supervising scientist report **198**

Integrated assessment of wetland services and values as a tool to analyse policy trade-offs and management options: A case study in the Daly and Mary River catchments, northern Australia

Final Report September 2008

R de Groot, M Finlayson,
B Verschuuren, O Ypma & M Zylstra

Australian Government
Department of the Environment, Water, Heritage and the Arts
Supervising Scientist

It is SSD policy for reports in the SSR series to be reviewed as part of the publications process.

This Supervising Scientist Report has been formally refereed by one external independent expert.

Authors

Rudolf de Groot – Environmental Systems Analysis Group, Wageningen University, The Netherlands

Max Finlayson – Institute for Land, Water and Society, Charles Sturt University, Albury, Australia

Bas Verschuuren – Earth Collective/Foundation for Sustainable Development (FSD), The Netherlands

Olga Ypma – Former MSc student, Wageningen University (WUR), The Netherlands

Matthew Zylstra – Environmental Systems Analysis Group, Wageningen University, The Netherlands

with contributions from former Wageningen University (WUR) MSc students Sophie Bachet, Clement Mabire & Pujan Shrestha

Email address for corresponding author: dolf.degroot@wur.nl

This report should be cited as follows:

de Groot R, Finlayson M, Verschuuren B, Ypma O & Zylstra M 2008. *Integrated assessment of wetland services and values as a tool to analyse policy trade-offs and management options: A case study in the Daly and Mary River catchments, northern Australia*. Supervising Scientist Report 198, Supervising Scientist, Darwin NT.

The Supervising Scientist is part of the Australian Government Department of the Environment, Water, Heritage and the Arts.

Supervising Scientist
Department of the Environment, Water, Heritage and the Arts
GPO Box 461, Darwin NT 0801 Australia

ISSN 1325-1554

ISBN-13: 978-1-921069-09-3

ISBN-10: 1-921069-09-0

Printed and bound in Darwin by uniprint NT

Contents

Tables

Figures

Preface

This project was initiated in 2003 by Max Finlayson (***eriss***) and Rudolf de Groot (Wageningen University), based on their input into the Millennium Ecosystem Assessment (www.MAweb.org) and as a component of the Tropical Rivers Inventory and Assessment Project (TRIAP) – an initiative of Land & Water Australia and the National Heritage Trust as part of the (Australian) National Rivers Consortium. The research was carried out between May 2004 and May 2005 by six MSc students from the Environmental Systems Analysis Group, Wageningen University, The Netherlands: Sophie Bachet and Clement Mabire (France), Pujan Shrestha (Nepal), Bas Verschuuren and Olga Ypma (The Netherlands) and Matt Zylstra (Australia).

The project was supported by the National Centre for Tropical Wetland Research (NCTWR) with specific input from researchers from the Environmental Research Institute of the Supervising Scientist (***eriss***) and the Australian Centre for Tropical Freshwater Research (ACTFR). Logistical and personnel support for the fieldwork in the Northern Territory, Australia, was provided by ***eriss*** in Darwin and Jabiru.

We gratefully acknowledge the valuable assistance provided by ***eriss*** staff, Dr Peter Bayliss, Maria Grazia Bellio, Caroline Camilleri, Dr Rick van Dam, Don Elphick, John Lowry and Joan Mount, as well as Alicia Hogan and Claudia Sauerland for providing accommodation. We would also like to extend our thanks to all staff from ***eriss*** who regularly and willingly assisted in various capacities and welcomed the research group into the organisation.

We want to especially thank Emma Woodward for her daily supervision and support during the fieldwork between July and October 2004. Emma's enthusiasm and commitment to the role of project coordinator in smoothing logistics, identifying research avenues as well as providing useful perspectives and valuable assistance in understanding both the background and newly acquired information in the context of the ecological and social situation in the Northern Territory was much appreciated.

In Wageningen, The Netherlands, we want to thank Mishka Stuip for the considerable time invested in project coordination during the preparation phases.

Finally, we would like to sincerely thank the 50 or more interviewees (or 'stakeholders') including government employees, academics, community members and landholders who selflessly gave their time and patience in assisting our understanding of the issues and the values individuals attach to the wetlands in the Northern Territory. Their input was essential to the outcomes of this research.

Note on stakeholder quotes

Unless otherwise stated, all references to personal communication throughout the report were received during stakeholder interviews undertaken between July–October 2004. Many interviewees expressed a desire for their comments to remain as anonymous statements unless permission was sought in advance to use them otherwise. Therefore, due to limitations in recontacting interviewees, all quotes used respect these wishes and have been kept anonymous for this report. A database of all interviews is retained on a confidential basis by the author(s); therefore, queries regarding the use of statements or the accuracy of statements themselves should be directed to the author via the correspondence email address provided on the title pages.

Abbreviations and acronyms

AAPA	Aboriginal Areas Protection Authority
AFANT	Amateur Fishermens Association of the Northern Territory
CVM	Contingent Valuation Method
DBE	Department of Business and Employment
DIPE	Department of Infrastructure, Planning and Environment
DPSIR	Driving Forces (D), Pressures (P), State (S), Impacts (I) and Responses (R)
DRCRG	Daly River Community Reference Group
DRDPIFR	Department of Regional Development, Primary Industry, Fisheries and Resources
GPP	Gross Primary Productivity
INRM	Integrated Natural Resources Management
IUCN	International Union for Nature Conservation
KHA	Katherine Horticultural Association
MRCAC	Mary River Catchment Advisory Committee
NPP	Net Primary Productivity
NRETAS	Department of Natural Resources, Environment, the Arts and Sport
NTBIC	Northern Territory Buffalo Industry Council
NTCA	Northern Territory Cattlemen's Association
NTHA	Northern Territory Horticultural Association
TEV	Total Economic Value

Summary

In this report we present the results of a study carried out between May 2004 and May 2005 as a contribution to the Tropical Rivers Inventory and Assessment Project (TRIAP) of Australia's Tropical Rivers Program. The aim was to provide a framework for the analysis of the ecosystem services provided by the wetland and riverine ecosystems of northern Australia. The analyses drew heavily on the conceptual framework provided by the Millennium Ecosystem Assessment (MA) where ecosystem services were defined as 'the benefits people obtain from ecosystems'. These benefits include: *provisioning services* such as food and water; *regulating services* such as flood and disease control; *cultural services* such as spiritual, recreational, and cultural benefits; and *supporting services* such as nutrient cycling that maintain the conditions for life on earth. The term 'ecosystem services' is now broadly used to encompass what can also be referred to as ecosystem goods and services and/or ecosystem functions and, at times, also environmental services. For the purposes of this report – given that the study was undertaken using the recognised 'function analysis framework' – the terms ecosystem *services* and *functions* are considered to be interchangeable unless a distinction is made otherwise.

In accordance with the above, an assessment of the ecosystem services and values (ecological, socio-cultural and economic) of selected wetlands in northern Australia (with a focus on the Daly and Mary River catchments) was undertaken and the results incorporated into a practical framework and guidelines for integrated assessment and valuation of wetland services. Relevant policies and management strategies that address wetland functions and services in the Daly and Mary River catchments were analysed and trade-offs that contributed to the development of options for the sustainable 'multi-functional use' of the wetlands highlighted.

The assessment entailed consultation and active involvement with many stakeholders, such as governmental organisations, local associations and corporations, NGOs and community-based groups, and land-owners and managers to collect information and incorporate their views and respective interests. As this was a pilot study, the level of focus was primarily at the institutional level; more interviews would be needed to sufficiently quantify results on an individual basis, for example, for farming or Aboriginal communities. The benefits of this approach were multiple in that it enabled the collation and analysis of existing information that could be used to support existing conservation, natural resource management, and social initiatives within the study areas and identified information gaps. In this respect it was based on the outcomes and approaches suggested in the Millennium Ecosystem Assessment for undertaking social and ecosystem-based analyses in complex systems.

Results and conclusions

The following section provides an overview of the main results obtained through the application of the integrated assessment approach in the Daly and Mary River case studies.

1 Main ecosystem services

Many ecosystem services derived from or provided by the wetlands were identified. The main services provided by the wetlands were: (1) *Provisioning services*: 1a) Carrier functions, including use of (wetland) space for, amongst other activities, agriculture (cattle, buffalo), horticulture, crocodile farming, aquaculture, and mining (eg sand, gold); 1b) Production functions: harvesting natural resources such as food (eg bush tucker), commercial and

subsistence fishing, medicinal resources, raw materials, and ornamental resources (eg wood and leaves for handicraft); (2) *Supporting services*: including the provision of important habitat for wildlife and nursery areas for many taxa as well as soil formation and retention; (3) *Regulating services*: covering the critical role of ecological and biophysical processes such as climate regulation, water supply (for flora, fauna and human use), regulating runoff, erosion control, disturbance prevention, nutrient regulation and waste treatment (water quality regulation), and biological control; (4) *Cultural and amenity services*: including important non-material benefits such as aesthetic information, recreation and tourism (boating, fishing, wildlife viewing, etc), spiritual and historic information, cultural and artistic information, and use in science and education.

It was established that local communities and other stakeholders were highly dependent on Northern Territory wetlands in many ways. As it was not possible to deal equally with all the ecosystem services identified, especially those in the regulation category, these (such as climate and nutrient regulation) have not been discussed further.

2 Ecological importance (value)

Both the Daly and Mary River catchments possess many wetlands of national importance that provide essential habitat for rare and endemic species, eg the freshwater whipray *(Himantura chaophyra),* bull shark *(Carcharhinus leucas)* and bamboo (*Bambusa arnhemica)*, and provide seasonal habitat refuge for many residential and migratory species, including birds such as the little curlew (*Numenius minutus)* and the magpie goose (*Anseranas semipalmata*), and fish such as the barramundi (*Lates calcarifer)*. The wetlands experience a markedly seasonal climate and flooding/drying regime and are extremely productive and support many plants and animals. The ecological value of the wetlands would qualify them for listing as 'internationally important' under the Ramsar Convention on Wetlands, as has occurred for the wetlands in nearby Kakadu National Park.

3 Socio-cultural importance (value)

Human well-being and wetland ecosystems are inextricably connected through non-material and anthropocentric values and many stakeholders attach socio-cultural importance to the wetlands in the Northern Territory. In this study, a typology was developed to identify socio-cultural values, including cultural heritage, spiritual and existence values, inspiration and expression, knowledge, sense of place, aesthetic quality and recreation.

4 Economic importance (value)

The current economic benefits provided by the main identified ecosystem services have been estimated at A$50.7 million for the Mary River catchment (approx A$450/ha) and A$82.4 million for the Daly River catchment (approx A$230/ha). These are relatively low figures compared to values found in literature for wetlands which on average are estimated at US$3000 (approx A$4000)[1] per ha/year or more. This was due to several factors: (a) monetary values were estimated for only 10 of 27 possible ecosystem services, (b) only net-values have been used (gross values, including effects on labour and capital investments would be at least five times higher); and (c) in case several values were found for one service, the lowest figure was used. The four economically most important ecosystem services identified and estimated were: carbon sequestration: A$87 million (based on expressed

[1] Using an exchange rate of 1 Australian dollar = 0.75 US dollars for the period of the study (2004/2005).

willingness to pay preferences); water use: A$46 million (potential consumer surplus based on licensed consumption), agriculture/horticulture: A$26.5 million (producer surplus based on net benefit), and tourism: A$21 million (producer surplus based on visitor expenditures). Taking into account the conservative approach used during the valuation process, it can be safely stated that the true contribution of wetland services to the local community and the regional economy is much higher than the values shown.

5 Trade-offs and competing interests

The economic values are based on assumed sustainable use levels and depend on the maintenance of the integrity of the wetlands. Since most ecosystem services are interdependent, maximising one service (eg pastoralism, mining, nature conservation) in isolation will most likely lead to the loss or reduced availability of others (eg fishing, recreation, cultural services). As a complete cost-benefit analysis would be necessary to ensure informed decision-making, the ecosystem services analysis framework was used to assess which services were utilised by which individuals or organisations and to what extent this led to competing interests. For example, regarding water supply, diverse stakeholders have competing interests. Some would prefer to see irrigation for agriculture given priority while others seek the maintenance of environmental and cultural 'flows' (eg protection of culturally significant sites that are at risk of being disturbed or damaged should there be a drop in the water table of the Daly River). Additionally, there is continued debate as to what extent any of the related economic, environmental or cultural values can be 'traded-off'; the framework can be used to assess potential trade-off scenarios such as those mentioned above.

6 Policy analysis

The policy analysis highlights both the sectoral and integrated effect of policies and institutions on the wetland services as well as providing a base for assessing consistency in policy. The analysis provided a broad picture of factors and conditions (in terms of policies, institutions and stakeholders) affecting the use of wetland services. The study indicated discrepancies between higher-level strategies and management practices that can help to make choices and set priorities for important management issues.

7 Management implications

Assessing the implications of the ecosystem services approach for wetland management and planning requires synthesising the results of all components of the integrated framework (ie identifying and valuing wetland services and values, stakeholder interests and conflicts over services, and policy and institutional contexts). A key implication for management is that by explicitly stating the functions and values of wetland ecosystems and identifying where benefits are likely to accrue, it provides justification for specific management actions and proposals. By highlighting potential trade-offs, the decision-making process can become more transparent and encourage consensus and communication between stakeholder representatives and government agencies.

The integrated assessment also emphasises the need to manage in a precautionary and adaptive manner as well as effectively acknowledging the importance of the values that stakeholders attach to various ecosystem services. Differences in perception about the importance of management issues are related to the contrasting values stakeholders attach to wetland services – expressed or implied – and which may or may not be reflected in management plans. Generally, wetland services in each catchment were addressed by

focusing efforts on mitigating a priority issue; for example, the control or reduction of weed infestations due to concerns over impacts on agricultural productivity and biodiversity (eg in the Mary River catchment), or the retention of culturally important activities, such as the customary harvest of wetland resources (eg in the Daly River catchment).

Recommendations

1 Greater in-depth analysis of services and values

This pilot study provided an overview and framework for the analysis of wetlands services and values, but more quantitative data is needed on the individual services. In future studies, it would be useful to focus in more detail on a more restricted geographical area, eg sub-catchment level, rather than the two large catchments included in this study. This would make it more feasible to assess the perceptions of stakeholders at a more specific level (eg through questionnaires) and to provide more reliable locally-relevant data for decision makers. A balance between the interests and perceptions of individual stakeholders and institutional interest in managing across catchments or other large-scale land units may need to be considered.

Future research would also benefit from a more sequential application of the framework; that is, research for the individual components of the framework is arranged to allow steps relating to trade-off analysis and management implications to be synthesised and analysed on the basis of the results obtained in the earlier ecosystem services identification and valuation steps.

2 Spatial analysis of ecosystem services to allow assessment of trade-offs in multi-functional use

Follow-up work should attempt to obtain better insight into the spatial distribution of the wetland services in order to allow more in-depth analysis of the possibilities and constraints for multi-functional use of the catchments. Ideally, a decision-support system should be developed to optimise trade-offs between conservation and (sustainable) use of wetland services, linking public participation (eg organisation of workshops or other forms of stakeholder involvement in the valuation and trade-off analysis) with geographical information (mapping) tools.

3 More focused policy analysis

The present research has been able to provide a broad overview and baseline information particularly in representing the existing institutions, policies and stakeholders, and has identified the institutions responsible for the management of wetlands in the research areas, list of policies associated with the functions and their interactions, and the existing extent of stakeholders' involvement in the catchment management. More detailed analysis is needed of individual issues or selected ecosystem services, or individual categories of policies to see how these affect and/or are affected by different factors at different scales (local scale, regional scale, national scale etc).

4 Indicators for integrated management

The importance of indicators (ecological, socio-cultural and economic) cannot be under-estimated for integrated assessment. Whilst the value of indicators for adaptive management is recognised, there are few guidelines or case studies on how to identify and apply them. A more detailed analysis should aim to identify indicators for integrated natural resource management and link these to potential indicators for ecosystem services.

1 Introduction

1.1 Background and problem statement

Wetland ecosystems provide many resources and services and are of great ecological and socio-cultural importance. As one of earth's most productive ecosystems, they directly and indirectly support millions of people by providing services (such as food and raw materials, flood control, erosion-prevention, water filtration, scenic beauty and recreational benefits) (Stuip et al 2002, Finlayson et al 2005a). The Millennium Ecosystem Assessment (MA) estimates conservatively that wetlands cover 7% of the earth's surface and deliver 45% of the world's natural productivity and ecosystem services of which the benefits are estimated at US$15 trillion a year (Finlayson et al 2005a).

Despite these benefits, the 'full value' of wetland functions is often ignored in policy-making, environmental management plans and corporate evaluations of development projects. This leads to unnecessary ecological damage, social problems and a waste of financial resources, which is now belatedly recognised through analysis of expensive wetland restoration actions (Finlayson et al 2005a). As a result of the failure to account fully for the multiple values of wetlands, including ecosystem services alongside the biodiversity values that have often been promoted, it has been speculated that around half of the earth's wetlands may already have been lost (Finlayson et al 2005a).

To ensure informed decision-making regarding the conservation and sustainable use of ecosystems, more and better information is needed on ecosystems and the full ecological, socio-cultural and economic values of the services they provide (eg Costanza et al 1997, de Groot et al 2002). Increasingly, scientific studies are showing that multi-functional sustainable use of ecosystems is, in most cases, economically more beneficial than non-sustainable, single purpose use if all services are taken fully into account (Balmford et al 2002). The applicability of these concepts in the Northern Territory of Australia is explored further in the analyses and discussion below. The benefits of this approach were multiple in that it enabled the collation and analysis of existing information that could be used to support existing conservation, natural resource management, and social initiatives within the study areas and identified information gaps. In this respect it was based on the outcomes and approaches suggested in the Millennium Ecosystem Assessment for undertaking social and ecosystem-based analyses in complex systems.

Wetland issues in the Northern Territory

Although the wetlands of northern Australia (such as those in the Daly and Mary River catchments) are widely recognised for their ecological value, the areas are increasingly under pressure from a range of issues such as water extraction, alien species, changing fire regimes and associated threats from current land-use activities, or potential intensification of development (Storrs & Finlayson 1997). Whilst the wetlands are not as disturbed as many of those in southern Australia, they cannot be considered pristine given the extent of, for example, invasion by weeds and feral animals and changes in the fire regime (Finlayson et al 2005b).

Emerging threats to these wetlands include the potential impacts of climate change (including increased saltwater intrusion into vulnerable freshwater ecosystems (Bayliss et al 1997; Finlayson et al 2005b) and managing the impact of soil erosion on wetlands as a result of, for example, recreational access to sensitive areas or increasing grazing pressure at waterholes

(Storrs & Finlayson 1997, LCNT 2005). The ability to respond effectively to such threats requires sufficient baseline (or reference condition) knowledge to enable informed and transparent decision-making supported by local capacity and resources (Finlayson et al 1999). At the same time, critical knowledge gaps exist within many management regimes across northern Australia (Finlayson et al 2005b).

Over the past few decades, there have been major changes in land tenure with more land coming under Aboriginal ownership and management. The successful and rapidly growing 'Caring for Country' movement is revitalising the traditional relationship between the cultural values and land management strategies of Aboriginal people on Aboriginal owned lands. This includes increasing possibilities for participation of Aboriginal people in wetland management (Storrs 2001, Jackson et al 2005). With some exemptions, it is recognised that traditional knowledge held by indigenous communities may be being lost (Jackson et al 2005) and the extent of interaction between scientists and local communties could be beneficially increased (Finlayson et al 1999). Further, convergences between the knowledge held by Aboriginal and non-Aboriginal people, and even between various non-Aboriginal sectors, are not seemingly being optimised and hence the overall knowledge and benefits are not being maximised (Finlayson et al 1999, 2005b). Despite this situation, increased convergence of knowledge is anticipated as further assessment of ecological and social interactions occurs across northern Australia. For example, the implementation of integrated natural resource management plans, such as that being implemented in the Northern Territory (www.nrm.gov.au/nrm/nt.html and www.nrmbnt.org.au/inrm_plan.shtml, accessed on 8 January 2008), as well as the Tropical Rivers and Coastal Knowledge initiative (www.track.gov.au, accessed on 8 January 2008) and the Southern Gulf Environmental Information Program (www.actfr.jcu.edu.au/Projects/sgeip/Reports.htm, accessed on 8 January 2008), and activities through cooperative alliances such as the Northern Australian Indigenous Land and Sea Management Alliance (www.nailsma.org.au/, accessed 8 January 2008).

Despite the fact that the above-mentioned issues are increasingly recognised, it is acknowledged that insufficent progress is being made in tackling them effectively. However, managing them is difficult due to a number of complex factors. Firstly, they are not 'stand-alone' issues, but inter-related where the severity of one will often ultimately affect the potential to mitigate another. Secondly, changes in land-use or activity – which are often tied to regional development aims or institutional processes – can exaggerate the severity of priority issues. Thirdly, many of these issues are most severe in remote, lowly populated or under-resourced landscapes. Finally, there are differing perspectives on the relative importance of management issues and why some issues should be considered a priority over others. These differences are related to the values and benefits stakeholders attach – expressed or implied – to specific services provided by wetlands and also by the ability of local communities to attract sufficient resources to support management responses (Finlayson et al 1999).

Towards solutions

The tropical rivers, floodplains, wetlands and estuaries of northern Australia are still relatively undeveloped compared to those of other regions in Australia, and there is increased interest in finding opportunities to productively develop land and water resources while still protecting downstream users and (wetland) areas of high conservation value (Land & Water Australia 2004, PWCNT 2000, Gehrke et al 2004). The Board of Land & Water Australia therefore initiated a Tropical Rivers Program with the aim to '…undertake research and knowledge exchange to support the sustainable use, protection and management of Australia´s Tropical Rivers' (Land & Water Australia 2004). The Tropical Rivers Inventory and Assessment

Project (TRIAP) aims to address these issues through an initial integrated data assessment and analysis of Australia's tropical rivers with three distinct research projects:

1 A multiple-scale inventory of the habitats and biota of the rivers and wetlands of tropical Australia, where necessary developing suitable classification of aquatic ecosystems;

2 A risk assessment of the major pressures on the habitats and biota of the rivers and wetlands of tropical Australia;

3 A framework for analysis of the ecosystem services provided by the habitats and biota of the rivers and wetlands of northern Australia.

This report deals with the last sub-project and is intended as a pilot study to ascertain the robustness of a framework developed elsewhere (de Groot et al 2002), and to also consider the extent of data and information available for analysis and for providing guidance for managers and policy.

1.2 Research issues and objectives

The fieldwork for this investigation (July – October 2004) was mainly carried out in the Daly and Mary River catchments (Figure 1) which include Australia´s largest seasonal wetlands still largely unaffected by river regulation or other substantial structural or hydrological modification (eg water extraction or agricultural development) (Storrs & Finlayson 1997). In addition, further information was collected at Kunbarllanjnja (also known as Oenpelli) in the catchment of the East Alligator River and was used to support the research, especially that for the cultural valuation, stakeholder analysis and subsequent management implications.

The main objectives of the research project were:

1 To develop a practical framework and guidelines for integrated assessment and valuation of wetland services;

2 To undertake an initial analysis of the services and their values (ecological, socio-cultural and economic);

3 To investigate trade-offs between land use options and policies affecting wetland services (incorporating the views and interests of the main stakeholders); and

4 To explore options with stakeholders for collaborative management and structural financing for the conservation and sustainable use of the ecosystem services in the region.

It was not intended to undertake a comprehensive integrated analysis; whilst desirable this was beyond the scope of the investigation as it would require considerable further data collation and collection. The analysis undertaken was done to test and refine the framework and where possible provide available data and an initial analysis to support initial policy recommendations. The latter was also based on the comprehensive analyses and outcomes presented in the Millennium Ecosystem Assessment.

1.3 Integrated assessment approach/framework

As a starting point, a framework based on that developed by de Groot et al (2002) (Figure 1) was adapted and implemented through six sub-components (Table 1).

Table 1 Sub-components in the analysis of ecosystem services and values of the Daly and Mary River wetlands

Sub-project	Working title*	Author	Chapter no
1	Function analysis and ecological valuation	Sophie Bachet	3 + 4
2	Socio-cultural importance of wetlands	Bas Verschuuren	5
3	Economic importance of the wetlands	Clement Mabire	6
4	Integrated assessment of stakeholder interests and trade-offs between wetland uses	Olga Ypma	7
5	Policy analysis and institutional aspects	Pujan Shrestha	8
6	Implications of an integrated ecosystem assessment for wetland management and planning	Matthew Zylstra	9

* All six sub-projects resulted in a separate Master's thesis report (see references) as well as a summary report for stakeholders (Ypma & Zylstra 2006)

The research comprised a literature review (policy and management documents and research publications) and interviews with individuals and representatives from the local community, government, industry and research organisations.

1.4 Study areas: the Daly and Mary River catchments

The study focused on the Daly and Mary River catchments with a smaller amount of effort in the Kunbarllanjnja region (Figure 1) within the Northern Territory. The catchments of the Daly and the Mary Rivers are shown; As the Kunbarlanjnja region is a subset of the catchment of the East Alligator River and is less formally defined its general position only is shown in Figure 1.

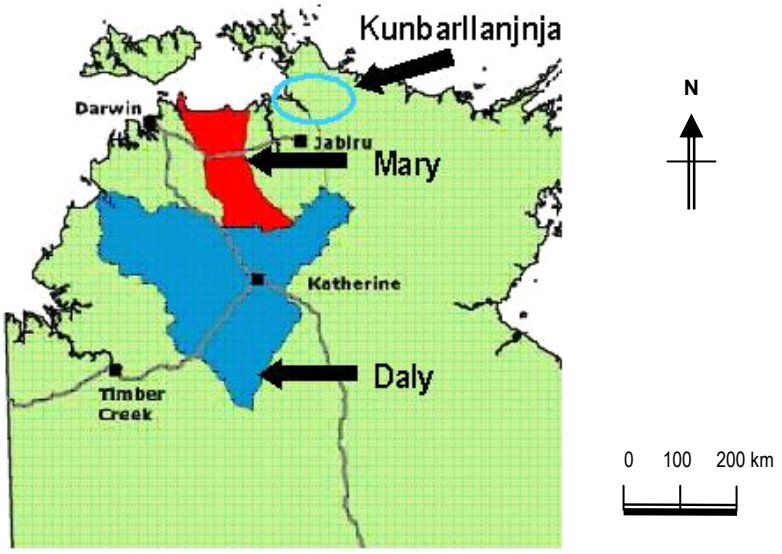

Figure 1 Location of the study areas

The Daly River catchment covers an area of 52 600 km^2 (Kennedy 2004), the Mary River 8062 km^2 (McInnes 2003) and Kunbarllanjnja 530 km^2 on the East Alligator River. The Mary River catchment and Kunbarllanjnja border Kakadu National Park which is listed as a Ramsar wetland of international importance and as a UNESCO World Heritage Site for its cultural and natural values (Finlayson & von Oertzen 1996). As these tropical rivers, floodplains, wetlands and estuaries have remained relatively undeveloped compared to those of other

regions in Australia, there is increased interest in finding opportunities to productively develop the land and water resources. At the same time many of these wetlands are considered to be essential for maintaining viable populations of many plant and animal species and have become to be seen as 'cultural icons' and an important part of the 'Northern Territory experience'.

The contrasting land-uses, activities and management objectives found within the research areas allows for the function analysis approach to be tested across three distinct areas where wetlands are utilised and valued for different reasons and where multi-functional outcomes provide a different mix of land-uses across all areas.

The Mary River has been subject to large-scale pastoral development and its hydrology and aquatic systems have been altered by the construction of barrages (physical obstructions placed across the river and on its floodplains) in order to mitigate saltwater intrusion (DIPE 2003c; Applegate 1999). There is an active management regime in the catchment with 'more or less precisely stated objectives' (Stakeholder pers comm, 2004); however, it has few actively represented indigenous interests remaining with those that remain having relatively loose connections with the land (Stakeholder pers comm, 2004). Wetlands in the catchment are primarily valued for their contribution to economic productivity through pastoralism, recreational and commercial fishing, tourism and sand mining; Whitehead et al (1992) points out their high biological value.

In contrast, the Daly River catchment remains largely unmodified with relatively pristine aquatic ecosystems. The wetlands in this catchment face pressure primarily from cattle grazing and the impacts of proposed intensification of agricultural development and the effect this would have on (ground) water use. There are significant indigenous interests with resident Aboriginal clans having strong cultural connections to the land. Similar to the Mary River, the Daly River is valued for its excellent recreational fishing potential; however, there is a broader societal attachment to the Daly River for its pristine beauty and conservation value. Wetlands in the Daly River region are primarily valued for their importance to the recreational fishing industry, tourism and horticulture as well as the central role they play in sustaining the well-being of Aboriginal communities in the region. The Daly River catchment was selected as a research area due to the ongoing interest (at a Northern Territory jurisdictional level) in developing and implementing a regional land-use plan for the region.

The Kunbarllanjnja floodplains in the East Alligator catchment in West Arnhem Land provide another contrast. Kunbarllanjnja is an Aboriginal community on formally recognised Aboriginal land and with strong cultural connections with the wetlands and the customary use of these areas. The floodplains traditionally deliver specific ecosystem services to the local community and contribute to a large customary economy. This customary economy is partly supported by the national social welfare system and by mining royalties (from the nearby Ranger uranium mine), but due to remoteness from Darwin (the provincial capital and main population centre) and inherent logistical difficulties it is largely dependent on core resources derived from the nearby wetlands (Stakeholder pers comm, 2004). Wetland management primarily focuses on mitigating threats (such as weeds and fire).

1.5 Research area delineations

The research areas are seen to be characterised by the fact that there are 'bits of information on all, but nothing complete on any of them' (Stakeholder pers comm, 2004). Additionally, the absence of an effective planning framework (as of 2004) to integrate local and adjacent interests and perspectives is common to all three areas.

Within the chosen catchments, the research focused on wetlands (according to the Ramsar definition) in the Daly River and Mary River catchments and the immediate floodplains surrounding Kunbarllanjnja.

The focus in the *Mary River catchment* was on the wetlands in the lower catchment covering 1126 km^2 or 14% of the total catchment), but taken within a catchment perspective.

Within the *Daly River catchment*, the situation is complicated by a number of sub-boundaries (natural and jurisdictional) existing within the catchment. The Daly River catchment refers to the whole catchment area including the Katherine, Fergusson, Fish and Douglas (River) tributaries and which reaches up to the Arnhem Land plateau and north to the mouth of the Daly River. The sub-catchment areas of significance within the Daly River catchment include: the Daly basin bioregion as a hydrologically defined area; the 'Daly Region' as a jurisdictional demarcation made for the Regional Land Use Plan being considered by the Daly Region Community Reference Group (DRCRG); and the Lower Daly as the area considered to be the lower half of the Daly River catchment and including the Daly River and Naiuyu communities – not part of the Daly basin, but included in the Daly Region. The largest township in the Daly River catchment, Katherine, falls within the Daly basin, but has not been included in the Daly Region. This complexity created some difficulty in applying an integrated catchment management approach; however, for the purposes of this research the primary focus was on wetland areas in the Daly basin (as identified in research undertaken by Begg et al 2001) and areas covered by the 'Daly Region' (as identified by the DRCRG) but which are not already included within the Daly basin (eg such as the Lower Daly). The total area included in the study thus amounted to 3582 km^2 (7% of the total catchment).

The Kunbarllanjnja catchment was not treated as a separate case study, but was included for analysing some of the cultural services provided by ecosystems as well as obtaining a greater appreciation of at least some of the important aspects of Aboriginal land management in more detail.

2 Framework and guidelines for integrated assessment of wetland services and values

A conceptual framework was used to systematically analyse wetland services, their values and potential trade-offs associated with their use. The main elements of the framework are shown in Figure 2 and described below.

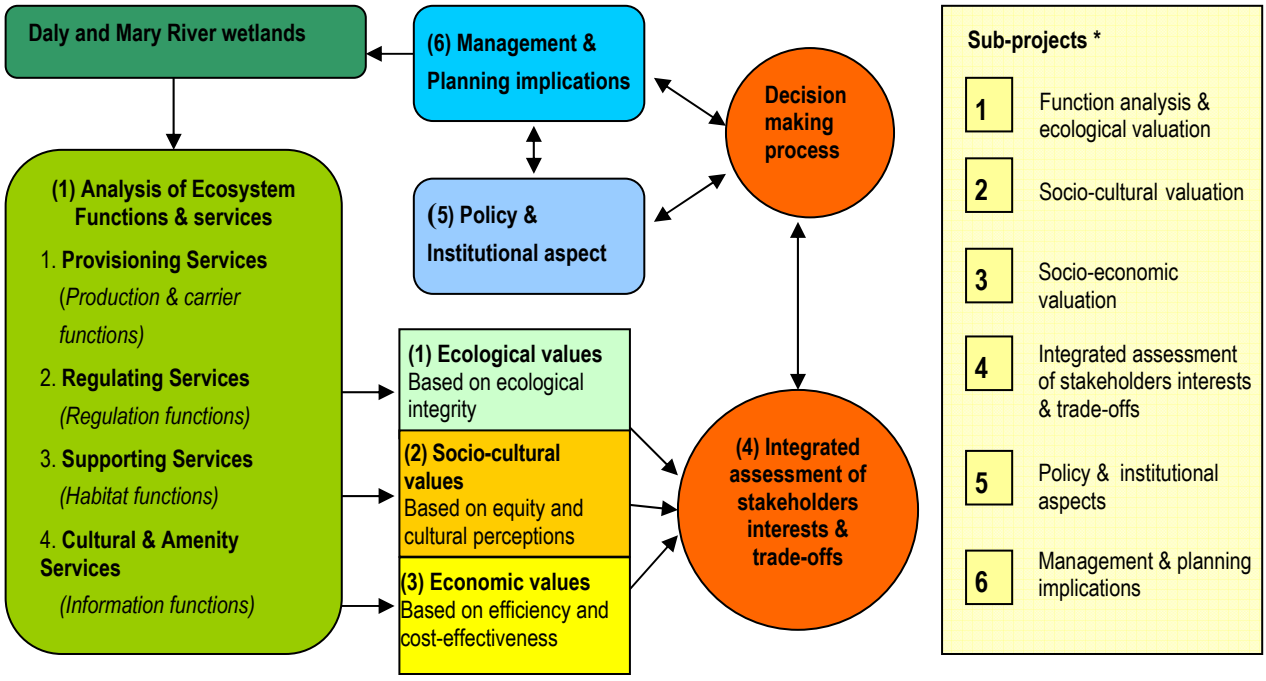

Figure 2 Conceptual framework for integrated assessment of wetland functions, values and trade-offs (adapted from de Groot et al 2002)

2.1 Function analysis: inventory of wetland services

In this step, wetland characteristics (processes and components) are translated into functions that provide specific services. These services are then quantified in appropriate units (biophysical or otherwise) to determine their value (importance) to human society based on actual or potential sustainable use levels.

2.1.1 Identification and selection of wetland services

Wetlands are composed of a number of physical, biological and chemical components such as soil, water, plant and animal species and nutrients. Interactions among and within these allow the wetlands to perform certain functions valuable to human well-being. Ecosystem functions have been defined as 'the capacity of ecosystem processes and components to provide goods and services that satisfy human needs, directly or indirectly' (de Groot 1992, de Groot et al 2002). According to the MA, ecosystem services are 'the benefits people obtain from ecosystems' whereby services are defined broadly and include both goods (ie resources) and services in the more narrow sense (ie benefits from ecosystem processes and non-material uses). Table 2 gives a generic typology of ecosystem services, noting that these may also be referred to as functions or goods and services.

