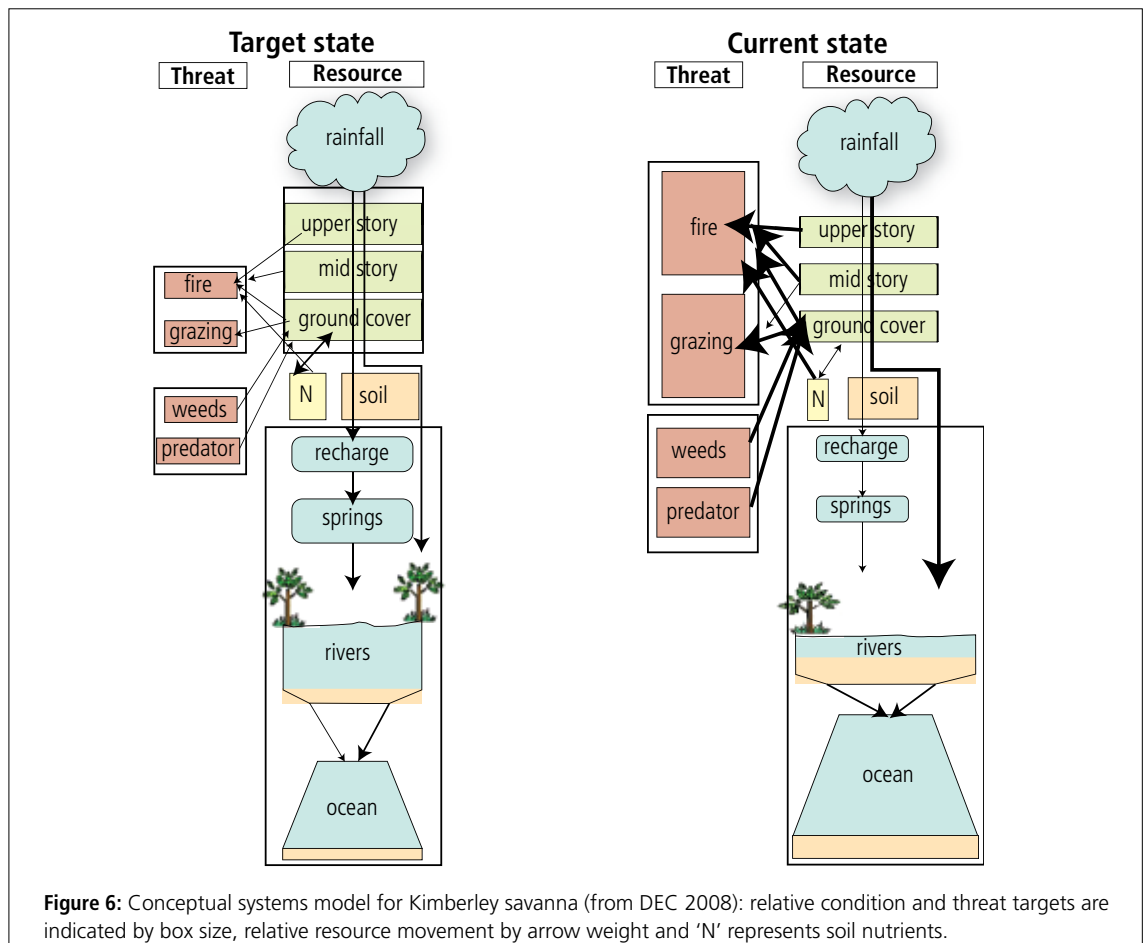


Above Introduced siratro (*Macroptilium atropurpureum*), a native of tropical America, is an aggressive weed seen here invading coastal monsoon vine thicket in the Dampierland Bioregion.

Above right Introduced black buffel grass (*Cenchrus ciliaris*), a native of Africa and India, causes considerable ecological change, seen here invading coastal dunes and sand plains in the Dampierland Bioregion.

Consequences include loss of savanna biomass and complexity; disruption of granivorous mammal and bird guilds during the resource bottleneck of the late-dry to early wet season (Franklin 1999, Woinarski *et al.* 2001), contraction/loss of rainforest patches (McKenzie *et al.* 1991, Russell-Smith and Bowman 1992), decline and extinction of medium size mammals (McKenzie *et al.* 2006, Woinarski *et al.* 2001 – note the Kimberley has not been colonised by foxes and rabbits), occlusion of drainage systems and loss of river pools (e.g. Ruprecht and Rogers 1998). The scale of this process is so great on the mainland that the coastal islands have a paramount protection role for the Kimberley's biodiversity. Inappropriate fire is the main driver of these changes but appropriate fire offers a management tool for reversing it (see Russell-Smith *et al.* 2002, 2003, EPA 2005).

