The Hydroecological Natural Heritage Story of Cape York Peninsula

An assessment of natural heritage values of water-dependent ecosystems, aquatic biodiversity and hydroecological processes

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2011

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Executive Summary

The field of hydroecology seeks to explain the relationships between hydrological processes, biotic structure and ecological processes at a variety of spatial scales. This report presents the hydroecological natural heritage story of Cape York Peninsula. Unlike many areas of Australia, freshwater-dependent ecosystems of Cape York Peninsula have high ecological integrity, possessing a diverse and unique array of aquatic, riparian and terrestrial biodiversity, near-natural flow regimes, and relatively intact riverine landscapes. These aquatic ecosystems not only provide clean water, food and recreation opportunities for human societies but have important intrinsic natural and cultural heritage values that are potentially significant from a national and international perspective.

The report outlines the potential natural heritage values of freshwater-dependent ecosystems, aquatic biodiversity and hydroecological processes of the region with respect to National and World Heritage selection criteria. The report documents:

1. the extent, variety and distinctiveness of aquatic ecosystem types in the region,
2. biodiversity and biogeographic patterns of freshwater-dependent flora and fauna,
3. hydroecological processes that sustain the natural integrity and biodiversity of freshwater-dependent ecosystems,
4. preliminary assessments of the National and International natural heritage significance of hydroecological features of Cape York Peninsula. These assessments are made using multiple lines of evidence, including indicators of significance, comparative analyses, and natural integrity.

Information in the report was compiled from the literature as well as expert knowledge and personal experience of the research team on the aquatic ecosystems of Cape York Peninsula. As much as possible, the report is written in lay person terms and in a creative way so that it can be read and appreciated by a broad audience.

1.0 Project brief and objectives

The Cape York Peninsula region (Fig. 1.1[1]) has a diverse range of aquatic ecosystem types (e.g. estuaries, rivers, lakes and wetlands) that are shaped and sustained by the movement of water through the landscape. Unlike many areas of Australia, freshwater-dependent ecosystems of Cape York Peninsula have high ecological integrity, possessing a diverse and unique array of aquatic, riparian and terrestrial biodiversity, near-natural flow regimes, and relatively intact riverine landscapes (Herbert *et al*., 1995; Pusey & Kennard, 2009; Kennard, 2010). These aquatic ecosystems not only provide clean water, food and recreation opportunities for human societies (i.e. ecosystem services, *sensu* Millennium Ecosystem Assessment, 2005; see also Postel & Richter, 2003) but have important intrinsic natural and cultural heritage values (Table 1.1) that are potentially significant from a national and international perspective. To achieve recognition and protection of these heritage values, the Queensland Government is committed to the identification and declaration of Areas of International Conservation Significance (AICS) as stipulated in the *Cape York Peninsula Heritage Act 2007*. These areas may form the basis of nominations for places within Cape York Peninsula to be considered for National and World Heritage listing.

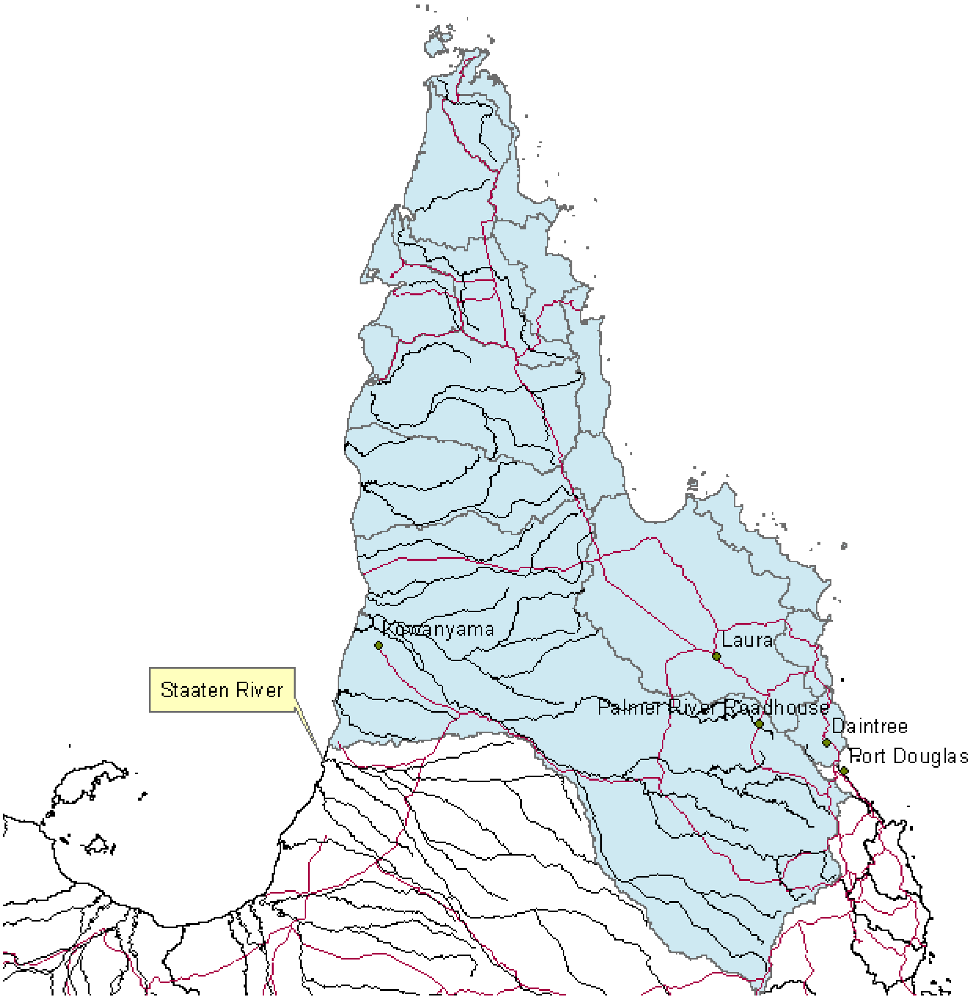


Figure 1.1. The Cape York Peninsula region.

[1] We recognise the importance of using catchment boundaries for demarcating the boundary of freshwater units for conservation and management (see Abell *et al*., 2007). We have therefore slightly modified the location of the southern boundary of the Cape York Peninsula region as defined in the *Cape York Peninsula Heritage Act 2007* to fully exclude the Staaten River and fully include the Mitchell River.

Table 1.1. Definitions of natural and cultural heritage. Definition of natural heritage and natural significance from the *Australian Natural Heritage Charter* (2002); definition of cultural significance adapted from the *Queensland Cultural Heritage Act 1992*

Natural heritage means:	**Cultural heritage** means:
• natural features consisting of physical and biological formations or groups of such formations, which demonstrate *natural significance* • geological and physiographical formations and precisely delineated areas that constitute the habitat of *indigenous species* of animals and plants, which demonstrate *natural significance* • natural sites or precisely-delineated natural areas which demonstrate *natural significance* from the point of view of science, conservation or natural beauty.	• Tangible items, such as monuments, buildings, artefacts, historical documents, and other objects, that demonstrate *cultural significance* • Intangible items, such as knowledge, laws, beliefs, customs, traditions, and other practices, that demonstrate *cultural significance.*
Natural significance means:	**Cultural significance** means:
• the importance of ecosystems, biodiversity and geodiversity for their existence value or for present or future generations, in terms of their scientific, social, aesthetic and life-support value	• the importance of aesthetic, architectural, historical, scientific, social or other value to the present generation or to past or future generations

As part of the process to identify and declare Areas of International Conservation Significance, the Queensland Government, in partnership with the Cape York Peninsula Scientific and Cultural Advisory Committee (CYPSCAC) and the Cape York Peninsula Regional Advisory Committee (CYPRAC), commissioned six preliminary overview studies or ‘Stories’ that review and synthesise biophysical and cultural heritage values of Cape York Peninsula – Geology (Willmott, 2009), Fauna (Winter, 2009), Flora (Wannan, 2009), Ethno-ecology (Ziembicki, 2010), non-Indigenous and Shared History (Horsfall & Morrison, 2010) and Cultural Heritage (Sutton, 2010). Collectively, these studies as well as past syntheses of natural heritage values (e.g. Valentine, 2006, Smyth & Valentine, 2008) have inadequately documented the hydroecology and heritage values of freshwater-dependent ecosystems of Cape York Peninsula. The Queensland Government and CYPSCAC have therefore recommended that a review paper be prepared that describes the national and international significance of the hydroecology of Cape York Peninsula within the context of a potential National and World Heritage listing.

The purpose of this report is to present the hydroecological story of Cape York Peninsula within an assessment framework that considers the natural heritage values of freshwater-dependent ecosystems and hydroecological processes of the region with respect to National and World Heritage selection criteria. The report will document:

1. the extent, variety and distinctiveness of aquatic ecosystem types in the region,
2. biodiversity and biogeographic patterns of freshwater-dependent flora and fauna,
3. hydroecological processes that sustain the natural integrity and biodiversity of freshwater-dependent ecosystems,
4. preliminary assessments of the National and International natural heritage significance of hydroecological features of Cape York Peninsula. These assessments are made using multiple lines of evidence, including indicators of significance, comparative analyses, and natural integrity.

This report considers biophysical (i.e. natural) heritage values of freshwater-dependent ecosystems of Cape York Peninsula. Whilst the freshwater-dependent ecosystems and hydroecological processes of Cape York Peninsula have very high cultural heritage and social significance at national and international scales (e.g. Stoeckl *et al*., 2006), particularly with respect to Indigenous heritage (e.g. Jackson & Morrison, 2007; Smyth & Valentine, 2008; Jackson, 2009; Sutton, 2010; Jackson *et al*., in press), a systematic and thorough treatment of cultural heritage significance is beyond the scope of this report.

2.0 Background to the Project

2.1 Overview of hydroecology and aquatic biodiversity

Biodiversity, as defined in the *Nature Conservation Act 1992* and recognised in the Queensland Government's draft biodiversity strategy, *Building Nature's Resilience: A Biodiversity Strategy for Queensland* (DERM, 2010a), is 'the natural diversity of wildlife, including plants and animals, together with the environmental conditions for their survival'. These documents recognise various components and scales of biodiversity: regional diversity (e.g. landscape diversity), ecosystem diversity (e.g. biotic community diversity, β-diversity), species diversity (e.g. species richness, endemism), and genetic diversity (e.g. molecular and phenotypic diversity). Hydroecological processes are fundamental determinants of biodiversity patterns in freshwater-dependent ecosystems at these various scales, and they play key roles in sustaining the environmental conditions required for the survival and viability of aquatic and terrestrial plants and animals (e.g. Lytle & Poff, 2004; Pusey & Kennard, 2009; Poff & Zimmerman, 2010).

The field of hydroecology seeks to explain the relationships between hydrological processes, biotic structure (e.g. species richness, composition, abundance) and ecological processes (e.g. food webs and trophic linkages, cues for reproduction, connectivity and migration opportunities for biota) at a variety of spatial scales (Pusey & Kennard, 2009; Poff *et al*., 2010). Key hydrological processes include the magnitude and seasonal pattern of river flows; the timing of extreme flows; the frequency, predictability, and duration of floods, droughts, and intermittent flows; daily, seasonal, and annual flow variability; rates of change in flow events; and surface water – groundwater interactions (Poff *et al*., 1997; Bunn & Arthington, 2002). Spatial variation in these hydrologic characteristics and processes is determined by variations in climate, catchment geology, topography and vegetation across landscapes (Pusey & Kennard, 2009). The hydroecological assessment presented in this report identifies places across Cape York Peninsula with unique and/or representative hydroecological features potentially worthy protection on the basis of their natural heritage values.

2.2 The World Heritage Convention and World Heritage Criteria

Cultural and natural heritage is recognised by the United Nations Educational, Scientific and Cultural Organisation (UNESCO) to be among the most priceless and irreplaceable assets belonging to human societies. Some components of heritage have exceptional qualities at the global scale, and places that have these qualities may be of "outstanding universal value" and worthy of special protection. In 1972 UNESCO adopted the *World Heritage Convention*, which has the aim of identifying, protecting, conserving, presenting and transmitting to future generations the world's cultural and natural heritage of outstanding universal value. Properties with heritage values of 'outstanding universal value', that is 'cultural and/or natural significance which is so exceptional as to transcend national boundaries and to be of common importance for present and future generations of all humanity, with permanent protection of this heritage being of the highest importance to the international community as a whole', are inscribed on the World Heritage List. The criteria for including properties on the World Heritage List have been developed to evaluate the outstanding universal value of properties (Table 2.1) and to guide their protection and management.

Table 2.1. The selection criteria and conditions for the inscription of properties on the World Heritage List, as defined in the *Operational Guidelines for the Implementation of the World Heritage Convention* (2008).

Selection criteria for properties with outstanding universal cultural values	
i.	to represent a masterpiece of human creative genius;
ii.	to exhibit an important interchange of human values, over a span of time or within a cultural area of the world, on developments in architecture or technology, monumental arts, town-planning or landscape design;
iii.	to bear a unique or at least exceptional testimony to a cultural tradition or to a civilization which is living or which has disappeared;
iv.	to be an outstanding example of a type of building, architectural or technological ensemble or landscape which illustrates (a) significant stage(s) in human history;
v.	to be an outstanding example of a traditional human settlement, land-use, or sea-use which is representative of a culture (or cultures), or human interaction with the environment especially when it has become vulnerable under the impact of irreversible change;
vi.	to be directly or tangibly associated with events or living traditions, with ideas, or with beliefs, with artistic and literary works of outstanding universal significance. (The Committee considers that this criterion should preferably be used in conjunction with other criteria);
Selection criteria for properties with outstanding universal natural values	
vii.	to contain superlative natural phenomena or areas of exceptional natural beauty and aesthetic importance;
viii.	to be outstanding examples representing major stages of earth's history, including the record of life, significant on-going geological processes in the development of landforms, or significant geomorphic or physiographic features;
ix.	to be outstanding examples representing significant on-going ecological and biological processes in the evolution and development of terrestrial, fresh water, coastal and marine ecosystems and communities of plants and animals;
x.	to contain the most important and significant natural habitats for in-situ conservation of biological diversity, including those containing threatened species of outstanding universal value from the point of view of science or conservation
Since 1992 significant interactions between people and the natural environment have been recognized as **cultural landscapes.**	

2.3 National Heritage Criteria

The Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) mandates the National Heritage List. The Minister for the Environment, Heritage and the Arts must be satisfied that a place meets one or more of the National Heritage Criteria (Table 2.2) before it can be included in the National Heritage List. Usually the Minister makes this decision after receiving a formal recommendation from the Australian Heritage Council, which is a body of heritage experts established by the *Australian Heritage Council Act 2003*. A place can only satisfy a National Heritage criterion if it has 'outstanding heritage value to the nation' for the reason set out in that criterion. The significance threshold 'outstanding heritage value' is used to determine whether a place has significant heritage values when it is compared to other, similar types of places. National Heritage values identified in an assessment must be described precisely and with respect to the geographical scope of the values.

Table 2.2. National Heritage Criteria against which the heritage values of a place are assessed, as stipulated in the *Environmental Protection and Biodiversity Conservation Act 1999.*

National Heritage Criteria
a. the place has outstanding heritage value to the nation because of the place's importance in the course, or pattern, of Australia's natural or cultural history
b. the place has outstanding heritage value to the nation because of the place's possession of uncommon, rare or endangered aspects of Australia's natural or cultural history
c. the place has outstanding heritage value to the nation because of the place's potential to yield information that will contribute to an understanding of Australia's natural or cultural history
d. the place has outstanding heritage value to the nation because of the place's importance in demonstrating the principal characteristics of: i. a class of Australia's natural or cultural places; or ii. a class of Australia's natural or cultural environments;
e. the place has outstanding heritage value to the nation because of the place's importance in exhibiting particular aesthetic characteristics valued by a community or cultural group
f. the place has outstanding heritage value to the nation because of the place's importance in demonstrating a high degree of creative or technical achievement at a particular period
g. the place has outstanding heritage value to the nation because of the place's strong or special association with a particular community or cultural group for social, cultural or spiritual reasons
h. the place has outstanding heritage value to the nation because of the place's special association with the life or works of a person, or group of persons, of importance in Australia's natural or cultural history
i. the place has outstanding heritage value to the nation because of the place's importance as part of Indigenous tradition.

