Priorities for identification and sustainable management of high conservation value aquatic ecosystems in northern Australia

Edited by Mark J Kennard
(Australian Rivers Institute, Griffith University)

February 2011

TRaCK
Tropical Rivers and Coastal Knowledge

Australian Government
Department of Sustainability, Environment, Water, Population and Communities
National Water Commission

TRaCK brings together leading tropical river researchers and managers from Charles Darwin University, Griffith University, the University of Western Australia, CSIRO, James Cook University, the Australian National University, Geoscience Australia, the Environmental Research Institute of the Supervising Scientist, the Australian Institute of Marine Science, the North Australia Indigenous Land and Sea Management Alliance, and the Governments of Queensland, the Northern Territory and Western Australia. TRaCK receives major funding for its research through the Australian Government's Commonwealth Environment Research Facilities initiative; the Australian Government's Raising National Water Standards Program; Land and Water Australia; the Fisheries Research and Development Corporation and the Queensland Government's Smart State Innovation Fund.

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Front cover – *Melanotaenia australis* (western rainbowfish, upper Katherine River form) displaying breeding colours in an aquarium. Photo by Dave Wilson.

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Front cover – *Melanotaenia australis* (western rainbowfish, upper Katherine River form) displaying breeding colours in an aquarium. Photo by Dave Wilson.

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Acknowledgements

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Jennifer Hale, Manager, Lake Eyre Basin High Conservation Value Aquatic Ecosystems (HCVAE) Pilot Project (provided a shoulder to cry on)

Di Conrick, DSEWPaC (provided advice on the draft ANAE classification scheme and the draft HCVAE Framework)

Belinda Allison, DSEWPaC (provided advice on ERIN metadata requirements)

John Patten, NSW Department of Environment, Climate Changes and Water (provided editorial comments on draft report)

Richard Kingsford and John Porter (kindly provided waterbird data)

Jodie Smith, Bureau of Rural Sciences, Department of Agriculture, Fisheries and Forestry (provided access to the 2009 updates of the Catchment Scale Landuse mapping and Integrated Vegetation datasets)

The analysis and maps presented in this report incorporate data which is © Commonwealth of Australia, Geoscience Australia

The NVIS Major Vegetation Subgroups were compiled by ERIN, Department of Sustainability, Environment, Water, Populations and Communities based on NVIS data provided by State and Territory and Commonwealth organisations:

Environment ACT, Department of Urban Services.
NSW Department of Natural Resources, NSW Department of Environment and Conservation, NSW Royal Botanic Gardens
NT Department of Natural Resources, Environment, The Arts and Sport
QLD Herbarium, Environmental Protection Agency.
SA Department for Environment and Heritage.
TAS Department of Primary Industries, Water and Environment
VIC Department of Sustainability and Environment
WA Department of Agriculture
Geoscience Australia, National Mapping Division
Bureau of Rural Sciences
National Land and Water Resources Audit

Glossary

Aquatic ecosystem	are those that depend on flows, or periodic or sustained inundation/waterlogging for their ecological integrity (e.g. wetlands, rivers, karst and other groundwater dependent ecosystems, saltmarshes and estuaries) but do not generally include marine waters (Auricht 2010). For the purposes of this project, the definition excludes artificial waterbodies such as sewage treatment ponds, canals and impoundments.
Aquatic ecosystem dependent species	are those that depend on aquatic ecosystems for a significant portion or critical stage of their lives or are dependent on inundation for maintenance or regeneration
Attribute	mathematical or statistical indicator or characteristic calculated from the raw biodiversity surrogate data and used to 'score' or characterise the Framework Criteria (often referred to elsewhere as 'index' or 'metric')
Biodiversity	variation of life at all levels of biological organisation (molecular, genetic, species, and ecosystems) within a given area
Biodiversity surrogate	commonly used in conservation assessment and prioritisation to optimally represent multiple components of unmeasured biodiversity. Biodiversity surrogates include taxa (e.g. species), the characters they represent (e.g. phylogenetic relationships) assemblages or environmental classes. Environmental classes (ecotopes) are often used as biodiversity surrogates as different types of environments are assumed to support different combinations of species.
Complementarity	the gain in representation of biodiversity when an area is added to an existing set of areas
Ecotope	the smallest ecologically-distinct features in a landscape classification scheme (e.g. a 'type' of lacustrine hydrosystem). The draft Australian National Aquatic Ecosystem (ANAE) classification scheme (Auricht, 2010) now refers to ecotopes as 'habitats'.
Framework Criteria	narrative expressions that describe six core biophysical characteristics that have been agreed by the Aquatic Ecosystems Task Group as appropriate for the identification of HCVAEs (these include Diversity, Distinctiveness, Vital habitat, Evolutionary history, Naturalness and Representativeness). In this project each criterion was quantified ('scored') mathematically or statistically using attributes calculated from the raw biodiversity surrogate data.
HCVAE	High Conservation Value Aquatic Ecosystem
Hydrosystem	large 'organising entities' designed to represent the variety of aquatic ecosystem types (e.g. estuaries, rivers, lakes, palustrine wetlands). The draft Australian National Aquatic Ecosystem (ANAE) classification scheme (Auricht, 2010) now refers to hydrosystems as 'aquatic systems'.
Planning unit	the spatial unit (in this project a hydrologically-defined subcatchment) at which the attributes and criteria for identifying HCVAE were applied.
Systematic conservation planning	a structured, step-wise and iterative approach to identifying priority areas for conservation management actions to best represent and sustain the biodiversity of regions in the most cost-effective way (often used synonymously with spatial conservation prioritization, etc). Most modern systematic planning approaches are based on the *CARE* principles: comprehensiveness, adequacy, representativeness and efficiency. Efficiency is usually provided by a complementarity-based strategy.

Executive summary

Northern Australia boasts a range of significant aquatic ecosystems and ecosystem types, including estuaries, rivers, lakes and wetlands. These ecosystems not only provide clean water, food and recreation but have important intrinsic ecological and cultural values. These ecosystems also support high biodiversity, including many unique species of aquatic plants and animals.

To increase knowledge about these aquatic ecosystems, the Australian Government commissioned the *Northern Australia Aquatic Ecological Assets Project* as part of the *Northern Australia Water Futures Assessment (NAWFA).* The objective of the NAWFA is to provide an enduring knowledge base to inform the protection and development of northern Australia's water resources, so that any development proceeds in an ecologically, culturally and economically sustainable manner. This project, one of a number under the NAWFA, was tasked to identify key aquatic ecological assets (i.e. highly valued components of the environment) in northern Australia.

The Northern Australia Aquatic Ecological Assets Project was undertaken by the Tropical Rivers and Coastal Knowledge (TRaCK) Commonwealth Environmental Research Facility in collaboration with the Department of Sustainability, Environment, Water, Population and Communities (DSEWPaC) and the National Water Commission (NWC).

The project consisted of three phases:

1. Contributions to the Northern Australia Land and Water Science Review 2009

The project contributed to the Northern Australia Land and Water Science Review 2009 by determining the impact of development alternatives on northern Australia aquatic ecosystems and aquatic biodiversity. The outcomes of this assessment are available in Pusey & Kennard (2009) and synthesised here (Chapter 2).

2. Broad-scale assessment and prioritisation of aquatic ecological assets across northern Australia

This component of the project aimed to identify key aquatic ecological assets in northern Australia and trial the draft Framework developed by the Aquatic Ecosystem Task Group (AETG) to identify High Conservation Value Aquatic Ecosystems (HCVAEs[1]). This involved:

1. Identifying, mapping and evaluating aquatic ecosystem characteristics in northern Australia based on the draft Australian National Aquatic Ecosystem (ANAE) classification scheme (Auricht, 2010)
2. developing a method to apply and assess the draft HCVAE Framework that is based on the best available science and knowledge
3. defining key knowledge gaps and making recommendations for further work to refine the draft HCVAE Framework
4. utilising a mixture of GIS analysis, systematic conservation planning methods, coupled with expert system approaches to further rank and validate the ecological value of assets, and to provide a comparison of these results against those derived from the HCVAE Framework.

Chapter 3 synthesises the outcomes of the broad-scale assessment and prioritisation of aquatic ecological assets across northern Australia (reported in full in Kennard 2010). This includes an evaluation of the HCVAE Framework and an application of alternative approaches to identifying high conservation value aquatic ecosystems. Geodatabases containing aquatic ecosystem mapping, classifications and all HCVAE

[1] At their meeting in October 2010, the AETG agreed to change the name of the "High Conservation Value Aquatic Ecosystem" Framework to the "High Ecological Value Aquatic Ecosystem" (HEVAE) Framework.

attributes, together with metadata and attribute tables are held by the Australian Government (DSEWPaC) and are synthesised in Appendices 8.1 – 8.2.

3. Fine-scale assessment and prioritisation of regional aquatic ecosystem assets

In collaboration with the State and Territory jurisdictions and DSEWPaC, the project team held a series of regional expert panel workshops. The purpose of these workshops was to identify Natural Heritage Values of wetlands in northern Australia and undertake fine scale assessments for key focal regions (or specific catchments) identified by jurisdictions as high priority or planned development areas. The fine scale assessment had a number of key aims including to identify high priority aquatic ecological assets and understand ecological thresholds in relation to flow regimes and maintenance of aquatic ecosystem assets.

In undertaking the fine scale assessments, the following approach was applied:

- For the Gulf of Carpentaria Drainage Division, work cooperatively with the Queensland Government Department of Environment and Resource Management (DERM) to utilise AquaBAMM and Queensland Wetland Mapping to identify and assess HCV assets and ecological thresholds in focal Gulf catchments.
- For the NT Arafura Sea portion of the Timor Sea Drainage Division, work cooperatively with NT Government Department of Natural Resources, Environment, The Arts and Sport (NRETAS) to identify and assess HCV assets in the Daly River catchment and possibly other high conservation value areas (i.e. contributing to ongoing work with the "Sites of Conservation Significance" project).
- For the Kimberley portion of the Timor Sea Drainage Division, work cooperatively National Heritage Assessment section of DSEWPaC (e.g. using the Australian Natural Heritage Assessment Tool – ANHAT) as well as the Western Australian Government Department of Environment and Conservation (e.g. through the Kimberley Science and Conservation Strategy).

A summary of the outcomes of these fine scale assessments and workshops is presented in Chapter 4 and full reports are presented in Appendices 8.3 – 8.6 and Rollason & Howell (2010).

In Chapter 5 we canvas some key challenges for sustainable management of aquatic ecosystems in northern Australia. In particular, we evaluate the concept of ecological thresholds and how useful it is for informing environmental management to sustain ecosystem values. Managers of high conservation value areas must achieve a balance between taking conservation action, evaluating the effectiveness of actions taken, and monitoring the general status of biodiversity conservation targets and the threats they face. We review approaches to estimating socioeconomic costs of different management actions and how these can be prioritised in a systematic and hierarchical framework (the concept of multiple management zones). Monitoring is a key component of adaptive management and can inform the decisions of management agencies. Unfortunately however, monitoring practices have generally been poorly connected with decision-making and this has led to an inability to assess the effectiveness or efficiency of the conservation management actions. We therefore present several frameworks to guide if, why, when and how monitoring should be implemented and how the outcomes of the monitoring will feed into adaptive management of aquatic ecological assets in northern Australia. Finally, in Chapter 6 we identify and synthesise key knowledge gaps and next steps.

TRaCK Tropical Rivers and Coastal Knowledge

PRIORITIES FOR IDENTIFICATION AND SUSTAINABLE MANAGEMENT OF HIGH CONSERVATION VALUE AQUATIC ECOSYSTEMS IN NORTHERN AUSTRALIA

TABLE OF CONTENTS

1. General Introduction

Mark Kennard

1.1 Background to the project

Northern Australia boasts a range of significant aquatic ecosystems and ecosystem types, including estuaries, rivers, lakes and wetlands. These ecosystems not only provide clean water, food and recreation but have important intrinsic ecological and cultural values. These ecosystems also support high biodiversity, including many unique species of aquatic plants and animals.

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The project consisted of three phases:

1. Contributions to the Northern Australia Land and Water Science Review 2009

The project contributed to the Northern Australia Land and Water Science Review 2009 by determining the impact of development alternatives on northern Australia aquatic ecosystems and aquatic biodiversity. The full review is available at: www.nalwt.gov.au/science_review.aspx and the chapter on aquatic ecosystems (contributed as part of this project) is presented in Pusey & Kennard (2009).

2. Broad-scale assessment and prioritisation of aquatic ecological assets across northern Australia

This component of the project aimed to identify key aquatic ecological assets in northern Australia and trial the draft Framework developed by the Aquatic Ecosystem Task Group (AETG) to identify High Conservation Value Aquatic Ecosystems (HCVAEs[2]). This involved:

1. Identifying, mapping and evaluating aquatic ecosystem characteristics in northern Australia based on the draft Australian National Aquatic Ecosystem (ANAE) classification scheme (Auricht, 2010)

[2] At their meeting in October 2010, the AETG agreed to change the name of the "High Conservation Value Aquatic Ecosystem" Framework to the "High Ecological Value Aquatic Ecosystem" (HEVAE) Framework.

2. developing a method to apply and assess the draft HCVAE Framework that is based on the best available science and knowledge
3. defining key knowledge gaps and making recommendations for further work to refine the draft HCVAE Framework

The broad-scale assessment interim report (Kennard 2010) is available from the NAWFA Ecological Program website: http://www.environment.gov.au/water/publications/policy-programs/nawfa-hcvae-trial-report.html.

3. <u>Fine-scale assessment and prioritisation of regional aquatic ecosystem assets</u>

In collaboration with the State and Territory jurisdictions and DSEWPaC, the project team held a series of regional expert panel workshops. The purpose of these workshops was to identify Natural Heritage Values of wetlands in northern Australia and undertake fine scale assessments for key focal regions (or specific catchments) identified by jurisdictions as high priority or planned development areas. The fine scale assessment had a number of key aims including to identify high priority aquatic ecological assets and understand ecological thresholds in relation to flow regimes and maintenance of aquatic ecosystem assets.

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The outcomes of these regional expert panel workshops and fine-scale assessments are presented in Appendices 8.3 – 8.6.

1.2 Structure of this report

The following chapters of this report synthesise the key findings from each stage of the project. Chapter 2 summarises the key risks and threats to aquatic ecosystems in northern Australia as identified in the Northern Australia Land and Water Science Review 2009. Chapter 3 synthesises the outcomes of the broad-scale assessment and prioritisation of aquatic ecological assets across northern Australia. This includes an evaluation of the HCVAE Framework and an application of alternative approaches to identifying high conservation value aquatic ecosystems. In Chapter 4, the outcomes of the fine-sale assessment workshops are summarised. In Chapter 5, we canvas some key challenges for sustainable management of aquatic ecosystems in northern Australia. In particular, we evaluate the concept of ecological thresholds and how useful it is for informing environmental management to sustain ecosystem values. Managers of high conservation value areas must achieve a balance between taking conservation action, evaluating the effectiveness of actions taken, and monitoring the general status of biodiversity conservation targets and the threats they face. We review approaches to estimating socioeconomic costs of different management actions and how these can be prioritised in a systematic and hierarchical framework (the concept of multiple management zones). Monitoring is a key component of adaptive management and can inform the decisions of management agencies. Unfortunately however, monitoring practices have generally been poorly connected with decision-making and this has led to an inability to assess the effectiveness or efficiency of the conservation management actions. We therefore present several frameworks to guide if, why, when and how monitoring should be implemented and how the outcomes of the monitoring will feed into adaptive management of aquatic ecological assets. Finally, in Chapter 6 we identify and synthesise key knowledge gaps and next steps.

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2. Risks and threats to aquatic ecosystems in northern Australia

Mark Kennard, Brad Pusey & Laura Jardine

2.1 What are the major threats and mechanisms of impacts?

The key aquatic ecosystem values and their vulnerability/ resilience to risks/threats, from hydrological disturbance, climate change, water resource development or other factors were reviewed in the chapter on aquatic ecosystems as part of the Northern Australia Land and Water Science Review 2009 (Pusey & Kennard 2009). Key findings are briefly summarised below.

The aquatic systems that support the distinctive and diverse biodiversity of northern Australia are in relatively good ecological condition because of the region's low population density and limited land and water use (NLWRA 2002; Woinarski et al. 2007; Pusey & Kennard 2009). None-the-less, there are a range of existing and potential threats that impinge on the natural values of these ecosystems and may reduce their future capacity to sustain aquatic biodiversity (van Dam et al. 2008; Pusey & Kennard 2009; Warfe 2010).

The key threats to aquatic ecosystems in northern Australia include:

- overgrazing by cattle, increasing runoff, erosion and stream bank degradation
- invading feral animals (pigs, buffaloes and cane toads) and weeds
- discharging nutrients from agricultural fertilisers or sewerage effluent causing algal blooms
- contaminating agricultural pesticides and herbicides
- increasing sediments and pollutants from mining and extraction industries
- extracting groundwater for irrigation and domestic/urban use
- increasing construction of physical infrastructure (dams, weirs, barrages, road crossings) changing natural flows, causing barriers to the movement of animals and increasing problems with weeds
- over-fishing and tourism activities

In addition to the threatening processes identified above, climate change is an added threat and is predicted to result in fewer lowland freshwater habitats as saltwater moves inland due to rising sea levels and increased storms. Water temperatures are predicted to rise, and the variability and severity of floods and droughts are predicted to increase. As a result, many more rivers may stop flowing through the dry season. These changes will directly affect aquatic biodiversity. In particular, fish are vulnerable to changes in water temperature and break up of their habitat. Overall, the species found in various aquatic habitats are likely to change as those that can tolerate saltwater expand their range, freshwater-dependent species become extinct and introduced species that can tolerate human disturbances invade.

Critical knowledge gaps exist concerning the key environmental drivers of aquatic ecosystems. Improved knowledge will allow scientists and managers to predict with greater certainty the responses of aquatic ecosystem to future environmental changes associated with water use, land use and climate change.

2.2 Multiple stressors and cumulative impacts

Many environmental problems are not caused by single large perturbations (the smoking gun scenario). Rather they are the result of many, often unrelated, impacts that combine to cause major changes (the “death from a thousand cuts” syndrome). Different kinds of disturbances may combine to yield more deleterious effects that are more serious and qualitatively different from the effects caused by any one of them (Orians & Soule 2001).

In reality, in all ecological systems the stresses which impact upon these critical forms of diversity, are numerous and resulting consequences are difficult to predict (Bunn et al. 2010). It is widely reported that the majority of ecological studies to date have examined singular pressures upon ecosystems (Omerod et al. 2010). Meanwhile managers and scientists alike are aware that singular human pressures (i.e., urban development, agricultural development) typically alter more than one ecosystem function, and that the effects are likely to be complicated by global phenomenon, like climate change (Ormerod at al. 2010). Science and managers are now pushing to understand the cumulative impacts of multiple stressors on ecosystem processes and assemblages, and the spatial and temporal scales over which effects arise, in light of the resilience of ecosystems.

Due to the range of ecosystem goods and services offered by river-floodplain ecosystems, these areas tend to be prone to human exploitation and therefore, tend also to be heavily impacted by anthropogenic pressures (i.e., agricultural development, urban development, cultural and tourism use, etc.). However, it is difficult to disentangle the influence of anthropogenic influences and natural processes (which can also act as stressors depending on the environmental context) on freshwater systems, as anthropogenic inputs may influence and interfere with natural processes, and the combination response can be antagonistic, synergistic and/or additive (Tockner et al. 2010).

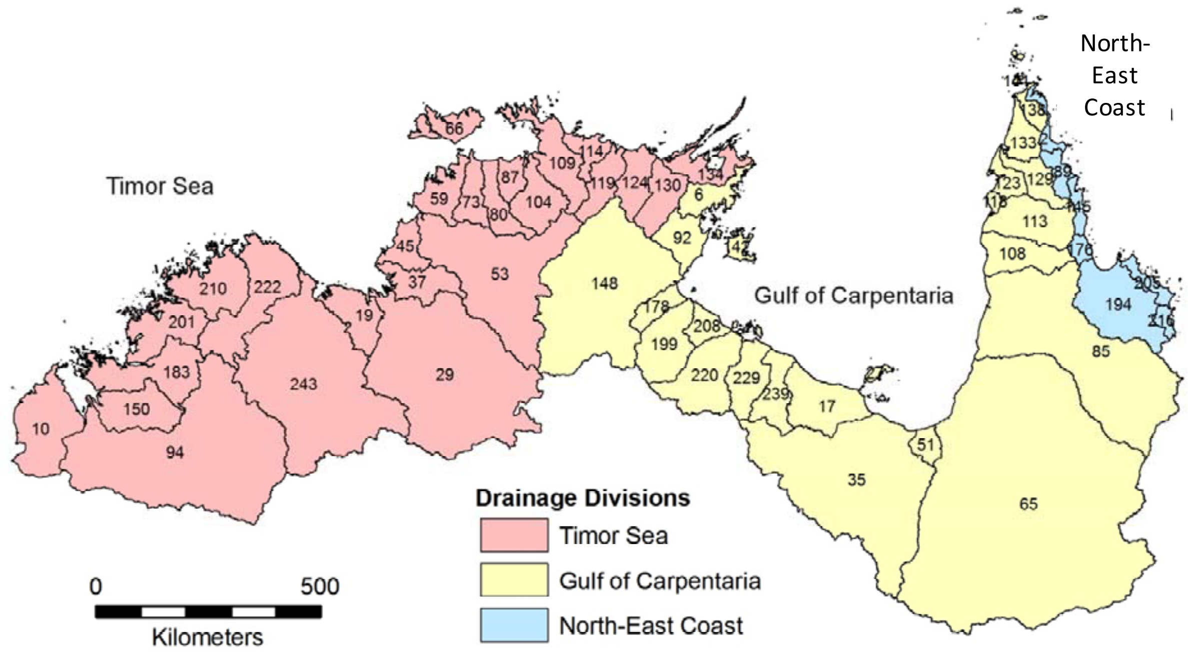
There are clear knowledge gaps in our understanding of how multiple stressors impact upon the resilience and overall functioning of aquatic systems in northern Australia, which makes it difficult for science to advise managers and stakeholders of aquatic ecological assets. Bunn et al. (2010) identify that the optimal spatial configuration of development, protection and restoration to minimize impacts on water resources and maintain essential ecosystem function remains largely unknown. There is also a lack of detailed knowledge on the spatial distribution of risks and threats to ecological assets in northern Australian rivers, as identified in Bayliss et al. (2008), Bartolo et al. (2008) and van Dam et al. (2008). Much of our current knowledge base regarding risks and threats to ecological assets in northern tropical rivers relies heavily on modelling (Pusey & Kennard 2009) in which sources of uncertainty include a lack of knowledge, investigator or modeller bias, misrepresentation of pathways and oversimplification (Bartolo et al. 2008). In addition, there are large parts of northern Australia for which no monitoring data exists, making it difficult to apply knowledge across the wider area (Wharfe 2010). There needs to be a stronger push to run well-thought scientific studies on the ground in northern Australia, which make definitive statements about cause-and-effect relationships and encompass multiple stressors (e.g. Fausch et al. 2010), while continuing to expand on current monitoring which helps to document decline over time (Downes 2010; Nichols & Williams 2006).

3. Broad-scale identification of aquatic ecological assets and assessment of conservation values across northern Australia

Mark Kennard, Doug Ward, Janet Stein, Brad Pusey, Virgilio Hermoso & Simon Linke

3.1 Identifying and mapping aquatic ecosystem assets across northern Australia

Aquatic ecological assets (based on hydrosystems and freshwater species biodiversity data) were identified and mapped for river basins within each drainage division. These included the Timor Sea, Gulf of Carpentaria and northern part of the North-East Coast) and regions across northern Australia used in the Northern Australia Sustainable Yields (NASY) study (Figure 3.1).



ID	Basin Name	ID	Basin Name	ID	Basin Name
2	JACKY JACKY CREEK	89	OLIVE-PASCOE RIVERS	145	LOCKHART RIVER
6	KOOLATONG RIVER	92	WALKER RIVER	148	ROPER RIVER
10	CAPE LEVEQUE COAST	94	FITZROY RIVER	150	LENNARD RIVER
17	SETTLEMENT CREEK	104	SOUTH ALLIGATOR RIVER	176	STEWART RIVER
19	KEEP RIVER	108	HOLROYD RIVER	178	TOWNS RIVER
27	MORNINGTON ISLAND	109	EAST ALLIGATOR RIVER	183	ISDELL RIVER
29	VICTORIA RIVER-WISO	113	ARCHER-WATSON RIVERS	194	NORMANBY RIVER
35	NICHOLSON-LEICHHARDT RIVERS	114	GOOMADEER RIVER	199	LIMMEN BIGHT RIVER
37	FITZMAURICE RIVER	118	WARD RIVER	201	PRINCE REGENT RIVER
45	MOYLE RIVER	119	LIVERPOOL RIVER	205	JEANNIE RIVER
51	MORNING INLET	123	EMBLEY RIVER	208	ROSIE RIVER
53	DALY RIVER	124	BLYTH RIVER	210	KING EDWARD RIVER
59	FINNISS RIVER	129	WENLOCK RIVER	216	ENDEAVOUR RIVER
65	FLINDERS-NORMAN RIVERS	130	GOYDER RIVER	220	McARTHUR RIVER
66	BATHURST AND MELVILLE ISL.	133	DUCIE RIVER	222	DRYSDALE RIVER
73	ADELAIDE RIVER	134	BUCKINGHAM RIVER	229	ROBINSON RIVER
80	MARY RIVER	138	JARDINE RIVER	239	CALVERT RIVER
85	MITCHELL-COLEMAN RIVERS	141	TORRES STRAIT ISL.	243	ORD-PENTECOST RIVERS
87	WILDMAN RIVER	142	GROOTE EYLANDT		

Figure 3.1. Geographic scope of the study area in northern Australia showing river basins (National Catchment Boundaries - NCB) and Drainage Divisions.

3.1.1 Hydrosystems

A spatially explicit, consistent and comparable aquatic system delineation and ecotope classification of aquatic assets was developed for northern Australia (within the Timor Sea, Gulf of Carpentaria and northern part of the North-East Coast Drainage Divisions) based on the draft Australian National Aquatic Ecosystem (ANAE) Classification Scheme. Using the a combination of the GeoScience Australia Geodata 250k Hydrography theme feature classes and the OzCoasts Geomorphic Habitat Mapping (Version 2), the ANAE classification scheme (Auricht 2010) was applied to delineate Lacustrine, Palustrine and Estuarine aquatic systems in northern Australia. Riverine hydrosystems were separately delineated based on the stream network derived from the national 9 second DEM for the Australian Hydrological Geospatial Fabric. Further application of the ANAE scheme involved the attribution of hydrosystems with ecologically relevant environmental data and statistical classifications to delineate hydrosystem ecotopes. Riverine, Lacustrine, and Palustrine hydrosystems and ecotopes were successfully delineated and classified for northern Australia, including the incorporation of perenniality and inundation frequency attributes.

The results of the delineation and classification process provide base level mapped aquatic assets for northern Australia at a scale of 1:250,000. This information provided a rich source of ecohydrological and biodiversity surrogate information for northern Australia and the necessary context for the delineation of HCVAEs of the region. Full details are provided in Chapter 4 of Kennard (2010) and example maps are given in Figures 3.2 – 3.6. Geodatabases containing this information together with metadata and attribute tables are held by the Australian Government (DSEWPaC) – see Appendix 8.1.

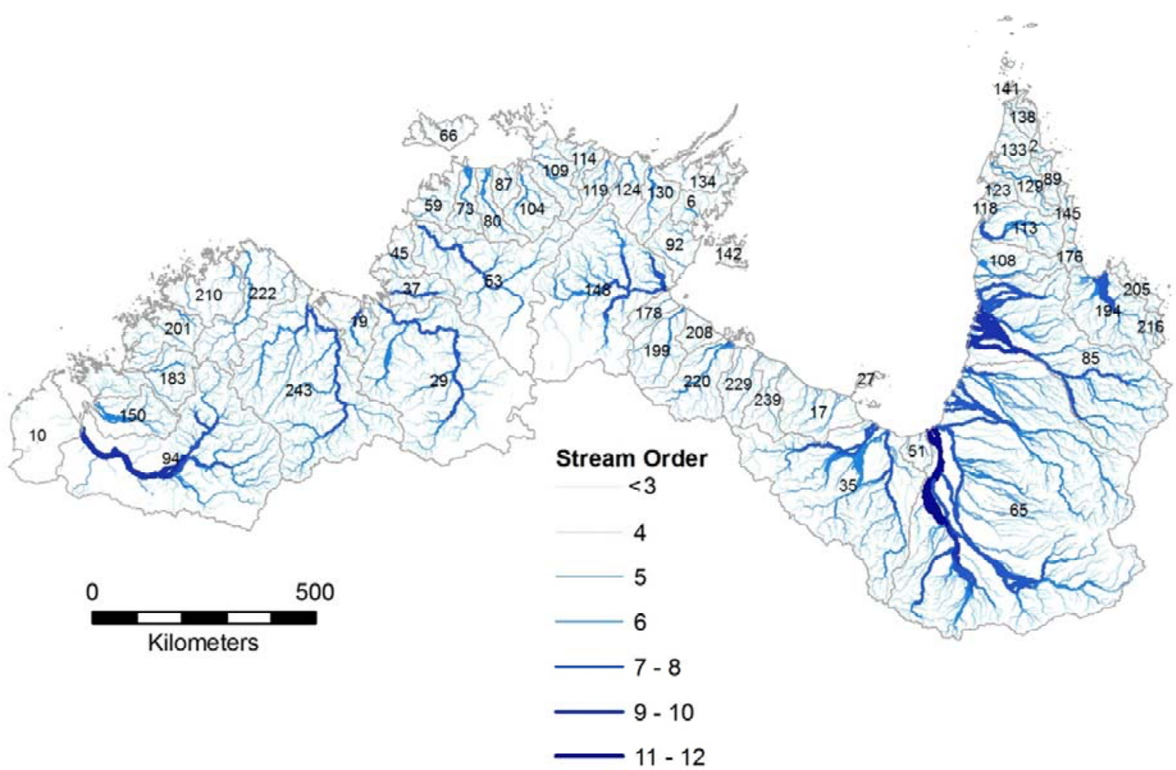


Figure 3.2. Distribution of riverine aquatic systems of northern Australia showing Strahler stream order. Strahler stream order is used to define stream size based on a hierarchy of tributaries such that high order streams represent the main channels of river systems and low order streams represent the upper most part to the drainage network.

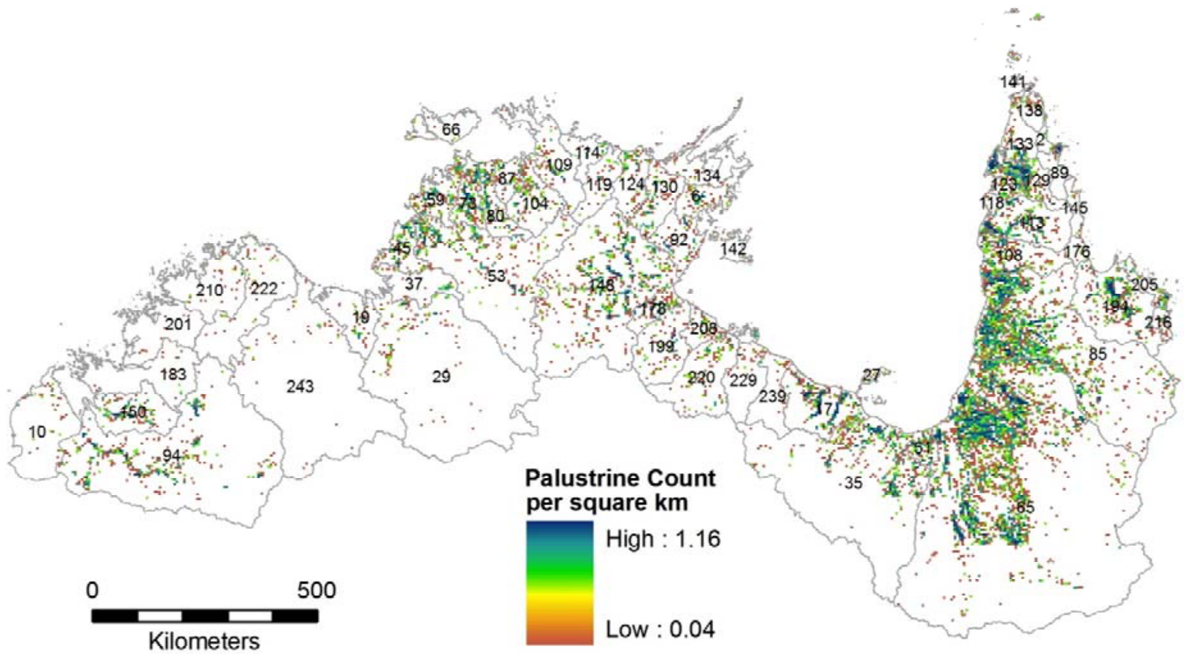


Figure 3.3. The number of palustrine aquatic systems per km^2 across northern Australia.

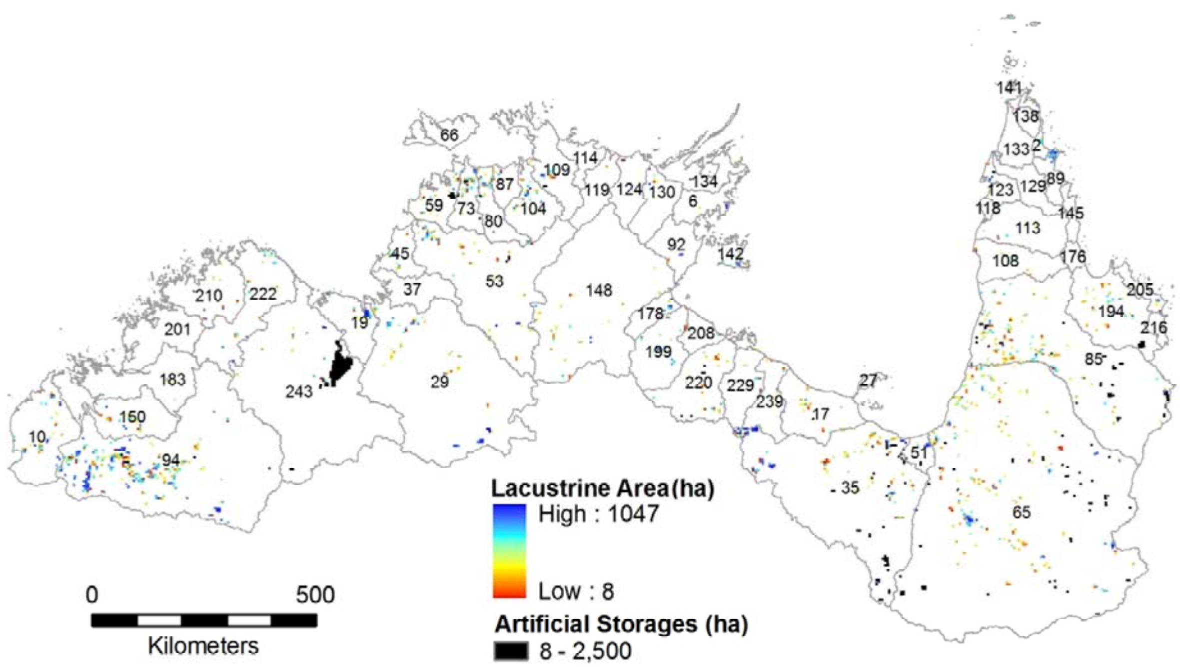


Figure 3.4. The area in hectares of lacustrine aquatic systems in 5 km^2 grids across northern Australia

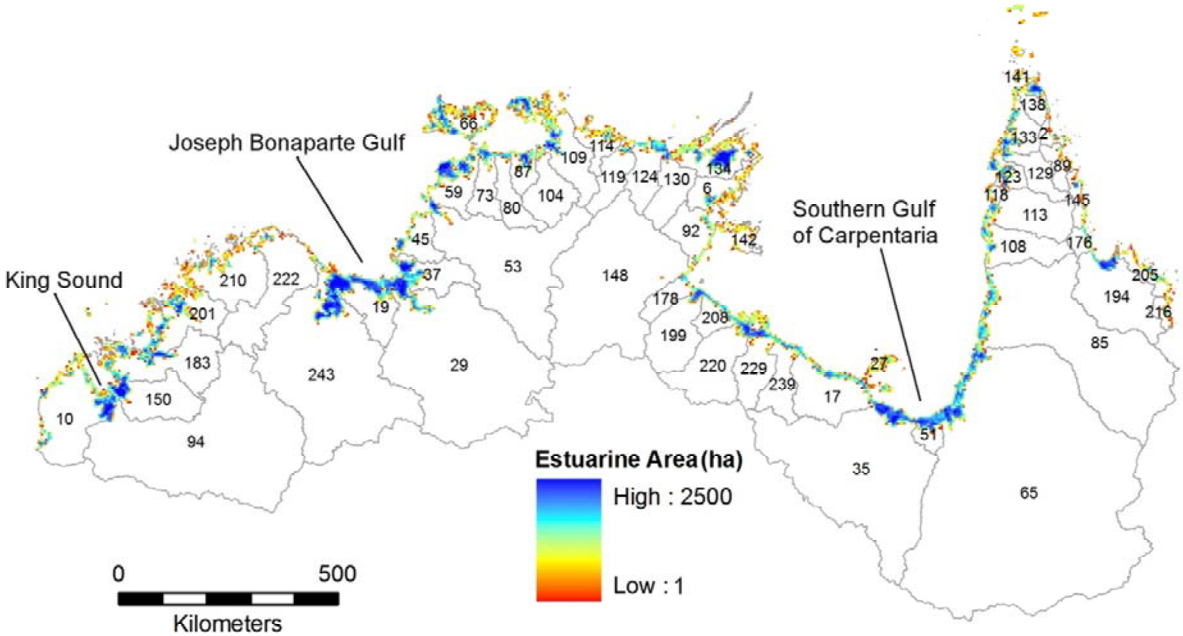


Figure 3.5. The area in hectares of estuarine aquatic systems in 5 km^2 grids across northern Australia.

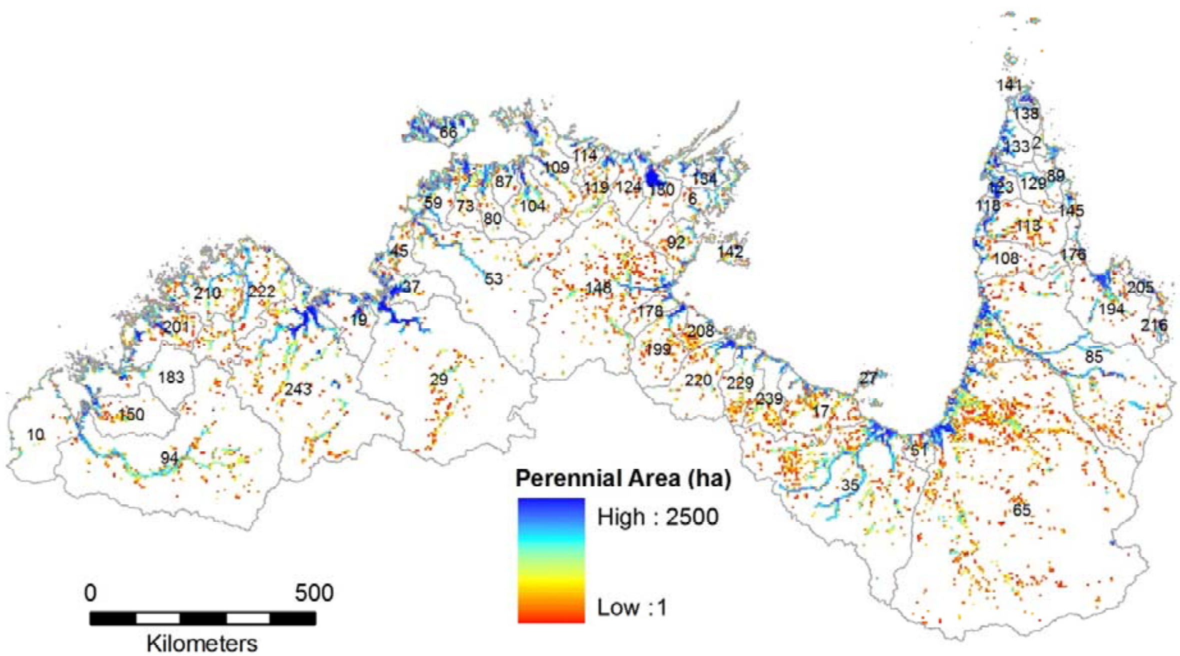


Figure 3.6. The area in hectares of perennial aquatic systems in 5 km^2 grids across northern Australia.

3.1.2 Freshwater species

We also assembled a comprehensive database with spatially explicit information on species occurrences for a range of freshwater-dependent taxonomic groups (macroinvertebrates, freshwater fish, turtles and waterbirds). This data encompassed the Timor Sea and Gulf of Carpentaria Drainage Divisions (Figure 3.7).

These species records were used to develop biodiversity surrogates for the conservation assessments (see Chapter 5 of Kennard (2010) for full details). Substantial spatial biases were found to exist in the availability of species distribution records. The use of such patchy data to derive biodiversity attributes can have potentially major implications for accurate and objective identification and prioritization of high conservation value areas. To address this problem, we developed predictive models of the distributions of macroinvertebrates, freshwater fish, turtles and waterbirds (see Chapter 7 of Kennard (2010) for full details). These predictive models were successfully calibrated and considered appropriate for making predictions of species distributions in unsurveyed areas (see Figure 3.8 for examples of these species predictions). Using predictive modelling and hydrosystem classifications, we were able to generate spatially explicit biodiversity surrogate datasets. This information was attributed to 5,803 hydrologically-defined planning units (sub-catchments) and used to assess their relative conservation values for the Timor Sea and Gulf of Carpentaria Drainage Divisions (Fig 3.9).

Limited species occurrence records for the northern part of the North-East Coast Drainage Division meant that reliable species distribution data could only be assembled freshwater fish and turtles at the river basin scale (rather than for individual sampling localities) (Fig 3.9). Conservation values for river basins in the northern part of the North-East Coast Drainage Division were therefore based on basin-scale fish and turtle biodiversity data and evaluated relative to the remainder of the study region (Timor Sea and Gulf of Carpentaria Drainage Divisions) (see Section 3.2 below).

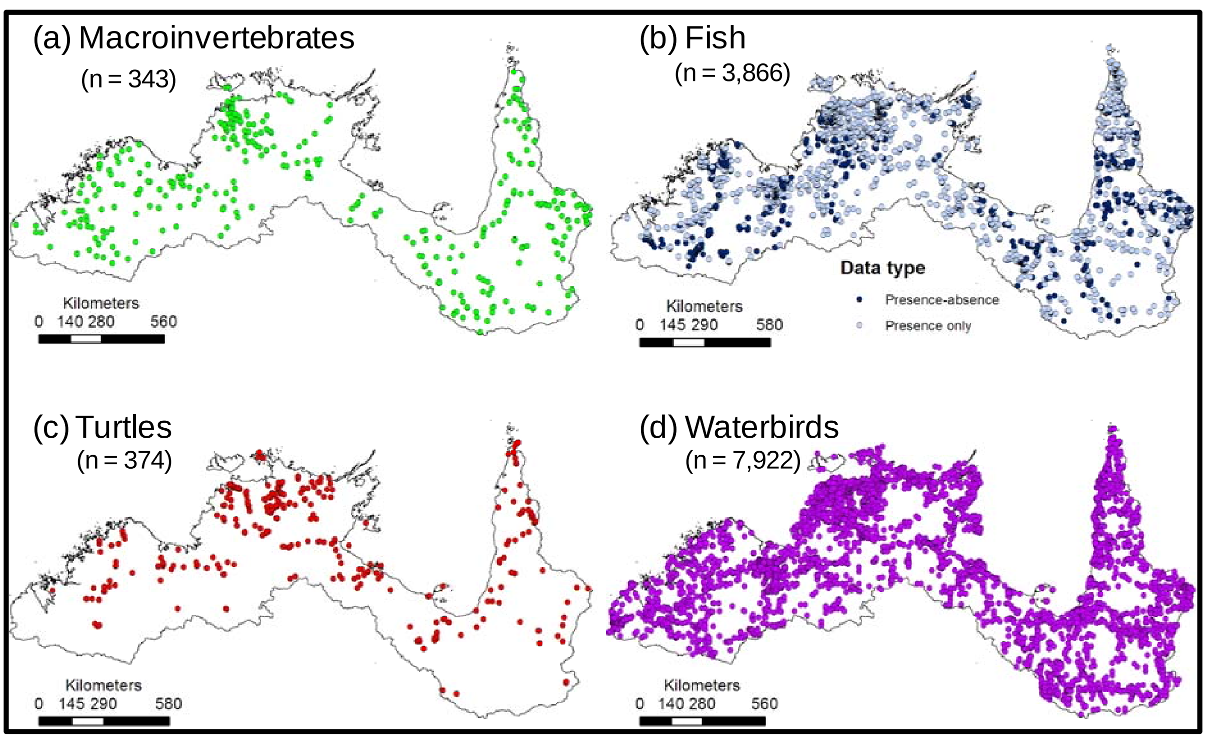


Figure 3.7. Sampling locations for (a) macroinvertebrates, (b) fish, (c) turtles and (d) waterbirds. The total number of unique sampling locations is given in parentheses. All points represent presence-only data, with the exception of fish where both presence-only and presence-absence data are shown.

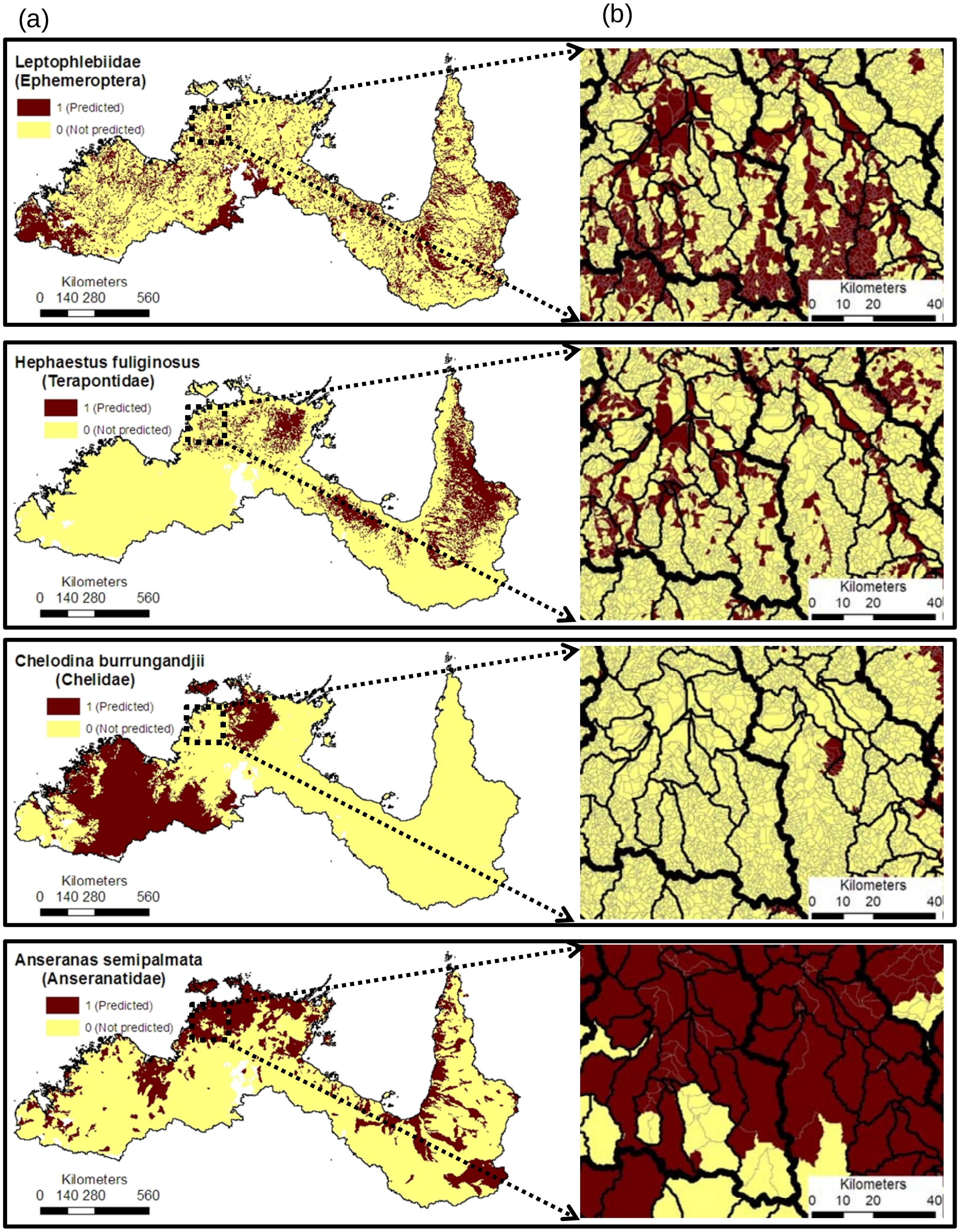


Figure 3.8. Examples of predicted distributions of selected taxa for each faunal group. Predictions are shown for (a) the entire study region and (b) the upper Mary River and South Alligator River, Northern Territory. Also shown in (b) are the spatial units used for predictive modelling of species distributions (grey polygons), the planning units used for conservation assessment (black polygons) and river basins boundaries (thick black lines).

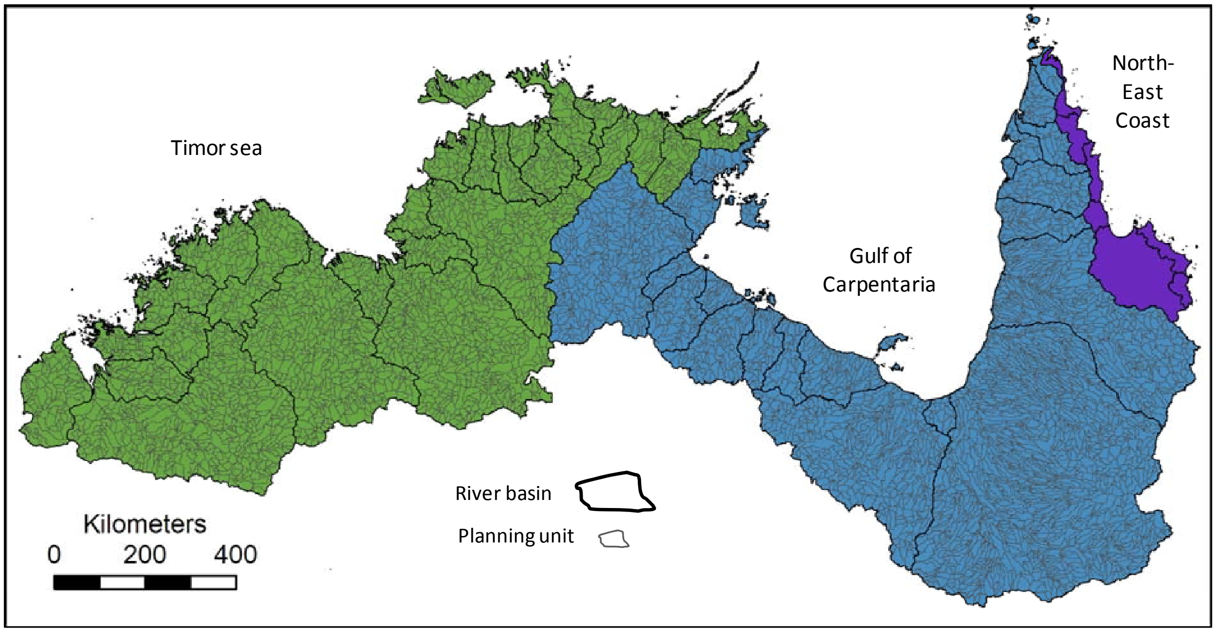


Figure 3.9. Planning Units (small grey polygons) used to assess relative conservation values for the Timor Sea and Gulf of Carpentaria Drainage Divisions. Relative conservation values for the North-East Coast Drainage Divisions were assessed at the river basin scale only.

3.2 Identifying high conservation value areas in northern Australia based on freshwater biodiversity attributes

A common approach to identifying and prioritising high conservation value areas is to compare spatial patterns in biodiversity attributes such as species richness and endemism for particular groups of animals or plants. The datasets assembled in this project facilitate this type of approach and examples are given below for freshwater fish and turtles at the river basin and sub-basin (planning unit) scales.

At the basin scale, rivers of northern Australia contain an average of 35.7 ± 1.3 (SE) fish species, although there is substantial variation between basins (Fig. 3.10a). A substantial proportion, about one quarter, of this variation in fish biodiversity is related to basin size; larger basins contain many species and smaller basins contain fewer (Fig. 3.11). Basins with high richness (>48 spp.) include the Daly, South Alligator and East Alligator rivers of the Northern Territory and the Jardine, Wenlock and Mitchell rivers of western Cape York Peninsula. Notably, although the Daly and Mitchell rivers are among the largest basins in the regions, high species richness is not restricted to the largest basins. For example, the Jardine River is the eighth smallest basin within the region, yet contains the equal highest number of species (51, shared with the South Alligator River). Similarly, the Wenlock and the East and South Alligator Rivers are not large but contain very rich fish faunas. The Endeavour and Olive-Pascoe rivers in the North-East Coast Drainage Division also have a comparatively high number of fish species for their size (Fig. 3.11). Northern Australian river basins with the highest fish species endemism (Fig. 3.10a) included the Fitzroy River, several smaller basins in northern Kimberley region, and the Jeannie and endeavour rivers in the North-East Coast Drainage Division. At the sub-basin (planning unit) scale (Fig. 3.10b), areas with highest fish species richness included lowland rivers in the Ord, Victoria and Daly river basins, lowland rivers of the northern Top End and in rivers of western Cape York Peninsula. Endemism at this spatial scale was highest for rivers in the northern Kimberley, the uplands of the Arnhem Land Escarpment and the tip of Cape York Peninsula.

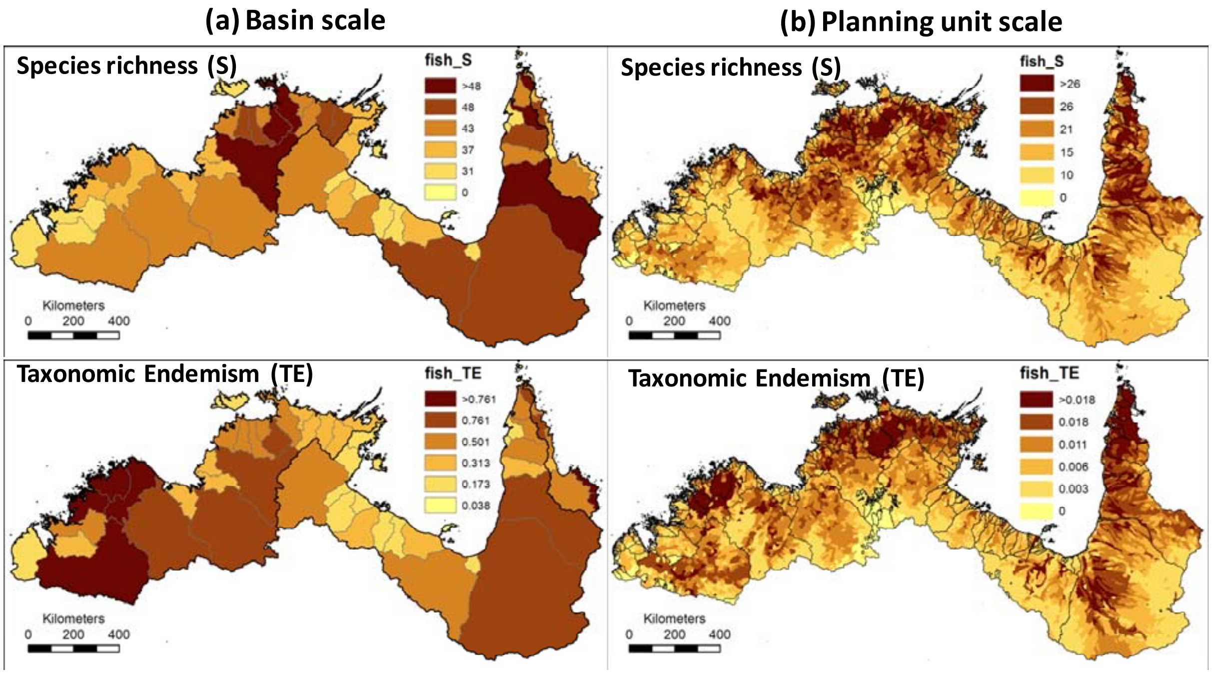


Figure 3.10. Spatial variation in fish species richness and endemism across northern Australia at two spatial scales: (a) entire river basins and (b) sub-basins (planning units).

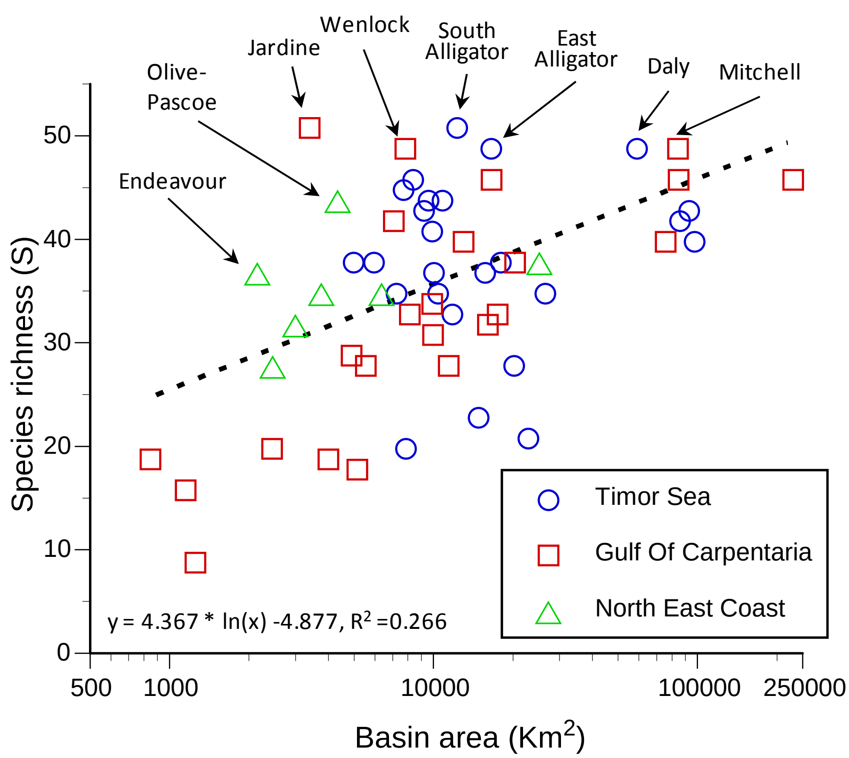


Figure 3.11. Fish species richness versus basin area (Km^2) for river basins of northern Australia.