Table 2 Typology of ecosystem functions, goods and services

Ecosystem functions			Description	Goods and services (types and examples)
1	Provisioning services	*Production functions*	Naturally produced, renewable resources	Food (eg fish, bushmeat)
				Freshwater
				Fibre, fuel and other raw materials (wood, fodder, etc)
				Biochemicals and medicinal resources
				Genetic material
				Ornamental resources
		Carrier functions	Artificial supply of resources and/or use of space for human activities	Cultivation (including aquaculture)
				Energy conversion (eg wind, solar)
				Mining (ore, fossil fuels, etc)
				Transportation (especially on waterways)
				Other spatial uses
2	Regulating services *(Regulation functions)*		Direct benefits from ecosystem processes	Air quality regulation
				Climate regulation (eg Carbon-sequestration)
				Watershed protection (water storage and gradual release)
				Erosion prevention
				Natural hazard mitigation (flood control and coastal protection)
				Waste treatment (eg air- and water purification)
				Biological control (of pests and diseases)
				Other regulating ecosystem processes
3	Supporting services *(Habitat functions)*		Life support services - indirect benefits from ecosystem processes; pre-conditional for most other services	Habitat for wildlife (maintenance of biodiversity and evolutionary processes)
				Nursery habitat (reproduction habitat for commercially used, or potentially useful, species)
				Maintenance of the nutrient-balance (at different scale levels)
				Soil formation
				Other life support services
4	Cultural & amenity services *(Information functions)*		Non-material benefits	Aesthetic information (enjoyment of scenery through scenic roads, housing-locations, etc)
				Recreation and eco-tourism
				Cultural heritage and identity
				Spiritual and religious experiences
				Inspiration and expression(eg as motive in books, film, painting, folklore, national symbols, architecture, advertising, etc
				Health & therapeutic value: effects of nature on human psyche and physical health effects on or relationship between people and ecosystems
				Sense of place: natural sites that link people to their landscape
				Knowledge (use of ecosystems for knowledge-building (eg in education (school excursions) and formal and informal research)

Depending on the purpose of the valuation, the stakeholders and their interests, and the ecological and socio-economic setting, different services will be relevant in the assessment and valuation process. The first step in this part of the assessment is to develop a checklist of the main services. Depending on the complexity of the wetland being valued, the services should be described for each of the main ecosystem types (eg river, lake, marsh etc) and, if possible, supported by maps to show the spatial distribution of the service. The selection of services to be included in the valuation process should be done in close consultation with the main stakeholders.

2.1.2 Quantification of the capacity of wetlands to provide services

Once the main services have been selected, the (actual and potential) capacity of the ecosystem to provide these services should be determined. The capacity of ecosystems to provide services depends on the biotic and abiotic characteristics which should be quantified with ecological, biophysical or other appropriate indicators. For example, the capacity of wetlands to provide fish can be measured by maximum sustainable harvest levels (in terms of biomass or another unit), the capacity to store water by hydrological parameters (eg water volume, flow velocity etc) and the capacity for recreational use by aesthetic quality indicators and carrying capacity for visitor numbers (Appendix I). As most functions and related ecosystem processes are inter-linked, sustainable use levels should be determined under complex system conditions taking due account of the dynamic interactions between functions, values and processes (De Groot et al 2002).

2.2 Valuation of wetland services

2.2.1 Total value and types of value

Once the main services have been identified and their (sustainable) availability has been quantified, the importance (value) of these services to human society can be assessed. Following the various perceptions and definitions of value and valuation (de Groot et al 2006), three main values can be defined which together determine the Total Value (or importance) of wetland services: ecological, socio-cultural and economic values (Figure 3). Each service may have different values simultaneously; for example, apart from the ecological importance of certain fish species, the same fish can be important as food or for recreational purposes, have spiritual importance as a totemic species, or have scientific importance for monitoring and benchmarking of water quality. This is true for most wetland services in the valuation process.

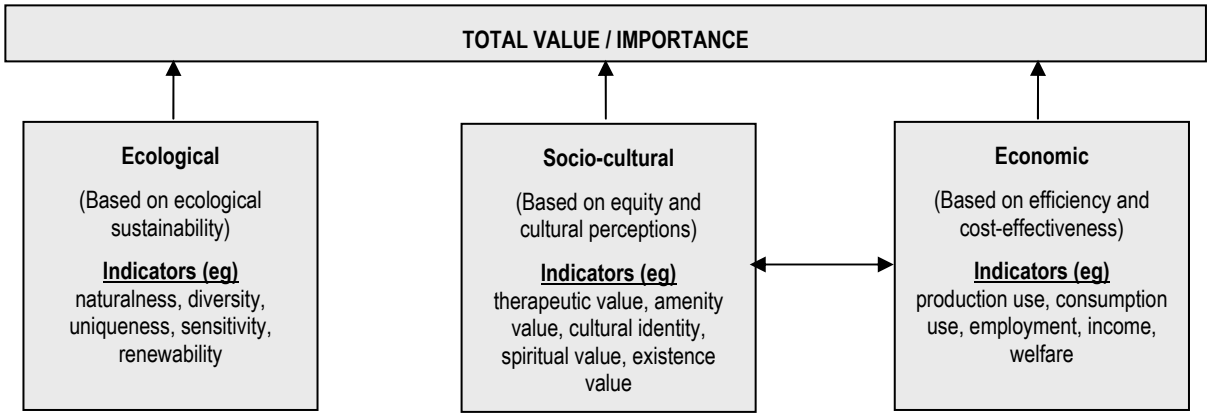

Figure 3 Types of values that can be attributed to ecosystem services

As each wetland and each decision-making situation is, strictly speaking, unique in space and time, data on these values should, to the greatest extent possible, be obtained through original research on the ecological, socio-cultural and economic indicators mentioned in Figure 3 for each decision-making situation. This is a time-consuming task, but fortunately an increasing amount of information can be found in the literature and through the internet. As the literature increases and databases become more complete and sophisticated (eg www.naturevaluation.org; http://esd.uvm.edu), a good start can be made through a desk study and application of Benefit Transfer techniques. Regardless of the methods used (field research, desk studies, internet-searches, benefit transfer), the involvement of stakeholders is important to collect and/or verify the data. An overview is provided of the main criteria and measurement units (indicators) needed to quantify the ecological, socio-cultural, economic and monetary importance of wetland services (sections 2.2.2–2.2.4).

2.2.2 Ecological valuation

The ecological importance (value) of ecosystems has been articulated by natural scientists in reference to causal relationships between parts of a system – for example, the value of a particular tree species to control erosion or the value of one species to the survival of another species or of an entire ecosystem (Farber et al 2002). At a global scale, different ecosystems and their species play different roles in the maintenance of essential life support processes (such as energy conversion, biogeochemical cycling, and evolution) (MA 2003). The magnitude of this ecological value is expressed through indicators such as species diversity, rarity, ecosystem integrity (health), and resilience, which mainly relate to the Supporting and Regulating Services. Table 3 lists the main ecological valuation criteria and associated indicators.

Table 3 Ecological valuation criteria and measurement indicators (from de Groot et al 2003)

Criteria	Short description	Measurement unit/Indicator
Naturalness/Integrity (representativeness)	Degree of human presence in terms of physical, chemical or biological disturbance	Quality of air, water, and soil
		Percentage of key species present
		Percentage of min. critical ecosystem size
Diversity	Variety of life in all its forms, including ecosystems, species & genetic diversity	Number of ecosystems/ geographical unit
		Number of species/surface area
Uniqueness/rarity	Local, national or global rarity of ecosystems and species	Number of endemic species & sub-species
Fragility/vulnerability (resilience/resistance)	Sensitivity of ecosystems to human disturbance	Energy budget (Gross Primary Productivity (GPP)/Net Primary Productivity (NPP)
		Carrying capacity
Renewability/recreatability	The possibility for (spontaneous) renewability or human aided restoration of ecosystems	Complexity and diversity
		Succession stage/-time/NPP
		Restoration costs

2.2.3 Socio-cultural valuation

For many people, natural systems including wetlands are a crucial source of non-material well-being through their influence on physical and mental health, and historical, national, ethical, religious, and spiritual values. A particular mountain, forest, or watershed may, for example, have been the site of an important event in their past, the home or shrine of a deity,

the place of a moment of moral transformation, or the embodiment of national ideals. These are some of the values that the MA recognises as the cultural services of ecosystems (MA 2003). According to Williams and Vaske (2002), this is a dimension which comes with realising that landscapes are socially produced:

> This suggests that their values are anchored in history and culture and not simply some enduring objective or visible properties. The point is not to deny the existence of a hard reality out there but to recognise that the value of that reality is continually created and recreated through social interactions and processes.

Based on literature, and the results of this study, Table 4 lists the main types of socio-cultural values and measurement units of ecosystem (wetland) services.

Table 4 Typology of socio-cultural values and measurement units*

Socio-cultural importance	Short description	Indicators – measurement units
Importance to human health	Therapeutic effects of nature on human psyche and physical health effects on or relationship between people and natural environments that create the potential for healing and enhancing physical and psychological well-being.	Suitability and capacity of the natural system to provide health services Restorative and regenerative effects on people such as decreased levels of stress and mental fatigue (restorative effects) Decreased need for health care services and medication Socio economic benefits from reduced health costs
(Cultural) Heritage	All the qualities, traditions or features of life that have been continued over many years and passed on from one generation to another, especially ones that are of historical importance or that have had a strong influence on society.	Historic sites and features Role in cultural landscapes Cultural traditions and knowledge Culturally significant species UNESCO world heritage, Man and Biosphere reserves, NHT listing, etc
Spiritual	Sacred, religious or other forms of spiritual inspiration derived from ecosystems. Importance of nature in symbols and elements with sacred and religious significance. Qualities of nature that inspire humans to relate with reverence to the sacredness of nature and differentiate cosmologies.	Presence of sacred sites or features Role of nature in religious ceremonies and sacred texts Oral tradition, song, chant & stories Totemic species, customary use of flora and fauna Traditional healing systems
Existence	Importance people attach to nature for ethical reasons (intrinsic value) and intergenerational equity (bequest value). The satisfaction derived from knowing that outstanding natural and cultural landscapes have been protected and exist as physical and conceptual spaces where all forms of life and culture are valued and held sacred.	Expressed preference for nature protection and conservation (eg through donations, voluntary work Contingent Valuation Method, CVM) Willingness to pay UNESCO world heritage, Man and Biosphere reserves, cultural landscapes etc
Recreation & tourism	Variety in landscapes with (potential) recreational uses including natural and cultural heritage. Increased health and well-being due to the restorative effects of experiences with nature and vegetation.	Capacity to provide for: eco-tourism; (recreational) nature study; cultural tourism; resource-based tourism (fishing, hunting) Presence of: scenic routes: recreational

Socio-cultural importance	Short description	Indicators – measurement units
Inspiration & expression	Ecosystems provide a rich source of inspiration for art, national symbols, architecture and advertising. Variety in natural features with cultural and artistic value. The qualities of nature that inspire human imagination in creative expression.	Use of nature as motive in books, film, painting, music Folklore, national symbols, flagship species Architecture, advertising, etc
Knowledge	Traditional knowledge, science, education and monitoring. The function of ecosystems as refuges, benchmarks and baselines that provide scientists and interested individuals with nature influenced by human change or conversion. The qualities of nature that enlighten the careful observer with respect to human relationships with the natural environment.	Traditional knowledge systems (TEK, traditional law, traditional healing systems etc) School excursions Scientific research Eco-tourism / nature education Bench marking (for flood control or vulnerability to climate change, food security etc) Monitoring (related to water watch, landcare, coast care, bush care etc)
Sense of place	People value the sense of place that is associated with recognised features of their environment, including aspects of the ecosystem. Those natural sites that link people to their landscape through myth, legend or history and form an integrated part of their identity.	Historical & heritage listed Storylines and sacred sites Sense of place studies Cohesion of family; social or cultural groups (eg through familiar or 'skin-names') Language and linguistic diversity Caring for country
Aesthetic	Preference for nature and natural elements related to the beauty of nature.	Preference for wilderness over cultivated landscapes Presence of scenic drives and routes Increased value of property in natural settings
Peace & reconciliation	Fostering regional peace and stability through cooperative management across (international) land or sea boundaries or as cultural spaces for the development of understanding between traditional and modern societies or distinct cultures.	Border crossing resource sharing Reconciliation between cultures Increased social integration Joint or co-management Border crossing resource sharing Leases of land and minerals Equitable sharing of Intellectual Property

* adapted from English & Lee 2003, de Groot et al 2002, Harmon & Putney 2003, MA 2003, Shultis 2003, Verschuuren 2006

To some extent, these values can be captured by economic valuation methods but are poorly represented by such techniques when determining the extent to which ecosystem services are essential to people's very identity and existence. An overview of methods suitable for assessing the socio-cultural importance people attach to ecosystem services is given in Table 6 (on stakeholder analysis).

Socio-cultural functions and values are delineated by public, societal and cultural preference and are hence subject to belief systems that are shaped by their own epistemologies. These cultural epistemologies act as determining factors when valuing (attaching value to) wetland services. The approach of the MA (2003) is followed in linking the benefits of ecosystem services to the concept of human well-being. Another important determinant is the concept of amenity which helps to understand how to bridge the gap between human well-being (perceived value) and the ecosystem itself. It is clear that amenity value can be attributed to almost all desirable and useful features of nature and hence to the socio-cultural importance of wetlands. Moreover, they can be regarded as desirable or useful primarily because they are the link between the ecosystem and human well-being (Figure 4).

2.2.4 Economic valuation

Some authors view socio-cultural values as a sub-set of economic values; others state that in practice economic valuation is limited to efficiency and cost-effectiveness analysis, usually measured in monetary units, disregarding the importance of, for example, spiritual values and cultural identity which are in many cases closely related to ecosystem services (de Groot & Ramakrishnan 2005). In this report, economic and monetary valuation are therefore treated separately whereby it is emphasised that ecological, socio-cultural, and economic values all have their separate role in decision making and should be seen as essentially complementary pieces of information in decision-making (Box 1).

Box 1 Uncertainties in economic valuation

There are many uncertainties regarding the accuracy of economic (monetary) values that may cause people to condemn the assessment as a whole. Moreover, economic valuation as such does not consider how people or individuals respond to resource allocations and does not regard the longer-term allocation of resources. Methods of economic valuation are static and ignore all non-linear interactions and complexities such as ecological thresholds, socio-dynamics and irreversibilities. It is therefore important to understand the limitations, caveats and pitfalls of economic valuation because when methods are inappropriate or flawed they are worse than useless; they perpetuate misunderstanding of the concept of value (Pagiola et al 2004). Klaus Töpfer (former Executive Director of UNEP) expressed it as follows: 'The value of ecosystems, landscapes, animals and plants cannot adequately be measured statistically or in merely financial terms as the values of biological, cultural and linguistic diversity are intimate to life in its entirety.' A solution can be to broaden valuation techniques to include socio-cultural and ecological aspects and balance them equally with economical aspects. When formalised, this method could become something like a decision support system. However, it is clear that numerous obstacles regarding indicators, scale and the nature of value have to be overcome before any reliable system can be developed. (Source: Verschuuren 2005).

Numerous studies have assessed the economic value of ecosystems (Barbier et al 1996, Costanza et al 1997; Daily et al 1997, and many others) and the concept of Total Economic Value (TEV) has become a widely used framework for looking at the utilitarian value of ecosystems (Figure 4). This framework typically disaggregates TEV into two categories: *use values* and *non-use values*.

Use value is composed of three elements: direct use, indirect use and option values. *Direct use value* is also known as extractive, consumptive or structural use value and mainly derives from goods that can be extracted, consumed or enjoyed directly (Dixon & Pagiola 1998).

Indirect use value is also known as non-extractive use value, or functional value and mainly derives from the services the environment provides (Dixon & Pagiola 1998). *Option value* is the value attached to maintaining the option to take advantage of the use value at a later date. Some authors also distinguish quasi option value which derives from the possibility that even though something appears unimportant now, information received later might lead us to re-evaluate it (Dixon & Pagiola 1998).

Non-use values derive from the benefits the environment may provide that do not involve using it in any way, whether directly or indirectly. In many cases, the most important such benefit is *existence value*: the value that people derive from the knowledge that something exists, even if they never plan to use it. Thus, people place value on the existence of blue whales or the panda, even if they have never seen one and probably never will. However, if blue whales became extinct, many people would feel a definite sense of loss (Dixon & Pagiola 1998). *Bequest value* is the value derived from the desire to pass on values to future generations (ie our children and grandchildren).

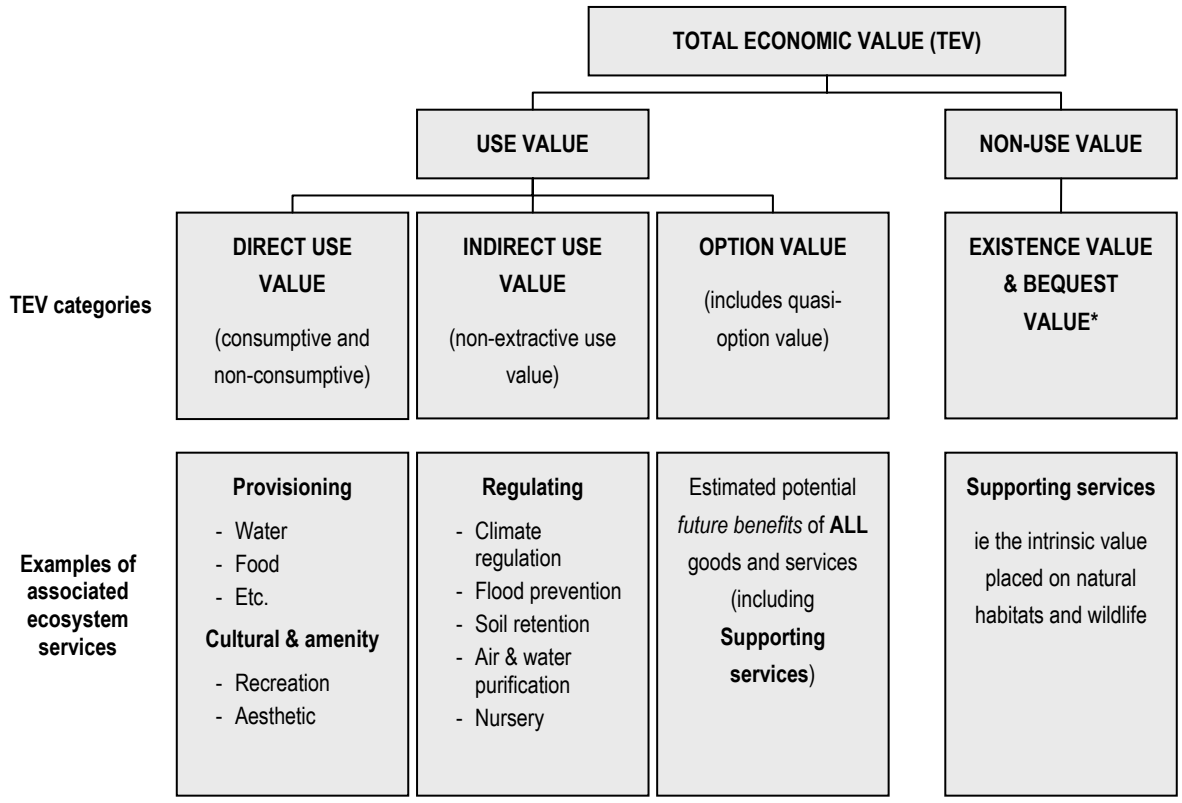

Figure 4 The total economic value framework

* Bequest value is often also shown as another kind of (future) use value

Source: adapted from MA 2003, based on Dixon & Pagiola 1998.

The economic importance of ecosystem services can be measured by their contribution to production, consumption and employment, eg in terms of number of people whose jobs are related to the use or conservation of wetland services, or the number of production units that depend on wetland services. Since both employment and productivity can be relatively easily measured through the market, this is usually quantified in monetary terms.

2.2.5 Monetary valuation

The (relative) importance people attach to many of the ecological, socio-cultural and economic values and the associated wetland services can partly be measured using money as a

common denominator. Monetary or financial valuation methods fall into three basic types, each with its own repertoire of associated measurement issues: (1) direct market valuation, (2) indirect market valuation, (3) survey-based valuation (ie contingent valuation and group valuation (see Table 5 for further details).

Table 5 Monetary valuation methods, constraints and examples*

Method		Description	Constraints	Examples
1. Direct Market Valuation	Market price	The exchange value (based on marginal productivity cost) that ecosystem services have in trade	Market imperfections and policy failures distort market prices	Mainly applicable to the 'goods' (eg fish), but also some cultural (eg recreation) and regulating services (eg pollination)
	Factor income or productivity. factor method	Measures effect of ecosystem services on loss (or gains) in earnings and/or productivity)	Care needs to be taken not to double count values	Natural water quality improvements that increase commercial fisheries catch and thereby incomes of fishers
	Public pricing	Public investments, eg land purchase, or monetary incentives (taxes/subsidies)		Investments in watershed-protection to provide drinking water, or conservation measures
2. Indirect Market Valuation	Avoided (damage) cost method	Services that allow society to avoid costs that would have been incurred in the absence of those services	It is assumed that the costs of avoided damage or substitutes match the original benefit. However, this match may not be accurate, which can lead to underestimates as well as overestimates.	The value of the flood control service can be derived from the estimated damage if flooding would occur
	Replacement cost and substitution cost	Some services could be replaced with human-made systems		The value of groundwater recharge can be estimated from the costs of obtaining water from another source (substitute costs)
	Mitigation or restoration cost	Cost of moderating effects of lost functions (or of their restoration)		Cost of preventive expenditures in absence of wetland service (eg flood barriers) or relocation
	Travel cost method	Use of ecosystem services may require travel and the associated costs can be seen as a reflection of the implied value	Over-estimates are easily made. The technique is data intensive.	Part of the recreational value of a site is reflected in the amount of time and money that people spend while travelling to the site
	Hedonic pricing method	Reflection of service demand in the prices people pay for associated marketed goods	The method only captures people's willingness to pay for perceived benefits; very data intensive	Clean air, presence of water and aesthetic views will increase the price of surrounding real estate
3. Surveys	Contingent valuation method (CVM)	This method asks people how much they would be willing to pay (or accept as compensation) for specific services through questionnaires or interviews	There are various sources of bias in the interview techniques. Also there is controversy over whether people would actually pay the amounts they state in the interviews.	It is often the only way to estimate non-use values. For example, a survey questionnaire might ask respondents to express their willingness to increase the level of water quality in a stream, lake or river so that they might enjoy activities like swimming, boating, or fishing.
	Group valuation	Same as CVM but then as interactive group process	The bias in a group CVM is supposed to be less than in individual CVM	
4. Benefit Transfer		Uses results from other, similar areas, to estimate the value of a given service in the study site	Values are site and context dependent and therefore in principle not transferable	When time to carry out original research is scarce and/or data is unavailable, Benefit Transfers can be used (but with caution).

* from Barbier et al 1996, King & Mazotta (undated), Wilson & Carpenter 1999, Stuip et al 2002

If no site-specific data can be obtained (due to lack of data, resources or time) *benefit transfer* can be applied (ie using results from other, similar areas, to approximate the value of a given service in the study site). This method is rather problematic because, strictly speaking, each decision-making situation is unique; however, the more data that become available on new case studies, the more reliable benefit transfer becomes.

Although Table 5 is based on literature sources, and reflects a broad consensus on monetary valuation methods, other views and terminologies exist. For example, Dixon and Pagiola (1998) use the term 'Change in output of marketable goods' as a combined term for Market Price and Factor Income; and they combine Avoided (damage) Cost, Replacement Cost and Mitigation Cost into so-called 'Cost Based Approaches'. A more detailed description of the monetary valuation methods in Table 5 is given below.

1 Direct market valuation:

- Market price: this is the exchange value that ecosystem services have in trade, mainly applicable to production, but also to some information (eg recreation) and regulation functions (eg water regulation services);
- Factor income (FI): many ecosystem services enhance incomes; an example is natural water quality improvements that increase commercial fisheries catch and thereby incomes of fishers;
- Public investments: New York City, for example, decided to use natural water regulation services of largely undeveloped watersheds, through purchase or easements (worth approximately US$100 million per year), to deliver safe water and avoided the construction of a US$6 billion water filtration plant. This implies those watersheds saved New York City an investment of US$6 billion and represents a Willingness To Pay (WTP) value of at least US$100 million per year (Chichilnisky & Heal 1998).

2 Indirect market valuation:

When there are no explicit markets for services, it is necessary to apply more indirect means of assessing values. A variety of valuation techniques can be used to establish the (revealed) Willingness To Pay (WTP) or Willingness To Accept compensation (WTA) for the availability or loss of these services:

- Avoided cost (AC): services that allow society to avoid costs that would have been incurred in the absence of those services. Examples are flood control (which avoids property damages) and waste treatment (which avoids health costs) by wetlands;
- Replacement cost (RC): services could be replaced with human-made systems; an example is natural waste treatment by marshes that can be (partly) replaced with costly artificial treatment systems.
- Mitigation or restoration cost: the cost of moderating effects of lost functions or of their restoration can be seen as an expression of the economic importance of the original service; for example, the cost of preventive expenditure in the absence of the wetland service (eg flood barriers).
- Travel cost (TC): use of ecosystem services may require travel. The travel costs can be seen as a reflection of the implied value of the service. An example is recreation areas that attract distant visitors whose value placed on that area must be at least what they were willing to pay to travel to it.

- Hedonic pricing (HP): service demand may be reflected in the prices people will pay for associated goods; an example is that housing prices at beaches usually exceed prices of identical inland homes near less attractive scenery.

3 Survey based valuation

- Contingent valuation (CV): service demand may be elicited by posing hypothetical scenarios that involve the description of alternatives in a social survey questionnaire. For example, a survey questionnaire might ask respondents to express their willingness-to-pay (ie their stated preference as opposed to revealed preference, see above) to increase the level of water quality in a stream, lake or river so that they might enjoy activities like swimming, boating, or fishing (Wilson & Carpenter 1999).
- Group valuation: Another approach to ecosystem service valuation that has gained increasing attention recently involves group deliberation (Blamey & James 1999; Coote & Lenaghan 1997, Sagoff 1998, Wilson & Howarth 2002). This evolving set of techniques is founded on the assumption that the valuation of ecological services should result from a process of open public deliberation, not from the aggregation of separately measured individual preferences. Using this approach, small groups of citizens are brought together in a moderated forum to deliberate about the economic value of ecosystem services. The end result is a deliberative 'group' contingent valuation (CV) process. With a group CV the explicit goal is to derive a monetary value for the ecological service in question, through group discussions and consensus building (after: MA 2003).

4 Benefit transfer

In case of human or financial resource constraints, the values of previous studies focusing on a different region or time period can sometimes be used. This practice of transferring monetary values is called 'benefit transfer'. An example is a case study done on Olango Island in the Philippines (White et al 2000), where the values for fishery – both for the local market and for life fish export – have been obtained from coral reef studies elsewhere in the Philippines. These data were combined with local data on seaweed farming and tourism (Stuip et al 2002).

As the extensive literature on monetary valuation of ecosystem services has shown, each of these methods has its strengths and weaknesses (see Farber et al 2002, Wilson & Howarth 2002). To avoid double-counting, and to make monetary valuation studies more comparable, ideally a type of 'rank ordering' should be developed to determine the most preferred monetary valuation method(s). Based on a large number of case studies, Figure 5 gives an overview of the monetary value of the main services provided by wetlands.

Figure 5 shows that the average Total Monetary Value of wetlands is estimated at US$3300 ha/year. On a global scale, the Total Economic Value of 63 million hectares of wetland around the world would, according to this table, amount to approximately US$200 billion per year (which is a conservative estimate since for many services no values were found). Costanza et al (1997) arrived at a figure of US$940 billion per year, mainly due to much higher estimates for several services (ie flood control (US$ 4539 ha/year), water treatment (US$4177 ha/year), and water supply (US$3800 ha/year).

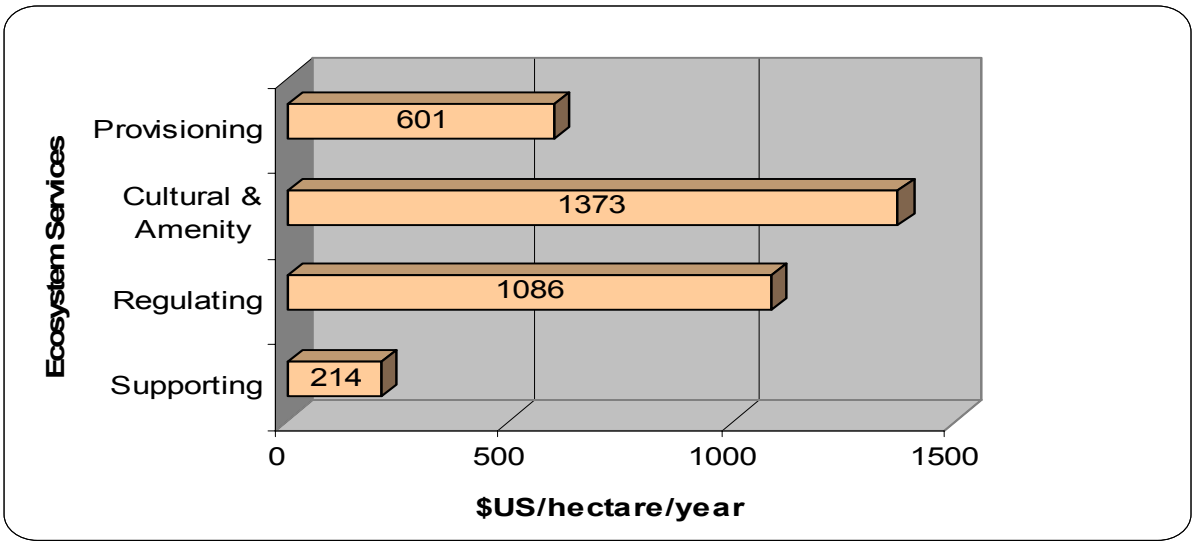

Figure 5 Total economic value (TEV) of the main services provided by wetlands (US$/ha/year)

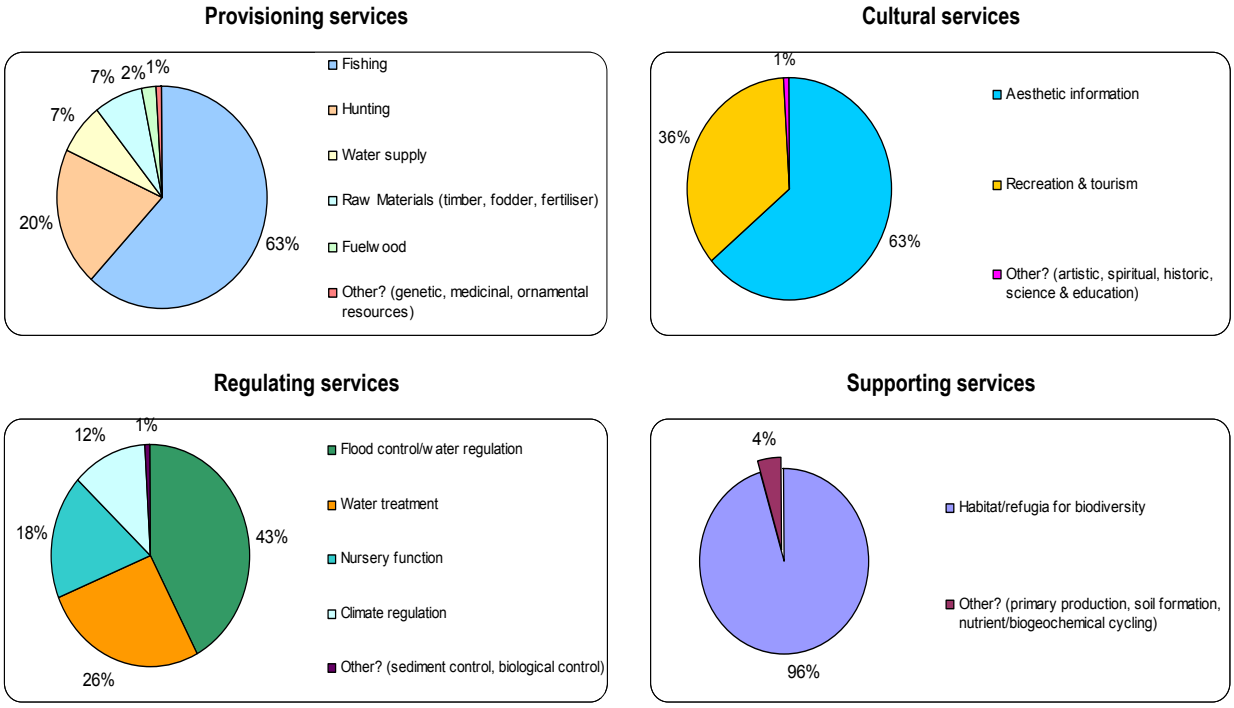

Figure 5a Breakdown of ecosystem service TEVs

1) All estimates are average global values based on sustainable use levels and taken from two synthesis studies: Schuyt & Brander 2004 (calibrated for 2000), and Costanza et al 1997 (calibrated for 1994); together they cover over 200 case studies. Most numbers are from the WWF study (Schuyt & Brander 2004), except the aesthetic information service and climate regulation.
2) In principle, the values given are additive; including the value for the habitat-service which is based on money actually spent for nature conservation (mainly private donations) as an expression of the (actual) Willingness to Pay for this service.

A way of looking at these very rough figures is that an annual benefit of US$200 billion at a 5% interest rate represents a capital (or Net Present Value) of US$4000 billion. Since about half of all the wetlands on earth have been destroyed, this means a capital loss of over US$4000 billion. Monetary valuation can thus help to make more balanced decisions regarding trade-offs involved in wetland use and conservation.

2.3 Stakeholder analysis and (participatory) assessment methods

The main stakeholders should be identified early in the assessment process because in almost all steps of the valuation procedure, stakeholder-involvement is essential, ie to determine the main policy and management objectives, to identify the relevant services and assess their value, and to discuss trade-offs involved in wetland use. A stakeholder is a person, organisation or group with interests in services provided by wetland functions. Stakeholders are both the people with power to control the use of wetland functions as well as those with no influence, but whose livelihoods are affected by changing use of functions (Buckles 1999, Brown et al 2001, Grimble & Wellard 1996). According to Brown et al (2001), stakeholder analysis is a system for collecting information about groups or individuals who are affected by decisions, categorising that information, and explaining the possible competing interests that may exist between important groups, and areas where trade-offs may be possible. It can be undertaken simply to identify stakeholders, or to explore opportunities for assisting groups or individuals in working together.

There are basically four steps involved in stakeholder analysis: identification and selection, prioritisation, analysis of interactions (type of relationships) between stakeholders, and analysis of opinions (based on judgement, perception, attitude, and/or well-being). Interpreting the results of the analysis is essential to assess management options and trade-offs (Grimble & Wellard 1996, AusAid 2000).