2.4 Cape York Peninsula Heritage Act 2007

The *Cape York Peninsula Heritage Act 2007* (CYPHA) was enacted by the Queensland Parliament in accordance with the Queensland Government's commitment to identify and protect the heritage values of Cape York Peninsula (Table 2.3). This legislation extends and remedies conflicts surrounding the Cape York Heads of Agreement, and provides a legal framework for sustainably managing natural, Indigenous and pastoral interest on Cape York Peninsula. A key purpose of the Act is to set a mandate for identifying and declaring Areas of International Conservation Significance (AICS). A Regulation pursuant to the Act may declare an AICS if the Minister for Environment is satisfied that the natural or cultural heritage values of the property meet one or more of the criteria for inclusion of properties on the World Heritage List. The nomination of the Cape York Peninsula region, or properties within the region, for World Heritage listing is also a priority management action within the draft Queensland Biodiversity Strategy, *Building Nature's Resilience: A Biodiversity Strategy for Queensland* (DERM, 2010a).

Table 2.3. Object of the Queensland *Cape York Peninsula Heritage Act 2007*

The objects of this Act are:
(a) to identify significant natural and cultural values of Cape York Peninsula; and (b) to provide for cooperative management, protection and ecologically sustainable use of land, including pastoral land, in the Cape York Peninsula Region; and (c) to recognise the economic, social and cultural needs and aspirations of indigenous communities in relation to land use in the Cape York Peninsula Region; and (d) to recognise the contribution of the pastoral industry in the Cape York Peninsula Region to the economy and land management in the region.
The objects are to be achieved primarily by providing for:
(a) the declaration of areas of international conservation significance; (b) the cooperative involvement of landholders in the management of the natural and cultural values of Cape York Peninsula; and (c) the continuance of an environmentally sustainable pastoral industry as a form of land use in the Cape York Peninsula Region; and (d) the declaration of indigenous community use areas in which indigenous communities may undertake appropriate economic activities; and (e) the establishment of committees to advise the environment Minister and vegetation management Minister about particular matters under this Act.

2.5 Other management instruments for protecting biodiversity and natural heritage values of freshwater-dependent ecosystems

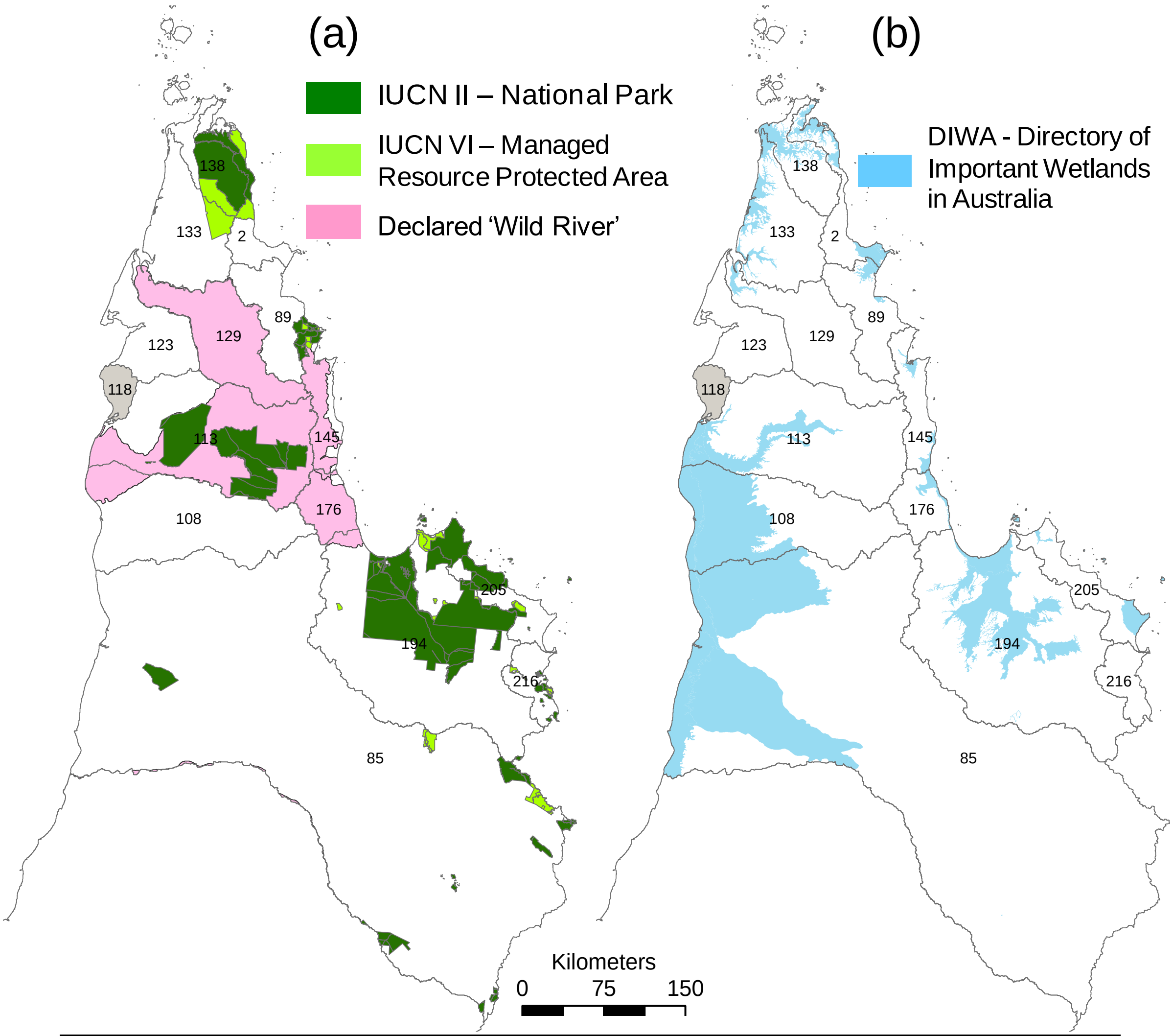
2.5.1 The protected area estate, Indigenous Protected Areas, and Wild River declarations

Protected areas are properties dedicated to the protection of the biological diversity and other natural and cultural resources of the property, managed through legal or other effective means [International Union for the Conservation of Nature (IUCN), 1994]. The current reserve system in Cape York Peninsula is composed of 80 reserves that cover 21,665 km^2 (CAPD, 2006, IUCN categories IA-VI; Fig. 2.1a). This equates to approximately 11.6% of the land area of Cape York Peninsula, with 85% of the 233 Regional Ecosystems (REs) of Cape York Peninsula within protected areas at some level and 37% of REs within protected areas at target levels stipulated in the draft *Protected Areas for the Future* (DERM, 2010b) document.

In Queensland, the protected area estate is administered by the *Nature Conservation Act 1992*. This Act was amended in 2007 to create a new class of protected area on Cape York Peninsula, namely 'National Park (Cape York Peninsula Aboriginal Land)' [NP(CYPAL)] where Traditional Owners have entered into an Indigenous Management Agreement (IMA) with the Queensland Government for the joint management of the land. Similarly, at the National level, Indigenous Protected Areas (IPAs) (see *Australia's Strategy for the National Reserve System 2009 – 2030;* Commonwealth of Australia, 2009) are gazetted for properties where Traditional Owners have entered into an agreement with the Australian Government for the conservation of biodiversity and cultural resources. Two of Queensland's three IPAs are in the Cape York Peninsula region: the *Kaanju Ngaachi Wenlock and Pascoe Rivers Indigenous Protected Area*, and the *Warul Kawa Indigenous Protected Area* (located on Deliverance Island off the Cape York Peninsula coastline).

Freshwater-dependent ecosystems have historically received poor protection within terrestrial protected areas (e.g. Allen & Flecker, 1993; Pringle, 2001; Dunn, 2003; Dudgeon *et al*., 2006). Recently scientists have urged the expansion of dedicated freshwater protected areas (e.g. Kingsford & Neville, 2005; Kingsford *et al*., 2005; Abell *et al*., 2007), including in northern Australia (Blanch 2008). In Queensland, the *Wild Rivers Act 2005* aims to preserve the natural values of rivers that have all, or almost all, of their natural values intact by establishing a framework that includes the declaration of wild river areas (Queensland Government, 2011a). A wild river declaration may include one or more of four types of management zone: (a) high preservation area, (b) preservation area (c) floodplain management area, and (d) subartesian management area. To date, eight wild rivers have been declared in the Gulf of Carpentaria and Cape York Peninsula: Settlement, Gregory, Morning Inlet, Staaten, Archer, Wenlock, Lockhart and Stewart basins (Fig 2.1a). The *Cape York Peninsula Heritage Act 2007* makes special provisions for the Minister of the *Wild Rivers Act 2005*, and confirms the protection of Native Title rights in wild river declarations.

The expansion of Queensland's protected area estate is one of three primary objectives of the Queensland Government's draft biodiversity strategy, *Building Nature's Resilience: A Biodiversity Strategy for Queensland* (DERM, 2010a). The companion document to this strategy, the draft *Protected Areas for the Future* (DERM, 2010b) (PAF), provides an overview of the general approach to be used for protected area selection needed to achieve the protected area targets outlined in the draft biodiversity strategy. The PAF methodology presently does not specify a methodology for assessing conservation needs of freshwater-dependent ecosystems in Queensland; consequently there are no conservation targets for freshwater-dependent ecosystems within the draft biodiversity strategy. However, a priority action in the draft biodiversity strategy is to 'Update the PAF to address freshwater and marine ecosystem conservation'. Until this revision is available, it remains unclear how freshwater protected areas (i.e. wild river declarations) will be expanded over the next ten years.



ID	Basin Name	ID	Basin Name	ID	Basin Name
2	JACKY JACKY CREEK	118	WARD RIVER	145	LOCKHART RIVER
85	MITCHELL-COLEMAN RIVERS	123	EMBLEY RIVER	176	STEWART RIVER
89	OLIVE-PASCOE RIVERS	129	WENLOCK RIVER	194	NORMANBY RIVER
108	HOLROYD RIVER	133	DUCIE RIVER	205	JEANNIE RIVER
113	ARCHER-WATSON RIVERS	138	JARDINE RIVER	216	ENDEAVOUR RIVER

Figure 2.1. (a) Designated protected areas (CAPD 2006). (b) Directory of Important wetlands in Australia (DIWA).

2.5.2 The Ramsar Convention and the Directory of Important Wetlands in Australia

The Convention on Wetlands of International Importance especially as Waterfowl Habitat (the 'Ramsar Convention', Ramsar, Iran, 1971) is an intergovernmental treaty that provides a framework for the conservation and wise use of wetlands and their resources through national action and international cooperation (Ramsar Bureau, 2009). The convention originally emphasised the conservation of wetlands primarily as habitat for waterbirds, however has recently broadened its scope to include all aspects of wetland conservation, recognizing that wetlands are important for sustaining biodiversity and for the well-being of human communities. Ramsar wetlands are designated if one or more criteria relating to the wetland's uniqueness, rarity, or representativeness, or its biological diversity, is satisfied. To date, no wetlands from Cape York Peninsula have been included on the Ramsar List.

In contrast, 33,833 km^2 of wetland from Cape York Peninsula is included within *A Directory of Important Wetlands in Australia* – DIWA (DSEWPaC, 2011; Fig. 2.1b). DIWA lists nationally important wetlands if they are a good example of a wetland type within a biogeographic region;

have an important hydrological or ecological role; are refuge habitat; support one percent or more of a plant or animal population; are habitat for a nationally endangered or vulnerable animals; or have cultural or historical significance (DSEWPaC, 2011). The directory provides key information about the location, condition and characteristics of important wetlands throughout Australia, with the application of this information in conservation and sustainable wetland use being a rationale for compiling and making accessible this information. There do not appear to be any prescriptive conservation management obligations associated with DIWA designation (DSEWPaC, 2011) so listed DIWA wetlands and their ecological values are not necessarily protected from current or future threatening processes. The largest DIWA sites in Northern Australia include the Northern Holroyd Plain Aggregation and Mitchell River Fan Aggregation in western Cape York Peninsula and the Marina Plains – Lakefield Aggregation in eastern Cape York Peninsula. These vast wetland complexes consists of a series of riverine, lacustrine and palustrine water bodies that provide dry season refuge for waterbirds and other freshwater dependent fauna and flora and are of high cultural significance to indigenous people.

2.5.3 The National Water Initiative

The National Water Initiative (NWI) is an intergovernmental agreement between the Commonwealth and the States, signed at the Council of Australian Government (COAG) meeting in 2004. The initiative reflects the shared commitment of Governments to improve water management in Australia, including improved water access entitlements for Indigenous people (Jackson, 2009) and the identification and protection of aquatic ecosystems of high conservation value (Kennard, 2010). With respect to the second point, the Aquatic Ecosystem Task Group representing the Australian, state and territory governments is developing a common framework for the various governments to use to identify and classify High Conservation Value Aquatic Ecosystems (HCVAE[2]; AETG, 2009a). 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 (AETG, 2009b). The draft HCVAE Framework, with its multi-criteria, is intended to 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 Environmental Protection and Biodiversity Conservation (EPBC) Act.

As outlined in the draft Framework (AETG, 2009a), the criteria for identifying HCVAEs for particular areas are:

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.

The full draft Framework has recently been applied and evaluated in northern Australia (Kennard, 2010; 2011). This involved selecting appropriate attributes to characterise the six Framework criteria and applying them to seven sets of biodiversity surrogate data (three aquatic ecosystem types and four water-dependent species groups). The full list of attributes and details on their rationale, methods of calculation and key supporting references are provided in 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 5,803 sub-basins across northern Australia.

[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.

The relative conservation value of each sub-basin based on each HCVAE Framework criterion is presented in Figure 2.2. 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. Notable 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 of Carpentaria 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.

The multi-criteria HCVAE Framework and individual biodiversity attributes (e.g. species richness) represent spatially explicit 'scoring' approaches to prioritising freshwater systems. Scoring approaches assess each area individually. Highest ranking areas can contain the same conservation features (species or types of natural environments and the fundamental currency of conservation assessments) which are duplicated, while other features remain completely unrepresented, especially if they occur only in low-ranking areas (Carwardine *et al.,* 2007). Importantly, none of the Framework criteria are designed to identify a set of areas that efficiently represent the full range of conservation features, or identify sets of areas that need to be managed to conserve species and the processes that sustain them.

Hermoso *et al*. (2010) implemented a systematic conservation planning analysis in northern Australia, the first time that such an approach has been carried out in freshwater ecosystems at this broad spatial scale and number of different biodiversity features in Australia and worldwide. They used Marxan software (Ball *et al.,* 2009) to conduct the analyses (one of the world's most widely used tools for systematic conservation planning in marine, terrestrial and freshwater systems). Their goal was to select a minimum set of areas to represent the full range of species (freshwater fish, turtles and waterbirds) and aquatic ecosystem types (i.e. classes of rivers, lakes and palustrine wetlands) in the region (based on the same set of 5,803 sub-basins used in the multi-criteria assessment described above). They evaluated the influence of various target levels of occurrence of the conservation features, and explored different longitudinal and lateral connectivity rules hypothesised to be important considerations in the selection and spatial configuration of high conservation value areas. They also penalised the selection of sub-basins that were disturbed by human activity as quantified using the River Disturbance Index (Stein *et al.,* 2002; see section 5.0). Three main focal areas of high conservation value were identified using the systematic conservation planning approach (Hermoso *et al.,* 2010): 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. 2.3). The spatial distribution of priority areas tended to be consistent across the biodiversity surrogates (e.g. species groups and aquatic ecosystem types) but differed from the ones identified using the multi-criteria HCVAE Framework (Fig. 2.2), illustrating that different priority areas would be identified using different methods.

At the State level, the objectives of the NWI are achieved through Water Resource Plans (WRP) pursuant to the *Water Resources Act 2000* (Queensland Government, 2011b). Water Resource Plans prepare for the allocation and sustainable management of water to meet Queensland's future water requirements. To date, a WRP has been completed and implemented for the Mitchell River and a draft WRP is in preparation for the Wet Tropics region, which includes the Daintree River.