Introduced plants thrive in the landscape where cattle and fire impacts have reduced the integrity of the native vegetation. Riparian areas have a wide variety of weed species, but the broader landscape is threatened by a few weed species that are more tolerant of low moisture levels such as buffel grass. Buffel is allelopathic, further simplifying the vegetation. This effect is particularly severe in riparian areas. New weeds are occasionally found in the Kimberley such as rubbervine, *Vachellia nilotica* and parthenium, indicating the need for stronger quarantine and surveillance measures. An issue that is receiving increasing attention is the westward spread of the cane toad toward WA. Significant efforts are being made to delay the arrival of the cane toad into WA, and to identify biodiversity assets at risk so that focussed protective measures can be implemented.





Rainforest

Fire has had a strong influence on the localised distribution and boundary characteristics of rainforests across northern Australia (e.g. Russell-Smith and Dunlop 1987, McKenzie and Belbin 1991). The size and shape of persisting patches often reflect the level of protection from fire offered by surrounding landforms and vegetation, and patches used by feral stock are the most frequently burned. As rainforests were prime food-gathering areas, Aborigines would not burn them, and would try to protect them from fires by burning the grassland around a rainforest patch early in the dry season (Mangglamarra *et al.* 1991). Fires burning in the wet or early dry seasons would generally not penetrate rainforest, which were too moist to burn at these times. However, rainforests are vulnerable to, and are degraded by, intense fires late in the dry season. Unfortunately, the small size of the rainforest patches has made them particularly vulnerable to disturbance. Patches in cattle country are being trampled, opened, invaded by flammable savannah grasses, and are contracting in size. They need to be fenced to exclude grazing stock, and savanna fire regimes need to be managed to prevent late dry season wildfires penetrating and damaging patches.

Above Closed-canopy rainforests are found on rugged sandstone slopes in the North Kimberley Bioregion.

Above left Coastal rainforest (evergreen and deciduous monsoon vine thickets) in the Dampierland Bioregion is listed as a Threatened Ecological Community.

Below Rainforests on lateritic scree slopes are found on Cape Bougainville, Mitchell Plateau and islands such as the Marets in the North Kimberley Bioregion.





Islands

The more than 2 500 islands along the Kimberley coast (340 have an area exceeding 20 ha) have an important role in Australian fauna conservation (Burbidge 1991). Not only do the islands support populations of various Kimberley endemic species (such as scaly-tailed possum, monjon - a rock-wallaby, Kimberley rock-rat, black grass-wren, rough-scaled python, Kimberley taipan, at least 15 lizard and frog species, and numerous plant, land snail and earthworm species), they are also refugia for a variety of threatened mammals that have disappeared from large areas of the mainland (e.g. golden-backed tree-rat, golden bandicoot, northern brown bandicoot, northern quoll and pale field-rat). Forty of the Kimberley's 76 terrestrial mammals are now known from the islands.

Not only do the islands provide a microcosm of the adjacent mainland's geological and biological diversity, they are also relatively isolated from many of the threatening processes affecting mainland ecosystems. In almost all cases, the Kimberley's coastal and off-shore islands are weed-free, have had no pastoral use and have not been colonised by feral animals. Exceptions are Koolan and Cockatoo which have been mined for iron ore since the 1960s, and Sunday and Adele which have introduced rat populations. Most of the islands do not show the fire-induced vegetation and soil changes apparent in the mainland savanna although the frequency of dry season fires appears to have increased in the last decade, along with increased visitor numbers (tourism etc). For instance, there have been extensive fires on both Augustus and Bigge, the two largest islands, during the last 5 years. DEC is currently surveying biodiversity on 20 of the largest islands to develop a conservation management plan in collaboration with traditional owners.



Above Coronation Island in the North Kimberley Bioregion showing rainforest on basalt (Carson Volcanics) and mangroves fringing the sheltered embayment.

Left Golden bandicoots (*Isoodon auratus*) persist in the North Kimberley and on some islands. They have disappeared from arid and semi-arid Australia over the last century.

On-ground conservation management priorities for regional ecosystems and special features

Better fire management

A change in current fire management, and feral animal and stock control practices across the entire landscape, including conservation reserves, is required to control erosion, vegetation simplification and fauna declines in savanna ecosystems (Legge *et al.* 2008). An early dry season mosaic fire regime needs to be imposed in an adaptive management framework to acquire the 'response' data needed to fine tune the regime for the various savanna ecosystems. Late dry season fires will need to be actively suppressed where possible.