Table 6 Methods used in the stakeholder analysis (non-exhaustive)

Can be used for: Method	Selecting stakeholders	Prioritising stakeholders	Analysis of interactions	Analysis of opinions
Checklist development (of stakeholders and issues)*				X
Literature and data review*	X	X		X
Desk research (eg of media attention)				X
Measuring environmental variables				X
Observation*	X	X		X
Questionnaires (with experts and/or key persons)				X
Interviews*	X	X	X	X
Workshops		X	X	X
Animation techniques (for group interaction)				X
Visual media (preferences)				X
Stories, portraits		X	X	X
Resource tenure & ownership maps	X	X	X	
Diagrams, maps	X		X	
Network assessment*	X	X	X	
Triangulation*	X	X	X	
Ranking		X		
Multi criteria analysis (MCA) / pebble distribution method (PDM)				X
Participatory rural appraisal (PRA)				X

Source: adapted from Chambers & Blackburn 2000, Wilson & Howarth 2002, De Groot et al 2006

* Methods primarily used in this study; Appendix II provides a detailed overview of methods used

Stakeholders can be categorised according to their degree of influence or importance in decision-making and management of ecosystem services. The identification of stakeholders marks the beginning of the formal stakeholder analysis process and is the first step towards successful conflict management and consensus building. The categorisation of stakeholders can be complicated by the fact that stakeholders tend to fall into more than one category (Brown et al 2001). The categorisation is adapted from Brown et al (2001) and Shepherd (2004), in terms of which stakeholders are more affected by a management decision or by activities of other stakeholders. Stakeholders can be identified in three categories:

- **Primary stakeholders** are generally local community members who have low influence over the outcomes of decisions, but whose welfare is important to the decision makers. Often, the primary stakeholders are those who stand to lose the most from a management decision, although this is not always the case.
- **Secondary stakeholders** are organisations that represent local people's interests in the wetlands. These secondary stakeholders are not directly dependent on the ecosystem services provided by wetlands. The organisations are predominantly the link between the primary stakeholders and the decision-makers. They can both be important and influential; they influence the decision-makers through lobbying.
- **Tertiary stakeholders** are mainly those engaged in the process of decision-making, for example on how relevant ecosystem services should be managed. Therefore, they have influence on the outcome of a process but they are relatively unimportant, as their welfare is not a priority.

Table 7 The typology of stakeholders on a macro- to micro- continuum

Continuum level	Spatial distribution of stakeholders	Examples of stakeholders
Macro-level	Global and international wider society	International agencies
		Future generations
↕	National	National governments
		NGOs
	Regional	Regional authorities
		Downstream communities
	Local off-site	Local officials
		Downstream communities
Micro-level	Local on-site	Aboriginal people
		Farmers

Source: Brown et al 2001, Grimble & Wellard 1996.

2.4 Policy analysis

Analysis of policy processes and management objectives is essential to set the stage for a discussion of why ecosystem valuation is necessary, and what kind of valuation is needed (eg to assess the impact of past or ongoing interventions, to analyse trade-offs of planned wetland uses (= partial valuation) or to determine the Total Value of the intact wetland). During this stage of the valuation process, it should also be determined how values can be generated that are relevant to policy and management decisions.

2.4.1 Why is policy analysis necessary?

Policies, institutions and governance aspects influence the kind of values that are taken into account in decision-making and management measures.

The aim of policy analysis is:

- to identify the types of information (and kinds of values) required and by whom;
- to understand the policy-making process and stakeholder interests, both in current practice and the desirable state, and how they influence the kind of information that is required;
- to enable key stakeholders to assign their own values and incorporate that into decision making, and to be able to compare different kinds of values;
- to describe the objective of the valuation within the policy and stakeholder context;
- to identify the main valuation questions in relation to the current and 'desired' policies;
- to ensure that valuation reflects policy-goals and aspirations for wetlands and those who use them.

2.4.2 Elements of policy analysis

The following five main elements have been included in Policy Analysis, based on the Department for International Development's (DFID) Sustainable Livelihoods website (see the guidance sheets for extra information: http://www.livelihoods.org) and the International Fund for Agricultural Development's (IFAD) Sustainable Livelihoods workshop on Methods for Institutional and Policy Analysis (http://www.ifad.org/sla/background/english/institution.ppt):

- **Social capital and actors**: to involve the appropriate stakeholder groups in the valuation process, the main actors and 'social capital' need to be identified. Questions to be asked include: What is the available knowledge on the current situation? What force is available to harness the problems? Who are the players? Who is affected? What techniques are available to elicit values from under-represented groups?
- **Policy context, statements and measures**: the current policy context needs to be analysed to see how policies interrelate, how they work together or against each other, and to be aware of opportunities and constraints.
- **Policy process and priorities**: through analysing existing policies and policy gaps, policy priorities can be identified.
- **Institutions and organisations**: institutions (rules, procedures and norms of society) and organisations (government, private sector and civil society) form the interface between policy and people. Questions to keep in mind while mapping the relevant institutions (and considered stakeholders) for a particular analysis or valuation: 'Why do policy statements often say one thing, but quite another is observed in the field?'; 'How do the realities of the micro-level situation feed into the policy making process?'.
- **Livelihood strategies**: An analysis of policies for sustainable livelihoods (and ecosystems) requires an understanding of the livelihood priorities, the policy sectors that are relevant, and whether or not appropriate policies exist in those sectors.

2.4.3 Methods for policy analysis

There are a number of different methods for policy analysis that can be applied to one or more of the five main elements of analysis. Table 8 gives a more detailed description of the main methods.

Table 8 Methods for analysing different elements of policy and policy process

Methods	Policy elements they can be applied to				
	Social capital & actors	Policy context, statements & measures	Policy process & priorities	Institutions & organisations	Livelihood strategies
Document analysis	X	X	X	X	X
Interviews	X	X	X	X	X
Policy mapping		X	X		
Policy ranking			X		
Visioning			X		
Power analysis	X			X	
Social maps	X			X	
Strategy flow diagrams	X				X
Institutional analysis	X			X	
Stakeholder analysis	X		X		
Actor network analysis	X		X		
Livelihood analysis					X
Preference ranking					X
Time lines		X	X		X

Source: Adapted from: http://www.livelihoods.org

A number of tools were used to elaborate the integrated assessment framework from a policy perspective. In particular, a DPSIR Analysis was used for understanding the causal relationships between various policy issues. DPSIR is an acronym for Driving Forces (D), Pressures (P), State (S), Impacts (I) and Responses (R). It is used to understand the entire chain of an (environmental) issue or problem beginning with its real causes, identifying its effects and subsequently arriving at potential responses needed. 'Driving forces' or the underlying causes of the problem describe the ultimate factors causing environmental change and leads to the 'pressure' on the environment. Pressures affect the 'state' of various environmental compartments (air, water and soil) in relation to their functions. Changes in the states of the compartments may have impacts on ecosystems, humans, materials and amenities and resources. Finally, the analysis leads to different policy options as a response, which could be sector specific, and/or source oriented and/or effect oriented and/or curative, to environmental problems (RIVM 2001). In this regard, the DPSIR Analysis was especially useful in understanding the impact of the ongoing and proposed development in the Daly River catchment.

2.5 Management implications

This last part of the study explored how information obtained through ecosystem function analysis, valuation and trade-off analysis can be used to address management options for multi-functional sustainable use of the study area. Two aspects are important: current management/institutional aspects; and potential economic incentives. Firstly, regarding

management and institutional aspects, we tapped into the experiences gained with Landcare Groups (especially in Australia), the Collaborative Management Working Group of the IUCN, and the participatory management case studies compiled for the Ramsar Convention on Wetlands. Secondly, for economics, there is an increasing number of examples on the use of function analysis and valuation in the development of economic incentives for community based nature conservation and sustainable resource use (Stuip et al 2002).

As already described for the Stakeholder Analysis, a number of methods were used to address the research objectives relating to the management implications of the integrated assessment: literature and document review; research 'networking'; semi-structured interviews; direct observation; and participant observation (see Table 6 and Appendix II for overview and explanation).

In all research it is necessary to have an informed understanding of the local situation and, with specific relevance to this study, the management environment and context. In the Northern Territory, this was highly necessary as management has been characterised by a history of contested and shared use of natural resources as well as differences in values, belief systems and perceptions toward resource management (LCNT 2004). Without having sufficient knowledge and appreciation of past management challenges, successes and failures, new research may well become lost in understanding past (political) conflicts and either fail to address research needs or have outcomes that do not suitably take into account certain NorthernTerritory 'realities'; therefore providing little added-value to future management and decision making. In this regard, a high priority was placed on understanding the research context before interviews with stakeholders were arranged.

Table 9 Focusing the research approach: a framework for researching current management contexts

Identified research target	Criteria and examples for fulfilling the research target
Key management bodies	Which stakeholders or agencies are involved in management?
	Preliminary stakeholder identification based on well-known groupings:
	Government institutions and departments
	Industry bodies and representative organisations
	Academic and research organisations
	Non-governmental organisations
	Community groups and volunteer programs
	Spiritual faith groups and institutionalised religions
Existing management plans	What management plans or approaches are applicable to wetland management in the selected research areas?
	Identify relevant management plans, including those specific to:
	Area (eg catchment, bioregion, basin, jurisdictional)
	Issue (eg weeds, water allocation, fire, saltwater intrusion)
	Resource (eg inland waters, biodiversity, coastal)
	Sectoral (eg fisheries, mining, pastoral, tourism)
	Identify management plans at different spatial scales (eg local, regional)
Identified research target	Criteria and examples for fulfilling the research target

Identified research target	Criteria and examples for fulfilling the research target
Existing research reports	What does relevant existing literature discuss with respect to the management context in the respective research area?
	Where available in reports, focus on:
	Descriptions and summaries of current management context
	Bottlenecks and research limitations attributed to management context
	Implications of research described with respect to management
	Recommendations given for future management scenarios
Management issues	What are the key management issues identified in the research area?
	Issue identification can be performed, *inter alia*, according to the following:
	Ecosystem functions and services (including ecosystem services under threat)
	Perceptions and values (institutions, stakeholders, media & wider public)
	Threats to stakeholders' source of income and/or livelihood
	Current focus in existing management plans and research reports
	Risk and uncertainties
	Governance and 'cross-scale' effects
	Acquisition and custodianship of information
	Environmental research (capacity & resources to obtain baseline data)
	Environmental monitoring & management evaluation (based on adequacy of processes & outcomes)
Management requirements (and aims)	What are the requirements of management in the area and what aims are being put forward?
	Sources for such information may include:
	Management plans
	Media news and articles
	Research reports, forums and studies
	Community discussion and stakeholder debate
	Government strategies, proposals, reviews
Management options	What options for management are being discussed (for the area)?
	See above information sources in 'Management requirements'
Management implications	What implications for future management approaches are being discussed?
	See above information sources in 'Management requirements'
	Can implications be linked to ecosystem functions, stakeholder satisfaction and perceptions of equity?

Source: adapted from Eliot et al 1999

The information obtained through the above processes is interlinked, as shown in Figure 2 which also shows how the outputs of the sub-projects will feed into each other and into the final analysis.

3 Inventory of ecosystem services provided by wetlands in the Northern Territory

As explained above, the first step in the Integrated Assessment is the translation of wetland characteristics (processes and components) into the main functions that provide specific services. The next three sections provide a more detailed description of the main wetland types in the study areas, the services provided by these wetland habitats, and the spatial distribution of the main services in the Daly River and Mary River catchments.

3.1 Main wetland types in the Daly River and Mary River catchments

There are basically six wetland types in the northern part of the Northern Territory (as identified by the Department of Infrastructure, Planning and Environment, DIPE 2003b):

- *Waterways*: the river channels;
- *Mangroves/saline tidal flats/saline mudflats (coastal and riverine riparian zones)*: periodically inundated by tides; the soil is more or less permanently waterlogged;
- *Riverine floodplain woodland*: swamp forest and woodland; Eucalyptus is the dominant overstorey species; this habitat receives a relatively rich supply of nutrients and often also sediment via surface run-off and groundwater from adjacent land;
- *Riverine floodplain/mixed grass-sedge-herbland floodplain*: mixed grasses, herbs and sedges;
- *Open water floodplains (billabongs)*: freshwater sources;
- *Freshwater riparian zones/forest*: includes Melaleuca, Bambusia, Bombax etc, along the rivers and further upstream than mangroves.

Each wetland type provides a different range of services. Whilst these types are recognised they have not been effectively mapped (Finlayson et al 2005b).

3.2 Overview of services provided by the wetlands in the Northern Territory

An overview of the information available on ecosystem services provided by the wetlands in the Northern Territory according to the classification explained above is given in Table 10. This information is incomplete as in many cases the association with wetlands has not been well articulated or quantified; the purpose of the tabulation is to provide initial information as part of the wider investigation of the importance of ecosystem services. In some instances it is not possible based on existing data or reports to differentiate the importance of both wetland and non-wetland ecosystems in providing the service.

Due to insufficient time for this pilot study, not all services could be studied in equal detail. In addition, some more complex regulation functions, such as the influence of wetlands on ‘climate change’ or processes of ‘nutrient regulation’ are not discussed in detail. The focus was on tangible services characteristic of the wetlands and readily identifiable by stakeholders, eg pastoralism and agriculture, tourism and recreation, habitat and biodiversity, and cultural and information services.

Table 10 Functions and services provided or supported by wetlands and floodplains in the Northern Territory

Functions and services		Use/importance
Provisioning services – production functions		
Food – fishing (commercial & subsistance)	Barramundi, shark, trepang, mud crab, Spanish mackerel, sawfish	Mary River catchment: approximately 9% of total Northern Territory fishery (Stakeholder pers comm 2004)
Food – hunting	Magpie goose, turtles, crocodiles	Licences are available for 25 crocodiles from the Mary River to be killed each year (Stakeholder pers comm 2004).
Food – gathering	Fruits, sponges, crocodile eggs, wider 'bush tucker' items	Comprise approximately 30% of the diet for traditional Aboriginal groups studied in Arnhem Land (DIPE 2003a)
Water supply	Water storage	Daly River catchment contains an estimated 3534 km^2 floodplain and dampland wetlands (Begg et al 2001). The Daly River has a dry season flow that is five times greater than any other river in the Northern Territory (Price et al 2000). Mary River catchment consists of 1280 km^2 of wetlands (Armstrong et al 2002). Depending on the season, the discharge of the river can vary between 1.4 m^3/s to 5 m^3/s (Armstrong et al 2002).
Medicinal resources	Use of plants for Aboriginal and non-Aboriginal medicine	Various plant species are used as traditional medicine by local Aboriginal people. Daly River has in parts been bioprospected (Marrfurra et al 1995).
Raw materials	Eucalyptus stems Twigs and vines	Used for didgeridoos and rhythm sticks; bark used for painting (Forner et al 2002, Taylord et al 2002) Fishtraps, spears, boomerang etc (Finlayson et al 1988)
Ornamental resources	Natural materials (plants, animals, minerals etc) used for cultural purposes	Used to make jewellery, baskets, etc (Finlayson et al 1988, Marrfurra et al 1995).
Provisioning services – carrier functions		
Cultivation / horticulture	Peanuts, melons, mangoes	Daly River catchment: 198 500 mango trees (26% of NT production) (Stakeholder pers comm 2004) Mary River catchment: estimated 25 000 ha of billygoat plum (*Terminalia ferdinandiana)* production
Pastoralism	Cattle, buffalo	Daly River catchment: 215 814 ha (4.6%) of land Mary River catchment: cattle numbers on the floodplain probably exceed 40 000 head during the dry season, stocked at around one beast per hectare. Current turnoff (beasts sold per year) is estimated by the Cattlemen's Association at 35 000 with a gross value of A$17.5 million (A$500 per head) 35 000 head of cattle (DIPE 2003a).
Buffalo farming		Daly River catchment: minor industry Mary River catchment: minor industry but more prevalent than in the Daly River catchment
Crocodile farming	Mostly estuarine crocodile	Skin used for leather for bags, souvenirs. Meat used for human consumption and animal feed.
Aquaculture	Trepang, shrimp, yabbies (red claw)	Very small scale
Mining	Sand	Two sand mining sites along the Mary River
Tourism infrastructure		Mary: 11 tourist facilities with 8 located in wetlands Conservation information centres Daly: contains several tourist facilities, but less developed than those in the Mary

Functions and services		Use/importance
Regulating services		
Water treatment	Recycling of nutrients & organic waste	Anecdotal; little scientific data
Flood prevention	Storage of water during wet season; slowing river velocity	Anecdotal; little scientific data (see Erskine et al 2003)
Storm mitigation	Coastal wetlands buffer wind & water extremes	Anecdotal; little scientific data
Soil retention & formation	Prevention of erosion and maintenance of arable land	Anecdotal; little scientific data
Biological control	Control of pests and diseases	Anecdotal; little scientific data
	Pollination	
Supporting services		
Habitat for wildlife	Protected area	31% of Mary River protected; highest density of estuarine crocodiles in the Northern Territory
	Endemic species	
	Migratory species	Daly River catchment: Nitmiluk National Park
Nursery habitat	Collection of eggs for crocodile farming	Saline coastal swamps provide an important nursery habitat for barramundi during the wet season; a major breeding area for magpie geese, herons and allies; middle reaches of the Daly River are a major breeding area for freshwater turtles (six species, notably *Carettochelys insculpta*), fishes, and the freshwater crocodile *(Crocodylus johnstoni)* (Faulks 1998).
	Barramundi nursery	
	Magpie goose	
Cultural & amenity services		
Aesthetic information	Scenic roads	Anecdotal: little scientific data
	Housing locations	
Recreation and eco-tourism	Bird watching	Daly River catchment: Nitmiluk National Park is the third most popular tourist destination in the NT with widespread recreational fishing and tourism (Bachet 2005, Stakeholder pers comm 2004)
	Hiking	
	Wetland tours (boating)	
	Recreational fishing & hunting	
	Scenic flights	
Cultural heritage and identity	Historic places of Aboriginal culture and early settlers	Mary River catchment: Point Stuart (Armstrong et al 2002)
		Daly River catchment: Nitmiluk National Park
Spiritual or religious experiences	Beliefs and spiritual connection of Aboriginal people (eg legends of the dreamtime)	Nitmiluk National Park
		Books about Aboriginal people and their cultural values
		Point Stuart
		Database of sacred sites with Aboriginal Areas Protection Authority (http://www.nt.gov.au/aapa/)
		Database of proposed land claims (National Native Title Tribunal; http://www.nntt.gov.au/)
Inspiration (eg as motive in books, film, painting, folklore, national symbols, architecture, advertising, etc)	Magpie goose	Motives in Aboriginal paintings and sculpture
		Daly River catchment: four art centres
		Mary River catchment: one art retailer (the Bark Hut)
Educational and scientific information	School excursions	Douglas Daly, Beatrice Hill and Coastal Plain research farms (Stakeholder pers comm 2004)
	Research	

3.3 Spatial distribution of the main services provided by the Daly and Mary River wetlands

Mapping of ecosystem services can be useful for showing the spatial extension and importance of each and where these may overlap. Mapping can also help identify (potential) sources of conflict: mapping is an important tool to understand (actual and potential) threats and pressures the wetlands are facing (eg conservation versus pastoralism interests with respect to fire and weed management); and mapping can also be useful in representing scenarios of potential change in the capacity of the ecosystems to provide services and when tracking land-use canges. The maps below give an indication of the spatial distribution of the main services provided by the wetlands in the Daly River and Mary River catchments.

Based on the information in Table 10 and the maps, a brief summary of the main ecosystem services and differences between the two catchments is given here:

- The Daly River catchment has both a greater presence of horticulture and pastoral activity; however, the Mary River catchment has more buffalo farming on the wetlands.
- The Mary River catchment has larger bamboo resources and density of estuarine crocodiles than the Daly and offers safari hunting for tourists. The wetlands of the Mary River catchment provide important breeding and nursery habitat for species such as the magpie goose.
- The wetlands of the Mary River catchment have recognised values related to its European settler heritage.
- The wetlands of the Daly River catchment have received more attention from researchers because of concerns about water allocation and future agricultural development in the Daly Basin. Considerable research has been undertaken in the Mary River in the past, particularly in relation to its biodiversity values and the extent of intrusion by saline tidal water (Jonauskas 1996).
- The Daly River catchment is perceived to be in a relatively pristine state and less developed than the Mary River and is highly valued for its recreational fishing and greater active representation of Aboriginal interests. There is also a perception that the course for future (sustainable) development in the Daly Basin can still be influenced before major changes have occurred.

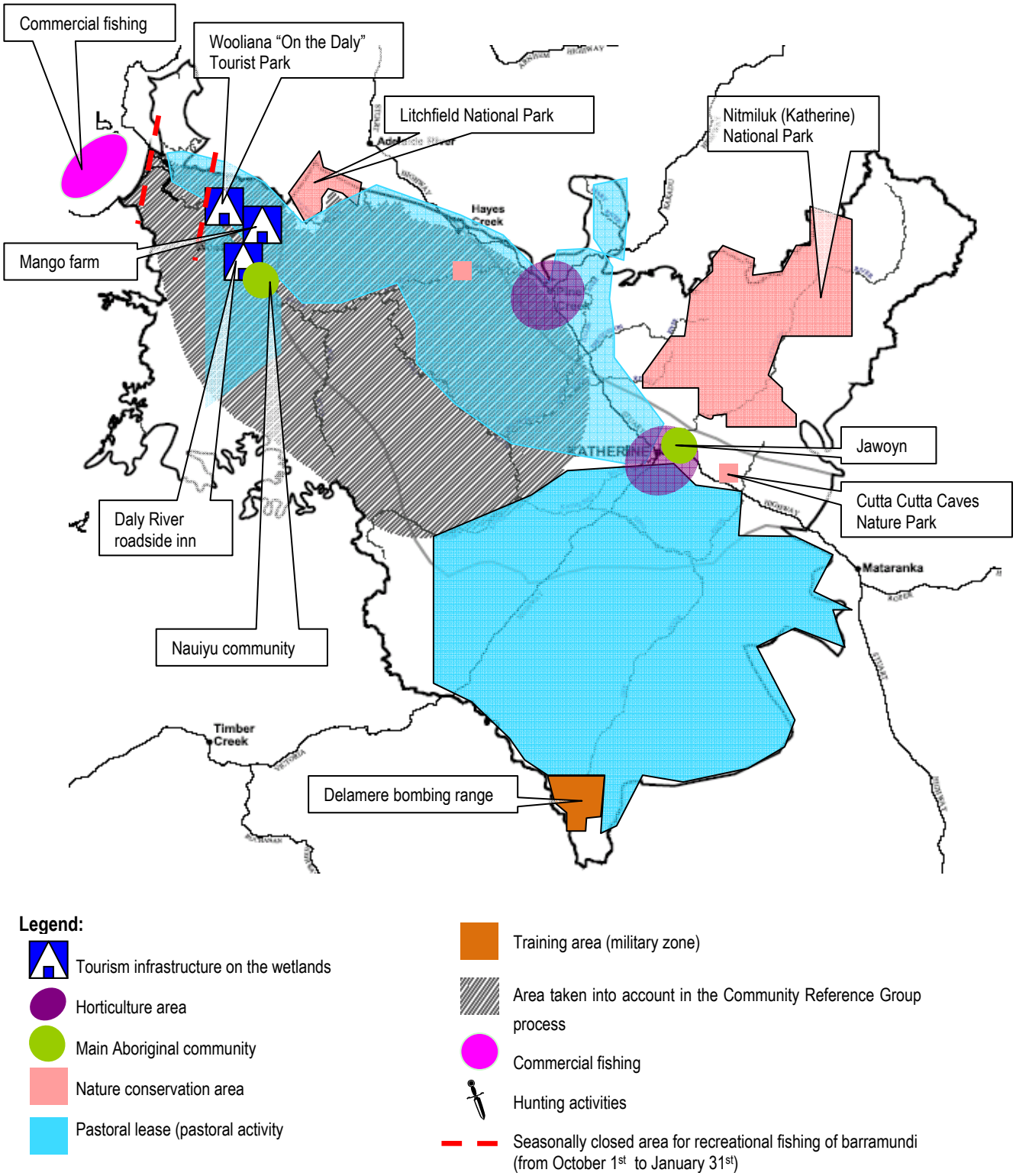

Figure 6 Map of Daly River catchment

Source: Northern Territory Government's Department of Infrastructure, Planning and Environment (DIPE), based on Australian Geodetic date 1966

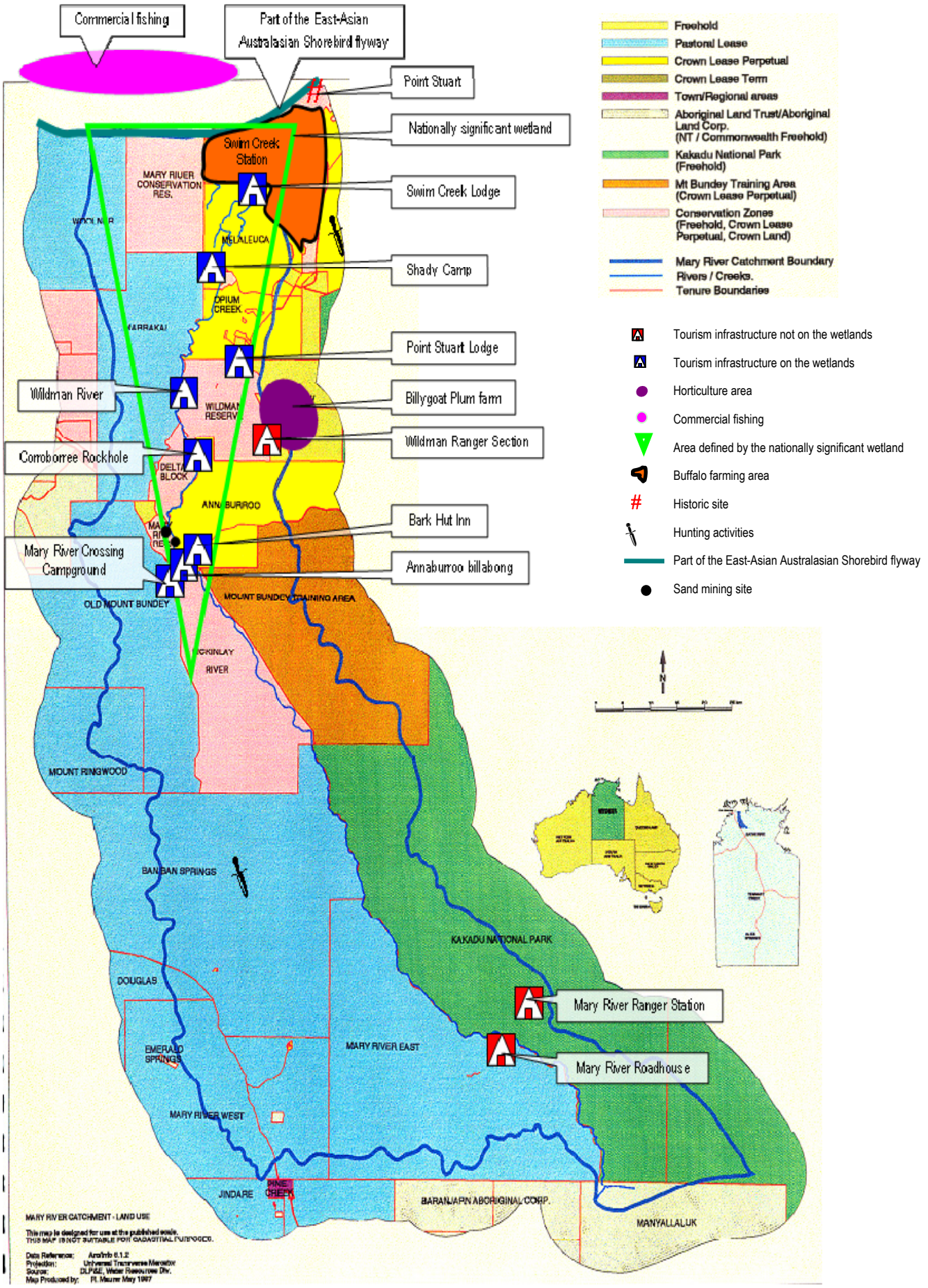

Figure 7 Map of Mary River catchment

Source: The Mary River catchment map is from Northern Territory Government's Department of Infrastructure, Planning and Environment (DIPE), but under its previous title of the Department of Land, Planning and Environment (DPLE) and based on its land use map of the Mary River catchment.

4 Ecological importance of wetlands in the Northern Territory

The ecological importance of an ecosystem can be assessed by various criteria (see Table 3); in this study four criteria have been analysed in more detail: (1) diversity (of habitats and species); (2) uniqueness/rarity (of habitats and species); (3) naturalness/integrity; (4) 'connectivity' (dependence of other ecosystems on the wetlands in the Daly and Mary River catchments).

4.1 Diversity

4.1.1 Habitat diversity

There are different types of wetlands present in both catchments. For example, the main wetland type in the Daly River catchment is permanent rivers and streams (Begg et al 2001). The Mary River catchment contains a smaller number of wetlands; however, a number of these are nationally and internationally recognised as providing important habitat diversity for native and migratory species.

Table 11 Wetland types in the Daly and Mary River catchments based on the typology used in the national wetland directory*

Wetland type
A6: Estuarine waters; permanent waters of estuaries and estuarine systems of deltas
A7: Intertidal mud, sand or salt flats
A8: Intertidal marshes; includes salt marshes, salt meadows, saltings, raised salt marshes, tidal brackish and freshwater marshes
A9: Permanent freshwater ponds (< 8 ha), marshes and swamps on inorganic soils; with emergent vegetation waterlogged for at least most of the growing season
B1: Permanent rivers and streams; includes waterfalls
B2: Seasonal and irregular rivers and streams
B4: Riverine floodplains; includes river flats, flooded river basins, seasonally flooded grassland, savanna and palm savanna
B6: Seasonal/intermittent freshwater lakes (> 8 ha), floodplain lakes
B9: Permanent freshwater ponds (< 8 ha), marshes and swamps on inorganic soils; with emergent vegetation waterlogged for at least most of the growing season
B10: Seasonal/intermittent freshwater ponds and marshes on inorganic soils; includes sloughs, potholes; seasonally flooded meadows, sedge marshes
B14: Freshwater swamp forest; seasonally flooded forest, wooded swamps; on inorganic soils

* http://www.environment.gov.au/water/publications/environmental/wetlands/directory.html

4.1.2 Species diversity

The Northern Territory's vertebrate fauna includes about 400 species of birds, 150 species of mammals, 300 species of reptiles, 50 species of frogs, 60 species of freshwater fish and several hundred species of marine fish (PWCNT 2004). In both catchments, the diversity of species is large with many similar species given the absence of major climate and habitat differences. The extent of diversity is considered an important ecological indicator with more diverse ecosystems usually able to deal better with large environmental changes such as droughts, floods, fires and salinity (Mussared 1997).

4.2 Uniqueness/rarity of habitats and species

4.2.1 Unique/rare habitats

Based on the classification outlined in Table 11, the Daly and Mary River catchments possess 11 wetland types, although the spatial extent and distribution of individual types differs greatly. The distribution of wetland types in the Daly Basin has been mapped in more detail (Begg et al 2001) than those in the Mary River catchment. Both catchments are of great importance for migratory shorebirds. The Mary River catchment is adjacent to Kakadu National Park which is part of the network of wetlands in Australia designated as internationally important under the Ramsar Convention and as part of the East Asian–Australasian Shorebird Site Network:
(http://www.environment.gov.au/biodiversity/migratory/waterbirds)

The wetlands of the Daly River and Mary River have not been designated as internationally important although Chatto (2003) reports that the coast of the Daly River catchment and other areas of the Northern Territory would qualify for nomination to the East Asian–Australasian Shorebird Site Network and/or as Ramsar sites. This demonstrates the equal importance of the Daly River coastal wetlands for these birds, even though they are not registered as such; registration of wetland sites as internationally important under such agreements is the prerogative of the Northern Territory Government which has previously decided not to assign individual recognition to its many important wetlands (Whitehead & Chatto 1996).

The Daly River catchment holds fewer nature conservation areas than the Mary River, which could be a negative factor in the ecological valuation of the catchment, in the sense that the wetlands may not be sufficiently conserved through such existing processes. However, there are proposals to conserve a wider range of biodiversity in this catchment (DIPE 2003a). Begg et al (2001) point out that the Daly Basin contains many valuable wetlands that may be threatened by further land and water development.

The high biodiversity value of the wetlands in the northern component of the Northern Territory has been reported in past reviews (eg Finlayson et al 1988, 1997, 2005b) and outlined in the national wetland directory. Comparative analyses with other wetlands have shown that wetlands in the Daly and Mary River catchments have high value and, as noted by Chatto (2003) amongst others, are an important part of the network of wetlands across northern Australia that supports many resident and migratory species. Given the wide recognition of the high diversity and productivity of these wetlands, it is somewhat surprising that more of them have not been given due recognition under international agreements.

4.2.2 Unique/rare species

An analysis of unique/rare species of the Daly River and Mary River wetlands is difficult due to the lack of data on many taxa, especially those, such as many invertebrate groups, that have received little inventory attention. Gaps in the species inventory of northern Australian wetlands have been reported by Finlayson et al (2006) when assessing the biodiversity of the relatively better known wetlands in Kakadu National Park.

Before 1990, there was very little information on the distribution and abundance of shorebirds around the Northern Territory coast and the adjacent wetlands (Chatto 2003). Information gathered between 1990 and 2001 has shown that the coast and coastal wetlands have globally significant numbers of many species of shorebirds, which either use the wetlands as a food source or for breeding (Chatto 2003). Some of these wetlands are in the Daly River and Mary River catchments (Bellio & Chatto 2004). The five most abundant waterbird species in the

Daly River catchment are the great knot (*Calidris tenuirostris)*, the greater sand plover (*Charadrius leeschenaultii),* the bar-tailed godwit (*Limosa lapponica)*, the lesser sand plover (*Charadruis mongolus)* and the red-necked stint (*Calidris ruficollis)*. Chamber's Bay in the Mary River catchment is an important area for five abundant species: little curlew (*Numenius borealis* or *Numenius minutus)*, the sharp-tailed sandpiper (*Calidris acuminata)*, the black-tailed godwit (*Limosa limosa)*, the marsh sandpiper (*Tringa stagnatilis)* and the lesser sand plover (*Charadruis mongolus)*.

The rare and endemic fish, for example the freshwater whipray *(Himantura chaophyra*) and the bull shark *(Carcharhinus leucas*), of the Daly and Mary River catchments are listed in Table 12. Whilst a species list is available, there is limited information on the importance of either catchment for most species, or indeed of the relative importance of particular habitats for anything except a small number of species (Allen et al 2002; Stakeholder pers comm 2004). As with other rivers, the Daly River and Mary River are recognised for their importance for barramundi, the major recreational angling species (Box 2).