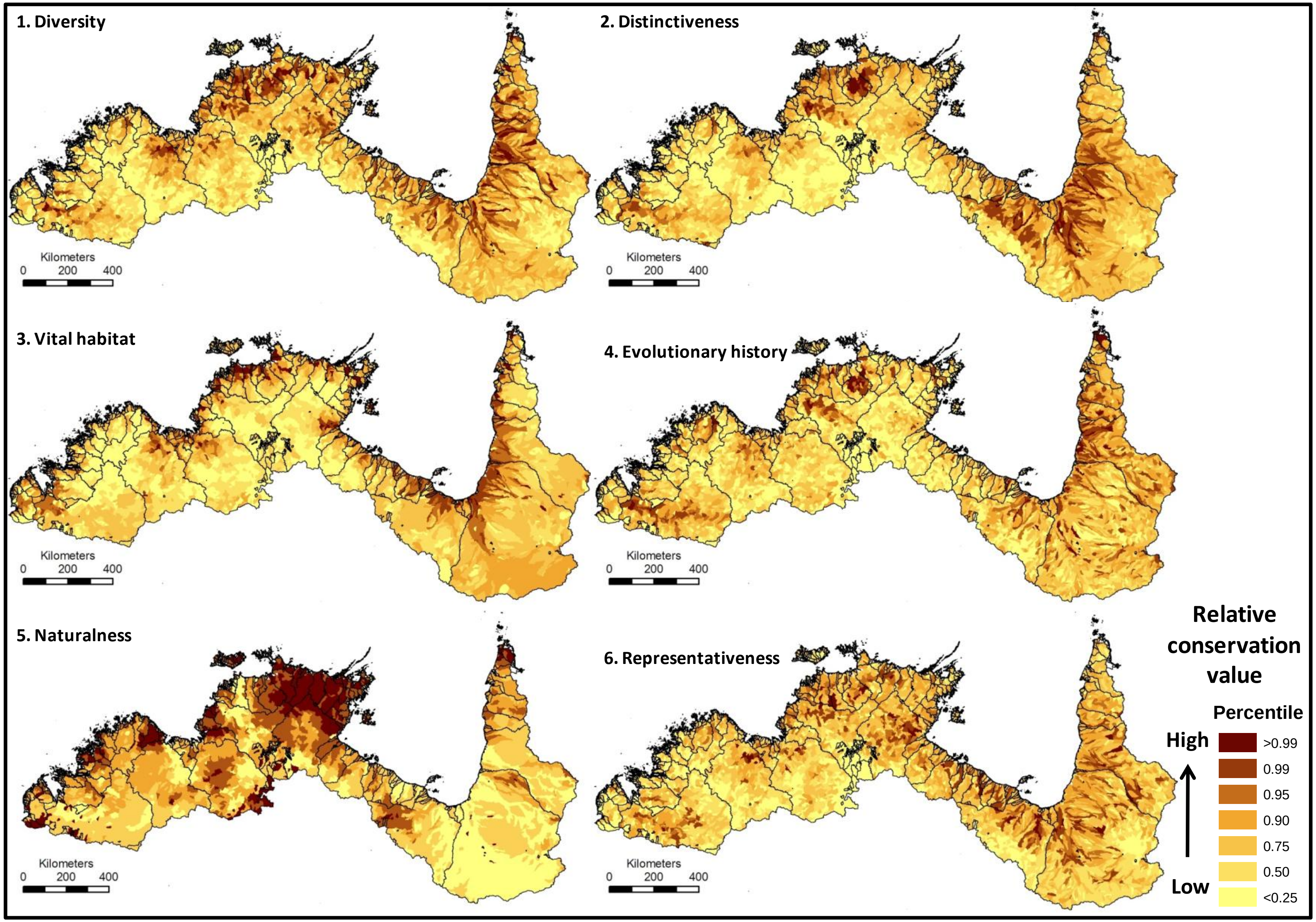


Figure 2.2. Relative conservation value for each sub-basin according to the six HCVAE Framework criteria (scores are calculated relative to the entire study region) (source: Kennard 2010).

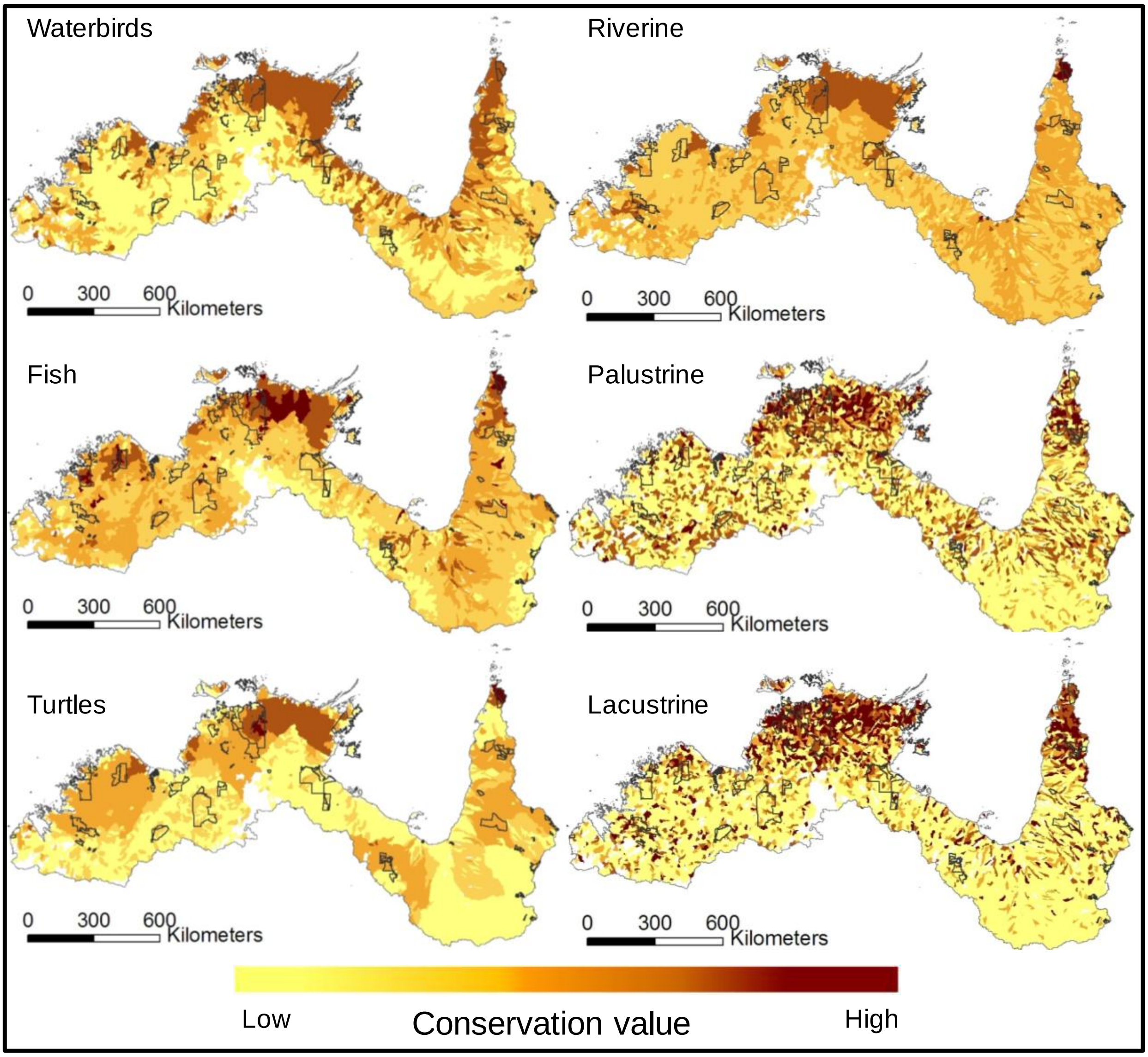
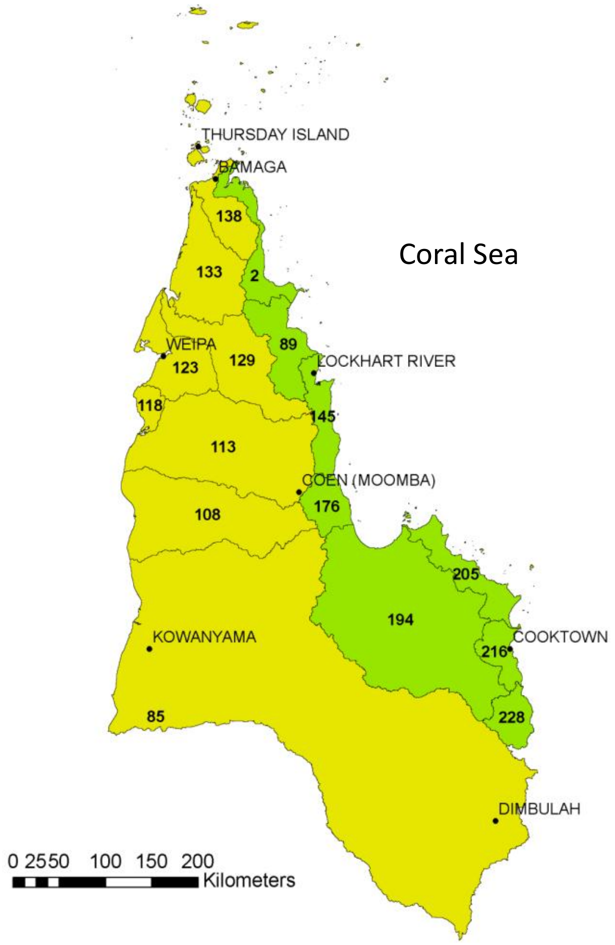


Figure 2.3. Relative conservation value of sub-basins in northern Australia identified using a systematic conservation planning approach. Relative conservation value represents the number of times that each sub-basin was included in the best solution after 100 runs (using Marxan software – Ball *et al.,* 2009). High values indicate highly irreplaceable areas, which were necessary most of the time to achieve the conservation goal of representing all taxa at specified distribution target levels for each biodiversity surrogate group. The solutions are averaged across four representation targets levels for each taxon (10 km^2, 100 km^2, 1000 km^2, 10,000 km^2) (source: Hermoso *et al.,* 2010).

3.0 Regional hydroecology of Cape York Peninsula in the Australian and global monsoon-savanna context

3.1 Drainage Divisions and River Basins

As part of the Australian Bureau of Meteorology 's water resources information system, a continent-wide catchment framework, known as the National Catchment Boundaries (NCB) has been developed to support Australian water resource management (Bureau of Meteorology, 2010). Under the NCB framework, Cape York Peninsula contains two drainage divisions: the East Coast and Gulf of Carpentaria drainage divisions. The East Coast drainage division contains eight river basins that drain east of the Great Dividing Range into the Coral Sea (Fig. 3.1). The Gulf of Carpentaria drainage division contains eight basins that drain west of the Great Dividing Range into the Gulf of Carpentaria (Fig. 3.1).



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205	JEANNIE RIVER
216	ENDEAVOUR RIVER
228	DAINTREE RIVER

Figure 3.1. National Catchment Boundaries (NCB) Cape York Peninsula drainage divisions and basins. The ID in the above table can be used to identify NCB basin name from the NCB basin map.

3.2 Climate

The hydrology of the rivers of Cape York Peninsula is controlled by landscape topography, climate and underlying groundwater. The majority of rainfall is associated with the southern monsoon and occurs during the summer months of October to March (Fig 3.2a). As a consequence, most stream flow also occurs in these months. High rates of evapotranspiration (Fig 3.2b) ensure that most rivers are intermittent and have long periods of little flow.

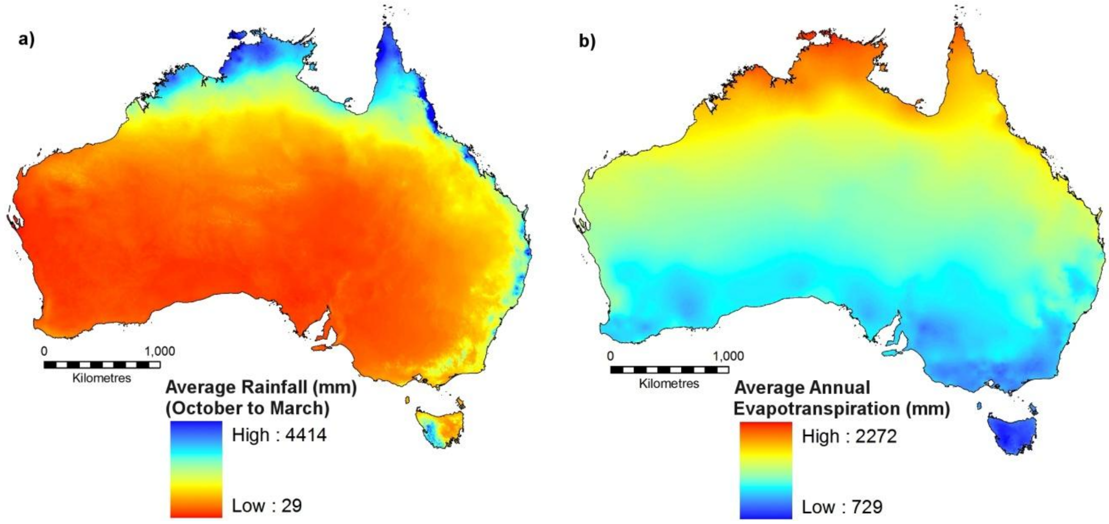

Figure 3.2. a) Average rainfall total during the 'wet' season (October to March) in northern Australia derived from long term rainfall records for the region; b) Average annual evapotranspiration for northern Australia derived from long term records for the region (source: Australian Bureau of Meteorology).

3.3 Aquatic system distributions

Freshwater aquatic systems can be classified broadly into different types of large 'organising entities' designed to represent the variety of aquatic ecosystem types (e.g. estuaries, rivers, lakes) (Auricht, 2010). Aquatic systems can consist of one ecotope (the smallest ecologically-distinct features in a landscape classification system) or an aggregation of ecotopes. For example, a complex of swamps along a river floodplain can be regarded as a single aquatic system. The types of aquatic systems (and their constituent ecotopes) addressed in this section are listed Table 3.1; (note that marine and coastal foreshore aquatic systems are not considered in this section). Information used in the analysis of aquatic system distributions presented in this section is drawn from the Queensland Wetland Mapping and Classification program (Environmental Protection Agency, 2005). The aquatic system mapping associated with this program is based on a combination of topographic water feature mapping, floristic ecosystem mapping, and waterbody inundation from historic time series of satellite imagery. The aquatic system map product used in the distribution analysis is at a scale of 1:100,000 or better.

Table 3.1. Cape York Peninsula aquatic systems and their associated ecosystem types (Auricht, 2010).

Aquatic System	Ecotope types present in Cape York Peninsula
Riverine	Rivers, streams and channelized water bodies that often have fringing aquatic vegetation (but not including the hyporheic zone).
Lacustrine	Large water bodies situated in a topographic depression or river channels that are largely open water features but may contain fringing aquatic and terrestrial vegetation.
Palustrine	Floodplains and vegetated wetlands such as marshes, bogs and swamps, and including small, shallow, permanent or intermittent floodplain water bodies.
Estuarine*	Semi-enclosed embayments receiving sea water and fresh water inputs, mangrove forests, saltmarshes, saltflats, intertidal flats.
Subterranean	Groundwater environments including the hyporheic zone and underground streams, lakes and water-filled voids

* Whilst not a freshwater hydrosystem owing to the typically elevated salinity, the integrity and function of estuarine systems is reliant on freshwater inputs and associated sediments; thus, estuaries are freshwater-dependent ecosystems.

3.3.1 Riverine aquatic systems

Riverine aquatic systems encompass an extraordinary diversity of habitats and form, ranging from tiny headwater creeks through to large tributary rivers and mighty main channel lowland rivers (Fig. 3.3). The stream networks that form rivers vary greatly in their structure, leading to a diversity of river forms. Rivers may be deeply incised in bedrock or may migrate across their floodplains at times of very high flow, abandoning old channels and creating new habitats. Streams may be intermittent or perennial depending on the extent to which groundwater contributes to dry season base flows. Isolated pools in intermittent rivers may be sustained by connection to groundwater or hyporheic (subsurface) flow during the dry season and may therefore persist over this period. Others without such connections, depending on their size, may dry up well before the wet season again renews flow. Waterfalls and other topographic features may pose significant barriers to upstream movement by fish and biota during low flow, but may also form significant habitats (e.g. the splash zone of the waterfalls) and contribute to overall aquatic habitat diversity.