The program needs to deliver biodiversity conservation benefits on-ground and over areas much greater than just the existing conservation reserve system. Much of the Kimberley is Aboriginal land and given the remoteness of the regions and sparsity of settlement, the positioning of logistical and human resources will be a major activity, so implementation will need to involve collaborations with local Aboriginal communities. DEC's Kimberley region staff already undertake ground and aerial burning programmes in various parts of the Kimberley in conjunction with the Fire and Emergency Services Authority (FESA), and often in collaboration with Aboriginal communities. Following the development of a Kimberley regional fire management plan, this program needs to be significantly expanded in close collaboration with FESA, indigenous communities and pastoral organisations, particularly in applying late wet, early dry season fire mosaics for protection of lands at landscape scales. Logistical and on-ground human resources will need to be expanded as part of costing, planning and implementing a wider program. Training and deployment of contract Aboriginal 'fire teams' is a promising recent development. DEC is collaborating in the EcoFire project (http://www.savanna.org.au/km/kimberley_ecofire.html) with the Australian Wildlife Conservancy, Kimberley Land Council, FESA, Department of Agriculture and Food and Pastoralists and Graziers Association.

There needs to be increased attention to fire management and weed control and closer attention to the spread of 'pasture improvement' species, particularly some grasses. There are opportunities for closer collaboration in monitoring and management of pastoral lands for sustained biodiversity, leading to healthier country for all concerned.

Below Populations of the white cypress pine (*Callitris columellaris*) have been dramatically reduced by the impact of frequent, hot fires.



Control of introduced herbivores

Feral cattle, donkeys and pigs need to be removed from conservation reserves and unallocated Crown land, and fenced out of rainforest patches that show evidence of substantial contraction (McKenzie *et al.* 1991). DEC's Kimberley region staff have appropriate experience in relation to methods, staffing requirements, logistics and costs. A new bait for feral pigs has recently become available.

Other activities

- Further investigation of the current status of individual species and particular savanna ecosystems is needed to better understand the specific impacts of threatening processes. As with the cane toad, the impact of feral cats needs to be assessed in the Kimberley.
- Develop and implement a Kimberley island management plan in collaboration with traditional owners.
- Priorities for wetland conservation have been assessed by the WWF (Vernes 2006). This report identifies a need to continue to monitor the water quality of wetlands in the Kimberley because, while most wetlands were in good condition, there was indication of some degradation, in particular in areas subject to disturbance by cattle and in river systems subject to flow impoundment such as the lower Ord (e.g. Davies 2000). Surveys of wetland flora and fauna are required in the Kimberley.
- Provide a new vegetation map for the Kimberley as a better basis for conservation planning and activities.

Conservation Reserve System priorities

There are 2.3 million hectares of conservation estate (national parks, nature reserves, conservation parks) in the Kimberley, or 4.4% of the Central Kimberley Region's land area, 14.6% of North Kimberley, 1% of Dampierland, 5.9 % of Ord Victoria Plains and 5.8% of Victoria-Bonaparte. The vegetation associations mapped by Beard (1979) are used by conservation planners to represent the pattern of regional ecosystems across the Kimberley. Only 73 of the 300 vegetation associations recognised in the Kimberley occur in the reserve system (May and McKenzie 2003, Graham and McKenzie 2004). Furthermore, these associations are mapped at a relatively coarse scale, and even a cursory on-ground inspection reveals finer-scale mosaic patterns within these map units, especially the woodland, mangrove and rainforest units, that reflect differences in species composition associated with changes in local edaphic factors such as soil, topographic location and underlying geology. If standardised, updated and overlaid on the vegetation maps along with a digital elevation model and the rainforest classification maps, the 1:250 000 surficial geology maps can provide a more refined representation of ecosystem boundaries for planning purposes. However, considerable ground truthing will be required and some vegetation types occur in patches that are too small to map at 1:250 000 scale. These include mound springs and the ephemeral wetlands on sheet sandstone.

The comprehensive and adequate representation of vegetation communities in the reserve system is a priority issue in the Kimberley. Several areas, including many of the coastal islands, have been proposed for reservation since the 1970s (Burbidge *et al.* 1991), and vegetation mapping at a resolution of 1:100 000 or better is urgently needed not only to guide fire management programs, but also to further refine the existing reserve system.