Table 12 Rare and endemic fish species in the Daly River and Mary River catchments

Species	Common name	Status	Presence in the Mary River catchment	Presence in the Daly River catchment
Glyphis sp A	Speartooth shark	Endangered (IUCN Red List 2008) Critically endangered (EPBC Act 1999)*	Recorded in East, West and South Alligator Rivers (Larson 2000; Taniuchi & Shimizu 1991). It is possible the shark inhabits the Mary River (Bachet 2005).	Mouth of the Daly River (Stakeholder pers comm 2004)
Glyphis sp C	Northern river shark	Critically endangered (IUCN Red List 2008) Endangered (EPBC Act 1999)	Recorded in East, West and South Alligator Rivers (Larson et al 2000; Taniuchi & Shimizu 1991). It is possible the shark inhabits the Mary River (Bachet 2005).	Mouth of the Daly River (Stakeholder pers. comm, 2004)
Carcharhinus leucas	Bull shark	Near threatened Thorburn et al 2003)	Possibly (Bachet 2005)	26 in the middle reach of the Daly River (Thorburn et al 2003)
Pristis microdon	Freshwater sawfish	Endangered Thorburn et al 2003) Vulnerable (EPBC Act 1999)	Possibly (Stakeholder pers comm 2004, Bachet 2005)	1989 recorded in Daly River (Taniuchi & Shimizu 1991) 2003: one caught in the middle reach of the Daly River ((Thorburn et al 2003)
Himantura chaophyra	Freshwater whipray	Vulnerable (Thorburn et al 2003)	Possibly (Bachet 2005)	1989 recorded in the Daly River (Taniuchi & Shimizu 1991) 2003: 8 caught in the middle reach of the Daly River (Thorburn et al 2003)

Source: Allen et al 2002, Larson 2000, Peverell et al 2004

*The *Environment Protection and Biodiversity Conservation Act 1999* (the EPBC Act)

Box 2 Barramundi (*Lates calcarifer*)

The life cycle of the barramundi can be divided into four phases (Allsop et al 2006). The first is the spawning in the river mouth early in the wet season, with the larger females producing 32 million eggs a season. The second occurs when the high tides wash the eggs and the larvae into the coastal swamps. The third is when the juveniles return to the rivers and migrate upstream at the end of the wet season. The fourth phase occurs when the maturing males move downstream at the beginning of the wet season. While large numbers of small barramundi swim upstream at the end of the wet season, it is now realised that some do not have a freshwater phase in their life cycle and spend their entire lives in an estuarine habitat. As with some other fish species, barramundi change sex as they mature; they generally mature as males in their third to fifth year and then change to females between four to eight years if in saltwater.

Many wetland plants are cosmopolitan although the bamboo species, *Bambusa arnhemica*, is endemic to northern Australia and ecologically important (Box 3). Many fruit bats are known to roost in riparian habitats in the Daly River and Mary River catchments, as they do in other catchments; around 250 000 fruit bats have been observed in the Mary River catchment during the flowering of *Melaleuca* swamp forests (Armstrong et al 2002). Furthermore, at least 15 frog species have been recorded in the Mary River catchment and the Dugong (*Dugong dugong*) and the Indo-Pacific Dolphin (*Sousa chinensis*) are regularly seen in the coastal waters of the Mary River catchment (Armstrong et al 2002); although important, these are not seen as overly significant.

Box 3 *Bambusa arnhemica*

Bambusa arnhemica is endemic to the northern part of the Northern Territory. It is assumed by some that bamboo has no specific role in supporting other species; ie if it disappeared, we would 'only' lose an endemic species, but it is unlikely that other flora or fauna species would be placed at risk (Stakeholder pers comm 2004). However, this assumption is not based on any *comprehensive* assessment of the ecological role of bamboo or its association with other species. On the other hand, it is welll known that bamboo has been used by Aboriginal people for many generations and is known to be unified linguistically with the word for 'didjeridu' in some parts of the Daly River catchment. The occurrence of bamboo according to Aboriginal people is told in a Dreamtime creation story that talks about a didjeridu playing bird.

There are no animal specialist feeders on bamboo. The buff-sided robin (*Poecilodryas cerviniventrisuses*) uses it as a habitat, but nothing is known on the impact that the loss of bamboo would have on this bird; it would most certainly find another habitat (Stakeholder pers comm 2004). When the bamboo flowers, Gouldian finch (*Erythrura gouldiae*), various cockatoos and other birds eat the seeds; however, with the flowering being so disparate, these birds do not rely on the bamboo seeds; ie they will eat them when present but will not overtly seek out the seed when it is not flowering.

4.3 Naturalness/integrity

The native fauna and flora of the Daly River and Mary River wetlands face impacts of weeds and feral animals, resulting in biodiversity loss. Exotic weeds, for example mimosa, *Mimosa pigra*, exclude native plants (CTWM & CINCRM 1998). Feral water buffalo (*Bubalus*

bubalis) and feral pigs *(Sus scrofa)* spread the seeds of mimosa. The Daly River region is one of the three 'hot spots' for feral pigs in Australia and has a high risk of infestation of mimosa (CTWM & CINCRM 1998). Nearly all of the freshwater wetlands in the Mary River catchment are vulnerable to the invasion and degradation by mimosa, introduced pasture species and weeds, which are capable of invading deeper waterbodies (Armstrong et al 2002). These freshwater wetlands are also very sensitive to damage by introduced herbivores such as cattle and buffalo (Armstrong et al 2002). These problems, in conjunction with the use of wetlands by many vertebrate species at different stages of the seasonal cycle, mean that 'substantial degradation of individual areas may affect mobile species throughout their ranges' (Armstrong et al 2002).

4.4 Connectivity

Many ecosystems depend on the continued presence and integrity of other ecosystems, for example coral reefs depend on the integrity of forests in the watershed to avoid siltation from erosion, downstream cultivated fields depend on upstream wetlands to maintain water quality, and many ecosystems are connected through migratory birds and other species. Wetlands often play a crucial role in maintaining ecological integrity in the wider surroundings. For example, the Mary River catchment is a 'nursery' for many animal species that frequent Kakadu National Park. As an example, the Mary River wetlands are important breeding grounds for magpie goose (*Anseranas semipalmata*) that move between wetland systems and for the breeding of freshwater *(Crocodylus johnstoni)* and estuarine crocodiles *(Crocodylus porosus)* (Stakeholder pers comm 2004). As already mentioned, the Daly and Mary River catchments are both of great importance for migratory shorebirds, even though they are not registered as such. They are undoubtedly also important for some offshore fisheries, although the individual importance of the wetlands and estuaries is somewhat difficult to ascertain given the available information.

5 Socio-cultural importance of wetlands

5.1 Tools for assessing socio-cultural importance

Socio-cultural importance can be assigned to many ecosystem services given the connections between human well-being and ecosystems such as wetlands (Finlayson et al 2005a). However, the attachment of socio-cultural values to ecosystem functions is most apparent at a regional scale and specifically when involving cultures that have a holistic view of their environment. Socio-cultural values can exist alongside other functions (eg plants for food production, water for drinking and aquaculture) that are of primary importance to the people who depend on these (eg regulation functions such as water allocation and production functions such as agriculture). It is expected therefore that these would be expressed or recognised as underlying drivers in debates over management, planning and policy. In reality, socio-cultural values are often used as a vehicle for strengthening decision making rather than being the decisive (objective) source for decisions that are often based on more easily assessable market-based arguments. Due to the differences in the numeric nature of expressing market based values and socio-cultural values, they can be seen as burdensome in the debate surrounding decisions governing the development of natural resources or ecosystems such as wetlands, and dependent on how respective actors in a debate wish to support their case (Stakeholder pers comm 2004).

Box 4 Need for an assessment framework

> There's no framework for them to say how to go about it but they [development projects] are being established. There could be a value assessment framework but how to come up with one is a different thing. Easy package things saying 'this is the basis of what you want' with [tick] boxes and tasks so that it is a blueprint to be used across the Top End. (Stakeholder pers comm 2004)

In developing a typology for categorising the importance of cultural services, the issue of 'making the priceless count' is probably the most challenging. An assessment framework that provides a readily usable package with ready made questions and tick boxes might meet the immediate needs of managers and policy makers, but is unlikely to do justice to the intricacies of the social and cultural issues being considered. However, the need to enhance planning and decision making in the Northern Territory based on cultural values that explicitly portray the linkages that people have with wetlands (and other ecosystems) and their natural resources is recognised. The value of socio-cultural services has been raised in cost-benefit analyses conducted in the Mary River (Jackson 2004); however, a conceptual framework for identifying the importance of these services in relation to other services does not exist (at the time of writing). This is particularly important when dealing with Aboriginal cultural values that may not be known to – or recognised by – non-Aboriginal interests (Jackson et al 2005).

In preparing an overview of the socio-cultural services known in the wetlands of the Daly and Mary Rivers, a literature research was conducted to identify possible categories of services and values. Specifically, the Ramsar Convention's listing of 10 cultural aspects of wetlands was used as a starting point and adapted for local circumstances. The typology of socio-cultural services from the wetlands of the Daly and Mary Rivers was presented in Table 4. Some of these services are examined in greater detail below.

5.2 Importance to human health

The importance of ecosystems to human mental and physical health is recognised throughout the literature (Posey 1999, Harmon 2003, MA 2003). The link between ecosystems and human well-being is a significant issue within the context of development in the Daly River catchment – in particular where cultural issues have recently been raised as part of wider community-based consultations (Jackson 2004), and more widely within Aboriginal society when dealing with land/water management (Jackson 2004).

The therapeutic effects of nature on human psyche and physical health stem from a relationship between the intrinsic qualities of nature and anthropocentric values. This relationship has been described as 'the intrinsic qualities of natural areas that interact with humans to restore, refresh, or create anew through stimulation and exercise of mind, body and soul (ie re-creation)' (Harmon 2003). To a certain degree, these intrinsic qualities are measurable; however, it can be difficult to find reliable indicators. Health statistics or other data might not be available or readily attributable to the presumed 'health effect'. As indicators should reflect the perceived relationship between the measurable socio-economic benefits and the perceived health effect caused by the natural environment, it is necessary to ensure that other factors that influence the perceived psychological or physical health improvements are separated; further research may be needed to develop suitable methods to properly assess the fluid and complex nature of benefits from nature-based recreation activities (Shultis 2003). Nevertheless it is possible to compile an overview of the benefits derived from nature-based leisure activities, taking into account personal, socio-cultural economic and environmental benefits. Table 13 lists a number of benefits that are attributed by Shultis (2003) to illustrate the interactions that could occur.

Table 13 Health benefits from interactions with nature (derived from Shultis 2003)

Psychological benefits	
▪ Holistic sense of wellness	▪ Positive changes in mood and emotion
▪ Stress management (prevention, mediation and restoration)	▪ Prevention and reduction of depression, anxiety, and anger
▪ Catharsis	
Psycho-physiological	
▪ Cardiovascular benefits	▪ Respiratory benefits
▪ Reduction and prevention of hypertension	▪ Reduced incidence of disease
▪ Reduced serum cholostrol-triglicerides	▪ Improved bladder control for the elderly
▪ Improved control or prevention of diabetes	▪ Increased life expectancy
▪ Prevention of some cancers	▪ Management of menstrual cycles
▪ Reduced spinal problems	▪ Management of arthritis
▪ Decreased body fat and obesity/weight control	▪ Improved functioning of the immune system
▪ Improved neuropsychological functioning	▪ Reduced consumption of alcohol and use of tobacco
▪ Increased bone mass and strength in children	
▪ Increased muscle strength and better connective tissue	

These benefits can all be related to what has become known in the Northern Territory through the slogan – 'healthy country healthy people' – that has been used by the Northern Land Council's 'Caring for Country' program that incorporates many of the notions listed in Table 13. In this study, it was possible only to attribute a value for the general relationship

between human health and wetlands; the more precise the data on these 'links', the more accurate the valuation.

5.3 (Cultural) heritage

The heritage value of a particular landscape comprises its importance in shaping the history and national identity of individuals and people collectively. Heritage has been described in the Oxford dictionary as 'all the qualities, traditions or features of life that have been continued over many years and passed on from one generation to another, especially ones that are of historical importance or that have had a strong influence on society'. Emphasis is also placed on inter-generational factors and their influence on society. These qualities have also been recognised through the Ramsar Convention where social and cultural values are seen as supplementing physical or tangible cultural heritage as a priority for conservation and wise use.

Many societies place high value on the maintenance of either historically and/or culturally important landscapes or culturally significant species (Posey 1999). While heritage values can be defined in terms of a resource's intrinsic (objectively measurable) and extrinsic (largely subjectively measurable) qualities they are often not integrated into the management process (Carter & Bramley 2002). This is a well-known problem that stems from the lack of definition of intangible cultural values, especially where the fact of defining intangible values is not itself culturally neutral (English 2000). Incorporating intangible values in management of cultural heritage is a challenge that has recently been attempted by UNESCO (2003) (Box 5).

Box 5 UNESCO definition of intangible cultural heritage

'Intangible cultural heritage' refers to the practices, representations, expressions, knowledge, skills – as well as the instruments, objects, artefacts and cultural spaces associated therewith – that communities, groups and, in some cases, individuals recognize as part of their cultural heritage. This intangible cultural heritage, transmitted from generation to generation, is constantly recreated by communities and groups in response to their environment, their interaction with nature and their history, and provides them with a sense of identity and continuity, thus promoting respect for cultural diversity and human creativeness of mutual respect among communities, groups and individuals, and of sustainable development.

Within the Northern Territory, one definition of cultural heritage is that from the ICOMOS Burra Charter of 1999: 'All the qualities, traditions or features of life that have been continued over many years and passed on from one generation to another, especially ones that are of historical importance or that have had a strong influence on society' (ICOMOS 1999, Young 2004). The intangible cultural values acknowledged by UNESCO can be incorporated into this definition with explict recognition of oral traditions and expressions, including language as a vehicle for the intangible cultural heritage, performing arts, social practices, rituals and festive events, knowledge and practices concerning nature and the universe, and traditional crafts. The so-called tangible heritage values have been considered in the economic valuation component of the project. The more intangible values have been considered in the cultural component.

5.4 Spiritual and existence values

Spiritual values of wetlands incorporate the importance of nature in symbols and elements with sacred and religious significance. They embody the qualities of nature that inspire humans to relate with reverence to the sacredness of nature which is at times considered to be a component of spiritual or religious feelings and existence values. The latter encompass feelings of satisfaction and symbolic importance derived from knowing that outstanding natural and cultural landscapes have been protected and exist as physical and conceptual spaces where all forms of life and culture are valued (Harmon 2003). Existence values are taken to include the importance people attach to nature for intrinsic ethical reasons and for bequesting these values to future generations; these values are based on 'belief systems' that can differ greatly. In the Northern Territory, there is often an explicit difference in human-ecosystem relationships between Aboriginal people and non-Aboriginal people. One view of this is expressed in the following text from an Aboriginal person from the East Alligator River:

White man got no dreaming

Him go nother way

White man him go different

Him got road belong to himself

It has been argued that non-Aboriginal people have a different relationship with nature from Aboriginal people and that this has been derived from the Christian religion – a subject that has been an area of debate in social sciences for many years (Schama 1995, Howitt 2001). At the same time, there is a recognised 'frontier mentality' that has severely impacted on the ecosystems and socio-cultural relations of the Northern Territory with enormous change having occurred as a consequence of land use and development attitudes that were on the whole very different from those previously practised by Aboriginal people (Howitt 2001). Aboriginal spirituality and culture are seen as being materialised in the landscape through sacred sites and features that are part of a living landscape where everyday life is connected to history in a dynamic manner (NLC 2004). The existence values can be measured in several ways, though the absence of data and quantitative information restricted the analysis in this project, although some were covered in the economic valuation.

5.5 Recreation and tourism

There are many recreational and tourism activities in wetlands, ranging from passive to more active forms and covering local residents to tourists. Tourism and recreation have also been classified under amenity services by De Groot and Ramakrishnan (2005), but regardless of the classification the social and cultural benefits received from wetland-based recreation and tourism can be large and interact with other services (such as health benefits). The benefits derived from recreation and tourism (generally called leisure) include personal, social, cultural, economic and environmental benefits.

Many recreational values are attributed to the intrinsic qualities of ecosystems through interactions that restore, refresh or create anew through stimulation of the mind, body and soul (Harmon 2003). While it is apparent that some recreational activities contribute more to the physical well-being of individuals than others, the relationship between the environment and the psyche is less understood (Shultis 2003). Other benefits derived from leisure that are

applicable in the context of this study relate to personal development and growth, economic benefits and to some extent environmental benefits such as ecotourism, cultural tourism, bird watching tours, walking trips, wetland tours, recreational fishing, hunting and scenic flights.

In many cases, these recreational activities are supported through infrastructure such as tourist information centres that themselves may attract tourists to the area; the opportunities for recreation or tourism depend on the facilities provided on one hand and the extent of facilities required for a certain activity. The main example used in this project is the value of recreational fishing, rather than the more diffuse analysis of the direct values of individual tourists. The facilities needed for recreation are usually incorporated in standard economical cost benefit analysis of the tourist sector.

5.6 Inspiration and expression

Ecosystems provide a rich source of inspiration that is expressed in art, national symbols, architecture and advertising, but also arises from natural features with cultural and artistic value (De Groot et al 2002). Furthermore there is extensive use of nature as motivation factor in books, film, painting, folklore, national symbols, architecture, advertising, etc. All of these are creative expressions of the qualities of nature that inspire human imagination, consciously and subconsciously (Harmon 2003). There are numerous examples of the importance of inspiration and expression related to wetlands in both Daly and Mary River catchments with commercial enterprises selling Aboriginal artwork inspired by wetlands. At a national level, the importance of Aboriginal art to the local economy has been widely recognised (Altman 2003). The income-generating potential of the arts industry is important (Altman 2003).

5.7 Sense of place

People value the sense of place that is associated with recognised features of their environment, including aspects of the ecosystem. They value those aspects or natural sites that link people to the landscape through myth, legend or history. Sense of place, heritage, and identity value are closely related and often different for each user group. As Lee (2003) put it, ‘One person’s wilderness is another person’s home’. By looking at this issue at a landscape scale, the individual people and their stories are found – such as those about the abundance of fish, the beauty of water birds, the quality of the cattle, the school that flooded last year, and ancestral spirits that live in the lagoon by the old tree. These stories are an expression of people’s sense of place and illustrate the underlying reasons for attaching value to, for example, the Daly River wetlands.

In this study, collective values have been considered rather then individual values as they also form the basis of sense of place of communities, as expressed by ICOMOS (1992) ‘Communities come to value places which are the settings of important events or which become symbols of identity and aspiration’; the Burra Charter ‘Embracing the qualities for which a place has become a focus of spiritual, political, national or other cultural sentiment to a majority or a minority group’ and the Australian Heritage Commission (AHC 1992), ‘special meaning is attached to places by groups of people (rather than by an individual) and how we can take account of these values in our heritage assessment processes’.

6 Economic value of goods and services

6.1 Total economic value

The results of the economic analysis of 10 selected services provided by the wetlands in the Daly River and Mary River catchments are shown in Table 14. The current economic benefits provided by wetland services, based on sustainable use levels, has been estimated at approximately A$51 million for the Mary River catchment (on average A$450/ha) and A$82 million for the Daly River catchment (on average A$230/ha)**.** For the analysis of the individual services, direct market values were used as much as possible. In cases where markets did not exist for a particular service, an indirect approach was used; for example, extrapolated market prices from a current market in South Australia for the water use and the financial value of the funds allocated by the government for nature conservation.

The values presented correspond to the *net benefit* attributed to the producer surplus (PS) or the consumer surplus (CS). Some services generate important gross benefits, but due to high production or use costs (for example labour and equipment needed to harvest or use the service) the net benefits are low. It could be argued that these costs can be seen as being beneficial to the Northern Territory economy (especially related to employment opportunities) and thus should be considered as a benefit from the ecosystem. If the analyses were based on gross benefits, the total current use value would be much higher. In cases where more than one value was found for a given service, the lowest figure was used.

Taking into account the conservative approach used during the valuation process and the fact that only ten services were analysed, the total economic value is probably a considerable underestimate of the true contribution of the respective catchments, and hence wetland related services, to the regional economies.

It should also be noted that the services provided by these ecosystems are treated as independent in the analyses whereas, given the ecological interlinkages in wetlands, they are more likely to be inter-dependent (for example, water supply depends highly on water availablility *and* water quality). Maximising one service (for example, pastoralism, mining or conservation) will most likely lead to degradation and possibly loss of other services (for example, maximising intensive agriculture may lead to over-consumption of water, increased erosion and decreased biodiversity).

It should be noted that the figures given in Table 14 are net benefits, ie substracting labour and equipment needed (which explains, for example, the low value for sand mining). Employment generated by the various services was estimated (based on 2002/2003 figures – Mabire 2005) at 20 people for sand mining, 800 for crop growing, 25 for buffalo herding, 100 for pastoralism, 50 for crocodile hunting and egg-collection, 200 for nature conservation and 400 for tourism (including recreational fishing and hunting). Thus, total employment generated by nature-based activites was about 1600 persons in both catchments (2002/2003 figures). The value tied to this job creation has not been included in the monetary valuation.

In order to obtain a better understanding of the relative importance of the different categories of services, the data from Table 14 were grouped and re-expressed in terms of the contribution of each category to the total economic value of wetlands in each catchment (Figure 8). On this basis, the regulating services provide the largest economic benefits with the provisioning services (natural production) registering as the lowest. This can be partly explained by the absence of data for most natural production services.

Table 14 Monetary value of ecosystem services provided by wetlands in the Daly and Mary River catchments (estimated values were determined for 2004 – based on Mabire 2005) – rounded figures)

	Wetland areas in the Mary River catchment (1126 km²)		Wetland areas in the Daly River catchment (3582 km²)	
Goods & services	**Benefit description**	**Value (A$)**	**Benefit description**	**Value (A$)**
Provisioning services – Carrier functions	20 000 000 (40%)		11 000 000 (8%)	
Sand mining	PS* based on the net benefit from sand extraction	24 000	No data	
Crop growing	PS from net benefit from wetland contribution to crop production	19 000 000	Same	7 500 000
Buffalo herding	PS based on the net benefit from the buffalo herding	90 000	NA	
Pastoralism	PS based on the net benefit from pastoralism	906 430	Same	3 524 000
Provisioning services – Production function	250 000 (0.5%)		250 000 (0.2%)	
Crocodile harvest	PS based on the net benefit from crocodile hunting and egg sells	252 000	Same	252 000
Supporting services – Habitat function	1 560 000 (3%)		240 000 (0.1%)	
Nature conservation	Revealed WTP*. Current funds allocated to nature conservation	1 560 410	Same	238 922
Regulating services – Regulation function	26 800 000 (53%)		106 900 000 (77%)	
Water use	Potential CS* based on the licensed consumption	5 700 000	same	40 650 000
Carbon sequestration	Revealed WTP *to avoid environmental damages	21 112 500	same	66 260 000
Cultural services – Information function**	2 150 000 (4%)		20 450 000 (15%)	
Tourism	PS based on the expenditures for sightseeing	1 730 000	same	20 400 000
Recreational fishing	PS based on the expenditures for recreational fishing	270 000	same	43 000
Recreational hunting	Producer surplus based on expenditures on recreational hunting	150 000	No data	
TOTAL current use value		~50 760 000		~138 840 000
Current use value/ha		~A$450/ha		~A$390/ha

* Consumer Surplus (net benefit) (CS), Producer Surplus (net benefit) (PS), Willingness To Pay (WTP)

** excluding sale of Aboriginal art which amounts to AS$38 million/year for the Northern Territory as a whole

It should also be realised that the carrier functions (human enhanced productivity of ecosystems (eg agriculture) or use of non-renewable resources (eg mining) usually go at the expense of most other services. Yet the contribution of the 'natural services' of wetlands to the economy in both catchments is quite considerable: 60% in the Mary River catchment and even up to 92% in the Daly River catchment.

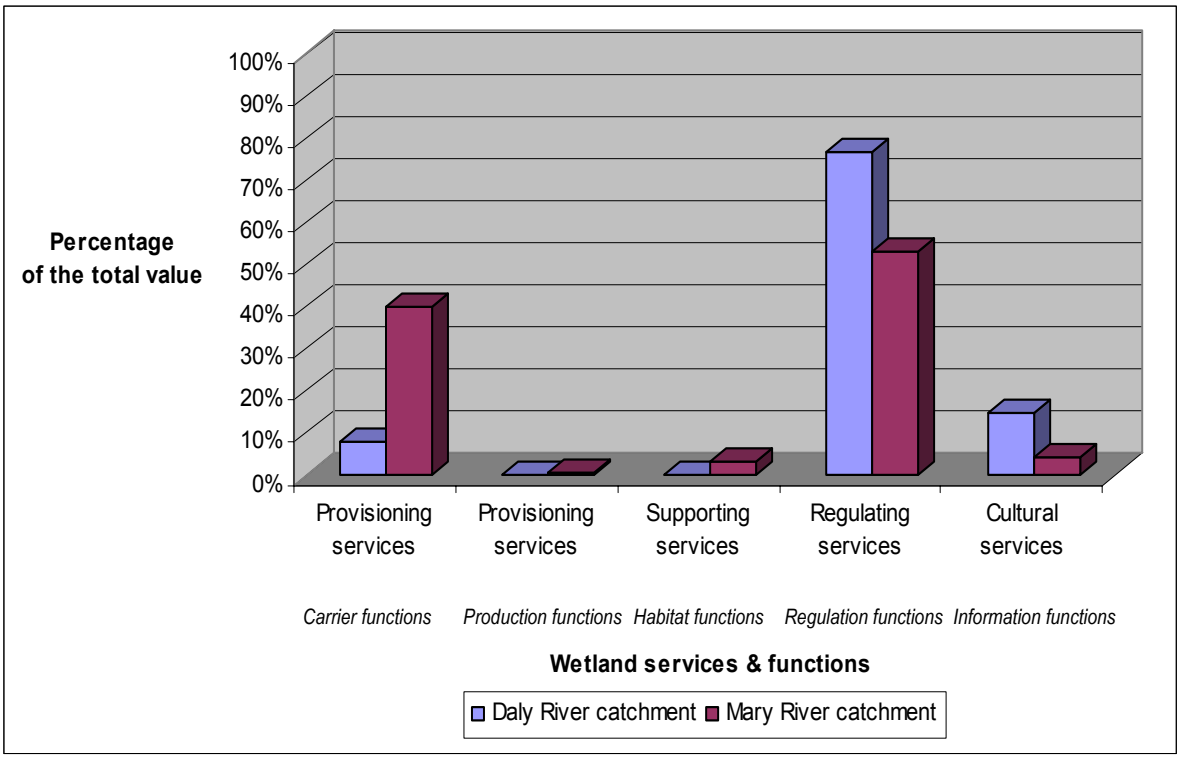

Figure 8 Relative importance of the main categories of ecosystem services in the total economic benefits

The following sections (6.2 through 6.5) briefly describe how the monetary values in Table 14 were calculated; for more detail the reader is referred to the original analysis in Mabire (2005).

6.2 Economic value of provisioning services

6.2.1 Carrier functions (use of space/substrate)

Sand mining

Sand mining is a marginal industry, which has been partially valued based on the extraction occurring in the Mary River catchment. Current use seems to be sustainable and the economic benefit of A$24 000 has been calculated using the market price (producer surplus). Recently, at least one other proposal to extract sand from the Mary River was rejected due to potential damage to the river and to tourism (Stakeholder pers comm 2004). Limited data were available for sand mining in the Daly River catchment and were provided in association with other (general) mining activities and could therefore not be calculated. The economic perspective for sand mining partly depends on the development of the horticulture sector which is the main user of the coarse sand that is obtained. If this industry is recognised as beneficial, it could be expanded given the large amount of sand available in the rivers.

Crop growing

In the Mary River catchment horticulture is rather limited and this study only looked at commercial production of billygoat plum (*Terminalia ferdinandiana*), a native fruit tree. The

consumer surplus of harvesting this fruit was estimated at A$19 million/year. In the Daly River catchment there is more intensive agricultural production, including sorghum, maize, sesame, peanuts, mung beans, soy beans and hay and grass-seed. The contribution of the wetlands (through natural flooding and irrigation) to the crop growing in the Daly River catchment was estimated at A$7.5 million (consumer surplus).

Buffalo herding

Buffalo are considered 'feral animals' that were initially introduced for grazing on waterlogged areas that are less suited for grazing by cattle. The buffalo is primarily raised for meat production and export to Southeast Asia. For the Mary River catchment, the grazing industry has an estimated (sustainable use) value of A$90 000. The current market is considered to be weak, although options to develop this further are being considered by individuals and governmental agencies. Buffalo hunting is becoming increasingly popular despite its high price (up to A$5 000 per animal). This form of tourism is being developed in the Mary River catchment and could provide opportunities for expansion (see tourism service in section 6.5).

The pastoral industry

The 'pastoral industry' is the oldest European settler economic activity in the Northern Territory and is still widely promoted by the Northern Territory government. The industry generates an estimated A$17.5 million with a producer surplus of A$906 400 from the wetlands in the Mary River catchment. In the lower Daly River catchment, pastoral grazing can be worth up to A$8 million with a producer surplus of A$3 524 000 from the wetlands. These values are considered to be conservative and based on extensive production techniques; intensification of production is being promoted through the clearing and development of improved pastures of 100 km². This development could increase the pressure on the wetlands, water resources and the biota (Begg et al 2001). Further research should investigate the impacts of natural grazing and enhanced grazing techniques.

6.2.2 Production functions (use of natural resources)

Crocodile hunting and egg-harvesting

Crocodile eggs are collected and wild animals are captured in each catchment. Since crocodiles are protected species, their commercial exploitation is limited with permits being required to harvest eggs and catch wild animals. Based on potential sustainable use levels, egg harvesting for crocodile production farms is estimated to be worth A$18 000 and wild animal catching is estimated to be worth A$234 000 (same value for both catchments). The total value for this service is thus estimated to be worth A$252 000 in both catchments.

Harvesting wild food and products for Aboriginal art

These services are being used in both catchments, and very important to the indigenous communities, but data on the economic importance was too fragmented to draw conclusions at the catchment level (see also 6.5 on cultural and amenity services).

6.3 Economic value of supporting services

Habitat service (use for nature conservation)

In addition to the importance of natural and semi-natural ecosystems to support all (or most) other ecosystem services (ie provisioning, regulating and cultural), natural habitats are important places of refuge to maintain biodiversity and essential ecological processes

(eg nutrient cycling). To avoid double counting with the benefits of other ecosystem services, the 'habitat service' is only valued based on the 'willingness to pay' (actual or stated) for conserving species and ecosystems 'in their own right'.

1 Actual or revealed value

The actual or revealed willingness-to-pay for conservation (as an expression of the importance or value we place on nature conservation) can be derived from expenditures on conservation activities such as weed management, feral animal eradication, fire management and other wetland-related conservation projects (eg landcare groups). For the wetlands in the Mary River catchment this was calculated to be on average A$1 560 410/year between 1996–2001; for the wetlands in the Daly River catchment A$238 922/year (1999–2000).

2 Stated willingness to pay

Another approach to determine the value people place on nature 'in its own right' (ie independent from the direct and indirect benefits they get through all the other services) is asking their willingess to pay (WTP) for conservation programs (admittedly it is very difficult to determine to what degree people do not, consciously or sub-conciously, take these use-values into account in their answer). Based on a Contingency Valuation undertaken in Kakadu National Park, the average stated WTP of residents in the Northern Territory for conservation of protected areas was A$14/ha/year (ranging from A$6.40 to A$107.40). Since it is very difficult to extrapolate these values to the catchment level they were not included in the calculation of the Total Economic Value.

6.4 Economic value of regulating services

Water use

The economic benefits of water use have been calculated using the (hypothetical) market value of the volume extracted under licence although the Northern Territory does not have a relevant pricing regulation scheme in place for water use. The high consumption calculated in both catchments is strongly related to the extent of development, especially within the agriculture sector which uses a high amount of water for irrigation. In 1996/97, 27 099 million litres of water were consumed in the Daly River catchment with an estimated economic value of A$40.65 million. In 1996/97, 3 794 million litres of water were consumed in the Mary River catchment with an estimated value of A$5.7 million. Depending on future decisions about the development of irrigation, the pressure on the water resources could increase and potentially place some species such as pig-nosed turtle, barramundi or magpie goose under threat (Stakeholder pers comm 2004).

CO_2 sequestration

Vegetation plays an important role in atmospheric gas regulation by producing oxygen and sequestering carbon dioxide. Based on various literature sources, this study used an average of 10 tonnes C fixed by wetlands/ha/year. The marginal damage costs of carbon dioxide emissions were estimated at US$14/tonnes (median of 28 studies (Li et al 2004)) and the recommended value after a statistic analysis was around US$50/tonnes of C fixed. Model estimates of costs of emission stabilisation and Kyoto compliance range from US$5 to US$69/tonnes with a median value around US$17/tonnes (www.ethree.com). In this study, a conservative value of US$15/tonnes is used which corresponds well to a US study on the annual willingness to pay to reduce the CO_2 of one tonne (Li et al 2004). Thus considering the surface area of wetlands in both catchments, the indirect economic benefits for the CO_2 sequestration within the Mary River catchment was estimated at A$21 112 500 and

A$66 260 000 in the Daly River catchment. Further measurements that consider the local circumstances and include methane emissions are needed for a more rigorous estimate.

6.5 Economic value of cultural and amenity services

Tourism and sightseeing

The value of sightseeing tourism has been estimated from the expenditure of visitors to the wetlands in the catchments and producer surplus (net benefit to the suppliers of sightseeing activities). In the Mary River catchment the total net economic benefits attributable to sightseeing tourism are approximately A$1 730 000 per year whereas the benefits attributable to the Daly River catchment are much greater reaching a value of A$20 400 000. Tourism is being promoted in the Daly River catchment and the region is becoming more accessible due to the development of infrastructure and the reduction of travel costs. Nature-based activities are well developed due to the diversity of ecosystems and the combination of tourism and nature conservation which is meeting the increasing demand from visitors for more 'bush', 'natural' and 'cultural' experiences.

Recreational fishing

Fishing is considered part of northern Australian culture (Palmer 2004) and the Northern Territory with its large rivers, the lure of catching barramundi, combined with the beauty of the environment represents an exceptional attraction (Stakeholder pers comm 2004). Strict regulations have been established concerning the number and the size of the fish caught per day and per recreational fisher (Coleman 2004). The average net economic benefits from recreational fishing have been estimated at A$270 000/year for the Mary River catchment and at A$43 000/year for the Daly River catchment. With commercial fishing now mostly excluded from the rivers of both catchments, the fish population is growing quickly which implies a high potential for this activity in both catchments (Stakeholder pers comm 2004).

Recreational hunting

Recreational hunting is a marginal activity with net economic benefits of approximately A$150 000 per year. The magpie goose is a target species due to its abundant occurrence in the whole Northern Territory, but other hunting activities are being developed. Buffalo, pig, horse and donkey are classed as feral species (pests) and are increasingly being targeted and included in safaris that propose a combination of activities for prices of more than A$5 000 per tour. Since these animals are classified as pests that threaten the environment and/or human health and safety, there are growing questions about the sense in creating an economic dependency through maintaining an undesirable resource (Stakeholder pers comm 2004). However, this activity currently attracts a high price. The prospect of crocodile hunting being permitted in the future also raises the spectre of more high cost safari hunting.

Aboriginal art

In addition to being a central component of Aboriginal culture and expression, the sale of Aboriginal artwork provides important opportunites to generate income for local Aboriginal communities. Indigenous art is increasingly valued in international markets and the value of paintings, sculptures and any other craft objects is increasing (Altman 2003). The total market for the Northern Territory represents a gross value of A$38 million per year (Mabire 2005). Since it is difficult to attribute this value to wetlands in the two study areas, it was not taken into account in the Total Value calculation.

7 Stakeholder analysis

Because of the various ecosystem services derived from wetlands in the Northern Territory, there are many people interested in – or affected by – their use and management. Ideally, the role of each stakeholder in the use of each service, and the effects of changes in the availability of that service on each stakeholder, should be analysed in detail as a basis for developing options and to support decision making. As this was not possible within the project, five wetland services have been selected for a more in-depth stakeholder analysis.

The stakeholder analysis consists of several steps (refer Table 6 and Appendix 2): (1) analysis of the role of the (main) stakeholders in the use of five selected services (in terms of how they depend on the service and how they influence it); (2) analysis of the effects of environmental changes, or human activities on the services (selected issues/pressures are: erosion, land clearing, introduced plants, fire and water extraction); (3) analysis of the views of the main stakeholders on these issues ('stakeholder-issue analysis'); (4) analysis of the (actual and potential) conflicts and synergies among the stakeholders on each issue (stakeholder-stakeholder analysis); and (5) analysis of trade-offs and conflict management.