The structure and physical character of Cape York Peninsula's rivers is significantly influenced by the proximity of the Great Dividing Range to the east coast, and the transition to increasing annual rainfall to the north. With the exception of the Normanby River catchment, the catchments to the east of the Great Dividing Range are relatively small and drain into the Coral Sea. Most catchments to the west of the Great Dividing Range experience a large decrease in elevation as the rivers drain to the west into the Gulf of Carpentaria. This effect is most notable in the Mitchell catchment. The rugged hill terrain in much of the headwater areas of the Mitchell River (ranging up to 1200 m elevation) grades to Australia's largest fluvial megafan that dominates the western part of the catchment. Despite being only the 13^{th} largest by area, the Mitchell River catchment has one of the highest mean annual discharge volumes in Australia (>8,000,000 ML/y) (Brooks *et al*., 2009). A characteristic feature of catchments to the south west of Cape York is the distributary and often complex anabranching nature of the floodplain drainage networks (e.g. the Coleman, Holroyd, Archer and Watson River systems) (Fig. 3.3). These distributary systems associated with fluvial megafans are unique to Cape York Peninsula and the southern Gulf of Carpentaria, and are found nowhere else in tropical Australia. Lower catchment slope is characteristic of the wide flat landscape of south west Cape York Peninsula, leading to streams having fewer first and second order streams and a greater proportional length of very large rivers (> 6^{th} order) (Fig. 3.3). To the east of the Great Dividing Range the catchments are dominated by the Normanby River system that drains via a complex network of channels into the extensive salt flats areas of Princess Charlotte Bay. Amongst the catchments to the east, the Daintree River is distinct due to both higher rainfall and catchment slope, leading to a high drainage network density. The differences in structure and physical character of Cape York Peninsula's rivers lead to differences in the structure and distribution of aquatic habitat. This, in turn, is important in determining the distribution of aquatic biota.

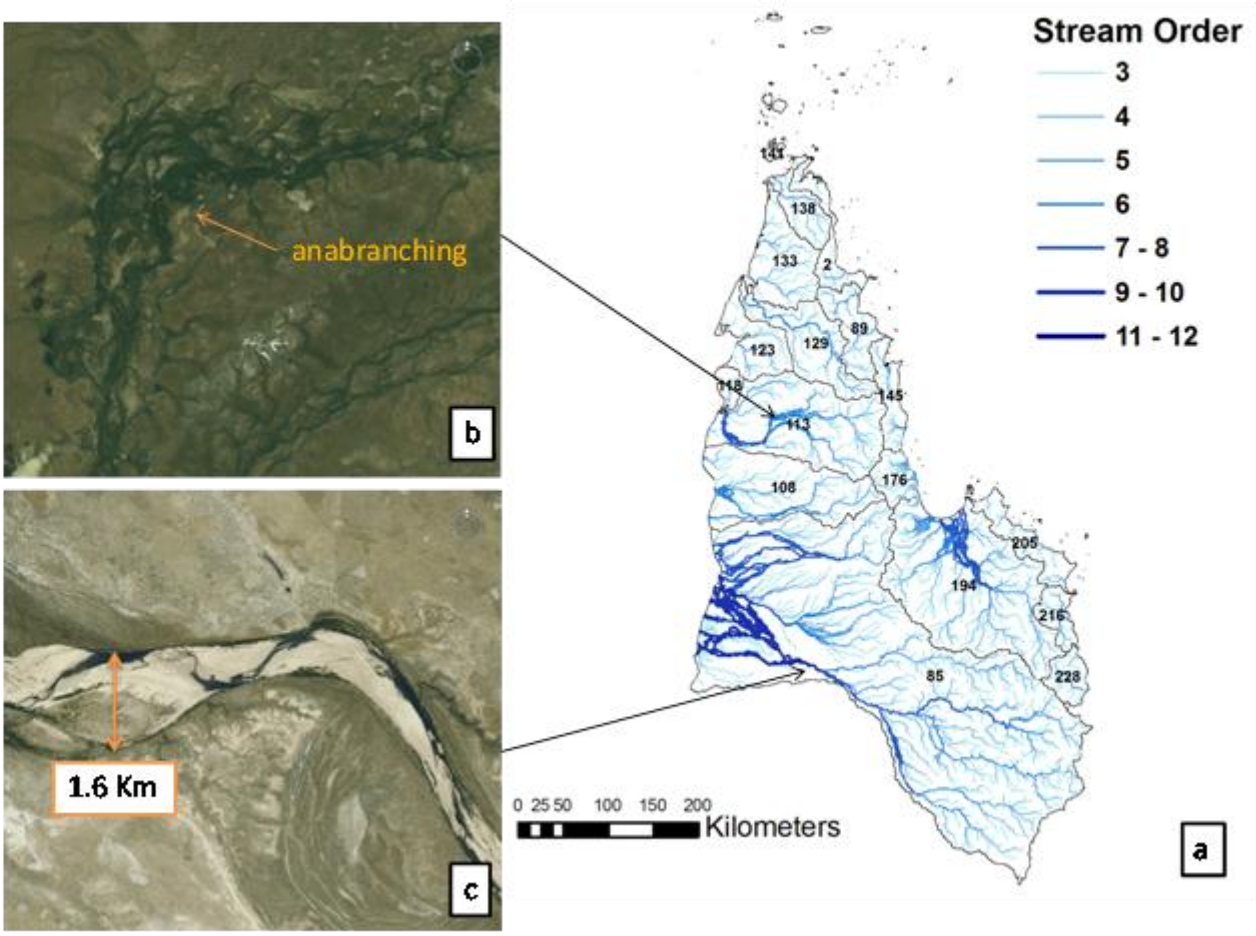

Figure 3.3. a) Distribution of Riverine aquatic systems of Cape York Peninsula showing Strahler stream order. Strahler stream order is used to define stream size based on a hierarchy of tributaries such that high order streams represent the main channels of river systems and low order streams represent the upper most part to the drainage network. Inserts: b) the anabranching Riverine system of the Archer River; and c) the broad main channel of the Mitchell River.

3.3.2 Lacustrine (lake) aquatic systems

Natural lakes are not a significant aquatic system on Cape York Peninsula. There are no lakes formed by glaciers, tectonic movement or volcanism. The most common form of lacustrine systems on Cape York Peninsula is ox bow lakes and coastal dune lake systems. Ox bow lakes (also to as billabongs or lagoons) are formed when a meandering river channel becomes so sinuous as to join back upon itself and "pinch off" of a segment of the meander loop (Fig. 3.4). This remnant channel section then becomes isolated as the channel migrates away with time. Such lakes retain much of their riverine character and much of its former fauna and flora which do not specifically require flowing water habitats. Oxbow lakes are important in the floodplain environment as they frequently form permanent aquatic habitats and thus provide refuge for aquatic organisms when other, shallower, floodplain wetlands dry out. While not being a significant aquatic system in terms of areal extent, ox box lake systems are wide spread across the savannas of northern Australia. The greatest densities of ox bow lake systems in northern Australia are found on the Fitzroy floodplain in Western Australia and on the floodplain of the Mitchell River on Cape York Peninsula (Fig. 3.4).

Coastal dune lakes are non-tidal, freshwater aquatic systems that occur in siliceous sands along coastal dune areas. The origin, evolution and processes involved in the formation of coastal dune lakes are diverse. Lakes may be formed in sand hollows created by wind (known as deflation hollows) or between parallel dunes (that is, in dune swales) (Pusey *et al.,* 2000) (Fig. 3.4). These lakes depend on local catchment runoff (rainwater) and/or groundwater. They are generally permanent in nature but may be semi-permanent or temporary depending on their location and climatic conditions. The water level of coastal dune lakes may change quite markedly between seasons. Globally, dune lake systems are a rare aquatic system but on Cape York Peninsula, large areas of coast dune lake systems occur at Shelburne Bay (Fig. 3.4) and Cape Flattery.

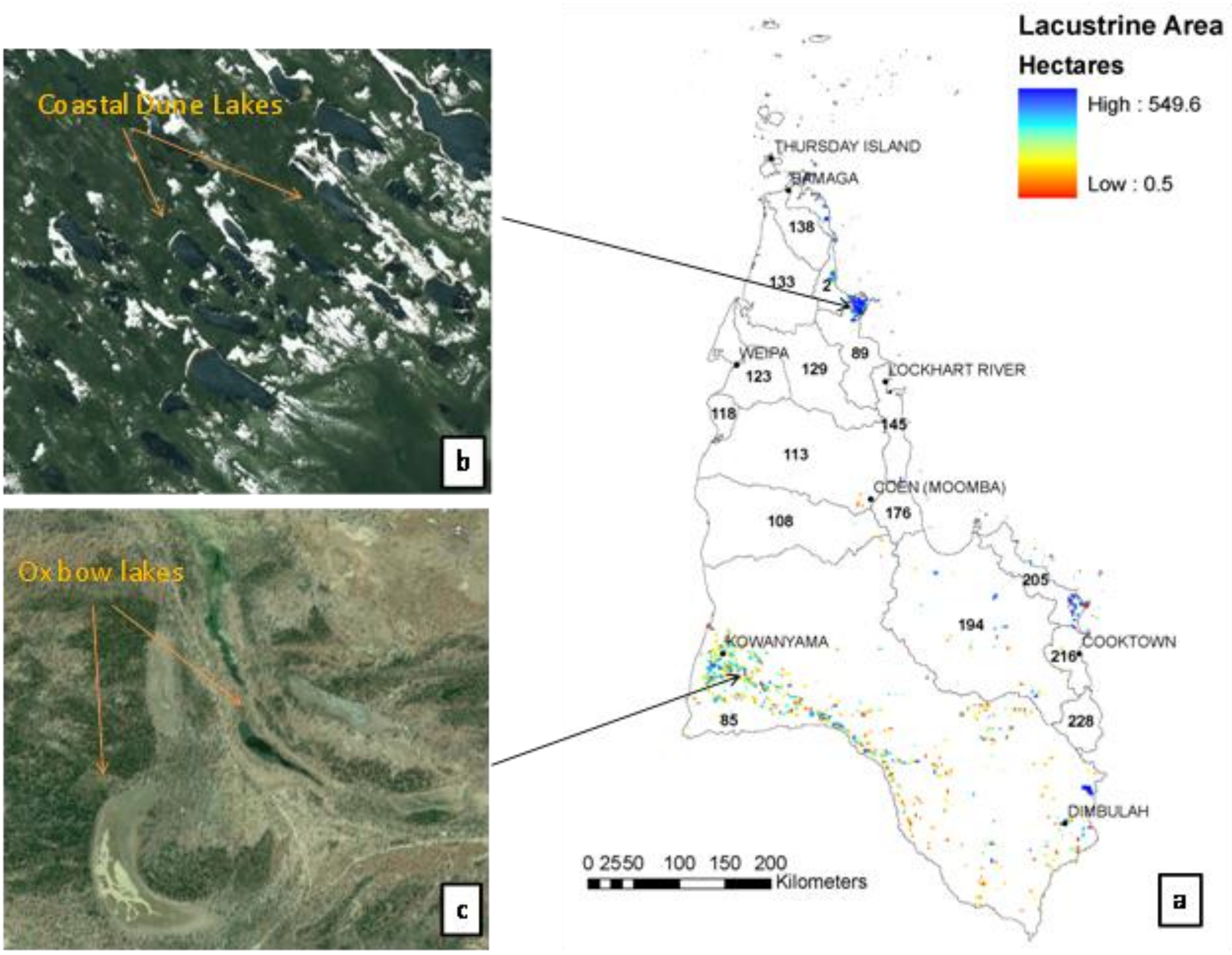

Figure 3.4. a) The area in hectares of lacustrine aquatic systems in 2.5 km^2 grids across Cape York Peninsula. Inserts: b) Coastal dune lakes systems at Shellburne Bay in the Jacky Jacky Creek catchment; and c) Ox bow lake systems on the floodplain of the Mitchell River catchment.

3.3.3 Palustrine (floodplain) aquatic systems

Across the savanna landscapes of northern Australia, the greatest density and areal extent of palustrine systems are found on Cape York Peninsula and the southern Gulf of Carpentaria. On Cape York Peninsula they comprise a significant component of the catchment area for river systems such as the Normanby, Mitchell, Coleman, and Holroyd catchments (Fig. 3.5). The presence of water in palustrine systems is largely determined by seasonal flooding derived from local rainfall and overbank flow from rivers in the wet season. As water spills out over the river banks, it can slow and spread out to fill palustrine waterbodies or form vast shallow palustrine wetlands (e.g. in the Jardine River system) (Fig. 3.5). Sediment and attached nutrients settle out and water clarity increases, which when combined with high water temperatures typical of summer, provides perfect conditions for high primary production. Many palustrine waterbodies do not persist through the dry season; at best they are greatly reduced in size. Whilst this may result in the dieback of much plant and animal biomass generated during the wet season, it provides a bountiful harvest for many waterbird species and terrestrial fauna that feed upon fish and frogs, and insects abundant in these waterbodies. It also provides very important opportunity for the cattle grazing industry. Grass production during the wet season provides forage for cattle throughout the long dry season.

On Cape York Peninsula, large palustrine systems such as those associated with the extensive wetland areas in the Wenlock, Jardine and Ducie river systems near the top of Cape York Peninsula provide habitat across a range of trophic levels, from small invertebrates to large predators such as crocodiles. Small, less permanent palustrine waterbodies cannot support large predators. However, in large cumulative numbers such as on the extensive floodplains of the Mitchell and Normanby River systems (Fig. 3.5), a high density of small water bodies can provide a great diversity of habitats, supporting a high diversity of bird species.

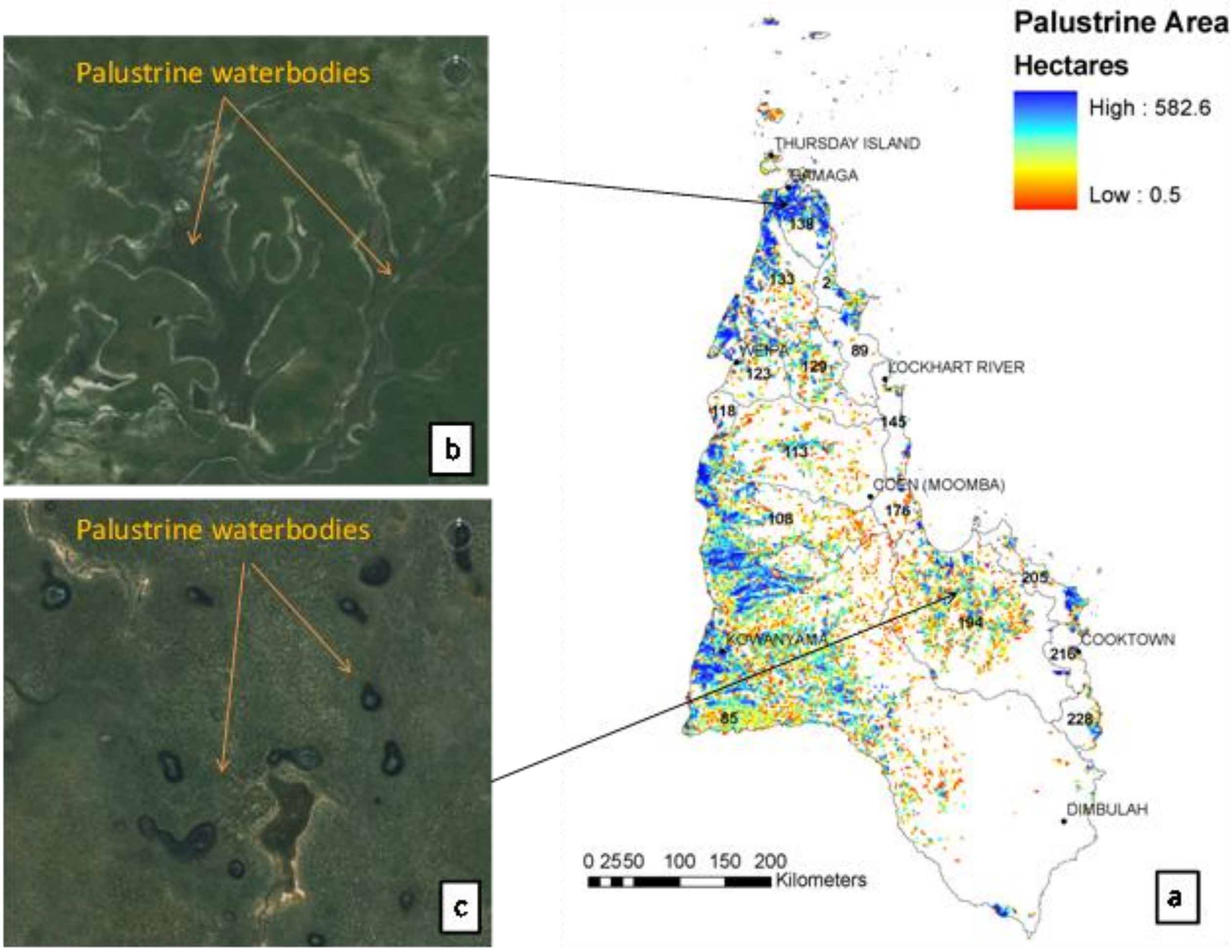

Figure 3.5. a) The area in hectares of palustrine aquatic systems in 2.5 km^2 grids across Cape York Peninsula. Inserts: b) Palustrine systems in the Jardine River catchment; and c) Palustrine systems on the floodplain of the Normanby River catchment.