Spatial patterns in freshwater turtle species richness and endemism is displayed in Figure 3.12. The Daly and South Alligator River basins each contain the highest number of turtle species (eight) in northern Australia. Turtle endemism was also highest in these river basins, together with the Victoria, Nicholson-Leichardt, Jardine and Jacky Jacky Creek basins (Fig 3.12a). These patterns were similar when turtle endemism was mapped at the sub-basin (planning unit) scale (Fig. 3.12b).

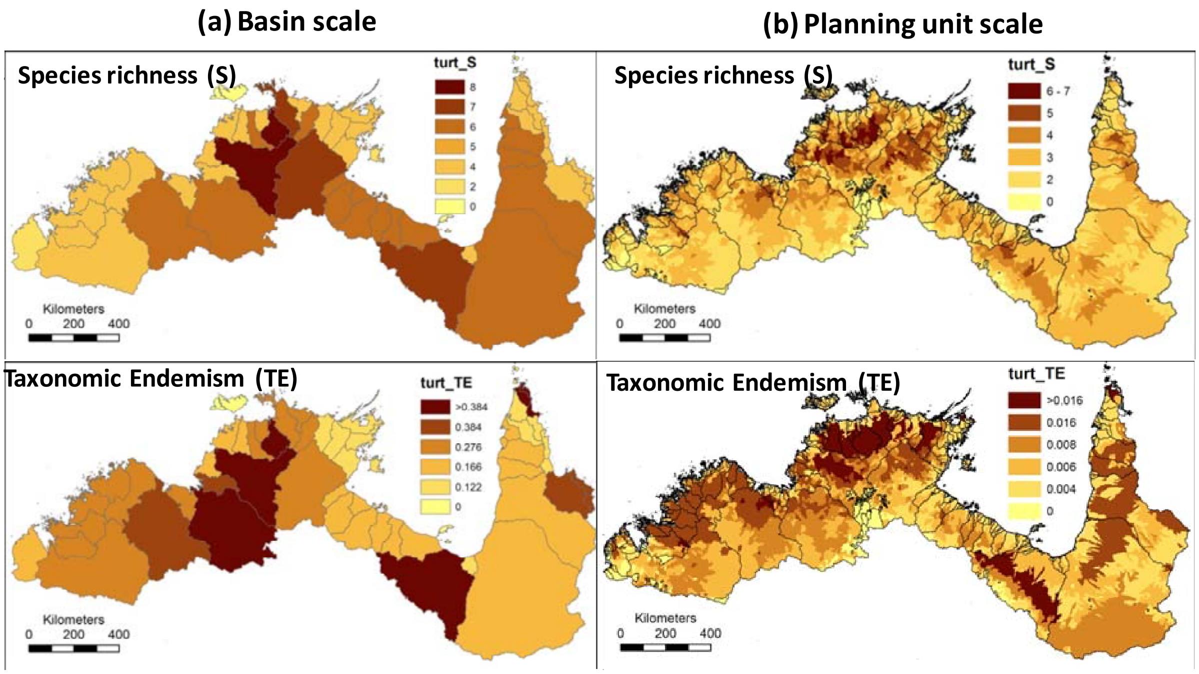


Figure 3.12. Spatial variation in turtle species richness and endemism across northern Australia at two spatial scales: (a) entire river basins and (b) sub-basins (planning units).

3.3 Identifying key aquatic assets against the draft HCVAE Framework Criteria

3.3.1 Background to HCVAE framework

The National Water Initiative (NWI), an agreement between the Australian Government and all the States and Territories, is a comprehensive strategy to improve water management across the country. The NWI states that there is a '*national imperative to ensure the health of river and groundwater systems'*. All States and Territories need to '*identify and acknowledge surface and groundwater systems of high conservation value, and manage these systems to protect and enhance those values*' (clause 25x). To meet these needs a systematic approach to the identification and management of High Conservation Value Aquatic Ecosystems or HCVAE is required (e.g. Georges & Cottingham 2002; Saunders et al. 2002; Kingsford et al. 2005; Fitzsimons & Robertson 2005). This approach should clearly appreciate the inherent differences between terrestrial and aquatic ecosystems and the respective methods available for defining and measuring conservation value (Dunn 2003; 2004). To this end, the Aquatic Ecosystem Task Group (AETG) was formed to develop a framework to identify and classify High Conservation Value Aquatic Ecosystems (HCVAEs).

The draft HCVAE Framework is designed to have multiple uses. The Framework will be used to:

1. establish a core set of criteria for identifying aquatic ecosystems of high conservation value
2. improve knowledge of the extent, distribution and characteristics of HCVAE
3. differentiate between HCVAEs of national and regional importance;
4. improve information sharing between NRM bodies, governments and other stakeholders
5. improve cross-jurisdictional coordination and cooperation
6. assist meeting national and international obligations for protection of aquatic ecosystems
7. guide Australian Government investment decisions

Several trials have been undertaken to test the applicability of the criteria to different ecosystem types. The full draft Framework has recently been applied and evaluated in the Lake Eyre Basin (Hale 2010) and northern Australia (this study).

Six core biophysical criteria have been agreed as appropriate for the identification of nationally significant HCVAEs, and draft guidelines have been developed for their implementation (refer to Kennard 2010 for more details).

As outlined in the draft Framework, the criteria for identifying High Conservation Value Aquatic Ecosystems are as follows:

1. Diversity – It exhibits exceptional diversity of species or habitats, and/or hydrological and/or geomorphological features/processes.
2. Distinctiveness – It is a rare/threatened or unusual aquatic ecosystem; and/or it supports rare/threatened species/communities; and/or it exhibits rare or unusual geomorphological features/ processes and/or environmental conditions.
3. Vital habitat – It provides habitat for unusually large numbers of a particular species of interest; and/or it supports species of interest in critical life cycle stages or at times of stress; and/or it supports specific communities and species assemblages.
4. Evolutionary history – It exhibits features or processes and/or supports species or communities which demonstrate the evolution of Australia's landscape or biota.
5. Naturalness – The aquatic ecosystem values are not adversely affected by modern human activity to a significant level.
6. Representativeness – It contains an outstanding example of an aquatic ecosystem class, within a Drainage Division.

3.3.2 Implementing the draft HCVAE Framework to identify and prioritise aquatic ecological assets

We implemented the draft HCVAE Framework to identify and prioritise aquatic ecological assets in the study region. This involved an exhaustive process (described in Chapter 8 of Kennard 2010)) of selecting appropriate attributes to characterise the six Framework criteria (which are: Diversity, Distinctiveness, Vital habitat, Evolutionary history, Naturalness and Representativeness) and applying them to the seven sets of biodiversity surrogate data (three hydrosystems and four species groups). The full list of attributes is listed in Table 3.1 and details on their rationale, methods of calculation and key supporting references are provided in Chapter 8 of Kennard (2010). A total of 65 raw attributes were calculated from these data, integrated into 22 attribute types that shared similar properties and these were integrated to characterise the six Framework criteria for each of the 5,803 planning units. A geodatabase containing this information together with metadata and attribute tables are held by the Australian Government (DSEWPaC) – see Appendix 8.2.

Table 3.1. Attributes used to characterise each of the draft HCVAE Framework Criteria. Attributes for each criterion were calculated for each of the biodiversity surrogate sets where suitable data was available (depicted with dark shading). Abbreviations used for biodiversity surrogates are: macroinvertebrates (Bug), fish (Fish), turtles (Turt), waterbirds (Bird), riverine ecotopes (Riv), lacustrine ecotopes (Lac) and palustrine ecotopes (Pal). Attributes for Criterion 5 (Naturalness) were summarized for the planning unit (PU) (i.e. were not based on the biodiversity surrogate data). See Chapter 8 of Kennard (2010) for rationale, methods of attribute calculation and key references.

Criterion, Attribute type and code	**Biodiversity surrogate set**							
	Bug	Fish	Turt	Bird	Riv	Lac	Pal	PU
1. Diversity								
Richness (S,)	■	■	■	■	■	■	■	
Diversity (H')	■	■	■	■				
Richness Index (I_i)	■	■	■	■				
Phylogenetic Diversity (PD)	■	■	■	■				
2. Distinctiveness								
Rarity Index (Q_i)	■	■	■	■	■	■	■	
Rare & Threatened species score (R&T)		■	■	■				
3. Vital habitat								
Number/area permanent/perennial dry season refugia (P)					■	■	■	
Degree of natural longitudinal connectivity (con)								■
Number of migratory bird species (Mbird_S)				■				
4. Evolutionary history								
Number of monospecific Genera (monG)		■	■	■				
Number of species endemic to each NASYagg Region (SES)		■	■					
Taxonomic endemism index (TE)	■	■	■	■	■	■	■	
Phylogenetic Endemism index (PE)	■	■	■	■				
5. Naturalness								
Catchment Disturbance Index (CDI)								■
Flow Regime Disturbance Index (FRDI)								■
6. Representativeness								
Representativeness (R)	■	■	■	■	■	■	■	

We also evaluated the extent of redundancy between attributes and performed sensitivity analyses (using seven different methods) to establish a robust method of scoring and integration of individual attributes to generate scores for each criterion. Based on this method, we implemented the draft Framework to identify HCVAEs of northern Australia.

The relative conservation value of each planning unit (referential to the entire study region) based on each HCVAE Framework criterion is presented in Figure 3.13. Diversity varied extensively within the study region, being highest in a band located near the coast and decreasing further inland. This pattern corresponded to a change from large lowland rivers with extensive floodplains to smaller headwater streams. The Kimberley region, with the exception of the Fitzroy and Ord River basins, was comparatively less diverse than elsewhere, especially in the vicinity of the Kimberley Plateau. In contrast, rivers draining the Arnhem Land Escarpment were very diverse. Three separate domains of high Distinctiveness were present: the southern Gulf region; the western half of the Top End of the Northern Territory; and the Fitzroy River of the Kimberley region. Isolated patches with high Distinctiveness also occur outside of these three regions but are very limited in extent. Areas containing Vital habitat were similar to those identified for Distinctiveness except they were more concentrated in the lowland and coastal parts of river basins. Areas of high conservation value with respect to Evolutionary history were patchily distributed within and between individual river basins. Notably high areas occurred in the Alligator Rivers region and the Daly River in the Northern Territory; the Drysdale, Edward and Fitzroy Rivers of the Kimberley region; and throughout the southern Gulf region and western Cape York Peninsula, including the Jardine River. Vast areas of northern Australia were rated highly with respect to Naturalness. Rivers of the southern Gulf of Carpentaria (e.g. Flinders, Norman and Mitchell), the Darwin region and parts of the Ord and Fitzroy Rivers in the Kimberley scored lower for this criterion. The most Representative areas were distributed patchily across northern Australia.

We trialled a variety of scoring thresholds to identify which subsets of planning units may qualify as being of high conservation value based on the criteria (Fig 3.14). Using the strictest threshold, we identified the set of planning units potentially containing HCVAEs for each of three reporting scales: (1) the entire study region (total of 275 planning units representing 6.9% of the total area), (2) each drainage division (total of 282 planning units representing 6.9% of the total area), and (3) each NASY region (total of 308 planning units representing 7.7% of the total area). The spatial distribution of these planning units is displayed in Fig 3.15. Planning units having met at least one criterion for a given threshold level were distributed widely across the entire study region and planning units having met four or more criteria were concentrated in isolated patches of the Kimberley region in north-western Australia, the northern top end of the Northern Territory and the tip of Cape York Peninsula. Refer to Chapter 9 and Appendix 9.1 of Kennard (2010) for details on the location and characteristics of potential HCVAEs identified using this process. A subset of potential HCVAEs (defined as planning units having met two or more criteria at the 99th percentile threshold for any of the three reporting scales) are listed in Table 3.2.

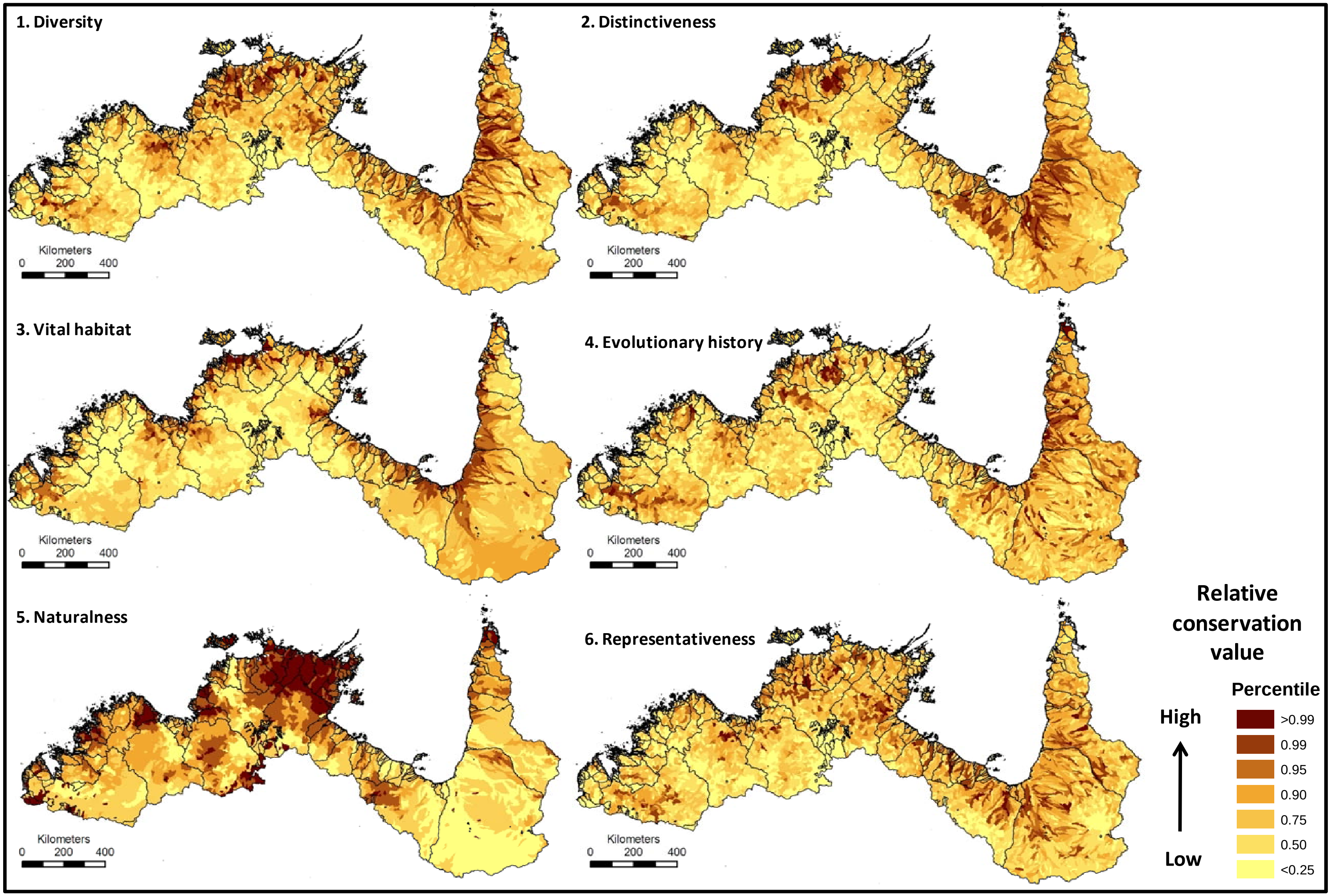


Figure 3.13. Relative conservation value for each planning unit based on each HCVAE Framework criterion (scores are calculated referential to the entire study region).

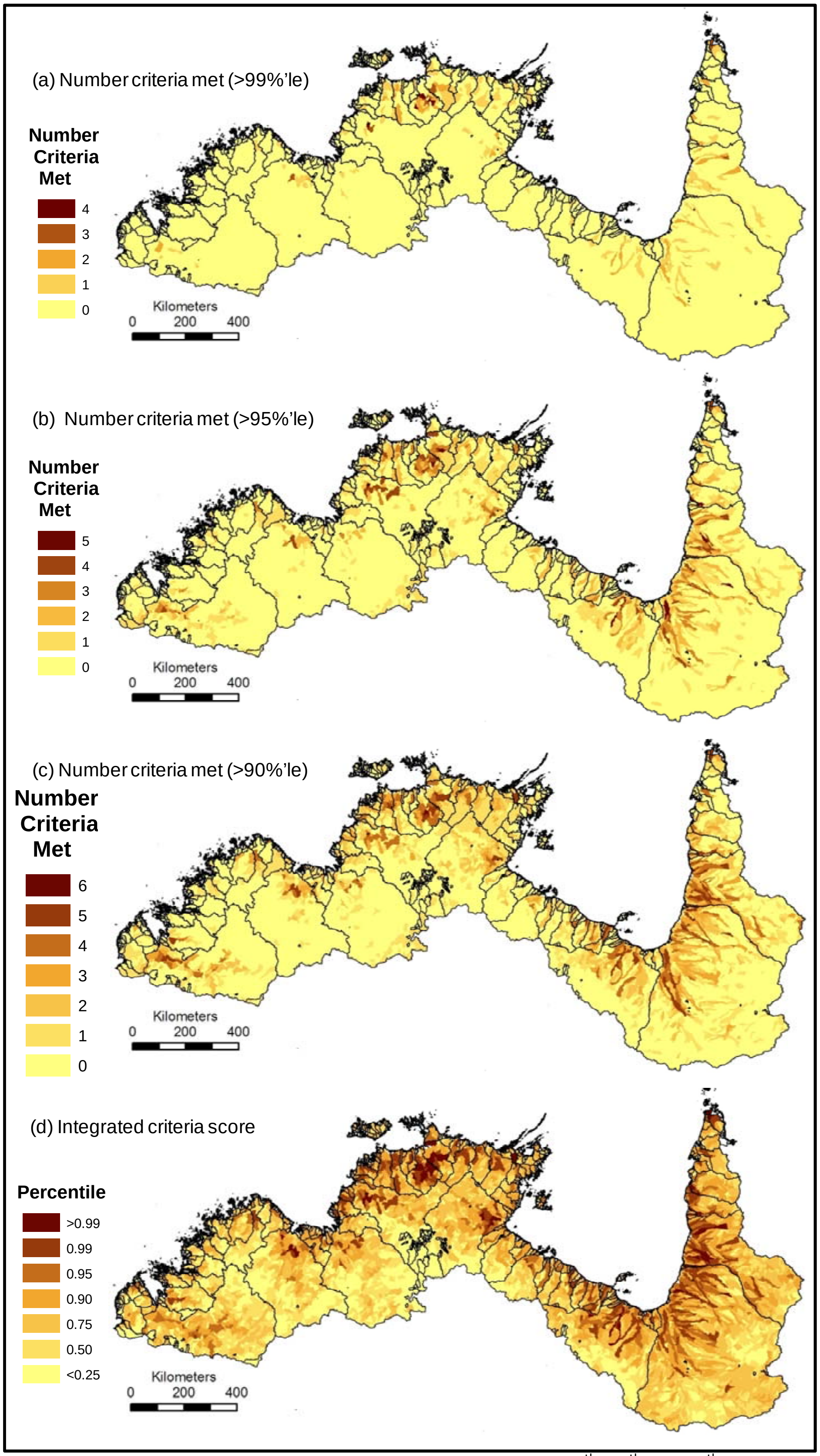


Figure 3.14. The number of criteria met for each planning unit defined using 99th, 95th and 90th percentile thresholds (a, b and c, respectively). Also shown is the integrated HCVAE score for each planning unit (integrated across all six criteria using Euclidean distance). Scores are calculated referential to the entire study region.

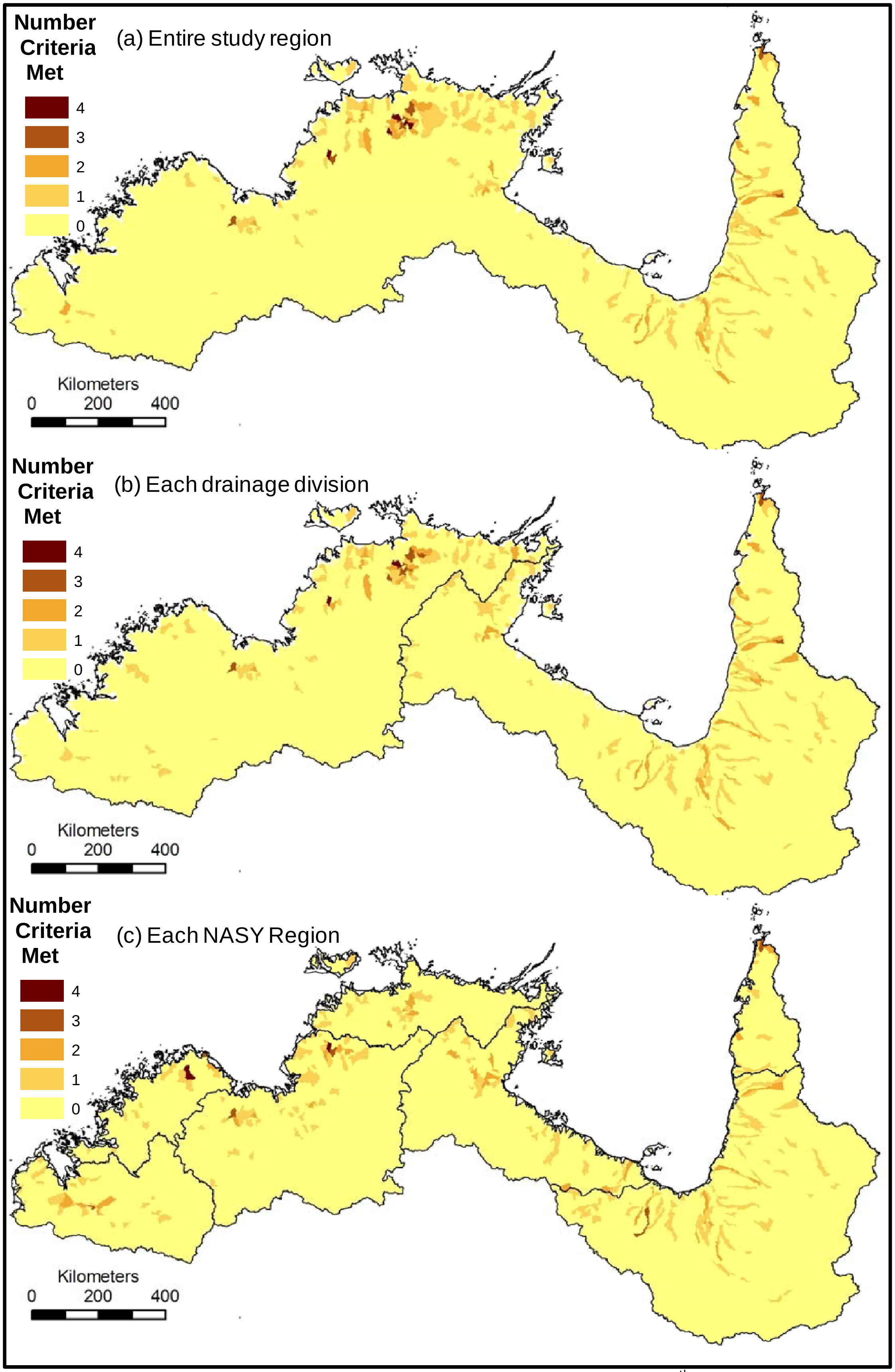


Figure 3.15. The number of criteria met for each planning unit defined using the 99th percentile threshold and referential to (a) the entire study region, (b) each drainage division, and (c) each NASY region.

Table 3.2. HCVAEs defined as planning units having met two or more criteria at the 99th percentile threshold for any of the three reporting scales (entire study region, each Drainage Division and each NASY region). The numeric code of each planning unit (PU), and the drainage division (DD), NASY region (RG) and AWRC river basin in which they occur is listed. Also shown are the major named hydrosystems occurring within each planning unit. Hydrosystem codes are: riverine (R), lacustrine (L), palustrine (P) and springs (S). For each planning unit and each reporting scale, the individual criteria met (1) and the total number met (∑) are also shown. Criteria are: (1) Diversity, (2) Distinctiveness, (3) Vital habitat, (4) Evolutionary history, (5) Naturalness, (6) Representativeness. Note: due to the limitations of the HCVAE Framework identified during this project, the project team does not recommend that this list be used to guide any future investment decisions (e.g. management of areas for broader natural resource management outcomes).

					Entire study region							Drainage Divisions							NASY Regions						
					Criteria							Criteria							Criteria						
PU	DD	RG	AWRC	NAMED HYDROSYSTEMS	1	2	3	4	5	6	∑	1	2	3	4	5	6	∑	1	2	3	4	5	6	∑
4	GC	1	Jardine	JARDINE RIVER(R)				1			1				1			1		1		1			2
3	GC	1	Jardine	SANAMERE LAGOON(L), BIFFIN SWAMP(P), COWAL CREEK(R), ELIOT CREEK(R), JARDINE RIVER(R)	1		1	1			3	1		1	1			3		1	1	1			3
6	GC	1	Jardine	JARDINE RIVER(R)				1			1				1			1		1		1			2
170	GC	1	Wenlock	GIBSON WATERHOLE(P), WENLOCK RIVER(R)	1		1				2	1		1				2			1				1
583	GC	1	Archer	TIMINIE CREEK(L), ARCHER RIVER(R), EAST ARCHER RIVER(R), WEST ARCHER RIVER(R)	1		1				2	1		1				2	1		1				2
721	GC	1	Archer	ARCHER RIVER(L), BOUYEL LAKE(L), TEA TREE LAGOON(L), ARCHER RIVER(R)	1		1				2	1		1				2							
992	GC	1	Holroyd	HOLROYD RIVER(R), KENDALL RIVER(R)	1		1				2	1		1				2	1						1
1232	GC	2	Coleman	EDWARD RIVER(R)			1	1			2			1	1			2			1				1
1362	GC	2	Coleman	COLEMAN RIVER(R)				1		1	2				1		1	2				1		1	2
1391	GC	2	Coleman	CATTLE SWAMP(L), COLEMAN RIVER(R), STAN LAGOON(R)	1			1		1	3	1			1		1	3	1			1			2
1433	GC	2	Coleman	MALAMAN CREEK(R)	1			1			2				1			1							
1410	GC	2	Coleman	SWORDFISH HOLE(L), COLEMAN RIVER(R), LIGHTNING CREEK(R), MALAMAN CREEK(R)	1	1					2	1	1					2	1	1					2
1498	GC	2	Coleman	COLEMAN RIVER(R)	1			1			2	1			1			2	1						1
1695	GC	2	Mitchell	MOSQUITO WATERHOLE(L), CROSBIE CREEK(R), EIGHT MILE CREEK(R)	1					1	2	1					1	2	1						1
2026	GC	2	Mitchell	BURRUM CHANNEL(R), MITCHELL RIVER(R)	1			1			2	1			1			2	1						1
2036	GC	2	Mitchell	CHRISTMAS WATERHOLE(L), SCRUTTON RIVER(R)	1			1			2	1			1			2							
2297	GC	2	Mitchell	DIAMOND CREEK(R), MITCHELL RIVER(R), TEA-TREE CREEK(R)	1						1	1	1					2	1						1
3325	GC	2	Gilbert	BANCROFT WATERHOLE(L), BIRD WATERHOLE(L), BLACKFELLOW LAGOON(L), BULLOCKY LAGOON(L), COBBLE LAGOON(L), WOMBIES LAGOON(L), BULL_SWAMP_DAM(P), FOUR_MILE_SWAMP(P), FREDS_LAGOON(P), GALAH_WATERHOLE(P), GREEN_SWAMP_DAM(P), NINE_MILE_LAGOON(P), OLD_STATION_ WATERHOLE(P), PLUM_HOLE(P), TWO_MILE_WATERHOLE(P), SMITHBURNE_RIVER(R)	1	1					2	1	1					2	1	1					2
3533	GC	2	Gilbert	PICKLE LAGOON(L), VELOX LAGOON(L), EINASLEIGH RIVER(R), GILBERT RIVER(R), MAXWELL CREEK(R), WALKER CREEK(R)		1					1		1	1				2			1	1			2
4739	GC	2	Norman	WILSONS LAGOON(L), CLARA RIVER(R), MAY LAGOON(R), NORMAN RIVER(R)		1				1	2		1				1	2						1	1
3930	GC	2	Flinders	PIDGEON WATERHOLE(L), UHRS LAGOON(L), BYNOE WATERHOLE(P), BYNOE RIVER(R), FLINDERS RIVER(R)	1	1					2	1	1					2	1	1					2
4633	GC	2	Flinders	FLAT HOLE CHANNEL(R), FLINDERS RIVER(R)		1				1	2		1				1	2		1				1	2
4689	GC	2	Flinders	SAXBY RIVER(R)		1					1		1					1		1				1	2
4730	GC	2	Flinders	TEATREE WATERHOLE(L), CLONCURRY RIVER(R), FLINDERS RIVER(R), SANDY CREEK(R), IANS SPRING(S)		1				1	2		1				1	2						1	1
4732	GC	2	Flinders	FLAGSTONE WATERHOLE(L), MCDOUGALLS WATERHOLE(L), MONKEY WATERHOLE(L), FLINDERS RIVER(R)		1		1			2		1		1			2		1					1
4825	GC	2	Flinders	CHARLO WATERHOLE(L), CLONCURRY RIVER(L), BRANCH CREEK(R), CLONCURRY RIVER(R)		1					1		1					1		1				1	2
5047	GC	2	Flinders	COCKATOO WATERHOLE(L), EARLES CAMP WATERHOLE(L), FISHERIES WATERHOLE(L), LYRIAN WATERHOLE(L), SAXBY RIVER(R)		1					1		1					1		1	1				2
5271	GC	2	Flinders	FIFTY FOUR WATERHOLE(L), WASHPOOL LAGOON(L), CAROLINE CREEK(R), CLONCURRY RIVER(R), FLINDERS RIVER(R)		1		1			2		1		1			2		1					1
3833	GC	2	Nicholson	GIN ARM CREEK(R), NICHOLSON RIVER(R)	1			1			2	1			1			2	1			1			2
4120	GC	2	Nicholson	BEAMES BROOK(R), ONE MILE CREEK(R)				1		1	2				1		1	2				1		1	2
4353	GC	2	Nicholson	BEAMES BROOK(R), CARTRIGE CREEK(R), FOUR MILE CREEK(R), GREGORY RIVER(R), MACADAM CREEK(R), MILLAR CREEK(R), RUNNING_CREEK(R)	1	1					2	1	1					2	1	1		1			3
4347	GC	2	Nicholson	ARCHIE CREEK(R), GREGORY RIVER(R), WILLIS WATERHOLE(R)		1		1			2		1		1			2		1		1			2
4330	GC	2	Nicholson	POLEYS LAGOON(L), LAWN HILL CREEK(R)						1	1														
3802	GC	3	Nicholson	BAMADJINA CLAYPAN(L), DJUMBARANA CLAYPAN (CALVERT LAKE)(L), LILIGI CREEK(R)																1		1			2
3161	GC	3	Settlement	PEACOCK WATERHOLE(L), BALLYS LAGOON(P), PEACOCK LAGOON(P), STONEBALL WATERHOLE(P), CLIFFDALE CREEK(R)				1			1									1		1			2
3169	GC	3	Settlement	BUNDELLA WATERHOLES(L), CLIFFDALE CREEK(R)																1		1			2
3838	GC	3	Settlement	CLIFFDALE CREEK(R)																1		1			2
824	GC	3	Roper	MAINORU RIVER(R)						1	1								1					1	2
1092	GC	3	Roper	PANIPANIN WATERHOLE(L), WONMURRI WATERHOLE(L), WARIEJAL WATERHOLE(P), PHELP RIVER(R)	1					1	2	1						1	1					1	2
1093	GC	3	Roper	LAKE ALLEN(L), BRIGHT CREEK(R), WILTON RIVER(R)															1	1					2
1183	GC	3	Roper	NAMALURI WATERHOLE(L), ROPER RIVER(R), TURKEY LAGOON CREEK(R), WUNGGULIYANGA CREEK(R)						1	1			1			1	2	1					1	2
1318	GC	3	Roper	LOMARIEUM LAGOON(L), NULLAWUN LAGOON(P), ROPER RIVER(R)			1			1	2			1	1			2	1		1				2
157	TS	4	Buckingham	LAKE EVELLA(L), BUCKINGHAM RIVER(R), KALARWOI RIVER(R), WARAWURUW0I RIVER(R)			1				1			1	1			2							
156	TS	4	East Alligator	MANJDJALANJARRK (UNAWAHLURK BILLABONG)(L), WOELK (RED LILY LAGOON)(L), EAST ALLIGATOR RIVER(R)	1		1				2	1		1				2	1						1
186	TS	4	East Alligator	COONJIMBA BILLABONG(L), GURNDURRK (CORNDORL WATERHOLE)(P), MAGELA CREEK(R)	1	1		1			3	1	1		1			3		1		1			2
198	TS	4	East Alligator	TIN CAMP CREEK(R)	1		1				2	1		1				2	1						1
222	TS	4	East Alligator	EAST ALLIGATOR RIVER(R)	1				1		2	1			1	1		3							
311	TS	4	South Alligator	GURDURUNGURANJDJU (ALLIGATOR BILLABONG)(L), UNG.GURLINJ (LEICHHARDT BILLABONG)(L), AMBARRAWARRKU(P), DJUNDA (RED LILY BILLABONG)(P), NGARRABABA (BUCKET BILLABONG)(P), SOUTH ALLIGATOR RIVER(R)	1	1	1	1			4	1	1	1	1			4			1				1
328	TS	4	South Alligator	NOURLANGIE CREEK(R)	1	1		1			3	1	1		1			3				1		1	2
348	TS	4	South Alligator	NOURLANGIE CREEK(R)	1	1		1			3	1	1					2							
375	TS	4	South Alligator	NAMARRGON CREEK(R), NOURLANGIE CREEK(R)		1				1	2		1				1	2		1				1	2
356	TS	4	South Alligator	DEAF ADDER CREEK(R), NOURLANGIE CREEK(R)	1	1		1		1	4	1	1		1			3		1					1
363	TS	4	South Alligator	JIM JIM BILLABONG(L), JIM JIM CREEK(R), SOUTH ALLIGATOR RIVER(R)	1	1		1			3	1	1		1			3				1			1
373	TS	4	South Alligator	YIRRIRRI(L), BARRAMUNDIE CREEK(R), SOUTH ALLIGATOR RIVER(R)		1		1			2		1		1			2							
358	TS	4	South Alligator	GURDURUNGURANJDJU (ALLIGATOR BILLABONG)(L), JIM JIM CREEK(R), SOUTH ALLIGATOR RIVER(R)		1		1			2		1		1			2							
372	TS	4	South Alligator	SOUTH ALLIGATOR RIVER(R)		1		1			2		1		1			2							
402	TS	4	South Alligator	BARRAMUNDIE LAGOON(P), BARRAMUNDIE CREEK(R), SOUTH ALLIGATOR RIVER(R)		1		1			2				1			1							
401	TS	4	South Alligator	SOUTH ALLIGATOR RIVER(R)		1		1			2		1		1			2							
407	TS	4	South Alligator	ANBALAWALA(L), GALURRUYU(L), JIM JIM CREEK(R)	1	1		1			3	1	1		1			3		1					1
416	TS	4	South Alligator	DEAF ADDER CREEK(R)		1		1	1	1	4		1		1			2				1			1
516	TS	4	South Alligator	LONG BILLABONG(P), COIRWONG (GOWONJ) CREEK(R), SOUTH ALLIGATOR RIVER(R)	1	1		1		1	4	1	1		1			3	1	1					2
457	TS	4	South Alligator			1			1		2		1					1							
470	TS	4	South Alligator	JIM JIM CREEK(R)		1				1	2		1				1	2							
506	TS	4	South Alligator			1				1	2		1				1	2							
172	TS	4	Mary	PALM LAGOON(L), MARY RIVER(R)			1	1			2			1	1			2			1				1
300	TS	4	Mary		1		1				2	1		1				2							
444	TS	4	Mary	MCKINLAY RIVER(R)	1					1	2	1					1	2							

					Entire study region							Drainage Divisions							NASY Regions						
					Criteria							Criteria							Criteria						
PU	DD	RG	AWRC	NAMED HYDROSYSTEMS	1	2	3	4	5	6	∑	1	2	3	4	5	6	∑	1	2	3	4	5	6	∑
339	TS	4	Adelaide	LAKE BENNETT(L), HEATHERS LAGOONS(P), ADELAIDE RIVER(R)	1					1	**2**	1						**1**	1						**1**
678	TS	5	Daly	DALY RIVER(R)																1		1			**2**
707	TS	5	Daly	NANCAR BILLABONG(L), RED LILY LAGOON(L), CHILLING CREEK(R), DALY RIVER(R)	1	1	1	1			**4**	1	1	1	1			**4**	1	1	1	1			**4**
767	TS	5	Daly	CHILLING CREEK(R), DALY RIVER(R), MULDIVA CREEK(R)	1	1		1		1	**4**	1	1		1		1	**4**	1	1		1		1	**4**
811	TS	5	Daly	HOT WATER BILLABONG(L), DALY RIVER(R), FISH RIVER(R)	1	1		1			**3**	1	1					**2**	1	1		1			**3**
794	TS	5	Daly	BAN BAN LAGOON(L), RUBY BILLABONG(L), DALY RIVER(R), DOUGLAS RIVER(R)															1			1			**2**
812	TS	5	Daly	ANWOOLLOLLA LAGOON(L), DALY RIVER(R)													1	**1**	1	1					**2**
821	TS	5	Daly	ALLIGATOR LAGOON(L)		1					**1**		1					**1**	1	1					**2**
815	TS	5	Daly	HOT WATER BILLABONG(L), BAMBOO CREEK(R), DALY RIVER(R), PEGGY SPRING(S)																1		1			**2**
1740	TS	5	Victoria	BUFFALO SPRING(P), THE ELBOW WATERHOLE(P), ANGALARRI RIVER(R), VICTORIA RIVER(R)						1	**1**						1	**1**	1					1	**2**
1830	TS	5	Pentecost	MOOCHALABRA DAM(L), KING RIVER(R), WEST ARM(R)	1		1			1	**3**	1		1			1	**3**	1		1			1	**3**
1897	TS	5	Ord	OLD STATION BILLABONG(P), ORD RIVER(R)	1					1	**2**	1					1	**2**	1					1	**2**
2050	TS	5	Ord	KING RIVER(R)															1					1	**2**
835	TS	6	Drysdale	KING GEORGE RIVER(R)													1	**1**	1	1				1	**3**
1025	TS	6	Drysdale	DRYSDALE RIVER(R), JOHNSON CREEK(R)				1			**1**				1			**1**	1	1		1		1	**4**
1060	TS	6	Drysdale	CASUARINA CREEK(R)																			1	1	**2**
3972	TS	7	Fitzroy	JORDAN POOL(L), LAKE ALMA(L), LAKE SKELETON(L), LULIKA POOL(L), FITZROY RIVER(R), MINNIE RIVER(R)	1			1			**2**	1						**1**	1	1					**2**
4121	TS	7	Fitzroy	FITZROY RIVER(R), MINNIE RIVER(R)													1	**1**		1				1	**2**
4366	TS	7	Fitzroy	FITZROY RIVER(L), TRAGEDY POOL(L), FITZROY RIVER(R), SNAKE CREEK(R)	1						**1**	1						**1**	1			1			**2**
4339	TS	7	Fitzroy	FITZROY RIVER(L), NINE MILE POOL(L), SIX MILE CREEK(L), LOONGADDA POOL(P), SIX MILE POOL(P), FITZROY RIVER(R)				1			**1**								1	1		1			**3**
4119	TS	7		TROYS LAGOON(L), MOUNT WYNNE CREEK(R)															1			1			**2**
4418	TS	7	Fitzroy	FITZROY RIVER(L), COOGABING POOL(P), ROCKY HOLE(P), FITZROY RIVER(R)															1	1					**2**

3.4 ADEQUACY OF THE HCVAE FRAMEWORK AND PROTECTED AREA SCHEMES TO *REPRESENT* THE DISTRIBUTION OF BIODIVERSITY SURROGATES IN NORTHERN AUSTRALIA

A key objective of this project was to identify aquatic ecological assets in northern Australia, with one approach being a trial of the draft HCVAE Framework. In order to test the findings from the HCVAE trial, and provide a critique of the draft HCVAE Framework, the project was also tasked to utilise a mixture of GIS analysis, systematic conservation planning methods, coupled with expert system approaches to further validate and assess potential ecological assets in northern Australia.

A fundamental goal of conservation assessments should be to efficiently identify sets of areas that should be managed to conserve species and the processes that sustain them. When deciding on a particular approach to identify areas for conservation, it is important to consider what ecological values we are seeking to preserve as this will inform us on the most appropriate identification method to be used. The draft HCVAE Framework, with its multi-criteria, can be used to identify a range of values for conservation, including nationally important ecosystem functions, areas important to connectivity between other ecosystems, and critical habitats of species protected under the EPBC Act.

The multi-criteria HCVAE Framework represents a spatially explicit 'scoring' approach to prioritising freshwater systems. Such approaches continue to be used in Australia and elsewhere, and are also used in broad-scale terrestrial assessments, e.g. global biodiversity hotspots based on species richness, rarity, endemism, etc. Importantly however, none of the Framework criteria are designed to identify a set of areas that efficiently represent the full range of species or types of natural environments (so-called biodiversity surrogates or conservation features and the fundamental currency of conservation assessments). This is a key limitation of the HCVAE Framework. Scoring approaches such as the HCVAE Framework assess each area individually, potentially creating a situation where the highest ranking areas contain the same conservation features which are duplicated within the results, while other features remain completely unrepresented, especially if they occur only in low-ranking areas (Carwardine et al. 2007). We therefore considered it important to evaluate the extent to which the set of areas identified using the HCVAE Framework as being of high conservation value contribute to the goal of comprehensively and efficiently representing the full range of biodiversity surrogates.

The project also evaluated the extent to which the existing set of conservation reserves (based on the most recent available (2006) version of the Collaborative Australian Protected Area Database; CAPAD 2006 – see Fig. 3.16) encompasses the distribution of freshwater biodiversity surrogates in the Timor Sea and Gulf of Carpentaria Drainage Divisions. The project also evaluated the extent to which the set of Queensland's 'Wild Rivers' Declared under State Government legislation (Fig. 3.16) encompasses the distribution of freshwater biodiversity surrogates present in the northern part of the North-East Coast Drainage Division and the Queensland part of the Gulf of Carpentaria Drainage Division. The purpose of this exercise was not to make recommendations for future conservation planning and management actions, but rather to evaluate the extent to which potential northern Australia aquatic ecological assets are protected under existing land management arrangements.

Protected areas are not the only mechanism for the conservation of biodiversity (see Section 5.4) but are nevertheless a cornerstone of conservation (Herbert et al. 2010). Mixed protection schemes where statutory reserves go hand in hand with community efforts and other kinds of regulation (Cowling et al. 2003) may also be needed to achieve conservation goals (Linke et al. 2008, Section 5.4). The conservation of freshwater ecosystems and biodiversity is rarely the basis for declaration of protected areas (e.g. National Parks and other conservation areas) unless it is considered important for maintenance of terrestrial biodiversity patterns and processes (Saunders et al. 2002; Nel et al. 2007). We assume here that a conservation reserve system designed primarily for maintenance of terrestrial biota may also have significant value for aquatic systems, although this has yet to be adequately demonstrated in Australia. Assessing the spatial extent of representation of freshwater biodiversity within protected areas is a prerequisite for identifying and filling protection gaps (Herbert et al. 2010) – a priority of the Ramsar Convention on Wetlands of International Importance (Ramsar Bureau 2009) and the Convention on Biological Diversity (2006).

The project found that the existing protected areas and the set of planning units identified as containing HCVAEs were ineffective or inefficient at representing the distribution of some biodiversity surrogates. The existing network of protected areas in northern Australia do not encompass the distribution of 12 species of fish, one species of turtle, one riverine ecotope and one lacustrine ecotope known to occur in the Timor Sea and Gulf of Carpentaria Drainage Divisions (Table 3.3). The declared 'Wild Rivers' of Queensland do not encompass the distribution of four species of fish, two species of turtle, one riverine ecotope, two lacustrine ecotopes and one palustrine ecotope (Table 3.3) known to occur in the northern part of the North-east Coast Drainage Division and the Queensland part of the Gulf of Carpentaria Drainage Division.

The HCVAE Framework does not specifically seek to identify areas that efficiently represent major components of freshwater biodiversity or identify sets of areas that need to be managed to conserve species and the processes that sustain them. Where biodiversity conservation is the goal, a more appropriate biodiversity-driven approach should be used. This was confirmed by the project's findings. The set of planning units identified as containing HCVAEs by meeting at least one Framework criterion using the strictest threshold (99^{th} percentile) did not appear to perform much better in representing the full range of biodiversity surrogates in that 11 species of fish and one palustrine ecotope were not represented within these planning units (Table 3.3). Even if the criterion thresholds were relaxed to the 90^{th} percentile, two fish species were still not represented. These results indicate that the HCVAE Framework criteria are potentially inefficient or ineffective at identifying a subset of areas to represent all biodiversity surrogates. This is especially evident when the planning units are ranked by their integrated HCVAE score (i.e. integrated across all six criteria using Euclidean distance) and the total number of taxa represented at least once is counted as individual planning units are sequentially added (Fig. 3.17). Turtles required about 30% of the entire study region to be selected before all 13 taxa are represented. Fish required more than 85%

of the study region to be selected before all 103 taxa are represented. This is likely due to the extreme rarity of some turtle and fish taxa (see Chapters 5 and 7 of Kennard 2010), and that the criteria did not prioritise planning units containing these taxa.

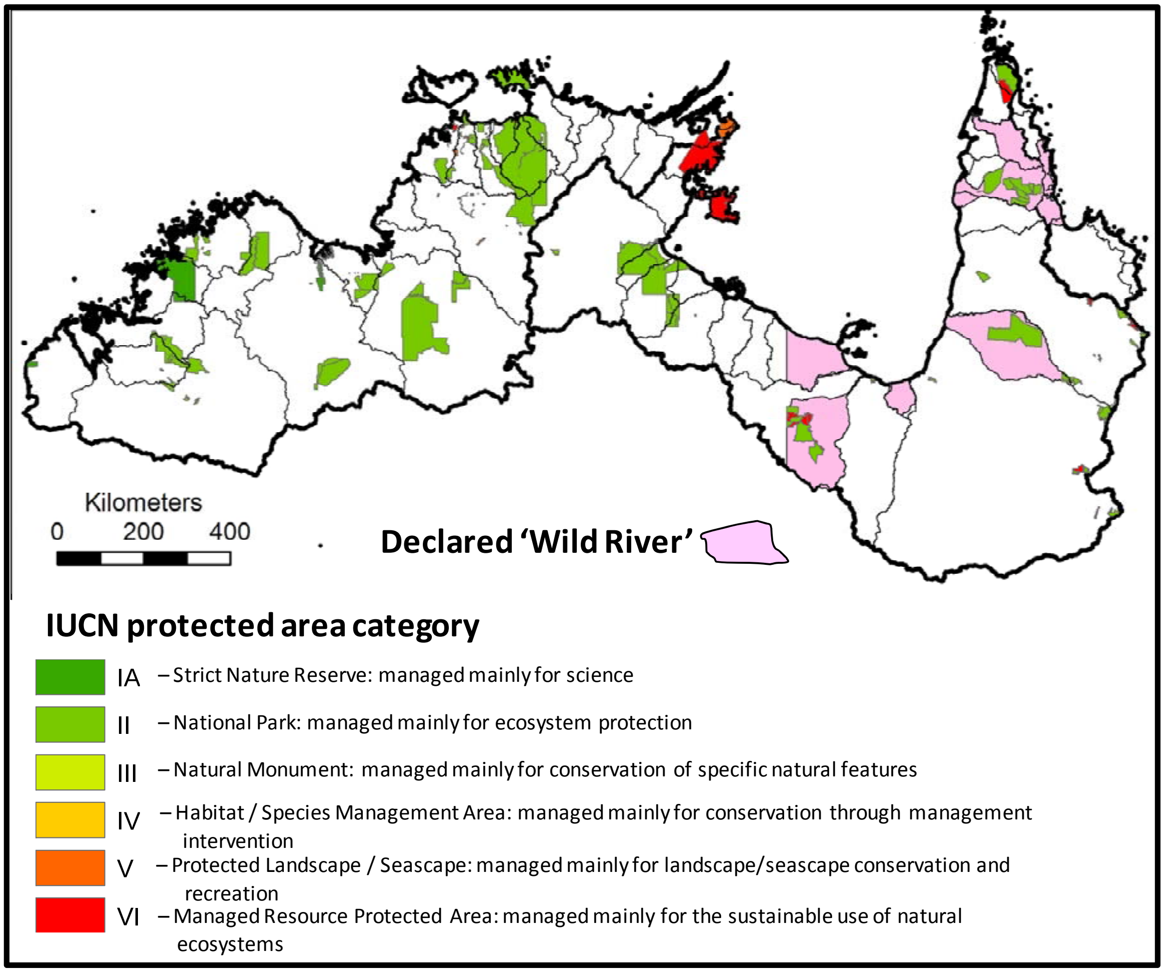


Figure 3.16. Location of declared 'Wild River' basins in Queensland and the distribution of protected areas (CAPAD 2006) in the Timor Sea and Gulf of Carpentaria Drainage Divisions. A Wild River declaration is a statutory document under the Wild Rivers Act, which aims to preserve a river that has all, or almost all, of its natural values intact. This is done by regulating, through the declaration, certain new development activities that have the potential to impact on the river's natural values (Queensland Government 2011). Protected areas are defined according to the IUCN (1994): "A protected area is an area of land and/or sea especially dedicated to the protection and maintenance of biological diversity, and of natural and associated cultural resources, and managed through legal or other effective means".

Table 3.3. The total number of taxa or hydrosystem ecotopes in each biodiversity surrogate set that are *not* currently represented within existing protected areas, or Wild Rivers (Qld), or in the set of planning units identified as being HCVAEs based on each percentile threshold.

			Potential HCVAE planning units		
Biodiversity surrogate set	**Existing protected areas (IUCN)**	**Wild Rivers (Qld)**	99th percentile threshold	95th percentile threshold	90th percentile threshold
Fish	12	4	11	2	2
Turtles	1	2	0	0	0
Waterbirds	0	0	0	0	0
Riverine	1	1	0	0	0
Lacustrine	1	2	0	0	0
Palustrine	0	1	1	0	0

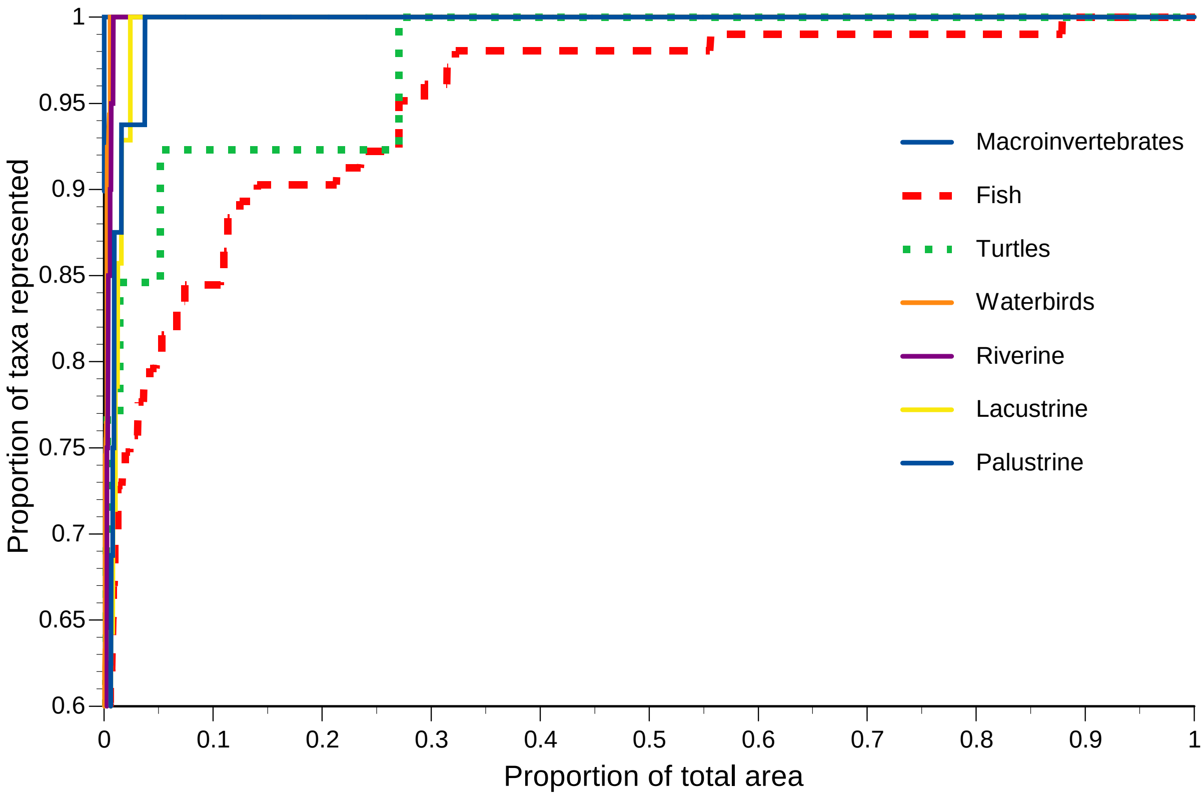


Figure 3.17. The proportion of the total study region (by area) required to represent at least one occurrence of each taxon within each planning unit when the planning units were ranked by their integrated criteria score.

The existing protected areas and the set of planning units identified by the Framework criteria as containing HCVAE encompassed only a very small proportion of the total distribution of many taxa (Fig. 3.18). For example, up to 80% of all taxa across the biodiversity surrogate sets had less than 5% of their total distributions contained within existing protected areas (Fig. 3.18a). Of the taxa present in Queensland's 'Wild Rivers' of the Gulf of Carpentaria, up to 50% had less than 5% of their total distributions within these rivers (Fig. 3.18b). Similarly, the set of planning units identified by the Framework Criteria as containing HCVAE encompassed less than 5% of the distribution of up to 40% of taxa (Fig. 3.18c).

Clearly, a set of ecological assets can never be identified to represent all elements of biodiversity and the ecosystems that sustain them. However, using a set of biodiversity surrogates for which quantitative and comprehensive distribution data is actually available for northern Australia (i.e. iconic freshwater-dependent taxa and aquatic ecosystem types), the analyses presented here serve to highlight the gross under-representation of biodiversity surrogates in the existing set of protected areas and those areas identified through the HCVAE Framework trial.

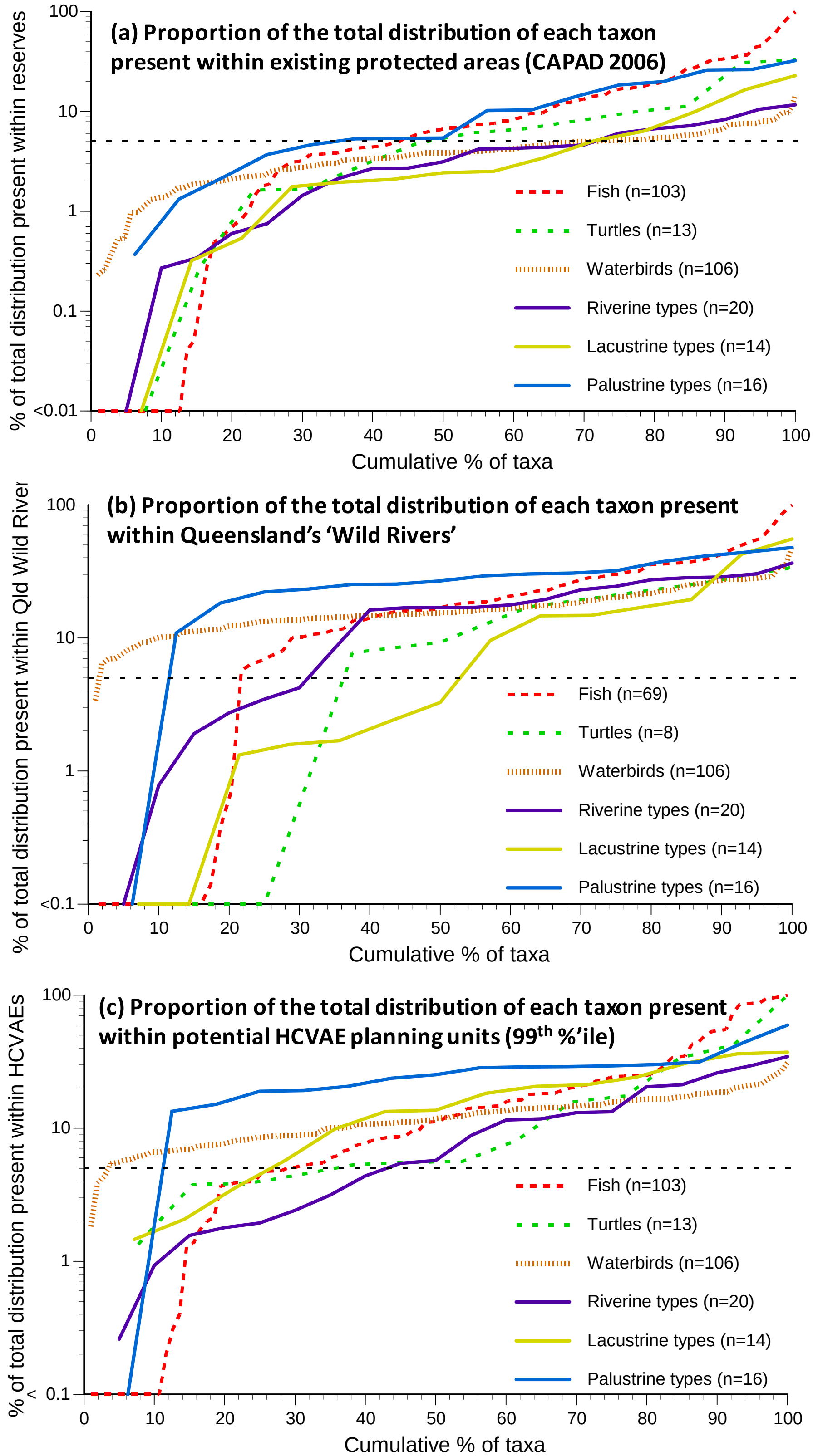


Figure3.18. Proportion of the total distribution of each taxon present within (a) existing protected areas, (b) Queensland's 'Wild Rivers', (Gulf of Carpentaria only) and (c) potential HCVAE planning units (defined using the 99th percentile threshold) for fish, turtles, waterbirds, riverine types, lacustrine types, and palustrine types. The total number of taxa within each biodiversity surrogate set is given in parentheses. The horizontal dashed line indicates the proportion of taxa represented at 5% of their total distribution.