7.1 Role of the main stakeholders in the use of the selected services

The five wetland services for more in-depth analysis are selected based on stakeholder interests in the wetlands. The services are: i) agriculture and pastoralism; ii) food; iii) maintencance of biodiversity; iv) water supply; and v) knowledge (education and formal and informal research). The stakeholders were divided into primary, secondary and tertiary categories (Table 15).

(1) The *primary stakeholders* are those who are directly affected on a daily basis by the decisions of policy-makers. They encompass Aboriginal and non-Aboriginal residents, pastoralists and horticulturalists, conservation rangers, and recreational fishers etc. The interests of the primary stakeholders variously include maintaining a stable income, conserving those components of the wetlands that are seen as important for fishing and hunting, as well as protecting cultural areas (eg Aboriginal sacred sites).

(2) The *secondary stakeholders* are those who represent the interests of the primary stakeholders and assist in communicating these interests to the government. They can also encourage the primary stakeholders to get involved in the decision and management processes or in the execution of policy and management practices. They include agricultural associations such as the Northern Territory Cattlemen's Association (NTCA), Northern Territory Horticultral Association (NTHA), Amateur Fishermens Association of the Northern Territory (AFANT), Environment Centre of the Northern Territory (ECNT), landcare groups and research institutions, for example Charles Darwin University (CDU), CSIRO and the Environmental Research Institute of the Supervising Scientist (***eriss***). The interests of the secondary stakeholders are similar to the interests of the primary stakeholders.

(3) The *tertiary stakeholders* are those who make the policy and management decisions that affect the wetland services and related stakeholders. They include the Department of Business and Employment (DBE), the Department of Regional Development, Primary Industry, Fisheries and Resources (DRDPIFR) and the Department of Natural Resources, Environment, the Arts and Sport (NRETAS). The interests of the tertiary stakeholders are to develop a sustainable economical income for the primary stakeholders and/or conserve biodiversity.

Table 15 Example of main stakeholders using the selected wetland services

Role in selected wetland services					
Stakeholders	**Agriculture/pastoralism**	**Food (recreational & subsistence hunting & fishing)**	**Maintenance of biodiversity (conservation)**	**Water supply**	**Knowledge (education & informal and formal research)**
Primary stakeholders					
All residents (Aboriginal people and non-Aboriginal people)	No data found	Gathering bushfood and hunting	Assisting in planting native plant/tree species	Drinking water	Passing on traditional knowledge, assisting in research on locating plant and animal species
Pastoralists & horticulturists	Cattle graze on wetlands, crops/fruit are cultivated (for example mangos near the Daly River), service supports income	No data found	Conduct land management (eg controlled fires)	Irrigation water for crops and drinking water for cattle (outside the wetlands)	No data found
Fishers (commercial and recreational)	No data found	Commercial fishing takes place near the mouth of the Daly and Mary River	Catch-and-release program, undersized fish are released in order to maintain population growth	Service supports fishing activity	Assist in population of fish species
Tourists (local & regional)	No data found	Fishers can sometimes keep fish for own consumption: A bag limit of five barramundi in the Daly River and two barramundi in the Mary River (NTG 2007)	No data found	Service supports recreational acitivties	No data found
Conservation rangers (Wagiman-Guardagun Ranger Group, Malak Malak Land Management rangers)	No data found	Potential hunting of feral pigs (eradication of feral pigs is part of the INRM plan 2004; undertaken by rangers)	Conducting land management (eg eradicating weeds, pest animals (for example cane toad), controlled fires, etc)	Service supports habitat of flora and fauna	Assist in research (eg in monitoring water quality in the Daly River) and learn skills in land management
Secondary stakeholders					
Agricultural associations (eg NTCA, NTHA, KHA, NTBIC)	Service provides their members with an income, agricultural development in Daly River catchment would potentially enlarge contribution to local and NT economy	No data found	No data found	Lobby for their members on dividing the water resource of the Daly River	No data found

Role in selected wetland services					
Stakeholders	**Agriculture/pastoralism**	**Food (recreational & subsistence hunting & fishing)**	**Maintenance of biodiversity (conservation)**	**Water supply**	**Knowledge (education & informal and formal research)**
Environmental organisations (eg ECNT, Greening Australia)	Concerned about the impact of land clearing	No data found	Maintain biodiversity and set up campaigns on biodiversity issues	Concerns on effects to the storage of fresh water in aquifers by extracting water for cultivation purposes	Educate and inform people on the environment and related issues
Landcare Council of NT & landcare groups (eg Wangamaty (Lower Daly) Landcare, Mary River Landcare Group)	Manage pastoral land (eg Mary River Landcare Group)	No data found	Conduct land management practices to maintain biodiversity	Service supports habitat of flora and fauna	Conduct training workshops, raising environmental awareness at schools, assist in environmental research
Receational organisations (eg AFANT)	No data found	Informing fishers on allowable amount of fish catch	Make fishers aware of opportunities to participate in catch data collectiion and provide information to fishers to help prevent the spread of weeds	Service supports recreation activities	Promote research on fish species
Research institutes (eg Charles Darwin University, ERISS, CSIRO)	Research on production capacity of pasture species	No data found	Raising awareness on ecology, provide (eg government) with policy and management recommendations on conservation	Research on water flows requirements	Research on ecology and socio-cultural values of wetlands
Tertiary stakeholders					
Commercial NT government departments (eg DRDPIFR, NRETAS)	Supporting pastoralists. Making plans for agricultural development in Daly River catchment.	No data found	Making assessments and developing management plans for conserving biodiversity	Developing plans for allocating water resources among users (eg drinking water, irrigation etc)	Research on improved pasture species and mixed farming
NRETAS (Parks & Wildlife Service)	Research on causes for changes on pastoral land	No data found	Making assessments and developing strategies to maintain biodiversity	Service supports habitat of flora and fauna	Conducts research on a-biotic and biotic features – flora and fauna

Key points that emerge from Table 15 include the following:

- Agriculture/pastoralism: predominantly used by (Aboriginal and non-Aboriginal) pastoralists who manage the land in different ways in order to sustain an income. This can involve using native and introduced pasture species for cattle grazing and potentially landclearing. The pastoralists are represented through several stakeholder organisations (eg landcare groups) and provide substantial support for the local and Northern Territory economy and can in some instances receive support from some tertiary stakeholders (eg DRDPIFR).
- Food: the main stakeholder activities are the gathering of 'bush food' and hunting feral animals (eg pigs and horses) for personal consumption as well as for commercial purposes (Stakeholder pers comm 2004).
- Maintenance of biodiversity: the stakeholders have an interest in conserving the biodiversity of the wetlands; however, their motives for doing so may differ and include ecological, cultural or economical purposes.
- Water supply: used for different purposes with the main general uses drinking water and irrigation. Some stakeholders are keen to ensure there is sufficient water to sustain the biophysical processes that support the wetlands.
- Knowledge (education and research): the main stakeholder interests in this service are passing on of local knowledge to future generations and conducting research on the ecology of the wetlands.

7.2 Effects of environmental change or human activities on the services

The main environmental pressures on the Daly and Mary River wetlands are erosion, the use of introduced pasture species, land clearing outside the wetlands, use of fire to control weeds, and water extraction. The effect of these on the wetland services is summarised in Appendix 4.

Erosion is a natural process that can be accelerated by land use practices and can occur as a result of past or present overgrazing by cattle (pastoralism) or the removal of vegetation by repeated hot fires (MRCAC 2001; Armstrong et al 2002). Tracks regularly used by cattle in the Daly River catchment have caused erosion and contributed to increased sediment transport in the river and the establishment of sandbars (DRCRG 2004d). In the Mary River catchment, land clearing outside the wetlands has resulted in erosion (MRCAC 2001). Erosion can affect the biodiversity of wetlands through loss of habitat and deterioration of the water quality (Armstrong et al 2002).

Land clearing distant from wetlands may affect some wetland services through, for example, changing the pattern of water run-off and infiltration to ground water stores, or by increasing the rates and types of sedimentation. This can change the distribution and abundance of wetland vegetation and animal communities (PWCNT 2000).

The *introduction of pasture species* is a component of a wider tendency to introduce plants for horticultural or ornamental purposes and to increase pastoral production, or they were introduced accidently (Armstrong et al 2002). Pastoral species introduced into the wetlands include olive hymenachne (*Hymenachne amplexicaulis*) and paragrass (*Urochloa mutica*) while gamba (*Andropogon gayanus*) and buffel grass (*Cenchrus ciliaris*) have been introduced elsewhere in the catchment (LCNT 2004). Within the 'Draft INRM plan for the Northern Territory' it is stated that 'weeds can affect the ecological function of wetlands,

radically change the composition of surrounding vegetation, affect the hydrological regime or contribute to higher fuel loads and consequent increased wildfire frequency in surrounding vegetation' (LCNT 2004).

The *use of fire* to manage the vegetation, including invasive species, has also increased pressure on the wetlands. Due to the spread of introduced grasses the frequency and intensity of fires in some wetlands have been increased (LCNT 2004). Some plant species and communities within wetlands are more sensitive, and may decline under frequent and/or late dry season and wet season burning regimes. The decline in plant communities can result in effects on the animal communities located in wetland habitats (LCNT 2004).

Forecasted developments *in water use* and the development of further infrastructure could have dramatic impacts on the flora and fauna, as well as on the Aboriginal culture which still has a strong relationship with the natural environment. Environmental degradation could come at a high cost to the local population in social and even monetary terms with the expected increase in extreme events (eg flooding).

7.3 Analysis of the views of the main stakeholders on water use

Based on information provided in the previous sections, it becomes possible to analyse and disentangle some of the many actual and potential conflicts and common interests between the main stakeholders.

Water derived from the wetlands is a critically important resource for stakeholders within the Daly and Mary River catchments and is a topic of discussion between stakeholders, especially within the Daly River catchment as a consequence of proposed agricultural development. The Daly Basin is the focus area of the Daly Region Community Reference Group (DRCRG) which developed a draft Integrated Regional Land Use Plan as a framework for ensuring that any development was ecologically sustainable. The DRCRG came across environmental, social, economic, cultural and heritage values of the focus area and identified the special connection Aboriginal Traditional Owners have to the land (Clare Martin MLA 2003). One issue identified by the DRCRG was the water supply with an emphasis on water allocation and potential land uses. The discussion on dividing the water served to make competing interests transparent, as shown in Figure 9 and the following text.

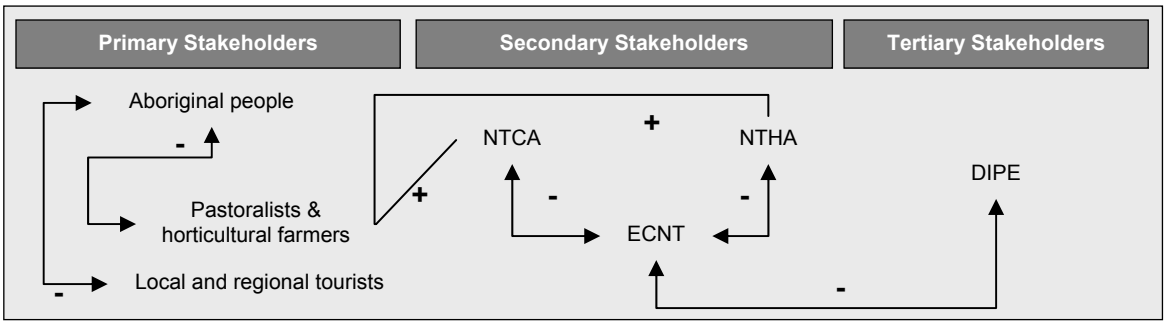

Figure 9 Stakeholder diagram of main parties concerned with the water supply service in the Daly River catchment (based on DRCRG 2004a)

Note: '+' indicates cooperation or one of the stakeholders gives/receives support; '-' indicates potential competing interests between stakeholders. NTCA: Northern Territory Cattlemen's Association, NTHA: Northern Territory Horticulture Association, ECNT: Environment Centre of the Northern Territory, DIPE: Department of Infrastructure, Planning and Environment.

Competing interests between primary stakeholders

Land owners have the right to take water for riparian use – rural stock and domestic – sometimes under a licence (DRCRG 2004a). This consumptive use is competing with the non-consumptive water use. Therefore, a potential competing interest occurs between pastoralists, horticultural farmers and Aboriginal people based on needs and cultural beliefs. In the Northern Territory, the Water Act confirms that the water is owned by the Government (DRCRG 2004a). In contrast, Aboriginal people view water resources as an inter-related part of their 'country' (Jackson 2004; Authority of the Senate 2003).

> Aboriginal people have never drawn a distinction between the land and the water that flow over, rest upon or flow beneath it. The land and waters are equal components of 'country', all that require care and nurturing, and for which there are ongoing responsibilities (Jackson 2004).

The origins of water and its features and appropriate use are highly significant to Aboriginal people as it determines their way of life, sense of identity, economy and cosmology (Jackson 2004; DRCRG 2004b). There are diverse traditional stories associated with water (Jackson 2004).

Besides the potential competing interest between pastoralists, farmers (consumptive use) and Aboriginal people (consumptive and non-consumptive), there are also potential competing interests with local and regional tourists. This competing interest is based more on using the water for recreational purposes and cultural purposes. Local and regional tourists use the water for receation and for fishing. Some Aboriginal people are concerned about the impact of fishing boats on the Daly River, especially as an additional cause of erosion. Others are concerned that the boats are taking over the river and that 'anchors are being put into the river bed'(DRCRG 2004c). The response of one fisher during an interview was that they do not use anchors, but tie the boat to a tree and therefore do not see the concern.

> We are talking about water, but these people are sitting on my ancestors under the river, that river is really alive. You can knock them about. And when you come back it will walk away to another place (DRCRG 2004c).

> On top the land may be white fella country – Western people – but underneath it is black fella country – Aboriginal people (DRCRG 2004c).

Competing interests between secondary stakeholders

The wider environment (flora and fauna) is another element that competes for the water in the wetlands. This means that different stakeholders are competing with the flora and fauna of the wetlands in terms of water requirements for production and survival purposes and maintenance of biodiversity in the wetlands. The agricultural associations such as Northern Territory Cattlemen's Association and Northern Territory Horticultural Association are representing their members who need the water for irrigating their properties either for pastoral purposes or for growing crops. A representative of the horticultural association stated the following during a public meeting of the DRCRG:

> Currently people have land that they are developing but may not be using all of the water they need for the total area. If the final stages of the development are implemented these people would be disappointed to find that the water had already been allocated (DRCRG 2004d).

> The resource must be appropriately shared. It is unfair to say that user x will have 100% of their entitlement, and another will have less. 'No impact' will need to be within the overall allocation of some sort of standard flow figure. All licence holders need to be treated equally (DRCRG 2004d).

In terms of water allocation the Environment Centre of the Northern Territory (ECNT) is concerned about the effects of water abstraction by the agricultural sector on the Daly River ecosystem as well as the effects of agricultural development.

> During the dry season areas such as the Daly Region and other rivers in the Northern Territory rely on groundwater – so if we go down the path of allocating water up front, just because we want irrigated agriculture that will potentially lead to serious problems with our river systems (Authority of the Senate 2003).
>
> There is a significant underpricing of water resources in the Northern Territory. The fact it is free is probably misleading advertising, but that also highlights the fact that is how it is perceived by agricultural growers in the Northern Territory, and maybe that is how it is being seen by other sectors around the country. It is actually portraying the Northern Territory as having free or very low-priced water (Authority of the Senate 2003).

Although both stakeholder groups indicate in their statements that the wetland service 'freshwater' has to be shared between the production sector and environment, they disagree about the amounts of water that should be directed to agriculture for irrigation water and for the environment.

Competing interest between secondary and tertiary stakeholders

Some stakeholders are also wary of irrigation development given the experience of the Murray-Darling Basin; this is one of Australia's largest drainage systems and now supports approximately 75% of Australia's irrigation agriculture, but with resultant lower flows and changes in seasonal flow patterns leading to widescale degradation (MDBC 2004). The ECNT is concerned that 'the Northern Territory Government is repeating the same development mistakes that are leading to the collapse of the Murray-Darling River system and that the Minister should give the public a chance to make decisions about the Daly before agriculture development has gone too far' (ECNT 2003).

In addition to this general competing interest, the ECNT has a potential competing interest with the governmental department NRETAS (formerly DIPE) responsible for collecting the water flow data that will provide information for decisions on water allocation (DRCRG 2004b). As the ECNT has doubts about the accuracy of the water flow data, it formally requested (through the Freedom of Information Act) access to the data, a request that was granted by the NT Government (DRCRG 2004e). The ECNT considered this a necessary step towards resolving its competing interest about the data.

7.4 Trade-offs and conflict management

The competing interests of stakeholders has led to different potential trade-offs. On the issue of reducing the use of introduced pasture species for cattle grazing, more research on the production capacity of native pastures is recommended as an alternative (Ypma 2005). This may mean a shift in thinking by and more funding support to research farms (eg Douglas Daly Research Farm) by the government department DRDPIFR (formerly DPIFM), which undertakes research on introduced pasture speces, to enable them to better inform pastoralists about the production capacity of native pastures. The government could also stimulate the use of native pastures by providing subsidies. In relation to land clearing the government has a measure of control through a permit system and could make use of this to ensure that when clearing is allowed that ecological buffer zones are left and maintained. Similarly, Aboriginal people could be consulted before land is cleared to ensure that important sites are not damaged.

Trade-offs are potentially more difficult when considering water abstraction for both consumptive and non-consumptive use; the extent of environmental water requirements are not well known.

Feral animals can also pose a dilemma or vested interest. On the one hand there is an expectation that they will be controlled, but on the other some stakeholders can obtain financial income through using them as a basis for safari hunting. In these instances, it is a question about the balance between the damage incurred by the pest species and the income obtained, and whether such hunting is a suitable control mechanism, ie is it sustainable?

Conflict management in the shape of negotiation is considered to be the most appropriate method to manage the diverse competing interests of the stakeholders. It can create mutual understanding between stakeholders about their interests and belief systems and identify ways in which they can potentially work together. Similarly, research into competing issues can at times be promoted by involving stakeholders in the research itself and in appropriate circumstances allowing them control over how their knowledge will be used. If successful these steps can create more understanding and commitment to the research and its results.

8 Policy and institutional analysis

For decision-making about wetland uses it is important to identify and analyse the institutional context and policies that influence the ways in which wetlands are used. A broad approach was taken in defining 'institution' and embraced both the terms 'policy' and 'roles or organisations with special legal status'. The former was depicted as rules-oriented institutions and the latter as roles-oriented institutions. During the analysis, the relationship between the policies (rules-oriented institutions) and ecosystem services were studied. For the roles-oriented institutions, their role and importance in the management of wetlands in the research areas were indicated.

8.1 Organisations (roles-oriented institutions)

Under the roles-oriented institutions, different governmental departments and other institutions were identified at national, intergovernmental, territory and local level. These institutions had various roles and mandates and were active in various fields such as education and awareness, funding, research and development, and community awareness.

The institutions at *higher levels*, such as the federal Department of the Environment, Water, Heritage and the Arts and intergovernmental organisations, were more active in the fields of regulation and funding. Their roles were more oriented towards development of specific policies and regulations, monitoring and enforcement. They also play a vital role in motivating the local institutions by providing substantial funding (eg the Natural Heritage Trust Fund, administered by the Federal Department had been an important source of funding for research and the development of various management programs to conserve and protect wetlands in the research area).

The institutions at *lower levels*, such as the Northern Territory Government and catchment authorities, had a greater role to play in the implementation of such higher-level regulations. These institutions generally had more contact with community and local people to include them in planning and resource use decisions (eg NRETAS formed the Daly Region Community Reference Group consisting of all the landholders, industry groups, conservation groups and other stakeholders to discuss the future development of Daly River catchment). At the catchment level, the local groups essentially consisted of the users of resources within the catchment and appeared to be more effective and influential in managing the local resources, provided that there was a proper consultative forum and appropriate support from the government (eg Mary River Catchment Advisory Committee overseeing the implementation of the Integrated Catchment Management Plan of the Mary River catchment).

There were also some other institutions that were difficult to categorise (perhaps *cross level*), such as research units and special group representative institutions (such as the Northern Land Council (NLC), Aboriginal Areas Protection Authority (AAPA) and Key Centre forTropical Wildlife Management, Charles Darwin Univeristy (CDU), which at the time played a major role in research and education, and on representing the concerns and interest of special groups of local people, such as Traditional Owners.

8.2 Policies (rules-oriented institutions)

Under rules-oriented institutions, lists of policies (especially legislation) and strategies were identified and associated with the individual ecosystem services provided by wetlands.

Identified policies were first categorised into two types as primary policies and secondary policies. Primary policy included the policy that was directly associated with a given ecosystem service and was a promoter or regulator for that particular service (eg *Mining Act 1980 (NT)* is a primary policy for the provisioning service: 'raw materials'; or (carrier) function: 'mining'). Secondary policies included many other policies that were not directly a promoter or regulator of a given service, but nevertheless had substantial power and capacity to define the ways in which the given service was utilised (eg the *Aboriginal Land Rights (Northern Territory) Act 1976*, which is the secondary policy for the mining function and would decide if mining is allowed in Aboriginal Land or not).

Both primary and secondary policies exerted positive and negative influence on the ecosystem services identified. The positive influence was present when policies promoted the sustainable use of the services and safeguarded their over-exploitation. The mechanisms for doing this were basically provided through the provisions prescribed in legislation, such as: by granting of title (eg Aboriginal freehold, pastoral lease, mining lease); by giving consent to the conversion of land for a given use (mining, agriculture purposes); by declaring the control district and management plans (eg water control district, pastoral district); by prescribing mechanisms to monitor the changes; and/or by issuing a moratorium, if needed, to control the degradation of resources (eg Interim Development Control Order in the Daly River catchment to halt the ongoing land clearing). Primary policies such as the *Fisheries Act*, *Pastoral Land Act 1992 (NT)*, *Mining Act* and *Water Act 1992* (NT) were examples of policies that had a positive influence on the services of fishing, pastoralism, mining, and water supply respectively.

The negative influence of policies exist when the conduct of a given activity or use of a given service was not consistent with the use of another service. The result was that the additional procedures that might be required for the use of a given service (eg difference in the application procedure for mining on Crown land and Aboriginal land); additional time (eg the extra negotiation period needed for the consent of all the authorities); and additional cost (eg the compensation to be paid or the extra royalties to be paid). The negative influences did not completely stop the use of a given service; nevertheless, it made it more difficult due to the extra requirements. For example, secondary policies such as the *Aboriginal Sacred Sites Act*, *Pastoral Land Act* and *Mining Act* had negative influences on some of the carrier and habitat functions identified.

An important consideration is that positive and negative influences are linked to the continuity of the use of the service by the primary user supported by the policy. But when seen from the perspective of the entire system especially in terms of conservation values, social values, cultural tradition etc, it may be hard to justify the influence as being positive or negative. For example, the impact of the *NT Weeds Management Act 2001* on the pastoral function is negative only when seen from the point of sustainability of pastoral activity; however, if seen from the perspective of nature conservation related to the issue of improved pasture species becoming potential environmental weeds, the impact of the *Weeds Management Act* on the environment is clearly positive. The same applies to the *Aboriginal Land Rights Act* and the *Northern Territory Aboriginal Sacred Sites Act 1989 (NT)*, as these Acts tend to have a perceived negative influence on some of the carrier functions such as pastoralism, mining etc. Seen from the perspective of social values, cultural traditions and ecosystem health, these Acts clearly have a positive impact on society and the environment.

8.3 Policy interactions

The study found that policies interact in active, passive and mixed ways. Active interaction, when the policies were consistent with each other, promoted the intended activity and enabled it to proceed smoothly, or also fostered more than one service at a same time. For example, active interaction between the Strategy for Conservation of Biological Diversity of Wetlands of the NT and *Territory Parks and Wildlife Conservation Act* (TPWCA) promote supporting (provision of habitat) and cultural services (information and recreation) at the same time. Passive interaction – when the policies are inconsistent with each other – disturbed the intended activity and or limited the use of one service to the fullest extent. For example, the passive interaction between the Pastoral Land Act and Weeds Management Act neither supports the pastoral carrier function fully nor safeguards ecosystem services (nature conservation), especially when improved pasture species become weeds.

The majority of the interactions between policies were of 'mixed' interaction, which existed when there were incomplete and unclear mechanisms in both policies to address an issue or a problem. For example, the Fisheries Act recognised traditional Aboriginal fishing but it also grants licences to fish in areas claimed by Aboriginal people and limited the issue of commercial Aboriginal coastal licenses to Aboriginal people. Hence the Fisheries Act had a 'mixed' interaction with ALRA/Native Title (see Table 16).

Table 16 Interaction between the Fisheries Act and secondary policies for fisheries

Fisheries (commercial & aquaculture)	**ALRA & Native Title**	**Water Act**	**Mining Act**	**ASSPA**	**Marine Act**
Fisheries Act	(Mixed Interaction)	(Passive interaction)	(Passive interaction)	(Passive interaction)	(Mixed interaction)
	The Fisheries Act does recognise the traditional fishing by Aboriginal people but it also grants access to fisheries resources in areas claimed by Aboriginal communities and has no provisions for Aboriginal commercial coastal licence	The Water Act recognises aquaculture under beneficial use category but it doesn't quantify specific water allocation for such purposes	Both Acts have no clear provisions for addressing the impact of offshore mining on the fish resources	Both Acts have no clear provisions for fishing conditions or requirements in having Aboriginal sacred sites	Both the Acts regulate the commercial vessels used for fishing purposes, but it is not clear under which single Act a particular vessel is regulated

8.4 Stakeholder involvement in policy development

The research adopted two approaches for assessing the views and involvement of stakeholders. One approach dealt with assessing the existing state of stakeholders' involvement in the decisions in the Daly and Mary River catchments. The other dealt with the linking stakeholders groups with the policy and the use of ecosystem services through the perspective of representation and perspective of organisation of stakeholders.

In the first approach, the existing mechanisms for stakeholder involvement in catchment management were explored. In the Daly River catchment, a statutory community group did not exist and a catchment-wide management plan was not available. However, the consultative forum (Daly River Community Reference Group – DRCRG) brought together different stakeholder groups responsible for developing a Regional Land Use Plan for a defined area. Limited group representation, limited timeframe and lack of scientific information to underpin decision-making were found to be key problems affecting the operations of the consultative group. In the Mary River catchment, there was a statutory group – the Mary River Catchment Advisory Committee – that could oversee a catchment-wide management plan (Integrated Catchment Management Plan of Mary River Catchment), but this was affected by issues such as the composition of the committee (eg it was chaired by a governmental official) and the limited government support given to the stakeholder groups.

The second approach identified the linkages between stakeholders, ecosystem services and policy, and explored these from the perspective of stakeholders' representation and from the perspective of stakeholders' organisations. In the case of stakeholders' representation, a check was made to see if all the stakeholder groups linked to a given ecosystem service were represented in a policy or not. In most of the cases the same stakeholder groups utilising a given service provided by wetlands were also addressed in the policy, but their concerns were not equally reflected in that policy. For example, the Pastoral Land Act favours the interests of pastoralists and had insufficient provision to address the concerns of other stakeholders affected by pastoralism and interested in the diversification of pastoral land for purposes such as mixed farming, eco-tourism and biodiversity conservation.

In the case of stakeholders' organisations, it was observed that stakeholders organised themselves in different ways and that this reflected their interest in different ecosystem services. For example, organised interest groups were more interested in the 'carrier' functions supported by the ecosystem (eg mining horticulture etc) or, in other words, optimising the provisioning services that are economically valuable to those groups (eg minerals, water for crops). In contrast, community-based groups were more concerned with the maintenance of regulating and supporting services – such as those that were important for their area and were under threat, such as reductions in significant habitat, erosion control, flood prevention, and/or necessary water to maintain environmental and cultural flows.

9 Management implications

The results of this project support the message that an integrated, cross-sectoral and ecosystem-based approach to management is needed to secure the benefits that wetlands provide to support human well-being. This accords with the outcomes of the Millennium Ecosystem Assessment (2005).

9.1 Awareness of ecosystem services and benefits

There is a growing recognition in the Northern Territory of the diverse benefits and services provided by wetland ecosystems to broader society (PWCNT 2000; LCNT 2004). There is also a growing understanding of the need to recognise the values derived from wetlands and incorporate them into management and planning frameworks (PWCNT 2000; LCNT 2004). Whilst this is now being recognised in terms of 'higher-level' strategies for wetland management, it is not yet being translated to operational management at catchment or local level. Many of the existing approaches for wetland management across the Daly and Mary River catchments do not explicitly address or recognise the ecosystem services provided by wetlands.

Current management approaches at a regional and catchment level and for both indigenous and non-indigenous management are principally *issue-based*. Therefore, wetland services are being addressed indirectly in current management plans as a result of management actions that are primarily designed to mitigate a perceived priority issue. A number of specific management responses appear to (positively) address key wetland services, however, there is no current systematic approach or larger program for addressing wetland services in management or mechanisms for monitoring their ability to sustain services and benefits which currently support regional well-being.

Table 17 Summary of most and least addressed wetland services in management plans analysed

	Wetland services	
Research area	**Most addressed**	**Least addressed**
Daly River catchment	Provisioning: food	Provisioning: water supply
Draft Wagiman Land Management Plan	Cultural & heritage	Regulating: water regulation (emerging focus)
Mary River catchment	Provisioning (carrier): pastoral	Regulating: water regulation
Revised ICMP Mary River	Supporting: habitat (breeding & nursery)	Provisioning: water supply

9.2 Implications of function analysis for management

This section brings together the results of the analyses made above and contains a synthesis of the major outcomes.

The primary aim of the project was to apply the function analysis framework to the Daly and Mary River catchments and to provide an initial overview of how the analysis can be applied across different catchment areas – each with their own distinct forms of land use, management and objectives. Effective application of the function analysis framework requires the inclusion of at least the following:

- a clear understanding of management and policy objectives and the purpose for applying the framework;
- functions or services to be identified for the spatially defined (catchment) area and ranked in importance;
- determining suitable environmental indicators (performance and state) as a benchmark for ecosystem service assessment and monitoring; valuation (ecological, economic and socio-cultural) of these services;
- analysis of trade-offs related to wetland use options and selected functions; understanding the constraints within the existing policy framework for options/outcomes to guide policy measures;
- development of strategic management objectives to assist the successful implementation of the desired course of action at an operational ('on-ground') level.

Effective application of the framework requires stakeholder and expert involvement as an essential component in all steps. It is acknowledged that this approach is unlikely to overcome all problems due to information gaps and uncertainties in presenting specific implications for management; it is emphasised that where information gaps and/or uncertainty occur that ecosystem-based approaches that incorporate adaptive management and the precautionary principle should be adopted.

An example is given below of how an integrated ecosystem assessment can be applied to managing the water supply service in the Daly River catchment.

9.3 Implications of function analysis for water management in the Daly River catchment

The water supply service in the Daly River catchment has been the subject of considerable debate and central to much of the discussions in the DRCRG process, particularly related to what constitutes a sustainable limit for water abstraction, ie what is needed to maintain necessary environmental flows, as well with the emerging discussion of 'cultural flow', if such a target can actually be defined (see also DIPE 2003a; Erskine et al 2003; Jackson 2004). As a result, the process undertaken throughout this integrated assessment can potentially contribute to the current understanding of the value of the water supply service to various stakeholder groups and how that can influence management planning.

Analysis in Appendix 4 illustrates that the water supply service is vulnerable to all issues and threats identified in the Daly River catchment: water extraction, water impoundment, land clearance and agriculture, weeds, feral animals, pastoral activity as well as mining and tourism/recreation. Prior to undertaking a detailed analysis of the water supply service, it can already be asserted that water supply is central to all current and future activity in the Daly River catchment – economic development, ecological integrity and socio-cultural well-being. Therefore, water supply in the Daly River catchment clearly overlaps and supports other wetland services such as the provisioning services (food availability) function, cultural services (eg recreation and spiritual benefits) and supporting services (eg suitable breeding and nursery habitat).

At the time of conducting research for this report, no management plan – for the Daly River catchment as a whole – currently existed in terms of addressing water supply or extraction. However, the Daly Region Water Allocation Plan is linked to the development of the

Regional Land Use Plan by the DRCRG and was due for release in the months after this research was undertaken.

9.3.1 Implications of function valuations for water management (Sub-projects 1, 2 and 3)

The importance of water supply in the Daly River catchment has been a focus of analysis throughout the valuation processes of the sub-projects in the Integrated Assessment of Wetlands in Northern Australia. Key findings relevant to management are summarised in Table 18.

Table 18 Summary description of values for the water supply service in the Daly River catchment

Value type	Description of attached value to water supply service
Ecological value	Not directly assessed. However, whilst the water supply in the function typology is mainly linked to anthropocentric benefits such as the provision of water for consumption (drinking water, irrigation), maintenance of water supply levels (known as 'environmental flows') is critical in ensuring a range of vital ecological processes as well as supporting other services such as supporting (nursery and refugium) services. For example, sufficient water supply is a critical factor in the annual recharge of the Daly River wetlands and is vital to the lifecycle and nursery habitat of aquatic species such as barramundi (Stakeholder pers comm 2004) or refugium habitat for the pig-nosed turtle. See Begg et al (2001) and Erskine et al (2003) for a more detailed assessment of the importance of water supply and environmental flows in the maintenance of wetland ecological integrity.
Socio-cultural value	Socio-cultural values related to water supply include: (cultural) heritage; spiritual, recreation & tourism, inspiration & expression, knowledge, aesthetic, and importance to human health. Jackson (2004) also provides an overview of some of the key values and associations Aboriginal people have in relation to water supply service of wetlands of the Daly region; it determines Aboriginal way of life, sense of identity and cosmology – the understanding of how the world was formed. Water supply is also essential to Aboriginal culture for its life-giving qualities ('Living Water'), its role in preventing exposure of sacred sites located beneath the river level as well as needing to preserve cultural stories. A preliminary assessment of non-indigenous social values related to the Daly River can be found in Young (2004) with the notable outcome indicating that the NT public and inter-state tourists generally only attach a value of importance to the continued health of the Daly River itself – with less concern for the preservation of habitats (aquatic and non-aquatic) surrounding the river. Water supply is clearly important for the ongoing viability of (non-indigenous) enterprises in the area such as horticulture or pastoral activity which, in themselves, have a range of socio-cultural values for those that operate and benefit from such enterprises.
Economic value	The economic benefits attributable to water use (based on current returns on consumptive use) in the Daly River catchment have been calculated using an average price leading to a value of A$5.8/ha/annum. Future analysis would need to investigate future economic values (and opportunity costs) anticipated from different water use scenarios.

9.3.2 Implications of stakeholder & conflict analysis for water management (Sub-project 4)

The stakeholder analysis identified that the water supply service provided by wetlands in the Daly River catchment is of greatest importance to the largest cross-section of stakeholders at all levels – primary, secondary and tertiary. This is not surprising given that water is fundamental to all life on the planet and that issues over water resources elsewhere in Australia have shaped current perspectives in the Daly Region. However, the primary issue identified between stakeholders was how to deliver equitable outcomes in the water allocation process – for consumptive and non-consumptive uses – and how these outcomes will determine future land use.

Conflicting or competing uses of water were identified between a number of individuals, groups and institutions across and between all stakeholder groups – primary, secondary and

tertiary – eg between Aboriginal communities and agricultural and tourism interests as well as institutionally between NRETAS and ECNT. The stakeholder analysis in this report identified that the competing interests are not only based on needs but on beliefs. Given the extent and depth of attachment the relevant stakeholder groups have with regard to water supply, it is therefore clear that any threats, trade-offs, allocation or other management actions related to water supply needs to be undertaken with considerable precaution.

