Aquatic conservation values of the Daly River Catchment, Northern Territory, Australia

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Front cover image: Daly River, S Blanch

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Executive Summary

The Daly River Catchment (DRC) is in the wet-dry tropics of the Northern Territory, Australia. This report has assessed the Daly River system as being of national significance due to a range of aquatic conservation values (Recommendation 1, p viii). The aquatic conservation values identified in Table 1 should be protected, and where necessary rehabilitated, through relevant laws, planning, on-ground actions and the provision of assistance to Traditional Owners and other landholders (Recommendation 2). Its significance at a continental scale is threatened by proposals for significant water extraction, land clearing and agricultural development, as well as by invasive species, over-grazing and wildfires. Other Recommendations are provided on pp vii-ix.

This report is the first relatively comprehensive desktop assessment of significant known aquatic conservation values of the DRC. The document will assist governments and communities as they seek to manage and protect the natural resources of the catchment.

The DRC is of great social, cultural and economic importance to Indigenous and non Indigenous Australians, whose collective values are underpinned by a healthy environment. It is highly significant to Aboriginal people, with approximately twelve language groups living on country in the catchment or retaining strong cultural links with the Daly and its environs. Whilst this report does not address the significance of aquatic habitats to Indigenous people of the Daly River region or Indigenous knowledge, the river and its wetlands and estuary are fundamental to the lives of local communities (see, for example, Jackson 2004).

The DRC is one of several focal areas for agricultural development and intensification in northern Australia. Approximately 200,000 ha of land has been cleared in the DRC, which equates to about 4% of the catchment area. An additional 110,400 ha of land has been identified by NT Government agencies as being potentially suitable for clearing and agricultural development.

The catchment already supports significant agricultural development, which is focussed around Katherine, on the Tipperary group of stations, Douglas Daly Farms and Scott Creek. Additional water extraction is proposed, from both surface water systems and groundwater. Significant support exists amongst farming groups and some sections of NT Government agencies responsible for natural resources management and development for additional broad-scale land clearing and irrigated agriculture.

Many aquatic ecosystems of the DRC are likely to be assessed as being of high conservation value and hence warranting protection (see Table 1, p v). Under the Council of Australian Government's Agreement on a National Water Initiative, the NT Government is required to identify, manage, restore and protect high conservation value aquatic ecosystems (CoAG 2004, cf cll 25 ii.x and 79 i.f.).

The Daly has the highest base-flow of all rivers in the Northern Territory, and potentially the highest of any perennial free-flowing river in Australia's wet-dry tropics. It has the second-highest average annual flow to the Timor Sea of any Australian river.

Three significant limestone aquifers underlie the DRC. These store monsoonal rains during the wet season (Dec-Mar) and then discharge this water into the Daly River and its tributaries through the

dry season (Apr-Nov). The Daly's waters are dominated by calcium and magnesium ions due to spring-fed flows from limestone aquifers. This contrasts with most Australian river water, which is dominated by sodium and chloride ions. The naturally very low levels of nitrogen and phosphorus in the Daly's waters are significant and make the Daly highly susceptible to pollution from fertilisers and erosion causing sediments to be deposited into aquatic ecosystems.

These biophysical characteristics have contributed to some very significant biological conservation values. Middle reaches of the Daly River are listed on the Register of the National Estate. Approximately 353,400 ha of wetlands, including both floodplains and damplands, occur in the Daly Basin alone (a component of the DRC used by the Northern Territory Government for planning purposes).

The Daly's estuary and lower floodplain have been assessed as satisfying waterbird-based criteria for listing as a Wetland of International Importance under the Ramsar Convention (1971) (Chatto, 2005, draft, p33). This large complex of wetlands, occurring across an area of approximately 20 x 30 km, was found to support 14 significant waterbird sites and six significant breeding sites during waterbird surveys that commenced in 1990. It is the most significant area for waterbirds between Darwin and the Moyle River, with over 30,000 waterbirds recorded in May 1995.

The Daly supports the largest population of pig-nosed turtle in Australia, which is classified as 'near threatened' in the Northern Territory, and which also occurs in several rivers on the island of New Guinea. The species is an important food source and is of significant cultural value to Indigenous people. The DRC also supports the greatest number of species of freshwater turtles in Australian rivers (8 of the 12 species found in the NT).

The Daly is widely held by anglers to be the best barramundi-fishing river in Australia. It is known to contain 48 species of freshwater or estuarine fish, compared to 33 for the whole Murray Darling Basin (which has an area 19 times larger than the DRC). The presence of the threatened freshwater sawfish and freshwater whipray, possibly the threatened northern spear tooth shark, and the strawman contribute to its national significance.

Table 1. Summary of significant aquatic conservation values of the Daly River Catchment (DRC), Northern Territory.

Aquatic conservation value	Significance
Geomorphology, hydrology and water quality	
High base-flow during dry season due to discharge from aquifers	• Highest base-flow of all rivers in the Northern Territory, with end-of-dry season flows of approximately 12 cubic metres/second in the middle reaches. • Potentially has the highest base flow of any perennial river in Australia's wet-dry tropics. • The dry season flow is five times that of any other river in the Territory.
Discharge to the Timor Sea	• Second-highest average annual flow to the Timor Sea of any Australian river (6,730 billion litres per annum, compared to 6,900 billion litres for the East Alligator River).
Limestone and karst geology	• Three large limestone aquifers underlie the Daly River system which store monsoonal rains during the wet season and then discharge high flows through the dry: the Oolloo limestone, Tindall limestone and Jinduckin formation. • In the Katherine Region alone there are at least 283 sinkholes which allow for significant recharge to the Tindall Aquifer. • Water stored and discharged from these aquifers is relatively young in geological terms (30-500 years old), which illustrates the sensitivity of groundwater sources to water extraction. • Aquifers discharge to rivers through springs and seepage areas which are widespread and therefore difficult to manage. • Creation of large rare natural 'tufa dams' due to high levels of dissolved carbon dioxide and calcium carbonate in the water.
Water quality and nutrient regime	• Dominance of calcium and magnesium in river water due to spring-fed flows from limestone aquifers. This contrasts with most Australian river water that is dominated by sodium and chloride ions. • Very low levels of nitrogen and phosphorus, which makes the Daly River highly susceptible to pollution from fertilisers in surface run-off and through

	accession to aquifers and springs. • Trademark clear waters that support plant and animal growth are also threatened by sediment deposition from erosion in cleared and unmanaged catchments.
Aquatic biodiversity	
Floodplains and wetlands	• Middle reaches of the Daly River are listed on the Register of the National Estate. • Three wetlands are listed as being nationally important (but receive no legal protection from that protection): the middle reaches of the Daly River, parts of the Daly-Reynolds floodplain & estuary, and Katherine River Gorge. • Extensive wetland complexes occur across the floodplain, with large areas supporting flooded savannas. • Approximately 353,400 ha of wetlands, including both floodplains and damplands, occur in the Daly Basin alone (a component of the DRC used by the Northern Territory Government planning purposes).
Waterbirds	• Wetlands in the lower Daly floodplain and estuary have been assessed by the Parks and Wildlife Commission of the NT as satisfying waterbird-specific criteria for listing as Wetlands of International Importance under the Ramsar Convention. • These wetlands support high diversity and abundances of waterbirds, with 45 species recorded in aerial and ground surveys of wetlands between the Finniss and Moyle Rivers, which includes the lower floodplains of the Daly River. • These wetlands are also known to support some of the largest numbers of breeding colonies of colonial nesting waterbirds (such as egrets and ibis) in the Territory.
Turtles	• Largest population of pig-nosed turtle in Australia, which is classified as 'near threatened' in the Northern Territory, and also occurs in several rivers on the island of New Guinea. • Pig-nosed turtle and northern snapping turtle have strongholds in the Daly River system, with 25-50% of site records for the NT from the DRC.

	• Supports the greatest number of species of freshwater turtles in Australian rivers (8 of the 12 species found in the NT).
Fish	• Widely held by anglers to be the best barramundi-fishing river in Australia. • Forty-eight species of freshwater or estuarine fish, compared to 33 for the whole Murray Darling Basin (which has an area 19 times larger than the DRC). • Presence of several nationally and internationally threatened or rare species, including freshwater sawfish, freshwater whipray, strawman, plus anecdotal evidence of northern speartoothed shark in the estuary (H. Larson, NT Museum, pers. comm.). • Probably the largest and most secure population of strawman in Australia. • As with other Top End rivers, about one quarter of the fish species in the Daly also occur on the island of New Guinea.
Vine thickets	• Form much of the riparian zones along waterways where they bind the soil and contribute organic carbon (eg, falling leaves) which feed bacteria and hence the whole aquatic foodweb. • Support high levels of plant endemism, with 36 of the reported 585 species occurring nowhere else • Support animal and bird species that rely on these ecosystems, such as rainbow pitta, emerald dove and flying foxes.
Extent of native vegetation	• Approximately 95% of the catchment's native vegetation remains uncleared (215,814 ha cleared of a total 5,257,600 ha), which buffers aquatic ecosystems from sedimentation and pollution.