3.5 Utility of the Framework criteria for identifying aquatic ecological assets in northern Australia

Based on our approach to implementing the Framework and the outcomes of our analyses, we offer the following conclusions as to its utility for accurately and efficiently identifying areas of high conservation value.

The nature of the Framework (i.e. a multi-criteria scoring approach) means that the method combines potentially numerous individual attributes that by themselves can be (and often are) used to assess conservation value. The process of integrating these various attributes to form result against a particular criteria ultimately means a potentially major loss of transparency, in that it is unclear how many attributes (and which ones) contributed to the integrated score for that criterion. It is also unclear which components of biodiversity (the fundamental currency of conservation assessments) contribute most to the final rankings based on criterion scores. Although it is certainly possible to interrogate the underlying data and maps to understand why a particular area scored highly for a particular criterion or set of criteria, this is not a simple process. One solution to this issue is to greatly reduce the number of attributes used to characterise the Framework criteria to only a few key ones that are deemed by experts to be the most important indicators of conservation value (though this is obviously not a simple task). We conclude that the use of more attributes does not necessarily provide a better or more interpretable conservation assessment. In fact, the converse appears to be true.

As an example of the potential consequences of the integration process to generate criterion scores, our analyses showed that the final sets of highest conservation value planning units identified using the Framework did not actually represent up to 11 of the 103 fish species and one of 16 palustrine ecotopes (using the strictest threshold). These “taxa” were comparatively rare throughout the study region, but one might have expected certain Framework criteria such as (2) Distinctiveness or (3) Evolutionary history (which quantify aspects of rarity and endemism, respectively) to have identified appropriate areas as being of high conservation value. However, because the individual attributes describing rarity or endemism are integrated across multiple sets of biodiversity surrogates, and then further integrated with other attribute types to arrive at final criterion scores, individual rare species potentially indicative of indicate high conservation value can become swamped and fail to contribute meaningfully to the conservation assessment. A potential outcome of this is that species of high conservation value may be placed at risk because they are not represented in high value areas identified using other criteria.

The Framework, as it stands, considers all six criteria as having equal value for identifying HCVAEs and does not specify that planning units that meet a greater number of criteria as necessarily having an elevated conservation value, though this seems a reasonable assumption. As highlighted in the HCVAE Framework trial for the Lake Eyre Basin (Hale, 2010), this raises the issue of the purpose of the HCVAE identification. The draft HCVAE Framework indicates that the Framework will be used for a “number of purposes including to assist the Australian Government to focus and prioritise its natural resource management investments”. It is possible that these natural resource management investments could include restoration, rehabilitation, environmental water allocation, protection, etc but the Framework criteria are not specifically designed to identify which investment options are most appropriate for a particular area. To do this would require additional criteria/attributes based on the rehabilitation need and potential (Hale 2010). We agree with Hale (2010) that the criteria serve to identify assessment units that have the potential to contain HCVAE based on ecological value alone. Subsequent steps would include delineating key aquatic assets within the assessment units and specifying management options to maintain these values. We considered various options for how HCVAEs might be identified based on their combined criterion scores and whether some criteria should be treated as more important than others for assigning conservation value and identifying HCVAEs. However, we agree with the approach taken in the Lake Eyre Basin trial (Hale 2010) that the lack of clearly defined objectives for the identification of HCVAE, means that the criteria should be considered to be equally important.

3.6 An alternative approach to identify aquatic ecological assets in northern Australia: Systematic Conservation Planning

Although the HCVAE Framework does not specifically seek to identify areas that *represent* major components of biodiversity, the HCVAE Framework goes some way towards achieving this important conservation goal. However, the HCVAE framework may be limited in the extent to which it can achieve it comprehensively and efficiently. For this reason, the project trialled alternative approaches to identifying aquatic ecological assets in northern Australia. Chapter 10 of Kennard (2010) presents an alternative approach to identifying high conservation value aquatic ecosystems using a complementarity-based algorithm (Marxan, Ball et al. 2009) within a systematic conservation planning framework.

Systematic conservation planning (Margules & Pressey 2000) aims to identify an optimum set of areas that cost-efficiently represent the desired conservation features, using complementarity-based approaches and incorporating cost in the selection process. Complementarity is defined as the gain in representativeness of biodiversity when a site is added to an existing set of areas (Possingham et al. 2000). Methods that incorporate complementarity have been shown to lead to more effective representations of biodiversity features and more cost-efficient solutions than ad-hoc (Pressey & Tully 1994), scoring or ranking strategies (Margules et al. 2002; Pressey & Nicholls 1989).

Suggested advantages (Linke et al. 2011) of systematic planning approach over scoring systems such as the HCVAE Framework are:

1. *Explicit and quantitative targets or objectives.* These can be set and achieved in line with quantitative policy guidelines (e.g. Australia is committed to the protection of representative ecosystems and to the protection of rare and endangered species). For example, a set of targets might be to conserve 15% of each ecosystem type, or 50% of the range of all rare species. The equivalent index-based approaches can only set targets such as: to conserve the largest, most biodiverse, and/or rarest areas, which informs little about the overall amounts of each asset that will end up in our final set of conservation priority areas. Other objectives in systematic methods can be framed to promote the persistence of biodiversity processes (Pressey et al. 2007) or to represent ecosystems with stewardship covenants whilst minimizing the opportunity costs of reduced grazing to the landholder. Without explicit objectives and targets, index-based approaches struggle to deal with these kinds of trade-offs.

2. *Complementarity and efficiency.* Because the whole of a conservation area system is worth more than the sum of the parts, the systematic approach aims to select areas that complement each other and the existing network in terms of the conservation assets. Scoring approaches, in contrast, assess each area individually. Highest ranking areas can contain the same conservation features which are duplicated, while other features may remain completely unrepresented, especially if they occur only in low-ranking areas. This was the single most important motivation for developing systematic methods (Margules & Pressey 2000) that identify sets of complementary areas. Complementarity promotes efficiency. Accounting for spatially variable information on the cost of specific actions has been shown to substantially improve efficiency, compared with the approach of designating ‘priority areas’ and

considering actions and their costs *post hoc* (Carwardine et al. 2007). Scoring approaches (and some systematic assessments), tend to ignore cost *a priori*. Systematic conservation planning approaches have the advantage of being able to synthesize multiple alternative costs and actions, without using scoring techniques.

3. *Irreplaceability and flexibility.* Systematic conservation planning tools generate multiple alternative sets of areas that meet conservation objectives, providing flexible options and measures of irreplaceability (selection frequency, or a modelled approximation of the likelihood that an area is needed to meet the conservation objectives). Irreplaceability can be used as a quantitative measure of priority: areas with higher irreplaceability are likely to require more urgent action because, if they are lost, targets for one or more biological assets are unable to be met. Higher scores in index-based systems do not necessarily equate to a required urgency of action to protect assets.

4. *Adequacy and persistence.* Adequacy refers broadly to the persistence of biodiversity processes, including population dynamics, movement and migration, patch dynamics, catchment processes and river flows, and many others. Adequacy is difficult to quantify and implement, but systematic methods are being developed that achieve explicit objectives related to adequacy (Pressey et al. 2007). Some of these are being adapted specifically for freshwater systems to consider longitudinal and lateral connectivity (below).

In implementing the systematic conservation planning analysis in northern Australia (described in Chapter 10 of Kennard 2010), our goal was to efficiently select a minimum set of areas to represent the full range of biodiversity surrogates. In these analyses we evaluated the influence of various target levels of occurrence of species or environmental types, and explored different longitudinal and lateral connectivity rules that we hypothesised would be important considerations in the selection and spatial configuration of high conservation value areas. We also penalised the selection of planning units that were disturbed by human activity (as quantified using the River Disturbance Index; Stein et al. 2002). These analyses allowed us to evaluate whether more efficient ranking of aquatic ecological assets based on the goal of representing the full range of species or type of natural environments can be obtained in comparison to the outcomes of the conservation assessment generated using the Framework Criteria.

Three main focal areas of high conservation value were identified using the systematic conservation planning approach: the East Arnhem area and lower Daly River basin in the Northern Territory, the Kimberley region in Western Australia, and northern Cape York Peninsula in Queensland (Fig. 3.19). High conservation values were consistent across conservation features but differed from the ones identified using the multi-criteria approach, illustrating that different priority areas would be identified using different methods. The systematic approach proved to be more efficient at representing all the conservation features than the Framework approach (e.g., 12% vs 87% or 5% vs 24% of the total area was needed to represent at least once each fish and turtle species for the systematic and scoring approach respectively; Fig. 3.20).

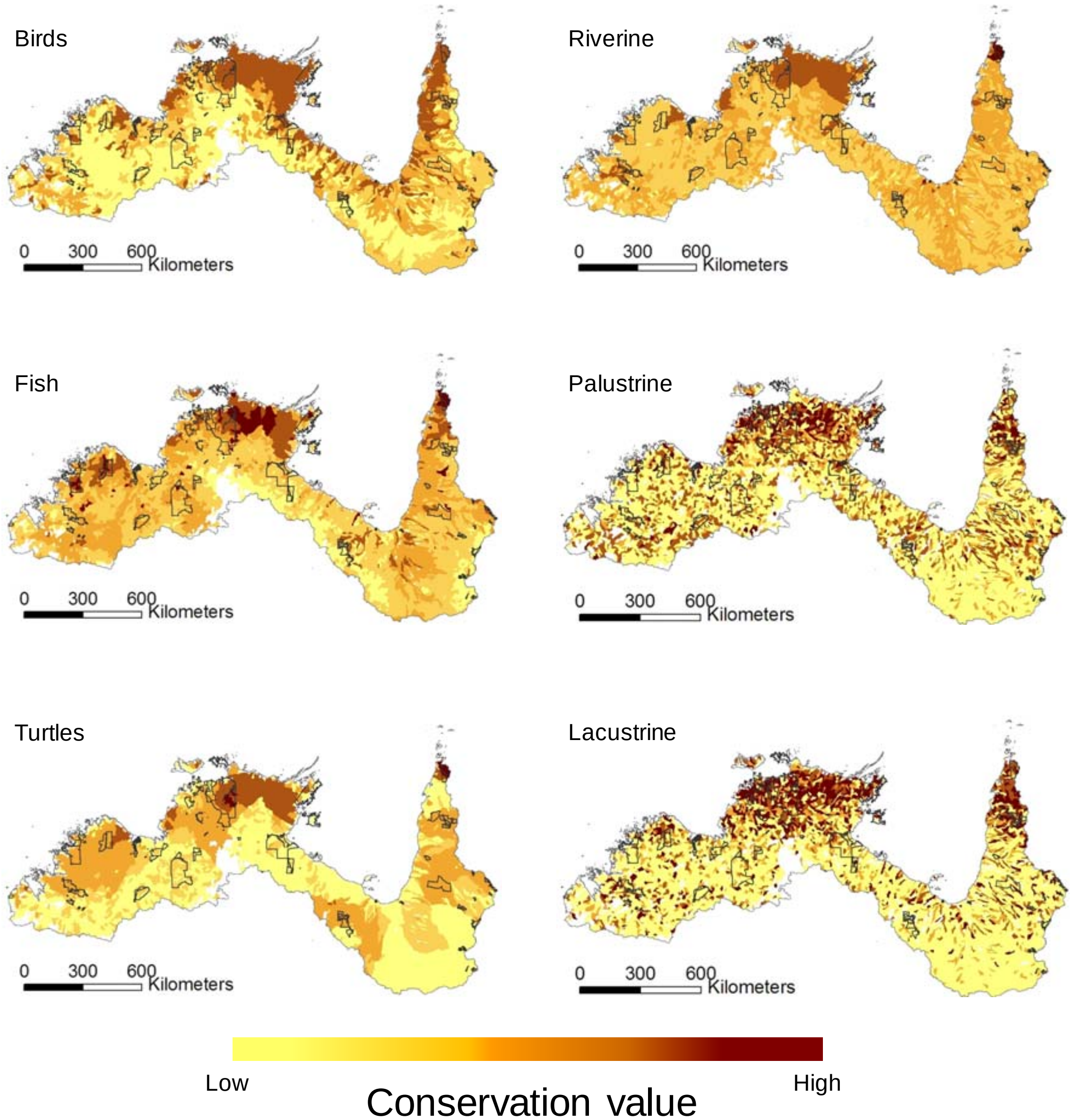


Figure 3.19. Relative conservation value of planning units in northern Australia identified using a systematic conservation planning algorithm. Relative conservation value represents the number of times that each planning unit was included in the best solution after 100 runs. High values indicate highly irreplaceable areas, which were necessary most of the time to achieve the conservation goal of representing of all taxa at specified distribution target levels for each biodiversity surrogate group. The solutions are averaged across four targets levels for each taxon ($10km^2$, $100km^2$, $1000km^2$, $10,000km^2$).

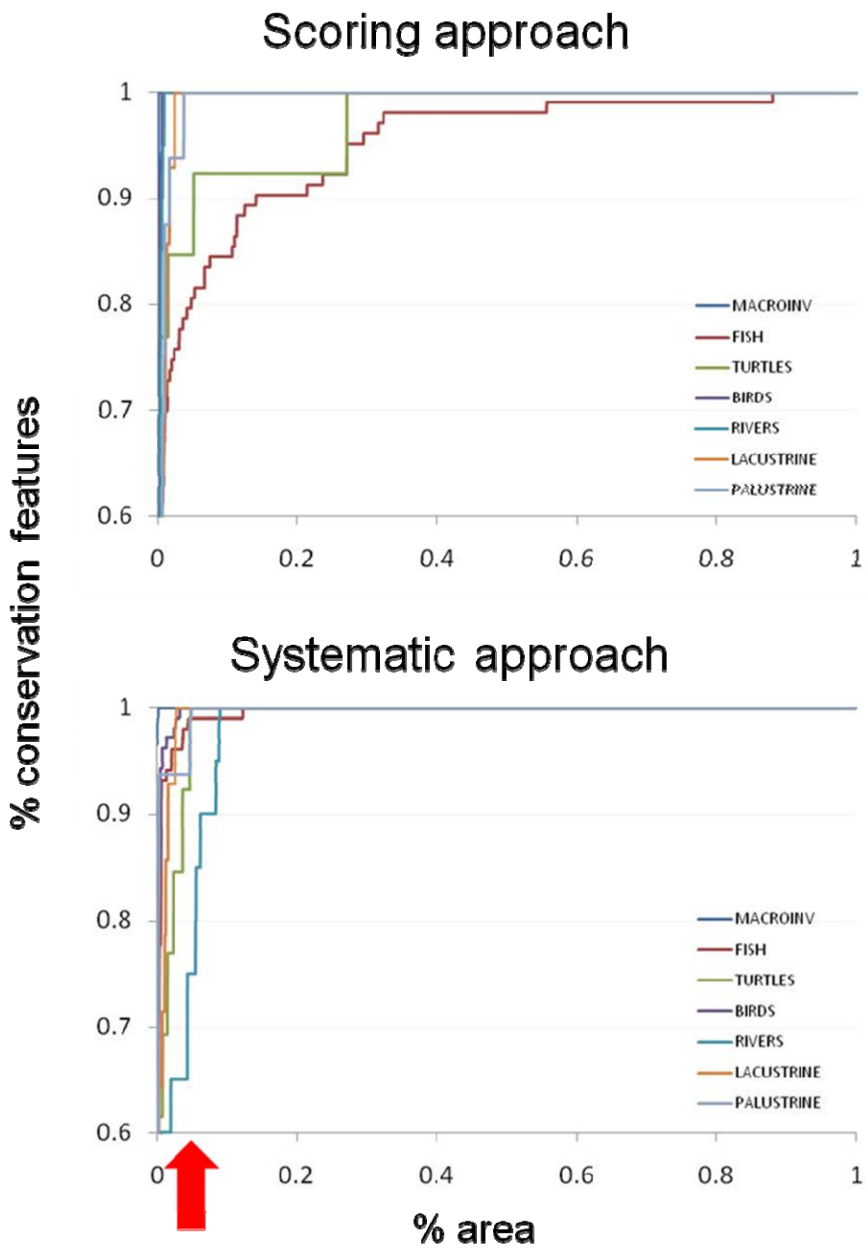


Figure 3.20. Accumulation rate of species representation across planning units ranked according to their conservation value. The current proportion of total area reserved (CAPAD 2006) is also indicated with an arrow (5%).

3.7 Identifying a subset of HCVAE of potential national significance to facilitate the management of HCVAE for broader NRM outcomes

The unique nature of northern Australia's biodiversity and the distinctiveness of its aquatic ecosystems are described in detail in the chapter on aquatic ecosystems prepared for the Northern Australia Land and water taskforce Science Review 2009 (Pusey & Kennard 2009). In addition, northern Australian wetlands of potential outstanding significance to the nation for their natural heritage values were identified and reported (see Section 4.2 for summary of this process and refer to Appendix 8.3 – Whalen (2010) for a full description and listing of candidate areas).

Using the HCVAE Framework to identify of a subset of HCVAE of potential national significance is difficult without undertaking an objective assessment that includes all of Australia. This was well beyond the scope of the present project. However, given the enormous spatial scale of the broad-scale HCVAE assessment area applied in Kennard (2010) (total land area of about 1.19 million km^2; encompassing about 15% of the Australian continental area and spanning Western Australia, the Northern Territory and Queensland), it might be reasonable to argue that the HCVAEs identified at the broadest reporting scale (i.e. across the entire study region) are of national significance. This is particularly so given that many water-dependent species and aquatic ecosystem types present in northern Australia do not occur anywhere else. Using this philosophy, a subset of potential HCVAEs of national significance (defined as planning units having met two or more Framework criteria at the 99^{th} percentile threshold for the reporting scale of the entire study region) are listed in Table 3.4.

Table 3.4. HCVAEs of potential national significance defined as planning units having met two or more criteria at the 99th percentile threshold at the reporting scale of the entire study region in northern Australia. The numeric code of each planning unit (PU), and the drainage division (DD), NASY region (RG) and AWRC river basin in which they occur is listed. Also shown are the major named hydrosystems occurring within each planning unit. Hydrosystem codes are: riverine (R), lacustrine (L), palustrine (P) and springs (S). For each planning unit and each reporting scale, the individual criteria met (1) and the total number met (∑) are also shown. Criteria are: (1) Diversity, (2) Distinctiveness, (3) Vital habitat, (4) Evolutionary history, (5) Naturalness, (6) Representativeness. Note: due to the limitations of the HCVAE Framework identified during this project, the project team does not recommend that this list be used to guide any future investment decisions (e.g. management of areas for broader natural resource management outcomes).

					Entire study region						
					Criteria						
PU	DD	RG	AWRC	NAMED HYDROSYSTEMS	1	2	3	4	5	6	∑
3	GC	1	Jardine	SANAMERE LAGOON(L), BIFFIN SWAMP(P), COWAL CREEK(R), ELIOT CREEK(R), JARDINE RIVER(R)	1		1	1			**3**
170	GC	1	Wenlock	GIBSON WATERHOLE(P), WENLOCK RIVER(R)	1		1				**2**
583	GC	1	Archer	TIMINIE CREEK(L), ARCHER RIVER(R), EAST ARCHER RIVER(R), WEST ARCHER RIVER(R)	1		1				**2**
721	GC	1	Archer	ARCHER RIVER(L), BOUYEL LAKE(L), TEA TREE LAGOON(L), ARCHER RIVER(R)	1		1				**2**
992	GC	1	Holroyd	HOLROYD RIVER(R), KENDALL RIVER(R)	1		1				**2**
1232	GC	2	Coleman	EDWARD RIVER(R)			1	1			**2**
1362	GC	2	Coleman	COLEMAN RIVER(R)				1		1	**2**
1391	GC	2	Coleman	CATTLE SWAMP(L), COLEMAN RIVER(R), STAN LAGOON(R)	1			1		1	**3**
1433	GC	2	Coleman	MALAMAN CREEK(R)	1			1			**2**
1410	GC	2	Coleman	SWORDFISH HOLE(L), COLEMAN RIVER(R), LIGHTNING CREEK(R), MALAMAN CREEK(R)	1	1					**2**
1498	GC	2	Coleman	COLEMAN RIVER(R)	1			1			**2**
1695	GC	2	Mitchell	MOSQUITO WATERHOLE(L), CROSBIE CREEK(R), EIGHT MILE CREEK(R)	1					1	**2**
2026	GC	2	Mitchell	BURRUM CHANNEL(R), MITCHELL RIVER(R)	1			1			**2**
2036	GC	2	Mitchell	CHRISTMAS WATERHOLE(L), SCRUTTON RIVER(R)	1			1			**2**
3325	GC	2	Gilbert	BANCROFT WATERHOLE(L), BIRD WATERHOLE(L), BLACKFELLOW LAGOON(L), BULLOCKY LAGOON(L), COBBLE LAGOON(L), WOMBIES LAGOON(L), BULL_SWAMP_DAM(P), FOUR_MILE_SWAMP(P), FREDS_LAGOON(P), GALAH_WATERHOLE(P), GREEN_SWAMP_DAM(P), NINE_MILE_LAGOON(P), OLD_STATION_ WATERHOLE(P), PLUM_HOLE(P), TWO_MILE_WATERHOLE(P), SMITHBURNE_RIVER(R)	1	1					**2**
4739	GC	2	Norman	WILSONS LAGOON(L), CLARA RIVER(R), MAY LAGOON(R), NORMAN RIVER(R)		1				1	**2**
3930	GC	2	Flinders	PIDGEON WATERHOLE(L), UHRS LAGOON(L), BYNOE WATERHOLE(P), BYNOE RIVER(R), FLINDERS RIVER(R)	1	1					**2**
4633	GC	2	Flinders	FLAT HOLE CHANNEL(R), FLINDERS RIVER(R)		1				1	**2**
4730	GC	2	Flinders	TEATREE WATERHOLE(L), CLONCURRY RIVER(R), FLINDERS RIVER(R), SANDY CREEK(R), IANS SPRING(S)		1				1	**2**
4732	GC	2	Flinders	FLAGSTONE WATERHOLE(L), MCDOUGALLS WATERHOLE(L), MONKEY WATERHOLE(L), FLINDERS RIVER(R)		1		1			**2**
5271	GC	2	Flinders	FIFTY FOUR WATERHOLE(L), WASHPOOL LAGOON(L), CAROLINE CREEK(R), CLONCURRY RIVER(R), FLINDERS RIVER(R)		1		1			**2**
3833	GC	2	Nicholson	GIN ARM CREEK(R), NICHOLSON RIVER(R)	1			1			**2**
4120	GC	2	Nicholson	BEAMES BROOK(R), ONE MILE CREEK(R)				1		1	**2**
4353	GC	2	Nicholson	BEAMES BROOK(R), CARTRIGE CREEK(R), FOUR MILE CREEK(R), GREGORY RIVER(R), MACADAM CREEK(R), MILLAR CREEK(R), RUNNING_CREEK(R)	1	1					**2**
4347	GC	2	Nicholson	ARCHIE CREEK(R), GREGORY RIVER(R), WILLIS WATERHOLE(R)		1		1			**2**
4330	GC	2	Nicholson	POLEYS LAGOON(L), LAWN HILL CREEK(R)						1	**1**
824	GC	3	Roper	MAINORU RIVER(R)						1	**1**
1092	GC	3	Roper	PANIPANIN WATERHOLE(L), WONMURRI WATERHOLE(L), WARIEJAL WATERHOLE(P), PHELP RIVER(R)	1					1	**2**
1318	GC	3	Roper	LOMARIEUM LAGOON(L), NULLAWUN LAGOON(P), ROPER RIVER(R)			1			1	**2**
156	TS	4	East Alligator	MANJDJALANJARRK (UNAWAHLURK BILLABONG)(L), WOELK (RED LILY LAGOON)(L), EAST ALLIGATOR RIVER(R)	1		1				**2**
186	TS	4	East Alligator	COONJIMBA BILLABONG(L), GURNDURRK (CORNDORL WATERHOLE)(P), MAGELA CREEK(R)	1	1		1			**3**
198	TS	4	East Alligator	TIN CAMP CREEK(R)	1		1				**2**
222	TS	4	East Alligator	EAST ALLIGATOR RIVER(R)	1				1		**2**
311	TS	4	South Alligator	GURDURUNGURANJDJU (ALLIGATOR BILLABONG)(L), UNG.GURLINJ (LEICHHARDT BILLABONG)(L), AMBARRAWARRKU(P), DJUNDA (RED LILY BILLABONG)(P), NGARRABABA (BUCKET BILLABONG)(P), SOUTH ALLIGATOR RIVER(R)	1	1	1	1			**4**
328	TS	4	South Alligator	NOURLANGIE CREEK(R)	1	1		1			**3**
348	TS	4	South Alligator	NOURLANGIE CREEK(R)	1	1		1			**3**
375	TS	4	South Alligator	NAMARRGON CREEK(R), NOURLANGIE CREEK(R)		1				1	**2**
356	TS	4	South Alligator	DEAF ADDER CREEK(R), NOURLANGIE CREEK(R)	1	1		1		1	**4**
363	TS	4	South Alligator	JIM JIM BILLABONG(L), JIM JIM CREEK(R), SOUTH ALLIGATOR RIVER(R)	1	1		1			**3**
373	TS	4	South Alligator	YIRRIRRI(L), BARRAMUNDIE CREEK(R), SOUTH ALLIGATOR RIVER(R)		1		1			**2**
358	TS	4	South Alligator	GURDURUNGURANJDJU (ALLIGATOR BILLABONG)(L), JIM JIM CREEK(R), SOUTH ALLIGATOR RIVER(R)		1		1			**2**
372	TS	4	South Alligator	SOUTH ALLIGATOR RIVER(R)		1		1			**2**
402	TS	4	South Alligator	BARRAMUNDIE LAGOON(P), BARRAMUNDIE CREEK(R), SOUTH ALLIGATOR RIVER(R)		1		1			**2**
401	TS	4	South Alligator	SOUTH ALLIGATOR RIVER(R)		1		1			**2**
407	TS	4	South Alligator	ANBALAWALA(L), GALURRUYU(L), JIM JIM CREEK(R)	1	1		1			**3**
416	TS	4	South Alligator	DEAF ADDER CREEK(R)		1		1	1	1	**4**
516	TS	4	South Alligator	LONG BILLABONG(P), COIRWONG (GOWONJ) CREEK(R), SOUTH ALLIGATOR RIVER(R)	1	1		1		1	**4**
457	TS	4	South Alligator			1			1		**2**
470	TS	4	South Alligator	JIM JIM CREEK(R)		1				1	**2**
506	TS	4	South Alligator			1				1	**2**
172	TS	4	Mary	PALM LAGOON(L), MARY RIVER(R)			1	1			**2**
300	TS	4	Mary		1		1				**2**
444	TS	4	Mary	MCKINLAY RIVER(R)	1					1	**2**
339	TS	4	Adelaide	LAKE BENNETT(L), HEATHERS LAGOONS(P), ADELAIDE RIVER(R)	1					1	**2**
707	TS	5	Daly	NANCAR BILLABONG(L), RED LILY LAGOON(L), CHILLING CREEK(R), DALY RIVER(R)	1	1	1	1			**4**
767	TS	5	Daly	CHILLING CREEK(R), DALY RIVER(R), MULDIVA CREEK(R)	1	1		1		1	**4**
811	TS	5	Daly	HOT WATER BILLABONG(L), DALY RIVER(R), FISH RIVER(R)	1	1		1			**3**
1830	TS	5	Pentecost	MOOCHALABRA DAM(L), KING RIVER(R), WEST ARM(R)	1		1			1	**3**
1897	TS	5	Ord	OLD STATION BILLABONG(P), ORD RIVER(R)	1					1	**2**
3972	TS	7	Fitzroy	JORDAN POOL(L), LAKE ALMA(L), LAKE SKELETON(L), LULIKA POOL(L), FITZROY RIVER(R), MINNIE RIVER(R)	1			1			**2**

4. FINE-SCALE ASSESSMENT AND PRIORITISATION OF REGIONAL AQUATIC ECOSYSTEM ASSETS IN NORTHERN AUSTRALIA

(MARK KENNARD)

4.1 BACKGROUND

In collaboration with the State and Territory jurisdictions and DSEWPaC, the project team has held a series of regional expert panel workshops. The purpose of these workshops was to undertake fine scale assessments for key focal regions (or specific catchments) identified by jurisdictions as high priority or planned development areas. The fine scale assessment had a number of key aims including to identify high priority aquatic ecological assets and understand ecological thresholds in relation to flow regimes and maintenance of aquatic ecosystem assets.

In undertaking the fine scale assessments, the following approach was applied:

- For the Gulf of Carpentaria Drainage Division, work cooperatively with the Queensland Government Department of Environment and Resource Management (DERM) to utilise AquaBAMM and Queensland Wetland Mapping to identify and assess HCV assets and ecological thresholds in focal Gulf catchments.
- For the NT Arafura Sea portion of the Timor Sea Drainage Division, work cooperatively with NT Government Department of Natural Resources, Environment, The Arts and Sport (NRETAS) to identify and assess HCV assets in the Daly River catchment and possibly other high conservation value areas (i.e. contributing to ongoing work with the "Sites of Conservation Significance" project).
- For the Kimberley portion of the Timor Sea Drainage Division, work cooperatively with National Heritage Assessment section of DSEWPaC (e.g. using the Australian Natural Heritage Assessment Tool – ANHAT) as well as the Western Australian Government Department of Environment and Conservation (e.g. through the Kimberley Science and Conservation Strategy).

A summary of the outcomes of these fine scale assessments and workshops is presented below and full reports are presented in Appendices 8.3 – 8.6 and Rollason & Howell (2010).

4.2 Workshop on Natural National Heritage Values of Wetlands in Northern Australia

Refer to Appendix 8.3: Whalen, A. (2010) Report on the Workshop on Natural National Heritage Values of Wetlands in Northern Australia. Natural Heritage West, Heritage Division, Department of Sustainability, Environment, Water, Population & Communities.

The Department of Sustainability, Environment, Water, Population & Communities (DSEWPaC) (in collaboration with the project team) held an experts' workshop on the Natural National Heritage Values of Wetlands in Northern Australia at Charles Darwin University on the 22-23 March 2010. The workshop identified northern Australian wetlands of potential outstanding significance to the nation for their natural heritage values. Wetlands have been identified as an Australian Heritage Council theme of priority, arising out of the Council's need to compare wetlands found in the Kimberley region (as part of an ongoing National Heritage assessment) to other wetlands in northern Australia. The information gained from the workshop will also be used to help assess future National Heritage nominations that include natural wetland values.

The Workshop was attended by a range of scientists and government representatives with expertise in natural wetlands values. The attendance of several researchers from the CERF funded Tropical Rivers and Coastal Knowledge (TRaCK) research hub, whose research has had a specific focus on northern Australian river systems, was of particular benefit. Discussions at the workshop drew on other existing Australian Government water initiatives, including the High Conservation Value Aquatic Ecosystems (HCVAE) framework and the Northern Australia Water Futures Assessment, both of which are currently being developed by DSEWPaC.

The workshop identified in excess of 40 wetland/river sites across northern Australia that may possess natural National Heritage values. From workshop discussions, this list of 40 was shortlisted by consensus to 13 sites (listed in Table 4.1) considered to rank highly, potentially possessing significant values against the National Heritage List criteria.

It should be noted that this shortlist does not represent a final determination of northern Australian wetlands for future National Heritage listing. The data and expertise available at the workshop was not comprehensive and more information may be required to establish the natural heritage significance and values of wetlands across northern Australia. It is recognised that consultation would be undertaken with owners, occupiers and those with Indigenous rights or interests before any of these wetlands are added to the National Heritage list.

The shortlist will be used in the short term to inform the significance of wetlands of the Kimberley region as compared to other Australian wetlands, particularly with regard to refugial values and migratory birds. Longer term, information about the values of places on the shortlist will be supplemented by additional information as new research is completed across northern Australia, particularly work undertaken by the TRACK program (it was also noted, for example, that additional genetic work on fish populations in preparation may assist the comparison of the relative significance of river systems). The shortlist is seen as the beginning of the Australian Heritage Council's work in identifying wetland values of outstanding value to the nation.

Table 4.1. Shortlisted wetlands in Northern Australian with the most obvious potential for possessing national heritage values. For more details and rationale on selected wetlands refer to Appendix 8.3 – Whalen (2010).

State	Wetland	Aquatic ecosystem types
QLD	• **Cape Flattery/Bedford dune lake system**	*lacustrine, riverine, palustrine*
QLD	• **Jardine River & Newcastle Bay** • **Escape River Estuarine Complex**	*aggregation*
QLD	• **Normanby River floodplain**	*aggregation*
QLD	• **Olive River**	*aggregation*
NT	• **Arnhem Plateau** (i.e. rivers draining the plateau –Roper, Blythe, Liverpool, Goomadeer, East & South Alligator, Mary, Daly-Katherine, Mann) • **Warddeken Indigenous Protected Area** (in the Liverpool sandstone plateau country of Arnhem Land)	*springs, lacustrine, riverine, palustrine*
NT	• **Floodplains in the Kakadu area, including the Alligator Rivers**	*aggregation*
NT	• **The Arafura swamp complex**	*aggregation*
NT	• **Lower Douglas-Daly floodplain**	*aggregation*
WA	• **Paruku wetlands - Lake Gregory**	*lacustrine, palustrine*
WA	• **Roebuck Plains system** (Roebuck Bay and inland wetlands)	*palustrine, coastal*
WA	• **Eighty-mile Beach** • **Karajarri (La Grange) groundwater dependent ecosystems** (Walyarta (Mandora Marsh), McLarty Hills, Kurrijipa yajula (Dragon Tree Soak), Lunyirrkartiny (Munroe Springs), Whistle Ck, Injindina Springs etc.)	*palustrine, coastal*
WA	• **Dampier Peninsula mound springs and wetlands** (Bunda Bunda, Willie Creek, Carnot Bay, Disaster Bay, Pender Bay etc)	*springs, coastal*
WA	• **Mitchell, King Edward and Drysdale rivers** • **Prince Regent River** (including Roe and Moran Rivers)	*aggregation*

4.3 Workshop on Fine Scale Assessment of High Conservation Value Aquatic Ecosystems and Ecological Thresholds in the Daly River, Northern Territory

Refer to Appendix 8.4: Petit, N., Close, P. & Kennard, M. (2010) Fine Scale Assessment of High Conservation Value Aquatic Ecosystems and Ecological Thresholds in the Daly River, NT. Summary of NRETAS/TRaCK expert panel workshop held in Darwin, 14 September 2010.

A one day workshop was held at Charles Darwin University on the 14th September 2010 to complement the broad-scale assessment under the Northern Australia Aquatic Ecological Assets project. This workshop would undertake a fine scale assessment of High Conservation Value Aquatic ecosystems (HCVAE) for the Daly River catchment as a key focal region, with the aim of identifying specific ecological assets and understanding their ecological thresholds in relation to flow regimes and the maintenance of aquatic ecosystem assets. The structure of the workshop included a number of presentations in the morning session that provided background information on the HCVAE project and set the scene for group discussions in the afternoon session (see Appendix 2). The principal aim of the group discussion session in the afternoon was to identify local scale assets that occur within the Daly River catchment (e.g. lower floodplain, middle and upper reaches) that were identified as HCVAEs through the broad-scale assessment and other assessments.

The concept of ecological thresholds was discussed in detail in the morning session and was defined as the point at which a small or abrupt change in a driver may produce a large response in the ecosystem (or component). The use and application of thresholds to management is receiving substantial research interest. The ability to predict thresholds is important because of their influence on ecosystem services valued by humans. However, thresholds cannot always be clearly defined and ecological responses may lag behind the threshold timing. A key question in relation to these concepts is whether natural variability can be separated from a threshold response to some degree of anthropogenic change and whether thresholds can be used to trigger a management response. The relationship between “drivers” and “ecological responses” were discussed in relation to the identification of thresholds to trigger management actions. Multiple stressors such as climate change, invasive species, landuse, fire etc may constrain the usefulness of thresholds to trigger management actions. Given these difficulties in predicting thresholds and ecological responses and the general lack of data or ecological knowledge to address this issue in northern Australia, a precautionary approach to ecosystem management is probably most prudent.

The afternoon session also aimed to evaluate the ecological value and connectivity between these assets and identify ecological thresholds relevant to three key zones in the Daly River catchment (Fig 4.1).

Lower floodplain | Middle reaches | Upland

Figure4.1. Example high conservation value aquatic ecosystem types from three key zones within the Daly River catchment (the lower Daly River floodplain, the Daly River middle reaches and the Upper Katherine River).

For the lower Daly floodplain, refugial waterholes, bird nesting areas and riparian forest were important assets as well as small creeks that provide connectivity between the main river channel and the floodplain and waterholes. The workshop suggested that some assets on the floodplain need to be managed at variable spatial and temporal scales and that the ability of water-dependent biota to move between habitats is a key ecological process. For the middle reaches, it was important to consider not just the main channel but tributaries and off-channel waterholes, including palustrine waterbodies. Low-water riffle habitats are considered a critical asset in the middle reaches, partly due to their scarcity and their importance for aquatic productivity and habitat values. Reduction in dry season flows is likely to be the biggest impact on the ecological assets of the middle reaches because of the effect on riffle areas as well as potentially reduced longitudinal connectivity. The upper Katherine River encompasses the high elevation stone country of Arnhem Plateau where there are many high gradient cascades and waterfalls that reduce connectivity. Consequently there is a high level of endemism of fish and genetically distinct fish species. There are also distinctive off-stream palustrine wetland areas about which there is a general lack of information.

The principal outcome of the workshop was that there should be more concentration on the identification of fine-scale values, rather than the identification of ecological thresholds. Once fine-scale values have been identified, the discussion can then be broadened to include consideration of ecological thresholds if appropriate.

4.4 Aquatic Conservation Assessment using AquaBAMM for the Southern Gulf of Carpentaria, Queensland

Refer to Rollason, S.N. & Howell, S. (2010). Report: Aquatic Conservation Assessments (ACA), using AquaBAMM, for the non-riverine, riverine and estuarine wetlands of the Southern Gulf of Carpentaria (version 1.1 draft). Published by the Department of Environment and Resource Management, Brisbane.

The Aquatic Biodiversity Assessment and Mapping Method or AquaBAMM (Clayton et al. 2006), was developed to assess conservation values of wetlands in Queensland, and may also have application in broader geographical contexts. It is a comprehensive method that uses available data, including data resulting from expert opinion, to identify relative wetland conservation/ecological values within a specified study area (usually a catchment). The product of applying this method is an Aquatic Conservation Assessment (ACA) for the study area.

An ACA using AquaBAMM is non-social, non-economic and identifies the conservation/ecological values of wetlands at a user-defined scale. It provides a robust and objective conservation assessment using criteria, indicators and measures that are founded upon a large body of national and international literature, in combination with novel ideas from the developmental team. The criteria, each of which may have variable numbers of indicators and measures, are naturalness (aquatic), naturalness (catchment), diversity and richness, threatened species and ecosystems, priority species and ecosystems, special features, connectivity and representativeness. An ACA using AquaBAMM is a powerful decision support tool that is easily updated and simply interrogated through a geographic information system (GIS).

Where they have been conducted, ACAs can provide a source of baseline wetland conservation/ecological information to support natural resource management and planning processes. They are useful as an independent product or as an important foundation upon which a variety of additional environmental and socio-economic elements can be added and considered (i.e. an early input to broader 'triple-bottom-line' decision-making processes).

An ACA can have application in:

- determining priorities for protection, regulation or rehabilitation of wetlands and other aquatic ecosystems
- on-ground investment in wetlands and other aquatic ecosystems
- contributing to impact assessment of large-scale development (e.g. dams)
- water resource and strategic regional planning processes
- providing input to broader social and economic evaluation and prioritisation processes.

The Queensland Department of Environment and Resource Management (DERM) conducted ACAs using AquaBAMM for the non-riverine (i.e. palustrine and lacustrine) and riverine freshwater wetlands in three catchments of the Southern Gulf of Carpentaria. This project was conducted in collaboration with Griffith University (as part of the Tropical Rivers and Coastal Knowledge (TRaCK) program) and forms a part of the Northern Australia Aquatic Ecological Assets Project, a project under the Northern Australia Water Futures Assessment (NAWFA). Under the Ecological Assets Project, a trial of the High Conservation Value Aquatic Ecosystems (HCVAE) framework was conducted and fine scale assessments were subsequently completed in each state for key focal areas (or catchments).

In Queensland, DERM worked cooperatively with TRaCK project managers at Griffith University to undertake a fine scale assessment for three Queensland catchments—Flinders, Norman and Gilbert. This fine scale assessment used AquaBAMM and the Queensland Wetland Mapping to assess conservation values and priorities for riverine, non-riverine and estuarine wetlands in the Flinders, Norman and Gilbert catchments and produce an ACA.

In effect, there are six ACAs covering the region (one non-riverine and one riverine ACA for each of the three Southern Gulf of Carpentaria catchments). AquaBAMM uses combinations of criterion level scores to determine a wetland's final AquaScore and, based on these combinations, the following descriptions provide context for each AquaScore value category:

"Very high" wetlands:

These wetlands have very high values across all criteria (aquatic naturalness, catchment naturalness, diversity & richness, threatened species, special features and representativeness), or they have very high representativeness values in combination with very high aquatic naturalness, catchment naturalness or threatened species values. They may also be wetlands nominated by an expert panel for their very high special feature values, regardless of values across other criteria.

"High" wetlands:

These wetlands are mainly those that have very high aquatic naturalness or representativeness values in combination respectively with very high/high threatened species values or very high diversity and richness values. Other combinations of very high or high values amongst the criteria may also indicate one of these wetlands.

"Medium" wetlands:

These wetlands have varied combinations of high and medium values amongst the criteria.

"Low" wetlands:

These wetlands have limited aquatic and catchment naturalness values. They have varied combinations of medium and low values amongst the other criteria.

"Very low" wetlands:

These wetlands have very limited or no aquatic and catchment naturalness values and they lack any other known significant value. They may also be wetlands that are largely data deficient.

Examples of the outcomes of the ACA assessments for non-riverine and riverine wetlands for all three catchments are provided in Figures 4.2 and 4.3. An estuarine ACA was also attempted in the region although time and resources restricted the completion of the assessment within the given timeframes. However, it is anticipated that an estuarine ACA for the Southern Gulf of Carpentaria will be completed in the near future.

It is important to note that when conducting the non-riverine and riverine ACAs it was identified that there are issues surrounding the completeness and accuracy of the regional ecosystem and wetlands mapping in the Southern Gulf of Carpentaria. Additionally, concern was expressed over the lack of knowledge and significant data gaps within the study area by experts engaged in the process. For these reasons, the results outlined within this report are being treated as draft ACAs. DERM acknowledges that an improvement in the regional ecosystem and wetlands mapping and an increase in knowledge is required in order to improve the outcomes of ACAs in the Southern Gulf of Carpentaria.

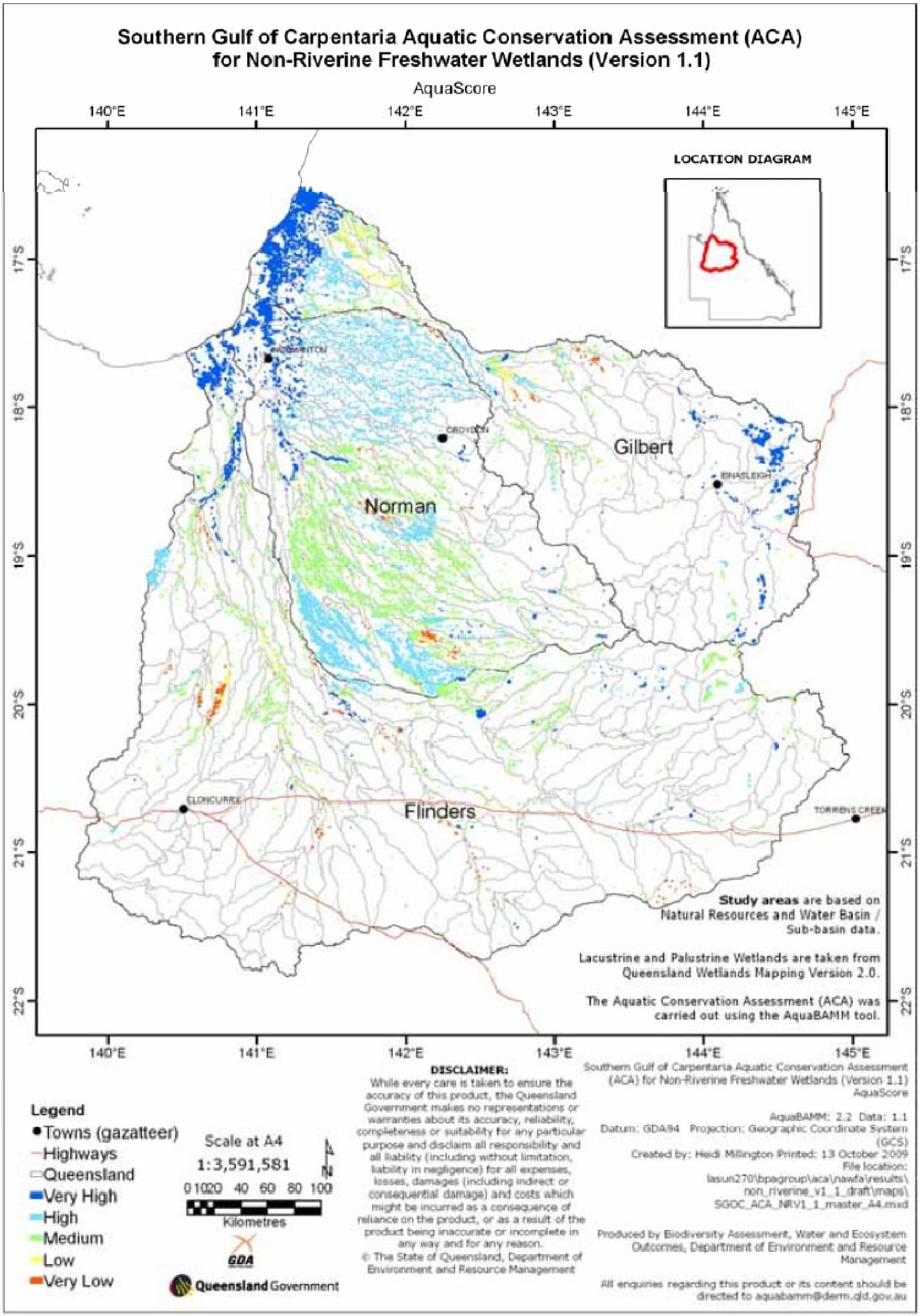


Figure 4.2. Non-riverine AquaScore for all catchments.

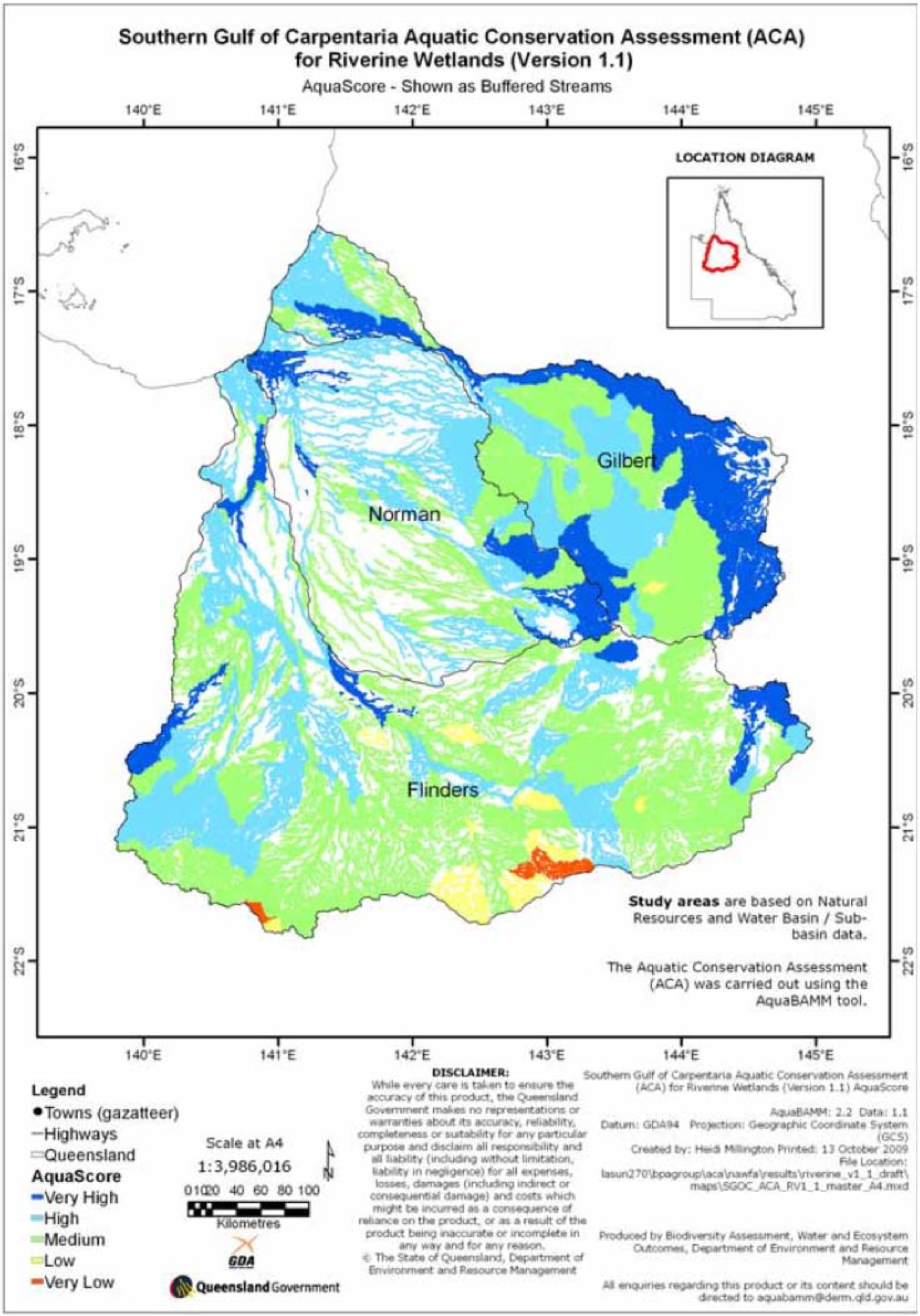


Figure 4.3. Riverine AquaScore for all catchments (coloured by buffered stream network)

4.5 Ecological Thresholds Workshop for the Gilbert, Flinders and Norman River Catchments, Southern Gulf of Carpentaria, Queensland

Refer to Appendix 8.5: Clayton, P. & Talbot L. (2010). Ecological Thresholds Workshop Outcomes Gilbert, Flinders and Norman River Catchments. RPS Report for the Department of Environment and Resource Management, Brisbane.

In Queensland, the Department of Environment and Resource Management (DERM) has been working cooperatively with project managers from the NAWFA project team at Griffith University to undertake an Aquatic Conservation Assessment (ACA), using the Aquatic Biodiversity Assessment and Mapping Method (AquaBAMM) and the Queensland Wetland Mapping, to assess aquatic conservation priorities for the Flinders, Norman and Gilbert catchments (Rollason & Howell 2010). With this foundation of identified aquatic ecological priorities and assets, plus hydrological and flows information available through the Queensland's Water Resource Planning process, an "ecological thresholds workshop" was held in Brisbane on Thursday 28th October 2010. Experts from across the state with direct technical knowledge or experience related to the target region attended the workshop.

The aim of the workshop was to conduct preliminary investigations on understanding ecological thresholds in relation to flow regimes and the maintenance of aquatic ecosystem assets for the Gilbert River, Norman River and Flinders River catchments. The workshop aimed to review existing information, collate flow and ecological factors pertinent to the understanding of conceptual flow models, identify data gaps and propose a way forward for subsequent stages of the EAP and NAWFA. Specifically, the workshop had the following aims:

- Discuss the usefulness (strengths and weaknesses) of the HCVAE process as it relates to thresholds;
- Review the aquatic ecosystem assets and priorities identified through the DERM ACA process;
- Review hydrological and water resources information;
- Agree on local scale assets (e.g. particular floodplain lakes, and wetlands, riverine reaches, ecological processes, species, communities, etc) that require focus through the workshop;
- Consider flow-related threats to the ecological assets in all target catchments;
- Where possible, discuss ecological thresholds and 'limits of acceptable change' in relation to the identified assets and threats.
- Identify data gaps that diminish our contemporary understanding of ecological thresholds and potential management options for this geographic region; and
- Make recommendations for the next stages of the EAP and NAWFA.

Aquatic ecological assets (both locations and critical processes) were agreed by consensus, and flow-related threats to these assets were identified. This outcome is a useful contribution to the next stages of EAP and NAWFA.

It was clear that the greatest impediment to quantifying ecological thresholds is an immature technical understanding of most of the assets, and of the mechanisms and consequences of the flow-related threats. Future effort should be focussed on filling these data gaps with fine-scale assessment and investigation for this geographic area; however, the distillation of assets and threats at the catchment scale through this workshop has provided a way forward for the EAP.

The main outcomes of the workshop are summarised in the following statements or recommendations:

1) 'Assets' in this context include high priority location-based spatial units as well as critical ecological processes.
2) Do not singularly rely upon HCVAE or ACA output to drive ecological threshold debate. High value spatial units are important but an equal/balanced focus on ecological processes and connectivity is important.
3) In the same way that aquatic ecological function and landscape connectivity may be mistakenly ignored where debate focuses only on high value spatial units, significant ecosystems and discrete high value parts of the landscape may be mistakenly ignored where debate focuses only on aquatic ecological process. Both types of aquatic ecology asset need consideration.
4) In fragmented or more developed catchments/landscapes, emphasis on high value spatial units is likely to be more appropriate. However, in 'intact' or less developed catchments/landscapes, such as those in northern Australia, emphasis on critical ecological process and function may provide greater opportunity to ensure sustainable outcomes. A shift in emphasis may be important, depending on ecosystem context, when investigating ecological thresholds and water resource management but it is certain that a holistic multi-scale approach is necessary.
5) For the Gilbert River, Norman River and Flinders River, critical ecological processes are satisfactorily captured as a result of work in the WRP process.
6) Flow-related threats to aquatic assets are understood in both a generic sense and, in a small number of cases, a detailed technical sense.
7) Data and technical understanding are insufficient to develop current notions of asset and threat into ecological threshold and planning outcome. More work is required but this workshop outcome provides a way forward.
8) Do not assume that the importance of balancing consideration of critical ecological processes and high priority spatial units means that mapping of high priority spatial units is less important in its own right. While scientists generally look at process and connectivity, mapping of high priority assets is important to planners (in particular) and provides frameworks for action where knowledge gaps prevent timely understanding of process.
9) There are many data gaps and deficiencies in our technical understanding if the objective is to quantify ecological thresholds in these northern Australian ecosystems. For a small number of flow-related threats identified in this workshop, however, further steps may be possible where interpretation and assessment relies on data we do have such as gauged hydrological data, flood modelling data, or water quality data.

As indicated in the last statement above, there are some flow-related threats and potential water resource management options that are supported by a relatively greater amount of data and a relatively better technical understanding of process. The workshop reached consensus that, although the majority of threats require much further work, a small number may better placed for progression toward quantification of ecological thresholds as a subsequent stage of the EAP and NAWFA.

The following flow-related threats were considered in this category:

- Threats associated with tailings dam and dam management in relation to flood events.
- Threats that can be linked to rules already established in the WRP and ROP for the region and that can be modelled relative to existing model nodes.
- There are lessons to be learned from work across the Gulf region. For example, threats that can be interpreted and extrapolated by detailed analysis of IQQM modelling and pre and post development data (e.g. fisheries data is available for the Leichardt River, which is the adjoining catchment to the west of the Flinders, prior to dams being constructed which could be used to interpret and extend understanding by comparison post-construction of dams).
- Threats that relate to bulk flow characteristics and water harvesting.

4.6 Fine Scale Assessment of High Conservation Value Aquatic Ecosystems in the Upper Fitzroy and Mitchell River Catchments of the Kimberley Region, Western Australia

Refer to Appendix 8.6: Close, P., Cossart, R., Petit, N. & Kennard, M. (2010). Fine Scale Assessment of High Conservation Value Aquatic Ecosystems in the Upper Fitzroy and Mitchell River Catchments of the Kimberley Region of Western Australia. Summary of the workshop, held in Kununurra, 11 – 12 November 2010.