9.3.3 Implications of policy and institutional analysis for water management (Sub-project 5 and 6)

Water supply is regulated through the Water Act with results of the policy analysis indicating that water supply is positively addressed through the Water Act as the primary policy which stipulates when and how water resources are protected, managed and equitably allocated to different sectors. Secondary policy for water quality monitoring includes guidelines aimed at protecting and enhancing water quality as well as ensuring reliable allocation plans. Secondary policies such as the Pastoral Land Act and the Mining Act were identified as having potential negative effects on the water supply function through the provision of activities that may consume or pollute water resources.

In addition to these conflicting policies related to water supply, numerous concerns have been raised about the effectiveness of the Water Act in enforcing water licences for water harvest, the ability to adequately account for cultural requirements for water, and that commitments made at a national level (National Water Reforms in 1994/95) have not yet materialised in the Water Act.

9.4 Potential for ecosystem function analysis to be applied to wetland management and planning in the Northern Territory

Ecosystem function analysis is an integrated assessment tool which can potentially contribute to effective management and planning by offering greater accountability in actions and therefore assisting in reconciling competing interests to allow for the equitable allocation of resources. Before competing interests can effectively be reconciled, it is necessary for decision-makers to have a clear understanding on the nature of the interests at stake – what is driving them and why are they important to the stakeholders concerned. By its very nature, a function analysis approach allows for a more transparent and objective approach in decision-making processes that take into account local concerns and the effectiveness of management actions.

Box 6 A strategic approach

> '...it's such a big area and there's so little money coming in that we need to have a strategic approach or we're just never going to tackle anything. We need to make sure what we are doing is hitting the ground.'
> (Stakeholder pers comm 2004)

9.4.1 Function analysis in strategic management

There is a clear potential for ecosystem function analysis as a tool in integrated assessment to be used for strategic level management and planning in the Northern Territory. In addition to offering potential outcomes of justification and transparency in decision-making, there lies

practical potential in being able to target resource management priorities and 'at-risk' ecosystem services. However, the approach must be seen as not only being relevant but compatible with current approaches to resource management currently being implemented in the Northern Territory. This is particularly important at the current time in the NT where a new strategic approach to natural resource management is being implemented through the INRM Planning process.

As INRM targets have already been established through an extensive consultation process, a function analysis approach will have its greatest potential in being utilised to determine target priorities for wetland management (ie Inland Waters and Coastal & Marine) as well as being valuable in future monitoring and evaluation of management targets and actions. Ecosystem functions and services can also be applied in defining the role of indicators in monitoring, ie why a certain indicator is an effective indicator for measuring ecosystem health or if indicators adequately address a representative cross-section of key ecosystem services (including socio-cultural and socio-economic aspects).

9.4.2 Increased transparency and accountability

At a broader level, the implications for management and planning relate to the potential for a function analysis approach to increase transparency and accountability in decision-making. Function analysis as a tool in integrated assessment illustrates the value of wetland ecosystems to human well-being. Whilst the importance of wetland ecosystems services to sustainable management is mostly well-known and described, a justification that encourages consensus for required management actions is often missing or, at least, not effectively communicated. Therefore, a function analysis approach not only has potential in facilitating a more objective justification for trade-offs that may be required in decision-making; it can also assist in engaging stakeholders in constructive dialogue by developing a 'common language'.

9.4.3 Prioritisation of stated INRM management targets

Function analysis will realise greater potential for wetland management in the NT when it can be applied within current strategic approaches to management at both a regional and catchment-scale. Function analysis can assist in the prioritisation of stated management targets in the Draft Integrated Natural Resources Management Plan by identifying 'at-risk' services. Function analysis also has potential in defining priorities for strategic management by building an understanding and awareness at an ecosystem level of what makes a particular issue and issue for stakeholders as part of a broader value assessment framework. At an operational level for wetland management, function analysis has benefits in focusing management on priority issues when only limited resources are available. Highlighting the ecosystem functions addressed by on-ground management actions can add extra support to funding applications as well as providing a basis on which to communicate the real value of actions related to wetland management.

9.4.4 Increase awareness and communication of ecosystem services and benefits

It is acknowledged that the uniqueness of the Northern Territory situation presents many challenges to ecologically sustainable management. In this regard, substantial political will is required to translate the valuable elements of ecosystem-based approaches such as those advocated by the Ramsar Convention on Wetlands, Convention on Biological Diversity and the

Millennium Ecosystem Assessment into tangible and practical management outcomes that balance the objectives of economic development, ecosystem integrity and human well-being.

There is no 'magic bullet' to solve the many issues that threaten healthy wetland ecosystems in the Northern Territory; however, more can be done to ensure sustainable outcomes through the effective implementation of ecosystem-based approaches. This requires 'whole-of-government' support and a need to build greater awareness and appreciation for the many critical services that healthy ecosystems provide for human well-being. The challenge is therefore to communicate ecosystem values and benefits in a clear language that engages Government and wider society. Based on this emerging knowledge, the challenge then for society is to listen – and for Government to act.

10 Discussion

10.1 Discussion of research results

10.1.1 Function analysis

At least 27 ecosystem services provided by the wetlands in the Daly and Mary River catchments were identified as directly or indirectly benefiting humans. Similar services were identified within the two catchments; however, there were more of certain services in one catchment as opposed to the other. In both catchments, pastoralism is – from an economic perspective – the main service derived from (or 'carried' by) the wetlands. The floodplains provide an important grazing area for cattle and, to a lesser extent, buffalo during the dry season. However, whilst this is an important activity from a socio-economic perspective there is justified concern that present grazing practices may compromise the abilty of wetlands to sustain other important services, such as supporting (eg native habitat), cultural (eg tourism & recreation), regulating (maintenance of water quality) and some provisioning services.

Other important wetlands services identified included: native habitat (as a supporting service) providing important refuge and breeding areas for key species (eg magpie goose and barramundi); the role of native vegetation (as a regulating service) in mitigating erosion and maintaining the water regime; groundwater supply (as a provisioning service) in providing water for agriculture and horticulture as well as maintaining river flows (as a regulating and supporting service); and wetlands areas (as a cultural service) in providing important value for Aboriginal cultural identity, tourism and recreation, and science and education.

10.1.2 Ecological importance

The wetlands in the Daly and Mary River catchments have significant and recognised 'ecological importance'; 'significant' in the essential habitat they provide for diverse resident and migratory species and 'recognised' with the listing of some wetlands as having national or international importance (eg for migratory birds). Many of these wetland areas contain important species that may be threatened through ecosystem disturbance (eg loss of key habitat) from expanded or intensified development.

10.1.3 Socio-cultural importance

It is recognised that the importance of the human-wetland relationship resides with the perceptions of the people who benefit from the ecosystem services provided by wetlands. Therefore, the discriminatory principle applied in the construction of the typology of socio-cultural values is that it preferably needs to be capable of accommodating different cultural value systems, which in practice is very difficult. For example, the strong relationship between Aboriginal culture and wetlands represents a high intangible value that can hardly be quantified.

One indicator that can be used to quantify cultural values is to measure cultural expressions (eg artwork) related to the ecosystem under study. Rather than counting the amount of wetland-inspired artwork sold by art centres (which would be useful for economic valuation), it was decided that the intangible benefits reside with the artist, the community he or she lives in and the people who buy wetland-inspired art for inspirational or aesthetic reasons. Hence the assessment of the number of articles sold can only indicate the magnitude of the importance of these services if the reasons for valuing such services are properly understood and respected.

10.1.4 Economic and monetary importance

The economic valuation of ecosystem services involves the implementation of several methods such as those based on market prices (direct or indirect) and questionnaire-based methods that require large amounts of data. Due to the large geographic size of the study area and the limited project time and logistical constraints, comprehensive data collection has not been possible. The valuation therefore has only been partly realised using statistical data available from government departments or industry councils, and a non-representative series of interviews with local stakeholders. Hence, the objective of the study was not to conduct a full economic valuation of the wetlands but to provide an initial, comprehensive overview, and a rough indication of the extent of the many different economic benefits provided by the wetland services. Considering these constraints and uncertainties, the study has used very conservative estimates of individual wetland services and the Total Economic Value calculated is surely an under-estimate of the true contribution of the wetlands to the local and regional economy and people's welfare.

10.1.5 Trade-offs and stakeholder analysis

The diverse and different interests of stakeholders are inherently difficult to weigh against each other. In order to decide what the trade-offs are between specific ecosystem services, more information is needed on the perception of different types of ecological, socio-cultural and economic values. *Multi-criteria analysis* can be a useful tool to explore which values stakeholders think are most important. The analysis can be applied in two ways: through questionnaires and workshops. The questionnaires have to be clear, concise and appropriate to the stakeholder target group. For example, interviews held in some Aboriginal communities may benefit from using photos or drawings in questionnaires, firstly to allow better understanding of the potential trade-offs and secondly to ensure that the correct opinion of the interviewee is elicited.

The second way of applying a multi-criteria analysis is through *workshops*. The researcher or decision-maker has to explore the best ways to organise a workshop as there are different stakeholder groups in the Daly River and Mary River catchments that have different levels of influence over the potential trade-offs. The format and the location need to be chosen in such a way that all the stakeholder groups feel comfortable in sharing their points of view. Within these workshops, areas of consensus and potential competing interests will emerge. As a result, the workshop mediator needs to be able to control the situation and facilitate the discussion in a direction that allows communication to remain open between stakeholders.

10.1.6 Policy analysis

It is clear that wetlands perform diverse functions and provide an array of services that, while benefiting various sectors of society, are also subject to different perceived values and priorities from these interest groups. Assessing such values and benefits is essential for decision-making. It is also equally important to identify and study the institutional and political aspects, as these are higher-level actions that can alter how wetlands are used, and can augment or compete with such uses. The mechanisms and priorities adopted by such institutions can ultimately affect the assessment thereby affecting the decision-making process. As such, the present research focused on how the policy and institutional aspects influence the function of wetlands, and the services provided by them in the Daly and Mary River catchments.

10.1.7 Management implications

A function analysis approach to integrated assessment can offer a significant contribution to the ecologically sustainable management and wise use of wetlands in northern Australia. In line with outcomes of the Millennium Ecosystem Assessment (2005), the results highlighted in this synthesis support the message that an integrated, cross-sectoral and ecosystem-based approach to management is needed to sustain the critical services provided by wetland ecosystems. There is also a growing understanding in the Northern Territory of the need to recognise the values derived from wetlands and incorporate them into management and planning frameworks. This requires 'whole-of-government' support and a need to build greater awareness and appreciation for the diverse benefits that healthy ecosystems provide for human well-being. If this is achieved, then it is far more likely that current and future strategies advocating the practical and sustainable management of wetlands will receive the full support and backing that is desired by many in the wider community.

The potential for an ecosystem function analysis approach to be incorporated into wetland management in the Northern Territory depends on whether stakeholders and decision-makers believe it can address their grievances with current resource management and decision-making processes. At a strategic level, function analysis has the potential to identify 'at-risk' ecosystem functions and focus natural resource management targets accordingly as well as assisting in the equitable allocation of resources through identifying where the benefits from ecosystem services accrue. At an operational level, function analysis can assist in focusing management on priority areas, provide justification and support for funding and communicate the real value of management actions. Function analysis can be applied to address certain bottlenecks in management and decision-making; however, the Northern Territory offers a complex management reality and inevitably the application of any conceptual framework will be challenged in its ability to adapt and deliver under circumstances shaped by historical, political and cultural conflict over natural resources.

Adaptive management

Applying an integrated ecosystem assessment approach has a number of significant implications for wetland management in the research areas. At an ecosystem service level, the assessment results reinforce the need to negotiate between conflicting interests and policy to allow more effective management at an ecosystem level so that the ecosystem retains its capacity to sustain wetland function integrity over time. This may require limiting certain forms of land use in certain areas or working towards enforcing more sustainable land-use practices. The need to adopt the precautionary principle as part of an effective approach to adaptive management is needed both in principle and practice. The results show the importance of stakeholder views in determining how ecosystem services should be managed but that significant knowledge gaps remain in understanding the potential trade-offs and values that stakeholders attach to particular services. At present, there is little understanding of how management actions may inadvertently contribute to trade-offs relating to stakeholder interests in ecosystem services.

The major weakness of the assessment was the inability for it to deliver clear and area-specific implications for the management of wetland services across the respective research areas and, subsequently, analyse implications of trade-off options for management. This was mainly due to the fact that the integrated assessment framework was not applied to the research in the way that was originally intended – that is, to assess sequentially the outcomes of the ecosystem service valuations, stakeholder and conflict analysis and policy analysis and investigate the implications these results would have on present regimes for wetland

management across the research areas. The synchronised timing of the individual sub-projects prevented this step being done effectively.

Subsequently, the focus shifted to a primary analysis on how wetland servicess are currently being addressed in management plans and actions. As the results indicate, there is still considerable merit and value in this approach alone in terms of understanding how current management responses can potentially impact on wetland services. However, a complete analysis to determine management and planning implications would need a consistent choice of key ecosystem services across each valuation type within the integrated assessment and to then determine how they are linked to relevant stakeholder interests and addressed in policy and institutional frameworks.

10.2 Discussion of research methods and process (and approach)

A number of outcomes relevant to the method arose from this analysis. The following methods and approaches have been identified due to their potential in addressing research questions more effectively for similar research in the future.

10.2.1 Integrated Wetland Assessment Framework

The key aim of the project was to develop and test an Integrated Assessment framework based on de Groot et al (2002). An important recommendation is to involve stakeholders in the assessment as early as possible; for example, by organising a workshop at the start of the project to obtain an overview of the main wetland services of importance; ie those of high perceived value, or vulnerable to land-use change, to be taken into account (however, even in that case, first a desk-study is necessary as input into the workshop with a preliminary list of functions and stakeholders), followed by more detailed stakeholder consultation (eg through questionnaires and interviews) on values and trade-offs.

A second recommendation is to use a formal multi-criteria analysis to investigate which wetland services are considered important by the stakeholders and which trade-offs are considered by the stakeholders to be acceptable and which are not.

An important recommendation is to facilitate greater accessibility of ecosystem-based approaches to the public and decision-makers, and to simplify and harmonise the language being used (eg between the choice of ecosystem (or environmental) ‘goods’, ‘services’, ‘benefits’, ‘functions’ and/or ‘values’) to deliver a clear and consistent message.

10.2.2 Case study area/spatial scales

A thorough ‘test’ of the conceptual framework requires a clearly defined and more spatially limited case study area so that methodological limitations can be minimised. A spatially defined area (both ecologically and institutionally) would allow for a better evaluation of the framework’s potential to be undertaken. This is due to the opportunity of, firstly, allowing for better definition of policy and management objectives according to the defined area (ecosystem boundaries); secondly, allowing for a more complete valuation and aggregation of ecosystem services; and finally, providing clearer options for trade-offs relating to stakeholder interests in the ecosystem services. Results would then provide clearer and more robust implications for wetland ecosystem management and planning.

There appear to be challenges in applying a function analysis approach for integrated assessment over large areas especially in a data poor environment. Whilst catchment or river-basin scales are advocated in the Millennium Ecosystem Assessment and guidance for the Ramsar Convention on Wetlands, it is uncertain to what extent the approach can be applied at a scale found, for example, within the Daly River catchment where firstly, there are substantial seasonal changes in 'inundated' wetland areas and, secondly, where considerable knowledge gaps remain for wetland areas regarding, for example, ecological functioning and socio-cultural values. In addition, over larger scales it becomes more difficult to avoid the 'double-counting' of services or to suitably provide analysis and implications for single functions or services when many interlink with or underpin other services.

10.2.3 Semi-structured interviews

The semi-structured interview used in this assessment can be justified as a valid approach. The open and in-depth nature of the interview allowed flexibility in revising questions throughout the interview based on responses that provided unexpected (and subsequently valuable) knowledge shared by the interviewee. The Northern Territory, for reasons of climate, modern history, culture and lifestyle, is known for being 'laid-back', casual and relaxed but also 'straight-talking'. Whilst there were individual cases where these stereotypes did not hold true, it is a feature of the 'Territorian way-of-life' that these ideals be nevertheless pursued. In this regard, many interviews were held in an informal setting and in an informal manner. This clearly has the advantage of relaxing the interviewee (and the interviewer) and increasing the chances of them taking the time 'open up' and share their perceptions. On the other hand, it meant that considerable time was sometimes 'lost' as the discussion, firstly, 'warmed-up', and secondly, meandered to areas that were not strictly relevant to the research but nevertheless very interesting. The building of trust, a perception of equity or 'fair go', and the maintenance of personal relationships is critical to stakeholder engagement and is therefore another reason why it is important that stakeholder interviewees feel there is a willingess to listen on behalf of the researcher - even if the topic of discussion may not be directly related to the direct needs and interests of the researcher.

10.2.4 Field research techniques

The attendance of stakeholder interviews was arranged in a way that could incorporate the maximum amount of group members without compromising the effectiveness of the interview or the ability of any of the group members to obtain the information required to address their research questions. Due to the known inherent sensitivities of land management across much of the Northern Territory, it was anticipated that some interviewees might be reluctant to discuss certain issues. Questioning was therefore prepared with these sensitivities and suitable 'fall-back' positions in mind.

Additionally, it was understood that the depth of research may be limited by the time and distances required for travel between research areas as well as the potential to access some stakeholders and wetlands – particularly on Aboriginal land where a research permit is required.

10.2.5 Limitations of time

'Insufficient time' is cited as a limitation in many exploratory research assessments. However, in the Northern Territory it also has another dimension. Socio-cultural values of Aboriginal people are central to many of the Northern Territory landscapes and wetland areas and therefore cannot be dealt with on the same time-scales as when collecting data on economic

or ecological values. Aboriginal culture tends not to share the same perspectives of time as Western culture. Therefore to fully explore the implications of socio-cultural values for wetland management and planning, sufficient time needs to be allowed to receive permits for access to Aboriginal land, build relationships with local communities and offer a commitment to give 'something back' to the community in return for their assistance.

Such constraints can apply broadly to all forms of stakeholder consultation. An integrated assessment requires time to obtain sufficient baseline information collection, to consult with a representative selection of stakeholder, to understand stakeholder views and positions, to build relationships, to educate stakeholders involved in the process, and, particularly in terms of articulating socio-cultural values, time is required for analysis, reporting and reviewing. In addition, it will require time to broaden stakeholder perspectives of the issues at hand to ensure integration. Smith and Maltby (2003) note that integration is limited by the tendency for ecosystem managers to have limited vision and be interested only in the areas where they work, without being aware of the interactions with neighbouring localities – or reading outside of their discipline. However, despite the time (and cost) required, an effective integrated assessment process with clear objectives will almost certainly save more time and money in the long run as well as reducing conflicts and potentially building long-term relationships between stakeholders. However, a continual challenge for such processes is that it is difficult to document this unofficial side of integrated management, ie the time taken in the building up of relationships, and to communicate that to Government and decision-makers in such a way that they can appreciate the time and financial outlays required to achieve successful integrated outcomes.

10.2.6 Limitations of timing

There are a few limitations regarding 'timing' that should be mentioned so that future projects avoid similar pitfalls. As already identified, one of these is the timing and synchronisation of individual components of the research. Ideally, the management and planning analysis should be delayed until the results from the other components of the integrated assessment framework are fully synthesised. Secondly, there was a conceptual factor in that there are large seasonal variations in the spatial extent of wetlands in the catchment research areas. Understanding these variations by visualising them 'first-hand' may alter some of the perceptions taken in the analysis. Finally, and as has been identified earlier, the Northern Territory has since completed a number of planning processes that were not completed when the research for this study was undertaken. Therefore, analysis was based on draft plans or on processes that may have changed with the release of new plans. This brings an amount of uncertainty in terms of how current the results will remain; however, these planning processes were followed closely to ensure that a relatively accurate impression of potential outcomes for wetland management was obtained.

11 Recommendations

The main objective of this (pilot) study was to develop a comprehensive framework to analyse ecosystem services provided by selected wetlands in the Northern Territory. The framework developed by De Groot et al (2002) was used and applied ('tested') to analyse the functions and ecosystem services provided by wetlands in the Daly River and Mary River catchments (further information on the functions and values of the wetlands and data on ecosystem service valuation, decision-making and management can be found on www.naturevaluation.org).

The study also explored possibilities to use the function analysis framework in assessing trade-offs with regard to multi-functional use of the wetland services, and how to incorporate that information in planning, management and decision-making for sustainable development. As this was a pilot study, further research is needed to improve the knowledge base on the functions and ecosystem services provided by the wetlands, and the 'full value' of these wetlands as well as their importance to human well-being and sustainable development in the Northern Territory.

11.1 Recommendations for further research

1 More in-depth analysis of services and values

This pilot study provided a comprehensive overview and framework for the analysis of services and values of the wetlands in the Northern Territory, but much more quantitative data are needed on the individual services.

For future studies, it would be important to focus on a smaller area than the two catchments included in this study. A smaller area would make it possible to conduct questionnaires among tourists, local people and users of the wetlands. In other words, it allows for perceptions of stakeholders to be assessed at an approriate level resulting in reliable data for decision makers. Additionally, the design of questionnaires should take due account of analytical tools such as Multi-Criteria Analysis because the type of question(ing) determines the type of analysis to be performed or the other way around.

2 Spatial analysis to allow analysis of trade-offs in multi-functional use

Follow-up work should attempt to obtain better insight in the spatial distribution of the wetland services to allow more in-depth analysis of the possibilities and constraints for multi-functional use of the catchments. Ideally, a decision-support system should be developed to optimise trade-offs between conservation and (sustainable) use of wetland services, preferably in a participatory manner (eg by organising workshops or other forms of stakeholder participation in the valuation and trade-off analysis).

3 Different policy scales

The present research has been able to provide a broader overview and baseline information particularly in representing the existing institutions, policies and stakeholders. This research outlined the overall institutions present for the management of wetlands in the research areas, list of policies associated with the functions and their interactions, and the existing situation of stakeholders' involvement in the catchment management. However, more detailed analysis is needed by taking one issue, or one category of function, or one category of policies, to see how it affects and is affected by different factors at different scales (local scale, regional scale, national scale etc). For example, one category of ecosystem services (production,

regulation, habitat, carrier) could be taken and the impact on it by different categories of policies (conservation policies, planning policies, development polices, natural resource allocation policies) could be studied. It will be interesting to find the extent of such impacts and influences, with and without stakeholders' involvement.

4 Indicators for integrated ecosystem management

The importance of indicators (ecological, economic and social) cannot be underestimated for integrated assessment. Smith and Maltby (2003) state that, 'Monitoring of appropriate indicators is vital for adaptive management, but there are few guidelines or case studies on this subject'. In the context of the Northern Territory, Scott (2004) emphasised that environmental indicators (and the precautionary principle) 'must take precedence where there is a poor knowledge base'. Indicators for the Northern Territory are being developed and adapted as part of the INRM planning process (ie to be included in the INRM Plan). Finally, in the case of the Mary River catchment, Armstrong et al (2002) recommend an extensive list of monitoring actions to address key knowledge gaps; a more detailed analysis would be useful in linking these actions to function indicators.

11.2 Recommendations for policy

In order to have an effective institutional arrangement, it is important to define clearly the roles and mandates of each institution and promote sectoral co-operation and coordination, particularly between legislation, government departments and among the various branches within the departments (eg the Weeds Branch and Pastoral Land Board under Department of Natural Resources, Environment, the Arts and Sport should co-operate on the issue of weeds).

The study indicated that there was no single institution in the research area (neither a single policy, nor a single authority) overseeing the protection and conservation of wetlands explicitly. The conservation of wetlands seemed to be a side-product of other development and conservation efforts. Delegating responsibilities to a single institution to plan, operate and maintain systems for monitoring and supervising the activities that affect the wetlands in the research areas can be an important step forward (eg developing a legal policy for wetland management and or having a section or branch in a department to coordinate the protection and management of wetlands).

A few summarised recommendations are provided below:

- The multiple indirect legislative impacts on the functions and services provided by wetlands should be minimised through a frequent review of policies to harmonise them and to ensure consistency in their objectives and management approach (eg the recent review of guidelines for clearing native vegetation under the Pastoral Lands Act and Planning Act is a good step forward).
- There should be direct legislative protection of wetlands, in line with national and international guidelines, which should be able to demonstrate how to involve people with traceable outcome and reporting mechanisms.
- The various issues (such as weeds, feral animals, fire etc) associated with functions and services provided by the wetlands can be minimised by avoiding disjointed management approaches across the land tenures (eg pastoral land, crown land), and by promoting joint planning and management schemes across all the land tenures (eg regional weed management plan).

- Individual management of various issues at the local level should be integrated at higher level planning framework (eg the recent Northern Territory INRM Plan which strategically fits other local management plans into an overarching plan).
- A structured planning process and improved mechanisms to identify the gaps and inconsistency with other approach should be endorsed (eg by proper stakeholder consultation).
- Establishing Integrated Catchment Management is an opportunity to promote wetland conservation in the context of catchment planning as it provides a forum for stakeholders' involvement in the management approach, hence developing a custodial catchment authority with a statutory strategic plan across the entire catchment should be considered, particularly for the Daly River catchment.
- In line with the previous point, the catchment authority and the plan should consider the diverse perceptions on the same issue and act as a forum to plan, develop and resolve conflicts between the stakeholders. Recognition of all stakeholder groups and opportunities to involve them is essential for the 'whole of government approach' to conservation.
- Building on existing local land management activities (such as indigenous ranger programs, Landcare, Rivercare movements), further local management activities should be an important priority for governments with suitable incentives and resources (funding, training) to ensure their sustainability.

The current information base for much of Northern Territory has tended to largely address 'apparent' reasons for wetland degradation and loss, without directing sufficient attention to 'underlying' socio-economic and political reasons (Finlayson & Spiers 1999). Therefore, to contribute to the development of an improved knowledge base for sustainable wetland use – and one that avoids sectoral and jurisdictional divisions – a thorough analysis of policy and management implications must include a comprehensive and integrated ecosystem assessment of relevant economic, political, and socio-cultural driving forces. More importantly, it is necessary to understand the continued relevance these forces have in contributing to increasing ecological pressures and impacts on the region's ecosystems.

11.3 Recommendations for management

There are a few important caveats to be considered when offering recommendations for management in the Northern Territory. Some of these have been described earlier and relate to the considerable constraints that are faced in effectively managing extensive wetland areas in the Northern Territory. Many of these constraints are well known and have been articulated through research reports and current planing processes such as in the INRM Plan. Given the sensitive nature of resource management in the Northern Territory, it is not advisable to make far-reaching and sometimes unqualified 'throwaway' statements of 'how things should be' as an 'outsider', ie not being resident or a participant in the everyday realities and challenges experienced by resource managers and stakeholders.

Therefore, it is not the intention to re-emphasise well-known recommendations; however, at the same time, the existence of challenges for effective resource management should not be seen as a justification for assuming continuation along the path of 'business as usual'. While there are significant structural impediments to forging a more effective, integrated and comprehensive approach, there are a number of steps that can be taken to yield positive results for natural resource and wetland management in the Northern Territory. These steps

are summarised as recommendations below with an emphasis on the opportunities of an ecosystem function analysis approach to assist in ecologically sustainable wetland management.

1 Adopt a holistic ecosystem services approach within current management frameworks

Examples in the body of this report illustrated how an ecosystem services/function analysis may be applied to current natural resource management planning at a strategic level in terms of understanding what management targets are actually addressing at an ecosystem level. The outcomes of such analysis are likely to assist in prioritising targets and making options for potential trade-offs, risks and uncertainties more transparent. At a catchment level, adopting an ecosystem services/functions approach will assist in developing required value assessment frameworks to assist in equitable resource allocation and multi-functional outcomes. It will also assist in understanding the value of on-ground management in terms of how actions are assisting with the maintenance of key ecosystem services. Concerted efforts need to be made to bridge the current gap between operational and strategic management objectives and outcomes.

Additional recommendations relate to potential improvements in analysis methodology and its application for management across the research areas of the Northern Territory. The principles of the ecosystem services/function analysis approach could be adopted within current management frameworks to assist in developing value assessment frameworks and providing trade-off options for multi-functional outcomes. Options available through the Ramsar Convention on Wetlands – both in technical guidance and for listing of wetlands – should be investigated for potential benefits for management. Finally, wetland management would benefit from a program that increases education and awareness of the value that healthy ecosystems provide to broader society. Once ecosystem benefits are known and their values clearly communicated, then it should facilitate a greater acceptance of decisions that assist in the ecologically sustainable management of wetland resources.

2 Investigate options available through the Ramsar Convention on Wetlands

The Ramsar Convention on Wetlands offers detailed technical and policy guidance for adopting ‘wise-use’ approaches to wetland management. Such guidance is in line with the ecosystem-based approach taken in this thesis with function analysis as well as through the Millennium Ecosystem Assessment. The Northern Territory Government could potentially gain advantages by listing more sites under the Convention (Stakeholder pers comm, 2004). In addition, the practical experience of wetland managers in the Northern Territory could also be profitably shared in terms of refining and operationalising guidance advocated through international agreements; the procedures for ensuring this occurs are based firmly within the sovereign institutional procedures for implementing such agreements nationally. Listing wetlands under the Ramsar Convention across different tenures can be resource and time intensive; however, benefits include the flexible nature of the listing, the recognition a Ramsar listing provides to the wetland owner, and the enhanced priority the wetland receives for Natural Heritage Trust and National Action Plan on Salinity funding (Scott 2004). Finally, it must be reiterated that conservation measures (through zoning, protected areas or listing) designed to protect sensitive wetland ecosystems must be addressed at an ecosystem level with sustainable management arrangements encompassing entire landscapes:

> A quest to assign importance to the separate pieces of the [wetland] jigsaw is quixotic, because we can ill afford to lose any of them. It is the integrity and linked ecological function of the whole that must be protected and maintained (Whitehead & Chatto 1996 in Scott 2004).

3 Increase education and awareness of ecosystem benefits in society

Box 7 Need for environmental education

> 'As far as on-ground environmental education, the only people that are getting that are schoolkids...through their curriculum. There is no [other] environmental education happening so where do people get the information from?' (Stakeholder pers com 2004)

Not only does there need to be a significant conceptual shift in the way Government and policy-makers approach natural resource management, it needs to be coupled with a program of communicating the value of ecosystems in a consistent and coherent way to broader society. Governments can be paralysed or are understandably unwilling to adopt politically unpopular decisions. This is particularly the case in the Northern Territory where Government is more easily at the mercy of a small population with politically influential sectoral groups that have greater access to Government. The Northern Territory public is generally aware of the need to protect ecosystems and understand's the attachment to certain environments; however, it would appear that they are not yet ready to accept some of the tough trade-offs required to preserve ecosystem benefits for human well-being into the future. Once the benefits of ecosystems are known and their values clearly communicated, there is likely to be a greater acceptance of decisions that assist in the ecologically sustainable management of wetland resources.

Box 8 An objective framework for decision-making

> 'We [the Government] are certainly in favour of a more objective framework for decision-making which can at least put all the cards on the table. We are getting to the stage in the NT when we need to make some hard decisions and need to have some trade-offs. So some of the things you're working on may have some value for not only wetland management but for broader management – that's why I have some sense [of interest] in seeing what comes out of your work'. (Stakeholder pers com 2004)

It is clear that the analysis and recommendations above also resonate with the conclusions advocated in the Millennium Ecosystem Assessment and technical guidance to the Ramsar Convention. Specifically, they reinforce the fact that the prevailing sectoral approach to management does not deliver equitable or acceptable outcomes to society as a whole. Instead it is clear that integrated ecosystem-based approaches will ultimately lead to more equitable and sustainable outcomes for natural resource management and planning.

References

Allen GR, Midgley SH & Allen M 2002. *Field guide to the freshwater fishes of Australia*. Western Australian Museum, Perth.

Allsop Q, de Lestang P, Griffin R & White G 2006. *Barramundi – your questions answered*. Fishnote No 27, Department of Primary Industry, Fisheries and Mines, Darwin NT (http://www.iucredlist.org/).

Altman J 2003. *Developing an indigenous arts strategy for the Northern Territory: Issues paper for consultations with practitioner, organisational and bureaucratic stakeholders*. Centre for Aboriginal Economic Policy Research (CAEPR), The Australian National University, Canberra.

Applegate RJ 1999. Saltwater intrusion and the Mary River wetlands of the Northern Territory. In *An international perspective on wetland rehabilitation*. ed WJ Streever, Kluwer Academic Publishers, Dordrecht, The Netherlands, 113–120.

Armstrong M, Woinarski J, Hempel C, Connors G & Beggs K 2002. A plan for the conservation of biodiversity in the Mary River catchment, Northern Territory. A report prepared for Project 97151 of the Natural Heritage Trust. Parks and Wildlife. Department of Infrastructure, Planning and Environment, Darwin NT.

AusAid (Australian Government's overseas aid program) 2000. Chapter 1 The logical framework approach. Commonwealth of Australia www.ausaid.gov.au/ausguide/ausguidelines/1-2-6.cfm (accessed: 10/02/05).

Australian Heritage Commission (AHC) 1992. Commonwealth legislation available at: http://www.frankston.vic.gov.au/fhs/stage2-vol-1/aust_heritage_commission.htm (last accessed at 04-09-2005).

Authority of the Senate 2003. Proof Committee Hansard. Senate. Rural and Regional Affairs and Transport. References Committee. Reference: Rural water usage in Australia. Commonwealth of Australia. www.aph.gov.au/hansard (accessed: 01/08/04).

Bachet S 2005. Analysis of the functions and ecological importance of the Daly and Mary River catchments in northern Australia. MSc thesis, Environmental System Analysis Group, Wageningen University (WU), The Netherlands (109 pp + appendices)

Balmford A, Bruner A, Cooper P et al 2002. Economic reasons for conserving wild nature. *Science* 297, 950–953.

Barbier E, Acreman BM & Knowler D 1996. *Economic valuation of wetlands: A guide for policy makers and planners*. Ramsar Convention Bureau, Gland, Switzerland.

Bayliss B, Brennan K, Eliot I, Finlayson CM, Hall R, House T, Pidgeon R, Walden D & Waterman P 1997. *Vulnerability assessment of predicted climate change and sea level rise in the Alligator Rivers Region, Northern Territory Australia*. Supervising Scientist Report 123, Supervising Scientist, Canberra.

Begg GW, van Dam RA, Lowry JB, Finlayson CM & Walden DJ 2001. *Inventory and risk assessment of water dependent ecosystems in the Daly basin, Northern Territory, Australia*. Supervising Scientist Report 162, Supervising Scientist, Darwin NT.

Bellio MG & Chatto R 2004. Status of Australia's birds: Waterbirds of the Northern Territory – threats and issues. In *Status of Australia birds*. Wingspan, December 2004.

Bird RD (ed) 1994. *Country in flames: Proceedings of the 1994 symposium on biodiversity and fire in North Australia*. Biodiversity Unit, Department of the Environment, Sport and Territories, and North Australia Research Unit, The Australian National University, Darwin NT.

Blamey RK & James R 1999. Citizens' juries — An alternative or an input to environmental cost-benefit analysis, Paper presented at the Conference of the Australian and New Zealand Society for Ecological Economics Griffith University, Brisbane, Australia, 5–7 July 1999.

Brown K, Tompkins E, Adger WN 2001. *Trade-off analysis for participatory coastal zone decision-making*. Overseas Development Group. University of East Anglia. Norwich, United Kingdom.