Kimberley rainforest patches are too dispersed and compositionally dissimilar to be adequately represented by existing conservation reserves. Although a series of additional conservation reserves have been proposed to ensure adequate representation of Kimberley rainforest types, the community is so dispersed that the persistence of its richness in the region relies on patches being functionally networked, which cannot be guaranteed by any feasible reserve system so there must be active management and protection of patches both inside and outside reserves.

Information Gaps

While there is a reasonable amount of published and unpublished data and information on the Kimberley, most of these data are broad scale with poor resolution, patchy with varying levels of resolution, or specific to a site (Waples 2007). Information can also be difficult to access for a variety of reasons, including information collected by consultants to industry and private research data.

Survey effort has generally focused on DEC managed lands and a considerable proportion of specimens (and thus species information) have been collected along roads, further biasing the information. The central and south-eastern Kimberley remains largely unexamined, as do the vast tracts of Aboriginal land along the northwest coast. Few surveys have had a systematic, quantitative design that was, or can be, repeated to detect changes through time. Their coverage of different plant and animal taxa has been selective, rather than comprehensive. Most surveys have been limited to the dry season, although many species are prevalent only in the wet. This clearly hampers our biodiversity knowledge – for example, herbarium data reveal that one in eight collections made in the wet are new species records for the Kimberley (Kevin Thiele, pers. comm.).

Consequently there are gaps in species inventory as well as in knowledge of species distribution and status. A systematic, site-based, biodiversity survey of the entire Kimberley is required to provide a context for interpreting localised datasets, guiding land management and assessing development proposals. In this context, there is an immediate need to provide a clearer understanding of the interacting effects of fire regimes, grazing and weeds as influences on the processes threatening Kimberley ecosystems (the mechanisms of change).

Better maps of vegetation, soil and environmental geology (at scales of 1:100 000 or better) are needed to provide improved resolution on patterns in biodiversity for conservation planning (McKenzie *et al.* 2003).

Key References

See Attachment 4, which is arranged under four sub-headings.

Attachment 1. Bioregional descriptions



The North Kimberley Bioregion occupies the north-western part of the Kimberley Craton and has a hot, tropical, sub-humid climate with summer rainfall. Its main landscape mosaics are rugged Proterozoic sandstone outcrop with shallow sandy soils supporting savanna woodlands of woollybutt and Darwin stringybark over hummock grasses, and Proterozoic volcanic strata with red and yellow earths supporting savanna woodland of species such as Darwin box and cabbage gum over sorghum grass. Riverine forests of paperbark and pandanus occur along drainage lines, small patches of monsoon rainforest are scattered through the savanna and extensive mangals occur in estuaries and sheltered embayments. Two subregions are recognised. The Mitchell subregion has a diverse array of exposed basement strata dissected by rivers, and a rugged sunken coastline, deeply embayed. Skeletal sandy soils incompletely mantle sandstone boulder country, and there are significant areas of various volcanic surfaces, as well as lateritised uplands with open forests, and alluvial floors along major river valleys. The Berkeley subregion is less dissected than the Mitchell, and dominated by an upland of mainly Pentecost sandstones more continuously mantled by (sandy) soils supporting an open savanna woodland with few rainforest patches.

The Central Kimberley Bioregion comprises hilly to mountainous country with skeletal sandy soils supporting hummock grass communities with scattered trees on parallel siliceous ranges of Proterozoic sedimentary rocks, and with earths on Proterozoic volcanics in valleys supporting ribbon grass with scattered trees. Open forests of river red gum and pandanus occur along drainage lines. Three subregions are recognised. The Pentecost subregion, the true central Kimberley, is mostly underlain by Pentecost sandstone strata, with King Leopold and Warton sandstone ranges along its southern peripheries. Large areas are mantled by Cenozoic soils and there is moderate dissection by several rivers. The Hart subregion's landscapes are dominated by dolerite, exposed where the basement is folded at the eastern edge of the Kimberley Craton. It is the driest subregion, has a rugged topography, and is the headwaters of the Ord and Fitzroy Rivers. The Mount Eliza subregion forms the south-western periphery of Kimberley Craton, and is very rugged with intense folding and exposure of basement strata.



Above In sheltered embayments and creek systems along the Kimberley coast dense stands of mangroves occur. They are often fringed on the landward side by expansive tidal mudflats.

Above left Freshwater creeks are a feature of the Kimberley landscape and are often fringed by paperbarks (*Melaleuca* spp.) and screwpines (*Pandanus* spp.) with emergent aquatics such as waterlilies (*Nymphaea violacea*) being common.