A one and a half day workshop was held at the Frank Wise Research Institute (Department of Agriculture and Food, WA) on the 11^{h} and 12th November 2010 to complement the broad-scale assessment of high conservation value aquatic ecosystems under the Northern Australia Aquatic Ecological Assets project. This workshop undertook a fine scale assessment of High Conservation Value Aquatic Ecosystems (HCVAE) for two focal catchments: the upper Fitzroy and Mitchell rivers.

The aim of this workshop was to identify specific ecological assets and associated threats and knowledge gaps. The structure of the workshop included a number of presentations in the morning session that provided background information on the HCVAE project, and Kimberley values and threatening processes to set the scene for group discussions in the afternoon session. The principal aims of the group discussion session in the afternoon was to identify local scale assets that occur within the focal catchments (e.g. lower floodplain, middle and upper reaches) that were identified as HCVAEs through the broad-scale assessment and other assessments.

Six high conservation assets were identified in the Mitchell River catchment, including lagoonal habitats, permanent dry seasonal refugia, seepages and springs and perched, groundwater-dependent wetlands. A variety of threats identified included managed stock, fire and sedimentation. In the Fitzroy catchment, sixteen high conservation assets were identified, including a variety of mid and upper catchment spring fed tributaries and wetlands, large permanent dry season refugia on the Fitzroy main channel and floodplain water holes and swamps. A variety of threats were identified for each asset including managed and unmanaged stock, feral animals, weeds, sedimentation, recreational fishing and tourism.

There was a general consensus that the broad-scale of the assessment of HCVAEs is too broad and provides limited benefit to management and monitoring undertaken by the variety of organizations represented at the workshop (jurisdictions, ranger groups and researchers). Rangers highlighted their interest in applying the data gathered at the workshop into annual work plans, identification of priority areas for weed, feral and fire control and directing future on-ground investment. The rangers also called for the incorporation of indigenous ecological knowledge as an important part of the identification of and sustainable management of aquatic ecosystems across the Kimberley. There was acknowledgement of the consideration of HCVAEs in water allocation planning and determining ecological water requirements. There is also a general need for improved knowledge and mapping of species endemism of aquatic ecosystems across the Kimberley region.

5. Sustainable management of aquatic ecosystems in northern Australia

Mark Kennard, Laura Jardine & Virgilio Hermoso

5.1 Background

In this section we canvas some key challenges for sustainable management of aquatic ecosystems in northern Australia. In particular, we evaluate the usefulness of the concept of ecological thresholds that has been argued can inform environmental management to sustain ecosystem values. Managers of high conservation value areas must achieve a balance between taking conservation action, evaluating the effectiveness of actions taken, and monitoring the general status of biodiversity conservation targets and the threats they face. We review approaches to estimating socioeconomic costs of different management actions and how these can be prioritised in a systematic and hierarchical framework (the concept of multiple management zones). Monitoring is a key component of adaptive management and can inform the decisions of management agencies. Unfortunately however, monitoring practices have generally been poorly connected with decision-making and this has led to an inability to assess the effectiveness or efficiency of the conservation management actions. We therefore present several frameworks to guide if, why, when and how monitoring should be implemented and how the outcomes of the monitoring will feed into adaptive management of aquatic ecological assets.

5.2 Ecological thresholds and alternate stable states in aquatic ecosystems

An ecological threshold refers to the point at which a small or abrupt change in a driver may produce large responses in the ecosystem (or component). The concept emerged in the 1970's from the idea that ecosystems often exhibit multiple ''stable'' states, depending on environmental conditions.

Predicting thresholds is important because they can influence ecosystem goods and services of value to humans. Recovery from a shift to an alternative stable state might not occur until stressor levels are reduced significantly. Thus identifying potential thresholds is seen as an important aspect of managing ecological systems.

Identification of ecological thresholds in relation to flow regimes and maintenance of aquatic ecosystem assets is an extremely challenging task. Ecological responses can range in functional form from no change to linear to curvilinear to threshold, depending on the underlying hydro-ecological mechanisms and, in some cases, on the specific geomorphic context. However, incomplete/uncertain knowledge can preclude the identification of precise ecological thresholds. Recent reviews and case studies have identified a number of challenges and limitations with the usefulness of the thresholds concept to inform environmental management.

Recent reviews and case studies (e.g. Hugget 2005; Lindenmayer & Luck 2005; Groffman et al. 2006; Clements et al. 2010; Dodds et al. 2010; Samhouri et al. 2010) have identified a number of challenges and limitations with the usefulness of the thresholds concept to inform environmental management. For example, thresholds are not always clearly defined or identifiable in many environmental systems, particularly as there is a tendency for ecosystem responses to lag behind changes in controlling variables. This makes it particularly challenging to separate natural ecological responses to long term cycles from anthropogenic changes. The difficulty in identifying precise ecological thresholds also makes it extremely challenging to identify clear reference points (thresholds) that can be used to trigger management actions. Another major difficulty is the ability to identify clear thresholds in a complex world of multiple stressors (e.g. water resource development, climate change, invasive species, land use change, etc).

Given the challenges in predicting thresholds and alternative states, the precautionary approach to ecosystem management is probably the most prudent. In general, a mechanistic understanding of ecological dynamics is required to predict thresholds, where they will occur, and if they are associated with the occurrence of alternative stable states. We lack enough ecological information in most systems to make a priori mechanistic predictions of where thresholds will occur, although a variety of univariate methods have been used to indicate thresholds in ecological data. Management decisions that might cause a system to approach an ecological threshold should be viewed with caution because the alternative state could be costly in terms of economic damages, lost opportunities, and restoration efforts.

For an assessment of ecological thresholds for aquatic ecosystem assets in the Daly River catchment, refer to Appendix 8.4 – Petit et al. (2010). A further investigation to understand ecological thresholds in relation to flow regimes and the maintenance of aquatic ecosystem assets in the Gilbert, Flinders and Norman Rivers of the southern Gulf of Carpentaria, Queensland, is available in Appendix 8.5 – Clayton & Talbot (2010).

5.3 Estimating socioeconomic costs of different management actions

5.3.1 Planning efficiently: Incorporating costs in conservation planning

There are many market and non-market economic benefits to humans of maintaining functionally intact freshwater systems. Conversely, over large geographic areas there are also potentially enormous socioeconomic and ecological costs that can result from impaired systems. Protection will almost always be more economical than restoration, though particular areas may have important conservation values that warrant mitigation of threats and/or restoration (Abell et al. 2007; Linke et al. 2007).

Conservation practices cannot be implemented for free. Different costs are associated with conservation, such as acquisition of land to be protected, implementation of management actions to maintain or restore conservation values or transaction costs, associated with negotiation and economic exchange (Naidoo et al. 2006). Given that conservation usually competes with other human uses, it does not only entail direct implementation costs, but also additional socio-economic implications in the areas under protection. These are called opportunity costs and are a measure of what could have been gained via the next-best use of a resource had it not been put to the current use (e.g., gross economic production of a cropping area if it had to be protected and not cultivated anymore).

The achievement of conservation goals is clearly linked to the ability of conservation plans to incorporate social and economic costs (Carwardine et al. 2008b). The lack of implementation of most conservation plans suggests conservation planners have historically not been concerned with practical factors that will influence implementation, such as the costs of plans (Naidoo et al. 2006). For example, the lack of consideration of costs in the identification of priority areas for global mammal conservation led Ceballos et al. (2005) to find solutions that overlapped with important cropping areas. The efficacy of such a plan would be seriously compromised by the ability to protect the biodiversity in areas with a high opportunity cost. In a recent review of the global mammal assessment Carwardine et al. (2008a) incorporated cost in the identification of priority areas for the global conservation of mammals. They achieved the same biodiversity outcomes as Ceballos et al. (2005) while reducing the opportunity costs and conflicts with agricultural human activity by up to 50%. These kinds of approaches do not only reduce potential conflicts between conservation and economic activities, but also makes them more feasible and easy to attain (e.g., cheaper to implement, thereby enhancing efficiency). Beyond showing efficiency gains, incorporating costs into conservation planning can be used to demonstrate the tradeoffs between obtaining higher levels of a conservation target and the increase in cost necessary to obtain it.

The monetary cost of conservation actions can be used in several ways in conservation planning. In a cost–benefit analysis (Boardman et al., 2005) the costs and the benefits of conservation actions are estimated (in monetary terms), which allows direct comparisons between the real economic cost of implementing the conservation plan and the benefits for the biodiversity that will be protected. However, accurate estimates of economic values of conservation benefits are not easily attained. This is the reason why cost benefit analyses are usually replaced by cost-effectiveness analyses (Naidoo et al. 2006). These analyses use the costs of conservation in monetary terms, but the benefits remain in the original units. Cost-effectiveness analyses try to find the most efficient way of achieving the target goals (how to get the maximum benefit at the minimum cost). The most efficient plan is the one that delivers a given conservation target for the least cost or, alternatively, maximizes the conservation target level for a given cost (Ando et al. 1998). Cost-effectiveness analyses are broadly implemented in systematic conservation planning (Margules and Pressey 2000).

Some studies have considered how the inclusion of spatially explicit information on economic cost can affect the outcomes of conservation planning. For example, Ando et al. (1998) and Polasky et al. (2001) used systematic conservation planning to locate optimal places for land acquisition for conservation in terrestrial ecosystems. Stewart & Possingham (2005), Richardson et al. (2006), and Klein et al. (2008) used similar methods to try to find the most cost-effective way for protecting marine biodiversity while minimising the impact of conservation on local fisheries. These studies share a common point: the consideration of the spatial heterogeneity of conservation costs in the planning process influences the spatial configuration of reserves but it helps achieve conservation goals (protection of biodiversity) in more efficient ways. Despite the broad application of systematic conservation planning in marine and terrestrial ecosystems, relatively few examples exist in freshwater conservation (but see Linke et al. 2007, 2008, 2011; Moilanen et al. 2008; Hermoso et al. 2010a,b) and conservation costs have not yet been effectively addressed in the freshwater realm.

5.3.2 Measures of cost and cost surrogates in conservation planning

Different approaches to estimating and using costs have been used in conservation planning. Given the difficulty in obtaining real monetary cost of conservation actions, surrogates of that cost are commonly used. Among the different surrogates, area is one of the most commonly used in conservation planning. This approach seeks to achieve the conservation targets (e.g., representing all the targeted conservation features, such as species) in the minimum possible area. It is assumed that the lower the area to protect the cheaper it will be to implement the conservation plan. However, a homogeneous cost per area unit is assumed when using area as cost (Naidoo et al. 2006; Carwardine et al. 2008b). This is an oversimplification of the, in some cases, enormous spatial variation in conservation costs (Balmford et al. 2003; Ferraro 2003).

As mentioned above, the consideration of the spatial heterogeneity of conservation costs is essential to achieve conservation targets in the most efficient way. In fact, incorporating the spatial heterogeneity of costs into planning is just as or even more important than incorporating the spatial heterogeneity of environmental benefits in shaping the spatial distribution and configuration of priority areas for conservation (Polasky et al. 2001; Ferraro 2003). This is the one of the reasons why other spatially-explicit non-monetary proxies of cost are often used. Distance to roads (Williams et al. 2003) or human population density (Rouget et al. 2006) are two examples of these non-monetary spatially-explicit surrogates. Although these surrogates do not inform about the real monetary cost of conservation they help to avoid focusing priority areas for conservation in zones where human uses might compromise the long term persistence of biodiversity values [e.g., avoid highly populated areas, as in Rouget et al. (2006)]. In addition, when considering these surrogates, potential conflicts of conservation and human uses can also be reduced (e.g., if high priority areas can be located in areas that are not being intensively used by humans, conservation may be easiest and cheaper to implement). However, a real monetary cost of conservation practice is lacking in these approaches. The use of real estimates is highly desirable not only because of bringing efficiency to conservation planning, but also because it helps to have a clear idea of how much budget would be needed to achieve some conservation goals, as commented above.

Given that different management actions could be needed to achieve the conservation targets, monetary estimates of conservation cost should be ideally linked to particular conservation actions (See Table 5.1 for examples of candidate management actions to mitigate different threatening processes). For example, Carwardine et al. (2011) considered that four main management actions would be needed to maintain current biodiversity values of the Kimberley region (implement appropriate fire management, manage domestic and feral cattle and other feral herbivores, weed management, and control of key introduced predators, particularly cats). They estimated the cost in dollars associated with the implementation of each action. Monetary cost varied across the region depending on different land tenure or spatial allocation within the region. This brought to the planning process the spatial heterogeneity of costs commented above. Then they used this information to estimate the monetary cost of maintaining the Kimberley region's biodiversity in the next 20 years. They also evaluated the expected number of extinctions under different budget scenarios. However, this kind of approach is not often used given the difficulties in getting the data and the uncertainties associated with the estimates (Carwardine et al., 2011).

Table 5.1. Examples of threats to aquatic ecosystem integrity in northern Australia and candidate management actions to mitigate these threats. Each of these candidate actions has a socioeconomic cost associated with it which depends on current land use, current threat intensity and future vulnerability to anthropogenic change.

Threats	Candidate management actions
Land/water use	
Flow alteration (dams, water extraction)	Environmental flow allocations
Water infrastructure (Dams/weirs)	Fish passage devices (e.g. rock-ramp fishway, fish ladder, fish lift)
Fire	Fire management
Nutrients	Nutrient interception/mitigation
Toxicants	Toxicant interception/mitigation
Sedimentation	Sediment removal (e.g. dredging), catchment revegetation
Riparian degradation	Riparian fencing and revegetation
Overexploitations (e.g. overfishing)	Regulation and enforcement
Introduced species	
Weeds	Weed control (e.g. spraying, manual removal, etc)
Feral animals (incl livestock)	Feral animal control (e.g. shooting, riparian fencing, etc)
Climate change	reduce carbon emissions
Sea level rise	Tidal barrages
Thermal alteration	Protection of existing thermal refugia from other threats
Flow alteration	Environmental flow allocations

5.3.3 Knowledge gaps and future challenges to effectively quantify and incorporate conservation costs in freshwater conservation planning

To effectively tackle conservation cost in freshwater conservation planning some knowledge and methodological issues must be addressed. Firstly, a set of conservation actions to help to effectively deal with the threats to freshwater biodiversity must be identified. The occurrence of different threats is not homogeneous across different regions, so they should be specifically characterised and mapped for the planning area (e.g. Bartolo et al. 2008). The vulnerability of conservation features to these threats should also be evaluated, given that conservation efforts could be focused on irrelevant threats that do not affect local biodiversity. For example, Hermoso et al. (2010c) found that invasive species were the main drivers of freshwater fish diversity loss in a Mediterranean basin, while habitat perturbation did not have a direct effect on native assemblages. Spending money on the remediation of habitat perturbation may not be the most cost-effective way of tackling conservation issues in this basin, while the control and/or eradication of invasive species would better benefit the conservation of local freshwater fish diversity. Further efforts are needed to better understand how different perturbation factors, and their interactions, affect local biodiversity in Australian freshwaters and how they are spatially distributed.

Once a set of conservation actions are clearly identified, and the areas where they could be implemented are spatially located, information on their monetary cost must be gained. Although this is a key step as highlighted above, it has never been objectively addressed in freshwater conservation planning. Carwardine et al. (2011) used expert criteria to obtain rough estimates of conservation action's cost for the Kimberley region. Similar approaches have been used in different regions of the world, such as South Africa (Frazee et al., 2003), or global assessments (Balmford et al. 2003). Conservation costs should ideally be available for each conservation action. This would allow the trade-offs between different action's cost and benefits to be used in the identification of the most efficient combination of actions to achieve the conservation goals (Carwardine et al. 2011). However, better information on the spatial distribution of threats is required in freshwater conservation planning as well.

The cost of each conservation action must be accompanied by an estimate of the efficacy of each action. Efficacy will inform the expected benefit of each action for the targeted conservation features. This piece of information is basic when seeking for the most cost-effective conservation plan (cheap actions may not be the most effective and may lead to costlier solutions in the end). The information on the efficacy of conservation actions relies on expert knowledge (e.g., Carwardine et al. 2011). However, more objective estimates of the benefits of conservation actions gained through monitoring programs could help enhance the efficacy of a conservation plan. Efficacy also relates to the certainty in the knowledge on the importance or weight that different factors have in the biodiversity loss process (are invasive species or habitat degradation the main drivers of biodiversity loss?). The lack of certain estimates means that conservation budgets could be spent ineffectively on inappropriate conservation actions. Adaptive management plans, where the information gained through well-defined monitoring programs in early stages of the plan or from previous experiences can be incorporated in the decision making process (see also Section 5.5). This would greatly enhance the efficiency of conservation actions.

Current planning tools are not suitable to solve complex conservation planning problems, where the trade-offs of different conservation actions must be accounted for in order to find the best combination of actions that allow the conservation targets to be achieved in the most efficient way. Further research is needed to develop new methods that make the integration of these complex trade-offs in the decision-making process when planning for conservation.

5.4 MULTIPLE ZONES AS MANAGEMENT OPTIONS

Appropriate governance frameworks are required to fund and implement management actions to sustain the conservation values of aquatic ecosystems in northern Australia and elsewhere. Blanch (2008) argued that the Natural Resources Management Ministerial Council or the Council of Australian Governments provide the most appropriate forums for negotiating cooperative governance arrangements to achieve sustainable management of northern Australia.

Many strategies are available for conserving freshwater systems, encompassing everything from large-scale integrated catchment management to small-scale restoration of individual habitats (Cowx 2002; Saunders et al. 2002; Abell et al. 2007). Mixed protection schemes where statutory reserves go hand in hand with community efforts and other kinds of regulation (Cowling et al. 2003) may also be needed to achieve conservation goals (Linke et al. 2008). For example, Abell et al. (2007) suggested a mixed portfolio of different protection categories, together with best-practice land management to achieve conservation outcomes in rivers (Fig. 5.1). They proposed the term *freshwater focal area* (Fig. 5.1a) to describe the location of a specific freshwater feature requiring protection (e.g. hotspots of richness or endemism, spawning or nursery areas for a focal species, the known range of habitat for an endangered species). Freshwater focal areas are relatively common, but known by a variety of other names (e.g. the European Union's Habitats Directive (Council Directive 92/43/EEC), which requires the protection of 'Special Areas of Conservation' within the Natura 2000 network). Another potential example could be freshwater areas identified as being of high conservation value according to the HCVAE Framework. Management interventions may or may not occur directly in a freshwater focal area, but when they did occur they would likely be fairly restrictive, to prevent direct disturbance to the feature of concern. Freshwater focal areas would not by definition be small or localized; for instance, an unfragmented river might be managed along its length as a rare example of a functionally connected system (Abell et al. 2007).

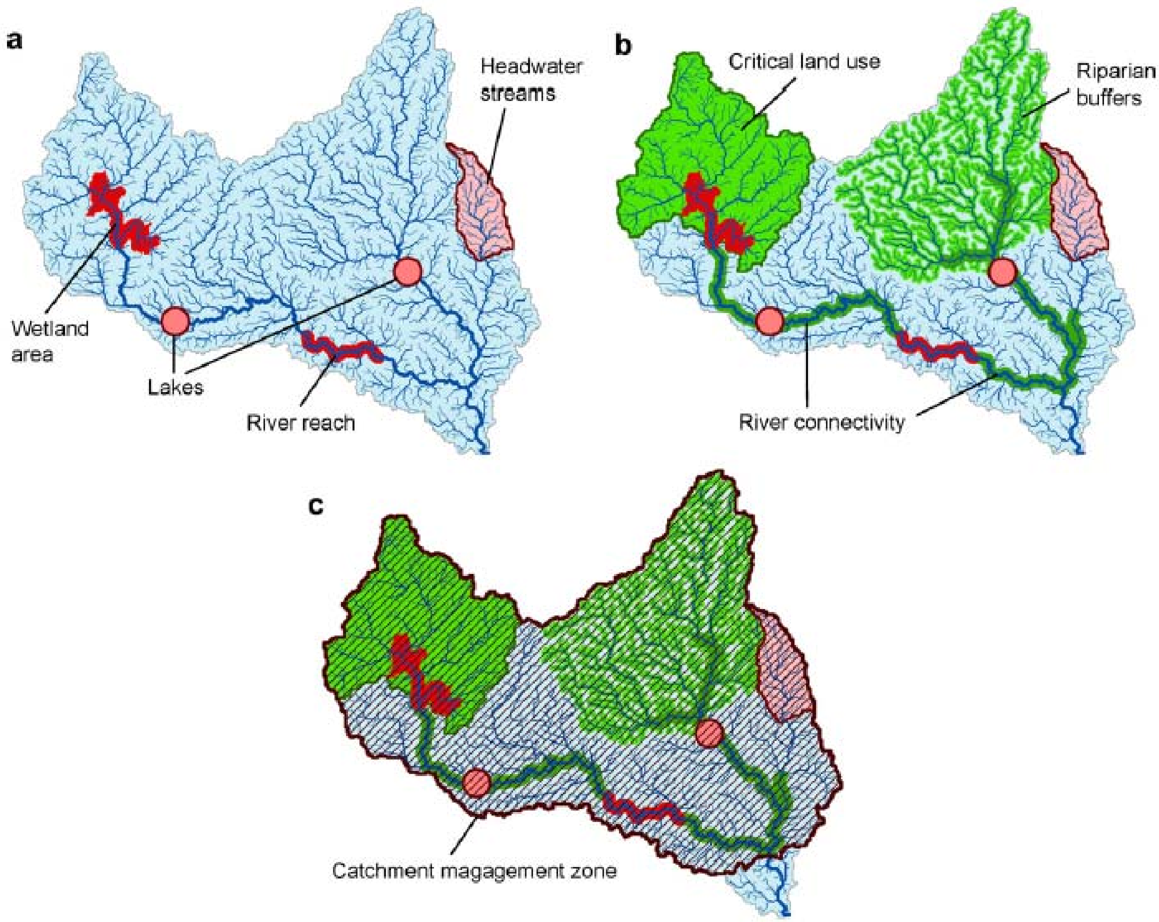


Figure 5.1. Schematics of proposed freshwater protected area zones. (a) Freshwater focal areas, such as particular river reaches, lakes, headwater streams, or wetlands supporting focal species, populations, or communities. (b) Critical management zones, like river reaches connecting key habitats or upstream riparian areas, whose integrity will be essential to the function of freshwater focal areas. (c) A catchment management zone, covering the entire catchment upstream of the most downstream freshwater focal area or critical management zone, and within which integrated catchment management principles would be applied. (Source: Abell et al. 2007).

At the next level of the hierarchy, Abell et al. (2007) proposed the term *critical management zone* to describe those places whose management is essential to maintaining functionality of a focal area (Fig. 5.1b). They suggested that restrictions be tailored to the specific function of the zone but that it would not necessarily exclude all human uses. For example, a wetland area essential for regulating downstream water flows might be identified as a critical management zone for a drought-prone freshwater focal area, and construction in or draining of the wetland might be prohibited. Or, the length of a river constituting the migration corridor of one or more focal freshwater species might be a critical management zone between two focal areas – separated spawning and nursery areas, for example – and that critical management zone might be designated free of instream barriers. Use restrictions for critical management zones might also be temporal, designed to coincide with time-specific events like seasonal spawning migrations. Riparian zones along and perhaps directly upstream of freshwater focal areas could also be examples of critical management zones (Abell et al. 2007).

Finally, Abell et al. (2007) proposed the term *catchment management zone* to describe the entire upstream catchment of a critical management zone (Fig. 5.1c), though this could also include downstream areas if hydrologic connectivity with estuarine and coastal areas was deemed ecologically important (e.g. for diadromous fish species). Within a catchment management zone, basic catchment management principles would be applied (e.g. maintaining riparian buffers, restricting activities on steep slopes, treating all wastewater to established standards, and restricting the use of pesticides and fertilizers) and could also include prohibitions against the introduction of invasive species. In addition to supporting biodiversity conservation, these areas would also contribute to the maintenance of ecosystem services such as clean water and recreational opportunities (Abell et al. 2007).

The terminology used by Abell (2007) integrates basic tools of conservation biology, such as corridors and buffer zones, with broadly accepted catchment management ideas. As suggested by Abell et al. (2007), zoning is common in conservation planning, and for freshwaters the idea has been recommended by the Ramsar Convention (Ramsar Resolution VIII.14) and formalized in Article 7.3 of the European Union's Water Framework Directive.

5.5 Designing a monitoring framework

Managers of high conservation value areas must achieve a balance between taking conservation action, evaluating the effectiveness of actions taken, and monitoring the general status of biodiversity conservation targets and the threats they face (Possingham et al. 2001; Nichols & Williams 2006; Salzer & Salafsky 2006). Conservation managers often struggle with decisions concerning the optimal allocation of limited resources among these competing needs (Salzer & Salafsky 2006).

Monitoring conservation outcomes is an important, yet challenging task. Monitoring helps to (Wildlife Conservation Society 2002):

- determine whether or not a project is meeting its objectives and having a positive conservation effect;
- identify which actions lead to the success or failure of a particular conservation strategy;
- evaluate and revise our conceptual model of why and where conservation efforts are needed; and
- ensure that all participants in the project learn from the experience and can improve their implementation of future conservation programs.

Without monitoring, we run the risk of pouring considerable resources into ineffective activities that do not succeed in conserving biodiversity values.

Monitoring can be useful to improve conservation management in that it can be used for detecting trends in ecological condition, identifying emerging threats, testing hypotheses, and evaluating the efficacy of management interventions (Orians & Soule 2001). It is important however, to distinguish between different types of monitoring programs for conservation, namely targeted (or focused) monitoring and surveillance monitoring (Nichols & Williams 2006). Targeted monitoring is defined by its integration into conservation practice, with monitoring design and implementation based on a priori hypotheses and associated models of system responses to management. Surveillance monitoring on the other hand, is not guided by a priori hypotheses and their corresponding models and risks an inefficient use of conservation funds and effort (Nichols & Williams 2006).

Monitoring is a key component of adaptive management and can inform the decisions of management agencies (Fig. 5.2). Unfortunately however, monitoring practices have generally been poorly connected with decision-making and this has led to an inability to assess the effectiveness or efficiency of the conservation management actions (Field et al. 2007). Indeed, there are often circumstances where implementing a monitoring program may not be the best allocation of scarce management funds given the potentially high costs of monitoring, the immediacy of threatening processes, and possible more beneficial ways in which conservation funds could be spent (i.e. on rehabilitation, threat mitigation, etc).

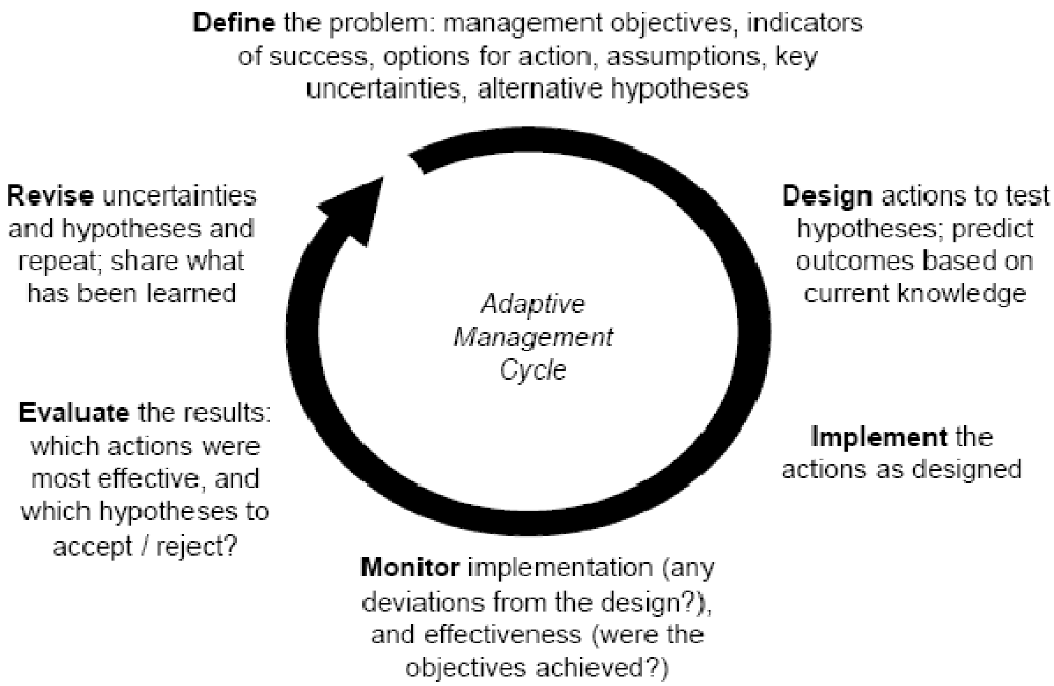


Figure 5.2. The adaptive management cycle (source: Murray & Marmorek 2004).

Thus careful and informed decisions need to be made as to when investment in a monitoring program to improve conservation management outcomes is appropriate. McDonald-Madden et al. (2010) presented a simple framework (in the form of a decision tree) to allow managers and policy advisors to make decisions about when to invest in monitoring to improve management (Fig. 5.3). McDonald-Madden et al. (2010, p. 549) explain the use of the decisions tree as follows: “The first step in the monitoring decision tree is to state clearly the objective(s) of the conservation program (Q1). Objectives must be realistic, explicit, measurable, and relevant to management. The second step is a review of existing information on threats and possible management options to address those threats (Q2). Where threats and management actions are well understood (the certainty attached to the term ‘well’ will be a case specific quantity), the next step is to assess whether monitoring can usefully inform management (Q4, 5, 7). However, it is also important not to delay management simply because of imperfect knowledge about management actions. See main text for examples of these assessments in practice. The fourth step is to consider constraints (most notably time (Q9) and resources (Q11)) on our ability to implement the type of monitoring or research that is needed. Even if considerable financial or human resources are available, there may not be sufficient time to correctly identify trends or incorporate monitoring results into future management. Where insufficient resources exist for active adaptive management, an assessment of other monitoring options might identify alternate cost-effective strategies (Q13). Working through this decision tree yields recommendations on whether and how to implement monitoring for management (Recommendations 3, 6, 8, 10, 12, 14, 15). In some cases monitoring might not be possible or justified, given for example the urgency of the conservation issue or where only one clear management option exists. In all cases, monitoring for reasons other than improving management must be considered after progressing through this decision tree.”.

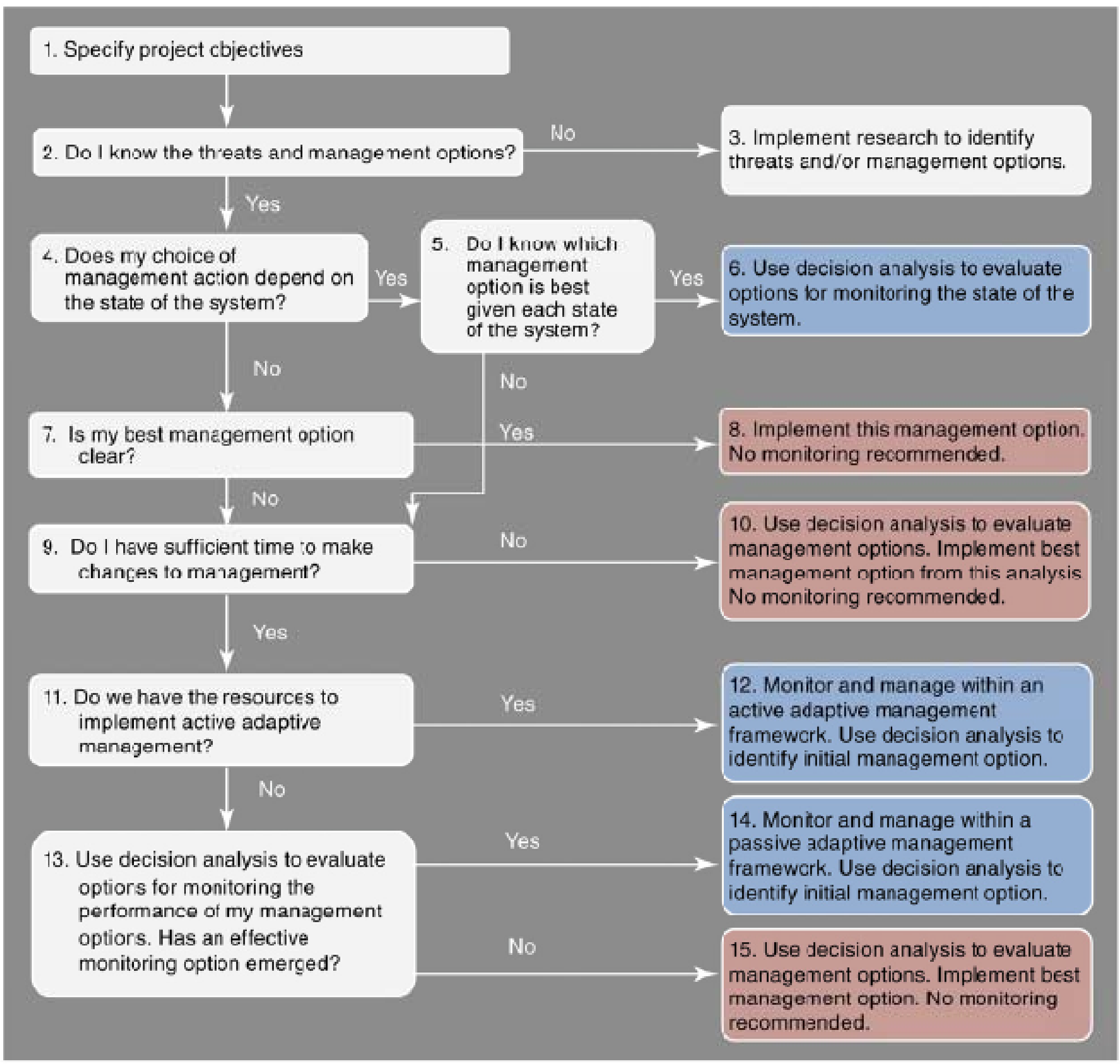


Figure 5.3. Decision tree for deciding when to monitor to improve conservation management (Source: McDonald-Madden et al. 2010).

If monitoring is recommended, then Possingham et al. (2001) recommended that the design of an effective monitoring program should follow a series of systematic steps:

1. Specify goals
2. Identify stressors
3. Develop conceptual models
4. Select indicators
5. Establish sampling design
6. Define methods of analysis
7. Ensure links with decision making

An explicit statement of the goals of the monitoring program is essential and may include goals relating to detecting trends, identifying emerging problems, testing hypotheses, or evaluating the efficacy of particular management interventions. A conceptual model describing the role of natural and human-induced stressors and ecosystem responses provides an overview of scientific understanding of how the system works and is useful to determine what measures of system performance are likely to be useful monitoring indicators. The design of a monitoring program requires careful consideration of candidate species and processes (including threats) for measurement. Selection of indicators should therefore be made in light of the overall goals and underlying conceptual models of the ecosystem of interest. For monitoring programs to be useful they must be informative, reliable and be linked with decision-making objectives in a cost-efficient manner (i.e. in an adaptive management framework).

Active adaptive management places an explicit value on learning about the effectiveness of management by monitoring its outcomes and differs from passive adaptive management in which learning occurs serendipitously and is then incorporated into management plans (McCarthy & Possingham 2007). Monitoring programs designed and embedded in an active adaptive management framework offer the best chances of using limited conservation management funds effectively but there is a tradeoff between allocating funds for management actions versus allocating them for monitoring. It is often not clear how conservation resources should be split between learning about the effectiveness of management through monitoring and actually managing the system based on what is known currently (Possingham et al. 2001; McCarthy & Possingham 2007). For example, McCarthy & Possingham (2007) argued that in cases where the costs of monitoring are large relative to the costs of management, it would be necessary to decide on the proportion of the resources to allocate to monitoring. If costs of monitoring are a substantial proportion of the budget, then there would be less incentive to invest resources in learning.

Salzer & Salafsky (2006) presented a conceptual framework to help guide conservation practitioners towards a logical allocation of resources between taking action and different types of monitoring depending on the situation that they are facing (Fig. 5.4). These resource allocation decisions involve a number of critical decisions:

- finding the right balance between investing in taking action *versus* monitoring (see above),
- identifying the purpose of the monitoring (e.g. assessing the status of biodiversity values *versus* measuring effectiveness of management actions to sustain those values)
- subdividing monitoring resources across different types of monitoring indicators (i.e. diagnostic *versus* early warning indicators)

The framework consists of a decision tree that includes an explicit evaluation of three questions (Salzer & Salafsky 2006):

1. Are there substantial threats facing the conservation entities?;
2. Are there clear and feasible actions known to be effective at abating identified threats?; and
3. Does the project team have high confidence in their understanding of the overall conservation situation?

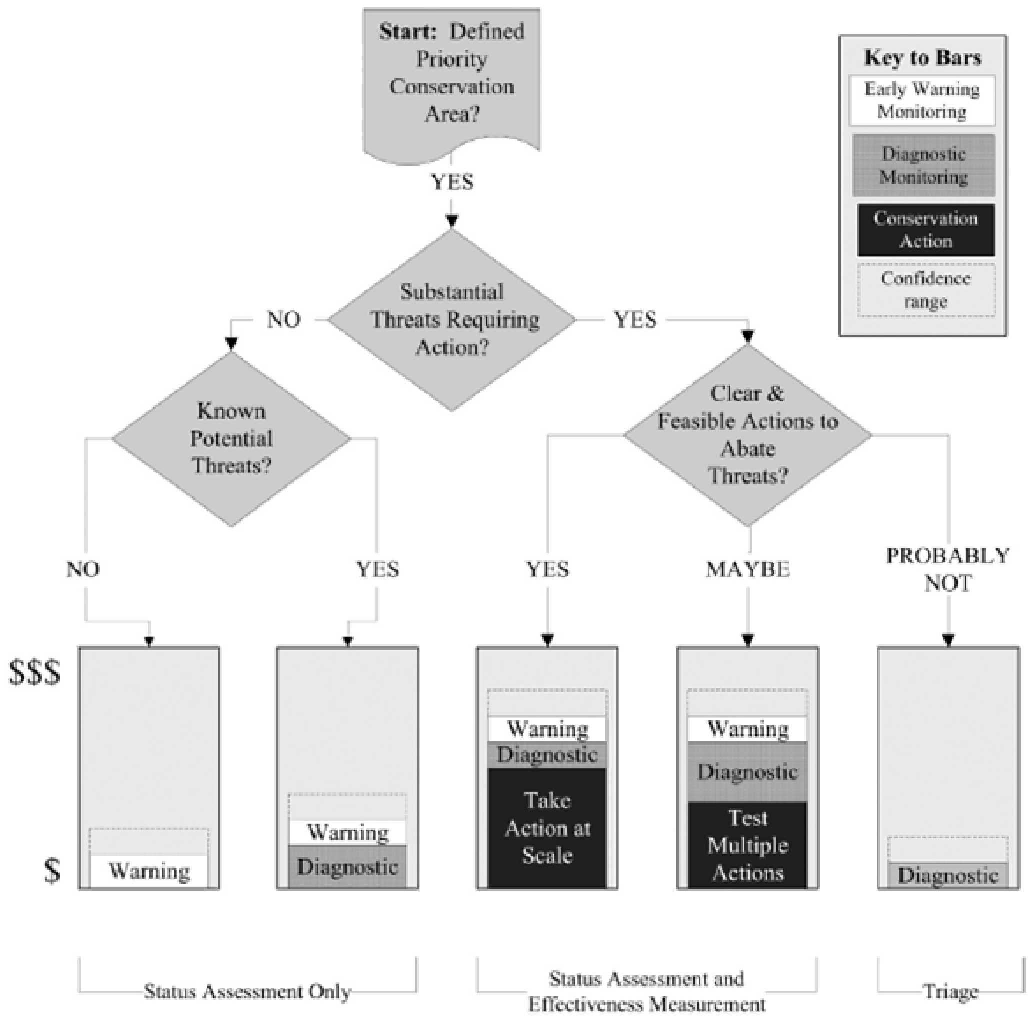


Figure 5.4. Decision tree for allocating resources between taking conservation action (black portion of bars), monitoring early warning indictors (white portion of bars labelled as "Warning") and monitoring diagnostic monitoring indictors (shaded portion of bars labelled as "Diagnostic"). The dashed line at the top of the bars indicates a range of resource investment that varies based on the level of confidence in the situation analysis (Source: Salzer & Salafsky 2006).

The development of a detailed monitoring framework for aquatic ecological assets in northern Australia was well beyond the scope of the project – previous experience has shown that it takes years of scientific development and community engagement before the monitoring framework can be finalised. Examples of the detailed work required include: the development of a National framework for the Assessment of River and Wetland Health (FARWH – Norris et al. 2007); the trial of the FARWH in the wet/dry tropics of northern Australia (Dixon et al. 2010); and, the development of a water quality monitoring framework for the Katherine and Daly River catchment (Risby et al. 2009).

In developing a monitoring program for aquatic ecological assets in northern Australia we recommend careful consideration of the various frameworks outlined above to guide if, why, when how monitoring should be implemented and of how the outcomes of the monitoring will feed into adaptive management of aquatic ecological assets. We do not recommend instituting a monitoring program for aquatic ecological assets or a subset of representative sites until these issues are addressed.

Nevertheless, there are number of issues specific to northern Australia and the HCVAE Framework that can help to guide future development of a monitoring program for aquatic ecological assets in the region. First, there needs to be a clear articulation of the goals of the monitoring program. Such monitoring goals could include (but are not necessarily limited to):

- Maintenance of ecological/conservation values that resulted in the asset being identified as an HCVAE
- Identification of threatening processes that might impact on those values
- Responses to management interventions intended to protect, mitigate or restore those values

Second, there needs to be a careful consideration of the costs and benefits of monitoring to achieve any or all of the goals listed above. The choice of candidate indicators and actions will also necessarily vary depending on the goal of the monitoring program (see Table 5.2 for examples) as well as constraints to implementation the monitoring program imposed by available budget, human resources and technical impediments. Remote sensing technologies do, however, offer an affordable means of sampling over large spatial scales and potentially long time frames for monitoring environmental and ecological changes relevant to aquatic ecological assets (e.g. Ludwig et al. 2007, Goetz et al 2008, Ward & Kutt 2009).

Third, there needs to be an identification of the appropriate governance arrangements to coordinate the development of the monitoring program (e.g. through the Aquatic Ecosystem Task Group) and identification of appropriate agencies or organisations to implement the monitoring program (e.g. government Natural Resource Management Agencies, regional NRM boards, indigenous organisations, community groups, private consultants, etc).

Table 5.1. Examples of candidate monitoring indicators and actions to address three potential goals of a monitoring program for aquatic ecological assets in northern Australia.

Monitoring goal	Examples	Candidate monitoring indicators and actions
Maintenance of ecological/conservation values over time (link to method of defining values, e.g. Framework criteria)		
	HCVAE Framework Criteria 1. Diversity.	Monitor indicators of diversity for particular biodiversity groups (e.g. continued high species richness of fish or aquatic macroinvertebrates)
	HCVAE Framework Criteria 2. Distinctiveness	indicators of Distinctiveness (e.g. continued presence of rare/threatened species)
	HCVAE Framework Criteria 3. Vital habitat	Monitor indicators of Vital habitat (e.g. continues to support important waterbird populations)
	HCVAE Framework Criteria 4. Evolutionary history.	Monitor indicators of Evolutionary history (e.g. continues to support species of evolutionary significance)
	HCVAE Framework Criteria 5. Naturalness	Monitor indicators of Naturalness (e.g. continues to remain minimally impacted by human activities and other threatening processes – see also below)
Identification of threatening processes		
	Flow alteration (dams, water extraction)	monitor indicators of flow alteration using modelled flow data
	Water infrastructure (Dams/weirs)	Monitor development of new water infrastructure (Dams/weirs) using remote sensing
	Fire	Monitor changes in seasonal fire regimes using remote sensing
	Nutrients and toxicants	Monitor nutrient and toxicant inputs downstream of agricultural and urban developments using standard water quality assessment protocols
	Sedimentation	Monitor changes in sedimentation rates and extent upstream or within HCVAE areas using standard methods (e.g. sediment rods, bathymetry, particle size distributions, remote sensing)
	Riparian degradation	Monitor changes in riparian vegetation structure and extent using field surveys and/or remote sensing
	Overexploitations (e.g. tourism overfishing)	Monitor changes in human visitation rates, fish catches, etc
	Introduced weeds	Monitor changes in the distribution and density/abundance using field surveys and/or remote sensing
	Feral animals (incl livestock)	Monitor changes in the distribution and density/abundance using field surveys and/or remote sensing
Responses to management interventions to protect/restore values		
	Environmental flow allocations	Monitor flow-sensitive physical indicators (e.g. hydraulic habitat) and/or ecological indicators (e.g. fish recruitment)
	Fish passage devices (e.g. rock-ramp fishway, fish ladder, fish lift)	Monitor movement of biota (e.g. fish, and crustaceans) downstream, within and upstream of fish passage devices using field sampling, tagging, hydroacoustics, etc
	Fire management	Monitor changes in water quality, riparian vegetation, etc using methods described above
	Nutrient and Toxicant interception/mitigation	Monitor changes in water quality using methods described above
	Sediment removal (e.g. dredging), catchment revegetation	Monitor changes in sedimentation using methods described above
	Riparian fencing and revegetation	Monitor changes in riparian vegetation using methods described above
	Regulation and enforcement	Monitor changes human activities in response to regulation and enforcement
	Weed control (e.g. spraying, manual removal, etc)	Monitor efficacy using field surveys and/or remote sensing
	Feral animal control (e.g. shooting, riparian fencing, etc)	Monitor efficacy using field surveys and/or remote sensing

6. Key knowledge gaps & priorities

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The assessment of northern Australian aquatic ecosystem values and threats (Pusey & Kennard 2009) and the broad-scale assessment of aquatic ecosystem assets (Kennard 2010) both listed a number of specific knowledge/information gaps and made numerous recommendations on directions and priorities for future research. These are synthesised here.

6.1 Knowledge gaps and priorities for managing and conserving freshwater ecosystems in northern Australia (from Pusey & Kennard 2009)

6.1.1. Water resource management and planning

- **Environmental water requirements**. We currently have limited capacity to predict the consequences of altered flow regimes on aquatic plants and animals. The main channel has received some attention and there needs to be additional effort on better understanding low-flow ecology. The ecological water requirements of floodplain systems remain virtually unstudied yet these are likely to be critical for the health of aquatic ecosystems. This needs to be underpinned by better modelling of groundwater-surface water interactions.
- **Connectivity and movement.** Links between the river ecosystems and the estuarine zone (in both directions) need to be better understood. In particular, the role of fauna (e.g. fish and crustaceans) in maintaining connections between components of the river-floodplain system and the environmental triggers for movement of different species and life stages are important knowledge gaps. We also need to better understand the connectivity to estuarine and coastal processes and the implications of more intensive land use for these ecosystem and the assets they support, such as commercial and recreational fisheries (see below).
- **Systematic monitoring of aquatic ecosystem health** using indicators based on current work to identify critical processes and key species for monitoring as well as the approaches being trialled through the Framework for the Assessment of River and Wetland Health (FARWH) in tropical Australia.
- **Systematic conservation planning including river connectivity.** Research is needed to develop tools and apply them to identify and prioritise high conservation value aquatic ecosystems. Once identified, these areas need to be managed appropriately to maintain their high conservation values (e.g. through legislative, natural resource management and land-use planning instruments; Blanch 2008).

6.1.2. Understanding the impacts of land use intensification on river-floodplain, estuarine and coastal ecosystems

- We currently lack the tools and underlying science to predict how intensive land use will affect the fluxes of water, sediment, nutrients and other contaminants to river and coastal ecosystems. New agricultural developments in Northern Australia combined with a program of scientific monitoring and assessment will provide an opportunity to integrate planning, management and science within an adaptive cycle. Not only would resource management benefit from access to available knowledge and tools, the science development would benefit from the learning gained from such large-scale ‘natural experiments’.
- Prediction of the sediment and nutrient loads coming from different land use units is a major knowledge gap. There is a need to identify and quantify the key processes and mechanisms which generate sediment and nutrient loads and how these change in response to changes in landscape position, land-use, hydrology and management/mitigation.
- Similarly, we need better information to help predict the movement and fate of agrochemicals, particularly in groundwater systems where better understanding of surface water - groundwater interactions is required.

- We need a much better understanding of the effects of the above changes in material fluxes on ecological processes. As well as the focus on in stream processes, this should include greater consideration of the riparian zone as a critical interface between land and river ecosystems.
- In addition to studying more intensive land management such as irrigated agriculture, this should also consider some of the flow on effects of intensification such as weed and feral animal impacts and altered fire regimes.

6.1.3. Managing coastal development to maintain healthy rivers, estuaries and coasts

- With increased focus on developing catchments, water resources and coastal areas, there is also a growing need to better understand the potential trade-offs involved in these decisions. So more research is needed to improve our relatively poor understanding of coastal processes and to identify effective indicators and monitoring approaches for the estuarine zone.

6.1.4. Planning for and adapting to climate change impacts on tropical rivers, coasts and communities

- Better predictions of the implications of climate change on water resources for northern Australia are emerging, but the environmental and ecological consequences and the opportunities for adaptation need to be fully quantified.
- This also applies to the implications of rising sea levels for coastal ecosystems, particularly for low-lying coastal wetlands and floodplains.
- Thermal tolerances and thresholds of aquatic biota are also poorly understood for most flora and fauna in northern Australia. This makes it difficult to identify and appropriately manage species most at risk from climate change.

6.2. Assessment of the effectiveness and applicability of the draft ANAE classification scheme and the draft HCVAE Framework (from Kennard 2010)

The broad-scale assessment of aquatic ecosystem assets described in Kennard (2010) involved the application of the draft Australian National Aquatic Ecosystem (ANAE) classification scheme and the draft HCVAE Framework and criteria. Through these applications we were able to assess their effectiveness and applicability. As reported in Kennard (2010), we make the following assessments and recommendations:

6.2.1. Applying the draft Australian National Aquatic Ecosystem Classification Scheme

1. **Further development of the ANAE classification scheme**. The draft ANAE Classification Scheme (Auricht, 2010) describes different aquatic ecosystems and the attributes which could be used to define “habitat” types across Australia within an integrated regional and landscape setting. While the current version of the ANAE scheme provides some implementation guidelines further development is recommended. Ideally, the ANAE scheme should offer further guidance on choice of appropriate attributes, methods of measurement or derivation, applicable spatial and temporal scales and so on to ensure consistent application across jurisdictions.
2. **Bottom-up versus top-down classification**. We employed bottom-up (i.e. data-driven) ecotope classifications to generate environmental surrogates for biodiversity for the HCVAE assessment. We recommend this approach when consistent high quality datasets are available (rather than top-down classifications as described in the ANAE scheme.

3. **Integrated classification across hydrosystem types**. Further development of the ANAE scheme will be required to ensure that all integral components of aquatic ecosystems are effectively recognized across spatial scales, perhaps as emergent properties (i.e. bottom-up classifications as employed in the preset study) of the currently separate classifications of hydrosystems.

6.2.2 Improvements to aquatic ecosystem mapping

4. **Refinement and validation of mapping**. The draft ANAE scheme to delineate hydrosystems was successfully implemented for the northern Australia HCVAE trial area. However, time constraints of the project meant that further development of the Geodata Estuarine, Lacustrine and Palustrine hydrosystem delineation is required. Further delineation of the estuarine ecosystems could be undertaken by using existing mangrove mapping, and the location of barrages to delineate the transition zones between Estuarine and Riverine hydrosystems. Further validation of the Geodata derived hydrosystems (e.g. the Lacustrine hydrosystem) could be undertaken using existing hydrosystem delineation such as the Queensland Wetland Mapping and Classification data set.
5. **Use of new remote sensing approaches**. Remotely sensed information on flood frequency, extent and duration, available for a number of catchments in northern Australia could be generalised and used to update the existing attribution of hydrosystem inundation frequency. With suitable resourcing, the remote sensing archive could be used to evaluate and update the hydrosystem perenniality attribute.

6.2.3 Improvements to aquatic biodiversity data

6. **Limits to available biodiversity datasets.** Fundamental knowledge of the distribution of many freshwater dependent flora and fauna is lacking for much of northern Australia. We considered but did not assemble datasets other water-dependent fauna (i.e. frogs, crocodiles, lizards, snakes, riparian birds) or aquatic, semi-aquatic and riparian flora due to resource and/or data constraints. Whilst this project assessed molecular(genetic)-level, phylogeographic data for a selected number of taxa, there remain substantial sampling gaps (particularly in the Kimberley region) for these species and many other species. More extensive phylogeographic data sets (in terms of both completeness of spatial coverage and greater number of taxa) would be very useful in future efforts to delineate freshwater bioregions and would enable more rigorous assessments of molecular-level patterns of biodiversity at a range of spatial scales.
7. **Limits to available biodiversity for particular aquatic ecosystem types.** Improved knowledge of the macroinvertebrate biodiversity of subterranean systems, springs and off-channel floodplain habitats is required. Limited data meant that the conservation values of these hydrosystems were not assessed with respect to macroinvertebrate biodiversity, despite the high likelihood that such habitats are of conservation significance.
8. **Using genetic methods to inform conservation assessments.** Future research efforts that apply molecular data to freshwater biodiversity assessments in northern Australia should consider within- and between- river basin scale patterns of genetic-level biodiversity. Landscape genetic approaches could be coupled with phylogeographic analyses to identify the key landscape features (e.g. flow regime, river structure, landscape topography) that subdivide populations of freshwater species, thereby providing key information about genetic connectivity (or isolation) among populations. This would enable molecular-level patterns of biodiversity to be considered at the planning unit scale and allow measures of population connectivity to be applied in conservation planning assessments.
9. **Improving predictive models of species distributions**. We used predictive models of species distributions to mitigate the problem of incomplete sample coverages. Greater confidence in the outputs from the predictive models could be obtained by improving the model validation process using true presence/absence data for all faunal groups. Therefore a research priority should be to collect these data in the future. The use of multiple predictive modelling methods and generation of consensus predictions would allow better quantification of uncertainty in the extrapolation of species distributions for use as biodiversity surrogates in conservation assessments.

6.2.4 Identifying high conservation value areas using the draft HCVAE Framework

10. **Better articulation of the purpose of HCVAE identification process**. We feel that implementing the draft HCVAE Framework criteria goes some way to identifying areas that are of potentially high conservation value. However, greater clarity as to the purpose of the HCVAE identification may further increase the efficient investment of resources to manage these areas effectively. The Framework criteria are not specifically designed to identify which management options are most appropriate for a particular area and require further development in this regard.
11. **Minimising uncertainty in data used to characterise the HCVAE Framework criteria.** The lack of clear objectives as to the purpose of the HCVAE identification meant that it was difficult to select a subset of the most import attributes to characterise the criteria. Instead there was the strong temptation to characterise each criterion in as many ways as possible. We recommend that this temptation be resisted. Our overall philosophy was to only apply attributes that could be calculated from the biodiversity surrogates datasets, rather than applying attributes based on other data which was of variable quality and spatial extent and that would therefore potentially yield large gaps and uncertainties in the outcomes of an HCVAE assessment.
12. **Loss of transparency through data integration**. The nature of the Framework (i.e. a multi-criteria scoring approach) means that the method combines potentially numerous individual attributes that by themselves can be (and often are) used to assess conservation value. However, the integration process ultimately means a potential loss of transparency, in that it is unclear how many attributes (and which ones) contribute greatly to the integrated score for each criterion. It is important however that this integrative approach remains fully transparent; that is, it must be clear how many and which attributes contribute most to the integrated score for each criterion.
13. **Simpler is probably better**. It is unclear which components of biodiversity (the fundamental currency of conservation assessments) contribute most to the final rankings based on criterion scores. Although it is certainly possible to interrogate the underlying data and maps to understand why a particular area scored highly for a particular criterion or set of criteria, this is not a simple process. One solution to this issue is to greatly reduce the number of attributes used to characterise the Framework criteria to only a few key ones that are deemed by experts to be most important indicators of conservation value (though this is obviously not a simple task). We suggest that the use of more attributes does not necessarily provide a better or more interpretable conservation assessment. In fact, the converse appears to be true.
14. **Choice of scoring thresholds for criteria.** The draft HCVAE Framework states that an ecosystem meeting any one of the criteria could be considered an HCVAE, but that appropriate thresholds for nationally significant HCVAE are yet to be determined. It is unclear what threshold should be used to discriminate those planning units that “meet” each criterion (i.e. that their criterion score exceeds the threshold and therefore could be considered to be of high conservation value based on that criterion). The choice of threshold is a somewhat arbitrary decision, but can have potentially important consequences for identifying which and how many planning units are considered of high conservation value.
15. **Relative importance of criteria for selection of HCVAEs.** It is unclear whether some criteria should be considered more important than others for identifying HCVAEs and whether particular planning units that meet a greater number of criteria are concordantly of higher conservation value. We agree with the approach taken in the Lake Eyre Basin trial that the lack of a specified purpose, for the identification of HCVAE, means that the criteria be considered to be equally important. We assumed that conservation value increased with increasing number of criteria met (i.e. a planning unit that met all six criteria had a greater potential for containing an HCVAE than a planning unit that met only one criterion).

6.2.5 Promoting efficiency in the identification and management of high conservation value areas

16. **Biodiversity representation and efficiency**. A fundamental goal of conservation assessments should be to efficiently identify sets of areas that need to be managed to conserve species and the processes that sustain them. The draft HCVAE Framework may be limited in the extent to which it can efficiently contribute to this

conservation goal and ideally will require complementary approaches such as systematic planning that specifically address biodiversity representation in a more efficient way.