Recommendations

1) **Recognition of the aquatic conservation values of the Daly River Catchment**
Significant aquatic ecosystems of the Daly River Catchment should be recognised as being of Territory, national or international significance in light of the range of aquatic conservation values identified in Table 1. These values should receive appropriate legal protection and funding for on-ground management and rehabilitation. The capacity of landholders and Traditional Owners to care for aquatic ecosystems in the catchment should be raised through training assistance in preparing and implementing property management plans.

2) **Maintenance of aquatic conservation values through planning processes and on-ground works**
The aquatic conservation values identified in Table 1 should be protected, and where necessary rehabilitated, through relevant planning and on-ground actions. These include *inter alia* the proposed Integrated Land Use Plan for the Daly Basin, the Daly Water Allocation Plan, management of native vegetation and biodiversity on pastoral leasehold lands, decisions made regarding subdivision and agricultural development, management of weeds and feral animals, stock management, and management of the impacts of fishing and tourism**.**

3) **Protected area management for particularly significant aquatic ecosystems**
Various river, wetland and estuarine ecosystems in the Daly River system warrant further recognition under Territory, national and international agreements and laws. In particular,

   a) The Daly River system should be protected under the proposed Territory 'Living Rivers' Program, promised by the Territory Labor Party during the 2005 NT election campaign (ALP, 2005). Protection under this program should extend to all aquatic ecosystems in the DRC that contribute significantly to the maintenance of ecological processes and aquatic biodiversity in the Daly River system. Implementation of this program should include culturally appropriate consultation with Indigenous groups and Traditional Owners, other landholders, community groups, fishers and industry.

   b) Various wetland complexes in the DRC are likely to satisfy one or more criteria for listing as Wetlands of International Importance under the Ramsar Convention on Wetlands (1971). Various wetlands in the lower reaches and estuary are known to satisfy waterbird criteria alone (Chatto, 2005). Subject to gaining the support and consent of landholders, Traditional Owners and any Native Title claimants, wetlands should be assessed for nomination as Ramsar sites. Under the Ramsar Convention, a broad range of wetlands may be designated as being of international importance, including river channels, floodplains, karst systems and estuaries. Currently no Ramsar sites exist in the DRC.

   c) Various components of the DRC may be eligible for recognition as being places of National Heritage under the federal *Environment Protection and*

Biodiversity Conservation Act. Parts of the Daly River and associated ecosystems may meet the legal requirement of being of 'significant' and 'outstanding' national heritage value and hence warrant recognition as a 'heritage river' under the EPBC Act. The support of landholders, Traditional Owners and Native Tile claimants should be sought prior to any nomination. Under the EPBC Act, a place may be listed on the National Heritage List on both natural and cultural heritage grounds. The value of listing the Daly River as a 'heritage river' under these provisions depends on the extent to which the proposed Territory 'Living Rivers' program provides adequate protection and recognition for the river system.

d) Other forms of protected areas, on both private and public lands, should be established in consultation with Traditional Owners and landholders to manage and conserve aquatic ecosystems of particular environmental and cultural significance. Protected area options include *inter alia* national parks and nature reserves, Indigenous Protected Areas or other forms of Indigenous Land Use Agreements, property agreements, covenants, and river parks along the Daly and its tributaries (Jackson 2004). The Territory Parks and Conservation Masterplan proposes various options in this regard.

In relation to approaches (a)-(d) above, any form of additional legal protection must be accompanied by adequate levels of on-going funding, capacity building programs and natural resource management planning to assist Indigenous and other landholders to effectively manage and protect areas so protected. Depending on the approach(s) adopted, Traditional Owners should have majority representation, legal ownership or some other effective means of management control, on management structures to oversight the establishment and management of new protected areas or other forms of legal recognition.

4) Consultation with Indigenous and non Indigenous communities

The aquatic conservation values identified in this report have cultural, economic and social significance to many people, including both Indigenous and non-Indigenous communities who live in or maintain connections with this region. Indigenous knowledge regarding these values is substantial, yet poorly appreciated by many non-Indigenous people, and should be incorporated into management planning through culturally appropriate engagement.

5) Filling knowledge gaps

a) Research needs: fish, sediment and nutrient transport and monsoon vine thickets

- Research into the environmental water requirements of fish, particularly of threatened species and barramundi, and the likely effects of increased water extraction is required.

- The water needs of monsoon vine thickets needs to be understood to guide the management of water extraction to conserve these key groundwater dependent ecosystems.

b) Biological and hydrological survey needs

Comprehensive biological and hydrological surveys of the DRC are required. Key gaps in the knowledge base are:

- fauna of karst systems (ie. flooded limestone caves);
- freshwater and estuarine fish;
- aquatic plants and water dependent vegetation;
- wetlands (areas outside the Daly Basin Bioregion);
- aquifer recharge and discharge sites; and,
- freshwater turtles.

c) Monitoring of the movement of sediments and agricultural chemicals into rivers

The application and fate of agricultural chemicals, including fertilisers, insecticides and herbicides, in agricultural developments should be rigorously monitored. Monitoring should examine the transport of sediments and chemicals into aquatic ecosystems through wind and water erosion, run-off and seepage into aquifers. Information generated should underpin the development of best management practice guidelines for the agricultural sector.

6) **Review legal regimes for managing and conserving aquatic ecosystems**
Laws and policies which provide for the conservation and management of the aquatic conservation values in the DRC, such as the *Water Act 1992*, *Fisheries Act 1988*, the *Pastoral Land Act* and the *Territory Parks and Wildlife Conservation Act* should be reviewed and rewritten to reflect world's best practice natural resource management and aquatic ecosystem protection legislation.

INTRODUCTION

The Daly River Catchment (DRC) is in the wet-dry tropics of the Northern Territory, Australia (see Figure 1). Extensive scientific studies of the environmental water requirements of the Daly River were conducted in recent years (see reports cited in the summary report of Erskine *et al.*, 2003). However, these and other reports did not seek to undertake a comprehensive assessment of the aquatic conservation values of the DRC.

Tthe DRC is one of several foci areas for agricultural development and intensification in northern Australia. Land clearing for agricultural development increased post World War II, with large areas cleared in the 1960s (Scott Creek; 20,000 ha) and 1980s (Tipperary Station; 130,000 ha) (information provided to the Daly River Focus Group by NT Government agencies, 2004).

Approximately 215,000 ha of land has been cleared in the DRC, which equates to about 4.1% of the catchment area. An additional 110,400 ha of land has been identified by the NT Department of Business, Industry and Resource Development as being potentially suitable for clearing and agricultural development (DBIRD, 2004). Additional information provided by the NT Department of Infrastructure, Planning and Environment included 123,650 ha with good agricultural and irrigation capability from surface water and 214,930 ha with good agricultural and irrigation capability from groundwater (Smith *et al.,* 2004).

A moratorium on land clearing in part of the DRC was put in place by the NT Government in November 2003 and has recently been extended until 2007 (ALP, 2005).

The catchment supports the majority of irrigation development in the NT, which is focussed around Katherine. Additional water extraction is proposed, from both surface water systems and groundwater. Yet data detailing existing levels of water extraction indicates extraction levels already exceed maximum extraction levels set by NT Government policy (information provided to the Daly Region Community Reference Group by NT Government agencies, 2004). Significant momentum exists within NT Government agencies to permit up to an arbitrary 20% of river flows to be extracted within certain flow bands.

This report provides the first relatively comprehensive assessment of the aquatic conservation values of the DRC. The assessment draws primarily upon information published in the scientific literature and from various reports by NT Government agency staff, as well as from observations made by researchers and people familiar with the Daly River.