Left Tropical savanna on the foot slopes of the King Leopold Ranges in the Central Kimberley Bioregion.



Above Pindan (*Acacia*) shrubland is the dominant vegetation of the sandy plains of the Dampierland Bioregion.

The Dampierland Bioregion is the hot, semi-arid, northern edge of the Canning Basin which underlies the Great Sandy Desert. It has two distinct subregions. The Fitzroy Trough subregion contains the middle and lower catchment of the Fitzroy River, and is dominated by alluvial plains that support woodlands over perennial bunch and annual cane grass understoreys, interrupted by riverine forests of river gum and cadjeput. Devonian limestone barrier reef structures preserved along the Trough's northern and eastern edges support scattered vine thicket trees and shrubs over hummock grass. The Pindanland subregion comprises gently undulating sandplain landscapes with wooded shrublands dominated by wattles, and occasional low hills with hummock grasslands. The region's extensive coastal plains comprise mudflats that support mangal, samphire and couch grasslands fringed by low paperbark forest, as well as beach strand and coastal limestone outcrops with shrub-*Spinifex* communities.

The Victoria-Bonaparte Bioregion in Western Australia comprises Phanerozoic strata mantled by Quaternary marine plains that support extensive samphire-couch grasslands on their northern (seaward) periphery, where there are also monsoon vine thicket rainforests on coastal dunes and mangroves on tidal mudflats and waterways. The inland periphery of these plains include occasional mound springs supporting paperbark and swamp rainforests. In eastern and southern areas are red earth and black soil plains with an open savanna dominated by tall annual cane grasses associated with flood plains of the lower Ord and Keep Rivers, punctuated by abrupt ranges with incised plateaux of Proterozoic sandstone partially mantled by skeletal sandy soils that support savannas of low open trees with hummock grass understoreys. Between the western edge of the plains and Cambridge Gulf there are Devonian limestone ranges, supporting low open rainforests (monsoon vine thickets) and areas of hummock grassland.

The Ord Victoria Plains Bioregion in Western Australia is a lithological mosaic of (1) abrupt Proterozoic and Phanerozoic ranges mantled by shallow sand and loam soils supporting hummock grasslands with sparse low snappy gum and bloodwood trees, (2) Cambrian volcanics and limestones that form the extensive plains of the upper Ord River valley with short-grass on dry calcareous soils and medium-height grassland communities on cracking clays and across which riverine forests of red river gum fringe drainage lines, and (3) cracking clay plains and lateritised upland sand plains with sparse trees on Phanerozoic strata. The first two form the Ord Subregion, and are drained northwards by the Ord River. The third, in the south, is known as the Kimberley Interzone Subregion. A gently undulating, elevated erosional plain, it is drained southward into the desert by Sturt and Wolfe Creeks, and separated from the dissected valley of the Ord River by steep breakaways. The plateau is covered by cracking clay plains developed over volcanics, although large areas are covered by thick laterite covered by extensive desert sandplains. The climate is dry hot tropical, semi-arid with summer rainfall.

Attachment 2. Known special landscapes, ecosystems and species (modified from May and McKenzie 2003)