3.3.4 Estuarine aquatic systems

Estuaries form the interface between freshwater and marine ecosystems and are areas of high production and biodiversity. The geomorphology of estuaries and coast lines are a function of the complex interplay between coastal energy regimes (i.e. waves and tides) and the riverine inputs (i.e. water and sediment discharge) from the contributing catchments. The geomorphology of a given estuary with its attendant tide and wave regime and freshwater inputs essentially dictates the availability of habitats within the estuary (or delta) and the associated ecosystem dynamics. Given the distinct characteristics of the Cape York Peninsula estuaries it is likely that they differ fundamentally in a range of their ecosystem functions compared to those in southern Australia. The most fundamental difference between Cape York Peninsula and southern Australian estuaries can be attributed to the dramatic differences in tidal regimes. Tides within the Gulf of Carpentaria are diurnal (1 tide per day) with a maximum range up to approximately 3m at the tip of the Cape

York. While the east coast tropical tides are also semi-diurnal, the tidal range tends to be more akin to those in the Gulf of Carpentaria. By contrast the majority of the southern Australian coastal zone has semi diurnal tides with a range that is much less than 2m.

The presence of large and extensive stands of mangrove forest is another feature of Cape York Peninsula estuaries (Fig. 3.6). Mangroves form critical habitats for many species of animals (fish, prawns, crabs and birds) especially juvenile forms and are thus important in commercial fisheries as well as the maintenance of overall biodiversity. Although many mangrove species are salt tolerant, freshwater inputs are crucial to their long-term survival (FAO, 2007). Extensive supratidal habitats often occur on the landward side of the mangrove fringe. These salt flats and salt marshes are typically only inundated by the largest of tides (e.g. flood tides) and even then, the extent of inundation is minimal. However, freshwater flooding of these habitats during the tropical wet season combined with high tides may form extensive shallow wetlands which form critical habitat for many species of fish (Pusey *et al*., 2004b), including species of great commercial and recreational value (Robins *et al.,* 2005). Salt flats and marshes (Fig. 3.6) are also critical for many species of migratory birds and fish. On Cape York Peninsula, the magnitude of the tidal regimes combined with the regularity of large wet season floods produces extensive areas of mangroves and saltflats compared to elsewhere in southern Australia. Extensive areas of these estuarine habitats are often associated with large embayments such as those of the Embley River system at Weipa, Princess Charlotte Bay in the Normanby River system, and Newcastle Bay and the Jardine River system at the tip of Cape York (Fig. 3.6).

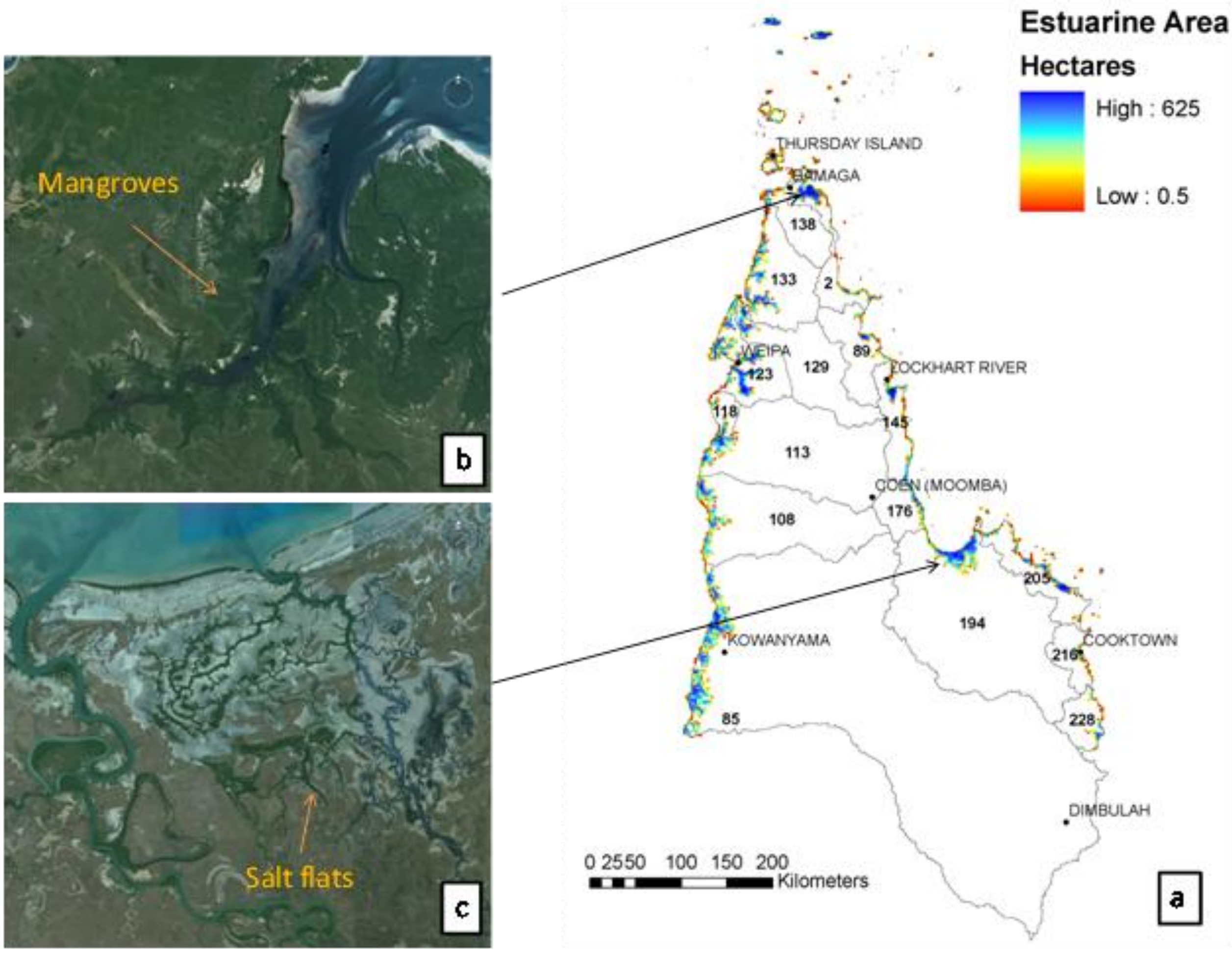

Figure 3.6 a) The area in hectares of estuarine aquatic systems in 2.5 km^2 grids across Cape York Peninsula. Insets: b) Mangrove dominated estuarine systems in Newcastle Bay near the tip of Cape York; and c) Saltflat dominated estuarine systems in Princess Charlotte Bay in the Normanby River catchment.

3.3.5 Subterranean aquatic systems

Subterranean aquatic systems occur under ground and are usually, but not always, associated with groundwater aquifers. This aquatic system also includes the hyporheic zone, the saturated soil interface between the river, land and groundwater. Subterranean aquatic systems have been little studied in northern Australia but early indications are that they contain an extremely diverse and important fauna with many endemic species and it is only recently that the integrity of these systems has received attention. The long-term sustainability of subterranean aquatic systems is intimately linked to the maintenance of groundwater (excepting those circumstances where the subterranean system is impervious and relies on capturing surface runoff). Recent research in Australia (summarised in Humphreys, 2008) suggests that many subterranean organisms occur in small and very patchily-distributed populations, making them extremely vulnerable to disturbance with little chance of recovery. Petheram and Bristow (2008) noted that the maintenance of ecological values associated with groundwater will be very challenging in the more arid parts of northern Australia where aquifer recharge areas need to be several orders of magnitude larger than the area being irrigated by water drawn from underground aquifers.

Groundwater-dependent ecosystems have recently been recognised to contain globally important biodiversity and Australia is a global hotspot for subterranean biodiversity in both terrestrial (troglofauna) and aquatic (stygofauna) habitats (Pusey & Kennard, 2009). The subterranean fauna was initially reported to be most diverse in carbonate karst areas (a landscape formed by the dissolution of soluble rocks, including limestone and dolomite) but more recently has been found to inhabit voids in pseudokarst (typically in sandstone, lava or laterite), alluvial aquifers, lacustrine and groundwater calcretes, pisolites, fractured rock and basalts. Cape York Peninsula contains no notable karstic areas (Humphreys, 2008) and is unlikely to contain a well developed stygofauna. However, the recent discovery elsewhere of stygofauna in pseudokarstic habitats such as occur in sandstone areas of Cape York Peninsula suggests that this type of fauna may occur in the region.

4.0 Distinctive hydroecological features of Cape York Peninsula

4.1 Hydroecological characteristics and processes

4.1.1 Riverine hydrology and flow regime diversity

Ecologists and environmental managers increasingly recognize that the natural hydrological (flow) regime is the fundamental driver of processes that shape the physical and ecological nature of aquatic ecosystems (Poff *et al.,* 1997). Critical components of the natural flow regime include the magnitude and seasonal pattern of flows; timing of extreme flows; the frequency, predictability, and duration of floods, droughts, and intermittent flows; daily, seasonal, and annual flow variability; and rates of change in flow events (Poff *et al.,* 1997; Bunn & Arthington 2002; Fig. 4.1). Spatial variation in these hydrologic characteristics is determined by variations in climate and mediated by catchment geology, topography and vegetation (Winter, 2001). These factors interact at multiple spatial and temporal scales to influence connectivity between hydrosystems, physical habitat for aquatic and riparian biota, the availability of refuges, the distribution of food resources, opportunities for movement and migration, and conditions suitable for reproduction and recruitment (Naiman *et al.,* 2008).

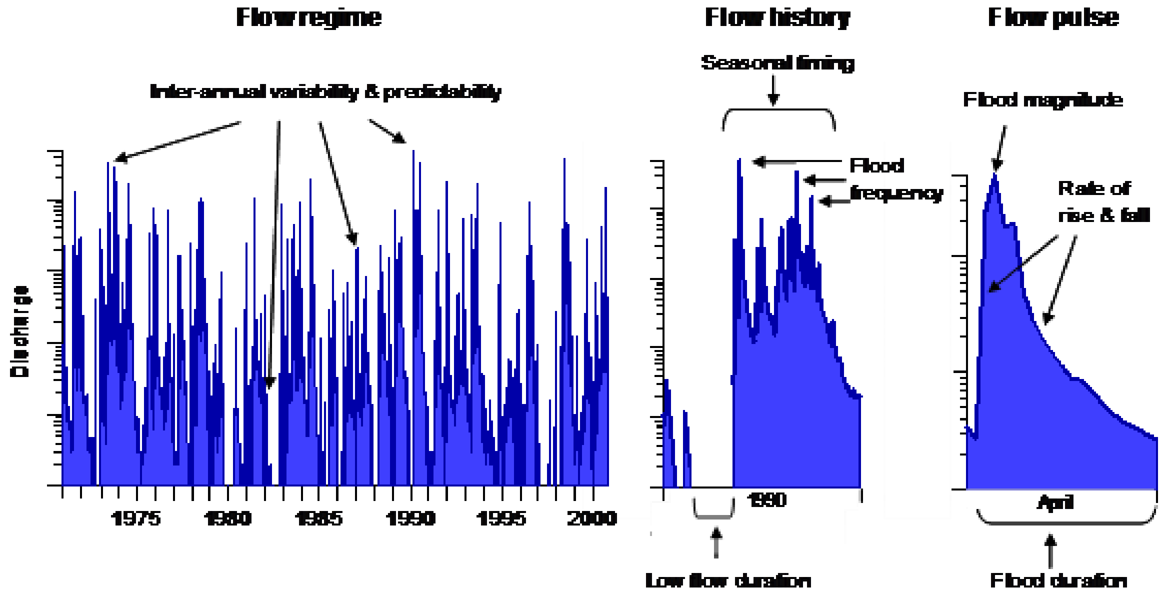

Figure 4.1. Different components of the natural flow regime are ecologically important over a range of temporal scales.

The maintenance of these key components of the natural flow regime is critical to protecting and maintaining freshwater biodiversity, natural ecological processes, and the essential goods and services provided by aquatic ecosystems (Bunn & Arthington, 2002). For example, variation in river flow influences the transmission of materials and energy through aquatic food webs within and between different parts of the aquatic ecosystem (e.g. between groundwater and surface water and between, headwaters, main channel, floodplain and estuaries). This is critical to the maintenance of biodiversity and the natural functioning of aquatic ecosystems. Similarly, variations in flow regimes drive variation in physical habitat structure, a key determinant of the types and rates of organic matter production and transmission, as well as the abundance and diversity of aquatic plants and animals

Northern Australia contains six of the 12 different flow regime types identified in Australia (Kennard *et al.,* 2010) and of these, only three have been detected in Cape York Peninsula (Fig. 4.2). These are 1. Stable baseflow; 3 – stable summer baseflow; and 10 Predictable summer highly intermittent. Highly unpredictable and highly intermittent flow regimes (classes 7, 11 and 12) are absent (note however that smaller ungauged tributary and headwater streams may belong to these classes).

Topography is a major influence on riverine flow regimes in Cape York Peninsula. Many of the streams east of the GDR have a hydrology characterised by stable summer baseflows (class 3). In this sense, they resemble rivers of the Wet Tropics which are uniformly of this class. High summer flows are due to southern migration of the monsoonal trough and cyclonic activity in the Coral Sea. In addition these catchments also receive substantial dry-season rainfall from orographic forcing of moisture laden south-easterly winds (which predominate during this time) by the GDR and its close proximity to the coast. Cloud capture by the highest peaks may also contribute to high dry season baseflows. Class 3 streams occur in the east and West branches of the Normanby River, the catchments of which abut the northern boundary of the Wet Tropics region. Similar streams also in northern Cape York Peninsula (Wenlock River to the west and the Pascoe River to the east). This region experiences very high rainfall (1200-1600 $mm.yr^{-1}$) equivalent to that recorded in the Wet Tropics region (Sturman & Tapper, 2001). Both rivers have their origins in the Iron Range area and some local orographic forcing may increase precipitation and runoff. Personal experience suggests that groundwater inputs (e.g. from creeks such as Hot Water Creek) may also contribute to dry season flows. They also resemble some streams and rivers further to the west (i.e. Leichhardt River, Roper River and Daly River) but in these cases, high dry season baseflows are maintained by groundwater. Groundwater inputs may also sustain high dry season baseflows in some rivers of eastern Cape York Peninsula (e.g. the Hann River in the Normanby basin, see also section 4.1.2).