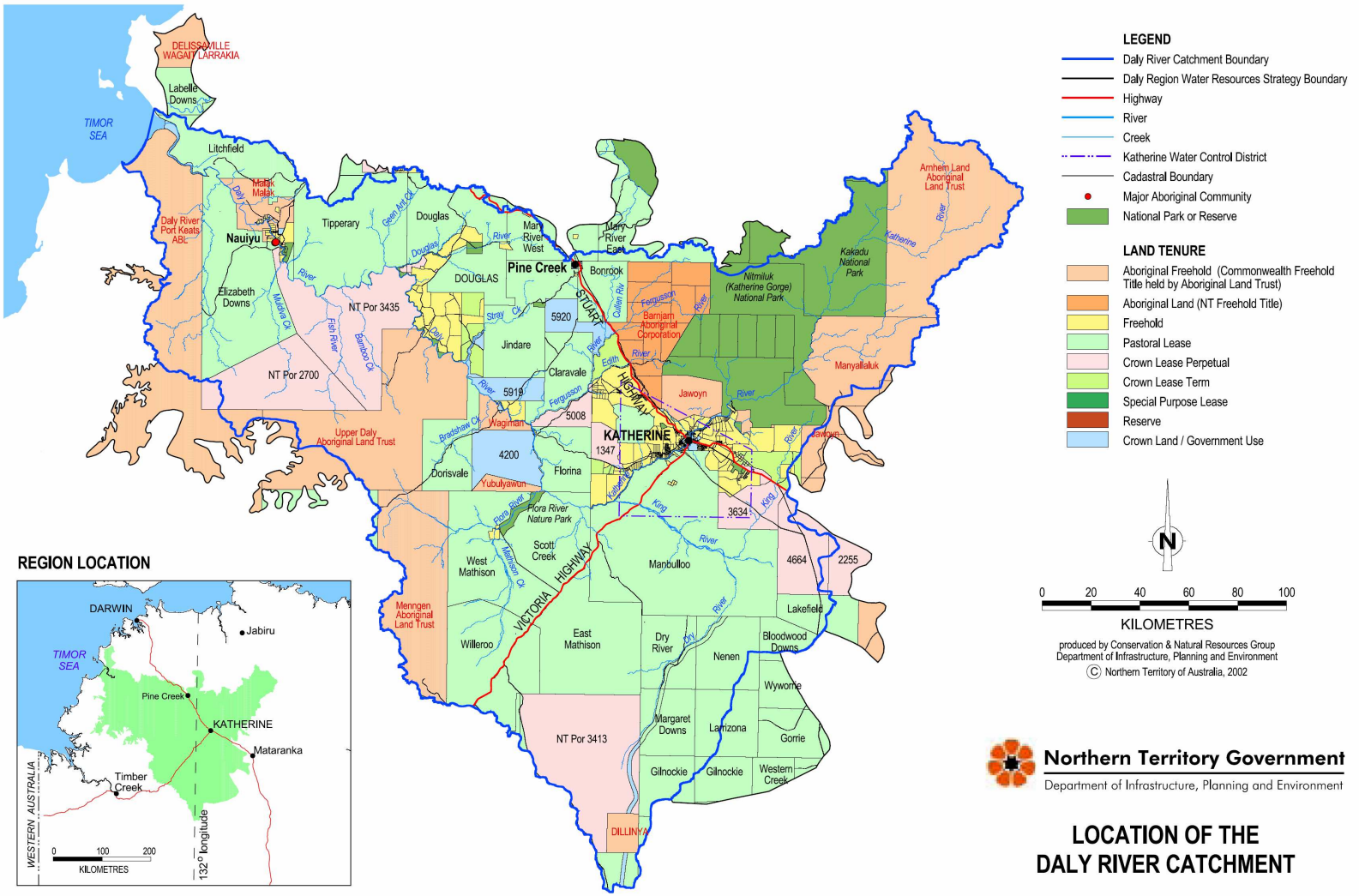

Figure 2 The Daly River Catchment (figure provided by the Conservation and Natural Resources Group, DIPE, NT Government)

Description of aquatic ecosystems of the Daly River Catchment

Geomorphology

The Daly River Catchment (DRC) (area; 53,322 km^2 or 533, 322 ha; NGIS Australia, 2004, Table 6, p17) spans the spectacular sandstone escarpments, gorges and waterfalls of the Kombolgie geological formation to the broad floodplains and braided channels of the river mouth and estuarine reaches. It has the fourth largest discharge of tropical rivers occurring between Cairns and Broome (average annual outflow: 6,730 gigalitres; NGIS Australia, 2004, Table 6, p17). In geomorphologic terms, the catchment is fairly typical of adjacent catchments (Alligator, Victoria and Roper Rivers) in that there has been erosion to bedrock and peneplanation. The dissected plateaus are comprised of Precambrian sedimentary rock. Cretaceous rock outcrops occur throughout the catchment and are important recharge sites.

The DRC is underlain by limestone aquifers that store, transmit and yield water. Rainfall recharges three main aquifers (Tindall, Jinduckin and Oolloo) that reach capacity annually and discharge back to the Daly each dry season. Generally discharge via spring seepages or rock fractures is the same or close to annual recharge, indicating a strong correlation between annual rainfall and river flow. The waters of these aquifers differ in quality and contribution to the DRC, but collectively are responsible for the perennial flow and crystal clear waters of the dry season. The age of the water discharging to rivers varies, but has been dated as young as 30 years to as old as 500 years (Cook *et al.,* 2002). This is relatively young water compared to groundwater in the arid zone.

The shorter retention times of young groundwaters means groundwater resources require careful management as they respond rapidly to water extraction and reduced recharge. Imbalances in the hydrogeological cycle caused by excessive extraction are likely to have significant ecological effects on aquatic ecosystems within a relatively short period.

These aquifers have formed in limestone (also called carbonate rock) through the dissolution of carbonate from the slowly percolating waters of successive wet seasons. Although karst features are not uncommon in Australia and the world, the karst features of the Daly Basin are distinctive in that they are constantly being produced and maintained by large amounts of annual rainfall and percolation. Karstification of the underground systems is a permanent process, given the slow rate of infiltration Disruption to this process could occur through reduced recharge from water diversions, or accelerated run-off from cultivated land or soil seals.

Landscape Features

The power of water and storms during the wet season (November to April) is such that the landscape erodes and the river channels and banks reshape on an annual basis. On a longer timeframe, the Top End region has been influenced by rapid climatic oscillation over the last 20,000 years and this has "winnowed" the biota down to a core element of highly adapted and specialised species (Nix and Kalma 1972). The

vast floodplains of the Top End region and the DRC are also relatively young with the mangrove 'big swamp' phase only switching to freshwater wetlands over the last 4,000-6,000 years (Woodroffe and Mulrennan 1993).

The savanna landscape that dominates is highly leached, nutrient poor and weathered to a laterite surface with very shallow soil depths. Deeper red soils exist in some areas and support the tallest woodland communities as well as representing the sites of greatest agricultural potential. The open eucalypt forest is dominated by Darwin stringybark (*Eucalyptus tetradonta*) and Darwin woollybutt (*E. miniata*) to 20 m tall, with a grass understorey to 2.5 m, mainly perennial tall grasses (*Themeda australia, Sorghum plumosum, Sehima nervosum*; Aldrick and Robinson 1972). The savanna woodlands are intermixed by two major ecosystems, monsoon rainforest patches and wetlands. The significance of the numerous rainforests and wetlands is in the network of resources they provide and in their collective role in the landscape (Price *et al.,* 1995).

Rare and endemic heathland plants and associated fauna grow on the sandstone escarpment in the upper DRC. Creeks and rivers are generally incised, with the Daly River some 20 m below sea level in the middle reaches (at least 200 km upstream of the river mouth; Faulks 1998). Rivers and streams make their way to the coast, creating a vast floodplain during the annual monsoon rains. The wetland ecosystems are the most productive as evident from high densities of rodents and snakes. The floodplains surrounding the mouth of the Daly River coalesce with the Reynolds River to the North and the Moyle River to the South and extend up to 40 km inland.

Climate

The wet-dry monsoonal tropics are characterised by warm to hot temperatures. In the southern end of the DRC, dry season temperatures often fall below 10°C. The extremes in humidity and water availability have shaped the landscape. High rainfall, soil saturation and flooding are unavoidable in the wet season with 90% of the mean rainfall occurring between 1 October and 30 April. Mean annual rainfall for Darwin, Douglas-Daly and Katherine are >1600 mm, 1200 mm and 1010 mm respectively.

Monsoonal rainfall, late wet season convective storms, the cool dry and windy period, and the still humid months of the build up are all highly predictable seasons. Coupled with this predictability is variability in the timing, magnitude and geographic spread and location of these seasons. It is both the predictability of these climatic phases and the variability of these seasons that is the primary determinant of the success of agricultural ventures in the Katherine Daly Region (Mollah 1986, Mollah *et al.*, 1991). It is also the predictability and variability of these seasons that determines how the ecological character of the environment unfolds each year. For example, an interrupted start to the wet season can initially help germinate wild rice seeds on the floodplains, but then not allow seedlings to establish, thereby leading to gaps in this vegetation type and a lack of food resources for magpie geese (Wurm 1998). Overlying this annual pattern are longer-term 10-20 year cycles of high and low

rainfall. The period since 1974 has seen above average annual rainfall as compared to the relatively drier period of the 1950's – 1960's (P. Jolly, DIPE, pers. comm.). For example, the recent run of very high flows in above average wet seasons (1998-2003) have resulted in the progressive decline in the health and distribution of the dominant water plant, *Vallisneria nana* (S. Doody, pers. comm., University of Canberra; N. Rea, Charles Darwin University, pers obs.).

Hydrology

Overall, river hydrology is highly predictable with the wet season characterised by a series of flood peaks and the dry season characterised by high base-flow. Variability occurs in the timing of the onset and cessation of wet season floods. This distinctive pattern has exerted a strong influence over aquatic ecosystems for thousands of years. The climatic control over the hydrological regimes of aquatic and wetland ecosystems would be affected by harvesting of wet season flows, excessive extraction of surface and/or groundwater, and climate change.

In contrast to most other major Top End systems such as the Alligator Rivers, and the Mary, Adelaide and Victoria Rivers, flow is perennial in the Daly. Of the few perennial spring-fed rivers in the NT, the Daly River has the highest end of dry season flow (approximately 12 cubic metres/second at Mt Nancar; Begg *et al.,* 2001) and the highest annual discharge (6, 730 gigalitres, NGIS 2004, at p17). This discharge is approximately half that of the entire discharge of the Murray Darling Basin recorded at the Murray estuary under natural conditions. Limestone aquifers support the Roper River and the Blythe River in Arnhem Land, but they do not sustain high river flows as occurs in the Daly. The Daly River also appears to be one of the largest, if not the largest, spring-fed perennial river in Australia's wet-dry tropics. This would make it a river of national and even international significance.