17. **Improvements to systematic conservation planning**. There are some key challenges that, if addressed, would lead to greater objectivity in systematic conservation planning. The incorporation of uncertainties in the distribution of conservation features or the vulnerability to future change of candidate high conservation value areas (e.g. due to land use or climate change) would increase the ability to assess the resilience of these areas and the likelihood of long-term persistence of the conservation values that they contain. Setting scientifically defensible conservation targets (e.g. the number of populations or areas required to maintain species) would help improve the efficiency of the resilience of high conservation value areas to future changes.
18. **Estimating and incorporating socioeconomic costs of different conservation management actions**. Estimates of the socioeconomic costs of different conservation management actions (e.g. threat mitigation, restoration, stewardship, acquisition) should ideally be incorporated into the conservation assessment process. Here, the aim is to optimize the set of management actions and the places where they should be implemented, required to achieve biodiversity conservation goals with the minimum cost (or impact in local economies). This would provide the first step in developing a strategic, efficient and effective approach to identify high conservation value areas and guide on-the-ground management actions to conserve freshwater biodiversity.
19. **Involvement of stakeholders during the conservation assessment process**. Finally, we view the application of systematic planning as a tool to help in the decision making process in identifying high conservation value areas. The incorporation of expert and stakeholders' knowledge, needs and interests is a fundamental next step at achieving the implementation of an efficient and realistic conservation plan. This information should be seen as an additional tool to guide future decisions on conservation management rather than a rigid and strict conservation plan itself.

7. REFERENCES

Abell, R., Allan, J.D. & Lehner, B. (2007). Unlocking the potential of protected areas for freshwaters. Biological Conservation 134, 48-63.

Ando, A., Camm, J., Polasky, S. & Solow, A. (1998). Species distributions, land values and efficient conservation. Science 279: 2126-2128.

Auricht, C.M. ed (2010) Towards an Australian National Aquatic Ecosystem Classification. Report prepared by Auricht Projects for the Aquatic Ecosystem Task Group and the Department of Environment, Water, Heritage and the Arts. 14th July 2010.

Balmford, A., Gaston, K.J., Blyth, S., James, A. & Kapos, V. (2003). Global variation in terrestrial conservation costs, conservation benefits, and unmet conservation needs. Proceedings of the National Academy of Sciences 100: 1046-1050.

Ball, I.R., Possingham, H.P. & Watts, M. (2009). Marxan and relatives: Software for spatial conservation prioritisation. Chapter 14: Pages 185-195 in Spatial conservation prioritisation: Quantitative methods and computational tools. Eds Moilanen, A., K.A. Wilson, and H.P. Possingham. Oxford University Press, Oxford, UK.

Bartolo, R., van Dam, R. & Bayliss, P. (2008). Semi-quantitative risk assessments – The Relative Risk Model. In R Bartolo, P Bayliss and R van Dam (eds.) Ecological risk assessment for Australia's northern tropical rivers: Sub project 2 of Australia's Tropical Rivers - an integrated data assessment and analysis (DET18). A report to Land and Water Australia. Environmental Research Institute of the Supervising Scientist, Darwin, Australia.

Bayliss P, Bartolo R and van Dam R (2008) Quantitative Ecological Risk Assessments. In R Bartolo, P Bayliss and R van Dam (eds.) Ecological risk assessment for Australia's northern tropical rivers: Sub project 2 of Australia's Tropical Rivers - an integrated data assessment and analysis (DET18). A report to Land and Water Australia. Environmental Research Institute of the Supervising Scientist, Darwin, Australia.

Blanch, S. (2008). Steps to a sustainable northern Australia. Ecological Management and Restoration 9: 110-115.

Boardman, A.E., Greenberg, D., Vining, A. & Weimer, D. (2005). Cost Benefit Analysis: Concepts and Practice, Prentice Hall.

Bunn, S.E., Abal, E.G., Smith, M.J., Choy, S.C., Fellows, C.S., Harch, B.D., Kennard, M.J., & Sheldon, F. (2010). Integration of science and monitoring of river ecosystem health to guide investments in catchment protection and rehabilitation. Freshwater Biology. 55 (Suppl. 1): 223-240.

CAPAD (2006). Collaborative Australian Protected Areas Database. Australian Government Department of the Environment, Water, Heritage and the Arts.

Carwardine, J., Rochester, W.A., Richardson, K.S., Williams, K.J., Pressey, R.L. & Possingham, H.P. (2007). Conservation planning with irreplaceability: does the method matter? Biodiversity and Conservation 16: 245-258.

Carwardine, J., Wilson, K.A., Watts, M., Etter, A., Klein, C. J. and Possingham, H. P. (2008b). Avoiding Costly Conservation Mistakes: The Importance of Defining Actions and Costs in Spatial Priority Setting. PLoS ONE e2586. doi:10.1371/journal.pone.0002586.

Carwardine, J., O'Connor, T., Legge, S., Mackey, B., Possingham, H.P. & Martin, T.G. (2011). Priority threat management to protect Kimberley wildlife. CSIRO Ecosystem Sciences, Brisbane. ISBN 978 0 643 10306 1

Carwardine, J., Wilson, K.A., Ceballos, G., Ehrlich, P. R., Naidoo, R., Iwamura, T., Hajkowicz, S. A. and Possingham, H. P. (2008a). Cost-effective priorities for global mammal conservation. Proceedings of the National Academy of Sciences, 105: 11446-11450.

Ceballos, G., Ehrlich, P.R., Soberon, J., Salazar, I. & Fay, J.P. (2005). Global mammal conservation: What must we manage. Science 309: 603-607.

Clayton, P. & Talbot L. (2010). Ecological Thresholds Workshop Outcomes Gilbert, Flinders and Norman River Catchments. RPS Report for the Department of Environment and Resource Management, Brisbane.

Close, P., Cossart, R., Petit, N. & Kennard, M. (2010). Fine Scale Assessment of High Conservation Value Aquatic Ecosystems in the Upper Fitzroy and Mitchell River Catchments of the Kimberley Region of Western Australia. Summary of the workshop, held in Kununurra, 11 – 12 November 2010.

Convention on Biological Diversity (2006). Decision VII/4: biological diversity of inland water ecosystems. VII/4. CBD, Montreal.

Cowling, R.M., Pressey, R.L., Rouget, M. & Lombard, A.T. (2003). A conservation plan for a global biodiversity hotspot – the Cape Floristic Region, South Africa. Biological Conservation: 112, 191-216.

Cowx, I.G. (2002). Analysis of threats to freshwater fish conservation: past and present challenges. In: Collares- Pereira, M.J., Cowx, I.G., Coelho, M.M. (Eds.), Conservation of Freshwater Fishes: Options for the Future. Fishing News Books, Oxford, UK, pp. 201–220.

Dixon, I., Dobbs, R., Townsend, S., Close, P., Ligtermoet, E., Dostine, P., Duncan, R., Kennard, M. and Tunbridge, D. (2010). Field Trial of the Framework for the Assessment of River and Wetland Health (FARWH) in the Wet/Dry Tropics: Daly River and Fitzroy River Catchments. Tropical Rivers and Coastal Knowledge Consortium. Charles Darwin University, Darwin.

Downes B.J. (2010). Back to the future: little-used tools and principles of scientific inference can help disentangle effects of multiple stressors on freshwater ecosystems. Freshwater Biology, 55(Suppl 1): 60-79.

Dunn, H. (2003). Can conservation assessment criteria developed for terrestrial systems be applied to riverine systems? Aquatic Ecosystem Health & Management 6: 81-95.

Dunn, H. (2004). Defining the ecological values of rivers: the views of Australian river scientists and managers. Aquatic Conservation: Marine and Freshwater Ecosystems 14: 413-433.

Fausch, K.D., Baxter, C.V. & Murakami, M. (2010). Multiple stressors in north temperate streams: lessons from linked forest–stream ecosystems in northern Japan. Freshwater Biology 55 (Suppl. 1): 120-134.

Ferraro, P.J. (2003). Assigning priority to environmental policy interventions in a heterogeneous world. Journal of Policy Analysis and Management 22: 27-43

Field, S.A., O'Connor, P.J., Tyre, A.J. & Possingham, H.P. (2007). Making monitoring meaningful. Austral Ecology 32: 485-491.
Fitzsimons, J.A. & Robertson, H.A. (2005) Freshwater reserves in Australia: directions and challenges for the development of a comprehensive, adequate and representative system of protected areas. Hydrobiologia 522: 87-98.
Frazee, S.R., Cowling, R.M., Pressey, R.L., Turpie, J.K. & Lindenberg, N. (2003). Estimating the costs of conserving a biodiversity hotspot: a case-study of the Cape Floristic Region, South Africa. Biological Conservation, 112: 275-290.
Georges, A. & Cottingham, P. (2002). Biodiversity in inland waters - priorities for it's protection and management: Recommendations from the 2001 Fenner conference on the Environment. CRCFE technical report 1/2002, CRCFE, Canberra.
Goetz, S.J., Gardiner, N., Viers, J.H. (2008). Monitoring freshwater, estuarine and near-shore benthic ecosystems with multi-sensor remote sensing: An introduction to the special issue. Remote Sensing of Environment 112: 3993-3995.
Hale, J. (Ed.) (2010) Lake Eyre Basin High Conservation Value Aquatic Ecosystem Pilot Project. Report to the Australian Government Department of Environment, Water, Heritage and the Arts, and the Aquatic Ecosystems Task Group.
Herbert, M.E., McIntyre, P.B., Doran, P.J., Allan, J.D. & Abell, R. (2010). Terrestrial reserve networks do not adequately represent aquatic ecosystems. Conservation Biology 24: 1002-1011.
Hermoso, V., Linke, S., Prenda, J., and Possingham, H. P. (2010a). Addressing longitudinal connectivity in the systematic conservation planning of fresh waters. Freshwater Biology. Freshwater Biology 56: 57-70.
Hermoso, V., Kennard, M. J., and Linke, S. (2010b). Complementary approach to identifying HAVAEs-Systematic conservation planning. In Kennard, M.J. (ed). Identifying high conservation value aquatic ecosystems in northern Australia. Interim Report for the Department of Environment, Water, Heritage and the Arts and the National Water Commission. Tropical Rivers and Coastal Knowledge (TRaCK) Commonwealth Environmental Research Facility, Australian Rivers Institute, Griffith University.
Hermoso, V., Clavero, M., Blanco-Garrido, F. and Prenda, J. (2010c). Invasive species and habitat degradation in Iberian stream: an analysis of their role in freshwater fish diversity loss. Ecological Applications (in press).
IUCN (1994). CNPPA/WCMC "Guidelines for Protected Area management categories". Gland: (ISBN: 2-8317-0201-1).
Kennard, M.J. (ed) (2010). Identifying high conservation value aquatic ecosystems in northern Australia. Interim Report for the Department of Environment, Water, Heritage and the Arts and the National Water Commission. Tropical Rivers and Coastal Knowledge (TRaCK) Commonwealth Environmental Research Facility, Charles Darwin University, Darwin. ISBN: 978-1-921576-23-2. Available at: http://www.environment.gov.au/water/publications/policy-programs/nawfa-hcvae-trial-report.html.
Kingsford, R.T., Dunn H., Love D., Nevill J, Stein J. & Tait J. (2005). Protecting Australia's rivers, wetlands and estuaries of high conservation value: a blueprint. Report to Land & Water Australia; Canberra. Product Number PR050823.
Klein C, Chan A, Kircher L, Cundiff A, Hrovat Y, et al. (2008). Striking a balance between biodiversity conservation and socioeconomic viability in the design of marine protected areas. Conservation Biology 22: 691-700.
Linke, S., Norris, R.H. & Pressey, R.L. (2008). Irreplaceability of river networks: towards catchment-based conservation planning. Journal of Applied Ecology 45: 1486-1495.
Linke, S., Turak, E. & Nel, J. (2011). Freshwater conservation planning: the case for systematic approaches. Freshwater Biology 56: 6-20.
Linke, S., Pressey, R.L., Bailey, R.C. & Norris, R.H. (2007). Management options for river conservation planning: condition and conservation revisited. Freshwater Biology 52: 918-938.
Ludwig, J.A., Bastin, G.N., Wallace, J.F. & McVicar, T.R. (2007). Assessing landscape health by scaling with remote sensing: when is it not enough? Landscape Ecology 22: 163-169.
Margules, C.R. & Pressey, R.L. (2000). Systematic conservation planning. Nature 405: 243-253.
Margules, C.R., Pressey, R.L. & Williams, P.H. (2002). Representing biodiversity: data and procedures for identifying priority areas for conservation. Journal of Biosciences 27: 309-326.
McCarthy, M.A. & Possingham, H.P. (2007). Active adaptive management for conservation. Conservation Biology Volume 21: 956-963.
McDonald-Madden, E., Baxter, P.W.J., Fuller, R.J., Martin, T.G., Game, E.T., Montambault, J. & Possingham, H.P. (2010). Monitoring does not always count. Trends in Ecology and Evolution 25: 547-550.
Moilanen, A., Leathwick, J. & Elith, J. (2008). A method for freshwater conservation prioritization. Freshwater Biology 53: 577-592.
Murray, C. & Marmorek, D.R. (2004). Adaptive management: A spoonful of rigour helps the uncertainty go down. Proceedings of the 16th International Annual Meeting of the Society for Ecological Restoration, Victoria, British Columbia, Canada – August 23rd to 27th, 2004.
Naidoo, R., Balmford, A., Ferraro, P. J., Polasky, S., Ricketts, T. H. & Rouget, M. (2006). Integrating economic cost into conservation planning. Trends in Ecology and Evolution 21: 681-687.
Nel, J.L., Roux, D.J., Maree, G., Kleynhans, C.J., Moolman, J., Reyes, B., Rouget, M. & Cowling, R.M. (2007). Rivers in peril inside and outside protected areas: a systematic approach to conservation assessment of river ecosystems. Diversity and Distributions 13: 341-352.
Nichols, J.D. & Williams, B.K. (1996). Monitoring for conservation. Trends in Ecology and Evolution21: 668-673.
NLWRA (2002). National Land and Water Resources Audit. Catchment, river and estuary condition. Natural Heritage Trust, Canberra.
Norris, R.H., Dyer, F., Hairsine, P., Kennard, M., Linke, S., Merrin, L., Read, A., Robinson, W., Ryan, C., Wilkinson, S. & Williams, D. (2007). Assessment of River and Wetland Health: A Framework for Comparative Assessment of the Ecological Condition of Australian Rivers and Wetlands. Australian Water Resources 2005. A baseline assessment of water resources for the National Water Initiative. Level 2 Assessment. River and Wetland Health Theme. WRON Alliance Report to the National Water Commission. May 2007.
Orians, G. & Soulé, M. (Eds.). (2001). Conservation biology. Research priorities for the next decade. Island Press.

Ormerod, S.J., Dobson, M., Hildrew, A.G. & Townsend, C.R. (2010). Multiple stressors in freshwater ecosystems. Freshwater Biology 55 (Suppl. 1): 1-4.

Petit, N., Close, P. & Kennard, M. (2010) Fine Scale Assessment of High Conservation Value Aquatic Ecosystems and Ecological Thresholds in the Daly River, NT. Summary of NRETAS/TRaCK expert panel workshop held in Darwin, 14 September 2010.

Polasky, S., Camm, J.D. & Garber-Yonts, B. (2001) Selecting biological reserves cost effectively: an application to terrestrial vertebrate conservation in Oregon. Land Economics 77: 68–78.

Possingham, H.P., Ball, I.R. & Andelman, S. (2000). Mathematical methods for identifying representative reserve networks. In: Quantitative Methods for Conservation Biology. (Eds. S. Ferson& M. Burgman), pp. 291-305. Springer-Verlag, New York.

Possingham, H.P., Andleman, S.J., Noon, B.R., Trombulak, S. & Pulliam, H.R. (2001). Making smart conservation decisions. In Conservation Biology: Research Priorities for the Next Decade (Soule, M.E. and Orians, G.H., eds), Island Press.

Pressey, R.L. & Nicholls, A.O. (1989). Efficiency in conservation evaluation: scoring versus iterative approaches. Biological Conservation 50: 199-218.

Pressey, R.L. & Tully, S.L. (1994). The cost of ad hoc reservation: a case study in New South Wales. Australian Journal of Ecology 19: 375-384.

Pressey, R.L., Cabeza, M., Watts, M.E., Cowling, R.M. & Wilson, K.A. (2007). Conservation planning in a changing world. Trends in Ecology and Evolution 22: 583-592.

Pusey, B.J. & Kennard, M.J. (2009). Chapter 3 – Aquatic ecosystems of northern Australia. In: "Northern Australia Land and Water Science Review" (ed. P. Stone). Final report to the Northern Australia Land and Water Taskforce. CSIRO Publishing. Available at: http://www.nalwt.gov.au/science_review.aspx.

Queensland Government (2011). "Wild rivers". Queensland Government Department of Environment and Resource Management. Available at http://www.derm.qld.gov.au/wildrivers/index.html (accessed 10/02/2011).

Ramsar Bureau. (2009). Strategic Framework and guidelines for the future development of the List of Wetlands of International Importance of the Convention on Wetlands. Ramsar, Gland, Switzerland. Available at http://www.ramsar.org/pdf/key_guide_list2009_e.pdf (accessed 10/02/2011).

Richardson, E.A., Kaiser, M.J., Edwards-Jones, G. & Possingham, H.P. (2006). Sensitivity of marine-reserve design to the spatial resolution of socioeconomic data. Conservation Biology 20: 1191-1202.

Risby, L., Townsend, S. & Bennett, J. (2009). Towards a water quality monitoring and management framework for the Katherine and Daly River catchment. Charles Darwin University, Darwin. Available at http://www.track.gov.au/publications/registry/765 (accessed 10/02/2011).

Rollason, S.N. & Howell, S. (2010). Report: Aquatic Conservation Assessments (ACA), using AquaBAMM, for the non-riverine, riverine and estuarine wetlands of the Southern Gulf of Carpentaria (version 1.1 draft). Published by the Department of Environment and Resource Management, Brisbane.

Rouget, M., Cowling, R.M., Lombard, A.T., Knight, A.T. & Kerley, G.I. (2006). Designing large-scale conservation corridors for pattern and process. Conservation Biology 20: 549-561.

Salzer, D. & Salafsky, N. (2006). Allocating resources between taking action, assessing status, and measuring effectiveness of conservation actions. Natural Areas Journal 26: 310-329.

Saunders, D.L., Meeuwig, J.J. & Vincent, C.J. (2002). Freshwater protected areas: strategies for conservation. Conservation Biology 16: 30-41.

Stein, J.L., Stein, J.A. & Nix, H.A. (2002). Spatial analysis of anthropogenic river disturbance at regional and continental scales: identifying the wild rivers of Australia. Landscape and Urban Planning 60: 1-25.

Stewart, R.R. & Possingham, H.P. (2005). Efficiency, costs and trade-offs in marine reserve system design. Environmental Modeling and Assessment 10: 203-213.

Tockner, K., Pusch, M., Borchardt, D. & Lorang, M.S. (2010). Multiple stressors in coupled river–floodplain ecosystems. Freshwater Biology, 55(Suppl. 1): 131-151.

van Dam, R., Bartolo, R. and Bayliss, P. 2008. Chapter 2: Identification of ecological assets, pressures and threats. In Ecological risk assessment for Australia's northern tropical rivers. Sub-project 2 of Australia's Tropical Rivers – an integrated data assessment and analysis (Eds. R. Bartolo, P. Bayliss and R. van Dam). A report to Land & Water Australia. Environmental Research Institute of the Supervising Scientist, Darwin.

Ward, D.P. & Kutt, A.S. (2007). Rangeland biodiversity assessment using fine scale on-ground survey, time series of remotely sensed ground cover and climate data: an Australian savanna case study. Landscape Ecology 24: 495-507.

Warfe, D.M., Douglas, M.M., Storrs, M. & Townsend, S.A. (2010). Asset Update on Inland Waters (Top End and Katherine Regions) for Northern Territory NRM Plan Review. Report to Northern Territory NRM from the Tropical Rivers and Coastal Knowledge (TRaCK) research hub.

Whalen, A. (2010). Report on the Workshop on Natural National Heritage Values of Wetlands in Northern Australia. Natural Heritage West, Heritage Division, Department of Sustainability, Environment, Water, Population & Communities.

Wildlife Conservation Society (2002). Monitoring conservation project effectiveness. Living landscapes Bulletin 6: 1-4.

Williams, P.H., Moore, J.L., KamdenToham, A., Brooks, T.M., Strand, H., D'Amico, J., Wisz, M., Burgess, N.D., Balmford, A. & Rahbek, C. (2003). Integrating biodiversity priorities with conflicting socio-economic values in the Guinean–Congolian forest region. Biodiversity and Conservation 12: 1297-1320.

Woinarski, J., Mackey, B., Nix, H. & Traill, B. (2007). The nature of northern Australia. Natural values, ecological processes and future prospects. ANU ePress, Canberra.

8. Appendices

Appendix 8.1. Ward, D., Stein, J. & Kennard, M.J (2010). NAWFA Aquatic Systems – Geodatabases, Metadata and Attribute Tables.

Appendix 8.2. Kennard, M.J. (2010). NAWFA HCVAE Attributes – Geodatabase, Metadata and Attribute Tables.

Appendix 8.3. Whalen, A. (2010). Report on the Workshop on Natural National Heritage Values of Wetlands in Northern Australia. Natural Heritage West, Heritage Division, Department of Sustainability, Environment, Water, Populations & Communities.

Appendix 8.4. Petit, N., Close, P. & Kennard, M. (2010). Fine Scale Assessment of High Conservation Value Aquatic Ecosystems and Ecological Thresholds in the Daly River, NT. Summary of NRETAS/TRaCK expert panel workshop held in Darwin, 14 September 2010.

Appendix 8.5. Clayton, P. & Talbot L. (2010). Ecological Thresholds Workshop Outcomes Gilbert, Flinders and Norman River Catchments. RPS Report for the Department of Environment and Resource Management, Brisbane.

Appendix 8.6. Close, P., Cossart, R., Petit, N. & Kennard, M. (2010). Fine Scale Assessment of High Conservation Value Aquatic Ecosystems in the Upper Fitzroy and Mitchell River Catchments of the Kimberley Region of Western Australia. Summary of the workshop, held in Kununurra, 11 – 12 November 2010.

APPENDIX 8.1

WARD, D., STEIN, J. & KENNARD, M.J (2010). NAWFA AQUATIC SYSTEMS – GEODATABASES, METADATA AND ATTRIBUTE TABLES.

Department of Sustainability, Environment, Water, Populations and Communities and the National Water Commission.
Tropical Rivers and Coastal Knowledge (TRaCK) Commonwealth Environmental Research Facility, Charles Darwin University, Darwin.

This data package comprises two types of data:

1. Aquatic System classes derived from the GeoScience Australia Geodata 250k Hydrography theme feature classes
2. DEM derived streams derived from the national 9 second DEM for the Australian Hydrological Geospatial Fabric.

AQUATIC SYSTEM GEODATABASES

NAWFA_Aquatic_Systems_V13.gdb

- this is the polygon, point, and line representation of the aquatic features

NAWFA_Aquatic_system_Attributes.gdb

- this is the tabular environmental data with unique (HYD_ID) for joining the attributes to the spatial features

NAWFA_Aquatic_Sytem_Ecotopes.gdb

- this is the tabular ecotope group numbers with unique (HYD_ID) for joining the attributes to the spatial features

DEM DERIVED STREAMS GEODATABASES

NAWFA_DEM_Derived_Streams.gdb

- Riverine Aquatic Systems based on the stream network derived from the national 9 second DEM for the Australian Hydrological Geospatial Fabric.

NAWFA_DEM_Stream_Attributes.qdb

- this is the tabular environmental data with unique (SEGMENTNO) for joining the attributes to the spatial features

NAWFA_Aquatic_Sytem_Ecotopes.gdb

* this is the tabular ecotope group numbers with unique (SEGMENTNO) for joining the attributes to the spatial features

FOR MORE INFORMATION, PLEASE REFER TO:

* NAWFA metadata_north_australia_aquatic systems.mdb
* NAWFA Lacustrine Palustrine and Estuarine Environmental Attributes.xlsx
* NAWFA Riverine Environmental Attributes.xlsx
* NAWFA Riverine Lacustrine and Palustrine Ecotope Classification LUT.xlsx
* Kennard, M.J. (ed) (2010). *Identifying high conservation value aquatic ecosystems in northern Australia*. Interim Report for the Department of Environment, Water, Heritage and the Arts and the National Water Commission. Tropical Rivers and Coastal Knowledge (TRaCK) Commonwealth Environmental Research Facility, Charles Darwin University, Darwin. ISBN: 978-1-921576-23-2. Available at: http://track.gov.au/publications/registry/843 or http://www.environment.gov.au/water/publications/policy-programs/nawfa-hcvae-trial-report.html
* Kennard, M.J. (ed) (2011). *Priorities for identification and sustainable management of high conservation value aquatic ecosystems in northern Australia*. Final Report for the Department of Sustainability, Environment, Water, Population and Communities and the National Water Commission. Charles Darwin University, Darwin. ISBN: 978-1-921576-30-0. Available at: http://track.gov.au/publications/.

APPENDIX 8.2

KENNARD, M.J. (2010). NAWFA HCVAE ATTRIBUTES – GEODATABASE, METADATA AND ATTRIBUTE TABLES.

Department of Sustainability, Environment, Water, Populations and Communities and the National Water Commission.
Tropical Rivers and Coastal Knowledge (TRaCK) Commonwealth Environmental Research Facility, Charles Darwin University, Darwin.

The geodatabase "NAWFA_HCVAE_data.gdb" comprises the following data:

Raw HCVAE attributes scores, integrated attribute type scores and final integrated HCVAE criterion scores (scaled from 0-1) for each Planning Unit polygon. Also indicated (with a 1) are the Planning Units "meeting" each criteria at the 90th , 95th & 99th %'ile threshold, respectively as well as the total number of criteria met for each planning unit at each %'ile threshold.

Within the geodatabase "NAWFA_HCVAE_data.gdb" are three data layers:

FINAL_HCVAE_ATTRIBUTES_ALL

- this HCVAE attribute data referential to the entire study region (_ALL)

FINAL_HCVAE_ATTRIBUTES_DD

- this HCVAE attribute data referential to each Drainage Division (_DD)

FINAL_HCVAE_ATTRIBUTES_NASY

- this HCVAE attribute data referential to each aggregated NASY Region (_NASY)

FOR MORE INFORMATION, PLEASE REFER TO:

- NAWFA metadata_north_australia_HCVAE_attributes.mdb
- NAWFA HCVAE attributes.xlsx
- Kennard, M.J. (ed) (2010). *Identifying high conservation value aquatic ecosystems in northern Australia*. Interim Report for the Department of Environment, Water, Heritage and the Arts and the National Water Commission. Tropical Rivers and Coastal Knowledge (TRaCK) Commonwealth Environmental Research Facility, Charles Darwin University, Darwin. ISBN: 978-1-921576-23-2. Available at: http://track.gov.au/publications/registry/843 or http://www.environment.gov.au/water/publications/policy-programs/nawfa-hcvae-trial-report.html
- Kennard, M.J. (ed) (2011). *Priorities for identification and sustainable management of high conservation value aquatic ecosystems in northern Australia*. Final Report for the Department of Sustainability, Environment, Water, Population and Communities and the National Water Commission. Charles Darwin University, Darwin. ISBN: 978-1-921576-30-0. Available at: http://track.gov.au/publications/.

APPENDIX 8.3.

WHALEN, A. (2010). REPORT ON THE WORKSHOP ON NATURAL NATIONAL HERITAGE VALUES OF WETLANDS IN NORTHERN AUSTRALIA. NATURAL HERITAGE WEST, HERITAGE DIVISION, DEPARTMENT OF SUSTAINABILITY, ENVIRONMENT, WATER, POPULATIONS & COMMUNITIES.

AUGUST 2010

REPORT ON THE WORKSHOP ON NATURAL NATIONAL HERITAGE VALUES OF WETLANDS IN NORTHERN AUSTRALIA

by

Anthony Whalen
Natural Heritage West, Heritage Division, Department of Sustainability, Environment, Water, Populations & Communities

The Department of the Environment, Water, Heritage and the Arts (DEWHA) held an experts' workshop on the *Natural National Heritage Values of Wetlands in Northern Australia*[1] at Charles Darwin University on the 22-23 March. The workshop identified northern Australian wetlands of potential outstanding significance to the nation for their natural heritage values. Wetlands have been identified as an Australian Heritage Council theme of priority, arising out the Council's need to compare wetlands found in the Kimberley region (as part of an ongoing National Heritage assessment) to other wetlands in northern Australia. The information gained from the workshop will also be used to help assess future National Heritage nominations that include natural wetland values.

The Workshop was attended by a range of scientists and government representatives with expertise in natural wetlands values (a list of attendees is at Appendix B). The attendance of several researchers from the CERF funded Tropical Rivers and Coastal Knowledge (TRaCK[2]) research hub, whose research has had a specific focus on northern Australian river systems was of particular benefit. Discussions at the workshop drew on other existing Australian Government water initiatives, including the High Conservation Value Aquatic Ecosystems (HCVAE) framework and the Water Futures Assessment of Northern Australia, both of which are currently being developed by DEWHA.

The workshop identified in excess of forty wetland/river sites across northern Australia that may possess natural National Heritage values. From workshop discussions, this list of forty was shortlisted to thirteen sites was considered to rank highly, potentially possessing significant values against the National Heritage List criteria. All forty sites are detailed in Appendix C. Shortlisted sites are identified in the column labelled *Are the values potentially nationally significant*?

It should be noted that this shortlist does not represent a final determination of northern Australian wetlands for future National Heritage listing. The data and expertise available at the workshop was not comprehensive and more information may be required to establish the natural heritage significance and values of wetlands across northern Australia. It is recognised that consultation would be undertaken with owners, occupiers and those with Indigenous rights or interests before any of these wetlands are added to the National Heritage list.

The shortlist will be used in the short term to inform the significance of wetlands of the Kimberley region as compared to other Australian wetlands, particularly with regard to refugial values and migratory birds. Longer term, information about the values of places on the shortlist will be supplemented by additional information as new research is completed across northern Australia, particularly work undertaken by the TRACK program (it was also noted, for example, that additional genetic work on fish populations in preparation may assist the comparison of the relative significance of river systems). The shortlist is seen as the beginning of the Australian Heritage Council's work in identifying wetland values of outstanding value to the nation.

Attachments

Appendix A – Map of 'Northern Australia'
Appendix B – List of Workshop Participants
Appendix C – Northern Australian wetlands, including 'shortlisted' sites with the most obvious potential for possessing national heritage values

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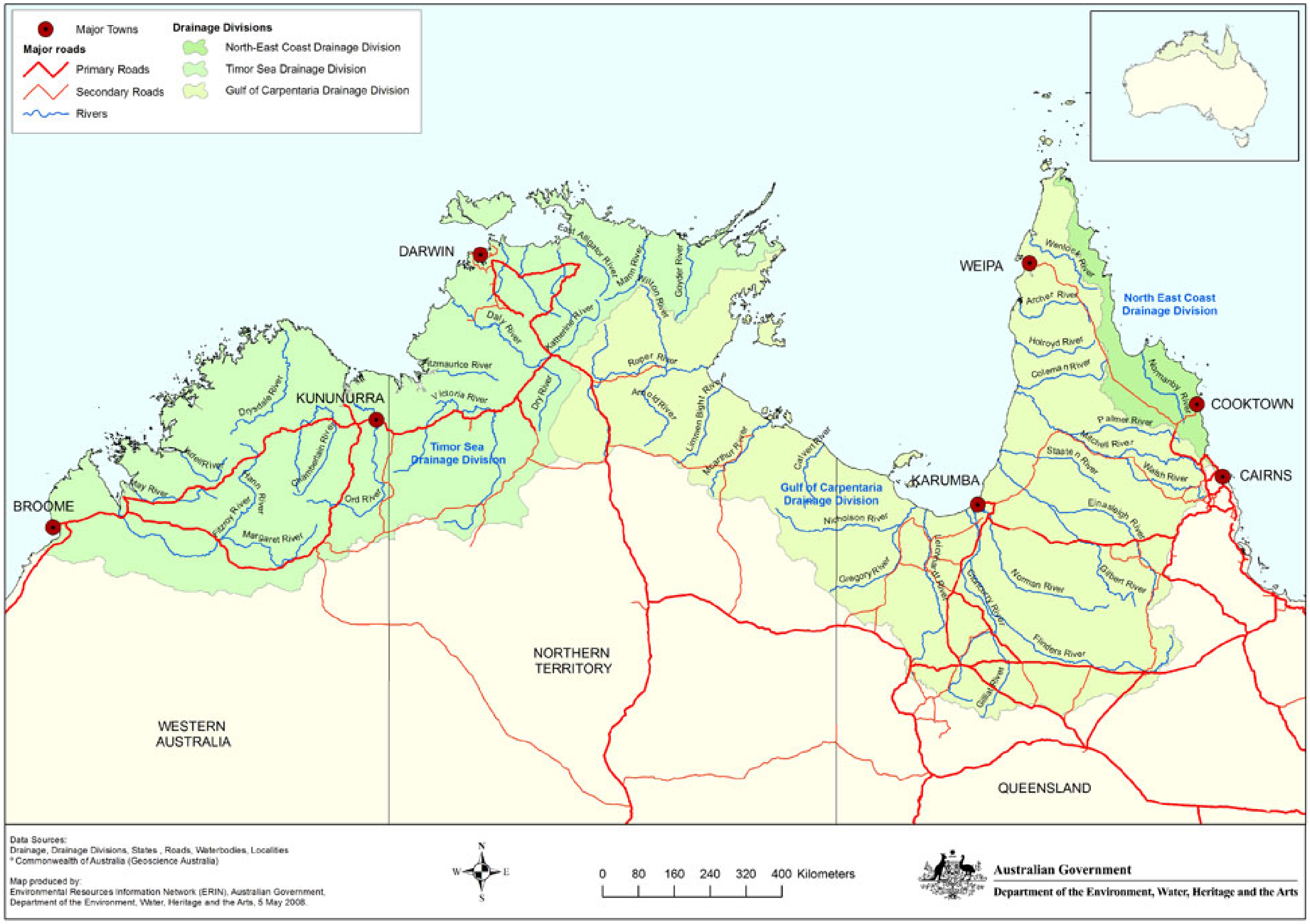
[1] ***Northern Australia*** generally is described by a line that starts just south of Broome, and goes across to the east coast just north of Cairns. It encompasses the Timor Sea and Gulf of Carpentaria drainage divisions, and that part of the North East Coast drainage division north of Cairns. See Appendix A.

[2] TRaCK draws together more than 70 of Australia's leading social, cultural, environmental and economic researchers. The hub's research focus is on the rivers and coastal environments of tropical north of Australia from Cape York to Broome.

Appendix A – Northern Australia (described by a line that starts just south of Broome, and goes across to the east coast just north of Cairns. It encompasses the Timor Sea and Gulf of Carpentaria drainage divisions, and that part of the North East Coast drainage division north of Cairns).



Appendix B

Northern Wetlands Workshop Participants

Name	Place of work	TRACK member
Peter Valentine (CHAIR)	Australian Heritage Council	
Peter Bayliss	CSIRO, Brisbane	Yes
Renee Bartolo	Environmental Research Institute of the Supervising Scientist, Darwin, NT	
Michael Douglas	Charles Darwin University, Darwin	Yes
Jane Hughes	Aust Rivers Institute, Griffith University, Brisbane	Yes
Chris Humphrey	Environmental Research Institute of the Supervising Scientist, Darwin, NT	
Mark Kennard	Aust Rivers Institute, Griffith University, Brisbane	Yes
Robert Cossart	Dept of Water, WA Gov, Kununurra	
Michael Storrs	NAILSMA, Darwin, NT	
Simon Ward	Dept of Natural Resources, Environment, The Arts and Sport NT Gov, Darwin	
Peter Macdonald	DERM, Qld Gov	
Geoff Sainty	Sainty and Associates, Sydney	
Brad Pusey	Aust Rivers Institute, Griffith University, Brisbane	Yes
Tanya Vernes	WWF, (Kimberley Wetlands Project Officer)	
Doug Ward	Aust Rivers Institute, Griffith University, Brisbane	Yes
Bruce Wannan	DERM, Qld	
Michael Quinn	Heritage DEWHA	
Geoff Larmour	Heritage DEWHA	
Anthony Whalen	Heritage DEWHA	
Carla Morgan	Heritage DEWHA	
Ryan Breen	Water Group DEWHA	

Appendix C - Northern Australian wetlands, including 'shortlisted' sites with the most obvious potential for possessing national heritage values

Are the values potentially nationally significant?	Wetland	What is special?	References
Yes	**QLD** **Cape Flattery/Bedford dune lake system**, *(lacustrine, riverine, palustrine)*	o Rare sand dune geomorphology. Oligotrophic acidic stained dune lakes and stream systems linked to origins and adaptations of fauna o Presence of fish species otherwise restricted to west of the Great Dividing Range with disjunct distributions indicative of former wider distributions perhaps during periods of lowered sea level o Aquatic habitats in this region include lakes, both perched and window types, as well as freshwater streams and small short estuaries. o The dune lake system of Cape Flattery contains the largest number of individual aquatic dune habitats (e.g. individual wetlands) in northern Australia. It experiences low visitation rates (important for oligotrophic systems) o Samples of *Pseudomugil gertrudae* (spotted blue eye) from nearby Cape Bedford dune lake system are highly differentiated from other populations suggesting long-term isolation of habitat. Samples of *M. maccullochi* from Cape Bedford are slightly differentiated from Wet Tropics populations and highly differentiated from Jardine. This suggests that eastern northern Australia is a long term refugium. o Large dune lake system, high water purity – dune formations probably of international significance o Endemic crayfish, disjunct distribution of fish o High number of habitat types, including perched lakes, acidic streams, black water estuaries etc o Level of visitation much lower than other comparable perched lakes (Fraser Is) o Several hundred sq km and relatively undisturbed o <u>Comparative</u> o Cape York peninsula dune lakes (Lake Bronto, Lake Wichera, etc), Shelburne Bay and Harmer Creek, Wallum dune systems (interdunal wetlands) near Cairns (Cowley)	TRaCK - Mark Kennard, Brad Pusey, Ben Cook, Jane Hughes, Doug Ward, Peter Bayliss and Michael Douglas
Yes	**QLD** **Jardine River, Cape York** *(aggregation)*	o The Jardine river contains a high diversity of freshwater fishes, a portion of which is shared with southern Papua New Guinea (e.g. *Neosilurus brevidorsalis*) indicative of former connectivity. *Denariusa bandata* shows close genetic relationships with populations from the Fly River (PNG). Invertabrate fauna of Jardine River also shows strong relationship with Papua New Guinea (AHC 1995). o Fish fauna transitional between that of western rivers and eastern rivers as well as containing PNG elements - shows up as being a separate group from other Northern Aus rivers, more connected to PNG o Populations of *Pseudomugil gertrudae* and *M. maccullochi* are highly differentiated from other populations, suggesting a long-isolated freshwater region and that the Jardine probably represents a refugium o High biodiversity in swamp system/diversity of wetland types including mangrove	TRaCK - Mark Kennard, Brad Pusey, Ben Cook, Jane Hughes, Doug Ward, Peter Bayliss and Michael Douglas Australian Heritage Commission 1995, *Areas of Conservation Significance on Cape York Peninsula*, Cape York Peninsula Land Use Strategy.

Are the values potentially nationally significant?	Wetland	What is special?	References
		communities, saline flats, sedgelands, perennial waterbodies and swampy forested areas. Probably diversity in swamp development ages. Floating vegetation communities present (AHC 1995). o Contains species with highly fragmented distributions indicative of formerly more widespread fauna o Catchment formerly a shallow sea, hence sandstone lithology o Jardine Swamps contains features associated with prograding coastline including beach ridges and relic delta. o This type of river (perennial, oligotrophic, acidic, over a sandstone lithology acting as a vast unconsolidated aquifer) not present elsewhere in northern Australia. Highly oligotrophic extremely low solute concentrations – comparable water quality not observed elsewhere. o Large parts already protected and relatively undisturbed o The Jardine has a highly distinctive flow regime typified by perenniality. Only one other small stream in Arnhem Land within all of northern Australian was typified by this regime type. o Important breeding location for estuarine crocoldile. o <u>Comparative</u> o possibly incomparable - perhaps Shelburne rivers (smaller scale, Wenlock River, Jackey Jackey Creek, Jackson River	
Yes (perhaps in combination with Jardine)	**QLD** **Newcastle Bay - Escape River Estuarine Complex**	o Could be considered part of the Jardine River area o The site has the best development of mangroves in Australia (3.1.1a: Estuarine wetlands (e.g. mangroves)). *Rhizophora stylosa* (red mangrove) often completely dominates, forming a very even, closed canopy (5-30m tall) o The extent and structural development of mangroves is exceptional in a national context. Very high diversity (20+ sp). Includes the most extensive stands of medium and tall mangrove forests in Queensland (AHC 1995). o Notable for a sequence of inlets o a large, shallow, sheltered estuarine complex with low gradient foreshores composed of recent sediments that have been colonised by mangroves o There are some saline intertidal and supratidal flats included in the complex and some associated with the complex. o A distinctive feature is the relative rarity of saltflats in the marineterrestrial transition area. There are about 2,000 ha of saltflats on the site but most of them are located in the middle of mangrove islands. o <u>Comparative</u> o PNG, Scarden River	Bruce Wannan Australian Heritage Commission 1995, *Areas of Conservation Significance on Cape York Peninsula*, Cape York Peninsula Land Use Strategy.
Yes	**QLD** **Normanby River floodplain**	o Important habitat for waterbirds o high number of lacustrine/palustrine waterbodies o Endemic lineage within *O. selhemei* [is this a fish? Genus name?] that is sympatric	TRaCK - Mark Kennard, Brad Pusey, Ben Cook, Jane Hughes, Doug Ward, Peter Bayliss and Michael Douglas

TRaCK Tropical Rivers and Coastal Knowledge

Are the values potentially nationally significant?	Wetland	What is special?	References
	(aggregation)	with a more widespread lineage o diversity of flow regime types across the catchment. o Contains one species otherwise limited to west of the GDR (*Neoarius paucus* formerly known as *N. midgelyi*) o Riverine closed forests an important corridor (linking to Wet Tropics) and important for regional migration. Richness and high diversity of Cape York vegetation communities, fauna (AHC 1995) o Extensive mud flats o Important estuarine Crocodile breeding ground o Mollusc fossil sites o Riverine environment – high productivity o High habitat diversity, including wetlands, in a relatively small area o Comparative – lower reaches similar to west coast/west flowing rivers, Mitchell (less rainforest)	Australian Heritage Commission 1995, *Areas of Conservation Significance on Cape York Peninsula*, Cape York Peninsula Land Use Strategy.

Yes	**QLD**
	Olive River
	
	(aggregation)
		o Could be considered with Shelburne Bay
		o Interesting fish – high diversity in small systems, mix of east and west cape fauna and wet tropics, typical of west flowing streams, affinities to wet tropics and Fly River PNG – indicative of connectivity, reduction of diversity from north to south along coast.
		o Contains fish species otherwise restricted to the Jardine River and southern PNG
		o Contains a number of species otherwise mainly limited to the wet tropics region.
		o Illustrative of a more extensive past distribution of rainforest communities.
		o Significant woodland and heath community wetlands
		o High habitat diversity of all vegetation types, including wetlands in a small area
		o Shelburne dune lakes are among best examples of their type in the world (AHC 1995)
		o Comparative
		  o Wet Tropics rivers, smaller rivers around Shelburne Bay.
		  o Cape Flattery for dune lakes
			TRaCK - Mark Kennard, Brad Pusey, Ben Cook, Jane Hughes, Doug Ward, Peter Bayliss and Michael Douglas
			
			Australian Heritage Commission 1995, *Areas of Conservation Significance on Cape York Peninsula*, Cape York Peninsula Land Use Strategy.

Probably	**QLD** **Southern Gulf wetland aggregations** Mornington Inlet, Flinders, Norman, Gilbert (sth)	o These wetlands are a complex disjunct wetland aggregation of closed depressions in impeded drainage lines, floodouts, backplains and riverine channels merging with an extensive estuarine system of saline clay pans and tidal channels. o High area, density and connectivity of wetland features (lacustrine & palustrine) o Water flows beneath sand in the Gilbert that supports fauna o High diversity of Ariidae catfishes and other euryhaline fishes. o New species of plotosid catfish (*Porochilus* sp) from the Cloncurry River (Flinders Basin) o Many fish species, e.g. *Ambassis macleayi, Glossamia aprion* show significant population structure among Gulf rivers. Similar patterns are seen in *Cherax quadricarinatus* and *Macrobrachium rosenbergii*, with apparent lack of dispersal	TRaCK - Mark Kennard, Brad Pusey, Ben Cook, Jane Hughes, Doug Ward, Peter Bayliss and Michael Douglas

Are the values potentially nationally significant?	Wetland	What is special?	References
		east/west across the Gulf. *Scylla serrata* (mud crab) also shows significant population structure between the east and west of the Gulf. This implies that, despite apparent hydrological connectivity between Gulf rivers in the wet season, these species do not disperse between river mouths. However, all populations are closely related in the evolutionary sense. o Endemic Gulf species of freshwater mussel (undescribed) common in clearwater sites in Gregory, rare in other Gulf rivers. o Presence of highly restricted terpaontid grunter in Mitchell River (*Variichthys lacustris*) indicates former connection to southern PNG. o High area, density and connectivity of wetland features (lacustrine & palustrine) o Important waterbird habitat (e.g. Great billed heron abundant in these wetland types) o Significant information gaps o <u>Comparative</u> o Staatan and Mitchell (further north) o Reduced diversity of stenohaline species in Flinders/Norman has been used as an example of the effect of historic periods of greater aridity and of contemporary effects of reduced ambient temperatures associated with high latitudes. These latter two rivers have their headwaters at the highest latitudes of all northern Australian rivers.	
Probably	**QLD** **Southern Gulf** Gregory, Nicholson complex	o These wetlands are a complex disjunct wetland aggregation of closed depressions in impeded drainage lines, floodouts, backplains and riverine channels merging with an extensive estuarine system of saline clay pans and tidal channels. o Endemic Gulf species of freshwater mussel (undescribed) common in clearwater sites in Gregory, rare in other Gulf rivers. o Endemic species in the Gregory, hydrologically different to other river/wetland o Important waterbird habitat	
Yes	**NT** **Arnhem Plateau** (i.e. rivers draining the plateau –Roper, Blythe, Liverpool, Goomadeer, East & South Alligator, Mary, Daly-Katherine, Mann) **Warddeken Indigenous Protected Area** (in the Liverpool sandstone plateau country of Arnhem Land) *(springs, lacustrine, riverine, palustrine)*	o Each waterbody is genetically differentiated from other waterbodies. o High number of endemic fish species that exhibit disjunct distributions and high genetic differentiation between populations within individual rivers. o Endemic turtle species (*Chelodina burrungandjii* - Sandstone Snake-necked Turtle and a morphologically & genetically distinctive form of *Elseya dentata* [South Alligator]. o Geologically stable o long term evolutionary refugia o High diversity of wetland types, shallow heath land swamps, seasonal o Only permanent sections of flowing streams in the NT o whole plateau is the boundary rather than the catchment o recognised as a biodiversity hotspot o Endemic freshwater shrimp genus *Kakaducaris*, and other endemic species of	TRaCK - Mark Kennard, Brad Pusey, Ben Cook, Jane Hughes, Doug Ward, Peter Bayliss and Michael Douglas Page T, Short JW, Humphrey CL, Hillyer MJ & Hughes JM 2008. Molecular systematics of the Kakaducarididae (Crustacea: Decapoda: Caridea). *Molecular Phylogenetics and Evolution* 46, 1003–1014. Wilson GDF, Humphrey CL, Colgan DJ, Gray KA & Johnson RN 2009. Monsoon-influenced speciation patterns in a species flock of Eophreatoicus

Are the values potentially nationally significant?	Wetland	What is special?	References
		Leptopalaemon, suggesting very long-term isolation of these waterbodies. Also each waterbody is genetically differentiated form all others. o Populations of northern trout gudgeon (*Mogurnda mogurnda*) in upper Katherine highly differentiated from other populations in the middle and lower Daly River. This could suggest that plateau populations of other species are likely to be differentiated o High number of endemic fish species that exhibit disjunct distributions and high genetic differentiation between populations within individual rivers. Such species include exquisite rainbowfish (*Melanotaenia exquisita*), Katherine River gudgeon (*Hypeselotris burrawayi*), Midgley's grunter (*Pingalla midgleyi*), Mariana's hardyhead (*Craterocephalus marianae*) o spring fed rainforest o wetlands interspersed with (rare?) tropical heathland, comparative to Cape York heathlands re plant species endemism o More research needed o unrepresented in Reserves System o Significant fauna - Gouldian finch habitat, pygmy crocodiles [significance?], endemic macro-crustaceans o Plant and animal (isopods, frogs, turtles) Gondwanan relics o Adjoining Kakadu National Park, Warddeken is globally significant for its natural and cultural values. o The area is home to dozens of endemic plants, a host of threatened species and possibly a new and unique ecological community o Note - upper Katherine part of the Plateau – eastern boundary is unclear o Wardekken Indigenous Protected Area – declared September 2009. Wetlands – seasonal shallow heathland swamps, and permanent rivers, streams, seeps and springs – contained within 1,394,951 hectares of spectacular stone and gorge country mainly in the upper Liverpool River catchment on the western Arnhem Land plateau. o Wardekken Indigenous Protected Area adjoins Kakadu National Park (KNP). While KNP contains just a narrow strip of the main sandstone plateau and escarpment of the Arnhem sandstone massif (a location of significant endemic terrestrial (Woinaski et al. 2006) and freshwater biodiversity), virtually all of the Wardekken Indigenous Protected Area represents this unique and important land and biodiversity unit. o Accordingly, Warddeken is globally significant for its natural and cultural values. The area is home to dozens of endemic plants and animals (terrestrial and aquatic), a host of threatened species and possibly a new and unique ecological community – sandstone heathlands with seasonal wetlands. Unique freshwater crustaceans and possibly amphibians have only been recently discovered in the Area's wetlands.	Nicholls (Isopoda; Crustacea) *Molecular Phylogenetics and Evolution* 51(2), 349–364. Woinarski JCZ, Hempel C, Cowie I, Brennan K, Kerrigan R, Leach G, Russell-Smith J 2006. Distributional pattern of plant species endemic to the Northern Territory, Australia. Australian Journal of Botany. 54, 627–640.

Are the values potentially nationally significant?	Wetland	What is special?	References

		Thousands of individual occupation and rock art sites are also found here. It is managed under the International Union for Conservation of Nature (IUCN) Category VI, as a protected area with sustainable use of natural resources
		o Warddeken Land Management has successfully developed with industry an innovative carbon abatement partnership and is engaging in collaborative scientific research to position itself for entry into a future biodiversity credit scheme.
		o Comparative
		    o Stone country in the Daly, Fish River Gorge
		    o Sandstone/limestone area, comparable to other sandstone massives?	

Yes	**NT** **floodplains in the Kakadu area, incl the Alligator Rivers** *(aggregation)*	o High value for water birds and fish o Weed management an issue o Important habitat for threatened sp, e.g sawfish, snubfin dolphin, spear toothed and northern river shark (records also outside of Kakadu, for example the Daly and Fitzroy Rivers) o High Abundance of species, e.g. magpie geese (85% of dry season population) o Note: See ecological character description (almost complete) o Paleo studies, informing history of freshwater wetlands (mainly Sth Alligator River for Holocene.) o High number of type localities o Where should the boundary lie? The Nat Park boundary does not follow ecological character o The East Alligator River sits within the alligator river wetland region which includes the three other rivers the Wildman, West and South Alligator River. The east alligator stretches approximately 160km. The catchment size is approximately 15,876 km² stretching to the Timor Sea. The east alligator combined with the Wildman south and west rivers form the Alligator Rivers Coastal Floodplain. o The floodplains of the Alligator Rivers are unique in Australia in the diversity of wetland habitats and abundance of wildlife they support. More than two million waterbirds, notably Magpie Geese and ducks have been recorded, including internationally significant counts of more than 20 species. Large aggregations of shorebirds also occur seasonally in parts of the floodplain. The Site is also very important for threatened species; 32 threatened species have been recorded from the Site. o The site supports about three million waterbirds of over 60 species. Large populations of many other vertebrate and invertebrate species are also found (SKM 2007) o The four river systems of the wetlands are outstanding examples of the series of large rivers of the Torresian monsoonal biogeographic region draining into the Arafura Sea (SKM 2007) o Comparative	Stuart Halse, Peter Bayliss Sinclair Knight Merz, 2007, High Conservation Value Aquatic Ecosystems Project – identifying, categorising and managing HCVAE, Final Report, produced for the Department of Environment and Water Resources.

Are the values potentially nationally significant?	Wetland	What is special?	References
		o Mary, Adelaide, Finnis, Adelaide Rivers	
Yes	**NT** **The Arafura swamp complex** *(aggregation)*	o The Arafura swamp is located in Central Arnhem along the Arnhem coast in NT. The swamp occupies the Muckaninnie Plains of the Goyder and Gulbuwangay Rivers, which form the Glyde River near the downstream limit. o The Arafura swamp is possibly the largest example of a wooded swamp in Australia. The swamp has significant flora, fauna ecological, social and cultural heritage values. o The large and diverse wetland habitats of the Arafura Swamp support large numbers of waterbirds (over 300,000) at times. Magpie Geese and egrets are most often the dominant species, but at least eight other species, including the Black necked Stork, Brolga, Radjah Shelduck, and Royal Spoonbill, occur in internationally significant numbers. Numerous rainforest patches occur around the margin of the swamp, and seven threatened species are reported from the site. o Further fish research much needed o Larges stands of *Phragmites* (grass), good stands *Corypha* palms o Salt water intrusion is a significant threat to all nor o Paleo history records (Thompson research work) could be a national value under (c) o Significant fauna - False rat species (2 records), a possible endemic turtle (similar to pig nosed turtle?), Extensive salt water croc breeding o <u>Comparative</u> o Mary River no main water channel (salt intrusion and dieback), Cape York Melaleuca fresh water swamp	Stuart Halse/ Peter Bayliss / Renee Bartolo
Yes	**NT** **Lower Douglas-Daly floodplain** *(aggregation)*	o Largest perennial river in northern Australia o Overlays large karstic aquifers, groundwater likely to contain a significant stygofauna although this has not been investigated in detail. o Carbonate-rich groundwater has led to the formation of perhaps the continent's largest aggregation of tufa dams. o Perennial flow supports a very rich fish fauna. o Wet season flows in the river are high and the continuous dry-season flows of spring fed water result in a unique freshwater ecosystem that supports numerous threatened or otherwise important species o They support numerous waterbird breeding colonies and internationally significant numbers of waterbirds, particularly Magpie Geese and Wandering Whistling Ducks o The Daly's estuary and lower floodplain have been assessed as satisfying waterbird-based criteria for listing as a Wetland of International Importance under the Ramsar Convention (1971) (Chatto, 2005, draft, p33). This large complex of wetlands, occurring across an area of approximately 20 x 30 km, was found to support 14	TRaCK - Mark Kennard, Brad Pusey, Ben Cook, Jane Hughes, Doug Ward, Peter Bayliss and Michael Douglas

Are the values potentially nationally significant?	Wetland	What is special?	References
		significant waterbird sites and six significant breeding sites during waterbird surveys that commenced in 1990. o The Daly River supports a high diversity (eight species) of freshwater turtles which is the richest in Australia and includes most of the Australian population of the Pig nosed Turtle. Several species of threatened or rare freshwater fish also occur in the river, including Freshwater Sawfish, Freshwater Whipray and possibly Spear-tooth shark (Glyphis) o Divergent lineages of a range of species (sleepy cod) fish. Endemic lineage (species) of *Oxyeleotris lineolatus* and *Oxyeleotris selheimi* in Daly River. This suggests long isolation of the Daly River and in situ diversification o Urban threats to catchment area, growth rates of spirogyra impacts turtle pop o Lowland river and perennial flow sustains the largest contiguous area of lowland gallery forest in northern Australia. Note: This has been questioned) o Body of research on (groundwater dependent riverine veg) potential for (c)? o <u>Comparative</u> o Roper River	
Yes	**WA** **Paruku wetlands - Lake Gregory** *(lacustrine, palustrine)*	o the best Australian example of a large wet desert lake dependent on monsoonal rain for filling o Paruku Indigenous Protected Area was declared in September 2001. It covers around 430,000 hectares on the borders of the Great Sandy Desert and Tanami bioregions, south of the township of Halls Creek. o Paruku's spectacular wetlands are an internationally renowned haven for hundreds of thousands of birds. The IPA covers a collection of aquatic habitats known as Lake Gregory, including Mulan Lake (the largest waterbody), Lera Waterhole, and Salt Pan and Djaluwon Creeks. o Comprises all basins at the end of Sturt Creek drainage system o The entire Lake Gregory system comprises of Mulan Lake (= Lake Gregory), Lera Plain (= Lera Waterhole), Bulbi Plain, Yuinby Plain (= Yeunbi Plain), Guda Plain (= Kurdu Plain), Rilya Plain (= Rillyi Rillyi Plain) and Delivery Camp Plain (= Gillung Plain); also interconnecting channels and lower reaches of Sturt, Sesbania Creek and Goondy Goondy Creeks. o great waterbird lake, Important arid zone wetland, support bird populations o Bilby, Yellow Chat – rare species o *Eragrostis* grasslands, *Acacia maconochieana* o Evolutionary history, functioning wetland, reduced from a megalake o Indigenous cultural history closely tied to system over long period o Linkage to coast through groundwater systems – well known by TOs o <u>Comparative</u> – Barkley Lakes, Lake Eyre, Lake Mungo (as a palaeo-wetland)	Stuart Halse / Tanya Vernes / Rob Cossart
Yes	**WA** **Roebuck Plains system** (Roebuck	o significant staging point for migratory shorebirds, great tropical marine embayment with very high (benthic) diversity of mudflat invertebrates	Stuart Halse / Tanya Vernes / Rob Cossart

Are the values potentially nationally significant?	Wetland	What is special?	References
	Bay and inland wetlands) *(palustrine, coastal)*	o intertidal mudflats o unique suite of characteristics in Australia, compable to 12 other tropical mudflat systems o simpler mangrove species than other sites o mangrove bird significance o Roebuck Plains – linkage for water flow out to the Bay o Comparable – difficult to find a comparable site	
Yes	**WA** **Eighty-mile Beach** **Karajarri (La Grange) groundwater dependent ecosystems** (Walyarta (Mandora Marsh), McLarty Hills, Kurrijipa yajula (Dragon Tree Soak), Lunyirrkartiny (Munroe Springs), Whistle Ck, Injindina Springs etc.) *(palustrine, coastal)*	o most important shorebird site in Australia – Roebuck Bay is of higher value because of its other values o Mandora Marsh is the most inland mangrove, (comparable to Ningaloo inland mangroves) Mandora Marsh probably supports significant numbers of birds every 3-6 years on average, however, at least once each decade it is exceptionally important for waterbirds (C. Minton, pers. comm. from Envirnment Australia 2001) o Suite of wetlands – possibly for NH criteria (b) (Munroe and Injinada Springs)– Dragon Tree site, [Speak to Vic Seminuik if more information is required], including raised peat bog in tropical desert environment, perennial organic mound springs o The entire Karajarri complex is considered same system by Indigenous communities; TO knowledge of ground water systems is richer than Western knowledge at this stage o Significant fauna – 200,000 waterbirds [contact Stuart Halse if further information required] most important in terms of abundance, Endemic goby (Mandora Marsh) o Important dry season refugia o Comparative – difficult to find a comparable site, possibly Arnhem Land or the Southern Gulf?	Stuart Halse Environment Australia 2001, A Directory of Important Wetlands in Australia 3rd Edition, updated 5/3/2010.
Yes	**WA** **Dampier Peninsula mound springs and wetlands** (Bunda Bunda, Willie Creek, Carnot Bay, Disaster Bay, Pender Bay etc) Monsoon Vine *(springs, coastal)*	o Listed Threatened Ecological Communities (Disaster Bay, Bunda Bunda and Willie Creek), and is on the 'National Wetlands of Significance' o Sheer number of mound springs, east coast of Dampier o Some of the largest springs in the Kimberley o Freshwater wetlands rare in Kimberley o Important linkage roles, rare communities on West coast, together near potential development areas o Vine thickets – important, distinct (behind sand dunes), Naturally fragmented systems over large area but disjunct o Suite of species unique to Dampier - a few rare species, 3 endemic plants o Closer affinity to the south than other parts of the Kimberley o Further assessment of mound springs (threat analysis, rather than conservation/nat heritage focus??) o Comparative o ground water systems of the Canning Coast (e.g. LaGrange)	Tanya Vernes/ Rob Cossart

Are the values potentially nationally significant?	Wetland	What is special?	References
Yes	**Mitchell, King Edward and Drysdale rivers** **Prince Regent River** (including Roe and Moran Rivers) *(aggregation)*	o Mitchell River drainage system, including the headwaters of the river and tributaries, waterfalls (Mitchell Falls, Surveyors Pool), the estuary to the point where it broadens into Walmesley Bay (part of Admiralty Gulf) and associated tidal creeks and flats. (Includes Airfield Swamp. Marine waters more than 6 m deep at low tide are excluded.) o Prince Regent River system and large areas of mangrove on either side of the river mouth in Saint George Basin (DIWA wetland (5 criteria), Wild River and candidate Ramsar wetland. Wild Rivers are recognised as important, rare representatives of largely unchanged systems. o Escarpment country, highly dissected – difficult to find comparative sites o High turtle and fish endemism, genetically isolated. Endemic fish differences high between catchments, upper catchment habitat has protected from sea level changes o Unique freshwater mussels and isopods – Gondwanan links o Unique plants – *Ondinea purpurea* (King Edward wetlands), riparian and rainforest systems well up the catchment. High plant species richness around Cascade Falls o High wetland community diversity, mixture of wetland types – basalt, Tertiary, riverine systems o Is a UNESCO Biosphere Reserve and almost all of the catchment is within National Park (high integrity) o Rated as a Priority 1 (highly pristine) 'Wild River' in the AHC (1995) report and is the most pristine 'wild river' in the North Kimberley o Moran – high biodiversity but unsure which o The river system is a complex unit that is hard to separate into smaller units o Limited research o <u>Comparative</u> o Possibly the Berkeley and King George Rivers?	Rob Cossart Australian Heritage Commission 1995, *Areas of Conservation Significance on Cape York Peninsula*, Cape York Peninsula Land Use Strategy.