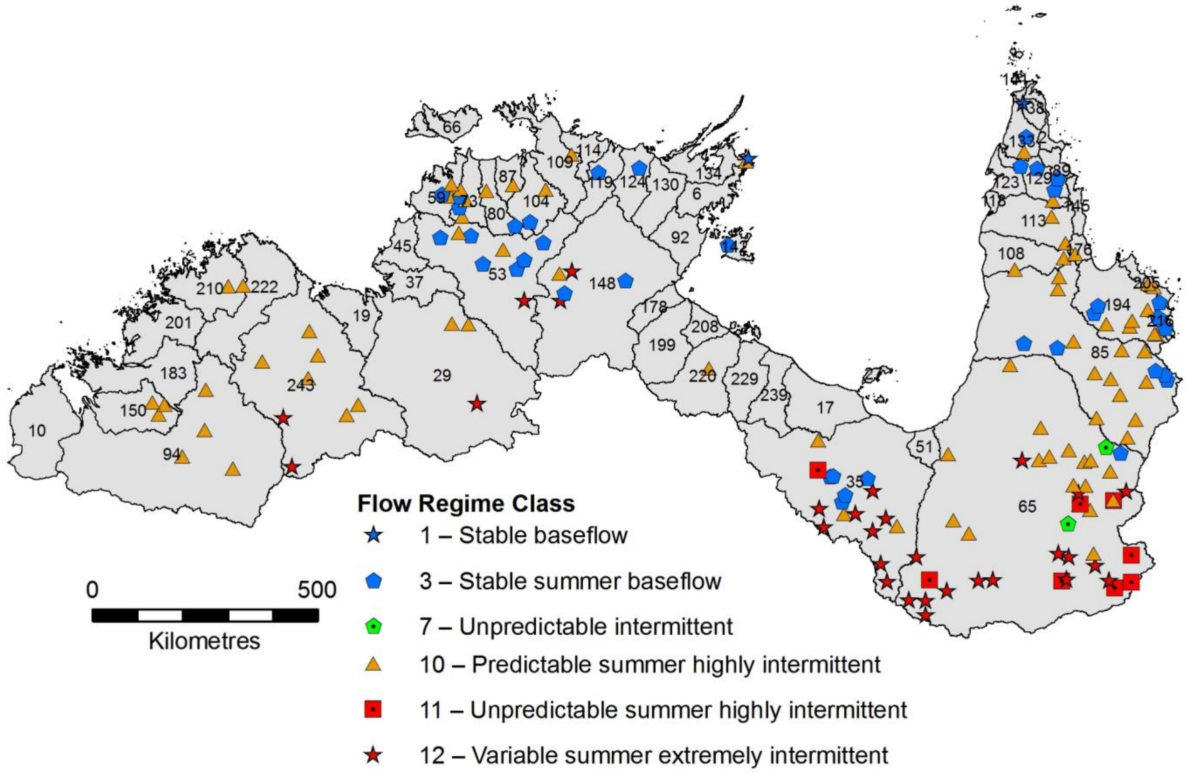

Figure 4.2. Flow regime diversity on the Cape York Peninsula region (based on Kennard *et al.,* 2010)

Catchments located west of the GDR are mostly deprived of moisture carried in the south-easterly winds (except for the upper reaches of the Mitchell River which is also more fully discussed below) and the dominant source of rainfall is the summer monsoonal low and cyclonic activity associated with deep lows formed in the Gulf of Carpentaria. Cyclones formed in the Coral Sea may also occasionally penetrate over or around the GDR. As a result, most streams of the western portion of Cape York Peninsula have an intermittent flow regime within class 10 (*predictable summer high intermittency*). This same pattern (class 10) is also observed in the Normanby River catchment on the east coast. This flow regime type is the most common across northern Australia.

Further to the north in the highest rainfall area of northern Australia (>greater than 1600 mm.yr^{1}), the Jardine River was classified as a class 1 stream (*stable baseflows*). This flow regime type is very uncommon in northern Australia. The high baseflow component in the Jardine River suggests groundwater input but the extensive swamps in this region (which may in themselves be surface expressions of groundwater) may contribute outflow during the dry season that subsequently maintains flow in the main channel. Thus the Jardine River has the most distinctive of flow regimes in all of Cape York Peninsula.

Most (10/15) of the streams within the Mitchell River catchment were of flow regime class 10 (*predictable summer highly intermittent*), the dominant flow signature for much of northern Australia. Three locations (gauges 919005, 919013 & 919001), all of small catchment area (89 - 540 km^2) and in the upper headwaters of the Mitchell River, were of class 3 (Fig. 4.2). These headwater perennial streams drained rainforest areas on the western border of the Wet Tropics streams and not surprisingly resemble streams of this region. Also within this class were the lower most gauges on the Palmer River (919204) and the Mitchell River (919009). Given that reaches upstream of both gauges were of flow class 2, this reflects the presence of significant groundwater inputs occur in the lower Palmer River and Mitchell River. Class 3 streams encompass a wide range of flows otherwise characterised by high baseflow and the absence of intermittency, the key factor being that they do not cease to flow. That such a wide range is encompassed within this flow class illustrates the pervasiveness of periods of no flow in other rivers of the tropical north.

The Mitchell River (Fig. 4.3) illustrates the extent of spatial variation in flow regime not fully captured by the continental classification and present at finer spatial scales. On average, maximum flows occur on the 16th February and there is little variation across the catchment in timing (SE of maximum flow = 1.8 days); maximum flows are derived from the same weather event across the entire catchment. Minimum flows, in contrast, occur over a wide time range (7th March to 21st December). The Tate and Walsh rivers in the catchment's south typically have a short period between the occurrence of maximum and minimum flows (mean = 136 days), whereas the Palmer River has a more prolonged period (mean = 229 days) and small tributaries in the upper Mitchell has an even more extended (mean = 288 days). The lower most gauge on the Mitchell River (919009 @ Koolatah) also has a long period (265 days) between maximum and minimum flows. Localised spring derived groundwater contributes to dry season flows in the lower Palmer and Mitchell River (see Figure 4.4 below). It is likely that these subtle spatial differences in flow regime have significant ecological implications such as influencing the types of species present, extent of migration, growth and synchrony of life histories with flow regime.

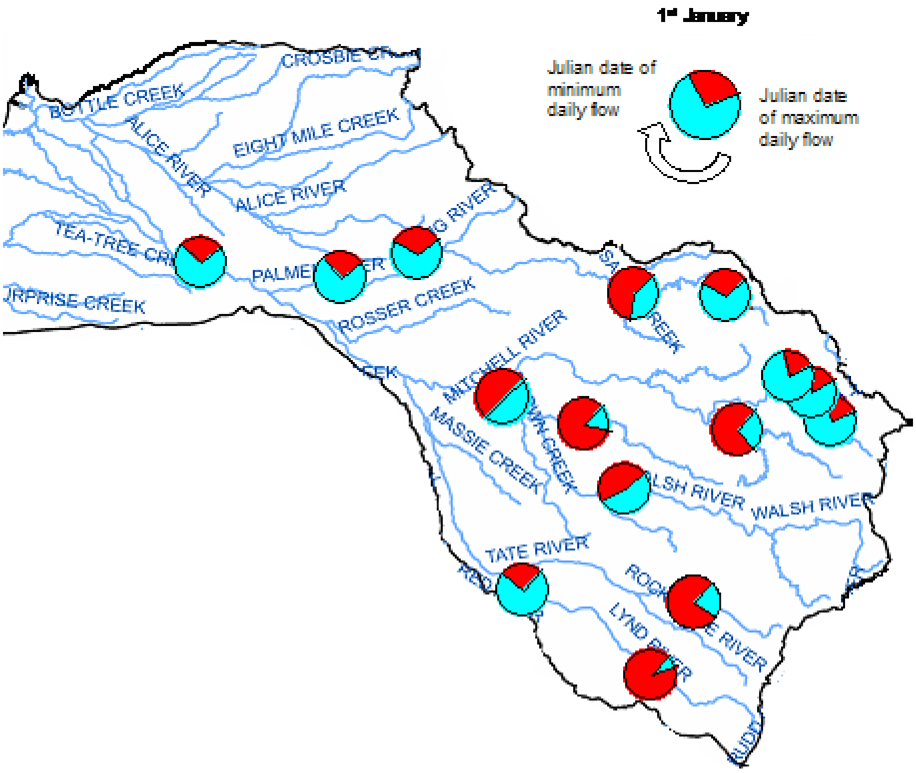

Figure 4.3 Spatial variation in the Mitchell River in the mean Julian date of occurrence of minimum and maximum daily flows.

4.1.2 Surface–groundwater connectivity, perenniality and aquatic refugia

Aquatic systems that have continuous water flow or contain water all year round are referred to as perennial systems. Non-perennial aquatic systems, in contrast, normally dry up or cease to flow for weeks or months each year. Perenniality is an important hydrological characteristic of aquatic systems and this is particularly the case for Cape York Peninsula. During the dry season across Cape York Peninsula the aquatic systems contract and the connectivity between riverine and the surrounding lacustrine and palustrine systems is significantly reduced. As the dry season progresses and the aquatic systems contract to perennial waterholes (Fig. 4.4), conditions can become harsh as water quality deteriorates and the available habitat contracts (Arthington *et al*., 2005). This is a period of limited resources for biota. Isolated perennial waterholes in the river channels and on floodplains play an important refugial role and become critical for sustaining aquatic biota during the dry season (Bunn *et al.*, 2006). Not all rivers across Cape York Peninsula recede to perennial waterholes, in some riverine systems baseflows are maintained by groundwater discharge derived from the Great Artesian Basin and other aquifers (Fig. 4.4). These perennial rivers provide important refugia within the dry season landscape for flow-dependent aquatic species. The loss of springs coincident with European settlement and associated with grazing has been reported for large areas of northern Queensland and is thought to have negative impacts on the maintenance of biodiversity (Fairfax & Fensham, 2002) and unlike springs in many southern Gulf of Carpentaria drainages, springs of Cape York Peninsula have remained active.

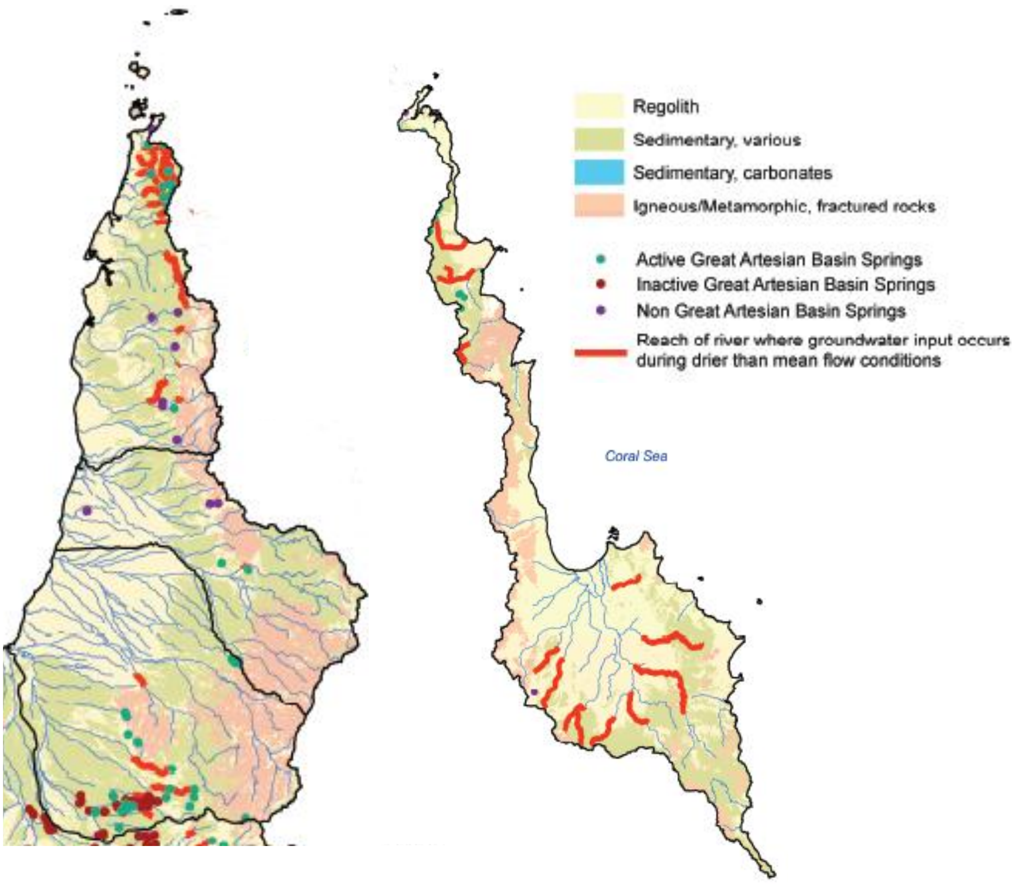

Figure 4.4. Surface–groundwater connectivity map for Cape York Peninsula. The few rivers that flow through the dry season are related to discharge from Great Artesian Basin aquifers (Source: CSIRO 2009).

Lacustrine and riverine aquatic systems have the greatest areal extent of perennial water bodies (47% and 40% respectively). Large areas of perennial lacustrine and riverine aquatic systems occur in the Mitchell and Normanby Rivers, as well as areas on the tip of Cape York and coastal floodplain areas of the Holroyd and Wenlock Rivers (Figure 4.5). The extent of perennial lacustrine systems on Cape York Peninsula is greater than found elsewhere in Tropical northern Australia which has less than 10% perennial lacustrine systems overall. The majority (73%) of all palustrine systems in Cape York Peninsula are non-perennial. However, large areas of perennial palustrine systems are associated with wetland areas of the Jardine, Ducie and Holryod river systems (Figure 4.5).

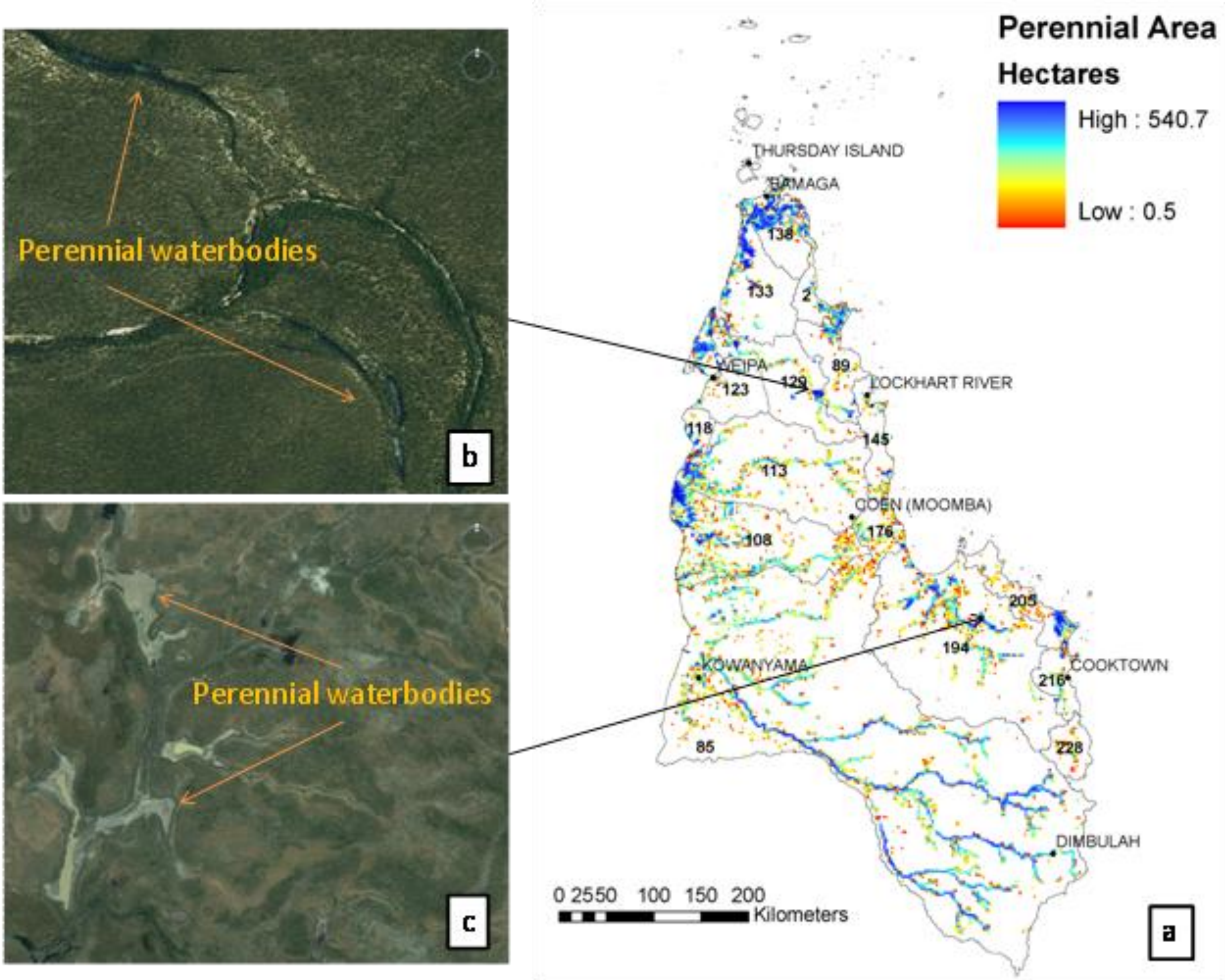

Figure 4.5. a) The area in hectares of perennial aquatic systems in 2.5 km^2 grids across Cape York Peninsula (perennial systems are defined here as having a 1in 10 year drying event based on a 20 yr Landsat satellite time series). Inserts: b) Perennial systems in the Wenlock River catchment; and c) Perennial systems in the Normanby River catchment.