The Daly River's dry-season flow is maintained by springs and seepages that discharge groundwater. The protection of springs and discharge sites is paramount because they are the conduit for the water which is the life-blood of the river. Many reaches of the Daly and its tributaries have significant spring input. The extent, type, temperature, origin and flow rate of springs has been discussed and recorded in part by Tickell *et al.* (2002) and White (2001). These have highlighted the major areas of spring discharge, including the location of some of the major springs. Some springs in the DRC are located in reserves (Douglas Hot Springs, Flora Nature Reserve) and many are recorded as sacred sites under Sacred Site legislation through the Aboriginal Areas Protection Authority (AAPA). Stock often utilise and degrade springs.

Similarly, recharge sites such as sink-holes and some extensive wetlands such as the southern areas of the upper Douglas River play a vital role in the region's hydrological cycle and provision of water to biota. Most recharge is thought to occur throughout the wider savanna. Therefore, managing and maintaining recharge requires a whole of catchment approach.

There are no management guidelines or protection status of discharge or recharge sites, despite these areas being the important connection between rainfall and dry season flow.

Water Quality

Of significant importance to the health of the Daly River and its tributaries is not only the sustained input of large quantities of groundwater, but the sustained input of high quality unpolluted water. Water quality is also central to providing the high water clarity of the Daly in the dry season. Intense physical weathering in the Daly has resulted in low nutrient and carbon levels. The leached landscape is left with little nutrient to wash into aquatic ecosystems. End of wet season concentrations of nitrogen and (dissolved reactive) phosphorus in the middle reaches of the Daly River in late April were found to be very low: 0.004 mol m^{-3} and <1µg L^{-1} respectively by Rea *et al.* (2002). However, as soon as run-off ceases, nitrogen levels in the river fall to very low levels (0.0005 mol m^{-3}) and are sometimes barely detectable (Rea *et al.,* 2002). Phosphorus is considered to be the more limiting nutrient than nitrogen (Rea *et al.,* 2002).

The very low levels of nutrients in Daly River water during the dry season is an important characteristic. Low nutrient levels dictate the ecological character of the river, primarily through constraining the growth of primary producers (Webster *et al.,* 2005). The growth of algae and higher aquatic plants is limited and this in turn limits the mass of predators and other prey. Input of nutrients and carbon to the environment and interruption to nitrogen and carbon cycles threatens the integrity of the aquatic ecosystem. Nutrient enrichment from fertiliser run-off and accession to water tables would result in an increase in primary production in the system. Most notable would be an increase in bottom-dwelling filamentous algae. This macroalgae grows on coarse gravel, rock, sand and aquatic plants, smothering the latter.

If nutrient enrichment was coupled with a decrease in flow, it would also likely result in higher concentrations of phytoplankton and algal blooms. Artificially elevated levels of nutrients also favours introduced species over native plants that are not adapted to higher resource availability or competitors. A high nutrient supply could change the species composition of the river if aquatic or riparian weeds were present. They would likely displace native plants, thereby removing an important aquatic habitat and food resource.

The calcium and magnesium carbonate rock that underlies much of the DRC, and the chemical (or ionic) composition of the water, differs from the underlying geology and chemical composition of the waters of most of the Top End coastal rivers. The Daly's dry season flow is dominated by the presence of calcium and magnesium ions due to the underlying limestone aquifers. In comparison, the waters of most coastal Top End rivers are dominated by sodium and chloride ions. When the Daly's groundwater mixes with the rain-fed surface waters, the chemical processes of magnesium and calcium ions attracting to the negatively charged particles of clay during wet season flow results in water-borne particles joining together (agglomeration) and settling on

to the bottom of the river bed (flocculation) (Rea *et al.,* 2002). Light then penetrates through the water to the river bed very quickly and the high water clarity supports the growth of benthic and water column primary producers such as *Vallisneria nana* and *Spirogyra*, which are key food sources for pig-nosed turtles. Precipitation of calcium carbonate ($CaCO_3$) along with optimal levels of dissolved carbon dioxide, temperature and pH also provides for the formation of 'tufa dams' in several reaches of the Flora and Douglas Rivers. These relatively uncommon features are so large and well developed in the DRC that they form natural dams on the Douglas and the Flora Rivers in particular and are tourist attractions in their own right.

Key ecosystems and species of aquatic conservation value in the Daly River Catchment

Karst

Karst is a type of limestone rock that has been shaped and hollowed by being dissolved by water. This process is called 'karstification'. Karst features include surface and subterranean landforms such as vertical shafts, losing streams, springs, dolines, aquifers, caves, solution sculptured limestone rock (karren) and where percolation of organic rich water produces smoothly rounded forms (rundkarren) or sharp-edged grooves (rillenkarren; Jennings 1985). Highly specialised invertebrates often live in the hollows within karst, such as aquatic crustaceans that are restricted to flooded caves. Karp (2002) has reported on the dimensions, location and geological and hydrogeologic control factors of 283 sinkholes in the Tindall Limestone of the Katherine region.

Disturbance of the processes that develop and maintain karst aquifers affects not only the performance of the aquifer but fauna that live in these underground caves. The connectivity between surface water and groundwater underpins all these values. The karst cave systems need to be protected so that the movement of water from rainfall to aquifers to rivers is protected.

Karst systems can be damaged by land clearing, fire and cropping. These activities remove the native vegetation that exists on top of these underground karst cave systems. The existing native vegetation is important for two reasons: decaying leaves and soil organic matter add carbon to water seeping into aquifers when they decompose (and release organic acids), and by trapping clay particles that can seep into karst systems and block them. These ecosystems are threatened by seepage from fertilisers, and from pollution of sinkholes. The extensive nature of underground drainage systems in the DRC means that specific karst features can be impacted by disturbances occurring miles from the affected area, such as from land clearing and agricultural development.

Changes to burning regimes also impacts on karst and cave fauna. Fire depletes the humus level of soils thereby altering the acid balance of percolation waters.

Endemism and species diversity

Endemic species are restricted to a certain area and occur nowhere else. 'Endemism' is a measure of how important an area has been for the adaptation of species. There are two parts of the DRC where endemism is a feature. In the upper part of the DRC, the dissected sandstone plateau of western Arnhem Land (Ingwersen 1995, Press *et al.,* 1995) supports small localised ranges of endemic species with poor dispersal ability. Approximately 50 vascular plants, and a number of invertebrates, fish, frogs, reptiles and mammals are endemic to this area. Monsoon rainforest patches also support endemism, with 36 of the reported 585 plant species belonging exclusively to this ecosystem (Liddle *et al.,* 1994).

Many types of flora and fauna have not been comprehensively surveyed. For example, there has been no survey of karst fauna, despite the findings that fauna from limestone aquifers can be large, diverse, and showing a high degree of endemism (due to species adapting within individual cave and karst complexes). There has been no comprehensive survey of aquatic or wetland plants or fish in the rivers and wetlands. An example of the likely knowledge gap in the DRC can be illustrated by the increase in described plant species in the better-researched Kakadu National Park. Between 1973 and 1996 the number of known plant species doubled from 954 to 1899 (Brennan 1996). New vertebrate species are also still being discovered in this region. The known fish fauna of Kakadu National Park more than doubled after a 1997 survey of estuarine and coastal fishes (Larson 1999).

Monsoon vine forests

Monsoon vine forests (also called monsoon rainforests or vine thickets) of the Top End are widely regarded as groundwater dependent ecosystems because they often occur where there is permanent water associated with springs and seepages. Monsoon forests can also occur on well-drained soils. Some of the forests are quite small (1-10 ha) but one patch on the Daly River is over 10 km long and 1 km wide in places. The importance and role of monsoon vine forests is in the network of rainforest patches that exists across Northern Australia. No one patch can maintain its values in isolation. More than 10,000 rainforest or 'monsoon vine thicket' patches have been recorded across Northern Australia (Russell-Smith *et al.,* 1992, Price *et al.,* 1995). The patches are important stepping stones for fruit eating animals that move between patches to obtain sufficient food. Flying foxes that live and eat in the shaded monsoon vine forests and caves are also important pollinators of savanna trees (Palmer and Woinarski 1999). The destruction of rainforest patches would reduce populations of fruit eating animals in remaining patches up to 50 km away (Price *et al.,* 2003).

Monsoon vine forests contain 13% of the NT flora in 0.5% of its area (Price *et al.,* 2003) and support bird species not found elsewhere (Woinarski 1993). The forests have a canopy that closes out much of the light, even though some of the vegetation is deciduous. Trees in the wetter evergreen forests include rotten cheesefruit or great morinda, native nutmeg and *Macaranga* species and in the drier monsoon forests black wattle, milkwood, kapok or bombax tree, banyan tree and peanut tree. Many types of vines grow in these forests including the crab's eye vine, round yams, long

yams, native jasmine, and wild passionfruit. Ground orchids and ferns also occur in the understorey. In the rainforest patches associated with the plunge pools of the escarpment, the tall endemic tree *Allosyncarpia ternata* forms single-species stands of closed forest (Russell-Smith *et al.,* 1992).

Not only do monsoon vine forests have high nature conservation and cultural values, their structure and longevity is important in regulating the runoff of sediments, carbon and nutrients into watercourses. Their roots bind river and stream banks during floods.