Unlikely	**QLD**
	Cape Tribulation coastal streams
		o Interesting fish and crustaceans. Recent discoveries of a series of potentially endemic apparently undescribed sicydine gobies
		o Rainforest streams
		o High diversity of wetland types for a small area
		o Further studies required on fish water fish (e.g. gobies)
		o Concentration of localised endemics
		o Short catchments but high rainfall (up to and over 4 m per year)
		o Significant diversity of frogs and freshwater fish in wet tropics
		o <u>Comparable</u>
		    o Lockhart, (sth of Cairns, yarrabar), Hinchinbrook
		    o [Apart from other rivers in QLD the short length perennial streams of Cape Tribulation may only be comparable only to parts of Tasmania]
			TRaCK - Mark Kennard, Brad Pusey, Ben Cook, Jane Hughes, Doug Ward, Peter Bayliss and Michael Douglas

Unlikely	**QLD** **Bloomfield and/or Daintree**	o Endemic species of spiny crayfish (*Euastacus robertsi*) and fish (Bloomfield River cod, *Guyu wujalwujalensis* and *M. maccullochi* lineage), suggestive of long period	TRaCK - Mark Kennard, Brad Pusey, Ben Cook, Jane Hughes, Doug Ward, Peter Bayliss and Michael Douglas

Are the values potentially nationally significant?	Wetland	What is special?	References
		of isolation. For example, the Bloomfield River Cod s thought to be a Miocene relic indicative of past cooler climate – illustrative of the effects of landscape structure in ameliorating the competitive and predation effects of more recently evolved northern fishes. Northern limit of the cod. o Rainforest river; has a waterfall close to river mouth o Comparative – other high discharge Wet Tropics rivers but this is the exemplar	
Unlikely	**QLD** **Pascoe & Lockhart Rivers**	o Rainforest rivers with perennial flow regime located in an area otherwise characterised by wet/dry tropical savanna o Mouth of the Lockhart is one of the most extensive and diverse estuarine areas on east coast of Cape York. o High diversity of vegetation types, including wetlands in a small area	
Unlikely	**QLD** **Embley River / Ducie / Tentpole Creek etc & bays around Weipa**	o Details?	Peter Bayliss
Unlikely	**QLD** **Wenlock (stronger claims) & Archer Rivers** *(aggregation)*	o Connects rainforest of McIllwraith - Iron ranges and the smaller ranges on the west coast o Seasonal refugia o Rich freshwater fish fauna o Many endemic plant and animal species o High habitat diversity of wetlands types in a small spatial area o Junction of Archer-Coen provides excellent example of flood plain morphologies and environments o Comparative - Gregory/Nicholson, Leichardt complexes	
Unlikely	**QLD** **Cawana Lake**	o Geological – example of wetland dammed by basalt flow with occurrence of sandy shoreline (?aeolian) with *Eucalyptus camaldulensis*. o Biological – largely unknown o key wetland refuge in dry season	Bruce Wannan
Unlikely Noting though possibly significant for its potential to yield information that will contribute to an understanding of Australia’s natural and	**QLD** **Tableland Wetlands:** o **Lynchs Crater** o **Bromfield Swamp** o **Euramo** o **Quincan**	o Palustrine marsh with floating herb mat and underlying peat. o Has been an important source of data for Pleistocene climate o Paleohistory of North Queensland (e.g. Kershaw 1971, 1975, 2007) o Rare (<1,000 ha) regional ecosystem o Lynch's Crater has provided a long and continuous pollen record through the last two glacial cycles from lake and swamp sediments and indicated changes in vegetation and biomass burning, around 45,000 yrs BP that are suggestive of initial impact of people on the landscape. o Integrity - Has been mined in the past yet retains many of its uncommon wetland features. o Comparative places that have paleo-environment significance – Arafura swamp wetlands, Mary River (Pleistocene, holocene) and possibly Wingecarribee swamp	Bruce Wannan Kershaw, A.P. 1971, 'Pollen Diagram from Quincan Crater, North-East Queensland, Australia', *New Phytologist*, vol. 70, no. 4, pp. 669-681. Kershaw, A.P. 1975, 'Stratigraphy and Pollen Analysis of Bromfield Swamp, North Eastern Queensland, Australia', *New Phytologist*, vol. 75, no. 1, pp. 173-91. Kershaw, A.P., *et al.* 2007, 'A complete pollen record of the last 230 ka from Lynch's Crater, north-eastern Australia',

Are the values potentially nationally significant?	Wetland	What is special?	References
cultural history.			*Palaeogeography Palaeoclimatology Palaeoecology*, vol. 251, no. 1, pp. 23-45.
Unlikely	**NT** **Roper River, Limmen Bight (Port Roper) and Port McArthur Tidal Wetlands System, Calvert (AWC)**	o includes tidal wetlands, mudflats, at/near Limmen Bight, in the far south west of the Gulf of Carpentaria o is a major migration stop over area for shorebirds (especially godwits and knots) o Is one of the most important coastal sites in the Northern Territory for shorebird numbers, especially the Port Roper mudflats. o The Sir Edward Pellew Group of Islands (at the mouth of the McArthur River) are significant for an aggregation of fauna, near shore populations of seagrass and dugongs. (The Pellew Islands and surrounds are listed on the RNE) o Scale of area, where to draw the boundary? o Comparative - Mudflats not that much different to other areas such as King Sound	Peter Bayliss (SKM 2009)
Unlikely	**NT** **Bays/dunes around Nhulunbuy; Wessell Islands**	o Diverse range of coastal rocky island systems, not so much a wetland value o Dune sys unusual in the north but not really a wetland value	Peter Bayliss
Unlikely	**NT** **Blyth-Cadell & Liverpool/Tomkinson Rivers**	o The Blyth-Cadell Floodplain & Boucaut Bay System is located on the Arnhem coast between the Darwin and East Arnhem Regions (west of Arafura Swamp) in NT within 35km of the Arafura swamp. The site comprises the entire contiguous floodplains of the Blyth and Cadell Rivers and Anamayirra Creek adjoining the intertidal mudflats of Boucaut Bay. o The area is recognised as a significant non-forested freshwater floodplain in Arnhem Land excluding the sites on Van Diemen Gulf. This site has not been formally assessed against Ramsar criteria but is likely to satisfy at least water bird based criteria (criterion 5: important waterbird aggregation site with >20 000 waterbirds; criterion 6: regularly supports >1% of the individuals in a population) for listing as a wetland of international importance under the Ramsar Convention. o Boucaut Bay is a major stop over area for migratory shorebirds, and regularly supports more than 20 000 waders in their non-breeding season, including internationally significant numbers of three species. The extensive seasonally flooded plains also support large aggregations of waterbirds in the dry season and a number of waterbird breeding colonies in the wet season. Water bird a sig value o NOTE: Supervising Scientist report available	Peter Bayliss
Unlikely	**NT** **Cobourg Peninsula (NP)**	o Creeks, floodplains etc eg Murganella Creek o It is one of three listed Ramsar sites in the Northern Territory. o The Cobourg Peninsula has extensive, relatively unmodified landscapes, which support a largely intact biota. The beaches provide regular nesting habitat for four species of threatened marine turtles (Green Turtle, Flatback Turtle, Leatherback and Olive Ridley), and significant numbers of seabirds (notably Black naped and	Peter Bayliss Sinclair Knight Merz, 2007, High Conservation Value Aquatic Ecosystems Project – identifying, categorising and managing HCVAE, Final Report, produced for the Department of

Are the values potentially nationally significant?	Wetland	What is special?	References
		Bridled Terns) breed on islands. The wetlands are recognised as being of international and national significance, and there are extensive areas of monsoon rainforest in coastal areas of the site. 21 threatened species are recorded from the Peninsula (SKM 2009) o Barrier dune wetlands o Comparative – Possibly Cape Londonderry?	Environment and Water Resources.
Unlikely	**NT** **Mary and Adelaide Rivers**	o These floodplains are a major breeding area (one of the most important in Australia) for Magpie Goose *Anseranas semipalmata*, a major breeding area for Saltwater Crocodile *Crocodylus porosus*, a major breeding area for herons and allies, a major dry season refuge area for waterbirds (magpie geese, ducks, herons); and a significant migration stop-over area for shorebirds (SKM 2009) o The Mary River floodplain wetlands are good examples of a major floodplain tidal wetland system typical of the Top End Region, but unusual in lacking a coherent river channel or major river estuary o The two major genetic lineages within pennyfish (*D. bandata*) are found sympatrically in the Adelaide river – high Phylogenetic Diversity for this species o Highest number of predators in the world at Fogg Dam (man made) o Integrity issues o Potentially significant for Criterion C regarding long term fish research o Comparative – to Alligator Rivers	Peter Bayliss Sinclair Knight Merz, 2007, High Conservation Value Aquatic Ecosystems Project – identifying, categorising and managing HCVAE, Final Report, produced for the Department of Environment and Water Resources.
Possibly, more research needed.	**Darwin Harbour** *(coastal, esturine)*	o A weel studies area with high mangrove diversity o Unique in that it is a very large mangrove harbour (largest in Australia) o Significant fauna - Snubfin dolphin population, Shorebird significance, Dugong population o Unique ponding system (dambos) o (cultural sig – WWII) o Comparative – Shoal Bay, Bynoe Harbour, North-west Kimberley	
Unlikely	**NT** **Finnis River floodplain**	o The Finniss River floodplain supports very large aggregations of waterbirds, including more than 1% of the world's populations of Magpie Geese and Pied Herons, and high densities of many other waterbird species. The floodplain supports important breeding activity by Saltwater Crocodiles, Magpie Geese and other waterbirds. Five threatened birds and one threatened plant are reported from this site (SKM 2009) o Endemic fish o Comparative – Adelaide River, Reynolds and Daly Rivers	Chris Humphrey
Unlikely	**NT** **Moyle River**	o water birds, fish o mudflat fringe bay, short river systems o Comparative - East Kimberley, Victoria River	Peter Bayliss

Are the values potentially nationally significant?	Wetland	What is special?	References
Unlikely	**NT** **Victoria, Keep Rivers**	o Victoria (and or Mitchell?) River has largest discharge o Victoria contains differentiated populations of mouth almighty (*Glossamia aprion)* and *Oxyeleotris selheimi* o Karst systems includes stromatilites, largest in area for its systems o Keep and Victoria River meet at Legune wetlands/mudflat – large scale o Comparative – Mimbi Caves, karst values and Devonian Reefs	
Unlikely	**WA** **Ord River, lower Ord floodplain and false mouth, Lake Argyle, Lake Kununurra**	o Interesting fish – high phlylogenetic distance between east and west o Ord river contains endemic lineage of *Oxyeleotris lineolatus* and highly differentiated population of mouth almighty (*Glossamia aprion)* o one of Australia's most important waterbird sites – regularly supports >200,000 birds – although it is artificial. o Original riverine system largely lost o Lake Argyle – robust against possible climate change issues, artificial lake system o Lake Kununurra has high plant richness o Refugial values o Well studied environment o The Ord's flow regime is a very artificial one and the river system should be ranked behind the some of the NT (and probably Qld) rivers. o Comparative – Leichhardt River (Qld)	TRaCK - Mark Kennard, Brad Pusey, Ben Cook, Jane Hughes, Doug Ward, Peter Bayliss and Michael Douglas
Possibly, more research needed.	**NT** **Blue Mud Bay**	o Important water bird area fresh water birds, Brolgas, Magpie Geese o Largest snub fin dolphin population in Southern Hemisphere o Note: PhD research underway [details on who is researching and which Uni] o Comparative – Cobourg, Prince Regent Sound (Mangrove)	Peter Bayliss
Possibly, more research needed.	**WA** **Jila country** – springs and groundwater systems of the GSD/DL (Udialla Springs, JIrrkaliy, Babakaman, Mangurrl, Jarngunan, Breaden Hills, desert wilas) *(springs)*	o South of the Fitzroy o Mangurrl, Jlrrkaliy – come up against Edgar Ranges, interesting species – Barramundy and freshwater crocs (periodically cut off from sea populations) o Rare stand of *Pandanus* plams o Significant for shorebirds o Geoheritage features – peat mounts, loess sites Seinuik and Griffith o Underground drainage systems o Udialla Springs – peat systems o Sharp gradients here not found elsewhere in N Australia o Comparable to LaGrange system – the same or separate? Desert Uplands possibly similar	Tanya Vernes/ Rob Cossart
Possibly, more research needed.	**WA** **Fitzroy River (Camballin floodplain)** *(aggregation)*	o The Fitzroy has an interesting rainfall gradient across the catchment (ie at right angles to the long axis of the river), with some good river pools, some tropical floodplains at Camballin and some desert ephemeral lakes in the southern part of the catchment. Plants o CALM Priority species include a number of water plants – *Fimbristylis sieberiana*	Stuart Halse/ Rob Cossart Allen, G.R., Midgley, S.H. and Allen, M. 2002, Field guide to the freshwater fishes of Australia. Western Australia Museum, Perth.

Are the values potentially nationally significant?	Wetland	What is special?	References

		(Cyperaceae), *Goodenia sepalosa* (Goodeniaceae), *Nymphoides beaglensis* (Menyanthaceae) and *Trianthema kimberleyi* (Aizoaceae)
		o Comparative
		  o Not possible on current data
		  o Cyperaceae higher for endemism to the north, likely due to restricted *Fimbristylis* species.
		Invertebrates
		o Little is known about the macro invertebrates, however it is believed the fauna is similar to that found elsewhere in northern Australia.
		o Richness – 70 families recorded in the Kimberley region, 26 of which do not occur in SW WA.
		o Giant prawn or cherabun (*Macrobrachium rosenbergii*) present – shift from fresh to brackish water over life cycle.
		o Freshwater mussels – high scores for endemism of Hyriidae
		Mammals and reptiles
		o Mammals recorded had affinities to both the north Kimberley and the drier Great Sandy Desert
		o Golden Bandicoot and Bilby likely to be found in associated drier communities e.g. Pindan
		o Water Rats – important habitat
		o Numerous reptiles, some at the extremes of there distribution (Storr et al. 1983, 1986, 1990)
		o Comparative
		  o stronger values for both mammals and reptiles in NW Kimberley
		  o some species at limit of range on Fitzroy, also a transition between wetter north and drier Great Sandy Desert
		Fish and turtles (evolutionary refugia)
		o Permanent pools and billabongs in river channels support important fish populations (Sutton 1998) – fish here are adapted to periodic cycles of inundation where they can take advantage of increased food and habitat resources – “flood pulse advantage” (Bayley 1991)
		o Richness - Rich by virtue of its size - 30 species of fish, 21 families (Doupe and Lenanton 1998)
		o Rarity - 30% are marine opportunists using the river in a transitory fashion. Rare fish including the sawfish and whipray have important breeding grounds important in Lower Fitzroy
		o Endemism – no true endemics but some species have important populations in the Fitzroy - include Greenway’s grunter (*Hannia greenwayi*), the western rainbowfish (*Melanotaenia australis*), two sawfish (*Pristis* spp.), the freshwater whipray (*Himantura chaophrya*) and the northern river shark (*Glyphis* sp. C)
			Doupe R, Lenanton R. 1998. Fishes of the Fitzroy River: diversity, life history and the effects of river regulation. In Limnology of the Fitzroy River, Western Australia: a Technical Workshop, Storey A, Beesley L (eds). Australian Society for Limnology, Edith Cowan University, The University of Western Australia, and Murdoch University; 18–21.
			
			Halse, S.A., Pearson, G.B. & Kay, W.R. 1998, Arid zone networks in time and space: waterbird use of Lake Gregory in north-western Australia. *Int. J. Ecol. Envir. Sci.* **24,** 207–22.
			
			Jaensch, R. & R.M. Vervest 1990. Waterbirds at remote wetlands in Western Australia, 1986-8. Part Two: Lake Macleod, Shark Bay, Camballin Floodplain and Parry Floodplain. RAOU Report No. 69.
			
			Morgan, D. 2008, Freshwater fishes of the Kimberley region of Western Australia, Unpublished report Centre for Fish and Fisheries Research, Murdoch University, Perth, Western Australia.
			
			Bayley, P.B. 1991, The flood pulse advantage and restoration of the river-floodplain systems. *Regulated rivers: Research and Management* 6: 75-86.
			
			Garnett, S. (ed.) 1992, *Threatened and extinct birds of Australia*, RAOU report number 82, Moonee Ponds, Victoria.
			
			Sutton, D.C. 1998, *Assessment of the natural environment values of the Fitzroy River region, WA*, June, a report to the Australian Heritage Commission.
			
			Tyler, M.J. and Doughty, P. 2009, *Frogs*

Are the values potentially nationally significant?	Wetland	What is special?	References

		o Comparative
		  o other systems have a higher endemism over smaller catchments (18 out of 48 for Kimberley as a whole (Sutton 1998)) Drysdale River (6 species), the Prince Regent (6 species), the Roe and Moran Rivers (4 species), Carson River (4 species) and Isdell River (3 species) (Morgan 2008, Allen et al 2002).
		Frogs (evolutionary refugia)
		o Richness – no ANHAT significance
		  o Fairly rich but the size of the system 21 (based on frogs.org.au distribution maps) out of 39 Kimberley frogs are on the Fitzroy (31 Wetlands workshop) (11 in Sutton 1998)
		o Frog endemism – top 5% nationally for Myobatrachidae and Hylidae
		  o Derby Toadlet (*Uperoleia aspera*)
		  o West Kimberley Toadlet (*Uperoleia mjobergi*) largely restricted to Fitzroy
		  o Hidden Ear Frog (*Cyclorana cryptotis*)
		  o Mole Toadlet (*Uperoleia talpa*) important sites in Fitzroy and Dampier Peninsula
		  o Wailing Frog (*Cyclorana vagita*) are only known from the lower Ord and Fitzroy catchments, the latter extends into NT (Tyler & Doughty 2009)
		o Comparative
		  o Greater endemism in north Kimberley
		  o Greater richness in north Kimberley (high rainfall area) and across N Australia (Tyler & Doughty 2009)
		Migratory birds (seasonal refugia)
		o All permanent water in the Fitzroy system provides potentially important dry season waterbird refugia.
		o The Camballin floodplain (30,000 ha) is an extensive black soil floodplain adjoining and extending north of the Fitzroy River. Streams of Camballin are part of the Fitzroy's anabranching. Has had some pastoral damage in past, recent management has improved situation.
		o Camballin features two principal claypan-swamps: Le Lievre and Moulamen.
		o Noonkanbah features the Mallallah and Sandhill swamps (Halse and Jaensch 1998)
		o High numbers of invertebrates and plants support the presence of waterbirds (Jaensch and Vervest 1990)
		o Richness
		  o 67 species of birds, 20 species on JAMBA/CAMBA (Sutton 1998), 1 species of of international significance, 3 of national (16th place) in Watkins (1993)
		  o ANHAT analysis demonstrated Charadriiformes richest locally at
			of Western Australia, 4th edition. Western Australian Museum Press, Perth, WA
			
			Watkins, D., 1993, *A national plan for shorebird conservation in Australia*, June, unpublished report, Australasian Wader Study Group.

Are the values potentially nationally significant?	Wetland	What is special?	References
		Roebuck Bay, highest on Fitzroy is found on the Derby map sheet, Parry floodplain high, Camballin low o Anseriformes (Ducks and swans) – regionally high, Roebuck slightly higher o Sylviidae (old world warblers) – nationally highest at Darwin, locally high at Kununurra/Perry floodplain and Roebuck, Fitzroy not significant o Endemism – nothing substantial o Charadriiformes highest nationally at Darwin, the Roebuck is high, Derby regionally high, Camballin lower (1.1%). o Sylviidae (old world warblers) – endemism nationally high at Roebuck and Darwin, not significant along Fitzroy o Anseriformes (Ducks and swans) – regionally high, Roebuck higher o Motacillidae (Pipits and wagtails) – Yellow Wagtail (Motacilla flava) a rare migratory has been sited at Derby, Kununurra – there are richer areas but it is a small species pool o Abundance - 20,000 (low years) - 38,000 birds (Jaensch and Vervest 1990) o Ecological significance/refugial role o major breeding area for Australian Pelican (Le Lievre swamp), 1,000 chicks in 1974 o Plumed Whistling-duck – (WA rank 1) 20,000 counted in 1986, national importance o Wood & Marsh Sandpipers – national importance (Watkins 1993) o Rare birds – Freckled Duck, Pectoral Sandpiper and the Long-toed Stint o Species of special concern – Yellow Chat, Kori Bustard (Garnett 1992) o <u>Comparative</u> o Roebuck Bay (coastal, mudflats) - 64 waterbird species recorded, 34 listed under international treaties (JAMBA, CAMBA and ROKAMBA), the highest richness in Australia for international migratories. Charadiiformes (waders) richness (61 species) (ANHAT analysis), 20 birds of international significance (Watkins 1993). Fourth most important site for waders in Australia. Abundance - 170,900 counted in 1983 o Gulf of Carpentaria - 19 species of international significance (Watkins 1993) o Eighty-mile Beach (coastal) – 15 of international significance (Watkins 1993), for abundance 472,000 were recorded over a month in 2001. o Lake Gregory (lacustrine) – 73 water bird species, 650,000 birds, important dry season, desert refugia (Halse, Pearson & Kay 1998), number 1 in state for Freckled Duck, more than 1% of flyway population. o Lake Argyle (lacustrine) – Over 270 species, large area, large numbers for migratory birds, 74 waterbird species, 22 species under treaties.	

Are the values potentially nationally significant?	Wetland	What is special?	References
		Highest count of birds in 1984 at 181,400 (Environment Australia 2001). o Parry Floodplain (9,000 ha, palustrine) – 77 waterbirds, 22 under treaties, 27,000 waterbirds counted in 1986. 4 species of international significance, 7 of national in Watkins (5th place in 1993). Number 2 in WA for abundance of Plumed Whistling-duck (EA 2001). Non-migratory birds (seasonal, evolutionary refugia) o Ecological significance/ refugial role o Purple-crowned fair-wren refugial riparian habitats o Gouldian Finch habitat o Australian Pratincole – international significance (Watkins 1993) o Raptors – including Red Goshawk, Grey and Peregrine Falcons o Comparative o Other parts of Kimberley o Roebuck Plains o Kimberley springs o Mangroves/rainforests – different species bird? Not as obligate as some mangrove dependent birds?	
Unlikely	**WA** **Walcott Inlet**, (including Jilariba wetlands, Walcott Inlet Rainforest Swamp (SH), Munja Lagoon (TV)	o Like the floodplains of the Lower Ord and the Camballin wetlands, Walcott Inlet's values are greatest in the late wet season/early dry season (perhaps coinciding with migratory shorebird departures). Regional rather than national importance. o Little research to date, aquatic studies just starting, difficult to compare at this time o Freshwater groundwater feeding into wetlands o Inlet split by different geology o Remnant rainforest patches in wetland systems o Near pristine conditions o Lower wetlands are affected by dynamic tides and currents	Stuart Halse / Tanya Vernes/ Rob Cossart
Unlikely	**WA** **Glenelg River**	o It has been proposed that the Glenelg is under-rated compared with the more iconic Prince Regent and Mitchell given more prominence	Stuart Halse
Unlikely	**WA** **Rivers of Joseph Bonapartes Gulf - Keep/Victoria.**	o It is possible that the Keep River is a point of secondary contact between divergent genetic lineages from the east and west respectively for some species	Peter Bayliss
Possibly, more research needed.	**WA** **Big Springs and associated springs north of Derby** (including Wollamore Claypan) + **Monsoon Vine Thickets** *(springs)*	o Listed as a Threatened Ecological Community it is a huge mound spring surrounded by smaller springs o *Terminalia macrocarpa* – southern limit o Important for bird refugia in large areas of mudflats o Rainforest species present o Aquatic species of interest o Comparative - Bunda Bunda (single spring) Big Springs (multiple springs), Yirrikala	Tanya Vernes / Rob Cossart

APPENDIX 8.4.

PETIT, N., CLOSE, P. & KENNARD, M. (2010). FINE SCALE ASSESSMENT OF HIGH CONSERVATION VALUE AQUATIC ECOSYSTEMS AND ECOLOGICAL THRESHOLDS IN THE DALY RIVER, NT. SUMMARY OF NRETAS/TRACK EXPERT PANEL WORKSHOP HELD IN DARWIN, 14 SEPTEMBER 2010.

Fine Scale Assessment of High Conservation Value Aquatic Ecosystems and Ecological Thresholds in the Daly River, NT.

Summary of NRETAS*/TRaCK expert panel workshop held in Darwin, 14 September 2010

TRaCK
Tropical Rivers and Coastal Knowledge

Neil Petit[1], Paul Close[2], Mark Kennard[1]

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Australian Government
Department of the Environment, Water, Heritage and the Arts
National Water Commission

Northern Territory Government
DEPARTMENT OF NATURAL RESOURCES, ENVIRONMENT, THE ARTS AND SPORT

* Note – this workshop summary has not yet been endorsed by NRETAS

TRaCK Tropical Rivers and Coastal Knowledge

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Summary

A one day workshop was held at Charles Darwin University on the 14th September 2010 to complement the broad-scale assessment under the Northern Australia Aquatic Ecological Assets project. This workshop would undertake a fine scale assessment of High conservation Value Aquatic ecosystems (HCVAE) for the Daly River catchment as a key focal region, with the aim of identifying specific ecological assets and understanding their ecological thresholds in relation to flow regimes and the maintenance of aquatic ecosystem assets. The structure of the workshop included a number of presentations in the morning session that provided background information on the HCVAE project and set the scene for group discussions in the afternoon session (see Appendix 2). The principal aim of the group discussion session in the afternoon was to identify local scale assets that occur within the Daly River Catchment (e.g. lower floodplain, middle and upper reaches) that were identified as HCVAEs through the broad-scale assessment and other assessments.

The afternoon session also aimed to evaluate the ecological value and connectivity between these assets and identify ecological thresholds relevant to the Daly River catchment. For the lower Daly floodplain, refugial waterholes, bird nesting areas and riparian forest were important assets as well as small creeks that provide connectivity between the main river channel and the floodplain and waterholes. The workshop suggested that some assets on the floodplain need to be managed at variable spatial and temporal scales and that the ability of water-dependent biota to move between habitats is a key ecological process. For the middle reaches, it was important to consider not just the main channel but tributaries and off-channel waterholes, including palustrine waterbodies. Low-water riffle habitats are considered a critical asset in the middle reaches, partly due to their scarcity and their importance for aquatic productivity and habitat values. Reduction in dry season flows is likely to be the biggest impact on the ecological assets of the middle reaches because of the effect on riffle areas as well as the potential reduced longitudinal connectivity. The upper Katherine River encompasses the high elevation stone country of Arnhem Plateau where there are many high gradient cascades and waterfalls that reduce connectivity. Consequently there is a high level of endemism of fish and genetically distinct fish species. There are also distinctive off-stream palustrine wetland areas about which there is a general lack of information.

The principal outcome of the workshop was that there should be more concentration on the identification of fine-scale values, rather than the identification ecological thresholds. Once fine-scale values have been identified, the discussion can then be broadened to include consideration of ecological thresholds if appropriate.

Acknowledgements

- Simon Ward and Michael Lawton (NRETAS) for assistance in designing and running the workshop
- All workshop attendees and presenters
- DEWHA and the NWC for funding the workshop
- Rose Jubber (CDU) for arranging the venue and catering
- Charles Darwin University for hosting the workshop

Background

The broad-scale assessment under the Northern Australia Aquatic Ecological Assets project has highlighted the high conservation values present in many areas of northern Australia (Kennard 2010). To complement this work, fine scale assessments were undertaken for key focal regions with the aim of identifying specific ecological assets and understanding their ecological thresholds in relation to flow regimes and the maintenance of aquatic ecosystem assets. The Daly River catchment was identified by NRETAS as a high priority catchment and therefore was the focus of this workshop.

Major rivers in the Daly Catchment include the Daly, Katherine, Flora and Dry Rivers. The area contains seven IBRA regions, these being: Darwin Coastal, Victoria Bonaparte, Ord River Plain, Sturt Plateau, Daly Basin, Pine Creek and the Arnhem Plateau. The wetlands of National Significance in this basin are the Katherine River Gorge, and Daly River Middle Reaches, and the Daly-Reynolds Floodplain-Estuary System. Other assets of note include a partial section of the World Heritage Listed Kakadu National Park. This region also harbours two species listed under the *EPBC Act 1999* as vulnerable flora, nine rare plants, 13 species of threatened flora and 16 species of threatened fauna. Kennard (2010) also identified several parts of the Daly River basin that have high conservation values from a Drainage Division and regional perspective, in particular parts of the lower Daly floodplain, middle reaches of the Daly River mainstem and the upper Katherine River.

The vast coastal floodplains of the Daly and Reynolds Rivers form one of the largest floodplains in the Northern Territory. They support numerous waterbird breeding colonies and internationally significant numbers of waterbirds, particularly magpie geese and wandering whistling ducks. The Daly River supports a high diversity (eight species) of freshwater turtles which is the richest in Australia and includes most of the Australian population of the pig nosed turtle. Several species of threatened or rare freshwater fish also occur in the river, including freshwater sawfish and freshwater whip-ray.

The catchment area of the Daly River features the three wetlands of national significance mentioned above. The river is fed by extensive up stream aquifer systems and, downstream, feeds into the extensive floodplains of the lower Daly system and Anson Bay. Wet season flows in the river are high and the continuous dry season flows of spring fed water result in a unique freshwater ecosystem that supports numerous threatened or otherwise important species.

The Daly River is largely unregulated, perennial and has a catchment of more than 50,000 km^2 (Begg et al., 2001), with less than 5% cleared (van Dam et al., 2008). There are no major impoundments on the river or its tributaries which are currently in good condition and of high ecological value, providing diverse habitat for key species, and having largely intact and diverse riparian vegetation (Douglas et al., 2005; Blanch et al., 2005).

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. Wetlands in the Daly River region are primarily valued for their importance to the recreational fishing and waterfowl hunting industries, tourism and horticulture as well as the central role they play in sustaining the well-being of Aboriginal communities in the region.

There is increasing pressure to develop this ‘apparently large’ water resource. Increases in agriculture are of particular interest in the Daly River catchment (Lamontagne et al., 2005), as this catchment has the largest area of suitable soil in the region. Concern regarding the added pressure of climate change and the current drought on the already flow-stressed southern rivers, is translating to additional pressure to use water resources in the north (Preston and Jones, 2008).

Some of the better data sets available for wetland-related pressures and values in the NT come from the Daly Catchment, largely driven by pressures in the area for pastoral/grazing, forestry and horticultural development. The bulk of the extraction from the system currently occurs from the groundwater in the area adjacent to the lower Katherine River and the Daly down to Mt Nancar. The potential ecological impacts of changes in river flows are only beginning to be explored in this system. Work on the water requirements of plants growing in and alongside rivers, aquatic macro-invertebrate populations, and the pig-nosed turtle in northern tropical rivers, identified the Daly River as the system at greatest risk from multiple threats and pressures (Erskine et al. 2003, 2004; Bartolo et al., 2008). A study of the environmental water requirements and ecological risk assessment for fish in the Daly River (see Pusey & Kennard 2009; Chan et al. 2010) revealed that several fish species in the catchment are potentially very sensitive to dry season water extraction. These included large-bodied fish of cultural and recreational importance (e.g. black bream, barramundi, mullet, sleepy cods) and less iconic, but nevertheless ecologically important species (e.g. blackmast, bony bream, rainbowfish and barred grunter). Quantitative risk assessments (using Bayesian Belief Network predictive models; Chan et al. 2010) developed for two high-risk species (black bream and barramundi) provide further evidence of the expected nature and degree of impacts from water extraction on fish populations in the Daly River. The predictive models reveal that historic levels of water extraction are unlikely to have affected natural variation in the abundances of sooty grunter and barramundi throughout the lower Katherine and Daly Rivers. However, if current water entitlements were fully utilized, consequent changes to the dry season flow regime and associated physical and ecological changes to the riverine environment would increase the probability of low and extremely low abundances of both species. These impacts are lessened further downstream, where flow modifications are ameliorated by tributary and spring inputs.

In regard to ecological thresholds, it is yet to be established whether environmental, conservation values in the catchment respond in a linear way with changes likely to occur in response to development such as water extraction, or whether there are thresholds beyond which environmental and conservation values might change abruptly. The Darwin workshop was set-up to investigate these ecological threshold issues by qualitatively considering the vulnerability/resilience of the assets and asset types to identified risks/threats, from hydrological disturbance, water resource development and other potential factors that may affect the Daly River catchment.

The workshop aimed to identify fine scale assets and where possible their ecological thresholds relevant to flow regimes and the maintenance of aquatic ecosystem services. It was envisaged that the workshop would also document an assessment of the risks to fine scale assets and their ecosystem services associated with a variety of threats. Together, the risk assessment and identifying fine scale ecological values would allow asset-specific threats to be prioritized, either for the development of management strategies or for actions to address significant knowledge gaps. The information gathered in this workshop provides important consolidation of existing understanding and a guide for future planning and research.

Aims

This workshop aims included:

- Assess the usefulness (strengths and weaknesses) of the HCVAE process
- Identify local scale assets (e.g. particular floodplain lakes, and wetlands, riverine reaches, etc) that occur within the Daly River Catchment identified as HCVAEs through the broad-scale assessment (Kennard 2010)
- Assess congruence between areas highlighted by the HCVAE study and those considered important by NTG
- Establish how water allocation is likely to affect HCVAE's
- Identify sensitive indicators of environmental condition of the HCVAE's
- Evaluate ecological value of the assets, connectivity between the assets and ecosystem services as they relate to (where possible) individual assets and asset types;
- identify (if possible) ecological thresholds relevant to the Daly River catchment in relation to flow regimes and the maintenance of aquatic ecosystem services.
- Consolidate existing knowledge on HCVAE's and condition-indicators including the identification and prioritisation of knowledge gaps
- explore opportunities for evidence-based policy and management.

Workshop Structure

A one day workshop started with a number of talks in the morning that provided background information of the HCVAE project and set the scene for group discussions in the afternoon session. The group discussions endeavored to evaluate the specific ecological values of nominated high conservation value areas and the connectivity between these assets and ecosystem services as they relate to individual assets and asset types.

Workshop participants were asked to provide key information on a variety of aspects of fine-scale assets in the Daly River. A list of "candidate" areas of high conservation value in the Daly have been identified based on the broad-scale HCVAE assessment (Kennard 2010), the "NT sites of Conservation Significance" (Ward & Harrison 2009) and a desktop assessment conducted as part of the NAWFA Ecological Assets project (SKM 2009). Workshop participants were asked to identify specific assets (e.g. particular floodplain lakes and wetlands, riverine reaches, etc) that occur within these candidate areas for further assessment and evaluation.

The workshop was designed to allow participants to identify ecological values of fine scale assets and where possible their ecological thresholds relevant to flow regimes and the maintenance of aquatic ecosystem services. In this way the afternoon sessions of the workshop would:

- Identify key flow-ecology links for each asset.
- Thresholds for these links are then described, where possible by identifying important seasonal flow bands (Figure 1), critical flow components, and their attributes including frequency, duration timing and magnitude (Figure 2).
- Consolidate existing knowledge on asset-specific flow thresholds.
- Identify critical evidence where it exists and identify the existence of important knowledge gaps.

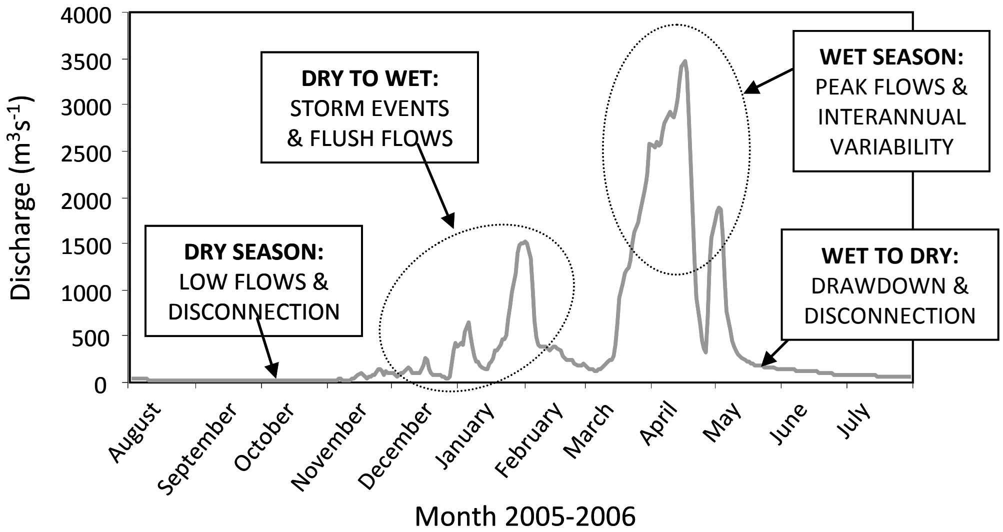

Figure 1. Sample hydrograph from the Daly River (Northern Territory), over one year from August 2005 to July 2006, illustrating key flow features of rivers across the wet-dry tropics of northern Australia.

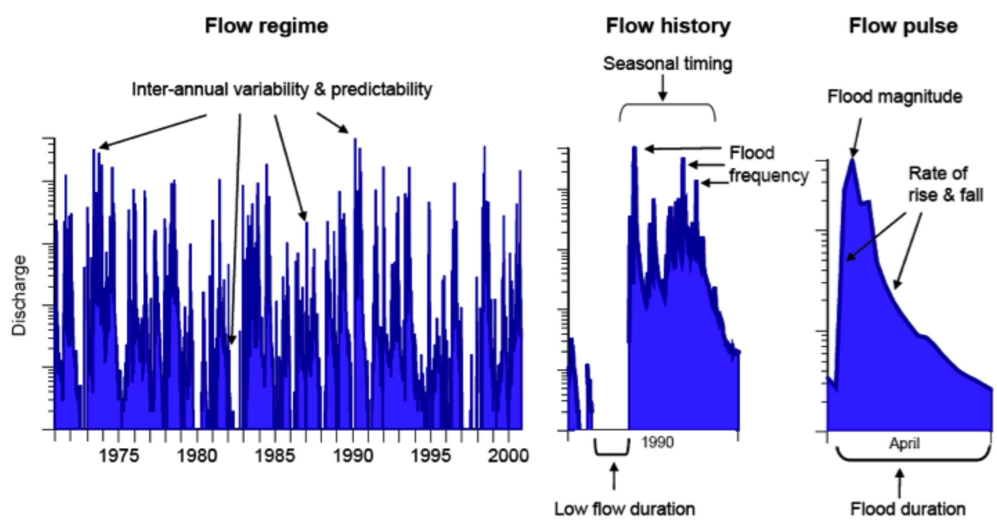

Figure 2. Different components of the natural flow regime are ecologically important over a range of temporal scales.

In the afternoon session the workshop also aimed to document an assessment of the risks to fine scale assets and their ecosystem services associated with a variety of threats including flow alteration, fire regimes, climate change, cattle disturbance, introduced fauna and weed species. The risk assessment would:

- qualitatively describe the likelihood and consequence of each of these threats for each asset using low, moderate and high criteria.
- identifying (where possible) ecological responses to each of these threats
- identify the level of certainty surrounding these predictions. Levels of certainty will also be expressed as low, moderate and high based on the type of knowledge predictions are based.

Workshop Agenda

Time	Topic	Speaker
8.45	Welcome/ Introduction	Paul Close
9.00	Overview of NAWFA programs and draft HCVAE framework	Cameron Colebatch (DEWHA)
9.30	HCVAE assets on the Daly and ecological thresholds	Mark Kennard (TRaCK)
10.00	Morning Tea	
10.15	Water planning and allocation for the Daly Basin	Kelly Howitt (NRETAS)
10.45	Conservation strategy, ecological assets and management of conservation areas in the Daly and other areas	Tony Griffith (NRETAS) Group Discussion
11.15	Overview of the TRaCK research and data in the Daly R	Michael Douglas (TRaCK)
11.30	TRIAP Risk Assessment for Daly R	Peter Bayliss (CSIRO)
11.45	FAWHA program on the Daly R	Simon Townsend (TRACK)
12.00	Lunch	
12.30	Workshop structure	Mark Kennard/Paul Close
1.00	Group Discussions	
2.00	Group Discussions	
3.00	Group Discussions	
3.30	Afternoon tea	
3.45	Group Discussions	
4.30	Knowledge gaps/indicators of environmental conditions	
5.00	Closing remarks	Mark Kennard
5.15	Close	

Workshop session summaries

Morning Session Presentations and Discussions

Seven presentations were given in the morning session to provide workshop participants with sufficient background to undertake a fine-scale assessment of ecological assets in the Daly River catchment. Presentations included the following topics relevant to the Daly River catchment:

- background on the NAWFA Progams and HCVAE Framework;
- identification of assets in the Daly River Catchment;
- water planning and allocation;
- conservation strategies;
- relevant ecological research, and;
- river health.

Summaries of these presentations, including pertinent discussion resulting from each presentation are provided below.

Overview of the NAWFA Programs (Cameron Colebatch, DEWHA)

1. Objective of the NAWFA programs is to provide an enduring knowledge base to inform protection and development of northern Australia's water resources, so that any development proceeds in an ecologically, culturally and economically sustainable manner.
2. The NAWFA Program includes four subprograms; *water resources*, *ecological* and *cultural and social* programs. The fourth component, *knowledge base* draws the previous three components together with the aim of providing an enduring knowledge base to support informed decision making in northern Australia.
3. *The Water Resource Program* seeks to provide for a better understanding of water availability in northern Australia. The principle project under this program was the NASY (Northern Australian Sustainable Yields) Project undertaken by CSIRO.
4. *The Ecological Program* seeks to provide for a better understanding of ecological assets in northern Australia, their watering needs, and the risks to them arising from changes to hydrological regimes. Key activities under this program include; mapping of aquatic ecological assets, trial of the HCVAE, and identification of ecological thresholds.
5. *The Social and cultural Program* seeks to provide for a better understanding of socio-cultural values, beliefs and practices in northern Australia associated with water, and the affect of any changes in water availability.
6. *The Knowledge Base Program* seeks to provide for an enduring knowledge base to support informed decision making in northern Australia. The intent of this is to support future water planning decisions in northern Australia. The anticipated content of the Knowledge Base includes; existing knowledge, data, information and research links, case studies, assessment reports, models and decision support tools.

Overview of the HCVAE Framework (Di Conrick, DEWHA)

1. The HCVAE aims *to provide a consistent approach to the identification and classification of High Conservation Values*. It includes method development and relies on the HCVAE and ANAE (Australian National Aquatic ecosystem) criteria.
2. The HCVAE method aims *to provide a consistent methodology incorporating identified datasets, regionalisation, spatial scales and integration techniques to enable HCVAE to be identified at a national, jurisdictional or regional scale.*
3. The HCVAE criteria include, diversity, distinctiveness, vital habitat, evolutionary history, naturalness and representativeness.
4. ANAE Classification Scheme aims *to provide a nationally agreed set of aquatic ecosystem classes that can be used to identify different aquatic ecosystems across Australia at varying and multiple levels.*
5. Guidelines for the development of the HCVAE Framework include: write guidelines incorporating information and recommendations from all projects; targeted public consultation; AETG approval; Ministerial endorsement and; implementation.
6. Current progress on the HCVAE Framework includes: HCVAE criteria trials (2008) for NSW estuaries, Victorian rivers, WA Mound Springs and the northern Murray-Darling Basin. The HCVAE framework has been trialed (2010) in the Lake Eyre Basin and in Northern Australia.
7. In 2010/11 the framework will be trialed in Tasmania (against the Tasmanian Conservation of Freshwater Environmental Values (CFEV) Program). The HCVAE Delineation guidelines will also be developed and trialed in the Lake Eyre Basin.

Discussion arising from the above two presentations included the following key points.

8. Potential similarities with RAMSAR components e.g. ecological character descriptions
9. Relationship of HCVAE to other programs such as FARWH, NT sites of significance etc.
10. Noted that the Northern territory jurisdictions don't have a tool for prioritization of aquatic ecological assets, and therefore are supportive of the development of the HCVAE framework. It was recognized that other states do have existing frameworks and, that therefore, those states will scrutinize the HCVAE process.
11. Noted that the HCVAE framework is flexible, depending on jurisdictional requirements and the local scale/regional scale constraints e.g. use of criteria and ranking procedures can use local tools e.g. Aquabam in QLD. Therefore the Framework is not fully prescribed and will offer alternatives where appropriate. AETG has final approval for HCVAE framework guidelines and recommendations.

Fine Scale assessment of aquatic ecological assets and the identification of ecological thresholds (Mark Kennard, GU/TRaCK).

1. This presentation provided information on identifying and managing High Conservation Value Aquatic Ecosystems in the Daly River and the identification of ecological thresholds.
2. There is a substantial knowledge base for the identification of assets in northern Australia and particularly the Daly river basin.
3. National parks, reserves and other protected areas have already been delineated in the Daly River Basin (CAPAD 2006). Information is also available for NT sites of significance and in the Directory of Important Wetlands.
4. Broad-scale assessment of HCVAE's used HCVAE Framework criteria (diversity distinctiveness vital habitat evolutionary history naturalness and representativeness) and the ANAE classification scheme within a combination of complimentary approaches including scoring systems, systematic planning tools and expert panel workshops.

5. Species distribution datasets for water birds, turtles, macroinvertebrates and fish. Data on frogs, crocodiles, lizards, snakes, aquatic plants and estuarine species were not used.
6. Predictive models were developed species distributions across the landscape thereby providing complete coverage of data within the study area.
7. Mapped aquatic ecosystem "types" according to the ANAE classification scheme (estuarine, lacustrine, palustrine and riverine). Included information on pereniality of hydrosystems.
8. Spatial scale of HCVAE assessments is the planning unit.
9. Background was provided on the integration of multiple attributes (see appendix).
10. HCVAE areas were identified using the Framework Criteria.
11. The appropriate scale for delineation and management of HCVAE's was discussed and presented. Large area HCVAE's are likely to include multiple landuses and associated ecosystem threats that will constrain management options and approaches. Small HCVAE's may be too small to sustain ecosystem structure and processes and management may fail to consider some of the wider threats that are impacting on the specific HCVAE. A possible solution is to adopt the approach described by Abell *et al.* 2007 including the establishment of conservation management zones defined as the entire catchment upstream of the focal area or critical management zone.
12. The concept of ecological thresholds was discussed and defined as the point at which a small or abrupt change in a driver may produce a large response in the ecosystem (or component). The use and application of thresholds to management is receiving substantial research interest. The ability to predict thresholds is important because of their influence on ecosystem services valued by humans.
13. Thresholds cannot always be clearly defined, and ecological response may lag behind the threshold timing. A key question in relation to these concepts is whether natural variability can be separated from a threshold response to some degree of anthropogenic change and whether thresholds can be used to trigger a management response.
14. The relationship between "drivers" and "ecological responses" were discussed in relation to the identification of thresholds to trigger management actions. Multiple stressors such as climate change, invasive species, landuse, fire etc may constrain the usefulness of thresholds to trigger management actions.
15. Given these difficulties in predicting thresholds and ecological responses, a precautionary approach to ecosystem management is probably most prudent.

Water Planning and Allocation (Kelly Howitt, NRETAS)

1. This presentation provided information on water allocation and planning in the Daly River catchment (in including plans for the Tindall Limestone and Oolloo Dolostone aquifers), strategies for allocation of water (e.g. environmental flows and managing climate variability) and monitoring and evaluation.
2. In the NT, the NT Water Act provides for: water extraction licensing; bore construction permitting; declaration of water control districts; water allocation planning and; beneficial use declarations.
3. *Water Control Districts* are declared to enhance water management in areas with competing demand and/or recognized environmental value. In these districts, bore construction permits, licenses for groundwater extraction are required and water allocation plans can be declared.
4. The Daly River is one of eight declared water control districts.
5. *Water Allocation Plans* – used to protect known EWRS and manage annual climate variability and water resource availability by defining the amount of water available for allocation and how water can be shared between consumptive uses and the environment.
6. Water planning and allocation in accordance with NWI objectives.
7. Water planning in the Daly River basin has prioritized groundwater resources with high connectivity to surface water systems and where there is existing and future development pressure. On this basis there are plans declared for the Tindall Limestone and Oolloo Dolostone aquifers

8. *Tindall Limestone Aquifer Water Allocation Plan*: declared 2009, minimum EWRs established, max extraction levels set, uses reliability of supply categories including total, high, medium, and low. A framework for water trading was established. Used modeled minimum flow to set extraction limits
9. *Oolloo Aquifer Water Allocation Plan*: Erskine *et al.* 2004 recommended minimum flows based on: prediction of the impact of water extraction on pig nosed turtles; water use by riparian vegetation; water requirements of water plants (*Vallisneria nana*); algal responses to reduces dry season flows, and; inventory and risk assessment of water dependent ecosystems. Water extractions are set depending on low-flow thresholds of Erskine 2004. Difference between natural flow and extraction according to these rules varies from 0-13%.
10. Monitoring and evaluation of Water Allocation Plans includes water use accounting, stream gauging an aquatic ecosystem health assessment at five year intervals.

Conservation strategy, ecological assets and management of conservation areas in the Daly and other areas (Tony Griffiths, NRETAS)

1. Reviewed application of HCVAE for identification of conservation values for Sites of conservation significance, Eco-link, development assessments, vegetation retention plans and offsets. HCVAE considered appropriate for all but sites of conservation significance as this processes has already been completed.
2. *Development assessments* (e.g. assess the impact of developments on conservation values under a variety of legislation (Planning act, Pastoral lands act, Environmental assessment act) based on the following criteria: threatened species, significant vegetation communities (mangroves, riparian, rainforests and wetlands), fragmentation, management of potential risks.
3. *Threatened Species Metric* based on the likelihood of threatened species being present and the significance of sites for each species. The potential detriment to threatened species populations is estimated by area of clearing in a cell grid multiplied by the value of the cell grid for each, or all threatened species.

Overview of TRaCK Research (Michael Douglas, CDU/TRaCK)

1. This presentation provided an overview of research conducted under the *Tropical River and Coastal Knowledge* (TRaCK) Research Program.
2. TRaCK's Aim: to provide science and knowledge that governments, communities and industries need for the sustainable management of Australia's tropical rivers and estuaries.
3. 16 TRaCK projects have undertaken research in the Daly River basin on ecological assets, river flows and ecological thresholds. These projects have covered a variety of related topics including environmental water requirements, socio-economic consequences of altered flows, links between ecological, socio-economic and management components, ecosystem function and environmental/ecological monitoring.
4. A summary the project, *Eco-hydrological regionalization of Australia's rivers was provided.* A variety of flow regimes are represented in rivers of northern Australia based on seasonality and predictability of flow and the contribution of baseflows (pereniality).
5. Key elements of other projects, particularly, *Indigenous Values of River Flows*, *Management Strategies in Tropical Rivers, Material Budgets* and *Environmental Flows* was also provided
6. Establishment of thresholds as part of the HCVAE process was considered ambitious, particularly in poorly known systems. but we do have some information on physical habitat (sediment transport, bank erosion, woody debris movement, macrophyte loss etc), Primary production (water clarity, depth and nutrients), hydrological connectivity (longitudinal and lateral).

Tropical Rivers Inventory and Assessment Project (TRIAP) risk assessment in the Daly River (Peter Bayliss, CSIRO/TRaCK)

1. This presentation provided an assessment of risk assessment techniques to assess the condition of HCVAE's using iconic species and whether simple threshold concepts are useful.
2. The impact of "uncertainty" on how aquatic ecosystems are managed was discussed. A probabilistic approach such as risk assessment or Bayesian Belief Networks was identified as the most useful approach for managing ecological values and ecological risks where uncertainity exists.
3. Spatially explicit semi quantitative approach using the Relative Risk Model RRM at catchment and subcatchment scales was discussed.
4. The use of data on iconic species and Bayesian Belief Networks (BBN's) to quantify risks to ecosystems (or components) was discussed. Two examples provided were instream ecosystem health and barramundi, and floodplain ecosystem health and magpie geese.
5. The use of ecological thresholds to inform management was also discussed using a number of examples including flow-ecology thresholds for barramundi and geese, invasive species impacts and management, water quality in coastal receiving waters.
6. It was concluded that because aquatic ecosystems are complex and characterized by multiple-equilibria thresholds of change, the use of ecology thresholds to inform management should be considered cautiously.
7. Thresholds very useful but incredibly difficult to derive without empirical data.

Overview of the Framework for Assessing River and Wetland Health (FARWH) (Simon Townsend, CDU/TRaCK)

1. This presentation provided an overview of the *Framework for Assessing River and Wetland Health* that was trialed in the Daly river catchment.
2. FARWH has six themes, each with a variety of indices.
3. The six core themes are: Catchment Disturbance Index (landuse and fire); Hydrological Disturbance Index (Flow Stress Ranking indices); Physical Form Index (Bank stability and connectivity); Fringing Zone Index (riparian vegetation indices); Water Quality (physico-chemical indices) and Aquatic Biota Index (fish, macroinvertebrates and invasive species)
4. Scores are range standardized (0-1)
5. Variety of Integration and aggregation techniques were identified and discussed.
6. The trial of FARWH in the Daly River catchment only considered perennially flowing streams. Only focused on dry season conditions. Thererfore only small persentage of the entire stream network was assessed. Site selection in 2 strata, developed and undeveloped
7. Recommendations: Good river health relative to temperate Australia Therefore, FARWH objective should be for early detection, rather than remediation. Sound knowledge of reference condition was needed, but very hard to define. Indicators needed to be sensitive to narrow disturbance gradients. Large sample numbers required for type 1 errors.
8. Based on these constraints it was concluded that the ability to detect changes in river health in the wet/dry tropics remains problematic in catchment scale assessments. Objectives for future river health assessment in the region should focus on the early detection of river health degradation.
9. The recommended approach for future river health assessments would include a two-tiered study including assessment of Catchment and Hydrological disturbance indices at the catchment scale, and small scale assessment of river health at selected impact and reference sites.

All presentations are presented in full in Appendix 2

Afternoon Session

For the afternoon session discussion focused on identifying fine scale attributes of HCVAEs within three areas of the Daly River including the lower Daly River floodplain, the Daly River middle reaches and the Upper Katherine River. A final session focused on potential outcomes of this fine scale assessment and the implications for management.