North Kimberley

- A drowned coastline with extensive coastal archipelagos from the Buccaneer Archipelago to Sir Graham Moore Island that form a virtually feral- and weed-free microcosm of the Mitchell Subregion and present an opportunity to protect intact ecosystems. In particular Augustus Island (17 952 ha) and Bigge Island (17 190 ha) are large, near-coastal, uninhabited islands with no known feral animals and a diverse intact terrestrial fauna.
- Off-shore islands such as Pelican, Troughton, Sterna, Browse, Bedwell (Rowley Shoals), Booby, Lacepede Islands, and Adele for turtle nesting, migrating shorebirds and seabird breeding.
- Mound springs and swamp rainforest.
- There is tropical laterite flora. In particular the *Livistona eastonii* palm community of the Mitchell Plateau, a palm dominated landscape, is unique in Western Australia.
- The flora and fauna of north-western margin appears to be still intact. Critical weight range mammal fauna persist in this region, such as golden bandicoot, scaly-tailed possum, monjon, nabarlek, golden-backed tree-rat and Kimberley rock-rat. None of the region's original mammals are regionally extinct yet, or are known to have disappeared from more than half of their former ranges across the region.
- The Cape Bougainville rainforest on laterite and volcanics has no hoofed feral animals and is the largest single patch of rainforest in the Kimberley.
- Airfield Swamp on the Mitchell Plateau is a large perched paperbark forest wetland.
- The Prince Regent Lineament encompassing the Prince Regent River.
- There are many endemic invertebrates, vertebrates and plants. Vertebrate species include scaly-tailed possum, monjon, black grasswren, three blindsnakes, grey whipsnake, rough-scaled python, four dragon lizards, seven geckos, 10 skinks and five frogs. Camaenid land snails have a large number of endemic species, and some endemic genera show strongly localised patterns of endemism. All the rainforest patches studied to date have endemic earthworm species associated with them. Endemic plants include *Cycas basaltica* and *Cycas lane-poolei*, *Acacia kenneallyi*, *Acacia smeringa*, *Gossypium londonderriense*, *Grevillea cravenii*, *Grevillea donaldiana*, *Grevillea maherae*, *Grevillea microstyla*, *Hibiscus peralbus*, *Typhonium peltandroides*, *Aurantiarca resinosa* and *Hibbertia ledifolia*.
- Sandstone ecosystems include areas of high species and ecosystem diversity and endemism. Rugged sandstone environments can provide fire protection to obligate seeders which are amongst the most vulnerable savanna plants. Regeneration is by seed only and soil seed stores can be eliminated by successive fires.
- Mangroves, riparian forests and rainforest patches are resource centres for distinct faunas, including wide-ranging vagile species that dependent on the archipelago of patches, e.g. rainbow pittas, fruit pigeons, and flying foxes. They also provide dry season refuges for a variety of savanna animals, and have numerous endemic species. Laterite rainforests are of particular interest.
- Significant wetlands include the Mitchell River System, Prince Regent River System, Yampi Peninsula #WA115, Walcott Inlet System including Munja Lagoon and the lower reaches of the Isdell and the Charnley Rivers, and Airfield Swamp and Glauerts Lagoon on Mitchell Plateau.

Central Kimberley

- One permanent freshwater lake (Gladstone Lake) is listed as nationally important for the maintenance of ecological processes, migratory species, and as a drought refuge, breeding and feeding ground for a diversity of taxa.
- Numerous endemic camaenid land snails show strongly localised patterns of endemism. All the rainforest patches studied to date have endemic earthworm species associated with them.
- 'Dry' rainforest patches are resource centres for a discrete fauna, including wide-ranging vagile species that depend on the archipelago of patches, e.g. rainbow pittas, fruit pigeons and flying foxes. They also provide dry season refuges for a variety of savanna animals and plants that are obligate seeders.

- Sandstone ecosystems include areas of high species and ecosystem diversity and endemism. Rugged sandstone and dolerite environments can provide fire protection.
- Riverine ecosystems support a distinctive fauna and provide dry season refuges for a variety of savanna animals.
- Declared rare flora (*Eucalyptus mooreana*) on the mountain summits of the King Leopold Ranges.
- Preserved Devonian landscapes of the Yampi Peninsula.

Dampierland

- Stranded remnants of a Devonian barrier reef system with Windjana and Geikie Gorges, Mimbi Caves and Tunnel Creek. The gorges are world-class tourist destinations and Tunnel Creek, which passes through the Napier range via a cave, supports colonies of the endemic Yellow-lipped Cave Bat and two monotypic genera endemic to Australia (Ghost Bat and Orange Horseshoe Bat).
- Off-shore islands (Lacepedes) for turtles and seabird colonies (Burbidge's Island paper).
- Rainforests and paperbark swamps associated with the organic profiles of mound springs on coastal mudflats and palaeorivers, and with primary coastal sand dunes on Dampier Peninsula.
- Camballin Floodplain is one of only two large riverine floodplains in the Kimberley.
- Also significant are the palaeoriver systems at Roebuck Bay and along the Eighty Mile Beach, where vast grasslands occur on wetland plains, and enormous numbers of migratory wading birds rely on extensive coastal mudflat systems.
- Mandora wetlands, with its mound springs, and where Halse recorded more than 5000 breeding waterbirds.
- *Keraudrenia exastia* and *Pandanus spiralis* var. *flammeus* are both declared rare species.

Victoria-Bonaparte

- Extensive mangrove community of the False Mouths of the Ord, including WA's only known Black Butcherbird population.
- Ramsar Convention wetlands on the Ord River floodplains and the man-made Lake Kununurra.
- Cambridge Gulf and its associated river systems and saltwater crocodile population.
- Black and red-soil communities of the Ord and Keep River floodplains.
- Stranded Devonian palaeo-reef system of the Ningbing Range with its peculiar vine thicket communities and strongly localised, endemic species and genera of land snails.
- Extensive Arafura Coastal Plain with its salt flat, grasslands, coastal creeks, sand dune rainforests and mound spring rainforests.
- Isolated spring and gorge rainforests associated with sandstone ranges that have endemic land snail and earthworm species and, along with riverine rainforests, act as refugia for a variety of otherwise sub-humid plants and vertebrates including Green-backed Gerigone, fruit pigeons and flying foxes.
- Major flatback turtle rookery at Cape Domett.
- Gorge network incising the plateau of the Cockburn Range.
- Adolphus, Pelican and Lacrosse islands in Cambridge Gulf.