Riparian zones

The riparian (or river-edge) zones of the DRC are dominated by paperbark species (*Melaleuca,* or 'ti-trees'), as well as river oaks (*Casuarina cunninghamii*), *Eucalyptus bella*, bombax tree and Leichardts tree (*Nauclea orientalis*). Four species of *Melaleuca* form the paperbark forests; *M. cajaputi* and another species tolerate longer flooding and are common in swamps and around billabongs, whereas *M. argentea* and *M. leucadendra* dominate the main watercourses where they can access a permanent supply of water. All paperbarks flower prolifically and attract large numbers of insects and nectar feeding birds.

Riparian vegetation along the Daly River exhibits distinct zonation patterns in both structure and water use (O'Grady *et al.,* 2002). *Melaleuca* species were found closest to the river, while *Eucalyptus* species occur on the levee banks. *Melaleuca* species used mainly river water or groundwater and *Eucalyptus* species used soil water.

Riparian zones in the DRC are regarded as significant and sensitive ecosystems in terms of the habitat value they provide and their role in controlling the behaviour of river channels and river health (Price *et al.,* 2003). Riparian zones often have a greater productivity and species richness than adjoining ecosystems. This can be attributed to their proximity to water and a greater supply of resources (space, food, shelter) and microclimates. Not only do these areas support many riparian species that occur nowhere else, they support many species that use the zone as a corridor and as a temporary refuge, especially during fire or drought.

Disturbance to the riparian zone can result in bank erosion, sedimentation of river beds and changes to channel morphology. If the buffer between aquatic ecosystems and land use is lost, pesticide, nutrient and soil run-off from adjacent paddocks increases and alters water quality with a cascade of adverse impacts. The loss of riparian zones equates to the loss of core habitat and dry season refuge for many species. When riparian vegetation is lost, the lack of shade causes greater extremes in water temperature, while fauna reliant on the fruit and seeds from this vegetation are also affected. Leaf litter and other organic matter, including insects from this zone, are a major contributor of carbon or energy that underpins the predator-prey interactions (or 'trophic structure') of aquatic ecosystems. For example, increased light, heat, temperature and nutrient additions to watercourses occur when riparian zones are degraded or lost. This can lead to increased growth of algae and aquatic weeds.

During the large floods in the last several years in the Daly River, many riparian trees have been uprooted and fallen into the river. This input of woody material is important for providing shelter for fish and other aquatic species from strong currents. The overwhelming majority of rivers and streams in the DRC have sandy channels and the logs and branches provide important habitat for fish (protection) and plants (anchor sites). The recent high flows illustrate the importance of the Daly riparian zone in holding the bank together and regulating sub-surface flow. Bank storage (the saturation of the riparian zone during flooding), is followed by the slow movement of water back into the river during the dry season.

Wetlands

Wetlands of the DRC are diverse, extensive and have considerable value but they are poorly conserved. Over 80% of wetlands in the smaller Daly Basin Bioregion, which comprises about two-fifths of the area of the DRC, occur outside the protected area network (Begg *et al.,* 2001, at p x). They are at high risk given that changes to hydrological and nutrient regimes are known to have a major impact on wetland condition. The ecological services these wetlands provide to people and the rest of the ecological system is poorly understood yet likely to be of great importance.

Comprehensive mapping of the wetlands in the Daly Basin Bioregion illustrates the extent of wetlands and the diversity of wetland types in this region (Begg *et al.,* 2001). This study dispels the myth that the savanna rangelands and forests of the Top End are a terrestrial landscape. Under the Ramsar Convention definition of wetlands, the DRC is home to a significant wetland landscape. Despite there being no rain for a large part of the year, water persists throughout the year either in perched (or raised) or spring-fed systems.

Wetlands within the Daly catchment are relatively intact, widespread and diverse. Begg *et al.* (2001) mapped seven different types of wetlands in the smaller Daly Basin: sumplands, stream sinks, springs, floodplain, waterholes, seepages and damplands. The study mapped approximately 3,534 km^2 (or 353,400 ha) of floodplain and dampland wetlands (Begg *et al.*, 2001, p25, Table 4). The total length of river and creek channels in this area exceeds 25,500 km.

Despite the extent and diversity of wetlands in the DRC (eg. seasonally inundated and permanent swamps, sink-holes, billabongs), their biology and ecology has been only poorly recorded. Nor has their wider role in catchment hydrology been extensively examined, despite the role that wetlands have in the hydrological cycle. Wetlands capture run-off and associated sediments, organic material and nutrients, thereby slowing and reducing run-off to creeks and rivers. They can be sites of recharge and discharge, as well as perched systems that provide water and habitat throughout the dry season. They are necessary for migratory waterbirds, turtles, reptiles, amphibians and mammals. The extensive wetland-savanna transition zone is also central to supporting fauna from both ecosystems, as a buffer zone and a temporary habitat used by terrestrial and aquatic species alike.

There is an urgent need to map wetlands across the entire DRC using the methodology used by Begg *et al.* (2001) for the smaller Daly Basin Bioregion, as recommended by these researchers (at p 93). The water needs of major wetland types need to be determined.

Water plants and algae

Water plants in the rivers and streams of the DRC have not been comprehensively surveyed. Faulks (1998) noted that aquatic macrophytes were generally uncommon in rivers with moving water. This is likely to be related to high wet season flows that prevent establishment and scour the riverbed and uproot plants. Nevertheless, there are several key species of water plants that live in rivers and streams, and because of their relative rarity in the river, the habitat role they provide cannot be overlooked. Throughout the middle reaches, the dominant species is *Vallisneria nana* (Rea *et al.,* 2002). This plant was noted at the time to be absent upstream of Dorisvale Crossing and downstream of the Douglas confluence with the Daly, underscoring the conservation values of the middle reaches of the Daly River given the habitat role played by this species. However, *Vallisneria* beds have been observed in the lower reaches of the river, between Nauiyu and Browns Creek (H. Sinclair, Daly River, pers. obs.).

Vallisneria beds grow over the dry season into long narrow meadows around the outer edge of meander bends where outcrops of the Oolloo dolostone occur. These beds also have habitat value for fish, turtles, crocodiles and macroinvertebrates (Rea *et al.,* 2002). *Vallisneria* not only provides food for the pig-nosed turtle in particular, but it provides a still refuge away from high currents and predators. Large populations of a species of aquatic snail were found embedded in the root mass of *Vallisneria* plants. These and other macroinvertebrates (Dostine *et al.,* 2002) would comprise a major component of the diet of fish.

Another group of plants previously unrecorded from the river are the charophytes (a form of freshwater algae) that behave like higher plants and that grow in beds on the sandy floor of rivers and wetlands. Five species have been recorded from the Daly (M. Casanova, charophyte biologist, pers. comm.). During the dry season beds of the benthic macroalgae (*Spyrogyra* spp) and charophytes (*Chara* spp) form across the floor of the main channel of the Daly River throughout the middle reaches (Rea *et al.,* 2002). These beds comprise a significant component of plant mass in the river and contribute to river productivity (Webster *et al.,* 2005). Charophytes were found to grow mainly on gravel substrates that comprise about half the riverbed in the middle reaches during the dry season. The remainder of the riverbed is mobile sand with small areas of rock outcrops.

Various reaches of the Daly River and its tributaries are also flanked by stream-edge plants such as reed (*Phragmites karka*), river pandanus (*Pandanus aquatilus*) and the fern *Blechnum orientale* and *Ampelopteris prolifera*. These and many other emergent,

floating leafed and submerged plants occur in the numerous billabongs and on the extensive floodplains when wet. One of the most notable plant species is lotus water lily (*Nelumbo nucifera*), which is important in the diet and culture of Aboriginal people.

In a recent broad survey of plankton in the Daly River, 206 species were recorded, including 36 new species for the Territory and five new species for Australia (Townsend *et al.,* 2002). Overall, concentrations of algae were very low (<2ug/L chlorophyll *a*), probably due to the sustained river flows that wash these microscopic plants downstream, preventing their populations from expanding and becoming problematic.

Macroinvertebrates

Aquatic macroinvertebrates include invertebrates such as aquatic insects, cherabin (see below) and other crustaceans, aquatic snails, and underground cave-dwelling species ('stygofauna'). Their larvae, and often other stages of their life cycle, live in water. They play an important role in cycling nutrients and carbon and provide an important food source for fish, waterbirds and other species. Many grow in the spaces between gravel and coarse sand grains of waterbodies or within the root mass or leaves of riparian plants or water plants.

Almost 200 species of aquatic macroinvertebrates, including three new species from the Douglas River, were recorded in waterways of the DRC by Dostine (2000). In a 12 km section in the middle reaches of the Daly River, 96 taxa were recorded, mainly larval or adult aquatic insects (Rea *et al.,* 2002). Most of these species were uncommon, that is, 79 of the 96 taxa comprised less than 1% of the total number of organisms. The most common species were from the midge family (chironomids). The high diversity and low abundance of most taxonomic groups was similar to that found for algae. High diversity may reflect different instream habitats and small scale resource patchiness.

Corbiculid bivalves, a type of clam, were abundant on the coarse sand substrates of pools. Two key types of freshwater snails, thiarid and viviparid gastropods, were abundant within the beds of *Vallisneria nana*. The highest number of species were found at the edge of the river, and the least number of species from pebble habitats with the highest velocities.