Buckles D (ed) 1999. *Cultivating peace: Conflict and collaboration in natural resource management*. International Development Research Centre & World Bank Institute, Ottawa & Washington DC.

Carter RW & Bramley R 2002. Defining heritage values and significance for improved resource management: an application to Australian tourism. *International Journal of Heritage Studies* 8 (3), 175–199.

Centre for Tropical Wetlands Management (CTWM) & Centre for Indigenous and Natural Cultural Resource Management (CINCRM) 1998. *Wise use of wetlands in Northern Australia: Indigenous use*. Darwin NT.

Chambers R & Blackburn J 2000. What is PRA? A policy briefing for the Institute of Development Studies, Sussex University, UK.

Chatto R 2003. The distribution and status of shorebirds around the coast and coastal wetlands of the Northern Territory. Technical Report 73/2003, Parks and Wildlife Commission of the Northern Territory, Darwin NT.

Chichilnisky G & Heal G 1998. Economic returns from the biosphere. *Nature* 391, 629–630.

Martin C 2003. Media Release. Government establishes Daly Region Community Reference Group. Northern Territory Government. http://www.ipe.nt.gov.au/whatwedo/dalyregion/refgroup/pdf/DalyRegionReferenceGroup.pdf, Clare Martin MLA, Chief Minister (accessed: 06/04/05).

Coleman A 2004. National Recreational Fishing Survey: The Northern Territory. Fisheries group, Department of Business, Industry and Resource Development, Darwin.

Coote A & Lenaghan J 1997. *Citizens' juries: Theory into practice*. Institute for Public Policy Research (IPPR), UK.

Costanza R, d'Arge R, De Groot RS, Farber S, Grasso M, Hannon B, Limburg KI, Naeem S, O'Neill RV, Paruelo J, Raskin RG, Sutton P & van den Belt M 1997. The value of the world's ecosystem services and natural capital. *Nature* 387, 253–260.

Daily GC, Alexander S, Ehrlich PR, Goulder L, Lubchenco J et al 1997. *Ecosystem services: Benefits supplied to human societies by natural ecosystems*. Island Press, Washington, DC.

Daly Region Community Reference Group (DRCRG) 2004a. Meeting Record for Meeting 2: 16–18 February 2004. Katherine. Day 3, Wednesday 18 February 2004.

www.ipe.nt.gov.au/whatwedo/dalyregion/refgroup/ meetings/ pdf/20040321mtg.pdf accessed: 07/04/05).

Daly Region Community Reference Group (DRCRG) 2004b. Meeting Record for Meeting 4: 17–19 May 2004.Nauiyu Nambiyu Community, Daly River. Public Meetings. Day 1, Monday 17 May 2004. www.ipe.nt.gov.au/whatwedo/dalyregion/refgroup/meetings/pdf/crg4day1.pdf (accessed: 08/04/05).

Daly Region Community Reference Group (DRCRG) 2004c. Media release. Daly Region Community Reference Group. Meetings in Katherine next week. www.ipe.nt.gov.au/whatwedo/dalyregion/refgroup/meetings/pdf/20040211 mediarelease.pdf (accessed: 14/07/04).

Daly Region Community Reference Group (DRCRG) 2004d. Terms of Reference. Northern Territory Government, Darwin NT, Australia.

Daly Region Community Reference Group (DRCRG) 2004e. Meeting Record for Meeting 4: 17–19 May 2004.Nauiyu Nambiyu Community, Daly River. Presentations and Meetings. Day 2, Tuesday 18 May 2004. http://www.ipe.nt.gov.au/whatwedo/dalyregion/refgroup/meetings/ pdf/crg4day2.pdf (accessed: 07/04/05).

De Groot RS 1992. *Functions of nature. Evaluation of nature in environmental planning management and decision making*. Wolters-Noordhoff, Groningen.

De Groot RS, Wilson M & Boumans R 2002. A typology for the description, classification and valuation of ecosystem functions, goods and services. In *The dynamics and value of ecosystem services: Integrating economic and ecological perspectives*. Special issue of Ecological Economics 41 (3), 393–408.

De Groot RS, van der Perk JP, Chiesura A & van Vliet AJH 2003. Importance and threat as determining factors for criticality of natural capital. *Ecological Economics* 44 (2–3), 187–204.

De Groot RS & Ramakrishnan PS (eds) 2005. Cultural and amenity services. In *Ecosystems and human wellbeing: Conditions and trends. Millenium Ecosystem Assessment*, Island Press. Washington, DC, 307–328.

De Groot RS, Stuip M, Finlayson CM & Davidson N 2006. *Valuing wetlands: Guidance for valuing the benefits derived from wetland ecosystem services*. Ramsar Technical Report 3, CBD Technical Series 27, Ramsar Convention Secretariat, Gland, Switzerland.

DIPE 2003a. Draft Conservation Plan for the Daly Basin Bioregion. Department of Infrastructure, Planning and Environment, Northern Territory Government, Darwin NT.

DIPE 2003b. Draft Conservation Plan for the Mary River region. Department of Infrastructure, Planning and Environment, Northern Territory Government, Darwin NT.

DIPE 2003c. Cost-benefit analysis of Mary River salinity mitigation. Australian Greenhouse Office, Commonwealth of Australia.

Dixon J & Pagiola S 1998. Environmental analysis and environmental assessment. *Forest Policy and Economics* 4 (2), 101–112.

Eliot I, Finlayson CM & Waterman P 1999. Predicted climate change, sea-level rise and wetland management in the Australian wet-dry tropics. *Wetlands Ecology and Management* 7 (1–2), 63–78.

Environment Centre of the Northern Territory (ECNT) 2003. What's new. Media Release. 'Easter Treeclearing Approvals for the Daly'. www.ecnt.org/whats_new/media_4_03_daly_river_clearing.html (accessed: 16/07/04).

English A 2000. An emu in the hole: Exploring the link between biodiversity and Aboriginal cultural heritage in New South Wales, Australia. *IUCN Parks Journal* 10(2),13–25.

English JA & Lee E 2003. *Managing the intangible, sanctuary of dreams. The full value of parks, from economics to the intangible*. Rowman & Littlefield, Oxford.

Erskine WD, Begg GW, Jolly P, Georges A, O'Grady A, Eamus D, Rea N, Dostine P, Townsend S & Padovan A 2003. *Recommended environmental water requirements for the Daly River, Northern Territory, based on ecological, hydrological and biological principles*. Supervising Scientist Report 175, Supervising Scientist, Darwin NT.

Farber S, Costanza R & Matthew W 2002. Economic and ecological concepts for valuing ecosystem services. *Ecological Economics* 41, 375–392.

Faulks JJ 1998. An assessment of the physical and ecological condition of the Daly River and its major tributaries: Part 1. Technical Report No TR99/10, July, Department of Lands, Planning and Environment, Katherine, NT.

Finlayson CM, Bailey BJ, Freeland WJ & Fleming MR 1988. Wetlands of the Northern Territory: The conservation of Australian wetlands. WWF-Australia, Surrey Beatty, Sydney, 103-126.

Finlayson CM & von Oertzen I 1996. The Kakadu region. In *Landscape and vegetation ecology of the Kakadu Region, Northern Australia*. eds Finlayson CM & von Oertzen I, Geobotany 23, Kluwer Academic Publishers, Dordrecht, The Netherlands, 1–15.

Finlayson CM, Storrs MJ & Lindner G 1997. Degradation and rehabilitation of wetlands in the Alligator Rivers Region of northern Australia. *Wetlands Ecology and Management* 5, 19–36.

Finlayson CM & Spiers AG (eds) 1999. *A compendium of information for managing and monitoring wetlands in tropical Australia*. Supervising Scientist Report 148, Supervising Scientist, Canberra.

Finlayson CM, Yibarbuk D, Thurtell L, Storrs MJ & Cooke P 1999. *Local community management of the Blyth/Liverpool wetlands, Arnhem Land, Northern Territory, Australia*. Supervising Scientist Report 137, Supervising Scientist, Canberra.

Finlayson CM, Bellio MG & Lowry JB 2005a. A conceptual basis for the wise use of wetlands in northern Australia – linking information needs, integrated analyses, drivers of change and human well-being. *Marine & Freshwater Research* 56, 269–277.

Finlayson, CM, D'Cruz R & Davidson NJ 2005b. *Ecosystem services and human well-being: water and wetlands synthesis*. World Resources Institute, Washington DC, USA.

Finlayson, CM, Lowry J, Bellio MG, Walden D, Nou S, Fox G, Humphrey CL & Pidgeon R 2006. Comparative biology of large wetlands: Kakadu National Park, Australia. *Aquatic Sciences* 68, 374–399.

Forner J, Atkinson J, Kinson T, Avalon K, Blanasi D et al 2002. Traditional Didjeridu harvesting on Jawoyn land, Northern Territory. Parks and Wildlife Service, Darwin NT.

Gehrke P, Bristow K, Bunn S, Douglas M et al 2004. Sustainable futures for Australia's tropical rivers. A strategy for developing research directions for Australia's tropical river systems. Outcomes from a forum at Charles Darwin University, 1–3 February 2004, CSIRO Land and Water Technical Report No 17/04.

Grimble R & Wellard K 1996. Stakeholder methodologies in natural resource management: A review of principles, contexts, experiences and opportunities. Paper presented at the ODA NRSP Socioeconomic Methodologies Workshop, 29–30 Apr, 1996, London, UK.

Guo Zhongwei Xiangming Xiao, Yaling Gan & Yuejun Zheng 2001, Ecosystem functions, services and their values – a case study in Xingshan County of China. *Ecological Economics* 38 (1), 141–154.

Harmon D 2003. The source and significance of values in protected areas. In *The full value of parks, from economics to the intangible*. eds Harmon D & Putney A, Rowman & Littlefield, Lanham, Oxford, 13–27.

Harmon D & Putney A (eds) 2003. *The full value of parks, from economics to the intangible*. Rowman & Littlefield, Lanham, Oxford.

Howitt R 2001. Frontiers, borders, edges: Liminal challenges to the hegemony of exclusion. *Australian Geographical Studies* 39 (2), 233–245.

ICOMOS Inc 1992. *The illustrated Burra Charter: Making good decisions about the care of important places*., Australian Heritage Commission, Canberra.

ICOMOS 1999. The Burra Charter: The Australia ICOMOS charter for places of cultural significance 1999, with associated guidelines and code on the ethics of co-existence. ICOMOS, Burwood, Australia.

IUCN 2008. The IUCN Red List of threatened species. IUCN, Gland, Switzerland (http://www.iucnredlist.org/)

Jackson S 2004. Preliminary report on Aboriginal perspectives on land use and water management in the Daly River Region, Northern Territory: A report to the Northern Land Council. CSIRO, Sustainable Ecosystems, Darwin NT.

Jackson S, Storrs M & Morrison J 2005. Recognition of Aboriginal rights, interests and values in river research and management: Perspectives from northern Australia. *Ecological Management & Restoration* 6 (2), 105–110.

Jonauskas P (ed) 1996. *Making multiple land use work: Proceedings of the wetlands workshop*. 6–7 December 1994, Department of Lands, Planning and the Environment, Darwin, NT.

Kennedy S 2004. An assessment of the terrestrial conservation values of the Daly River catchment and the threats posed by land clearing and agricultural development: Part One. Environment Centre of the Northern Territory and the Wilderness Society.

King D & Mazzotta M 2000 Ecosystem valuation web site. (www.ecosystemvaluation.org).

Land and Water Australia 2004. Australia´s Tropical Rivers Prospectus and Program Plan 2003/4 – 2009/10. Australian Government, Canberra.

LCNT (Landcare Council of the Northern Territory) 2005. Integrated Natural Resource Management Plan for the Northern Territory: Sustaining our resources – people, country and enterprises. Department of Infrastructure, Planning and Environment, Northern Territory Government, Landcare Council of the Northern Territory, Natural Heritage Trust, Darwin. http://www.ipe.nt.gov.au/whatwedo/inrm/ Accessed 16/05/2005

Larson HK 2000. Report to Parks Australia on estuarine fish monitoring of Kakadu National Park, Northern Australia. Museum and Art Gallery of the Northern Territory, Darwin.

Larson H, Gribble N, Salini J, Pilland R & Peverell S 2004. Sharks and rays. In *Description of key species groups in the Northern Planning Area*. National Oceans Office, Hobart Tas, Australia, 59–74.

Lee C (ed) 2003. The importance of sacred natural sites for biodiversity conservation. Proceedings of the International workshop held in Kunming and Xishuangbanna Biosphere Reserve. Peoples Republic of China, 17–12 February 2003.

Li H, Berrens RP, Bohara AK, Jenkins-Smith HC, Silva CL & Weimer DL 2004. Would developing country commitments affect US households support for a modified Kyoto protocol? *Ecological Economics* 48, 329–343.

Mabire C 2005. Economic importance of the wetlands in the Mary and the Daly River catchments in northern Australia. Environmental System Analysis Group, Wageningen University and Research Centre (WUR), The Netherlands.

Marrfurra P et al 1995. 'Ngan'gikurunggurr and Ngangiwumirri ethnobotany: Aboriginal plant use from the Daly River area, Northern Australia. Conservation Commission of the Northern Territory, Darwin.

Millennium Ecosystem Assessment (MA) 2003. *Ecosystems and human well-being: A famework for assessment*. Island Press, Washington DC. (http://www.MA-web.org.)

MRCAC (Mary River Catchment Advisory Committee) 2001. Revised Integrated Catchment Management Plan Mary River. Department Lands Planning and Environment, Northern Territory Government, Darwin Northern Territory.

McInnes R 2003. Cost benefit analysis of Mary River salinity mitigation. Northern Territory Greenhouse Unit. Office of the Environment and Heritage, Department of Infrastructure, Planning and Environment, Darwin NT.

Murray-Darling Basin Commission (MDBC) 2004. Water trading in the Murray-Darling Basin. http://www.mdbc.gov.au/publications/factsheets/fslm008_101.htm (accessed: 27/09/04).

Mussared D 1997. *Living on floodplains*. The Cooperative Research Centre for Freshwater Ecology, Murray-Darling Basin Commission, Canberra.

NLC 2004. Environmental management status reports for Aboriginal lands in the Northern Land Council region. A supporting document to the 'Caring for Country Strategy 2003–2006', Northern Land Council, Darwin NT.

Northern Territory Government (NTG) 2007. Northern Territory recreational fishing controls. Northern Territory Government, Darwin, Australia (http://www.nt.gov.au/d/Fisheries/Content/File/Recreational_Fishing_Controls_07.pdf)

Pagiola S, von Ritter K & Bishop J 2004. Assessing the economic value of ecosystem conservation. Environment Department Paper No 101, The World Bank Environment Department, Washington DC.

Palmer L 2004. Fishing lifestyles: 'Territorians', Traditional Owners and the management of recreational fishing in Kakadu National Park. *Australian Geographical Studies* 42 (1), 60–76.

Peverell S, Gribble N & Larson H 2004. Sawfish. In Description of key species groups in the Northern Planning Area., National Oceans Office, Hobart Tas, 75–84.

Posey D 1999. Cultural and spiritual values of biodiversity: A comprehensive contribution to the UNEP Global Biodiversity Assessment. UN Environment Programme, Nairobi.

Price O, Milne D, Connors G, Hardwood B & Woinarski J 2000. A conservation plan for the Daly basin bioregion. Draft, Parks and Wildlife Commission of the Northern Territory, Darwin NT.

PWCNT 2000. A Strategy for Conservation of the Biological Diversity of Wetlands in the Northern Territory of Australia. Parks and Wildlife Commission, Northern Territory.

PWCNT 2004. Mary River National Park (proposed). Fact sheet. http://www.nt.gov.au/ipe/conmgt/images/ MRNP2004.pdf (accessed: 11 Feb, 2005).

RIVM (National Institute of Public Health and the Environment) 2001. European environmental priorities: An integrated economic and environmental assessment. A report prepared by RIVM, EFTEC, NTUA, IIASA, Bilthoven, The Netherlands.

Sagoff M 1998. Aggregation and deliberation in valuing environmental public goods: A look beyond contingent valuation. *Ecological Economics* 24, 213–230.

Schama S 1995. *Landscape and memory*. Harper Collins, London.

Schensul SL, Schensul JJ & LeCompte MD 1999. Essential ethnographic methods: Observations, interviews and questionnnaires. AltaMira Press, Walnut Creek, California, USA.

Schuyt K & Brander L 2004. *Living waters. Conserving the source of life. The economic values of the world's wetlands*. Collaboration between WWF-International, Gland, and Institute for Environmental Studies, Vrije Universiteit, Amsterdam. WWF, Gland, Switzerland.

Schultz TJ, Townsend SA & Edwards CA 2002. Water quality monitoring in the Mary River catchment. Tech. Report 41/2002. Department of Infrastructure, Planning and Environment, Darwin, NT.

Scott G 2004. The Northern Territory Parks and Conservation Masterplan: A submission by Environment Centre NT, WWF & Threatened Species Network Australian Marine Conservation Society.

Shepherd G 2004. The ecosystem approach: Five steps to implementation. IUCN, Gland, Switzerland and Cambridge, UK.

Shultis J 2003. Recreational values of protected areas. The full value of parks, from economics to the intangible, In *The full value of parks, from economics to the intangible*. eds Harmon D & Putney A, Rowman & Littlefield, Lanham, Oxford, 59–76.

Shrestha P 2005. Analysis of policies, institutions and stakeholders as a tool in integrated assessment of wetlands in northern Australia: A case study of Daly River and Mary River catchments. Environmental System Analysis Group, Wageningen University, and Research Centre (WUR), The Netherlands, and National Centre for Tropical Wetland Research, Australia.

Smith RD & Malthby E 2003. *Using the ecosystem approach to implement the Convention on Biological Diversity: Key issues and case studies*. IUCN Ecosystem Management Series No 2, Gland, Switzerland.

Storrs M 2001. The role of western science in wetland management by Aboriginal communities in the 'Top End' of Australia. Science and local communities, strengthening partnerships for effective wetland management. Ducks Unlimited, Memphis, USA.

Storrs MJ & Finlayson CM 1997. *Overview of the conservation status of wetlands of the Northern Territory*. Supervising Scientist Report 116, Supervising Scientist, Canberra.

Stuip MAM, Baker CJ & Oosterberg W 2002. *The socio-economics of wetlands*. Wetlands International and Riza (Royal Institute for Sea Research), Den Haag, The Netherlands.

Taniuchi T & Shimizu M 1991. Elasmobranchs collected from seven river systems in northern Australia and Papua New Guinea. *Nature and Culture* (The University Museum, The University of Tokyo) 3, 3–10.

Taylord R, Cloake J & Forner J 2002. Harvesting rates of a Yolgnu harvester and comparison of selection of Didjeridu by the Yolngu and Jawoyn. Parks and Wildlife Commission of the Northern Territory, Darwin NT.

Thorburn DC, Peverell S, Stevens JD, Last PR & Rowland AJ 2003. Status of freshwater and estuarine elasmobranches in Northern Australia. Report to Natural Trust, Canberra Australia.

United Nations Educational, Scientific and Cultural Organisation (UNESCO) 2003. Text of the Convention for the Safeguarding of Intangible Cultural Heritage, Paris (http://www.unesco.org/culture/ich/index.php?pg=00006)

Verschuuren B 2001. Usable natural resources at Hustai National Park and its buffer zone. A study using PRA and secondary data to support management. BSc thesis, Larenstein Int. Agricultural College, Wageningen, unpublished.

Verschuuren B 2005. Integrated assessment of sociocultural importance of wetlands in northern Australia. A case study of the Mary, Daly and East Alligator River catchments. Environmental System Analysis Group, Wageningen University and Research Centre (WUR), The Netherlands, and National Centre for Tropical Wetland Research, Australia.

Verschuuren B 2006. Socio-cultural importance of wetlands in northern Australia. In Proceedings of UNESCO-IUCN 'Conserving cultural and biological diversity: The role of sacred natural sites and cultural landscapes' Tokyo, Japan (30 May to 2 June 2005) (http://unesdoc.unesco.org/images/0014/001478/147863E.pdf).

Verschuren P & Doorewaard H 1999. *Designing a research project*. Lemma, Utrecht.

White AT, Ross M & Flores M 2000. Benefits and costs of coral reef and wetland management, Olango Island, Philippines. In *Collected essays on the economics of coral reefs*. ed HSJ Cesar, CORDIO, Kalmar University, Sweden, 215–227.

Whitehead PJ, Wilson BA & Saalfeld K 1992. Managing the Magpie Goose in the Northern Territory: Approaches to conservation of mobile fauna in a patchy environment. In Conservation and development issues in North Australia, eds I Moffatt & A Webb, , North Australia Research Unit, Australian National University, Darwin, 90–104.

Whitehead PJ & Chatto R 1996. Northern Territory. In *A directory of important wetlands in Australia*. eds R Blackley, S Usback & K Langford, Australian Nature Conservation Agency, Canberra, 119–176.

Williams DR & Vaske JJ 2002. The measurement of place attachment: Validity and generalizability of a psychometric approach. USDA Forest Service, Fort Collins.

Wilson MA & Carpenter SR 1999. Economic valuation of freshwater ecosystem services in the United States 1971–1997. *Ecological Applications* 9 (3), 772–783.

Wilson MA & Howarth R 2002. Discourse-based valuation of ecosystem services: establishing fair outcomes through group deliberation. *Ecological Economics* 41, 431–443.

Young M 2004. Social values of the Daly Region: A preliminary assessment. Draft report to the Daly Region Community Reference Group, School for Social and Policy Research, Charles Darwin University, Darwin NT.

Ypma O 2005. Integrated assessment of stakeholder interests and trade-offs in use of wetlands functions: A case study of the Daly, Mary and Kunbarrlanjnja wetlands in northern Australia. Environmental System Analysis Group, Wageningen University and Research Centre (WUR), The Netherlands, & National Centre for Tropical Wetland Research, Australia.

Ypma O & Zylstra M (eds) 2006. Integrated ecosystem assessment of wetlands in the Northern Territory: A tool for NRM (Summary for Stakeholders). Environmental System Analysis Group, Wageningen University and Research Centre (WUR), The Netherlands.

Zylstra M 2005. Implications of an integrated ecosystem assessment for wetland management and planning in northern Australia. Environmental System Analysis Group, Wageningen University and Research Centre (WUR), The Netherlands, & National Centre for Tropical Wetland Research, Australia.

Appendix 1 Indicators of sustainable use of wetland services*

Services Comments and examples	Ecosystem process and/or component providing the service (or influencing its availability)	State indicator (ie how much of the service is present)	Performance indicator (how much can be used/ provided in sustainable way)
Provisioning services			
Food: production of fish, algae and invertebrates	Presence of edible plants and animals	Total or average stock (in kg) Fish community assemblages Benthic macro invertebrate & diatom community assemblages	Net productivity (in Kcal/year or other unit)
Fresh water: storage and retention of water; provision of water for irrigation and for drinking.	Precipitation or surface water inflow Biotic and abiotic processes that influence water quality (see water purification)	Water quantity (in m^3) Water quality – dependent on type of use (concentrations of nutrients, chemicals, etc) Hydrology	Net water inflow (m^3/year) (ie water-inflow minus water used by the ecosystem and other water needs)
Fibre & fuel & other raw materials: production of timber, fuel wood, peat, fodder, aggregates	Presence of species or abiotic components with potential use for fuel or raw material	Total biomass (kg/ha) Vegetation community assemblages	Net productivity (kg/year)
Biochemical products and medicinal resources	Presence of species or abiotic components with potentially useful chemicals and/or medicinal use	Total amount of useful substances that can be extracted (kg/ha)	Maximum sustainable harvest
Genetic materials: genes for resistance to plant pathogens	Presence of species with (potential) useful genetic material	Total 'gene bank' value (eg number of species & sub-species)	Maximum sustainable harvest
Ornamental species (eg aquarium fish)	Presence of species or abiotic resources with ornamental use	Total biomass (kg/ha)	Maximum sustainable harvest
Regulating services			
Air quality regulation (eg capturing dust particles)	Capacity of ecosystems to extract aerosols & chemicals from the atmosphere	Leaf area index NOx-fixation, etc	Amount of aerosols or chemicals 'extracted' – > effect on air quality
Climate regulation: regulation of greenhouse gases, temperature, precipitation & other climatic processes	Influence of ecosystems on local and global climate through land-cover and biologically mediated processes	GHG-balance (especially C-fix) DMS production Land cover characteristics	Quantity of greenhouse gases etc fixed and/or emitted and effect on climate parameters
Hydrological regimes: groundwater recharge/ discharge; storage of water for agriculture or industry	Role of ecosystems (especially forests and wetlands) in the capture and gradual release of water	Water storage capacity in vegetation, soil, etc or at the surface; hydrology Riverine physical structure & in-stream habitat	Quantity of water stored and influence of hydrological regime (eg irrigation)
Pollution control & detoxification Retention, recovery and removal of excess nutrients / pollutants	Role of biota and abiotic processes in removal or breakdown of organic matter, xenic nutrients and compounds	Denitrification (kg N/ha/y) Accumulation in plants Kg –BOD /ha/yr Chelation (metal-binding) Total N & P & flow leaving wetland or (sub)catchment Phytoplankton	Maximum amount of waste that can be recycled or immobilised on a sustainable basis Influence on water or soil quality

Services Comments and examples	Ecosystem process and/or component providing the service (or influencing its availability)	State indicator (ie how much of the service is present)	Performance indicator (how much can be used/ provided in sustainable way)
Erosion protection: retention of soils.	Role of vegetation and biota in soil retention	Riparian vegetation community assemblages: Vegetation cover Root-matrix Turbidity or Total Suspended Solids (TSS); Transparency	Amount of soil retained or sediment captured
Natural hazard mitigation: flood control, storm & coastal protection	Role of ecosystems in dampening extreme events (eg protection by mangroves and coral reefs against damage from hurricanes)	Water-storage (buffer) capacity (in m^3); extent of inundation Ecosystem structure characteristics Vegetation	Reduction of flood-danger and prevented damage to infrastructure
Biological regulation: eg control of pest-species and pollination	Population control through trophic regulation Role of biota in distrubtion, abundance and effectiveness of pollinators	Number & impact of pest-control species Number & impact of pollinating species	Reduction of human diseases, live-stock pests, etc Dependence of crops on natural pollination
Cultural & Amenity services			
Cultural heritage and identity (sense of place and belonging)	Culturally important landscape features or species	Presence of culturally important landscape features or species (eg number of World Heritage Sites)	Number of people 'using' ecosystems for cultural heritage and identity
Artistic inspiration: nature as a source of inspiration and expression for art	Landscape features or species with inspirational value	Presence of Landscape features or species with inspirational value	Number of people who attach inspirational significance to ecosystems Number of books, paintings, etc using ecosystems as inspiration
Spiritual significance	Sacred, religious or other forms of spiritual inspiration derived from ecosystems. Importance of nature in symbols and elements with sacred and religious significance.	Presence of sacred sites or features Role of nature in religious ceremonies and sacred texts Oral tradition, song, chant & stories Totemic species, customary use of flora and fauna Traditional healing systems	Number of people who attach religious or spiritual significance to ecosystems Number of manifestations of intangible heritage based on ecosystems
Recreational: opportunities for tourism and recreational activities	Landscape-features Attractive wildlife	Presence of landscape & wildlife features with stated recreational value	Maximum sustainable number of people and facilities Actual use
Importance to human health	Therapeutic effects of nature on human psyche and physical health and wellbeing	Capacity of the natural system to provide health services	Restorative and regenerative effects on people such as decreased levels of stress and mental fatigue Decreased need for health care services and medication Socio economic benefits from reduced health costs
Aesthetic: appreciation of natural scenery (other than through deliberate recreational activities)	Aesthetic quality of the landscape, based on eg structural diversity, 'greenness', tranquility	Presence of landscape features with stated appreciation Wetland condition	Expressed aesthetic value, eg: No. of houses bordering natural areas No. of users of 'scenic routes'

Services Comments and examples	Ecosystem process and/or component providing the service (or influencing its availability)	State indicator (ie how much of the service is present)	Performance indicator (how much can be used/ provided in sustainable way)
Educational: opportunities for formal and informal education & training	Features with special educational and scientific value/interest	Presence of features with special educational and scientific value/interest	Number of classes visiting Number of scientific studies etc
Supporting services			
Biodiversity & nursery: habitats for resident or transient species	Importance of ecosystems to provide breeding, feeding or resting habitat to resident or migratory species (and thus maintain a certain ecological balance and evolutionary processes)	Number of resident, endemic species Habitat integrity Minimum critical surface area Riverine physical structure & in-stream habitat Riparian vegetation community assemblages Condition of habitat at significant estuarine, coastal & marine sites Indicator species (eg macro-invertebrate indices)	'Ecological value' (ie difference between actual and potential biodiversity value) Dependence of species or other ecosystems on the study area Extent of regionally significant wetlands
Soil formation: sediment retention and accumulation of organic matter	Role of species or ecosystem in soil formation	Amount of topsoil formed (eg per ha/year)	*These services cannot be used directly but provide the basis for most other services, especially erosion protection and waste treatment*

* This table is based on De Groot et al (2006), LCNT (2005)

Appendix 2 Main methods for stakeholder analysis and participatory assessment used in this study

1 Data review

1a Literature research and document review

A broad array of published information sources has been studied: scientific research carried out in the study areas has been scoped including peer reviewed journal articles and papers produced within the international scientific community. Various international organisations and conventions have produced guidelines, manuals and resolutions on ecosystem values. Issues that come into play at the regional level include, eg intellectual property rights, rights of indigenous people to land and resources, Social Impact Assessment (SIA), Environmental Impact assessment (EIA) etc. Current management plans and policies by national, state and local government offer an invaluable source of information complemented by plans and strategies of regional organisations such as Aboriginal associations, cattleman's associations and tourist organisations often affiliated with the private sector, for example privatisation of water etc.

The focus of the literature research fell into three areas:

- Understanding the relevant theoretical frameworks and approaches (eg existing literature on: integrated assessment tools; ecosystem services and function analysis; ecosystem approach and adaptive management);
- Understanding the background and current management context of the research areas (eg existing literature and documents on: local, regional and national management approaches for (integrated) catchment, river and wetland management; previous research reports; current research programs and priorities; key stakeholders; existing policies, strategies, frameworks and guidance for wetland management;
- Understanding the ongoing management issues and shortcomings already well-described in relevant documents and literature, which have a direct or indirect impact on wetland management and may benefit from an ecosystem function-analysis approach.

1b Media research

Online (internet) news and daily newspapers provided a useful source of up to date information to monitor the development of ongoing issues and debates. The DRCRG process was a good example of a public discussion and working group making information regarding its findings publicly available online. This process was complemented by continuous media coverage. The use of the Internet by natural resource managers is a rather common practice that has rapidly evolved over the last decade.

2 (Participatory) observational research

There are several forms of observational research applicable to the assessment of ecosystem services. However, a proposal to undertake a form of Participatory Rural Appraisal (PRA) (Chambers & Blackburn 2000) was not progressed because of the limited time available for

the research and the expected difficulties in gaining permits allowing the researchers to conduct research with the permission of the responsible authorities or individual communities.

2a Direct observation

Direct observation formed an important component of the research. Whilst one can obtain information about attitudes and values through the interview process, it does not provide certainty on what stakeholders, resource managers and decision-makers actually do. Therefore observation was used firstly to understand the research areas and land uses and activities within them and secondly to view stakeholder interactions and activities in land management. Direct observation of research areas was a crucial initial step in simply being able to place already accumulated knowledge of issues and area descriptions into the practical context of seeing the area and appreciating the geographical magnitude; diverse and unique ecology; extent and location of specific land tenures and (social) activities (eg tourism, pastoralism, and Aboriginal community areas); and relevant management issues (eg fire and weed infestations). This was achieved through a number of field trips.

Direct observation through field trips was combined with scheduled interviews (usually of a semi-structured nature, see section 3 below); targeted or semi-random discussions/questionnaires with tourists, tourist operators, land owners, community members; as well as observations of stakeholder interactions and behaviour. These direct observation experiences proved very useful in observing first-hand, the broader management context of these areas, how the land owners perceive relevant land and wetland management issues and, finally, the extent to which wetland functions (and ecosystem services) and goals of sustainable multi-functional use are being addressed in the research areas.

2b Participant observation

Participant observation generally refers to situations where the researcher participates in the daily activities of a (sample) group on a structural basis (Verschuren & Doorewaard 1999). The most beneficial opportunity for participant observation of on-ground wetland management was with the Adjumarllarl Community Rangers working on the floodplains surrounding the Kunbarllanjnja community in the East Alligator River catchment. The Rangers' day-to-day management activities on the wetlands are varied throughout the seasons of the year; however, a primary focus is the control and eradication of the exotic invasive weed *Mimosa pigra*. The nature of the participant observation was to specifically work with the Rangers on the floodplains and assist in the patrol and application of herbicides to *Mimosa pigra* plants and seedlings. This technique was invaluable not only in understanding on-ground realities for wetland management in remote, sparsely populated areas but also for understanding the basis and objectives on which current management is organised. This helped address specific questions of how ecosystem services are being accounted for in wetland management; and, by experiencing management limitations and frustrations first-hand, provided an insight into how an ecosystem (services) approach may or may not deliver different outcomes for on-ground managers.

3 Interviews and questionnaires

In order to acquire information about individual stakeholders and stakeholder groups, it is important to involve stakeholders. A very important tool for stakeholder involvement in the assessment is the use of semi-structured interviews which can be used in all stages of the stakeholder analysis.

3a Semi-structured Interviews

Semi-structured interviews were the most utilised research method in the field. This style of interview is usually a face-to-face interview characterised by a limited degree of pre-structuring and an open style of interviewing (Verschuren & Doorewaard 1999). In particular, in-depth open-ended interviewing was the preferred method with interviewees. Despite being the most challenging method (in terms of maintaining a focus on the interview objectives), it allows a topic to be explored in detail, deepening the interviewer's understanding of the topic as well as being open to all relevant responses (Schensul et al 1999).

A list of subject areas was prepared as a guide during interviews with stakeholders and other individuals. It was usually necessary to tailor the subject areas to specific questions prior to individual interviews based on the expertise of the stakeholder and anticipated knowledge of a particular subject area. It was also vital to familiarise the interviewee with the nature of the project. This was achieved (after an introductory phone call or email) by sending (via email) a prepared (and accessible in terms of the language used) information sheet about the nature and reason for the research. Topics were introduced clearly when commencing the interview. Where possible, interviews were audio recorded with assurance given to the interviewee that they would not be quoted unless they had given permission to do so. Above all, it was necessary to approach each and every interview as 'listeners'; willing to listen and learn and to respect the views and knowledge of interviewees.

Semi-structured interviews provided significant advantages over more formal, structured and close-ended interviewing (or questionnaires). This is due to the fact that firstly, little in-depth knowledge of management in the research areas was assumed and, secondly, the research questions have potentially broad implications that could be better communicated in an open and in-depth interview. Finally, elements of one interview could be used to elicit a contrasting or conflicting response from another interview - as a means of verifying information and maintaining objectivity – and, therefore ensuring higher confidence in accurately addressing the research questions. The quotes of stakeholders, which appear in this report, support the fact that this form of interviewing encouraged open and honest responses form interviewees.

3b Questionnaires

For the purpose of conducting questionnaires, relevant questions initially have been added into a database. Using this database as a starting point a suitable questionnaire can be designed for most user groups or stakeholders. In practice questionnaires have not been used. The research method focused on semi-structured interviews with primary, secondary and key-stakeholders rather then surveying user groups of wetlands. Questionnaires demand a different type of questioning from a semi-structured interview therefore the database has only occasionally proved a useful source while preparing the semi-structured interviews.