Ord Victoria Plains

- Structure of the Bungle Bungle Range and its several endemics species (e.g. Woinarski 1992) and outlying populations of otherwise arid zone species, e.g. *Pseudomys desertor*.
- Rainforest patches associated with springs in ranges such as the Osmond Range, with their endemic land snails and earthworm species that provide dry season refuges for species such as fruit pigeons and flying foxes (McKenzie *et al.* 1991).
- The enormous man-made Lake Argyle with its extensive riparian zone (e.g. Kitchener 1978).
- Riverine forests acting as dry season refuges and corridors (Woinarski *et al.* 2000).
- Lake Gregory on a variety of Ramsar criteria, including abundant water birds and aquatic invertebrates (Halse *et al.* 1998a and b).
- Vast tracts of grassland on cracking clay soil plains in the eastern parts of the region, although their biota is poorly documented.

Attachment 3. Overall condition and trend of Kimberley bioregions

North Kimberley: There is a continuing general deterioration in the condition of the bioregion's main savanna ecosystems, rainforests and riverine forests, mainly due to fire and grazing (e.g. Vigilante and Bowman 2004a and b). Most of the important wetlands recognised (river systems, riverine floodplains, swamp rainforests, freshwater lakes and swamps) are in good condition, but deteriorating. The primary threatening processes for all these wetlands are changed fire regimes, grazing pressure from feral herbivores and changed hydrology. An investigation of the current status of individual species and ecosystems is urgent, along with research to build a better understanding of the impact of threatening processes and management opportunities (Graham and McKenzie 2004). A range of vegetation associations and 'at risk' ecosystems need to be reserved, and 44 of the region's plant, five mammal, three bird and six reptile species are considered to be rare or threatened, mainly due to changed fire regimes operating at the landscape scale (Gordon and McKenzie 2004). Although no feral vertebrates have colonised the coastal islands, and they are virtually weed-free, hot dry-season fires are becoming increasingly frequent.



Cascade Creek in the Prince Regent River Nature Reserve. Photo – David Bettini

Central Kimberley: The effects of late dry-season fires, feral animals and stock are equally evident in all three subregions, and substantial changes to vegetation structure are ubiquitous. The trend is for a continued decline, although it is fox and rabbit free and essentially uninhabited. Most of the region has a long history of pastoral use, with introduction of grass species for pasture improvement, and application of fire to create 'green-pick' late in the dry season. Gladstone Lake is not in pristine condition and declining because of grazing pressure from cattle. Riparian zones throughout the region are also declining in condition because of the independent or conjoint effects of changed fire regimes, grazing pressure from feral herbivores, weeds and changed hydrology in the catchments (e.g. Ludwig *et al.* 2005) as a result of decreasing perennial vegetation cover and loss of top soil. 23% of the region's original non-volant mammal fauna is known to be either regionally extinct or has disappeared from more than half of its former range across the region (McKenzie and Burbidge 2002). Research being carried out by AWC at their Mornington property is showing that good fire management is possible, and that this leads to fauna recovery (Legge *et al.* 2008).

Dampierland: The structure, density and composition of perennial vegetation throughout the region has declined. Twenty ecosystems are thought to be at risk, including rainforest, riverine forest, woodlands, pindan, mangroves, grasslands, herbland, sedgeland and rushland, and freshwater lakes. There is not enough information available to identify trends in their condition, although five are definitely in decline. Main threatening processes include changed fire regimes, grazing pressure and weeds. Several are threatened by human disturbance and changed hydrology. Most rivers, wetlands and claypans are in a fair or good condition, but declining, because of grazing and trampling by stock, tourist-use, siltation and altered flows, feral animals, changed fire regimes and, at two wetland sites, impacts due to their proximity to Broome. The lower Fitzroy is in poor condition; weeds such as noogoora burr dominate the understorey and large tracks of passion vine and some rubbervine occur in the riparian canopy. 45% of the region's original non-volant mammal fauna is now regionally extinct or has disappeared from more than half of its former range across the region. Two plant, 5 mammal, 2 bird and 5 reptile species are listed as threatened or vulnerable; the threatening processes are poorly understood or unknown in most cases, but thought to be changed fire regimes and grazing pressure operating at the landscape scale.