4.1.3 Flood inundation and connectivity

A characteristic feature of Cape York Peninsula is the occurrence of massive flood events associated with southern monsoon wet season. Floods across river basins of Cape York Peninsula vary significantly in their frequency, extent and duration. A characteristic feature of floods on the western side of Cape York Peninsula is that their spatial extents reflect the distributary character of their floodplains, such that floods, often of considerable magnitude, tend to 'fan' out across the floodplain (Fig. 4.6). This contrasts with the spatial extents of floods in other parts of Australia where floods most often converge to a river mouth. The eastern side of Cape York Peninsula has fewer large floodplains with the Normanby river system being the largest. Floods in the Archer River system can also be extensive and reflect the complex 'braided' channel networks of the floodplains in this region. Despite their magnitude, the floods on Cape York Peninsula tend to be of short duration. For example, inundated areas on the Mitchell River floodplain only remain for 2 to 3 months. The relatively short duration of flooding in these regions contrasts significantly with the duration of floods in the more equatorial/tropical regions of the top of the Northern Territory. In many of the river systems in this region, floodplains remain inundated for greater than 6 months.

Flood inundation frequency (a representation of how often and how long and area is flooded) (Fig. 4.6) has a strong influence on the characteristics of floodplain productivity. In floodplains with short inundation periods, the growth of aquatic plants is largely restricted to palustrine waterbodies and terrestrial grasses dominate the floodplain (N.E. Pettit, *pers. obs.*). Flood inundation frequency also has significant influence on the extent and duration of connectivity between the riverine environments and the neighbouring palustrine and lacustrine systems (Fig. 4.6). During the initial flood phase, reconnection of isolated dry season refugia occurs as flows provide an opportunity for fauna to move into more favourable aquatic environments. These floods connect the perennial aquatic systems that act as refugia during the dry season and represent important sources of recolonising biota (Paltridge *et al*., 1997; Perna & Pearson, 2008).

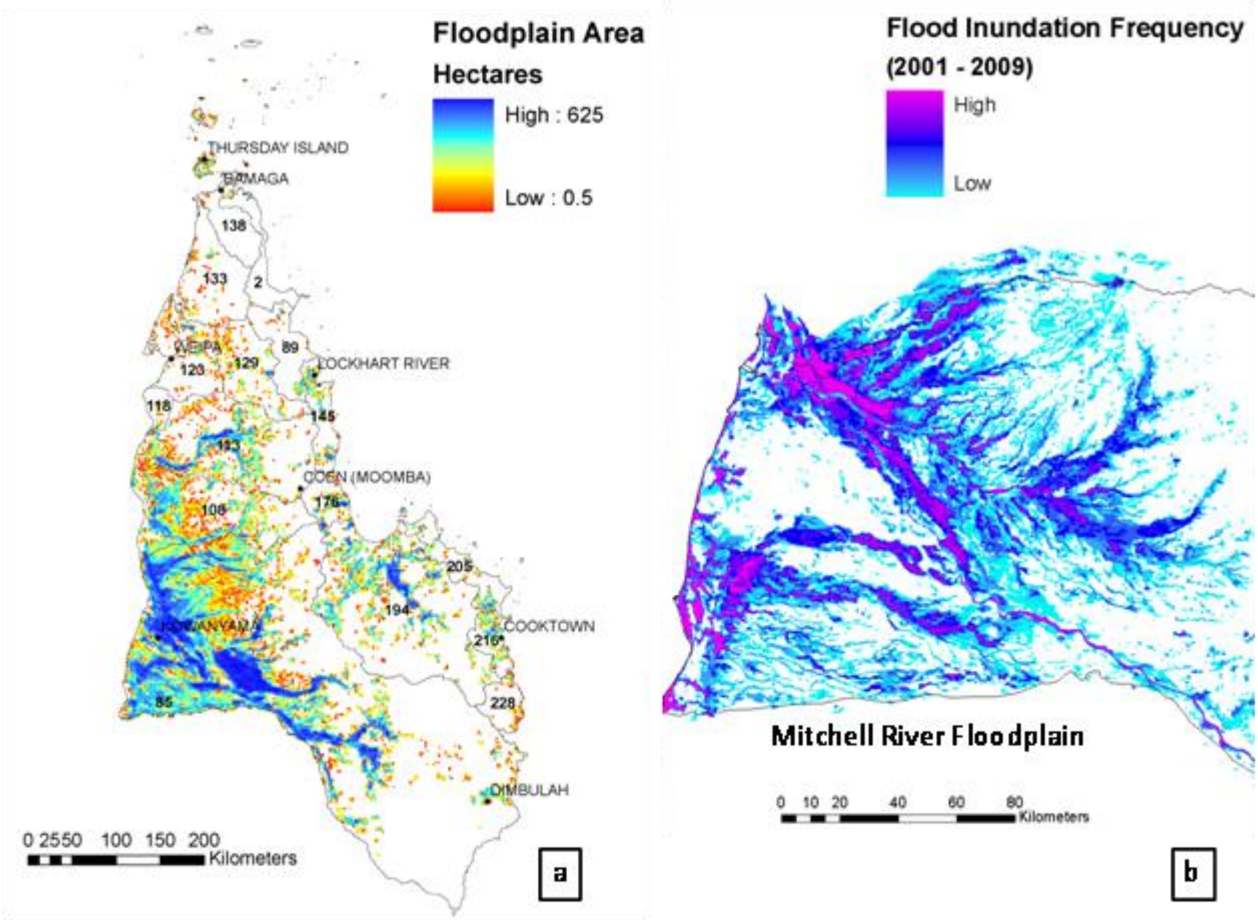

Figure 4.6. a) The area in hectares of Floodplain systems in 2.5 km^2 grids across Cape York Peninsula; and b) Mitchell River flood inundation frequency derived from MODIS satellite imagery using intermittent image captures between 2001 and 2009 (inundation frequency is calculated as the number of times an area is flooded over an image capture time period).

4.2 Extent, variety and distinctiveness of aquatic system types

4.2.1 Aquatic systems diversity

Species diversity is commonly measured using Shannon's diversity Index. In this section Shannon's diversity index is applied to estimate the spatial diversity of aquatic systems (Riverine, Lacustrine, Palustrine and Estuarine) described in section 3.3. Here, Shannon's diversity index is applied at two scales; 1) the NCB catchments, and 2) the smallest sub-catchments identified in the NCB framework. The index takes into account the number of aquatic systems and the evenness of the distribution of area of aquatic systems in a catchment or sub-catchment. High aquatic system diversity does not necessarily mean high species diversity. However, it is likely that high aquatic system diversity will provide a greater range and variety of aquatic habitats, and consequently a greater diversity of aquatic fauna and flora.

On Cape York Peninsula, the Olive-Pascoe catchment has the greatest diversity of aquatic systems, indicating that there is likely to be significant representations of each of the riverine, lacustrine, palustrine and estuarine systems in this catchment (Fig. 4.7a). The Mitchell River catchment also has high aquatic system diversity, though the size of the Mitchell River relative to other catchments on Cape York increases the likelihood of high aquatic systems diversity at the catchment scale. The analysis of aquatic system diversity using a much finer sub-catchment scale facilitates the delineation of aquatic system diversity at more local scales. The floodplain of the Normanby River catchment has significant areas of high aquatic system diversity, as does the floodplain of the Mitchell River (Fig. 4.7b). A feature of the west coast of Cape York Peninsula is the high aquatic system diversity along most of the coast. This likely reflects the interface between the extensive and often distributary floodplain and riverine aquatic systems with the more saline estuarine systems on the western side of the Cape. There is particularly high aquatic system diversity associated with the coastal areas of the Wenlock and the Embley River systems (Fig. 4.7b).

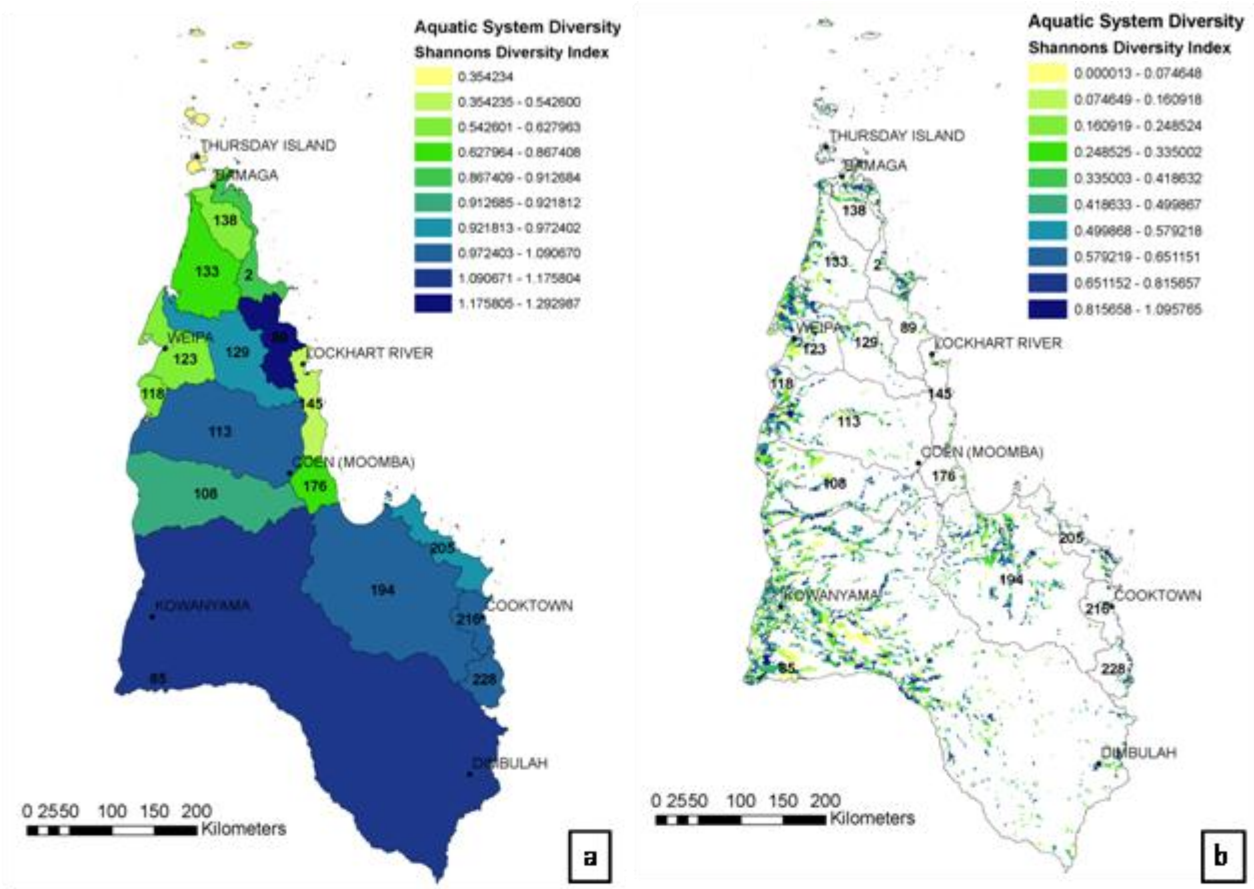

Fig. 4.7. Aquatic system diversity calculated using Shannon's Diversity Index which takes into account the number of aquatic systems and the evenness of the distribution area of aquatic systems for a) NCB catchments, and b) the smallest sub-catchments identified in the NCB framework.

4.2.2 Unique features of aquatic systems

The combination of the wet-dry tropical climate and associated large seasonal floods, the influence of the Great Dividing Range producing extensive megafan floodplains, and the magnitude of Caper York Peninsula's tidal regimes has produced unique combinations of aquatic systems found nowhere else in Australia or the world (Table 4.1).

Table 4.1. Unique features of aquatic systems of Cape York Peninsula

Aquatic System	Unique features
Riverine	• Catchments to the south west of Cape York are often distributary systems with complex anabranching floodplain drainage networks (e.g. the Coleman, Holroyd, Archer and Watson River systems) that are unique to Cape York Peninsula and the southern Gulf of Carpentaria. • Lower catchment slope is characteristic of the wide flat landscape of south west Cape York Peninsula, leading to streams having fewer first and second order streams and a greater proportional length of very large rivers (> 6^{th} order)
Estuarine	• The most fundamental difference between Cape York Peninsula and southern Australian estuaries can be attributed to the dramatic differences in tidal regimes. Tides within the Gulf of Carpentaria are diurnal (1 tide per day) with a maximum range up to approximately 3m at the tip of the Cape York. • On Cape York Peninsula, the magnitude of the tidal regimes combined with the regularity of large wet season floods produces extensive areas of mangroves and saltflats compared to elsewhere in southern Australia.
Lacustrine	• Globally, dune lake systems are a rare aquatic system. On Cape York Peninsula, large areas of coast dune lake systems occur at Shelburne Bay and Cape Flattery. • While lacustrine systems are not a significant aquatic system in northern Australia in terms of areal extent, high densities of ox bow lakes are found on the floodplain of the Mitchell River on Cape York Peninsula.
Palustrine	• Across the savanna landscapes of northern Australia, the greatest density and areal extent of Palustrine systems are found on Cape York Peninsula and the southern Gulf of Carpentaria. On Cape York Peninsula they comprise a significant component of the catchment area for river systems such as the Normanby, Mitchell, Coleman, and Holroyd catchments.
Flood inundation and connectivity	• A characteristic feature of floods on the western side of Cape York is that their spatial extents reflect the distributary character of their floodplains, such that floods, often of considerable magnitude, tend to 'fan' out across the floodplain. This contrasts with the spatial extents of floods in other parts of Australia where floods most often converge to a river mouth. • Despite their magnitude, the floods on Cape York Peninsula tend to be of short duration. The relatively short duration of flooding in these regions contrasts significantly with the duration of floods in the more equatorial/tropical regions of the top of the Northern Territory.

4.3 Aquatic biodiversity

Cape York Peninsula contains high diversity of freshwater-dependent species in terms of species richness and endemism (Pusey & Kennard, 2009; Kennard, 2010), with the Jardine River having especially unique biodiversity (Marshall *et al*., 2006). Recent molecular-based studies have corroborated the biotic uniqueness of freshwater fauna of Cape York Peninsula with respect to other regions in northern Australia (e.g. Cook *et al*., 2010) and among locations within Cape York Peninsula. For example, populations of Macculloch's rainbow fish, *Melanotaenia maccullochi*, and spotted blue eye, *Pseudomugil gertrudae*, in the Jardine River are highly divergent at the molecular level from populations of their respective conspecifics in the Cape Flattery/Cape Bedford area (Cook *et al*., unpublished data).

4.3.1 Freshwater fishes

Fish are an important component of the fauna of aquatic ecosystems of Cape York Peninsula. They contribute substantially to the overall biodiversity of the region and are critical components of aquatic food webs. Fish occur at all secondary levels of food webs, consuming primary production (algae, terrestrial detritus and fruits) and planktonic and epibenthic insects and crustaceans, as well as other fish. They also figure prominently in the diet of other aquatic or semiaquatic organisms, such as snakes and monitor lizards, waterbirds, crocodiles and, of course, people. Fish also shift carbon produced in one area (e.g. floodplains) to other areas as they move between upstream tributaries or downstream estuaries and near-shore marine environments. Fish are economically important (e.g. the commercial and recreational barramundi fisheries of northern Australia), as well as spiritually and culturally vital in the lives of Indigenous people of the north.