Lower Daly floodplain

The agreed boundary for the lower floodplain was defined as the area subject to inundation (based on 1:250k mapping). The workshop also recognized that the fine scale attributes related to areas identified within the broad-scale units. The important values within these areas included high fish and bird diversity, endemism, and a number of threatened species.

Aspects on the floodplain creeks such as Elizabeth Ck were considered important ecological assets for their role in providing access to floodplain resources (food/habitat) during particular stages of the flood hydrograph. These floodplain creeks are important in particular areas of the main river that are known to support populations of Barramundi and where off-channel lakes adjacent to the main river provide run-off to the river in wet season. It was also suggested that the riparian forest along the channel is important for supplying in-stream habitat in the form of woody debris. Floodplain lakes and oxbow lakes along the lower Daly are also likely to be important refugia for fish species such as pennyfish and blue-eye as well as other fish specific to those waterholes. The question was raised whether permanent floodplain lakes on the Daly River floodplain provide a refuge for barramundi. A key knowledge gap identified was the timing and movement of fish on the floodplain and to and from waterholes and the main channel.

Waterbirds on the floodplain were identified as being a significant high conservation asset and they display a high level of site fidelity (Figure 3). They are, however, highly mobile and there are large seasonal differences in bird numbers and species. Waterbirds therefore need to be managed at the whole floodplain scale, as well as on a seasonal basis. For example, waterbirds are likely to be most abundant in coastal parts of the floodplain in the wet season and in upstream sections of the floodplain in the dry season. Waterbirds also move between different rivers floodplains. The HVCAE identification process could be improved by using data for waterbird nesting and colony locations.

Figure 3: Waterbirds making use of a permanent floodplain waterhole in the dry season on the lower Daly River (photo N. Pettit).

Riparian forest along the main channel as well as forest lining creeks was identified as an important asset for the lower Daly River. Similarly, *Melaleuca* spp forests on the floodplain are an important asset for birds and other animals. Survival and recruitment of riparian and floodplain trees is thought to be closely linked to the timing, extent, frequency and duration of floodplain inundation.

Possible threats to floodplain ecological assets may include direct water pumping from refugia waterholes (such as Mission Hole) or the clearing of vegetation for agriculture. Changes to flow and run-off characteristics on the floodplain through upstream water abstraction are likely to have consequences for floodplain, river connectedness and therefore ecological assets. Other threats on the floodplain include weeds such as mimosa, para grass and salvinna, as well as increasing numbers of feral pigs. Altered fire frequency and intensity may a pose a threat to floodplain ecosystems, such as the effect on magpie geese habitat. Data on the fire regime for the floodplain is a knowledge gap.

Workshop participants suggested that some assets on the floodplain need to be managed at variable spatial and temporal scales and that this ability to move between habitats is a key ecological process. An example of this is the movement of waterbirds within and between floodplains.

Daly River middle reaches

When considering fine scale assets for the middle reaches it is important to consider not just the main channel but tributaries and off-channel waterholes, including palustrine waterbodies. The middle reaches of the Daly River are maintained by permanent groundwater baseflow and the connectivity through and within the reach created by this baseflow in the dry season gives the middle reach its value. The river bed in the middle reaches consists mostly of mobile sand. Low-water riffle habitats are therefore considered a critical asset in the middle reaches, partly due to their scarcity and their importance for aquatic productivity (Figure 4). Riffles are generally areas of high productivity providing a fairly stable substrate for the production of benthic algae and high concentrations of aquatic macroinvertebrates. These areas are in turn important for fish. For example, habitat duration curves for juvenile sooty grunter suggest that the riffle areas are an important habitat for this species. Presumably this is as they feed on macroinvertebrates congregating in the riffle areas. Depth of riffle habitats was also considered an important habitat constraint for the endangered pig-nosed turtle.

Figure 4: Riffle area at Oolloo crossing, an important in fine scale asset in the middle reaches of the Daly River (photo N. Pettit).

Reduction in dry season flows is likely to be the biggest impact on the ecological assets of the middle reaches because of the effect on riffle areas as well as the potential disconnection of flow. Only small reductions in flow can have a large effect on river ecology because of dependence on riffle area by many plants and animals. Water abstraction at low flow times can expose shallow channel benches which are critical areas for primary production. Threats to river connectivity in the middle reaches include barriers such as road crossings (eg. Beeboom) through dry season water abstraction to below the level of natural barriers. This therefore greatly reduces the movement of mobile aquatic animals such as fish and turtles.

Another asset that was considered important to be protected was the riparian forest. There is a potential affect of groundwater drawdown on this forest and particularly the rate of drawdown. Wood debris derived from the riparian forest is another important habitat asset. Flow variability was considered and important factor controlling woody debris recruitment and movement in the river. This will also be affected by low flows as wood is exposed that is being utilized by aquatic fauna. Groundwater drawdown may reduce wood recruitment as bank slumping through groundwater seepages is seen as an important mechanism by which wood enters the river. High flows in the wet season need to be maintained as these flows cause bank erosion and subsequent recruitment of wood to the river.

Tributaries that feed into the middle reaches of the river were considered to represent refugial areas for the main channel, for fish (habitat, shading, allochthonous inputs) and vegetation (disturbance).

Off channel spring-fed areas allow the establishment of rainforest patches, which are another asset important for biodiversity. These patches are likely to be detrimentally affected by groundwater drawdown. Lacustrine habitats adjacent to the main channel are thought to also have different aquatic macroinvertebrate and frogs fauna compared with fauna in the main channel, making them an important biodiversity asset. Tufa dams were considered a unique geomorphic feature in this part of the river that we know little about. What sustains them and are they sensitive to flow regime change were considered significant knowledge gaps

Other important considerations that were highlighted by workshop participants were the need to consider long term climatic cycles in management. Also, the importance of sediment transport and dynamics in ecological processes within the river were also identified.

Upper Katherine River

The upper Katherine River encompasses the high elevation stone country of Arnhem Plateau (Figure 5). There are a large number of natural barriers to movement of aquatic fauna and therefore limited connectivity between river reaches. Lack of connectivity has been the driver of the uniqueness of the biota in this area. For example, there is a high level of endemism of fish and the lack of connection has resulted in genetically distinct fish species. There are also distinctive off-stream palustrine wetland areas which we do not know a great deal about. Water temperatures in these reaches can become quite high in the wet season due to lack of riparian cover and the rocky channel bed so that thermal refuge for fish in canyons and plunge pools is likely to be a critical habitat asset in these reaches.

Threatening processes in this part of the river include impacts of feral animals such as pigs, buffalos, horses and donkeys. Effects of disturbance by these feral animals on waterbodies may be less due to bedrock nature of streams, however the scarcity of areas of organic material accumulation or sandy beds make these areas prone to disturbance. Another key issue in this region is fire management, particularly for lower order streams. Fires may affect the sensitive spring fed rainforests that occur in off-channel areas.

There is also likely to be effect of cane toad invasion on freshwater crocodile numbers and therefore the rest of the aquatic food web.

Figure 5: Reach of the upper Katherine river showing the rocky nature of the river bed, clear waters and the limited riparian cover (photo I. Dixon).

Management implications

Workshop participants were in agreement that there is still a lot we don't know in terms of managing the ecological assets of the Daly River. Underlying information and data on waterbodies is probably the most useful to jurisdictions. But also the modeling data is of some use as well. All data layers should be available to the jurisdictions and a subset of this to be made available to the public. Water allocation process is developing an inventory of ecological assets and there needs to a strong ecological justification so that stakeholders can clearly see why the limits on allocation are set.

Other key points that were highlighted included:

- The need for the identification of areas of high conservation value to the community, such as important cultural values.
- Ongoing communication between data users and data gathers (ie. Managers and researchers).
- The importance of the temporal currency of data.
- Need to be mindful of the over use of certain bits of data.

In general the workshop was considered a useful first step in engagement between managers and researchers on discussing HCVAEs and defining the ecological assets and thresholds that water managers need to be aware of. It was also suggested that a greater focus could have been made on using local expertise in identifying aquatic ecological assets in the fine scale assessment areas to compare these against those of the broad scale assessment. Consideration of theoretical ecological thresholds for biota on the Daly River was not considered appropriate for this workshop, particularly in light of the lack of data available to develop these thresholds.

Workshop Outcomes and Recommendations

Prior to the workshop, all participants were provided with background information on the aims of the workshop and the materials that had been developed to document information required for the fine-scale assessment of ecological values in the Daly River catchment. Participants were asked to engage in an open discussion to identify fine scale assets and undertake a risk-based approach for determining, where possible critical thresholds as they related to flow regimes and other ecological processes.

While some fine-scale assets were identified, much of the afternoon session was taken up with discussion on whether it was possible, or indeed appropriate to identify ecological thresholds given the current state of knowledge. These discussions identified a variety of concerns, including a lack of appropriate empirical data on eco-hydrological relationships and a lack of site specific knowledge to identify fine-scale values. Therefore the of the rather ambitious set of aims that were originally suggested for the workshop only the first three we addressed in any detail (see aims above).

Following an assessment of the workshop outcomes the following recommendations are provided for future HCVAE workshops:

1. Ensure participants have local, site specific on-ground knowledge of the assessment area. This will maximize the likelihood that fine-scale values will be identified.
2. Provide more detailed background information on the results of the broad-scale HCVAE assessment within the focal area. This would include some background on the HCVAE Framework and criteria, and a series of maps that identify planning units within the assessment area that were identified as having relatively high value (although these were provided at the workshop). This information would provide a strong basis for participants with local expertise to identify fine-scale values.
3. The workshop should concentrate on the identification of fine-scale values, rather than the identification ecological thresholds. Once fine-scale values have been identified, the discussion should be broadened to include consideration of ecological thresholds if appropriate.

References

Bartolo, R., Bayliss, P. and van Dam, R. (2008). Semi-quantitative Risk Assessments. In Ecological risk assessments for Australia's Northern Tropical Rivers, Environmental Research Institute of the Supervising Scientist, Darwin, Australia, 162-270.

Begg G.W., van Dam, R., Lowry, J.B., Finlayson, C.M. and Walden, D.J. (2001). Inventory and risk assessment of water dependent ecosystems in the Daly basin, Northern Territory, Australia. Report 162, Environmental Research Institute of the Supervising Scientist, Darwin, Australia.

Blanch, S., Rea, N. and Scott, G. (2005). Aquatic conservation values of the Daly River Catchment, Northern Territory, Australia. Report prepared by WWF-Australia, Charles Darwin University and the Environment Centre NT, Darwin.

Chan, T., Hart, B., Kennard, M.J., Pusey, B.J., Shenton, W., Douglas, M. Valentine, E. & Patel, S. (2010). Bayesian network models for environmental flow decision-making in the Daly River, Northern Territory, Australia. *River Research & Applications*. DOI: 10.1002/rra.1456.

Douglas M.M., Bunn, S.E. and Davies, P.M. (2005). River and wetland food webs in Australia's wet-dry tropics: general principles and implications for management. *Marine and Freshwater Research* 56, 329-342.

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. Report 175, Supervising Scientist: Darwin.

Kennard, M.J. (ed) (2010). Identifying high conservation value aquatic ecosystems in northern Australia. Interim Report for the Department of Environment, Water, Heritage and the Arts and the National Water Commission. Tropical Rivers and Coastal Knowledge (TRaCK) Commonwealth Environmental Research Facility, Australian Rivers Institute, Griffith University. Available at: http://track.gov.au/publications/registry/843.

Lamontagne, S., P.G. Cook, A. O'Grady, and D. Eamus. (2005). Groundwater use by vegetation in a tropical savanna riparian zone (Daly River, Australia). *Journal of Hydrology* 310:280-293.

Preston, B.L., and Jones, R.N. (2008). Evaluating sources of uncertainty in Australian runoff projections. *Advances in Water Resources* 31:758-775.

Pusey, B.J. & Kennard, M.J. (2009). Chapter 3 – Aquatic ecosystems of northern Australia. In: "Northern Australia Land and Water Science Review" (ed. P. Stone). Final report to the Northern Australia Land and Water Taskforce. CSIRO Publishing. Available at: http://www.nalwt.gov.au/science_review.aspx

van Dam, R., Bartolo, R. and Bayliss, P. (2008). Identification of Ecological Assets, Pressures and Threats. In Ecological Risk Assessments for Australia's Northern Tropical Rivers, Environmental Research Institute of the Supervising Scientist, Darwin, Australia, 141–161.

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Appendix 1 – Workshop Participants

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Appendix 2 – Workshop Presentations

Overview of the NAWFA Programs (Cameron Colebatch, DEWHA) and Overview of the HCVAE Framework (Di Conrick, DEWHA)

Fine Scale assessment of aquatic ecological assets and the identification of ecological thresholds (Mark Kennard, GU/TRaCK).

Water Planning and Allocation (Kelly Howitt, NRETAS)

Conservation strategy, ecological assets and management of conservation areas in the Daly and other areas (Tony Griffiths, NRETAS)

Overview of TRaCK Research (Michael Douglas, CDU/TRaCK)

Tropical Rivers Inventory and Assessment Project (TRIAP) risk assessment in the Daly River (Peter Bayliss, CSIRO/TRACK)

Overview of the Framework for Assessing River and Wetland Health (FARWH) (Simon Townsend, CDU/TRaCK)

APPENDIX 8.5.

CLAYTON, P. & TALBOT L. (2010). ECOLOGICAL THRESHOLDS WORKSHOP OUTCOMES GILBERT, FLINDERS AND NORMAN RIVER CATCHMENTS. RPS REPORT FOR THE DEPARTMENT OF ENVIRONMENT AND RESOURCE MANAGEMENT, BRISBANE.

RPS

Ecological Thresholds Workshop Outcomes

Gilbert, Flinders and Norman River Catchments

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APPENDICES

1.0 Introduction

The Northern Australia Aquatic Ecological Assets Project (EAP) is a project under the Northern Australia Water Futures Assessment (NAWFA), coordinated by the federal government but extended through state jurisdictional partnerships across northern Australia. As part of the EAP, a trial of the High Conservation Value Aquatic Ecosystems (HCVAE) framework which is being developed by the Australian Government and state jurisdictions through the Ministerial Council is being conducted at both a broad and a fine scale.

The EAP broad-scale assessments, already completed, have highlighted the high conservation values present in many areas of northern Australia. To complement this work, fine scale assessments were proposed to be undertaken for key focal regions with the aim of identifying specific ecological assets and understanding their ecological thresholds in relation to flow regimes and the maintenance of aquatic ecosystem assets. In Queensland, the Gilbert River, Norman River and Flinders River catchments, in the Gulf of Carpentaria Drainage Division, were identified as pilot catchments for consideration in this context.

To support the fine scale assessment of these priority catchments in northern Queensland, an "ecological thresholds workshop" was held in Brisbane on Thursday 28th October 2010, gathering experts from across the state with direct technical knowledge or experience related to the target region. The outcomes from this workshop, reported here, form part of the EAP.

1.1 Workshop Aims

In Queensland, the Department of Environment and Resource Management (DERM) has been working cooperatively with project managers from the NAWFA project team at Griffith University to undertake an Aquatic Conservation Assessment (ACA), using the Aquatic Biodiversity Assessment and Mapping Method (AquaBAMM)[1] and the Queensland Wetland Mapping, to assess aquatic conservation priorities for the Flinders, Norman and Gilbert catchments. With this foundation of identified aquatic ecological priorities and assets, plus hydrological and flows information available through the Queensland's Water Resource Planning process[2], the "ecological thresholds workshop" maintained focus on flow-related ecological threats and thresholds rather than asset identification.

The aim of the workshop was to conduct preliminary investigations on understanding ecological thresholds in relation to flow regimes and the maintenance of aquatic ecosystem assets for the Gilbert River, Norman River and Flinders River catchments. The workshop aimed to review existing information, collate flow and ecological factors pertinent to the understanding of conceptual flow models, identify data gaps and propose a way forward for subsequent stages of the EAP and NAWFA.

Specifically, the workshop had the following aims:

- Discuss the usefulness (strengths and weaknesses) of the HCVAE process as it relates to thresholds;
- Review the aquatic ecosystem assets and priorities identified through the DERM ACA process;
- Review hydrological and water resources information;
- Agree on local scale assets (e.g. particular floodplain lakes, and wetlands, riverine reaches, ecological processes, species, communities, etc) that require focus through the workshop;

[1] More information on AquaBAMM and the NAWFA ACAs can be accessed at http://www.derm.qld.gov.au/aquabamm
[2] More information on the Water Resource Plans can be found at http://www.derm.qld.gov.au/wrp/index.html

- Consider flow-related threats to the ecological assets in all target catchments;
- Where possible, discuss ecological thresholds and 'limits of acceptable change' in relation to the identified assets and threats.
- Identify data gaps that diminish our contemporary understanding of ecological thresholds and potential management options for this geographic region; and
- Make recommendations for the next stages of the EAP and NAWFA.

1.2 Rationale

Understanding aquatic ecosystems well enough to identify flow-related ecological responses is, itself, a complex task; however, quantification of 'thresholds' for 'assets' infers a requirement for additional knowledge about critical ecological limits and conservation values respectively. It is unlikely that these topics could ever be fully explored in a single workshop but a workshop should initiate some momentum in a discussion about flow-related aspects of aquatic ecosystem function and value in northern Queensland.

The geographic area of interest was pre-defined for the workshop and included the Flinders, Norman and Gilbert River catchments within the Gulf of Carpentaria Drainage Division. Even more specifically, aquatic ecological assets of relevance for discussion were already identified at a number of spatial scales through separate processes such as DERM's Aquatic Conservation Assessments using AquaBAMM. It was deemed un-necessary to focus on spatial scale or asset identification for the workshop as that had been identified through other processes, except where they are pertinent to matters of flow-related aquatic ecological response.

There are a number of ways to consider aquatic ecological 'thresholds' but possibly the most useful is that, after agreement on the 'assets' that set debate context, a focus on flow-related (or water-related) threats and limits of acceptable ecological change could provide direction for conclusions about water resource management options, ecological thresholds (if they are practically identifiable) and data gaps. The workshop participants looked for flow-related threats likely to manifest as critical escalations of negative conditions, changed environmental circumstances, ecological turning points, loss of wetland values or loss of wetlands. These threats and their environmental consequences may have already been known, may have only recently been noticed or understood, or may have been hypothesised based on expert wetland knowledge. In all cases, the notion of 'limits of acceptable change' was in mind to frame the discussions and to assist in assessing threats and consequences to assets around the region. Importantly, consensus about what an aquatic ecological 'asset' is for the purposes of the EAP is the critical first step.

1.3 Limits of Acceptable Change

The concept of 'limits of acceptable change' is not universally promoted because, to some, it infers assimilative capacity that can be expediently managed or allocated until a critical tipping point is reached. Many technicians take a more holistic ecological view that encompasses the idea of continuous gradients of change and environmental management by attention to broader ecological process and function. In any case, limits of acceptable ecological change is a concept that does provide focus for debate and, while its definition generates debate, it can galvanise expert thinking with respect to ecological threats and management options.

The concept of 'limits of acceptable change' is already a primary tenet of Ramsar wetland management in Australia and can be considered an appropriate context for discussion of significant northern assets also (notwithstanding that there are no listed Ramsar sites within the study area). Through these discussions, and with a focus firmly on flow regimes and flow-related ecological response, ecological 'thresholds' may become evident or data gaps that require filling to identify 'thresholds' will become evident. For reference, the detail in section 1.3.1 provides an understanding of limits of acceptable change as it has been applied in management of Australia's Ramsar wetlands.

1.3.1 Ramsar 'Limits of Acceptable Change'

Limits of acceptable change are defined by Phillips (2006), and included in the National Framework for Describing Ecological Character of Australia's Ramsar Wetlands (DEWR 2007), as "…the variation that is considered acceptable in a particular measure or feature of the ecological character of the wetland. This may include population measures, hectares covered by a particular wetland type, the range of certain water quality parameter, etc. The inference is that if the particular measure or parameter moves outside the 'limits of acceptable change' this may indicate a change in ecological character that could lead to a reduction or loss of the values for which the site was Ramsar listed. In most cases, change is considered in a negative context, leading to a reduction in the values for which a site was listed".

Limits of acceptable change and the natural variability in the parameters for which limits are set are inextricably linked. Phillips (2006) suggested that limits of acceptable change should be beyond the levels of natural variability. Wetlands are complex systems and there is both spatial and temporal variability associated with all components and processes so setting and assessing limits in consideration with natural variability is very important. What is required for this workshop is knowledge that a trend away from natural variability can be detected, or is likely to be detected, that considers frequency and magnitude of events, seasonal patterns and spatial variability.

2.0 Workshop Structure

2.1 Overview

The DERM ecological thresholds workshop was held over one full day on the 28th of October 2010.

Morning sessions were focused on provision of background information and, to this end, a number of guest speakers made presentations. These included topics such as:

- EAP and NAWFA project background, assessment history and proposed future direction;
- Aquatic ecological assets and conservation priorities as determined through DERM AquaBAMM assessments to date;
- Hydrological characterisation for the target geographic area and the priority catchments; and
- Jurisdictional and technical differences with respect to the definition and identification of 'assets'.

Afternoon sessions were focussed on interactive discussion of assets that should be the focus for consideration and flow-related ecological threats to those assets.

2.2 Agenda

The DERM ecological thresholds workshop agenda is shown below. Presentations received on the day, additional to those in the originally proposed agenda, are included for completeness.

TABLE 2.1 AGENDA

TIME	ITEM
9:00	**Tea and coffee**
9:15	Welcome, introductions and workshop purpose (Paul Clayton)
9:30	Introduction to the HCVAE agenda and the NAWFA projects (Cameron Colebatch)
10:15	Aquatic Conservation Assessment results for the Southern Gulf of Carpentaria (Selena Rollason)
11:00	**Morning Tea**
11:15	Group session 1 – Assets and Values Included an unscheduled presentation: Defining assets and values: the differences across projects and purpose (Jon Marshall)
12:15	Unscheduled presentation: Flow regime and rainfall variability by long-term non-parametric analysis of gauge data for

TIME	ITEM
	northern Queensland catchments (Arthur Knight)
12:45	**Lunch**
13:20	Hydrology in the Gulf (Greg Hausler)
14:00	Brief hydrological issues discussion
14:30	**Afternoon Tea**
15:00	Group session 2 – Identification of flow-related threats
16:30	Summary, conclusions and where to from here
17:00	**Close**

2.3 Attendees

The DERM ecological thresholds workshop was well attended and included participants with a range of technical and water planning expertise. The final attendees list is shown in the table below.

TABLE 2.2 ATTENDEES

ATTENDEE	AFFILIATION
Arthur Knight	DERM
Bruce Wannan	DERM
Cameron Colebatch	Department of Sustainability, Environment, Water, Population and Communities
Geoff Kavanagh	C&R Consulting
Glenn McGregor	DERM
Greg Hausler	DERM/RPS
Jennifer Martin	Department of Sustainability, Environment, Water, Population and Communities
John Bennett	DERM
Jon Marshall	DERM
Lorinda Talbot	RPS Group
Matthew Knott	C&R Consulting
Mike Ronan	DERM
Niall Connolly	DERM

ATTENDEE	AFFILIATION
Olwyn Crimp	PermaLife P/L and Northern Gulf NRM
Paul Clayton	RPS Group
Peter Bayliss	TRaCK
Peter MacDonald	DERM
Richard Hunt	DERM
Ross Smith	Hydrobiology Pty Ltd
Satish Choy	DERM
Selena Rollason	DERM
Tim Jardine	TRaCK

Note: TRaCK = Tropical Rivers and Coastal Knowledge (Griffith University)

3.0 Workshop Session Summaries

Full detail for each of the invited presentations is available from DERM but is not reproduced in this report. The emphasis in this report is on group discussion and the workshop outcomes, rather than presentation of background information.

The group discussion sessions saw enthusiastic debate and resulted in a large number of relevant and insightful ideas. Raw workshop notes have been provided in Appendix A; however, summary results only are presented in this section of the report.

The workshop focussed on three catchment study areas – the Norman, Flinders and Gilbert. Though these are adjacent catchments in the Gulf of Carpentaria region, they each have their own character and the workshop attendees agreed that each could be discussed separately. The following provides a summary of each catchment sourced from the Aquatic Conservation Assessments (Rollason, S.N. and Howell, S. 2010).

The **Norman River Catchment** covers an area of 50,027 square kilometres and is bounded by the Gilbert River basin in the north and the Flinders River basin in the south-west. The Norman River originates 200 kilometres south-east of Croydon in the western side of the Gregory Range, part of the Great Dividing Range. From there it flows in a north-easterly direction through the gulf savannah black soil plains, past Normanton and ultimately discharges into the Gulf of Carpentaria at the port town of Karumba. The Norman River is mostly a low gradient river and is joined by a number of major tributaries from the east, including the Clara and the Yappar Rivers, and Spear Creek from the south-west. The climate in the Norman basin is generally characterised by long, hot dry springs proceeding a hot, humid summer. Winter is cooler and dry but also very short. Rainfall in the region has high seasonal variability, but reasonable season reliability. The Norman basin's average annual rainfall is largely consistent throughout and, ranges between 650 and 850 mm, although timing and location of rainfall will vary. Most of the annual rainfall occurs during the wet season, with the rest of the year being dry. Mean annual runoff is approximately 2,346,000 ML. During the monsoon season, December to March, flooding is common but for the remainder of the year water becomes progressively scarcer and most rivers stop flowing and consist of a series of water holes. Due to high rainfalls and extensive low gradient plains and floodplains, the waterways in the region retain thousands of permanent and semi-permanent water bodies of significant ecological value. Of significance is the high natural integrity of wetlands in the region and that connectivity is generally very high throughout, with flood waters connecting many wetlands, and relatively few artificial in-stream barriers. Where the Karumba Plains occurs adjacent to the coast, wetlands form a very large and important interface between terrestrial and marine environments. The Karumba Plains also coincides with the Southern Gulf Aggregation, an area recognised as of national significance on the Directory of Important Wetlands.

The **Flinders River Catchment** is the largest basin draining to the southern section of the Gulf of Carpentaria, draining an area of approximately 109,716 km2. The main drainage, the Flinders River, rises in the western ranges of the Great Dividing Range northeast of the township of Hughenden. From there it flows westerly past Richmond towards Julia Creek and then north into the Gulf of Carpentaria coast 25 kilometres west of Karumba. The climate in the Flinders basin is generally characterised by long, hot dry springs proceeding a hot, humid summer. Winter is cooler and dry but also very short. The landscape varies from being semi arid in the southwest to being tropical monsoonal in the north with the regions summer climate influenced by the north-west monsoon. Rainfall in this region is very variable from year to year and within years. Most of the annual rainfall occurs during the wet season, with the rest of the year being extremely dry. There is also considerable variation in rainfall spatially throughout the basin. In the headwaters of the Flinders River, on the western slopes of the Great Dividing Range, average annual rainfall is about 700 mm. Rainfall then declines westerly, with an average annual rainfall in the south-west of only about 400 mm. But this increases again to more than 800 mm to the north along the Gulf of Carpentaria coastline. This rainfall produces a mean annual runoff of approximately 3,857,000 ML. The major occurrences of freshwater wetlands in the basin are on the depressions on the Tertiary plains and the alluvials. The middle Flinders basin also has the most extensive and well developed braided drainage network in the Gulf and this complex has important wetland values. These include extensive Coolabah and Red Gum dominated riparian systems and deep water channel habitats in lower sections that are refuge for a variety of fauna and flora. In addition numerous off-river lagoons, temporary wetlands and flooded pastures occur. Of significance is the high natural integrity of wetlands in the region and that connectivity is generally very high throughout, with flood waters connecting many wetlands and relatively few artificial in-stream barriers.

The **Gilbert River Catchment** covers an area of 46,282 square kilometres and is bounded by the Norman River basin in the west and the Staaten River and Mitchell River basins in the north-east. The Gilbert basin differs to the Flinders and Norman basins, in that a large proportion of the basin in the upstream section occurs in the higher relief Einasleigh Uplands bioregion. The Undara-Toomba Basalts subregion enters the basin in two areas and is significant for the unique, often spring-fed wetlands that occur, providing perennial refugia in the upper part of the basin. The climate in the Gilbert basin is dominated by the alternation of a summer north-west monsoon and winter south-east trade winds. Mean annual precipitation ranges between 750 and 850 mm in the upper basin in the Einasleigh Uplands. Precipitation on the coast is greater, averaging 1000 mm per year. Rainfall in the region has highly variable seasonally, but reasonably reliable. Most of the annual rainfall occurs during the wet season, with the rest of the year being dry. Mean annual discharge is approximately 4,895,000 ML/year but can vary greatly depending on the intensity of the monsoon. During the monsoon season, December to March, flooding is common but for the remainder of the year water becomes progressively scarcer and most river channels stop flowing and consist of a series of water holes. Due to intense rainfall events and extensive low gradient plains and floodplains, the waterways in the region retain thousands of permanent and semi-permanent water bodies of significant ecological value. Of significance is the high natural integrity of these wetlands and that connectivity is generally very high throughout, with flood waters connecting many wetlands, and relatively few artificial in-stream barriers.

3.1 Assets and Values

Aquatic ecological assets and values were discussed in detail, including notions of scale and potential management influence. The following summary workshop outcomes are relevant:

- The study area catchments are;
    - largely intact ecosystems;
    - subject to a water resource plan in which there are limited water allocations approved and sustainable diversion limits established; and

  - highly ephemeral systems in which a wet and dry phase is the defining ecological process.
- Assets and conservation priorities assessed through DERM ACA processes were agreed as a useful reference point for spatially specific 'assets' (i.e. defined patches in a geographic context).
- 'Values' can be defined in many ways depending on technical or social context.
- For EAP and NAWFA, it was agreed that 'asset' should refer to critical aquatic ecological processes as well as significant geographic spatial units.
- Given work already completed for the northern Queensland catchments of interest, there was no need through this workshop to further discuss spatial scale or 'asset' identification.
- For the purposes of identifying flow-related threats, ecological thresholds and/or potential water resource management options, <u>critical ecological processes</u> must be considered along with <u>critical geographic spatial units</u> (i.e. high conservation value/priority features and ecosystems). The former has often been overlooked and is not a common inclusion specifically for priority assessment in tools such as HCVAE or ACA.
- Process/function assets and location-based assets are both relevant and need to be considered together, particularly in "intact" ecosystems where landscape fragmentation is less. In fragmented landscapes, such as the southern and more settled/developed parts of Australia, focus on individual high priority location-based assets may be more appropriate but nonetheless should be cognisant of the ecological processes that support the ecosystems function.
- Location-based assets are satisfactorily identified in existing bodies of work such as DERM's ACA for the target region; however, discussion at the workshop was necessary to further explore 'critical ecological processes' with respect to potential assets (refer Section 3.2).

3.2 Critical Ecological Process

Through group discussion, it became evident quickly that a large amount of intellectual effort had already occurred to consider critical ecological processes in the study area. This work was done as part of the northern catchments water resource planning processes for the relevant WRP Technical Advisory Panel (TAP), and is available in a report by Hydrobiology Pty Ltd titled Ecological and Geomorphological Assessment for Gulf and Mitchell Water Resources Plan (Hydrobiology Pty Ltd, 2005).

Rather than unnecessarily repeating this work, there was consensus at the workshop to adopt the Critical Processes identified within this report as 'assets' and, therefore, as a basis for considering flow-related threats to assets. These critical ecological processes are summarised in the following sub-sections for reference.

No further discussion occurred relating to critical ecological processes.

The following sections contain the ecological processes identified in the TAP report, Ecological and Geomorphological Assessment for Gulf and Mitchell Water Resources Plan (Hydrobiology Pty Ltd, 2005). The sections are also titled in line with the TAP report.

3.2.1 Overbank Processes

- Onset timing of initial wet season overbank flows and/or local run off fill floodplain wetlands and establish aquatic habitat conditions for associated biotas seasonal feeding, breeding and recruitment processes.

- Flow heights and duration required to activate, replenish and reset habitat conditions within braided and distributary channels and drainage depression networks.
- Peak flow events create high flow velocities in prior and distributary channels, scour out accumulated organics and sediment loads, maintain deep water habitats and re-set aquatic plant communities within lower reaches of basins.
- Overland flows required to deposit silt and associated nutrients and create and maintain alluvial landforms.
- Flow heights and duration required to establish lateral habitat connectivity and facilitate aquatic biota movement and recruitment between main channel habitat and floodplain wetlands including opportunities for inter-basin movement via inundated floodplains and flood runner distributary channels.
- Flow heights and duration required to wet and irrigate floodplain vegetation communities sufficiently for inter-annual recruitment and survival.
- Localised run off and overbank flows responsible for filling back plain swamps, including nationally significant wetlands and wetland aggregations (i.e. Musselbrook Aggregation, Bluebush Swamp, Lignum Swamp, Mitchell Fan and South East Karumba Plain Aggregation).
- Seasonal draw down and wetting and drying cycles in floodplain wetlands responsible for maintaining high diversity and mosaic of successional wetland vegetation communities.
- Run off from small, steeper, hard rock catchments i.e. In the near coastal areas of the north west (Settlement) which is responsible for creating reliable freshwater inputs to associated coastal wetlands.

3.2.2 Within Bank Processes

- Onset timing of initial wet season flows and run off which fill channel wetland and establishing aquatic habitat conditions for progress of associated biotas seasonal feeding, breeding and recruitment processes.
- Peak flow events responsible for creating and maintaining high value deep water habitat
- Pulsed and sustained flow events, subsequent sustained flows recharge river bed sand aquifers and “wet up” anastomosing braided channel systems, creating precedent conditions for wide channel flows.
- Flow height and duration required to flood out physical barriers and establish longitudinal habitat connectivity and facilitate aquatic biota movement and recruitment between isolated in-channel aquatic refugia and lower catchment marine environments.
- Flow height and duration required to wet and irrigate riparian vegetation communities sufficiently for inter-annual recruitment and survival including criticality of dry season base flows in perennial streams required to sustain unique vegetation and fauna communities.
- In channel structures and vegetation and associated flows that create scours in stream sand beds creating channel habitat heterogeneity including deeper pools and dry season refugia formed from windows into sand bed aquifers.
- Permanence of pools that provide dry season aquatic refugia in non-perennial systems.

3.2.3 Groundwater Interaction Processes

- Groundwater aquifer recharge via infiltration of rainfall and surface flows in recharge areas including fractured rocks, sand sheets and riverbed sands

- Groundwater aquifer discharge responsible for maintenance of perennial base flows in major sub catchments of Nicholson Basin (Gregory, Lawn Hill), smaller streams of Settlement Basin, upper Gilbert and Staaten Basins, Upper Mitchell (Lynd sub catchment) and for maintenance of spring fed wetlands and permanent water bodies and contributions to seasonal surface and hyporheic flows of several basins (e.g. Gilbert, Mitchell).
- Groundwater discharge from large sand sheets (e.g. Doomadgee sand sheet). This discharge comes from the recharge associated with either surficial infiltration and/or from underlying geology and is responsible for maintaining hydrological and salinity regimes that support a high diversity of wetland types including brackish sedge swamp communities, which form regionally important estuarine crocodile breeding habitat. Since this water may be supplemented by a low flow from the underlying geology, it is possible that the water being discharged is aged.

3.2.4 Coastal Processes

- Perennial – semi perennial freshwater discharges to marine environment which create a salinity transitional zone and support a high diversity of highly productive fresh-brackish coastal wetlands including sedge swamps utilised for crocodile and waterfowl breeding.
- Flood flow associated discharges of sediment and nutrient to estuaries and deposition within inter-tidal and near shore environments. These provide the major productivity driver for coastal zone food webs and are closely linked to commercial fishery production.
- Overbank flood flows and local run off responsible for inundating coastal plain wetland basins and drainage depressions creating highly productive fishery nurseries (especially barramundi), waterbird and waterfowl feeding and breeding and moulting habitats and migratory shore bird feeding habitats.
- Tidal flow connectivity and (especially high spring tide) in-flows and inundation responsible for maintenance of range of salinity regimes (brackish – hyper saline), resetting of habitat conditions, associated high productivity of wetland plant and animal communities and recruitment and movement of biota.
- Estuary sediment exports responsible for maintenance of coastal landforms and geomorphological processes

3.3 Flow Related Threats

After reaching group consensus that potentially threatened aquatic ‘assets’ includes both location-based spatial units (such as high priority wetlands) and critical ecological processes (shown in Section 3.2), a workshop session was completed to identify flow-related threats to site specific assets and potential data gaps. The group divided into three by target catchment – Gilbert River, Norman River and Flinders River – and considered threats by location in the catchment: upper catchment, middle catchment and lower catchment. A large list of potential threats were identified, most of which were further identified as being understood far too poorly to allow assessment of ecological thresholds at this stage.

Ecological thresholds, and therefore potential water resource management options, were not an outcome of the workshop for the ‘assets’ identified because the flow-related threat issues might still be considered data deficient and require further fine-scale investigation.

By target northern Queensland catchment, the following were the flow-related threats outcome for the workshop. The threats and comments summarised below are presented separately for each of the three catchments; however, they may be considered to be generally consistent across the study area in most cases.

TABLE 3.1 FLINDERS RIVER CATCHMENT

LOCATION	THREAT	COMMENTS
Upper and Middle	Levee Development	• Would fragment connectivity between channel and floodplain = Threat to interchange of materials (C, nutrients) and biota system productivity and life history/reproduction of biota.
	Flood harvesting – in dry years	• Allocations > total flow volume. Taking in these years could lower extent and duration of floodplain inundation = same threats as above.
	Flood harvesting – First wet season event	• Triggers reproductive responses, pulse of nutrients and trigger primary production and therefore secondary production. • Specific threats: i. Removing reproductive cues ii. Reducing productivity of system iii. Contamination from mines and their dams
	Pumping from no-flow water holes	• Reduces resistance of waterholes during no-flow spells • Increase risk of serious pig/cattle damage when shallow • Decreases availability/quality of refuges – risk of populations
	Groundwater Extraction (Cloncurry River)	• Removal from shallow alluvial ground water • Could decrease dry season waterhole persistence via increasing seepage – same threats as #4. • This is a large data gap.
Lower	Flood harvesting – wet season total flow	• Discharge of fisheries production so decrease = decrease in fishing = decrease in money (tourism). Threat to fisheries. Threat + migratory birds.
	Barriers to movement of biota and decreased connectivity	• Many species move extensively from upper catchment to sea and on to the floodplain. • Reduced volume and duration of wet season connectivity from flood harvesting • Extend no-flow periods = decreased connectivity • Effect population viability of migrating species

TABLE 3.2 GILBERT RIVER CATCHMENT

LOCATION	THREAT	COMMENTS
Upper	Grazing	• Groundwater processes important and potentially affected by this threat
	Over extraction in the dry season – stock water	• Groundwater processes important and potentially affected by this threat
	Open cut mining	• Groundwater processes important and potentially affected by this threat
	Dam and weir construction and operation	• Over-bank processes important and potentially affected by this threat

LOCATION	THREAT	COMMENTS
	Increased water extraction – development driven	• Over-bank and within-bank processes important and potentially affected by this threat
	Barriers to aquatic fauna passage/movement	• Over-bank and within-bank processes important and potentially affected by this threat
	Habitat modification – wetlands and streams	
	Changed water quality	• Mining related water quality impacts primarily
	Soil erosion and sediment control	• Over-bank and within-bank processes important and potentially affected by this threat
Middle	Dam and weir construction and operation	• Over-bank processes important and potentially affected by this threat
	Increased water extraction – development driven	• Over-bank and within-bank processes important and potentially affected by this threat
	Barriers to aquatic fauna passage/movement	• Over-bank and within-bank processes important and potentially affected by this threat
	Over extraction in the dry season – stock water	• Groundwater processes important and potentially affected by this threat
Lower	Grazing	• Groundwater processes important and potentially affected by this threat
	Over extraction in the dry season – stock water	• Groundwater processes important and potentially affected by this threat
	Open cut mining	• Groundwater processes important and potentially affected by this threat
	Dam and weir construction and operation	• Over-bank processes important and potentially affected by this threat
	Increased water extraction – development driven	• Over-bank and within-bank processes important and potentially affected by this threat
	Barriers to aquatic fauna passage/movement	• Over-bank and within-bank processes important and potentially affected by this threat
	Habitat modification – wetlands and streams	
	Soil erosion and sediment control	• Over-bank and within-bank processes important and potentially affected by this threat
	Changed end-of system flows due to dam and weir operation	• Coastal processes important and potentially affected by this threat
	Changed water quality	• Mining related water quality impacts primarily

TABLE 3.3 NORMAN RIVER CATCHMENT

LOCATION	THREAT	COMMENTS
Upper	Threat to groundwater processes in this groundwater dependent zone	• Within bank processes most important • Perennial flows supplied by groundwater • Groundwater extraction potential issue but no identified threat

LOCATION	THREAT	COMMENTS
	Local stock + domestic (not licensed) having local groundwater drawdown impacts	
	Maintenance of local base-flow conditions to support locally dependant systems	
Middle	Drawdown of hyporheic zone reducing waterhole persistence during no/low flow periods	• Overbank processes important
	Climate change	• Data poor issue
	Acid sulphate soils	• Data poor issue
	Levee banks	• Overbank processes important
	Flood harvesting	• Overbank processes important
	Maintenance of flows during no/low flow periods	
	Sleeper licenses	• Data poor issue
	Future infrastructure development and impacts	• Data poor issue
Mid-Lower	Salinic-basalt groundwater harvesting	• Around Croyden and Normanton
Lower	Integrity of coastal wetland aggregations	
	Threats to lateral connectivity with adjacent catchments through harvesting interdependence of systems to support waterbirds	
	Maintenance of networks of waterholes to support diverse communities	• Mosaic of waterholes across broad spatial coverage
	Changed nutrient export regarding the Gulf prawn fishery	• Discharge versus fishery productivity/recruitment

4.0 Outcomes and Recommendations

Aquatic ecological assets (both locations and critical processes) were agreed by consensus, and flow-related threats to these assets were been identified. This outcome is a useful contribution to the next stages of EAP and NAWFA.

It was clear that the greatest impediment to quantifying ecological thresholds is an immature technical understanding of most of the assets, and of the mechanisms and consequences of the flow-related threats. Future effort should be focussed on filling these data gaps with fine-scale assessment and investigation for this geographic area; however, the distillation of assets and threats at the catchment scale through this workshop has provided a way forward for the EAP.

The main outcomes of the workshop are summarised in the following statements or recommendations.

1) ‘Assets’ in this context include high priority location-based spatial units as well as critical ecological processes
.
2) Do not singularly rely upon HCVAE or ACA output to drive ecological threshold debate. High value spatial units are important but an equal/balanced focus on ecological processes and connectivity is important.
3) In the same way that aquatic ecological function and landscape connectivity may be mistakenly ignored where debate focuses only on high value spatial units, significant ecosystems and discrete high value parts of the landscape may be mistakenly ignored where debate focuses only on aquatic ecological process. Both types of aquatic ecology asset need consideration.
4) In fragmented or more developed catchments/landscapes, emphasis on high value spatial units is likely to be more appropriate. However, in ‘intact’ or less developed catchments/landscapes, such as those in northern Australia, emphasis on critical ecological process and function may provide greater opportunity to ensure sustainable outcomes. A shift in emphasis may be important, depending on ecosystem context, when investigating ecological thresholds and water resource management but it is certain that a holistic multi-scale approach is necessary.
5) For the Gilbert River, Norman River and Flinders River, critical ecological processes are satisfactorily captured as a result of work in the WRP process.
6) Flow-related threats to aquatic assets are understood in both a generic sense and, in a small number of cases, a detailed technical sense.
7) Data and technical understanding are insufficient to develop current notions of asset and threat into ecological threshold and planning outcome. More work is required but this workshop outcome provides a way forward.
8) Do not assume that the importance of balancing consideration of critical ecological processes and high priority spatial units means that mapping of high priority spatial units is less important in its own right. While scientists generally look at process and connectivity, mapping of high priority assets is important to planners (in particular) and provides frameworks for action where knowledge gaps prevent timely understanding of process.
9) There are many data gaps and deficiencies in our technical understanding if the objective is to quantify ecological thresholds in these northern Australian ecosystems. For a small number of flow-related threats identified in this workshop, however, further steps may be possible where interpretation and assessment relies on data we do have such as gauged hydrological data, flood modelling data, or

4.1.1 Where can we go further with respect to thresholds?

As indicated in the last statement above, there are some flow-related threats and potential water resource management options that are supported by a relatively greater amount of data and a relatively better technical understanding of process. The workshop reached consensus that, although the majority of threats require much further work, a small number may better placed for progression toward quantification of ecological thresholds as a subsequent stage of the EAP and NAWFA.

The following flow-related threats were considered in this category:

- Threats associated with tailings dam and dam management in relation to flood events.
- Threats that can be linked to rules already established in the WRP and ROP for the region and that can be modelled relative to existing model nodes.
- There are lessons to be learned from work across the Gulf region. For example, threats that can be interpreted and extrapolated by detailed analysis of IQQM modelling and pre and post development data (e.g. fisheries data is available for the Leichardt River, which is the adjoining catchment to the west of the Flinders, prior to dams being constructed which could be used to interpret and extend understanding by comparison post-construction of dams).
- Threats that relate to bulk flow characteristics and water harvesting.

5.0 References

DEWR 2007. National Framework and Guidance for Describing the Ecological Character of Australia's Ramsar Wetlands: Module 2 of the National Guidelines for Ramsar Wetlands – Implementing the Ramsar Convention in Australia. Department of Environment and Water Resources, Canberra.

Hydrobiology Ptd Ltd (February 2005) Ecological and Geomorphological Assessment for Gulf and Mitchell Water Resources Plan, Final Report. Prepared for the Department of Natural Resources and Mines.

Phillips, B. 2006. Critique of the Framework for describing the ecological character of Ramsar Wetlands (Department of Sustainability and Environment, Victoria, 2005) based on its application at three Ramsar sites: Ashmore Reed National Nature Reserve, the Coral Sea Reserves(Coringa-Herald and Lihou Reeds and Cays), and Elizabeth and Middleton Reeds Marine National Nature Reserve. Mainstream Environmental.

Rollason, S.N. and Howell, S. (2010). Report: Aquatic Conservation Assessments (ACA), using AquaBAMM, for the non-riverine, riverine and estuarine wetlands of the Southern Gulf of Carpentaria (version 1.1 draft). Published by the Department of Environment and Resource Management, Brisbane

APPENDIX A RAW WORKSHOP NOTES

Arthur Knight (AK);
Bruce Wannan (BW);
Cameron Colebatch (CC);
Geoff Kavanagh (GK);
Glenn McGregor (GM);
Greg Hausler (GH);
Jennifer Martin (JE);
John Bennett (JB);
Jon Marshall (JM);
Lorinda Talbot (LT);
Matthew Knott (MK);
Mike Ronan (MR);
Niall Connolly (NC);
Olwyn Crimp (OC);
Paul Clayton (PC);
Peter Bayliss (PB);
Peter MacDonald (PM);
Richard Hunt (RH);
Ross Smith (RS);
Satish Choy (SC);
Selena Rollason (SR);
Tim Jardine (TJ)

Presentations

Introduction to the HCVAE agenda and the NAWFA projects
(Cameron Colebatch)

QUESTIONS/COMMENTS	PRESENTER RESPONSE
Who did the literature review? OC	Was done in house
What are social cultural values? JM	Stories, money value to communities, non resident values (barra fishing), intrinsic value (warm fuzzy feeling)
PM • Qld has methodology to ID assets in AquaBAMM, ACA report, Water Resource planning – methodologies for assessing environmental watering • Wetland mapping – ID assets. Methodology to address environmental watering • "C" part of ACA is debated – conservation planning – fraternity ID'd, aquatic systems poorly represented • Use of work wetlands/aquatic systems has many different meanings • The work Mike Ronan has done has identified and delineated of assets • In intact ecosystem = asset ID • Still has thinking of how to draw a line – individual, aggregation, sub catchment scale • Not picking small spots • Broader thinking around intact ecosystems • Systems are geomorphic focused • Also consider biological component – hydrobiology in aquatic ecosystems Expectation today to see - Threats and thresholds to broad region	

QUESTIONS/COMMENTS	PRESENTER RESPONSE
JE • Across all northern Australia • Broken into planning units • Species against planning units • North Australia data is poor • Data limitations big issue up north	NT workshop results and feedback • No fine scale assessment (AQUABAMM) • Can ID values to protect in asset • Data constraints • Broad threated and thresholds. Not exact figures • Don't be ambiguous Next project – surface and groundwater regimes and ecological processes for assets - Climate change, land use change
JM • What aspects of system are valued? • What emotion value? • What aspects can be managed? • What values can be managed – now and in the future? • Think of scale – scale of processes that are protecting the values that are being threatened. • Look at extremes of scale to deal with natural elements (eg climate change) • Biological connection – TRACK – population genetics component. Identification of where major biogeographic divide is for populations of fish and aquatic invertebrates • There is a need to consider this info in this task • This data expands across Qld, NT, Cape york and Kimberley • Contact Ben Cook – Griffith Uni	
MR • Challenge in how to deal with highly intact systems • Making sure we don't lose integrity of system you are looking at.	
SR • Expert panels identified such high level connectivity between catchments (through mapping) – this is a strong point to get across	
SC • Connectivity in terms of hydrology plus interdependencies. These interdependencies can be within continent and also within internationally.	
NC • Small scale catchments can connect	
OC • Think of taking water out • Floods = extra water, what is this doing? Cutting fauna off for 2yrs? • What does that do to the system?	
PC • Identification of low and high flow threats? • At a fine scale –there can be other values g. riffle zones	Values may be temporal – refugia – broad not specific

Aquatic Conservation Assessment results for the Southern Gulf of Carpentaria

(Selena Rollason)

QUESTIONS/COMMENTS	PRESENTER RESPONSE
How do you handle absence of records/data versus true absence? (JM)	• Don't punish wetland for lack of data. If species definitely isn't there = score of 0. • If experience says species is there – consider it as is. • Dependability scores identify if a species isn't there or if no one has looked
PM • HCVAE – AQUABAMM criteria appears consistent • Concerned about weighting to a score • Can you really sum to a final score? • Terms Aquatic ecosystems and wetlands are the same thing in Qld.	• Measures weighted and indicators ranked by expert panel. Averages determine weighting • Habitat mapping absent for marine areas • Wetland definition applied for AquaBAMM has been taken from wetlands program definition. This is utilised by the Qld Wetland Program and consistent with the 1999 Qld Wetland Strategy
Why no riverine in criteria 8? (JM)	• No riverine typology
MR • AQUABAMM Limitation is that groundwater is not on wetland mapping	
Is there an option to include evolutionary significant units? (GM)	• Not in current process • Could incorporate new measures in expert panel • Have incorporated climate change as new measure for example
BW • Data currency not an issue, data accuracy is the issue	• Removed records with an accuracy of >2km • TRaCK did species modelling presented to expert panel but reservation on models as GIS didn't support it. Possible inaccuracies, doesn't line up. • 1950+ flora, 1975+ fauna
PC • Don't use AQUABAMM as a development assessment, use as a decision support tool only • Scale – uses wetlands mapping - based on RE mapping • Sampling – data follows main roads as a result of accessibility	

TRaCK Tropical Rivers and Coastal Knowledge

Defining assets and values: the differences across projects and purpose

(Jon Marshall)

QUESTIONS/COMMENTS	PRESENTER RESPONSE
	Asset = • Different to HCVAE • Chosen because dependant upon flow regime long term • Sensitive to management types • Link to ecological values Ecological value = Aspects of aquatic ecosystem when society has an emotional investment, can be positive or negative. Assets are indicators of values • Risk to asset is risk to associated values • Values = protect, influenced by flow, water resource plans only identify treats to related to water management.
BW • Mapping isn't an issue. It's the areas around them that aren't maintained to support them. The ecological asset in a spatial context is lost	
JE • Will development of HCAVE framework impact on NWI commitment? • AETG put together questions to ask against criteria • Clause 25X – jurisdictions shall identify areas of HCV in water sharing plans and identify ways to protect functional systems to maintain those values • Groundwater dependant ecosystems can be in HCVAE	
MR • HCVAE looking at discreet areas not processes. Have a look at the process of a species related aspect. Consider areas and processes, not just areas. • Process is different to NWI/HCVAE- it is not only areas that are delineated, can be process in river system, cant delineate this in AquaBAMM	
PM • NWI said states should identify high conservation values, provide for environmental watering	

Flow regime and rainfall variability by long-term non-parametric analysis of gauge data for northern Queensland catchments

(Arthur Knight)

QUESTIONS/COMMENTS	PRESENTER RESPONSE
	• Characterising variability of flow regimes and rainfall • Holistic to understand hydro-aquatic values and systems • Empirical approach • Non parametric • Output is accurate to ecological regions, zonal statistic approach • Gauge stations normalised to long term means • No answer how to assess character. In gulf: • Reviewed data - issues with dates and quantities in gauge stations • Variability in confidence • Gilbert river lower flow but more persistent • Low flow durations increase over period • Matches with flow regime • Middle conditions • Reliability of rain fall
BW • Lots of Sands in Gilbert, not others • Flinders – medium and mean flow difference is factor of 3. Mean flow once every 3 yrs. Normal smaller, large catchment, more predictable than smaller • Can we ID overbank event? Norman example • Drying regime important to ecological processes • 8mth long drought Flinders example • Wetter than Norman • Biggest for floods in comparison • 1:5 – 1:6 year flood • 8mth long drought • Variability issues – not as bad as normal	• When flow happens how much is important • Number if flow pulse support different aquatic species Re: ID of overbank event • We use cross sectional data and rating curve. Can do for gauging station • Issues in Gilbert with sand movement over years
RH • Dry headwaters in Mitchell River • Sandy catchment • Sand provides more flow • Norman and flinders stopped flowing by April – may. After big flood event, flow stops quicker, water contracts into water holes	

QUESTIONS/COMMENTS	PRESENTER RESPONSE
RS • Difference in frequency breaks in low flow along Flinders. Gilbert extract water from sand, Flinders extract water from surface flows • Catchment run off is sheet not watercourse flow. Need to consider outside channel and bank	
SC • Scale without looking at is important • Hydrology operates at smaller scale • Water resource plan done and broad scale but need predictions at small scale.	

Hydrology in the Gulf

(Greg Hausler)

QUESTIONS/COMMENTS	PRESENTER RESPONSE
	• 200 000km2 area across Flinders, Gilbert and Norman. Flinders Basin • Rainfall 400mm/yr in west. Increases across N&E to 750mm/yr. • Evaporation: annual mean 3000mm. Not as variable. • Evaporation significantly greater than rainfall for the whole year • Once 24 gauging stations, now 10 • Extreme annual variation in rainfall. Over 1890 – 2006 in Flinders River at Walkers Bend. • Walkers bend summary (refer slide) • Chinaman creek off stream water storage for Cloncurry township reasonable supply from bed streams. Norman • Stream flows – recorded to Glenore Weir. Only one station above headwater of weir. Gilbert • Basin boundary on flat area • 30 stream flow recorders • Most down stream • Miranda downs example used • Synthetic and recorded flows at Miranda downs
JM • What is the average no flow spell dry season?	• 3+ months • Almost next to no low flow. 6-9mths no flow at walkers bend
NC • What areas are vulnerable and hydrologically sensitive? • Are streams recharged by ground or surface water?	• Water extraction in sand beds • Drawn down waterhole • Longer for flows to get through system • rainfall recharge
PC • What's the feel at full development, impacts?	• Less periods of flow. Impact negligible at high flow. • Some reduction in periods of low flow if more water extracted would be diversion of high flows.

Group Session 1

What is an example of an asset and value?

PARTICIPANT	COMMENT/NOTES
not assigned	• Subject of ecosystem services that come out of an asset. Extra analysis to identify ecosystem services. Look at process or area to identify threats. Values = loose if you lose asset. Often focused on biodiversity, this approach offers more. • Limitations – without finer end point – ID overbank flow and connects to wetland. Never ID how does it change character of area, Do we take the next step to make decisions • Rivers aren't pristine in area of concern. Point source pollutions, water extracted. Have ongoing 'insults' in catchment eg. Leichardt River Mining dams and impoundments impact on downstream prawn and fish. Impacted terrestrial along and aquatic in gulf • Grazing land 'D' condition. Soil transport high, Consider condition and impacts by grazing • Need better view of flow paths in system
BW	• A resource is has both conservation and economic value • TAP report ID hydro processes was out of context
SC	• There are other assets – Rare and Endangered Species, focus on HCVAE, some elements have r/E within that's why they are high values. • Assets can be a process or a place. Process assets are dependent on flow and management.
JM	• Identified values people had for fish in system • Values were – sustainable and diverse, low exotic impact, opportunity for recreational fishing, opportunity for indigenous fishing • What aspects does society care about in a system? • Modelling ecological components if what people care only not economic, not modelling $ return
JB	• Asset = Ecological, economic and social value
NC	• Murray Darling example – vale fish but don't want to lose water for cropping more

RS	• High value for "other reasons" a concern. Result =
	  • Data doesn't work at place level
	  • Highly variable systems
	  • Classification struggles with variability
	  • Place – concerned
	  • Process
	  • Connectivity is key driver.

SR	• ACA results – ability to drill down into layered information process
PC	• process and connectivity = relates to flow

Group Session 2

What are the critical processes?

Notes are presented by participant rather than as they occurred chronologically.

PARTICIPANT	COMMENT/NOTES
not assigned	• There is unknown unallocated water in plan? Possibly auctioning
BW	• Critical processes affected by flows have been identified in from hydrobiology report **(Page 108)** • What was WRP response? • Early season wets ground, high overflows. Need low to ensure high flow can overflow
GM	• WRP – requirement to establish limits through ROC. Should have been addressed (EFOs in WRP)
JM	• How do you ID thresholds? • Perennial systems and refugia protection needed
MK	• Threats – ID existing developments and proposed and determine the process in each one. Eg. Different mines impact different processes. Eg. Baseline (like ANSECC) guidelines to protect
MR	• Processes apply site scale, others are bigger, intercept processes with sites identified. • What ones are applicable at site scale, what ones are applicable at refugia scale • Extraction at high flows generally not an issue • Smaller flows more of a concern; evaporation an issue • ROC specifies allocated amounts for extraction. IDs amount assets need to ID what can be allocated. • This is important, where are HCVAES in relation to this unknown allocated water?
PM	• Are there sleeper licences not yet being extracted but approved? Greg Hausler – not many, modelling assumes full entitlement is used.
RH	• Assumptions about high flow on duration curve are incorrect. Mean values are assumed. • Allocations event not volumetric • Can't promise water based on highly variable mean flows • Offshore dependency isn't reviewed eg. Gulf fishing
SC	• Quantifying limits a challenge • Look at HCVAE structural and functional then ID critical processes and threats • Depends on node location

Group Session 3

What are the threats?