An uncommon aquatic bug, the naucorid *Aphelocheirus australicus*, is known to occur in the Daly River. It is known from only a few sites in northern Australia, including the Daly River, the upper South Alligator River in the NT and from near Cairns (Rea *et al.,* 2002). The genus is normally thought to be restricted to well-oxygenated water and is taken as a reliable indicator of high quality water (Lansbury 1985). Small scale variation in habitat structure and resource supply is also known to be important for maintaining a diverse macroinvertebrate fauna elsewhere (Sheldon and Walker 1998). Also in the Daly, the influence of large-scale catchment differences in flow, channel morphology and conductivity may play a role in the difference between an abundant and more diverse mollusc fauna in the middle reaches as compared to the upland tributaries (Dostine 2000).

Three species of an important type of freshwater snail (called *Notopala*) have been recorded from the Daly River (Dostine 2000, Rea *et al.,* 2002). There are only 18 species of *Notopala* in Australia. Many are confined to a small range or a single waterbody (Ponder 1994, 1997). Freshwater snails are vulnerable to change as they have poor dispersal ability and lack mobility. Their ecological requirements are poorly understood in Australia (Ponder 1994). In NSW, the marked decline in freshwater snails has been attributed to changes in flow and reduced water clarity (Sheldon and Walker 1993, Walker 1996).

Other aquatic invertebrate species live in the sandy sediments on the bed of the Daly River. Research from other rivers shows that macroinvertebrates that live in these sandy sediments (called the hyporrheic zone) often only occur in these restricted habitats, and play an important role in keeping pore spaces open between sand grains, cycling nutrients and carbon, and providing a food source for other species.

Macroinvertebrates that live in cave systems (hypogean fauna) and macroinvertebrates that live in groundwater aquifers (stygofauna) have not been surveyed in the DRC. Generally, such species occur only in these specialised habitats (ie. they often occur only in individual cave or aquifer systems). Subterannean macroinvertebrates are susceptible to impacts because of their limited mobility and restricted habitat range. As their entire life cycle depends on karst or cave environments, even small disturbances are potentially fatal. These species are adapted to the naturally low nutrient levels in these systems, some showing resistance to starvation and inability to tolerate high nutrient inputs because of low metabolic rates (Culver 1982). Nutrient enrichment from fertilisers is a major threat to karst fauna. Aquifer water quality is also affected by suspended sediment and mobilised clays from the soil that can enter aquifers and cause blockages to percolation routes, mainly where recharge is direct via sinkholes and rock fractures. Higher turbidity interferes with the feeding and respiration of underground cave life.

Changes from native vegetation to introduced plant species (crops and weeds) can also reduce recharge. This is because of the higher demand for water from faster growing crops and weeds and their greater transpiration rate. Introduced plants also lead to changes in the humus and soil, because the input and quality of organic material is different. In agricultural environments, exotic fauna can be introduced accidentally and may exclude or compete with native fauna for food and space.

Streams within the DRC are home to some large and commercially valuable crustaceans such as the giant freshwater prawn (cherabin; M*acrobrachium rosenbergii*) and the freshwater crayfish (redclaw; *Cherax quadricarinatus*). Both are harvested by Indigenous people and non-Indigenous people utilise them as bait. Elsewhere in the world, both species are at the centre of large-scale aquaculture industries.

Cherabin is endemic to the northern rivers of Queensland, the Northern Territory and Western Australia, as well as parts of the Indo-Pacific. Cherabin produce free-swimming larvae which need brackish water. They live on the river floor and especially around fallen logs. The Daly River is famous for its cherabin, which are a prime bait for barramundi. The role of these large prawns in the food web is not

known, however given their apparent abundance and size they are likely to be an important food source for large fish, lizards, monitors, turtles and crocodiles.

Redclaw is also endemic to the southerly flowing rivers of the island of New Guinea, the west and north flowing rivers of the Gulf of Carpentaria, and the east and north flowing rivers of the Northern Territory. Redclaw live in wetlands and waterholes with abundant vegetation. They obtain food by filtering small food particles from silt and mud.

The smaller atyid shrimps (*Caridina* spp), which are less than a few centimetres long, are widespread in tropical and subtropical streams. They are filter-feeders, collector-gatherers and omnivorous scavengers. Their collective biomass and abundance may give them a key role in the ecology of rivers such as the Daly (Pringle *et al.,* 1993). They usually inhabit trailing vegetation at stream banks and are also found associated with leaf packs accumulated in stream pools. They breed when water temperature is higher than 20^{o}C (Dudgeon 1985). Juveniles grasp trailing vegetation and roots thereby avoiding being swept away during wet season flood events. Studies on the ecology and role of the atyid shrimps are absent, despite their role as a food source for higher fauna such as fish and turtles.

Freshwater fish

Although recreational fishing is hugely popular in the NT, the distribution and fundamental ecological needs of fish is very poorly known (Price *et al.,* 2003). Only 150 of Australia's 4000 species of fish live solely in freshwater systems. In the DRC, 48 species of freshwater and estuarine fish have been recorded (Table 2). One species is endemic to the catchment (the Katherine River gudgeon). In comparison, 33 species occur in the entire Murray Darling Basin. The number of fish species in the DRC is similar to the numbers of fish species in the neighbouring Victoria River and Alligator Rivers (39 and 53 spp, Bishop and Forbes 1991). Most of the species found in the Daly are also found in other Top End streams. Rivers such as the Daly share about 25% of their fish species with rivers in southern New Guinea (Bishop and Forbes 1991).

Table 2. Freshwater and freshwater/estuarine fish species recorded in the Daly River Catchment (48 species in total).

Common name	Scientific name	Conservation status
Freshwater species		
Terapontidae		
Barred Grunter	*Amniataba percoides*	Non-threatened
Spangled perch	*Leiopotherapon unicolor*	Non-threatened
Sooty Grunter	*Hephaestus fuliginosus*	Non-threatened
Midgley's grunter	*Pingalla midgleyi*	Lower risk – near threatened[5]
Butler's grunter	*Syncomistes butleri*	Non-threatened
Eleotridae		
Northern trout gudgeon	*Mogurnda mogurnda*	Non-threatened
Empire gudgeon	*Hypseleotris compressa*	Non-threatened
Sleepycod	*Oxyeleotris lineolatus*	Non-threatened
Northern sleepycod	*Oxyeleotris selheimi*	Non-threatened
Katherine River gudgeon	*Hypseleotris* sp.	Data deficient[5]
Gobiidae		
Golden goby	*Glossogobius aureus*	Non-threatened
Flathead goby	*Glossogobius giuris*	Non-threatened
Chandidae		
Macleays glassfish	*Ambassis macleayi*	Non-threatened
Sailfin glassfish	*Ambassis agrammus*	Non-threatened
North-western glassfish	*Ambassis* sp.[2]	Non-threatened as *A. mulleri*
Pennyfish	*Denariusa bandata*	Non-threatened
Ariidae		
Salmon catfish	*Arius graeffei*	Non-threatened
Triangular shield catfish	*Arius midgleyi*	Non-threatened
Shovel nosed catfish	*Arius leptaspis*[2]	Non-threatened
Plotosidae		
Hyrtles tandan	*Neosilurus hyrtlii*	Non-threatened
Butterjew	*Neosilurus ater*[2]	Non-threatened
False-spine catfish	*Neosilurus pseudospinosus*[1]	Non-threatened
Obbes catfish	*Porochilus obbesi*	Non-threatened
Toothless catfish	*Anodontoglanis dahli*	Non threatened
Atherinidae		
Fly specked hardyhead	*Craterocephalus stercusmuscarum*	Non-threatened
Strawman	*Quirichthys stramineus*	Non-threatened
Pseudomugilidae		
Delicate blue-eye	*Pseudomugil tenellus*	Non-threatened
Melanotaeniidae		
Western rainbowfish	*Melanotaenia australis* (=*M.splendida australis*)	Non-threatened
Exquisite rainbowfish	*Melanotaenia exquisita*[1]	Rare

Belonidae		
Long tom	*Strongylura krefftii*	Non-threatened
Toxotidae		
Archerfish	*Toxotes chatareus*	Non-threatened
Oprimitive archerfish	*Toxotes lorentzi*	Non-threatened
Centropomidae		
Barramundi	*Lates calcarifer*	Non-threatened
Soleidae		
Freshwater sole	*Aseraggodes klunzingeri*[1]	Non-threatened
Clupeidae		
Bony bream	*Nematolosa erebi*	Non-threatened
Megalopidae		
Tarpon	*Megalops cyprinoides*	Non-threatened
Kurtidae		
Nursery fish	*Kurtus gulliveri*	Non-threatened
Apogonidae		
Mouth almighty	*Glossamia aprion*	Not-threatened
Estuarine/Freshwater species		
Pristidae		
Freshwater sawfish	*Pristis microdon*[3]	Critically endangered[5]
Dasyatidae		
Freshwater whipray	*Himantura chaophraya*	Vulnerable[5]
Carcharhinidae		
Bull shark	*Carcharhinus leucas*	Not listed
Northern spear-toothed shark*	*Glyphis* sp. (presumably sp.C)	Endangered
Sciaenidae		
Scaly jewfish	*Nibea squamosa*	Not listed
Paperhead jewfish	*Johnius novaeguineae*	Not listed
Lutjanidae		
Chinamanfish	*Symphorus nematophorus*	Not listed
Trichiuridae		
Hairtail	*Trichiurus* sp	Not listed
Polynemidae		
King threadfin	*Polydactylus macrochir*	Not listed