Ord Victoria Plains: A century of grazing pressure has led to massive degradation of alluvial surfaces and riverine vegetation, both denudation of vegetation and extremely deep sheet and gully erosion across the entire Ord Subregion (e.g. Sandercock 2004). Although large tracts of pastoral properties were compulsorily destocked, recovery has been gradual and weeds such as birdwood and buffel grass now dominate many of the region's ecosystems. Flood events are more severe as a result of higher velocity and volume of run-off from the savanna during rain-events stripping riverine vegetation, depositing enormous sandy bedloads in the upper and middle sections of the Ord River System that have occluding river pools, and depositing enormous banks of fine-textured sediment up to 20 metres deep in the lower Ord (e.g. Warman 1999, Wolanski *et al.* 2001, Sandercock 2004, Start and Handasyde 2002). Impoundments associated with the Ord Irrigation Area have drastically altered river flows, leading to major changes in riverine vegetation (Froend 2000, Ruprecht 2000) and loss of species such as the Purple-crowned Wren and Black Bittern. Riparian systems have attracted many serious weed infestations including noogoora burr, bellyache bush and castor oil plant, and large densities of feral donkeys and cattle have degraded the valley and slope surfaces of the Ord Subregion. As a result of the changes fire regimes exacerbated by grazing pressure, perennial grasses, shrubs and trees are far less prominent in savanna ecosystems across the region's landscapes, both the plains and uplands, and the simplified vegetation that now remains, is dominated by a small suite of annual grasses. Twenty-six percent of the region's original non-volant mammal fauna is now either regionally extinct or has disappeared from more than half of its former range across the region. This savanna simplification has create late-dry season resource gaps for granivorous vertebrates, such as the endangered Gouldian Finch (Franklin 1999).

Victoria-Bonaparte: The CRC for Tropical Savannas has systematically reviewed the environmental characteristics of the Ord River's riparian zone from the top of the catchment to the Cambridge Gulf (A.N. Start, pers. comm.). The impacts of water impoundment and flow control on the lower Ord River have been assessed by Froend (2000), Halse (2000), Loh *et al.* (2001), Ruprecht (2000), Semeniuk (2000), Start (2000) and Wyrwoll (2000). On-going changes to the status of fauna (particularly mammals) and flora are apparent, including continuing simplification of assemblages at the landscape level which are affecting vegetation structure (eg. loss of shrub layer), composition (eg perennial vs. annual grasses), vegetation cover, leaf litter, and soil organic-A horizons. Eighteen percent of the region's original non-volant mammal fauna is now either regionally extinct or has disappeared from more than half of its former range across the region.

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Darwin Woollybutt (*Eucalyptus miniata*) is one of the most widespread eucalypts across the Kimberley and Top End of Australia. Photo – Kevin Kenneally

Protecting the **Kimberley**

A synthesis of scientific knowledge to support conservation management in the Kimberley region of Western Australia



Part A: Marine environments: R.J. Masini, C.B. Sim and C.J. Simpson

Part B: Terrestrial environments: N.L. McKenzie, A.N. Start, A.A. Burbidge, K.F. Kenneally and N.D. Burrows

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Department of
Environment and Conservation

Our environment, our future



The State Government has made a commitment to develop an integrated Kimberley Science and Conservation Strategy to ensure the region's natural and cultural values are protected as its economic potential is fulfilled.

This synthesis has been prepared by the Department of Environment and Conservation as a starting point to summarise scientific knowledge relevant to biodiversity conservation in the Kimberley region. It is acknowledged that this document is not yet a comprehensive summary, particularly in respect of research conducted by other organisations and research that is unpublished.

Further information will be added during the course of stakeholder consultation and people are welcome to forward details of scientific knowledge about the region to Kimberley.Strategy@dec.wa.gov.au.



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Front cover

Cone Bay, Yampi Peninsula, showing a tidal river with mud flats, fringing mangroves and dissected mainland sandstone.

Back cover

(top row) Comb-crested jacana, golden-backed tree rat and green tree frog.

Photos – Jiri Lochman/Lochman Transparencies

(below) The kurrajong (*Brachychiton xanthophyllus*) is a deciduous tree restricted to patches of monsoon vine thicket in the north Kimberley and is gazetted as a Priority 4 species for conservation.

Photo – Kevin Kenneally