Notes are presented by participant rather than as they occurred chronologically.

PARTICIPANT	COMMENT/NOTES

not assigned	• Threats in area:
	  • Extraction of flow
	  • Regulation eg. Dam
	• Can we ID what values we don't want to lose? Eg. No dry season extraction or supplementation?

BW	• What is unacceptable threshold? • Issue is seasonal variability of flow magnitude. Build thresholds around periods of low flow. Top Gilbert – spring fed base flow further down – decreased hyperheic flows; further down decrease large in and out of stream flows • Need to know extent and frequency of overflow events
OC	• Need to talk to landowners to ID processes that are important. Sceptical about work done in Brisbane/outside the catchment
SC	• Need hydrology and HCVAEs for next phase

APPENDIX 8.6.

CLOSE, P., COSSART, R., PETIT, N. & KENNARD, M. (2010). FINE SCALE ASSESSMENT OF HIGH CONSERVATION VALUE AQUATIC ECOSYSTEMS IN THE UPPER FITZROY AND MITCHELL RIVER CATCHMENTS OF THE KIMBERLEY REGION OF WESTERN AUSTRALIA. SUMMARY OF THE WORKSHOP, HELD IN KUNUNURRA, 11 – 12 NOVEMBER 2010.

Fine Scale Assessment of High Conservation Value Aquatic Ecosystems in the Upper Fitzroy and Mitchell River Catchments of the Kimberley Region of Western Australia.

Summary of the workshop, held in Kununurra, 11 – 12 November 2010

TRaCK Tropical Rivers and Coastal Knowledge

Paul Close[1], Robert Cossart[2], Neil Pettit[1] and Mark Kennard[3]

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Australian Government
Department of the Environment, Water, Heritage and the Arts
National Water Commission

Government of Western Australia
Department of Water

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Summary

A one and a half day workshop was held at the Frank Wise Research Institute (Department of Agriculture and Food, WA) on the 11h and 12th November 2010 to complement the broad-scale assessment of high conservation value aquatic ecosystems under the Northern Australia Aquatic Ecological Assets project. This workshop undertook a fine scale assessment of High Conservation Value Aquatic ecosystems (HCVAE) for two focal catchments: the upper Fitzroy and Mitchell rivers. The aim of this workshop was to identify specific ecological assets and associated threats and knowledge gaps. The structure of the workshop included a number of presentations in the morning session that provided background information on the HCVAE project, and Kimberley values and threatening processes to set the scene for group discussions in the afternoon session. The principal aims of the group discussion session in the afternoon was to identify local scale assets that occur within the focal catchments (e.g. lower floodplain, middle and upper reaches) that were identified as HCVAEs through the broad-scale assessment and other assessments. Six high conservation assets were identified in the Mitchel River catchment, including lagoonal habitats, permanent dry seasonal refugia, seepages and springs and perched, groundwater-dependent wetlands. A variety of threats identified included managed stock, fire and sedimentation. In the Fitzroy catchment, sixteen high conservation assets were identified, including a variety of mid and upper catchment spring fed tributaries and wetlands, large permanent dry season refugia on the Fitzroy main channel and floodplain water holes and swamps. A variety of threats were identified for each asset including managed and unmanaged stock, feral animals, weeds, sedimentation, recreational fishing and tourism. There was a general consensus that the broad-scale of the assessment of high conservation value aquatic ecosystems is too broad and provides limited benefit to management and monitoring undertaken by the variety of organizations represented at the workshop (jurisdictions, ranger groups and researchers). Rangers highlighted their interest in applying the data gathered at the workshop into annual work plans, identification of priority areas for weed, feral and fire control and directing future on-ground investment. The rangers also called for the incorporation of indigenous ecological knowledge as an important part of the identification of and sustainable management of aquatic ecosystems across the Kimberley. There was acknowledgement of the consideration of HCVAE's in water allocation planning and determining ecological water requirements. There is also a general need for improved knowledge and mapping of species endemism of aquatic ecosystems across the Kimberley region.

Acknowledgements

- Frank Wise Institute, Department of Agriculture and Food Western Australia for workshop venue
- All workshop attendees and presenters
- DEWHA and the NWC for funding the workshop
- Michael Douglas (TRaCK), Rebecca Dobbs (CENRM-UWA) and Troy Sinclair (DEC) for assistance in workshop preparation and facilitation
- Alan Byrnes (Department of Water) for arranging the venue and catering

TRaCK Tropical Rivers and Coastal Knowledge

Background

The broad-scale assessment under the Northern Australia Aquatic Ecological Assets project has highlighted the high conservation values present in many areas of northern Australia (Kennard et al. 2010). To complement this work, fine-scale assessments are being undertaken for key focal regions with the aim of identifying specific ecological assets and understanding their ecological thresholds in relation to flow regimes and the maintenance of aquatic ecosystem assests.

The Western Australian Departments of Water (DoW) and Environment and Conservation (DEC) identified the north Kimberley as a critically important area in which to undertake these assessments. The Mitchell and upper reaches of the Fitzroy rivers were selected as focal catchments. These two catchments align with the DEC Kimberley Science and Conservation Strategy, the DoW's State Waterways Initiatives and the yet to be released Kimberley Regional Water Plan and the Australia Heritage Council's National Heritage Listing Assessment of the north and west Kimberley.

In identifying focal catchments for the fine scale assessment, the DoW and DEC considered the following criteria:

- Current and future planning needs for the area e.g. opportunity to contribute to existing or proposed planning processes and conservation actions
- Availability of suitable data
- Condition of the landscape, e.g. undeveloped versus developed
- High priority conservation areas and areas of potential national significance
- The presence of a broad cross-section of HCVAE classification types, e.g. estuarine, riverine, etc.
- Regionally representative

The area referred to as the North Kimberley is situated between Derby and Wyndham along the Gibb River Road and extending north to the coast. The North Kimberley sub-region covers roughly 17,185 km^2 within the Timor Sea Drainage division.

The North Kimberley is recognized for significant cultural and ecological values. And the Commonwealth Government has identified the North Kimberley as one of 15 National Biodiversity Hotspots. The area is rich in biodiversity and is the only area of mainland Australia that still supports an intact suite of mammalian fauna. The waterways and their catchments remain generally undisturbed due to their isolation, rugged topography and/or land tenure (**Figure 1**).

The North Kimberley has twenty-two of Western Australia's 49 Wild Rivers. Wild Rivers are defined as *"those rivers which are undisturbed by the impacts of modern technological society. They remain undammed, and exist in catchments where biological and hydrological processes continue without significant disturbance. They occur in a variety of landscapes, and may be permanent, seasonal or dry watercourses that flow or only flow occasionally"* (Williams *et al*, 1996).

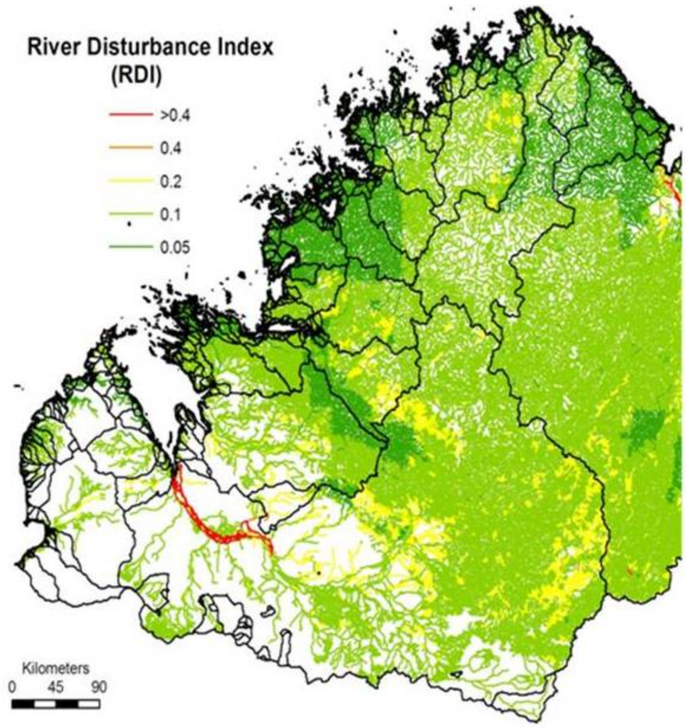


Figure 1. Levels of disturbance (River Disturbance Index) for waterways in Northern Western Australia

Permanent river pools are considered to be an ecologically important feature of most waterways within this savanna region. They act as refugia for aquatic biota during seasonal dry periods which then re-colonize other aquatic habitats that become available during the “wet” season. During the Dry season, when biota are restricted to discontinous pools, they are vulnerable to impacts from a range of threats including water quality degradation (due to livestock, water abstraction and fire). However, there are limited and in some cases no data about the spatial distribution and condition of these high conservation value reaches.

Kimberley Rivers support a diverse and unique array of aquatic species. The region has the most diverse fish population in Western Australia, with over 50 recorded species of which approximately 16 species are endemic (Allen *et al*. 2002). At present, the Kimberley has no introduced fish species in any of the major catchments. The region also supports important populations of turtles and migratory water birds (

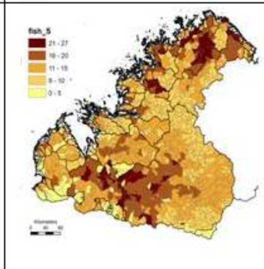
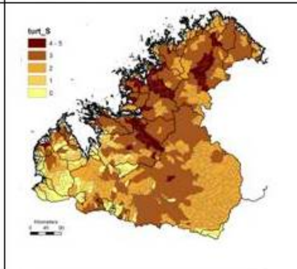
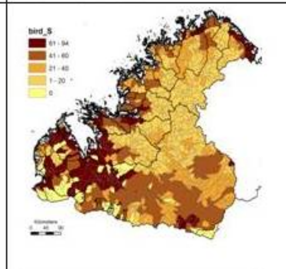
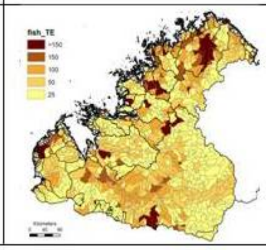
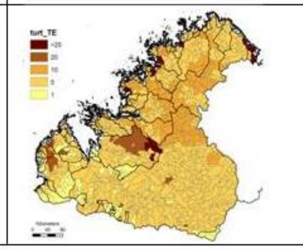
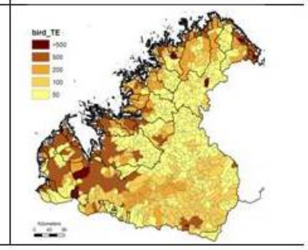
	Fish	Turtles	Waterbirds
Species richness			
Endemism			

Figure 2).

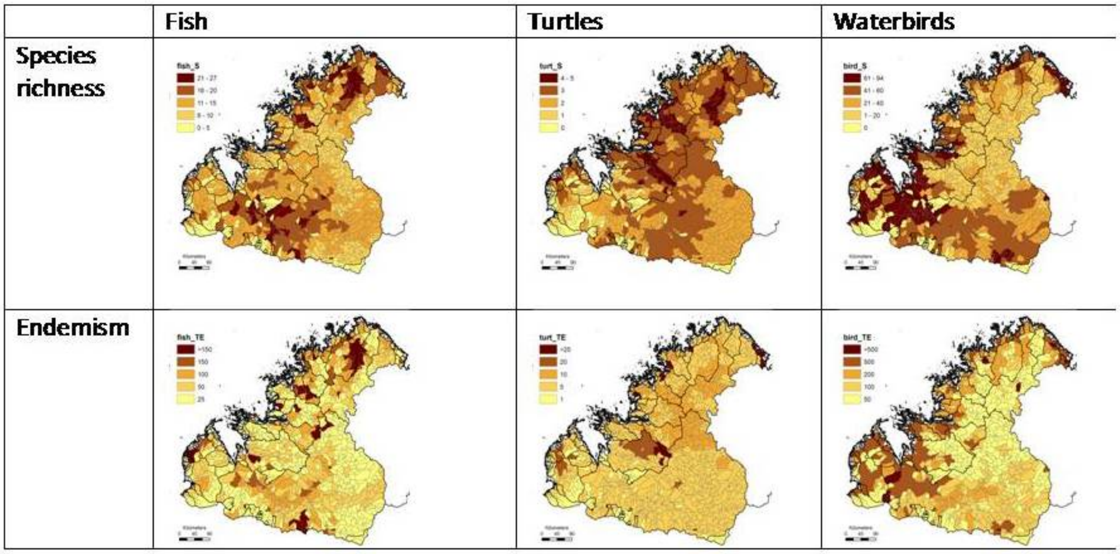


Figure 2. Species richness and endemism for fish, turtles and waterbirds in North Western Australia, identified from the broad scale assessment of High Conservation Value Assets (Kennard et al. 2010)

The region maintains stable populations of several threatened freshwater fish species listed in either the International Union for the Conservation of Nature (IUCN), the Australian Federal Government (EPBC Act) and/or under Western Australian State Legislation (*Fish Resources Management Act 1994*). These include the Freshwater Sawfish (*Pristis microdon*), Dwarf Sawfish (*Pristis clavata*), Northern River Shark (*Glyphis sp. C*), Freshwater Whipray (*Himantura chaophraya*), Barnett River Gudgeon (*Hypseleotris kimberleyensis*), Greenway's Grunter (*Hannia greenwayi*) and Prince Regent Hardyhead (*Craterocephalus lentiginosus*) (Morgan et al., 2004).

Many freshwater species in the north Kimberley have highly restricted geographic distributions (Morgan 2004). Recent studies have demonstrated that several freshwater species (both fish and turtles) are genetically diverse from other populations at the regional and national scale (FitzSimmons *et al.,* 2004, 2009; Tucker & FitzSimmons, 2006). The genetic diversity of these species and their geographic isolations is significant in terms of conservation management.

The North Kimberley and associated biological communities have been described as being under immediate threat (Australian Hertitage Database, 2008) from a variety of pressures such as feral animals, fire, weeds and broad scale developments that are currently impacting on, or are expected to impact on important biological resources as well as water quality and quantity. Additional pressures on the regions high conservation value aquatic ecosystems include recreation and tourism (e.g. eco-tourism enterprises), stock grazing, pastoral diversification and associated land clearing, mining, off shore developments, recreational fishing and aquaculture projects.

This area has seen substantial change in land management practices over the last 10 years, with the growth of tourism ventures, expansion of environmental and cultural conservation areas and proposed initiation of mineral resource development. The area has significant known mineral deposits, such as diamonds, iron ore, bauxite and uranium. Limited exploration data exists as rugged topography and poor infrastructure makes the region isolated and the deposits difficult to access. High exploration costs are major constraints for development of mineral deposits (Kimberley Development Commission, 2001).

Increases in tourism as well as the spread of weeds and feral animals and changed fire regimes, have resulted in increased pressure being placed upon the region's waterways, many of which have high conservation values.

While historic pastoral activity in much of the region has degraded some of the riverine habitats through weed invasion, feral animal damage and livestock access, the waterways across the North Kimberley are generally considered to be in good condition, especially those located in more inaccessible areas.

The DEC manages the Prince Regent Nature Reserve; Mitchell River and Drysdale River National Parks; Lawley River, Laterite and King Leopold Ranges Conservation Parks (Figure 2). An additional nine sites have also been proposed for the 'Conservation of Flora and Fauna' as part of the 2015 lease excision. These areas are currently included in pastoral leases associated with: Beverley Springs, Drysdale River, El Questro, Gibb River, Mt Elizabeth and Theda Stations. The Kimberley Land Council (KLC) is discussing the establishment of Indigenous Protected Areas (IPA) within the North Kimberley. There are also a number of Aboriginal reserves and private conservation estates located in the area. Although some representative examples of HCVAE are contained within the conservation estate, a lack of data of the ecological values of rivers has made it difficult to identify high conservation value aquatic ecosystems and hence management.

The Mitchell and upper reaches of the Fitzroy rivers have been identified as representative examples of northern Kimberley rivers containing a diverse array of high conservation value aquatic ecosystems. They were also chosen for their iconic status, having some level of access and infrastructure and active land management activities.

Despite significant research investment to understand ecosystem processes and management in the North Kimberley, understanding of the spatial distribution and connectivity between HCVAE's in the upper reaches of the Fitzroy and Mitchell rivers remains limited. Both catchments are experiencing landscape-scale impacts such as grazing and fire, as well as more focused tourism pressures in accessible locations. Whilst these pressures and landscape-scale impacts are common across the Kimberley, they remain poorly understood. They are a more prominent issue for land and water management in the north Kimberley than very high impact new projects such as mines and new irrigation precincts (which face other economic constraints).

Fitzroy River

The Fitzroy River is one of Australia's largest unregulated rivers with the catchment spanning the Kimberley from east to west and traversing a variety of geological and climatic gradients. The headwaters of the Fitzroy River, in the north and east of the catchment, receive flow from the Hann, Adcock, Manning and Little Fitzroy Rivers. These tributaries drain primarily rocky, bedrock country. The Margaret River drains the upper south-east catchment, and receives water from the Mary, Glidden, O'Donnell and Leopold rivers. This drier and low gradient country is characterised by wide channels of permeable sands, occasionally constricted by gorges (i.e. Dimond and Margaret River Gorges) with the Margaret River joining the Fitzroy River downstream from Gieke Gorge (Lindsay and Commander 2005). Downstream of this confluence, the remaining 300 km of river is characterised by a shifting, sandy riverbed with substantial anabranching and wide clay/loam floodplain (Storey *et al*, 2001). There are few major lower catchment tributaries (downstream of the Margret River confluence) and include the Christmas and Geegully creeks, which flow into the Fitzroy before it discharges into King George Sound.

In addition to variations in geology, there is also a strong north–south rainfall gradient. Mean annual rainfall increases from 464.5 mm/yr (Halls Creek Station) in the south-eastern Christmas Creek catchment, to a mean annual rainfall of 888 mm/yr (Mt Barnett Station) in the northerly Hann River catchment. This coincides with a runoff coefficient increasing from 3 to 25 percent of rainfall in the same direction.

River valleys are frequently flooded during the wet season and the region is groundwater-dependent in the dry. Pools are maintained into the dry season via shallow sub-surface flow, with sand bars partitioning the rivers in the region.

Mitchell River

The Mitchell River is located within the Mitchell subregion (NK1) of the North Kimberley Interim Biogeographic Regionalisation of Australia (IBRA) region. The Mitchell subregion is a dissected plateau featuring a combination of basalt, laterite and sandstone substrates. It receives the highest rainfall in north-western Australia and is the only locality in the Kimberley where a lateritic landscape receives high rainfall. These unique characteristics give rise to very diverse suites of fauna and flora. The Mitchell river area contains flora characteristic of both Gondwanan and Australasian origin (Handley 1996).

The Mitchell River area also has a very diverse avifauna with a total of 219 bird species recorded, including twenty-seven species of birds listed in the 1992 schedule 5 to the Japan Australia Migratory Birds Agreement (JAMBA), eleven of which are also listed in the schedule to the China Australia Migratory Birds Agreement (CAMBA). Six bird species are considered threatened or near threatened (Handley 1996). The Mitchell River system is listed as a wetland of national significance (DIWA listing) with a number of subregional wetlands of significance such as Airfield swap and Glauerts lagoon (Graham & McKenzie 2003). Whilst it has been reported that the Mitchell River contains a number of HCVAE's, the understanding of the spatial distribution of these systems is, in some cases, impeding the development and implementation of on-ground management actions.

In addition to the natural features of both these river systems, the North Kimberley has a range of archaeological sites, including middens, artefact scatters, grinding grooves, modified trees, quarries, paintings and burial sites. It is also a popular tourist destination with sites of particular aesthetic interest.

In regard to ecological thresholds for high conservation value aquatic ecosystems in the north Kimberley, it is yet to be established whether environmental, conservation values in the catchment respond in a linear way with changes likely to occur in response to development such as water extraction, or whether there are thresholds beyond which environmental and conservation values might change abruptly. Initially the workshop was set-up to investigate these ecological threshold issues by qualitatively considering the vulnerability/resilience of the assets and asset types to identified risks/threats, from hydrological disturbance, water resource development and other potential factors that may affect the identified assets. However in light of difficulties encountered in the identification of meaningful ecological thresholds as part of the Northern Territory fine scale assessment this objectives was removed for the Kimberley assessment.

The Kimberley fine scale assessment workshop aimed to identify fine scale assets and where possible document risks to assets and management options. The information gathered in this workshop provides important consolidation of existing understanding and a guide for future planning and research.

Aims

The workshop aims included:

- Identify local scale assets (e.g. particular floodplain lakes, and wetlands, riverine reaches, etc) that occur within the upper Fitzroy and Mitchell catchments
- Identify key risks to these high conservation assets within the two focal catchments
- Identify knowledge needs and their relative priorities
- Consolidate existing knowledge on HCVAE's in the region and across research and management disciplines.

Workshop Structure

A one and a half day workshop started with a number of talks in the morning that provided background information of the HCVAE project, current Kimberley assets, threats and management practices and set the scene for group discussions in the afternoon session (**Table 1**). In the group discussions workshop participants were asked to identify specific assets (e.g. particular floodplain lakes and wetlands, riverine reaches, etc) that occur within each of the focal catchments and describe the variety of threats and knowledge gaps associated with each. For the purposes of these discussions, workshop participants were allocated, on the basis of their local knowledge, to one of two groups, each group focusing on one of the focal catchments.

Twenty-four participants attended the workshop from a total of 35 invitees (**Table 2**). Participants included representatives from the jurisdictions (Departments of Water and Environment and Conservation), the Kimberley Land Council ranger program, North Australia Indigenous Land and Sea Management Alliance, TRaCK researchers, DEWHA and the Australian Wildlife Conservancy (Mornington Station).

Table 1. Workshop agenda

Time	Topic	Speaker
Thursday 11th November		
8.45	Welcome/ Introduction	Paul Close
9.00	Overview of the NAWFA programs	Hayley White (DEWHA) (Presented by Michael Douglas)
9:30	Relevant TRaCK research in the Kimberley	Michael Douglas (TRaCK)
10.00	Morning tea	
10.20	HCVAE Framework	Di Conrick (DEWHA) (presented by Paul Close)
10.40	HCVAE's and management implications in the Kimberley	Troy Sinclair (DEC)
11.00	EWR's and regional water planning process	Mike Braimbridge (DoW)
11.30	National Heritage assessment of the West Kimberley	Anthony Whalen (DSEWPC)
12.00	Broadscale scale HCVAE Assessment	Mark Kennard (TRaCK) (presented by Paul Close)
12.15	Lunch	
1.00	Workshop Introduction	Paul Close
1.15	Group Discussions (asset identification)	All
3.00	Afternoon tea	
3.30	Group Discussions (risk identification)	All
5.00	Summary and Close	
Friday 12th November		
8.30	Ngarinyin perspective on high conservation waterways	Sam Bayley and Kevin Dann (Wunggurr Rangers – KLC)
8.45	Conservation of ecological values on privately managed land	Sarah Legge (AWC)
9.00	Group Discussion (knowledge gaps)	All
10:00	Morning tea	
10.30	Knowledge gaps, assessment and summary	All
11.00	Where to from here	Paul Close
11.15	Close	

Table 2. List of participants and invitees

Name/Contact	Affilliation	Role
Paul Close	TRaCK	Facilitator
Neil Pettit	UWA/TRaCK	Facilitator
Robert Cossart	DoW	Participant
Troy Sinclair	DEC	Participant
Sarah Legge	AWC - Mornington Station	Presenter
Kevin Dann	Wunggurr Rangers - KLC	Presenter
Sam Bayley	Wunggurr Rangers - KLC	Presenter
Michael Douglas	TRaCK	Presenter
Mike Braimbridge	DoW	Presenter
Whalen, Anthony	DEWHA	Presenter
Jason Adams	Uunguu Rangers- KLC	Participant
Joseph	Uunguu Rangers- KLC	Participant
Neil Waina	Uunguu Rangers- KLC	Participant
Sylvester Maglamara	Uunguu Rangers- KLC	Participant
Hugh Wallace Smith	NAILSMA	Participant
Frances D'Souza	DoW	Participant
Peter Bayliss	CSIRO/TRaCK	Participant
Lindsay Baker	DEC	Participant
Doug Ward	GU/ TRaCK	Participant
Rebecca Dobbs	UWA/TRaCK	Participant
Karin Carnes	DEC	Participant
Michael Coote	DEC	Participant
Rob Warren	Uunguu Rangers- KLC	Participant
Mark Kennard	GU/TRaCK	Apology
Phil Palmer	KLC	Apology
Tom Vigilante	KLC	Apology
Tanya Vernes	WWF	Apology
Duncan Palmer	DoW	Apology
Stuart Halse	Bennelongia Consulting	Apology
Adrian Pinder	DEC	Apology
Andrew Storey	UWA	Apology
David Morgan	MU	Apology
Peter Davies	UWA	Apology
Katherine Tuft	AWC – Mornington Station	Apology
Hayley White (NAWFA)	DEWHA	Apology
Sonia Lennard	KLC	Apology

Workshop session summaries

Morning Session Presentations and Discussions

Nine presentations were given in the morning sessions to provide workshop participants with sufficient background to undertake a fine-scale assessment of ecological assets in the upper Fitzroy and Mitchell catchments. Presentations included the following topics relevant to the to focal catchments:

- Background on the NAWFA Progams and HCVAE Framework;
- Relevant ecological research undertaken by TRaCK
- HCVAE's and management implications in the Kimberley
- Environmental Water Requirements and the regional water planning process
- National Heritage Assessment of the west Kimberley
- Broad-scale HCVAE assessment across northern Australia
- Ngarinyin perspective on high conservation waterways
- Conservation of ecological values on privately managed land

Summaries of these presentations, including pertinent discussion resulting from each presentation are provided below.

Overview of the NAWFA Programs - presented by Michael Douglas (TRaCK) for Hayley White (DEWHA)

1. Objective of the NAWFA programs is to provide an enduring knowledge base to inform protection and development of northern Australia's water resources, so that any development proceeds in an ecologically, culturally and economically sustainable manner.
2. The NAWFA Program includes four subprograms; *water resources*, *ecological* and *cultural and social* programs. The fourth component, *knowledge base* draws the previous three components together with the aim of providing an enduring knowledge base to support informed decision making in northern Australia.
3. *The Water Resource Program* seeks to provide for a better understanding of water availability in northern Australia. The principle project under this program was the NASY (Northern Australian Sustainable Yields) Project undertaken by CSIRO.
4. *The Ecological Program* seeks to provide for a better understanding of ecological assets in northern Australia, their watering needs, and the risks to them arising from changes to hydrological regimes. Key activities under this program include; mapping of aquatic ecological assets, trial of the HCVAE, and identification of ecological thresholds.
5. *The Social and cultural Program* seeks to provide for a better understanding of socio-cultural values, beliefs and practices in northern Australia associated with water, and the affect of any changes in water availability.
6. *The Knowledge Base Program* seeks to provide for an enduring knowledge base to support informed decision making in northern Australia. The intent of this is to support future water planning decisions in northern Australia. The anticipated content of the Knowledge Base includes; existing knowledge, data, information and research links, case studies, assessment reports, models and decision support tools.

Overview of TRaCK Research (Michael Douglas, CDU/TRaCK)

1. This presentation provided an overview of Kimberley-based research conducted under the *Tropical River and Coastal Knowledge* (TRaCK) Research Program.
2. TRaCK's Aim: to provide science and knowledge that governments, communities and industries need for the sustainable management of Australia's tropical rivers and estuaries.
3. TRaCK is collection of 70 researchers from different organizations. These include DEC, DoW and Ranger groups in WA-Kimberley focus. The TRaCK research program was established in 2007 with the last of the projects to be finalized in early 2011. TRaCK worked widely in the wet/dry tropics with a focus on the Fitzroy, Mitchell (QLD) and Daly rivers
4. A variety of Kimberley-based TRaCK research have addressed ecological assets, river flows and ecological thresholds. These projects have covered a variety of related topics including environmental water requirements, socio-economic consequences of altered flows, links between ecological, socio-economic and management components, ecosystem function and environmental/ecological monitoring.
5. A summary of relevant TRaCK projects was provided:

   a. *The value of tropical river systems* – significant outcome included recognition that people were prepared to pay more (relative to economic e.g agricultural water use) to protect environmental, recreational and cultural values associated with aquatic systems in northern Australia. This included the recognition of the significant cultural value of waterholes for Aboriginal people.
   b. Indigenous values of rivers - provided information on methods and main findings including main species and how they were used (e.g. traded, eaten etc). This has important implications on flow and other management – e.g. normal flow objectives may not necessarily meet requirements of indigenous values
   c. *Eco-hydrological regionalization of Australia's rivers was provided.* A variety of flow regimes are represented in rivers of northern Australia based on seasonality and predictability of flow and the contribution of baseflows (pereniality).
   d. *Patterns in biodiversity* - species distributions and cryptic species. Probably much more diversity than what we think and particularly high diversity in the Kimberley
   e. *How tropical river systems work*. Included discussion of the drivers of biodiversity patterns. This project undertook investigations on foodwebs in the Daly (NT), Mitchell (QLD) and Fitzroy (WA) catchments. Patterns of flow in these rivers drive patterns of biodiversity. More plants and fish species were supported by perennial streamflows in the Daly catchment compared to those support by ephemeral flows in the Fitzroy catchment.
   f. *Aquatic foodwebs in Northern Australia:* explained that in southern Australia, terrestrial detritus supports aquatic foodwebs. In contrast, insects are eating local derived algae in northern Australian aquatic systems. In the Fitzroy catchment, fish are also utilizing a local algal-based foodweb whereas in the Daly and Mitchell rivers, fish are relying on food sources supported most likely from the floodplain. This shows that floodplain production is critical and that longitudinal connectivity in the Mitchell and Daly rivers is also important in the redistribution of energy. In contrast floods in he Fitzroy are only brief whereas in the Daly and Mitchell rivers they inundate floodplains for months.
   g. The importance of hydrology to ecology in northern Australia was discussed. It is vital that hydrological connections (longitudinal and lateral) are maintained.
   h. *Groundwater surface water interactions:* Key questions identified. Key trends and important management implications noted.
   i. *Monitoring and assessment*: Discussed the main aspects of the FARWH (Framework for Assessment of River and Wetland Health) project

Overview of the HCVAE Framework – presented by Paul Close (TRaCK) for Di Conrick (DEWHA)

1. The HCVAE aims *to provide a consistent approach to the identification and classification of High Conservation Values*. It includes method development and relies on the HCVAE and ANAE (Australian National Aquatic ecosystem) criteria.
2. The HCVAE method aims *to provide a consistent methodology incorporating identified datasets, regionalisation, spatial scales and integration techniques to enable HCVAE to be identified at a national, jurisdictional or regional scale.*
3. The HCVAE criteria include, diversity, distinctiveness, vital habitat, evolutionary history, naturalness and representativeness.
4. ANAE Classification Scheme aims *to provide a nationally agreed set of aquatic ecosystem classes that can be used to identify different aquatic ecosystems across Australia at varying and multiple levels.*
5. Guidelines for the development of the HCVAE Framework include: write guidelines incorporating information and recommendations from all projects; targeted public consultation; AETG approval; Ministerial endorsement and; implementation.
6. Current progress on the HCVAE Framework includes: HCVAE criteria trials (2008) for NSW estuaries, Victorian rivers, WA Mound Springs and the northern Murray-Darling Basin. The HCVAE framework has been trialed (2010) in the Lake Eyre Basin and in Northern Australia.
7. In 2010/11 the framework will be trialed in Tasmania (against the Tasmanian Conservation of Freshwater Environmental Values (CFEV) Program). The HCVAE Delineation guidelines will also be developed and trialed in the Lake Eyre Basin.

HCVAE's and management implications in the Kimberley – presented by Troy Sinclair (DEC)

1. Background was provided on the identification of assets, threats and knowledge gaps from a jurisdictional (DEC) perspective.
2. Numerous documents address ecological assets and environmental values including: SKM 2007, HCVAE of Australia, Directory of important wetlands, Mitchell subregion conservation report CALM 2003, DEC wetland Status report 2008, DoW 2008 river assessments, North Kimberley biodiversity hotspots.
3. A variety of threats to ecological values in the two focal catchments were discussed including feral pigs, cattle, weeds, mining, sedimentation etc.
4. Improvements to DEC's conservation actions were discussed. DEC Kimberley is steadily changing its paradigm of land management to be more inclusive of aboriginal people. DEC is also addressing threats of ferals, weeds and fire at landscape scale rather then just at the species, community or tenure level.
5. A history of the KSCS was provided:
    a. 2008 Pre-election commitment of Liberal government to allocate $9 mill to a Kimberley Science and Conservation Strategy
    b. 2009 Former Senator Chris Ellison undertook Public consultation
    c. 2009 Summary of public input released
    d. Early Oct 2010 Premier and Minister announces First announcement related proposal to create Camden Sound Marine Park
    e. Late Oct 2010 Further details of strategy released
6. The Kimberley Science and Conservation Strategy (KCSC) forms voluntary partnerships with pastoralists, Traditional Owners, private conservation groups, mining companies and local government to deliver coordinated on-ground management of fire, feral animals and weeds. This has included:
    a. establishment of the Landscape Scale Conservation Initiative – allocation of $2.5 million per annum to assist with the delivery of on-ground programs, with a strong focus on indigenous rangers (DEC and KLC).

b. identify priority marine research to assist management (Camdem, Roebuck and 80 mile beach)
c. creation of a conservation reserve corridor linking Drysdale NP and Prince Regent
d. creation of conservation reserves on up to 30 islands
e. upgrade of tourism facilities at several DEC parks
f. creation of new tourism experiences in the Kimberley
g. with Tourism WA, assist Aboriginal communities to identify and develop nature based and cultural tourism services at key sites

Fine Scale assessment of aquatic ecological assets and the identification of ecological thresholds – presented by Paul Close for Mark Kennard (both TRaCK).

1. Broad-scale assessment of HCVAE's used HCVAE Framework criteria (diversity distinctiveness vital habitat evolutionary history naturalness and representativeness) and the ANAE classification scheme within a combination of complimentary approaches including scoring systems, systematic planning tools and expert panel workshops.
2. Species distribution datasets for water birds, turtles, macroinvertebrates and fish. Data on frogs, crocodiles, lizards, snakes, aquatic plants and estuarine species were not used.
3. Predictive models were developed for species distributions across the landscape thereby providing complete coverage of data within the study area.
4. Mapped aquatic ecosystem "types" according to the ANAE classification scheme (estuarine, lacustrine, palustrine and riverine). Included information on pereniality of hydrosystems.
5. Spatial scale of HCVAE assessments is the planning unit.
6. HCVAE areas were identified using the Framework Criteria

Environmental flow requirements and the regional water planning process (Mike Braimbridge, DoW)

1. Provided information on the Western Australian water planning framework
2. Discussed the key steps in undertaking an environmental flow requirements (EWR) study
3. Identified that the level of effort afforded to research and management of EWR's is relative to the "risk" to the resource from water developments (e.g. % of allocation limit)
4. Identified the relevant State policies and legislation
5. Identified that the determination of EWRS comes down key questions, e.g. what is ecologically significant, how important is water in maintaining ecological values, what are the objectives management objectives etc.

National Heritage assessment of the West Kimberley – presented by Anthony Whalen (DEWHA)

1. Provided background to Australia's Heritage System and the National Heritage List (NHL). The relationship between biodiversity and the heritage list was discussed as well as the West Kimberley National Heritage Assessment
2. The Australian Heritage Council Act 2003: established the Australian Heritage Council (AHC) as an independent body that advises the minister on heritage listing protection and management
3. The EPBC Act 2003: amendments created the National Heritage List to recognize, celebrate and conserve places of outstanding heritage value to the nation
4. Governments have agreed that World Heritage nominations will generally include places from the NHL.
5. A National Heritage value must meet one or more of the statuary criteria for the NHL: natural heritage, indigenous heritage or historic heritage. Nine criteria cover aspects of historic, scientific,

aesthetic and social value including one specifically for places that are considered important as part of indigenous tradition.

6. National heritage values are recorded in the NHL and protected by the EPBC Act
7. Places in the NHL with outstanding biodiversity values are listed against the criteria: process (course, or pattern of Australia's natural history); rarity (species, communities or features; yield information (contribute towards understanding); class of place (for natural values); aesthetics.
8. The process of assessing biodiversity under the NHL was discussed. It required comparative information (see above) for the whole continent and scientifically robust and repeatable results. This led to the development of the Australian Natural heritage Assessment Tool (ANHAT). The ANHAT is a spatial tool that analyses 37,000 species using 29 million records from museums, herbaria and state agencies.
9. The ways in which the ANHAT addresses the NHL criteria were discussed.
10. Taxa covered in the assessment included terrestrial vertebrates and plants and invertebrates including the Gastropoda (land and freshwater snails), Bivalvia (freshwater mussels), Coleoptera (diving beetles, dung beetles), Rotifers, Odonata (dragonflies and damselflies), Lepidoptera (butterflies), Sparassidae (huntsman spiders) and Mygalomorphae (trapdoor spiders)
11. The west Kimberley NHA was discussed with specific reference to the two focal catchments.
12. The Michell catchment represented the highest (or close to highest) endemism values for the nation for the plant families: Zygophyllaceae, Tiliaceae, Combretaceae, Amaryllidaceae. Annual plant families showed high richness and endemism, particularly: Lentibulariaceae (bladderworts) and Stylidiaceae (triggerplants) The highest (or close to highest) species richness and endemism values for the nation were returned for: rodents (Rodentia), dragons (Diporiphora), geckoes (Gekkonidae), frogs (Hylidae - tree frogs and Myobatrachidae - Southern frogs), rats and mice (Muridae). The highest (or close to highest) endemism values for the nation were returned for mammals, "new endemic" species, important refuge, possums (Phalangeridae), microbats (Hipposideridae and Vespertilionidae), pythons (Boidea) and reptiles
13. Results of the NHA for the Fitzroy river catchment were also discussed.
    a. fish endemism – not nationally significant under criterion (a), comparable with other rivers across tropical Australia of approximately equivalent size (1 endemic species with 2 near endemic species)
    b. wetlands of the Fitzroy River (Camballin floodplain)
    c. important waterbird refugia, nationally there are a number of other systems in northern Australia of equal or greater significance under criterion (a)
    d. consensus of 2010 Heritage Wetlands workshop participants was that Roebuck Bay, Eighty Mile Beach, Lake Argyle and Lake Gregory were nationally more significant for bird values
    e. indigenous tradition cultural heritage values have been examined under criterion (d)

Ngarinyin perspective on high conservation waterways – presented by Sam Bayley and Kevin Dann (KLC ranger program)

1. Information provided in this presentation was compiled from discussions with traditional owners on special waterways in the Wilinggin Country
2. Types of special water places included springs, waterholes, rivers and creeks
3. Values of these places included: fishing, hunting, gathering (mussels, sugarbags bush figs etc). Many waterways were also identified as important dreaming sites and or sites with other special values (e.g. law, fertility, ceremony etc)
4. Threats to these assets and values include donkeys, pigs, cattle, fire, unwanted visitors (tourism), to much water use (e.g. for maintaining roads)
5. The importance of learning new values was emphasized. Traditional Owners readily provide knowledge to western science and management with the expectation that knowledge, training etc is provided in return. The importance of "two-way" transfer of knowledge between westerns and

traditional owners was discussed. This is currently being achieve in programs such as the "waterways Education Program", the Canberra University Turtle research program and TRaCK research activities

6. Traditional Owners have different criteria for assessing values many of which complement western values
7. Greater research success through active partnerships with Traditional Owners
8. Traditional Owners are keen to learn and be involved through programs such as the KLC Ranger programs, and Waterway Education program
9. Many cultural and ecological assets are the same e.g. same places but they have been identified using different criteria. Traditional Owners are very interested in interacting, learning and teaching both the younger generation and visiting westerners

Conservation of ecological values on privately managed land – Presented by Sarah Legge (AWC)

1. This presentation provide background on the management and research of high conservation values, associated threats and knowledge gaps on Australian Wildlife Conservancy (AWC) properties in the Kimberley (Mornington and Marion Downs stations.
2. Much of AWC's activities include "science-based conservation management" with a focus on terrestrial landscape management
3. AWC's Science program objectives include inventory, adaptive management (ecological health monitoring) and strategic research
4. ECOFIRE: 2007-2010. Fires too large to manage. Extensive and intensive fires remove pasture, damage cultural sites and biodiversity. Aim of project to change fire patterns in ways to benefit biodiversity. The Ecofire project has been successful in radically changing the seasonality and distribution of fire. Fire-scar footprint hasn't changed but the early dry season fires create a mosaic e.g. more unburnt land within the footprint. This has led to substantial benefits to biodiversity
5. Several monitoring programs were described in detail including the destocking of horses, donkeys and cattle, and the purple-crowned fairy wren monitoring program. The main components of ecological health monitoring include monitoring the threats, species and processes. The importance of selecting appropriate indicators was dicussed
6. A variety of HCVAE's within the AWC properties were identified, including
    a. Annie Creek (high quality riparian zone provides important habitat for both terrestrial and aquatic biota).
    b. Little Fitzroy fed by small creeks with permanent pools with Pandandus that act as refuges for mammals and birds.
    c. Large river pools on the Fitzroy river that provide the most upstream dry-season refugia in the catchment
    d. Significant threats to assets and values include weeds (*Parkinsonia*, rubber bush and grader grass) sedimentation of river pools, fire and unmanaged stock but manageable also grader grass

Identification of fine-scale assets, threats and knowledge gaps

Assets, relevant HCVAE criteria and attributes, associated threats and knowledge gaps identified for the Mitchell and upper Fitzroy rivers are shown in Tables 3 and 4 respectively. Six high conservation assets were identified in the Mitchel River catchment, these included lagoonal habitats, permanent dry seasonal refugia (Plate 1), seepages and springs and perched, groundwater dependent wetlands. A variety of threats identified included managed stock, fire and sedimentation. In the Fitzroy catchment, sixteen individual high conservation assets were identified, including assets in conservation reserves, privately owned land, and lands outside of the conservation estate. Assets included a variety of mid and upper catchment spring fed tributaries (Plate 2) and wetlands, large permanent dry season refugia on the Fitzroy main channel (Plate 3) and flood plain water holes and swamps. A variety of threats were identified for each asset including managed and unmanaged stock, feral animals and weeds, sedimentation, recreational fishing and tourism.

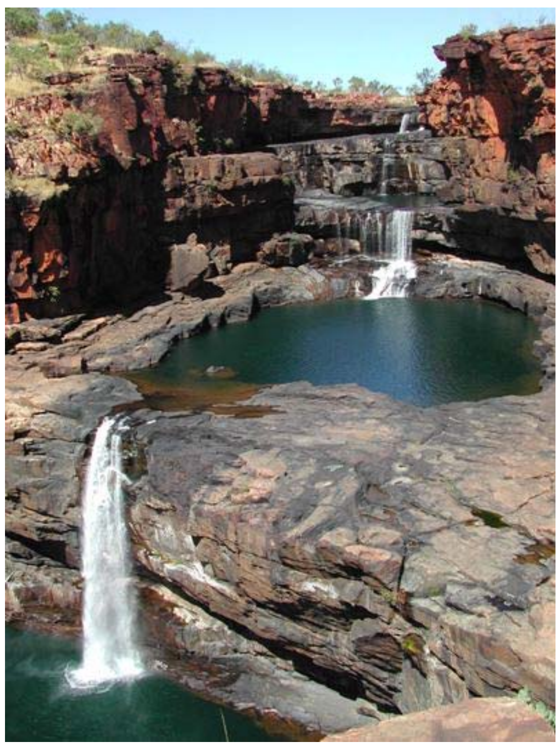


Plate 1: Mitchell Falls, HCVAE asset on the Mitchell River catchment (photo: T Sinclair)

Plate 2: Annie Creek, permanent spring-fed creek, HCVAE asset on the upper Fitzroy catchment (photo N. Pettit)

Plate 3: Bluebush, permanent refugial waterhole, HCVAE asset on the upper Fitzroy River (photo: N. Pettit).

TRaCK Tropical Rivers and Coastal Knowledge

TABLE 3: Assets, relevant HCVAE criteria and attributes, associated threats and knowledge gaps identified on waterways in the mid-upper Mitchell River Catchment

River system	Asset	HCVAE Criteria	Threat	Knowledge gap
Mitchell River	Glauert lagoons	Vital Habitat, representativeness, endemism etc	Cattle and fire	
Mitchell River	Permanent dry-season refugia old Mitchell homestead	Vital habitat, representativeness	Sedimentation from upstream disturbances, bank erosion from cattle disturbance	
Mitchell River	Many hills side seepages, south of plateau escarpment		Cattle and fire	
Mitchell River	pandanus springs (point3)	Vital habitat	Cattle and fire	
Mitchell River	Perched wetlands (eg airfield and point 4-8)		Fire mostly	
Mitchell River	Permanent dry-season refugia old Camp Creek		Sedimentation from upstream disturbances, bank erosion from cattle disturbance	

TABLE 4: Assets, relevant HCVAE criteria and attributes, associated threats and knowledge gaps identified on waterways in the mid-upper Fitzroy River Catchment

Waterway	Asset	HCVAE Criteria (attribute)	Threat	Knowledge gap
Hann River upper Barnett and Manning Rivers	Upper catchment spring-fed tributaries	Distinctiveness (R&T) Representativeness Vital habitat (P, con) Evolutionary history (TE) Naturalness (CDI, FRDI)	Tourism, feral animals weeds, late season fires, some fishing pressure (bream)	Reasonably well studied
Lower reaches of Annie Creek and Adcock River	Spring fed upper catchment tributary with intact riparian vegetation	Diversity (R, H) Distinctiveness (R&T) Vital habitat (P, con) Naturalness (CDI, FRDI)	Low fire and tourism, upstream cattle disturbance, feral animals	Some recent survey data
Springs on Gibb River Station	Spring fed wetlands, waterholes and swamps	Representativeness (R)	Isolated point source, human access	Biodiversity values and potential threats
Lake Gladstone	Rehabilitated wetland habitat	Representativeness (R) Vital habitat (Mbird_S)	Managed and unmanaged stock, feral animals, weeds, fire	Reasonably well known
Fitzroy River	Large, dry-season refugial waterholes in upper catchment	Representativeness (R) Vital habitat (P)	Low tourism, downstream movement of sediment	Reasonably well studied, pool infilling?

Waterway	Asset	HCVAE Criteria (attribute)	Threat	Knowledge gap
Hann River below confluence with Hann/Barnett	Refugial waterhole (Winjulgnardi)	Vital habitat (P) Naturalness (CDI) Representativeness (R)	Feral animals, weeds, late season fires, some fishing pressure	Biodiversity values
Pensioner Creek	Spring fed tributary	Vital habitat (P, con)	Groundwater extraction, feral animals, unmanaged stock, fire	Biodiversity values and distribution
Hann River – near DoW gauging station	Dingun: transitional habitat from sandy to rocky stream channel	Representativeness (R) Naturalness	General threats from upstream	Species distribution, diversity values, potential threats
Hann River -	Moll gorge: important site for riparian plants	uncertain	Low threats from tourism	Poorly known, Species distribution, diversity values, potential threats
Lower Leopold (Confluence Margaret)	Remote permanent waterhole with low level disturbance	Vital Habitat (P) Diversity (S, H') Naturalness (CDI)	Cattle, downstream movement of sediment	Sandy shifting pools – infilling?
Tunnel Creek (area DS of diamond Gorge to Geikie Gorge	Cultural values, Conservation reserve	uncertain	Mining, tourism, weeds, fire	Understanding of values, complex groundwater and surface water movement
Brooking Creek / George	Unique mid catchment tributary	Uncertain Representativeness (R)	Cattle, fire feral animals, weeds tourism	Poorly known
Geike Gorge	Major waterhole with biodiversity and cultural value	Representativeness (R) Vital habitat (P)	Pollution, fishing, tourism, cattle weeds, potential mining	Sedimentation
Me No Savvy - Mid Margaret to Margaret gorge	Remote permanent waterholes with low level disturbance	Representativeness (R) Vital habitat (P) Naturalness	Generally low	Poorly known
Jillyardi	Extensive perennial wetland, Permanent waterholes	Representativeness (R) Vital habitat (P) Naturalness	Cattle, weeds	Poorly known
Traine River	Permanent waterholes	Diversity (S, H')	Sedimentation, nutrient enrichment, fire, cattle	Do these waterholes always support elevated species richness

Comparison of fine scale assets with broad scale patterns within the Fitzroy catchment

A preliminary evaluation of the relationships between the variety of fine-scale assets identified in the workshop with broad-scale patterns of HCVAE criteria within the Fitzroy River catchment was undertaken. A variety of HCVAE attributes (e.g. fish endemism, vital habitat, representativeness) within the Fitzroy catchment were displayed for workshop participants. While there was congruence between the fine-scale identification of assets and broad-scale patterns for some HCVAE criteria, the general conclusion was that most of the fine-scale assets did not support the broader-scale patterns identified at the catchment scale. This is really not surprising given the very different scales at which the broad and fine scales operate and therefore the different level of management scale they are designed to facilitate.

Workshop Outcomes and Recommendations

Specific Workshop outcomes

- The workshop identified a variety of fine scale assets in the two focal catchments: sixteen assets in the Fitzroy and six in the Mitchell. The difference in numbers is mostly a reflection of the level of information available in each catchment. A variety of threats to these assets were also identified including invasion of weed species, feral animals (pigs) unmanaged stock, sedimentation of river pools, altered fire regimes.
- There was a general consensus that the scale of the assessment of high conservation values is too broad and provides limited benefit to management and monitoring undertaken by the variety of organizations represented at the workshop (jurisdictions, ranger groups and researchers). Whilst the framework was considered suitable the limited data available to support the identification of assets and resolution of mapping available is not suitable for the property scale or less.
- Rangers highlighted their interest in applying the data gathered at the workshop into annual work plans, identification of priority areas for weed, feral and fire control and directing future on ground investment. They identified a critical need to have exposure to this sort of asset identification initiative aligned with on-ground training and education initiatives such as the Waterways Education Program and the Working on Country program.
- There was consensus that the outcomes arising from this workshop should be provided to participants, particularly Traditional Owners, in the form of a plain English non-technical summary report, detailing the identified assets and their associated threats and knowledge gaps. This information was considered valuable for future planning and monitoring activities.
- The workshop did not attempt (in any great detail) to address ecological thresholds as they related to flow requirements and the maintenance of ecosystem values. It was recognized that these considerations require substantially more information, knowledge and expertise, particularly of flow ecology relationships, than was available during this workshop and in many case with the current knowledge of the assets.
- Consideration of HCVAE's in water allocation planning and determining ecological water requirements may include:
    - A better understanding of the ecological function of HCVAE and how ecological function may be modified or adversely affected by regulating surface water flows (i.e. ecosystem response to changes to the wetting and drying regimes associated with large-scale river regulation).
    - A better understanding of the role of surface water / groundwater connectivity in supporting HCVAE's and how abstraction may impact ecosystem function.
    - The impact of dewatering discharge on HCVAE, which may alter the hydrological regime by increasing peak flows and modifying the volume and seasonality of flows.

* As many HCVAE are located outside the state conservation estate, a coordinated and cooperative approach by all relevant land, water managers (both private and public) and funding agencies (state and commonwealth) is required.

Additional outcomes, recommendations and considerations

Additional outcomes were identified that address a variety of management priorities within the North Kimberely region. These included:

* Improved knowledge and mapping of species endemism.
* Identification of aquatic ecosystems that support high conservation value populations.
* Incorporation of Indigenous ecological knowledge as an important part in the identification of and sustainable management of aquatic ecosystems across the Kimberley. This knowledge has accumulated over hundreds of generations of actively caring for the land and water and provides a valuable source of information for western science, conservation and management, including identifying environmental assets and threats. The existing framework for the identification of HCVAE does not take in to consideration Indigenous ecological knowledge
* Identification of specific high value aquatic ecosystems for inclusion into the *Directory of important wetlands of Australia* (Environment Australia, 2001). The directory (pages 105 and 106) recognises that the list of Western Australian aquatic ecosystems is not definitive as there are "gaps in the information presented and in the omission of some poorly known, yet potentially important sites". The directory also recognised that more fieldwork and community/stakeholder consultation is required to ensure that the diversity of aquatic ecosystems in Western Australia is truly represented in future editions.

It is recognized that the HCVAE process, particularly the identification of fine-scale assets can be incorporated into the following activities, processes and recommendations

* The Australian Society for Limnology 45th National Congress paper, *Aquatic Protected Areas for the Protection of Inland Aquatic Ecosystems of High Conservation Value* (2006), in particular
* The development of existing inventories of aquatic ecosystems should be accelerated, using an agreed classification method, to encompass all major aquatic ecosystems and to include data on value, condition and threat.
* Australian aquatic ecosystems should be identified and mapped at ecologically meaningful scales, with a focus on northern and central Australia where relatively little scientific information has been collected.
* The role of catchment and regional planning should be reviewed and strengthened to improve the protection of aquatic ecosystems, supported by easily accessible and comprehensive ecosystem inventories.
* Australia's Strategy for the National Reserve System 2009-2030 (DEWHA, 2009) as endorsed by the Natural Resource Management Ministerial Council in June 2009, recommended that aquatic ecosystems need to be better protected in the National Reserve System. The Australian guidelines for establishing the national reserve system (ANZECC, 1999) are planned to be reviewed to better account for the needs of aquatic ecosystems including their water requirements, the impact of climate change and integrated landscape management. A systematic review may be required to ensure HCVAE's are adequately protected in a Comprehensive, Adequate and Representative (CAR) reserve system.

References

Allen, G.R., Midgley, S. H. & Allen, M (2002). Field guide to the freshwater fishes of Australia. Western Australian Museum, Perth

Australian Heritage Database (AHD), last accessed 21st January 2008, Department of Environment Heritage and the Arts, website; http://www.environment.gov.au/heritage

Australian Society for Limnology, 2006, Aquatic Protected Areas for the Protection of Inland Aquatic Ecosystems of High Conservation Value in 45th National Congress of the Australian Society for Limnology, 25-29th September 2006, Albury, New South Wales.

Department of the Environment, Water, Heritage and the Arts 2009, Australia's Strategy for the National Reserve System 2009-2030, report prepared for the National Reserve System Task Group of the Natural Resource Policies and Programs Committee, DEWHA, Canberra.

Environment Australia, 2001, A Directory of Important Wetland in Australia, 3rd edition, Environment Australia, Canberra

FitzSimmons, N. N,, J. Buchan, M. A. Reed, J. D. Miller, W. Kay, C. Moritz, C. J. Limpus, D. Blair and G. C. Grigg. 2004. Population genetics of Australia's crocodiles: a comparison between Crocodylus johnstoni and C. porosus. p. 65 In: Crocodiles. Proceedings of the 17th working Meeting of the Crocodile Specialist Group, IUCN – The World Conservation Union, Gland, Switzerland and Cambridge, UK

FitzSimmons, N.N., A.D. Tucker, E. Alacs, A. Georges G. Kuchling 2009. Comparative phylogeography of two freshwater turtles in the Kimberley Plateau, Western Australia. Australia Freshwater Turtle Symposium, 14-15 Feb, 2009, Brisbane, Qld.

Graham, G., and McKenzie, N.L. (2003) A conservation case study of Western Australia's Mitchell subregion (north Kimberley 1) in 2003, Department of Environment and Land Management, Perth, Western Australia

Handley, M. (1996) Australian Wetlands Conservation Project : final report. prepared for the Australian Heritage Commission, Canberra, Australia.

Kennard, M.J. (ed) (2010). Identifying high conservation value aquatic ecosystems in northern Australia. Interim Report for the Department of Environment, Water, Heritage and the Arts and the National Water Commission. Tropical Rivers and Coastal Knowledge (TRaCK) Commonwealth Environmental Research Facility, Australian Rivers Institute, Griffith University. Available at: http://track.gov.au/publications/registry/843.

Kimberley Development Commission (2001) Kimberley economic perspective: An update on the economy of Western Australia's Kimberley region, KDC

Lindsay R.P. and Commander D.P. (2005) Hydrogeological assessment of the Fitzroy alluvium, Western Australia, Department of Water, Hydrogeological record series HG 16

Morgan, D.L., Allen, M.G., Bedford, P. & Horstman, M. (2004). Fish fauna of the Fitzroy River in the Kimberley region of Western Australia - including the Bunuba, Gooniyandi, Ngarinyin, Nyikina, and Walmajarri Aboriginal names. Records of the Western Australian Museum 22: 147-161.

Storey, A.W., Davies, P.M. and Froend, R.H. (2001) Fitzroy River System: Environmental Values. Report prepared by University of Western Australia and Edith Cowan University for Water and Rivers Commission.

Tucker, A. D. and N. N. FitzSimmons. (2006). Population structure and function of Emydura and Chelodina in the Kimberley Plateau, Western Australia prior to arrival of invasive cane toads. 4th Annual Symposium on Conservation and Biology of Freshwater Turtles and Tortoises. IUCN/SSC Tortoise and Freshwater Turtle Specialist Group, p. 39. 8/13/06

Water and Rivers Commission (1999), The findings of the GIS preliminary identification and verification phases of the project, report prepared by PJ Williams, LJ Pen and JJ Alford, Water and Rivers Commission, Perth.

Williams PJ, Pen LJ, Stein JA, Stein JL, Prince B (1996). *The identification, conservation and management of wild rivers in the Kimberley region of Western Australia*. First National Conference on Stream Management in Australia, Merrijig, Victoria.