Notes

Records are derived from the Northern Territory Museum (Dr H. Larson, pers. comm.) unless otherwise stated:

1. Allen et al.(2002);

2. common species not recorded from the Daly River but for which distributional limits as defined by Allen et al. (2002) include the Daly River;

3. Last and Stevens (1994);

4. Conservation status as defined in Wager and Jackson (1993); or,

5. Pogonoski et al. (2002).

** No records of northern speartoothed shark exist for the Daly River. However, the species is known to occur in the Adelaide and East Alligator Rivers (Thorburn and Morgan, 2004), and anecdotal evidence indicates it may also be present in the Daly's estuary (see text).*

Fish such as the omnivorous banded grunter are tolerant of a wide range of conditions. Sailfin glassfish, empire gudgeon and sooty grunter are found frequenting the upper reaches of rivers and creeks with sandy floors. In shallow waters, spangled grunters are common. Salmon catfish seek food on the riverbed, while longtoms stay near the surface, especially under overhanging vegetation where they prey on small fish and prawns. Barramundi, sleepy cod and Butler's grunter are common in the main channels. Barramundi and ox-eye herring spawn in estuaries and their young develop in coastal swamps. Juvenile barramundi move into the mangrove estuaries and migrate upstream when 3-4 years old, then migrate back to salt water to breed. At this stage adult male barramundi change into females. Floodplain inundation is necessary for barramundi to breed successfully. The Daly River is widely considered by anglers as Australia's premier barramundi river and is the site for two major fishing competitions (the Barra Nationals and Barra Classic).

The importance of the ecological role that fish provide, as both consumers and prey, is not well understood in the Daly River. The significant role played by intact riparian zones with regard to fish assemblages (Pusey and Arthington 2003) extends to a multitude of direct and indirect effects stemming from control on light/shade and the input of inorganic and organic material. Relationships between river flow and the structure of fish communities (Pusey *et al.,* 2000) indicates the importance of providing environmental water requirements for fish. Of key importance to fish diversity is the maintenance of habitat heterogeneity and complexity (Pearson and Penridge 1992, Power 1992).

Freshwater sharks and rays

Elasmobranchs include freshwater and estuarine sharks and rays confined to tropical to warm-temperate regions. Elasmobranchs have only been recognised as important components of Australian tropical river ecosystems since the 1990s. They are Australia's largest freshwater fish and appear to have very specific habitat requirements. They are very vulnerable to netting and poaching.

The conservation status of elasmobranchs is generally very poor. Under the federal *Environment Protection and Biodiversity Conservation Act 1999*, freshwater whipray is listed as vulnerable, northern spear tooth shark is endangered, and freshwater sawfish is critically endangered. These species are most greatly threatened by legal and illegal commercial fishing operations, particularly where gill nets are used (eg. in the barramundi fishery).

The Daly River is one of a few rivers in northern Australia where freshwater sawfish (*Pristis microdon* and *P. clavata*) and estuarine/freshwater whiprays (*Himantura* sp.) are known to survive. Also, the strawman (*Quirichthys stramineus*) is restricted to only a handful of rivers (Midgley 1980), and seems to be most common in the Daly system. It is most likely that the Daly represents the largest and most secure population of this relatively rare species. Additionally, anecdotal evidence suggests the poorly known and endangered, northern speartoothed shark (*Glyphis* species A and C) may also occur in the Daly's estuary (H. Larson, NT Museum, pers. comm.).

Freshwater sawfish still occur in northern Australian waters but have been largely eliminated in nearby Asian waters. Anecdotal evidence suggests that they were once

more common over most of their Australian range. It is now confined to freshwater rivers and the upper reaches of estuaries in northern Australia (Last and Stevens 1994), usually at depths greater than 1 m, but sometimes in shallow waters when travelling upstream or hunting prey (Wilson 1999). It is a large, long-lived predator (at least 44 years; Tanaka 1991) and feeds by stunning smaller fish with side sweeps of its saw and by disturbing molluscs and small crustaceans in the sand and mud (Allen 1982, Cliff and Wilson 1994).

Anecdotal evidence exists of the occurrence of the northern speartoothed shark (*Glyphis* spp) in the DRC. Speartoothed sharks are currently known from only about 25 specimens of two species from Queensland and the Northern Territory. They are an enigmatic group confined to localised estuarine systems in the Indo-West Pacific region. The more common bull shark (*Carcharhinus leucas*) is also found in the DRC and freshwater rivers and seawater throughout northern Australia and is sometimes confused with the spear tooth shark. Female bull sharks are believed to give birth in estuarine areas and the juveniles then move into freshwater. Juveniles seem to be restricted to fresh or low salinity water.

The freshwater whipray (*Himantura chaophraya*), sometimes known as the giant freshwater stingray, is on the 2000 IUCN Red List of Threatened Species. It is listed as globally vulnerable and also critically endangered in Thailand. Freshwater whipray is the only Australian stingray to live entirely in fresh and brackish estuarine waters (Last and Stevens 1994). As a large freshwater species, which gives birth to few young, it is particularly vulnerable to fishing pressures and habitat alteration or destruction. The possibility of biological extinction in the wild is considered high (Compagno and Cook 1995). Commercial and recreational fishing and habitat degradation all have the potential to adversely affect this species.

The presence of these threatened and rare species makes the Daly River a significant refuge for these species.

Freshwater turtles

The DRC supports a greater diversity of freshwater turtles than any river system in Australia, with eight of the 12 freshwater turtle species found in the NT (see Table 2, after Price *et al.,* 2003). The high species richness of turtles is likely to relate to spatial and temporal variation in food and other resources related to the wet-dry tropical environment. The largely opportunistic feeding ecology of the turtles of the Top End may be an adaptation to a dynamic environment that allows them to exploit unpredictable food resources.

Pig-nosed turtle are opportunistic omnivores. Whilst they consume almost entirely *Vallisneria* in the dry season (Doody *et al.,* 2003), they also eat fruits, seeds and leaves from riparian plants (eg. *Ficus racemosa, Syzygium forte, Pandanus aquaticus*, and mangroves), snails, crustacea and fish.

In comparison, the northern snake-neck turtle is a carnivore, eating mainly snails. The northern snapping turtle is primarily herbivorous, consuming mainly aquatic algae (eg, *Spirogyra*) and some carrion, and freshwater sponges (*Corvospongilla* sp).

Table 3. The eight species of freshwater turtle found in the DRC (after Price *et al.,* 2003).

Common name	Scientific name
Pig-nosed turtle	*Carettochelys insculpta*
Redface turtle	*Emydura victoriae*
Upland yellowface	*Emydura subglobosa (ssp.worreli)*
Lowland yellowface	*Emydura tanybaraga*
Northern snapper	*Elseya dentata*
Common sawshell	*Elseya latisternum*
Northern snake-neck	*Chelodina rugosa*
Sandstone snake-neck	*Chelodina burrungandjii.*

Pig-nosed turtle and northern snapping turtle have 25-50% of their NT records from the Daly River, which is the most 'Daly-centric' of all recorded fauna (Price 2003). The species of most public concern is the pig-nosed turtle because it is the last remaining species from a family of turtles that has existed for 40 million years (Georges and Rose 1993). It occurs in four NT rivers as well as several rivers in New Guinea. The species' conservation status is 'near threatened' under the *Territory Parks and Wildlife Conservation Act*. The Daly River is thought to hold the largest population in Australia, with populations in New Guinea in decline (Georges and Rose 1993). The species' vulnerability relates to its high dependence on a single plant (*Vallisneria nana*) and its specific nesting requirements, namely fine sand banks adjoining water in the middle and lower reaches of rivers, sandy shores of river delta islands, and coastal beaches. In the dry season this turtle can be found in rivers, billabongs and plunge pools, while its habitat in the wet-season remains largely unknown (Georges and Rose 1993, Georges and Wombey 1993).

Pig-nosed turtles rely extensively on warm water discharged from springs to keep warm (average temperature of 30 degrees Celsius), particularly females during reproduction which rarely move from them (Doody *et al.,* 2001). This species has temperature dependent sex determination of the eggs, with warmer nests producing female turtles and cool nests male turtles (Doody *et al.,* 2004, Georges 1992). There is a possibility that if water levels are reduced due to water extraction for irrigation, nests may dry out earlier and become hotter, thus failing to produce any males (Georges *et al.,* 2003) and the fragmentation of the river into pools would prevent the movement of turtles looking for mates and the formation of the fine sand bars that are required for breeding. Changes to water temperatures in the rivers of cleared catchments was demonstrated by Lynch *et al.* (1984).

Other reptiles

The Daly River system supports large populations of freshwater crocodile (*Crocodylus johnsoni*) and saltwater crocodile (*C. porosus*). The freshwater crocodile

lays its eggs in river sandbars and are eaten by Gould's sand goannas and the local Indigenous population.