4 Network analysis

Key information sources and contacts could be identified and contacted in the relevant research areas by utilising existing or previous research networks developed in the region. The Northern Territory (and the research areas chosen) may be physically expansive with relatively isolated areas; however, the people-people networks are much less. It is a characteristic of resource management and environmental-related research in the Northern Territory that, in some way or another, it can appear that 'everyone knows everyone' or, at least, knows *of* everyone. This is highly beneficial to researchers who have only limited time

at their disposal and was therefore utilised in the group's combined research approach as well as on an individual level.

Another 'research tool' that was anticipated, but was more effective than first imagined was that of the 'snowball method'. The snowball method is the process whereby one or several interviews are conducted and the next people to be interviewed are selected on the basis of the results obtained in the first interviews (Verschuren & Doorewaard 1999). Many interviewees recommended other contacts who would be worthwhile to speak with and this became an invaluable method of furthering the research possibilities. Similarly, a 'backward effect', ie interviewees recommending a meeting with contacts who were the source or primary researchers for *their own* information, also became a useful way of verifying information and providing a more objective background for views expressed by stakeholders.

Additionally, opportunities for 'scaling-up' the research networks were made. That is, it was possible to gain an understanding of the context and potential for greater integrated management of wetland services by initiating contact with individuals who are (also) involved with initiatives and guidance developed from institutions/programs such as the Ramsar Convention's Scientific and Technical Review Panel, the Millennium Ecosystem Assessment, IUCN Task Forces and other international initiatives.

5 Triangulation

Triangulation is a way of augmenting and verifying information obtained from a number of methods such as observations, interviews and literature (triangulation of methods) (Verschuren & Doorewaard 1999). Triangulation validates information through cross-checking information using at least three methods (Verschuuren 2001). For example a (participatory) field observation can be confirmed by literature research and a stakeholder interview. Therefore, this approach was also used to during the research to substantiate the information received.

Appendix 3 Effects of main environmental issues on five selected wetland services

	Wetland service				
Stakeholder activities	**Agriculture/ pastoralism**	**Food**	**Maintenance of biodiversity *(conservation)***	**Water supply**	**Knowledge *(education & research)***
Cattle grazing on native and introduced pastures	(-) Grazing near water can cause *erosion*, less productive soil	(-) Potentially trampling on edible plants and animals (local scale)	(-) *Introduced plants* can affect biodiversity	(-) Potential decline in water quality. Potential effect on different water usages, for example drinking water	(+) Potential increase of research on the management of introduced and native pastures (eg other land management issues)
Land clearing *(mainly outside wetlands)*	(-) Large scale of *land clearing* can cause erosion , sediments end up in wetlands	(-) Potential decline in vegetation and animals	(-) Potential loss of biodiversity	(-) Potential decline in water quality. Potential effect on different water usages, for example drinking water.	(+) Research on conducting sustainable land clearing
Gathering bush food *(animals and plants)*	No data found	(-) Potential over harvesting of species	(-) Over harvesting means less biodiversity	No data found	(+) Providing information for researches on fauna and flora, for example location of species, population size
Hunting pest animals *(eg pigs and horses)*	(+) Potential less damage to pastoral land caused by feral pigs	No data found	(+) Less damage to vegetation of the wetlands	No data found	(+) Providing information on population of feral animals
Biodiversity conservation	No data found	(+) Supports plants and animals	(+ / -) Use of *fire*, shooting of feral animals, eradication of weeds to manage biodiversity	(+) Conserving vegetation could potential improve filtering of water resulting in support for different water usages	(+) Supports researches on flora and fauna
Drinking water	(-) High amount of water use could potentially pressure the available amount of water used for irrigation of pastoral land	(-) High extraction of water could potentially decrease the amount of animals and plants that rely on high amount of water	(-) High water extraction could potentially decrease biodiversity	(-) High extraction could decline water supply for ecology, irrigation and other usages	(+) Potential research on the ability of vegetation to filter water

Stakeholder activities	Wetland service				
	Agriculture/ pastoralism	**Food**	**Maintenance of biodiversity *(conservation)***	**Water supply**	**Knowledge *(education & research)***
Irrigation water	(-) High amount of water extraction for pastoral land can decline water supply for other land uses	(-) High extraction of water could potentially decrease the amount of animals and plants that rely on high amount of water	(-) High *water extraction* could potentially cause decrease in biodiversity	(-) High extraction could diminish water supply for ecology, drinking water and other usages	(+) Potential research on water requirements of wetlands and agriculture / pastoralism
Research on flora and fauna	No data found	(+) Potentially results in using more knowledge on edible flora and fauna	(+) Research can result in suitable management of habitats	(+) Potentially provides more knowledge on water requirements for flora and fauna	(+) More data known on wetlands ecology

Source: Ypma 2005

Appendix 4 Links between management issues and threats to wetland functions (Daly River catchment)

Table notes:

a) including groundwater and surface water extraction

b) including impoundment of dams, off-stream billabong storage, roads and bridges

c) including crop production (irrigated and dryland cropping) & horticulture

Wetland Functions	Management issues (potential threats to wetland functions)					
	Water extraction[a]	**Water impoundment**[b]	**Land clearing & agricultural intensification**[c]	**Weeds**	**Feral animals**	**Pastoral activity**
Regulating						
Disturbance prevention	Sediment transport may be affected through reduced flows; wetland vegetation (which assists with water flow/flood regulation) may be affected by reduced availability of groundwater at the surface (Begg et al 2001)	Potential changes to river and wetland flow regime: volume, rate, timing, direction and quality (larger dams would affect natural flow variability at a larger scale) possibly altering additional factors affected by normal flooding regimes such as temperature, oxygen content, ionic concentrations and silt load (Begg et al 2001)	Likely reduction in wetland water storage capacity due to fire as a land management tool; Land drainage may affect a wetland's ability to offer flood attenuation and water storage functions (Begg et al 2001); Increased potential for more damaging flooding due to increased sedimentation (from soil loss) (PWCNT 2004) which would also heighten the level of river bed increasing chances of flooding in certain areas (Stakeholder pers comm, 2004); Riparian vegetation is further from water source and may be negatively impacted (PWCNT 20044)	Weed species (such as Gamba grass *Andropogon gayanus*, Mission grass *Pennisetum polystachion*, Couch grass *Cynodon dactylon* and Buffel grass *Cenchrus ciliaris, Parkinsonia aculeatacan* and *Mimosa pigra*) invade and replace native plant communities (PWCNT 2004) and change the vegetation structure and water holding capacity of a wetland	Animals with hard hooves (such as water buffalo (*Bubalus bubalis*)) have significant potential to damage wetland vegetation and ability to control erosion – such degradation is increased through heavier grazing pressure with increased bank erosion and sedimentation (Begg et al 2001)	Animals with hard hooves have significant potential to damage wetland vegetation and therefore cause erosion – such degradation is exaggerated through heavier grazing pressure with increased bank erosion and sedimentation. Drainage lines and sites with evidence of cattle use tend also to have the highest weed incidence (PWCNT 2004).

Wetland Functions	Management issues (potential threats to wetland functions)					
	Water extraction[a]	**Water impoundment**[b]	**Land clearing & agricultural intensification**[c]	**Weeds**	**Feral animals**	**Pastoral activity**
Water regulation	Reduction in temporal and spatial extent of temporary wetlands and base-flow may affect ability to provide input into shallow groundwater aquifers assisting groundwater recharge. Potential affects on the natural variability of the water regime – drainage and natural irrigation (Begg et al 2001).	Large dams likely to affect water regime of the whole catchment and natural flow variability and flooding cycles (ie reduced frequency, size and duration) that drive downstream processes. Changes in flooding regimes may affect natural ability to regulate characteristics such as temperature, oxygen content, ionic concentrations and silt load (Begg et al 2001).	Altered catchment hydrology as a result of increased surface runoff can affect groundwater recharge and reduce the reliability of Dry season spring flows (Erskine et al 2003). Removal of water for irrigation may preclude it reaching its usual destinations, which are perennial springs (PWCNT 2004). Likely reduction in infiltration rates will reduce groundwater recharge rates (Erskine et al 2003).	Weed species (such as those identified above) invade and replace native plant communities (PWCNT 2004) and change the land cover characteristics, water holding capacity and the ability of a wetland to regulate flows	Water buffalo, as an example, can contribute directly to tree death by wallowing at the base of trees by rubbing trunks and damaging roots – loss of vegetation can affect the land cover characteristics and fauna of a wetland (PWCNT 2004)	Overgrazing can affect hydrological regime – disruption of flow patterns by cattle tracks, trampling, gully erosion and siltation of pools and natural waterholes. Grazing intensity primarily affects infiltration and runoff (Begg et al 2001).
Water supply	Reduction of flow in springs and rivers including reduction in Dry season base flows and possible impacts on water quality; draw-down of groundwater aquifer with possible effects on groundwater-dependent ecosystems (Begg et al 2001)	Dam construction may destroy upstream wetlands due to inundation and deterioration of water quality such as eutrophication (algal blooms) and anoxia (oxygen depletion (Begg et al 2001; PWCNT, 2004); Downstream effects on rivers and wetlands evidenced through changes in river channels habitats (eg channels, channel and back-flow billabongs) (Begg et al 2001)	Increased surface runoff through land clearing can decrease groundwater recharge and water availability for groundwater recharge and Dry season spring inflows (Erskine et al 2003). Soil washed into river after land clearing (eg anecdotal evidence from activities on Tipperary (Jackson 2004)) affects drinking water for Aboriginal communities downstream.	Effects on water availability in wetland areas as some weeds species uptake water in larger amounts than native vegetation and as well as reducing access to areas by restricting the ability to obtain water for drinking, irrigation and stock watering points	Feral pigs *(Sus scrofa)* generally foul waterholes; The wallowing of feral pigs in billabongs can lead to Aboriginal people picking up diseases, such as sparganosis, through drinking the water (Noakes (1999) by Jackson 2004)	Replacement of wetland vegetation with pasture grasses could increase groundwater uptake during the low flows of Dry season and result in less overall water availability

Wetland Functions	Management issues (potential threats to wetland functions)					
	Water extraction[a]	**Water impoundment**[b]	**Land clearing & agricultural intensification**[c]	**Weeds**	**Feral animals**	**Pastoral activity**
Soil retention	Reduction in temporal and spatial extent of temporary wetlands affecting ability to provide refuge to wildlife (Begg et al 2001)	Alteration of flooding regime may affect silt load reaching wetland areas	Extensive land clearing may result in increased surface runoff (over native woodland) typically resulting in an amplification of flood events, increased sedimentation, significant soil loss and accelerated soil erosion (PWCNT 2004, Erskine et al 2003). Cropping leads to increased soil loss rates and sediment yields (Erskine et al 2003). Wetland drainage through any number of activities such as cropping can lower hydrological values leading to susceptibility to erosion.	Potential for increased erosion through displacement of soil retaining native vegetation; possible also to have the opposite effect depending on weed's root structure or that the weed restricts access to areas that may have been subject to erosion through recreational or local community uses. Weed species can alter the fire regime – increasing incidences of wildfire and leading to increased erosion and sediment load reaching the river (Ecoz Environmental Services 2003).	Potential for increased erosion through displacement of soil retaining native vegetation; feral pigs can denude wetland vegetation and uproot plants which stabilise riparian or fringing areas – 'wallowing' of feral pigs in wetland areas also creates significant patches of exposed soil which contributes to erosion and sedimentation as soil is then easily washed/transported to other areas. Feral animal presence cam also lead to destruction of banks and bank collapse (Schultz et al 2002).	Heavier grazing pressure can damage wetland characteristics leading to increased runoff and greater erosion (Hairsine et al (1992) in PWCNT 2004)
Nutrient regulation	Wetland vegetation (which assists with nutrient retention) may be affected by reduced availability of groundwater at the surface	Dams may prevent normal detritus from flowing down the river; Water released form dams is usually colder as it is released from great depth (PWCNT 2004) and may subsequently impact on nutrient regulation dynamics on the wetland systems. Dams may also inhibit the 'rejuvenation' role of flood events on estuarine floodplains where nutrients are dispersed and flushed over aquatic habitats to allow for species recolonisation (PWCNT 2004).	Increased sediment delivery (of silt and clay) to the channel network is likely to increase turbidity and nutrient concentrations (Erskine et al 2003). Intensified agriculture and subsequent chemical runoff can lead to nutrient enrichment of surface water and groundwater water and result in blue-green algal blooms altering the ability for wetlands to regulate nutrients.	Potential to affect nutrient retention ability mainly through replacement of native vegetation communities	Potential to affect nutrient retention ability mainly through replacement of native vegetation communities	Potential to affect nutrient retention ability mainly through disruption of wetland flora and fauna communities

Wetland Functions	Management issues (potential threats to wetland functions)					
	Water extraction[a]	**Water impoundment**[b]	**Land clearing & agricultural intensification**[c]	**Weeds**	**Feral animals**	**Pastoral activity**
Waste treatment	Wetland vegetation (which assists in filtration of nutrients etc and assists pollution control, water quality) may be affected by reduced availability of groundwater at the surface (Begg et al 2001)	Constant release of water through dam walls can change rivers and upstream wetlands from seasonal to perennial (Begg et al 2001)	Cropping, horticulture and mining may involve potential pesticide or other chemical contamination of wetlands influencing carrying capacity of wetlands to offer effective pollution control (Begg et al 2001). Urban development can result in land drainage, increase contamination from domestic and industrial effluents and may affect a wetland's ability to offer water cleansing functions.	Potential to affect waste treatment capability ability mainly through replacement of native vegetation communities	Potential to affect waste treatment capability ability mainly through replacement of native vegetation communities	Potential to affect wetland waste treatment capability mainly through impact on water quality in wetland areas and interference with native vegetation which would otherwise perform a waste treatment function
Biological control	Potential altered structure of aquatic communities may affect trophic relationships	Increased surface water availability due to water impoundment could lead to increased mosquito populations and incidences of mosquito-borne viruses. Altered trophic dynamics with concentration of flows into a few channels providing a focal point for aquatic and terrestrial predators. Constant release of water through dam walls can change rivers and upstream wetlands from seasonal to perennial. Alterations to hydrological regime would possibly affect coastal ecosystems which are connected to the natural pattern of river discharge to the sea. Regulated flows will affect how wetland plants germinate, grow and reproduce (Begg et al 2001).	Altering of trophic dynamics with the introduction of foreign chemicals through pesticide use. Increased water temperature due to less water for the sun to heat and decreased oxygen levels – plants sown for crops may also become weeds (PWCNT 2004) (See adjacent column 'Weeds' for potential affect on wetland functions). Environmental cues for breeding may be interrupted (eg most native fish species respond to changes in river flow and water temperature to start breeding or migration behaviours) although most NT fish species are thought to breed in the Wet season when the impacts of irrigation on flows may be negligible (PWCNT 2004).	Potential alteration of tropic dynamics and ability for wetland systems to maintain balanced ecosystem functioning due to weed invasions	Feral pig populations assist in the spread of weeds (eg *Mimosa pigra*) as well as their ability to carry diseases (evidence suggests they are an end host of bovine tuberculosis which wetlands are unable to sufficiently control on a natural basis; likely alteration of tropic dynamics as new species enter the ecosystem - native wildlife populations are expected to decrease with the arrival of the cane toad (*Bufo marinus*) in wetland ecosystems	Affected/eroded sites from grazing pressure vulnerable to weed invasions – thus likely to displace native flora and fauna and leading to increased incidences of fire

Wetland Functions	Management issues (potential threats to wetland functions)					
	Water extraction[a]	**Water impoundment**[b]	**Land clearing & agricultural intensification**[c]	**Weeds**	**Feral animals**	**Pastoral activity**
Supporting						
Refugium	Reduction in temporal and spatial extent of temporary wetlands or drying of usually moist wetlands affecting ability to provide refuge to native fauna; Potential hydrological changes may result in reduced aquatic habitat – in particular spring inflows are essential for maintaining critical habitat for the pig-nosed turtle and elasmobranches (ie sharks, rays and sawfish) (Erskine et al 2003). Possible alteration of structure and dynamics of riparian communities along river and creek banks due to lower Dry season flows (Begg et al 2001).	Alterations to hydrological regime may affect coastal ecosystems which are connected to the natural pattern of river discharge to the sea. Dams obstruct passage of many fish and invertebrate species. Reductions in downstream flow and discharge variability result in loss of biodiversity as the life cycles of floodplain fauna are linked to natural fluctuations in water level and inundation of floodplains. Possible changes in vegetation type alter feeding opportunities and nesting habitat for waterbirds. Aquatic macrophyte communities can be altered through artificial increases in depths on billabongs and thus affecting native flora and fauna (Begg et al 2001).	Loss of wetland habitat (due to excess chemicals, soil loss and lack of water) can lead to loss of species (biodiversity) through a reduction and fragmentation of habitat (PWCNT 2004). Crop production can potentially disrupt hydrological regime, replace native vegetation, and negatively affect wetland dependent biota with replacement of wetland vegetation and using water during the critical Dry season. Conversion of a wetland to cropland usually involves the compete removal of native vegetation, hydrological manipulation and application of fertilisers affecting ecological character and reducing available habitat for native species of fauna (Begg et al 2001).	Evidence of dramatic changes in the abundance and diversity of native flora (Erskine et al 2003) and therefore also having substantial impact on the availablilty for native fauna populations such as evidenced with the magpie goose returning after an eradication program to control *Mimosa pigra* on the Oenpelli floodplains (Ecoz Environmental Services 2003). Weeds can also change the fire regime – increasing fire intensity – and negatively impact on habitat for native fauna (PWCNT 2004).	Indigenous community concerns about declining water quality on the river and fish habitat; Introduced weeds and grasses seen by indigenous communities as choking billabongs and not allowing animals to move between billabongs (Jackson 2004)	Pasture development likely to reduce diversity of flora and fauna as it can disrupt the hydrological regime and replace native vegetation with a monoculture of exotic grass and therefore impacting on available habitat for native fauna (Begg et al 2001)

Wetland Functions	Management issues (potential threats to wetland functions)					
	Water extraction[a]	**Water impoundment**[b]	**Land clearing & agricultural intensification**[c]	**Weeds**	**Feral animals**	**Pastoral activity**
Nursery	Reduction in temporal and spatial extent of temporary wetlands affecting ability to provide suitable habitat to maintain biological and genetic biodiversity. Potential reduction/disruption of flows to groundwater dependent ecosystems may affect quality of habitat (Begg et al 2001).	Survival of wetland animals (through their patterns of migrations, dormancy and recolonisation) are threatened by damming; Delays and/or reductions in first Wet season flows can affect river and wetland biota dependent on such catalysts for breeding, reproduction and other cycles. Road and bridge building cut off billabongs thus affecting fish passage and stagnating water due to lack of streamflow.	Conversion of wetland for cropping can indirectly disrupt fish recolonisation as a result of interfering with the connectivity of wetlands by drainage and infilling; Over-use of chemicals (or runoff with high oxygen demand) can result in toxic blue-green algae blooms, fish kills and organophosphate accumulation in wildlife populations (PWCNT 2004, Erskine et al 2003). Increased erosion from land clearing can lead to the development of sand slugs in downstream rivers which reduces the amount of diversity in aquatic habitat (Erskine et al 2003).	Weed species can alter the fire regime – increasing fire intensity – and negatively impact on habitat for native fauna (PWCNT 2004)	Impact on wetland vegetation which provides breeding habitat to native wildlife such as waterbirds; Fouling (and reducing water quality) in wetland areas which provide nursery habitat for fish species. Direct interference with breeding or reproductive processes (eg feral pigs raiding nests or digging up buried eggs such as has been observed with sea turtles nests on the northern Australian coastline).	Pasture development likely to reduce diversity of flora and fauna as can potentially disrupt the hydrological regime and replace native vegetation with a monoculture of exotic grass and thus impacting on suitable habitat for native fauna (Begg et al 2001)
Provisioning (Production)						
Food	Drying of normally moist wetlands would have 'deleterious consequences' to native fauna; Worst case scenario of flow cessation would impact on wetland biota and the ability of the ecosystem to produce resources (Begg et al 2001)	Dams obstruct the passage of many fish; There is a negative (Aboriginal) perception of any activity that stops the flow of river and disturbs movement of fish and turtle (Jackson 2004). Likely impact on Barramundi and other aquatic species for consumption due to habitat changes.	Jeopardising production functions from any number of activities would directly impact on the river as a 'livelihood' for Aboriginal communities (eg subsistence food sources such as four types of turtle in rivers and streams in the Daly area (Jackson 2004))	Weed species can invade and replace native plant communities (PWCNT 2004). Introduced weeds and grasses seen by indigenous communities as choking billabongs and restricting access to food resources and movements in the area.	Feral pigs reduce the abundance of favoured Aboriginal food source species such as pandanus and yams (Caley 1993 & Letts et al 1979 in PWCNT 2004). Feral animals such as pigs impact on turtle populations used as a subsistence food source for Aboriginal communities (Jackson 2004).	Fenced off areas on pastoral land may limit access to river and wetland areas considered important to local Aboriginal communities for subsistence fishing and hunting (Neville Brown in Jackson 2004)

Wetland Functions	Management issues (potential threats to wetland functions)					
	Water extraction[a]	**Water impoundment**[b]	**Land clearing & agricultural intensification**[c]	**Weeds**	**Feral animals**	**Pastoral activity**
Raw materials	Wetland vegetation (which provides bark, leaves etc as raw materials) may be affected by reduced availability of groundwater at the surface	Regulated flows will affect how wetland vegetation germinates, grows and reproduces (Begg et al 2001). Altered water regimes may mean some vegetation communities disappear while others prosper – affecting the type of raw materials available.	Reduction in native vegetation reduces the amount of raw materials available, particularly for local (Aboriginal) communities	Weed species can invade and replace native plant communities (PWCNT 2004). Introduced weeds and grasses seen by indigenous communities as choking billabongs and restricting availability of (traditional/ native) raw materials.	Potential economic opportunity obtained from the harvest of wild rice and lotus lily may be viable if not for the impact on these species from feral pigs (Jackson 2004)	Access to river sites important to local Aboriginal communities for collecting raw materials – pastoral activity can limit access
Genetic resources	Worst case scenario of flow cessation would impact on wetland biota and the ability of the ecosystem to produce resources	Potential impacts on resource availability due to anticipated reductions in biodiversity	Potential impacts on resource availability due to anticipated reductions in biodiversity	Potential impacts on resource availability due to anticipated reductions in biodiversity	Potential impacts on resource availability due to anticipated reductions in biodiversity	Potential impact considered negligible at this point in time except though native vegetation losses attributed to land clearing or through the spread of weeds
Medicinal resources	Worst case scenario of flow cessation would impact on wetland biota and the ability of the ecosystem to produce resources (Begg et al 2001). Wetland vegetation (which provides bark, leaves etc) may be affected by reduced availability of groundwater.	Potential impacts on resource availability due to anticipated reductions in biodiversity	Potential impacts on resource availability due to anticipated reductions in biodiversity	Potential impacts on resource availability due to anticipated reductions in biodiversity	Potential impacts on resource availability due to anticipated reductions in biodiversity	Potential restriction of access to river sites considered important to local Aboriginal communities for collecting traditional 'tucker' and bush medicines (Jackson 2004)
Ornamental resources	Worst case scenario of flow cessation would impact on wetland biota and the ability of the ecosystem to produce resources (Begg et al 2001). Wetland vegetation (which provides bark, leaves etc) may be affected by reduced availability of groundwater.	Potential impacts on resource availability due to anticipated reductions in biodiversity	Opportunities to enhance potential for suitable plant products on Aboriginal land for sale from wild harvest and/or propagation may be restricted by losses in native flora	Potential impacts on resource availability due to anticipated reductions in biodiversity	Potential impacts on resource availability due to anticipated reductions in biodiversity	Potential impact considered negligible at this point in time except though native vegetation losses attributed to land clearing or through the spread of weeds

Wetland Functions	Management issues (potential threats to wetland functions)					
	Water extraction[a]	**Water impoundment**[b]	**Land clearing & agricultural intensification**[c]	**Weeds**	**Feral animals**	**Pastoral activity**
Provisioning (Carrier)						
Pastoral	Drying of springs and permanent pools within creeks or other wetland types may reduce potential for stock watering holes or waterlogging of pastures; however, further investigation needed as to how threats listed above could further impact on pastoral activity – other targeted forms of water extraction are likely to provide economic gains for pastoral activity	Small scale water impoundment through ponded or water-logged pastures (or in some cases off-stream dams to supplement watering points) are generally valued in being able to provide ideal areas for stock grazing carrying capacity of the land; large-scale water impoundment is likely to limit other functions provided by wetlands in supporting pastoral activity	Land management tool of burning enhances grazing value of wetlands for cattle; Seasonally waterlogged damplands can provide important grazing sites (Begg et al 2001). Improved pasture production may have less severe impacts than other activities requiring land clearing due to better soil cover provided.	Weeds such as *Mimosa pigra* smother pastures by forming dense thickets and making areas inaccessible to stock and farmers – the preference of some weed species for wetland areas can block access to irrigation and stock watering points as well as impeding the mustering of buffalo and cattle	Feral pigs carry parasites and diseases and act as an end host for bovine tuberculosis with the occurrence of TB linked to the presence of TB in infected stock. Feral pigs root up soil to allow for weed invasion and spread weeds through body and defecation which impacts on pastures in wetland areas.	Pastoral activity can influence the ability of a wetland to maintain its pastoral function. For example, unsustainable practices may degrade wetland/floodplain areas valued for grazing and foul watering holes for stock. Cleared native vegetation may lead to increased erosion in wetland areas used for grazing.
Horticulture	Further investigation needed as to how threats listed above could impact on horticulture – it is expected that water extraction (for horticulture) will immediately benefit horticulture in the short term by increasing economic gains	Deemed a critical aspect to economically viable, all-year production in terms of being able to regulate constant water supply to guard against potential crop failure	Land clearance and possible drainage or conversion of wetlands required for intensification of agricultural development – in some cases, subdivision of already cleared properties could occur	Weeds such as *Mimosa pigra* that have a preference for wetland areas can potentially block access to irrigation points	Likelihood of potential crop damage from feral animals which also assist in the spread of weeds and therefore limiting potential agricultural productivity	Links and possible impacts are tenuous but can be indirectly linked through other potential impacts described in the table (eg competition for water resources, or desirable production (wetland) areas
Crop production	Further investigation needed as to how threats listed above could impact on crop production	Deemed critical to economically viable, all-year production in terms of being able to regulate constant water supply to guard against potential crop failure	Land clearance and possible drainage or conversion of wetlands required for intensification of agricultural development – in some cases, subdivision of already cleared properties could occur	Weeds such as *Mimosa pigra* that have a preference for wetland areas can potentially block access to irrigation points	Evidence of feral pigs inflicting moderate to severe damage to maize crops in the Douglas Daly region	Links and possible impacts are tenuous but can be indirectly linked through other potential impacts described in the table (eg competition for water resources, or desirable production (wetland) areas

Wetland Functions	Management issues (potential threats to wetland functions)					
	Water extraction[a]	**Water impoundment**[b]	**Land clearing & agricultural intensification**[c]	**Weeds**	**Feral animals**	**Pastoral activity**
Cultural						
Aesthetic	Potential impact on wetlands from altered ecosystem dynamics through reduced flows (or potential drying out of wetlands areas) will decrease the ability of a wetland to maintain an aesthetic function	Lowering of groundwater tables affects water dependent ecosystems such as paperbark swamps (PWCNT 2004). A die-off of such vegetation would also affect other functions (such as habitat and production) linked to the aesthetic function.	Deterioration of water quality (eg observation of brown water after Tipperary clearing (Jackson 2004). Daly River considered to be crowded with too many boats (Jackson 2004). Change of river colour at certain times after flooding which Aboriginal people have attributed to land clearing or inappropriate fires.	Replacement of native vegetation (and associated reductions in biodiversity) less aesthetically appealing. Weeds such as Ngurr Burr shades the banks creating unappealing bare ground (Jackson 2004).	Feral pigs have a substantial impact on wetlands after water recedes by digging up everything – 'it becomes just like one big ploughed field' (Noakes (1999) in Jackson 2004).	Tracts of land cleared for pastoral activity may decrease or increase the aesthetic value depending on personal perception and values
Inspirational & Artistic	Wetland vegetation (which provides materials or inspiration for artwork etc) may be affected by reduced availability of groundwater at the surface. Potential reduction of spring inflows could impact on the critical habitat for 'flagship species' such as the pig-nosed turtle, freshwater sawfish and speartooth shark (also affecting 'existence values') (Erskine et al 2003).	Indigenous artwork (for example the Merrepen Arts Centre at Naiuyu Community in the Lower Daly region) is often inspired by the river as a flowing and living entity: a source of life and Dreaming (stories) about the surrounding country – potential water impoundment would impinge on this function	Large-scale land-clearing can degrade wetland areas that hold artistic or inspirational value for artwork, postcards, films and documentaries	Large-scale infestations can degrade wetland areas that hold artistic and inspirational value for artwork, postcards, films and documentaries	Visible degradation of wetland areas which reduce aesthetic appeal (see Aesthetic) and overall inspirational value	May act as a source of inspiration for artists wishing to depict, capture or illustrate NT (pastoral) lifestyle and land uses or, alternatively, may detract from the artistic potential of native (intact) landscapes

Wetland Functions	Management issues (potential threats to wetland functions)					
	Water extraction[a]	**Water impoundment**[b]	**Land clearing & agricultural intensification**[c]	**Weeds**	**Feral animals**	**Pastoral activity**
Recreation & Tourism	Reduced base flows could result in a deterioration of water quality and associated impacts to aquatic life; Hydrological changes could affect available aquatic habitat for key recreational fishing species, eg Barramundi	Dam construction can impede the movement of recreational vehicles such as boats as well as indirect affects resulting from the above through loss of biodiversity (native flora and fauna), desirable habitat or aesthetic appeal	River considered by local indigenous communities to be crowded with too many boats (Jackson 2004). Erosion may be correctly or incorrectly attributed to frequency of boats for recreational fishing.	Weeds such as Ngurr Burr have displaced native grasses that previously formed an open and accessible area for Aboriginal communities to fish and socialise (Jackson 2004). Weeds such as *Mimosa pigra* can reduce access to recreational spots on the river and reduce abundance and/or diversity of native wildlife.	Indirect potential to decrease the value of the recreational experience through impacts on other information functions (as described – note also that impacts on Aboriginal cultural values (eg sacred site desecration) can impact on the tourism function – or the diversity of native fauna and flora	Pastoral activity may act as a source of inspiration for artists wishing to depict NT lifestyle, land uses or, alternatively, may detract from artistic potential of native landscapes
Spiritual	Potential effects on sacred billabongs which contain 'Dreaming' in the water (and which are normally filled by groundwater for the entire year) (Jackson 2004). Other wetlands (eg springs) on Aboriginal country considered sensitive to changes in groundwater levels (Jackson 2004). Fear that reduced water levels may dry-up billabongs and affect old camping and Dreaming places and other stories associated with the region's wetland areas.	See below	Erosion which breaks banks may destroy scared or significant sites (eg gravesites). Members of Aboriginal communities show feelings of anxiety, apprehension and being overwhelmed by possible environmental changes (eg shallowing of river and banks through erosion (not necessarily anthropogenic)) on how the way the river would be used (bought on, for example, by intensified agricultural development) and how this affects the future of the land (Jackson 2004).	Weeds may potentially limit access to or destroy sacred or significant sites of Aboriginal communities and other general anxiety related to the associated environmental changes and health of country	Possible anxiety in Aboriginal communities caused over environmental changes bought about by the existence of non-native and intrusive species; Can also be applied to non-Aboriginal people who are concerned about the impacts of such animals on once pristine areas which may offer memories from childhood or other experiences which offer a type of spiritual 'connection'	May impact on the overall way in which wetlands can offer a spiritual function to society; however, pastoral activity in itself offers certain sectors of society a spiritual value (eg pastoralists, community members of country communities and a proportion of tourists)

Wetland Functions	Management issues (potential threats to wetland functions)					
	Water extraction[a]	**Water impoundment**[b]	**Land clearing & agricultural intensification**[c]	**Weeds**	**Feral animals**	**Pastoral activity**
Cultural & Heritage	Can include all related changes in the river and the effects that has on the cultural values obtained from the river and wetlands. A strong cultural attachment is linked to the health of the Daly River by Aboriginal communities '…if the river changes our stories will be rubbish' (Joe Huddleston 2003 in Jackson 2004) and also non-Aboriginals where the 'mighty' Daly remains as a cultural icon and conforms to the 'frontier' landscapes prized by non-Aboriginal Territorians and inter-state travellers.	Regulation of rivers, especially impoundment for dams, is likely to damage the valued indigenous cultural principle: the unimpeded flow of a river body (Jackson 2004) and 'that the rivers must run free. Indigenous responsibilities and aspirations are embedded within a belief that the spiritual force of the river should never be blocked so that the increase of all species, including humans, is ensured'. (Water and Rivers Commission in the Kimberley (2003) in Jackson (2004))	Indigenous commitment to meeting land management and religious obligations as determined by traditional law and custom may be compromised by land-use changes. Loss of cultural stories if perceived changes in the river and surrounding areas - '…if the river changes our stories will be rubbish' (Joe Huddleston 2003 in Jackson 2004); Possible impact and destruction of sacred sites due to increased sedimentation; Possible threats of land clearing to 'family trees' (specific trees of significance to custodians based on habitat benefits, shade etc) as identified by Wagiman people in Jackson (2004).	Potential impact on both indigenous and non-indigenous cultural and heritage values through wetland loss. For Aboriginal communities on the Daly River, evidence suggests that weeds can restrict activities of cultural value, eg access to sacred or significant sites or access to wetlands areas supporting traditional harvest (see also Food).	Potential impacts or interference on culturally significant sites and wildlife in wetland areas – however, the feral animals themselves may not be negatively perceived by some Aboriginal people if they are a source of food (eg feral buffalo) or a connection exists with past memories and stories related to the country (eg feral horses).	May impact on the overall way in which wetlands can offer a cultural & historical function to society; however, pastoral activity in itself offers certain sectors of society a cultural value (eg pastoralists, community members of country communities, a proportion of tourists) and plays an integral role in preserving NT 'early settler' heritage
Science & Education	Changes in wetlands as described in the table will affect the ability of wetland areas to offer future educational value to both indigenous and non-indigenous Australians	Changes in wetlands as described in the table will affect the ability of wetland areas to offer future educational value to both indigenous and non-indigenous Australians	Has applicable elements to all information functions: Further subdivision of blocks for agriculture or changes in land use are likely to limit access of Aboriginal people to river and wetland areas with a feeling of being 'locked out of that country' (Jessie Brown in Jackson 2004). Access to river sites is important to local Aboriginal communities for purposes such as traditional burning & taking 'kids' out to teach them bush skills related to traditional 'tucker', medicines and telling them stories (Neville Brown in Jackson 2004).	Weeds infestation limits the access for Aboriginal people to take children to areas to teach them skills (eg fire management) and about country (Jackson 2004). Reduced biodiversity in areas of heavy weed infestations potentially limits opportunities for future scientific research and education on native flora and fauna.	Reduction in the number of native (prey) species particularly in relation to the introduction of the cane toad is likely to affect research, science and education activities on native fauna in the future	Limitations in access to areas of significance (eg through land-use changes, weed infestations) affects the ability for Aboriginal elders to teach children the stories associated with the wetlands of pastoral property. May enhance or decrease the function of wetlands to provide value to science and education.