Arafura file snakes, water pythons, olive pythons and keelback snakes confine themselves to permanent billabongs during the dry season and spread out across the floodplains in the wet season. Macleay's water snake stays in and near the rivers, hiding in exposed tree roots on the river banks and preying on fish, eels and frogs. In the monsoon rainforests, carpet pythons feed on rats, bandicoots, small wallabies, possums and fruit bats, while the green tree snake eats frogs, lizards and fish.

Reptiles of the paperbark swamps include the swamplands lashtail and Mitchell's water monitor. The swamplands lashtail's main diet is insects and it is inactive in the dry season, hiding under fallen timber or paperbark roots. The yellow-spotted monitor usually chooses higher ground on the floodplain for its burrow, while Gilbert's lashtail lizard perches on branches or termite mounds near waterholes, feeding on insects or smaller lizards.

Waterbirds

Extensive air and ground surveys of waterbirds across the Top End, including the floodplains and estuaries of the DRC, between 1990 and 2002 by the Parks and Wildlife Commission of the NT, demonstrated high diversities and abundance of waterbirds (Chatto 2000, 2005).

The Daly's estuary and lower floodplain has been assessed as satisfying waterbird-based criteria for listing as a Wetland of International Importance under the Ramsar Convention (1971) (Chatto 2005, draft, p33). Currently no wetlands in the DRC are listed under the Ramsar Convention.

This large complex of wetlands, occurring across an area of approximately 20 x 30 km, was found to support 14 significant waterbird sites and six significant breeding sites during waterbird surveys, which commenced in 1990. It is the most significant area for waterbirds between Darwin and the Moyle River, with over 30,000 waterbirds recorded in May 1995.

A total of 45 waterbird species were recorded in aerial and ground surveys of wetlands between the Finniss and Moyle Rivers, which includes the lower floodplains of the Daly River (Chatto 2005, p31). These wetlands are also known to support some of the largest numbers of breeding colonies of colonial nesting waterbirds (such as egrets and ibis) in the Territory (Chatto 2000).

Surveys of shorebirds in a 2500 km^2 area including the wetlands, floodplains and estuaries of the Daly, Finniss and Reynolds Rivers recorded over 560 000 shorebirds (Chatto 2000). This equated to 26.8% of the total number of shorebirds counted in surveys across the Top End.

On the coast north of the Daly River, the most abundant shorebird species was the bar-tailed godwit, while the little curlew had numbers greater than 1% of the Australian population at a number of sites. In the Daly River wetlands and floodplains around the river mouth, the most abundant species was the lesser sand plover, while whimbrels were in numbers greater than 1% of the Australian population at a single

site. These easily qualify this area for potential listing under the East Asian-Australasian Shorebird Site Network (Chatto 2000a). In the Anson Bay area (including North Perron Island) of this survey block, shorebird counts in excess of 27,000 (Oct 1995) and 22,000 (Mar 1991) met the criteria of over-wintering counts in excess of 5,000 and single species counts in excess of the 1% criteria. This qualifies the area for listing under the East Asian-Australasian Shorebird Site Network and Ramsar Convention.

The floodplains of the DRC also support large numbers of ducks (ie Rajah shelducks, Plumed whistling-ducks, wandering whistling-ducks and Pacific black ducks). All four species of egret, plus the glossy ibis, brolga, black-necked stork (jabiru) and the magpie goose gather for the abundant food provided by the wet season and many birds breed at this time of the year. The life cycle of the magpie goose (*Anseranas semipalmata*) is tied into the seasonal changes on the floodplains. It requires moderately deep water to nest and to support the plant food resources year round. These conditions are not as ubiquitous as they might seem and the use of different wetlands by magpie geese each year is evidence of their need to utilise a network of different floodplains in order to find the appropriate conditions they need. They are relatively restricted areas and any alteration would lead to the destruction of the goose colonies, as has happened over other parts of Australia.

Recommendations

1) **Recognition of the aquatic conservation values of the Daly River Catchment**
   Significant aquatic ecosystems of the Daly River Catchment should be recognised as being of Territory, national or international significance in light of the range of aquatic conservation values identified in Table 1. These values should receive appropriate legal protection and funding for on-ground management and rehabilitation. The capacity of landholders and Traditional Owners to care for aquatic ecosystems in the catchment should be raised through training assistance in preparing and implementing property management plans.

2) **Maintenance of aquatic conservation values through planning processes and on-ground works**
   The aquatic conservation values identified in Table 1 should be protected, and where necessary rehabilitated, through relevant planning and on-ground actions. These include *inter alia* the proposed Integrated Land Use Plan for the Daly Basin, the Daly Water Allocation Plan, management of native vegetation and biodiversity on pastoral leasehold lands, decisions made regarding subdivision and agricultural development, management of weeds and feral animals, stock management, and management of the impacts of fishing and tourism**.**

3) **Protected area management for particularly significant aquatic ecosystems**
   Various river, wetland and estuarine ecosystems in the Daly River system warrant

further recognition under Territory, national and international agreements and laws. In particular,

a) The Daly River system should be protected under the proposed Territory 'Living Rivers' Program, promised by the Territory Labor Party during the 2005 NT election campaign (ALP, 2005). Protection under this program should extend to all aquatic ecosystems in the DRC that contribute significantly to the maintenance of ecological processes and aquatic biodiversity in the Daly River system. Implementation of this program should include culturally appropriate consultation with Indigenous groups and Traditional Owners, other landholders, community groups, fishers and industry.

b) Various wetland complexes in the DRC are likely to satisfy one or more criteria for listing as Wetlands of International Importance under the Ramsar Convention on Wetlands (1971). Various wetlands in the lower reaches and estuary are known to satisfy waterbird criteria alone (Chatto, 2005). Subject to gaining the support and consent of landholders, Traditional Owners and any Native Title claimants, wetlands should be assessed for nomination as Ramsar sites. Under the Ramsar Convention, a broad range of wetlands may be designated as being of international importance, including river channels, floodplains, karst systems and estuaries. Currently no Ramsar sites exist in the DRC.

c) Various components of the DRC may be eligible for recognition as being places of National Heritage under the federal *Environment Protection and Biodiversity Conservation Act*. Parts of the Daly River and associated ecosystems may meet the legal requirement of being of 'significant' and 'outstanding' national heritage value and hence warrant recognition as a 'heritage river' under the EPBC Act. The support of landholders, Traditional Owners and Native Tile claimants should be sought prior to any nomination. Under the EPBC Act, a place may be listed on the National Heritage List on both natural and cultural heritage grounds. The value of listing the Daly River as a 'heritage river' under these provisions depends on the extent to which the proposed Territory 'Living Rivers' program provides adequate protection and recognition for the river system.

d) Other forms of protected areas, on both private and public lands, should be established in consultation with Traditional Owners and landholders to manage and conserve aquatic ecosystems of particular environmental and cultural significance. Protected area options include *inter alia* national parks and nature reserves, Indigenous Protected Areas or other forms of Indigenous Land Use Agreements, property agreements, covenants, and river parks along the Daly and its tributaries (Jackson 2004). The Territory Parks and Conservation Masterplan proposes various options in this regard.

In relation to approaches (a)-(d) above, any form of additional legal protection must be accompanied by adequate levels of on-going funding, capacity building

programs and natural resource management planning to assist Indigenous and other landholders to effectively manage and protect areas so protected. Depending on the approach(s) adopted, Traditional Owners should have majority representation, legal ownership or some other effective means of management control, on management structures to oversight the establishment and management of new protected areas or other forms of legal recognition.

4) Consultation with Indigenous and non Indigenous communities

The aquatic conservation values identified in this report have cultural, economic and social significance to many people, including both Indigenous and non-Indigenous communities who live in or maintain connections with this region. Indigenous knowledge regarding these values is substantial, yet poorly appreciated by many non-Indigenous people, and should be incorporated into management planning through culturally appropriate engagement.

5) Filling knowledge gaps

a) Research needs: fish, sediment and nutrient transport and monsoon vine thickets

- Research into the environmental water requirements of fish, particularly of threatened species and barramundi, and the likely effects of increased water extraction is required.
- The water needs of monsoon vine thickets needs to be understood to guide the management of water extraction to conserve these key groundwater dependent ecosystems.

b) Biological and hydrological survey needs

Comprehensive biological and hydrological surveys of the DRC are required. Key gaps in the knowledge base are:

- fauna of karst systems (ie. flooded limestone caves);
- freshwater and estuarine fish;
- aquatic plants and water dependent vegetation;
- wetlands (areas outside the Daly Basin Bioregion);
- aquifer recharge and discharge sites; and,
- freshwater turtles.

c) Monitoring of the movement of sediments and agricultural chemicals into rivers

The application and fate of agricultural chemicals, including fertilisers, insecticides and herbicides, in agricultural developments should be rigorously

monitored. Monitoring should examine the transport of sediments and chemicals into aquatic ecosystems through wind and water erosion, run-off and seepage into aquifers. Information generated should underpin the development of best management practice guidelines for the agricultural sector.

6) **Review legal regimes for managing and conserving aquatic ecosystems**
Laws and policies which provide for the conservation and management of the aquatic conservation values in the DRC, such as the *Water Act 1992*, *Fisheries Act 1988*, the *Pastoral Land Act* and the *Territory Parks and Wildlife Conservation Act* should be reviewed and rewritten to reflect world's best practice natural resource management and aquatic ecosystem protection legislation.

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