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. 4.8a). 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. 4.9). 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 is not large but contain a very rich fish fauna. 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. 4.9). Importantly, many streams in these species-rich basins are distinguished by perennial flow, in contrast to most streams and rivers of the region (Kennard *et al.,* 2010). This distinctive hydrological feature may ensure that seasonal changes in habitat and food availability due to the marked seasonal pattern of rainfall and runoff do not become so severe to result in the loss of species over time. Pusey *et al.* (2004a) also found that fish species richness was greater in perennial rivers of north-eastern Australia.

Northern Australian river basins with the highest rates of fish species endemism (Fig. 4.8a) include the Jeannie and Endeavour rivers in the North-East Coast Drainage Division. The high endemism for the Endeavour River reflects its transitional nature between the Cape region and the Wet Tropics. The Jeannie, Olive and Pascoe rivers also contain a number of species also found in the Wet Tropics region. At the sub-basin scale (Fig. 4.8b), areas with highest fish species richness included lowland reaches of most rivers. The lowland river reaches of western Cape York Peninsula are the most species rich of any in the Peninsula region. 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.

The composition of the fish fauna of the Peninsula region reflects a diverse array of evolutionary origins and a variety of processes. Based on the distributions of 167 exclusively freshwater fish species, Unmack (2001) divided Australia into 10 distinct zoogeographic provinces, many of which comprised two or more subprovinces. Northern Australia, as defined here, comprised only two provinces: the Northern and Kimberley provinces. Cape York Peninsula makes up part of the Northern Province. These provinces plus the Pilbara and the arid zone Central Australian Provinces were highly distinct from southern Australian provinces (Southwestern, Bass, Southern Tasmanian and Murray Darling).

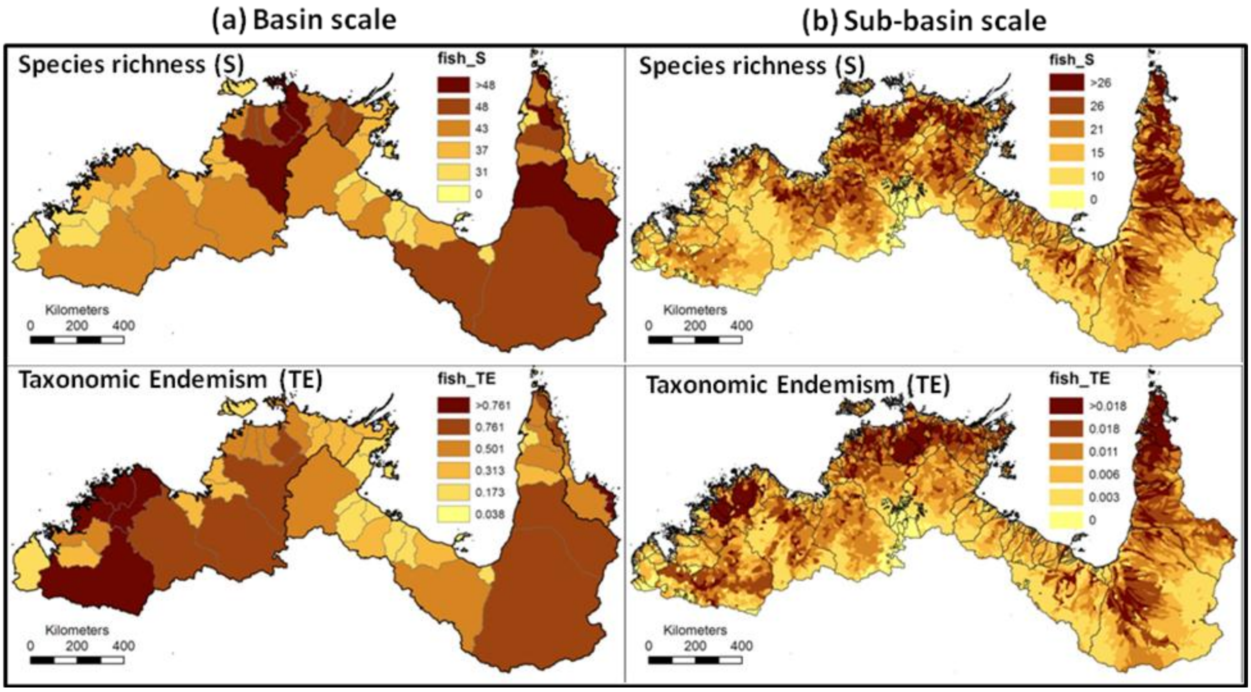

Figure 4.8. Spatial variation in fish species richness and endemism across northern Australia at two spatial scales: (a) entire river basins and (b) sub-basins (Source: Kennard 2011).

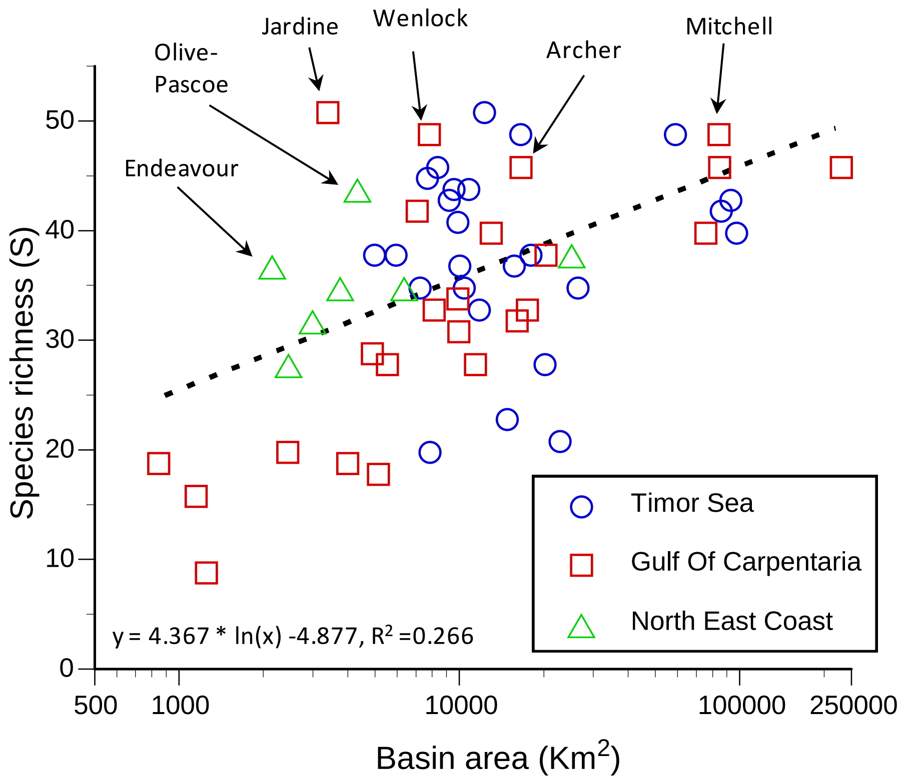

Figure 4.9. Fish species richness versus basin area (Km^2) for river basins of northern Australia. River basins within the Timor Sea, Gulf of Carpentaria and north-east coast drainage divisions are denoted by different symbols. Basins with high species richness in Cape York Peninsula are identified. The regression equation describing the relationship between species richness and basin size is given (source: Pusey *et al.*, in press a).

The spatial arrangement of zoogeographic provinces reflects the evolutionary origin of Australia's freshwater fishes. Although there is still much debate about the age and mechanisms responsible for defining the Australian fish fauna, it is generally accepted that many elements of the southern fauna are of Gondwanan origin, whereas most elements of the northern fauna are derived from northern marine families that invaded freshwater in the past 65 million years. The only truly Gondwanan representative is the saratoga, *Scleropages jardinii* (Fig 4.10). Unlike many other freshwater fish species of northern Australia, the entire evolutionary history of saratoga has been confined to freshwaters. Endemic to the Bloomfield River, *Guyu wujalwujalensis* (Fig 4.10) is also a relic of a former time. This species belong to the Percichthyidae (which includes Murray Cod and Yellowbelly) which is of southern origin and typically a temperate zone family. *Guyu wujalwujalensis* may have been isolated in the Bloomfield River from before the Miocene, originating during the Cretaceous marine introgressions which isolated high elevation areas into islands (Pusey & Kennard, 2000).

Figure 4.10. Fish species of note from Cape York Peninsula. Clockwise from upper left hand corner: Spotted Blue eye *Pseudomugil gertrudae,* Saratoga *Scleropages jardinii,* garfish *Zenarchopterus novaeguineae,* shortfinned catfish *Neosilurus brevidorsalis, Pingalla lorentzi, Guyu wujalwujalensis,* Lake Grunter *Variichthys lacustris,* Delicate Blue eye *Pseudomugil tenellus* and Penny fish *Denariusa bandata* (centre) (images by N. Armstrong, G. Schmida and D. Wilson).

It is notable that many of the species-rich groups present in the north, such as the ariid and plotosid catfishes, eleotrid gudgeons and terapontid grunters, are from families that are elsewhere almost entirely marine. These families may have also been present at the time of Gondwana, but the species would unlikely have occurred in freshwaters. It is as if northern Australian freshwaters became largely devoid of fishes; an empty space into which marine species could adapt and radiate, and ultimately fill. Thus, the fish of northern Australia and of Cape York Peninsula are a highly distinctive subset of the Australian freshwater fish fauna.

The composition of the fauna of Cape York Peninsula differs markedly relative to the position of the Great Dividing Range. In an examination of the biogeography of freshwater fishes of north-eastern Australia (which includes Cape York Peninsula), Pusey *et al*. (2008) found that the fish fauna of Cape York Peninsula is sufficiently distinct to differentiate it from other regions of Queensland and moreover, there is further significant differentiation within the region depending on whether basins are located east or west of the Great Dividing Range. The significance of the GDR as a determinant of fish assemblage composition is reduced in the immediate vicinity of the Cape itself where several species commonly recorded in eastern Cape York rivers (e.g. *Anguilla reinhardtii*, *A. obscura*, *Kuhlia* spp., *Giurus margaritacea* and *Oxyeleotris aruensis*) occur also in the Jardine, Ducie and Wenlock river basins of the northernmost Gulf region. These species either have an estuarine larval phase or are estuarine or marine spawners and, in the case of the eels, there is obviously some transmission of larvae into these two rivers despite the bulk of leptocephali (larvae) being transported down the east coast in the East Australia Current (Pusey *et al*., 2004b). Species characteristic of western rivers may occur in eastern rivers too. The GDR is of low relief (<500 m above sea level) in the most northern part of Cape York Peninsula, as opposed to further south, and may not therefore be an effective barrier to the transfer of species between regions.

A number of species occur in rivers of the tip of Cape York Peninsula as well as southern Papua New Guinea and are indicative of former connectivity between the two regions. Such species include *Zenarchopterus novaeguineae*, *Variichthys lacustris*, *Neosilurus brevidorsalis* and *Pingalla lorentzi* (Fig 4.10). Notably, the only other Australian locality for the latter species is in the Finnis River of the Top End of the Northern Territory.

The well developed palustrine hydrosystems of western side of Cape York Peninsula contain a number of floodplain specialist species such as *Pseudomugil tenellus, Porochilus rendahli* and *Variichthys lacustris* whereas the more acidic swamp and dune lake systems of the eastern Cape contain other species such as *Melanotaenia maccullochi*, *P. gertrudae, Oxyeleotris nullipora, N. obbesi and Iriatherina werneri* (Fig 4.10 and Fig 4.11).

Cape York Peninsula contains the highest number of rainbowfish (Melanotaeniidae) species in Australia (Fig. 4.11). This group of species are highly valued in the aquarium hobby worldwide and are accordingly of economic significance. By virtue of their numerical abundance and position within aquatic food webs (low level processors of algae and invertebrates and of terrestrial insects) rainbowfishes are also of substantial ecological significance. They are preyed upon by a vast array of other fishes and terrestrial and avian predators. The distribution of *Iriatherina werneri, Melanotaenia maccullochi* and *M. nigrans* is highly fragmented, indicative of previous connection between the Peninsula region and the Top End of the Northern Territory and with PNG. The widely distributed but typically allopatric subspecies *inornata* and *splendida* of the eastern rainbowfish *M. splendida* are separated by the GDR. However, an isolated population of *M. s. inornata* occurs in dune lakes of the Cape Flattery area on the east coast.

Species of recreational angling significance include the jungle perch, black bream and barramundi (Fig. 4.12). Barramundi are also of considerable commercial fishery significance. A recent estimate of the total value of output of the commercial fishing industry in northern Australia was almost $166 million in 2006/07 (Clarke *et al*., 2009). Recreational fishing is also valuable to the regional economy with fishers spending approximately $319 million per year on their sport in Queensland (Henry & Lyle, 2003). The popularity of recreational fishing amongst resident and visiting populations generates regional economic benefits from tourism and expenditure on travel, accommodation and fishing gear. Robinson (2001) found that in Queensland, where 25% of the population fishes, an average of $51/barramundi is spent by every angler, implying total expenditure per annum of $22 million on recreational fishing for barramundi.

Figure 4.11. Rainbowfishes of Cape York Peninsula. Clockwise from left *Melanotaenia maccullochi*, *M. splendid splendida, M. splendida inornata, Iriatherina werneri*, *M. nigrans* and *M. trifasciata* (images by N. Armstrong, G. Schmida and D. Wilson).

Figure 4.12. Examples of fish species of recreational angling significance in Cape York Peninsula; (left to right) *Kuhlia rupestris* Jungle Perch, *Hephaestus fuliginosus* Black Bream or Sooty Grunter, *Lates calcarifer* Barramundi (images by N. Armstrong, G. Schmida and D. Wilson).

4.3.2 Elasmobranchs (sharks and rays)

Elasmobranchs (sharks and rays) also occur in freshwater habitats of northern Australia, including Cape York Peninsula. These include the freshwater whip ray (*Himantura dalyensis*) and the freshwater saw fish (*Pristis microdon*) (Peverell, 2005; Pusey *et al.,* in press a). These iconic species have very high conservation values. Sawfish is listed as Endangered by the IUCN and Critically Endangered under the Commonwealth EPBC Act 1999 and whipray is rated as

Vulnerable by the IUCN. Several marine sharks regularly enter rivers, especially bull shark (*Carcharhinus leucas*) which uses lower reaches of rivers as nursery grounds. This species is listed as Near Threatened by the IUCN but not included in any Federal or State legislation. It is common throughout northern Australia but the young may be highly dependent on healthy freshwater habitats. Finally, the Speartooth shark *Glyphis glyphis* occurs in the very lowland reaches of rivers of western Cape York Peninsula. It is listed as Endangered or Critically Endangered (IUCN and EPBC, respectively). The Speartooth Shark was first discovered in the Bizant River on eastern Cape York in 1982, but it has not been recorded there since, and it may have been extirpated from that system (Pillans *et al*., 2010). In northern Australia, it is currently known from the Northern Territory and western Cape York, Queensland (Last & Stevens, 2009; Pillans *et al*., 2010).

4.3.3 Amphibians and reptiles

All species of frog on Cape York Peninsula are critically dependent on freshwater at some point in the life cycle (Pusey *et al*., in press b). Approximately 31 species of frog within nine genera (i.e. *Austrochaperina*, *Cophixalus*. *Lymnodynastes*, *Crinia*, *Cyclorana*, *Litoria*, *Notaden*, *Rana* and *Uperoleia*) and all four families (i.e. Microhylidae, Myobatrachidae, Hylidae, and Ranidae) of Australian frog are known from Cape York Peninsula. Of these 31 species, 10 are endemic to Cape York Peninsula, of which three are widely distributed across the region and seven are narrow range endemics, with the McIlwraith Range and Cape Melville being hot spots for frog endemism. Furthermore, most Australian species within the Microhylidae (narrow-mouthed frogs) occur in Cape York Peninsula or the Wet Tropics regions.

Six species (one species comprised of two distinct subspecies) of freshwater turtle from three genera: *Chelodina* (long-necked turtles) - *Chelodina canni* and *Chelodina rugosa; Myuchelys* (helmeted turtles) - *Myuchelys latisternum*; and *Emydura* (river turtles) - *Emydura tanybaraga, Emydura macquarii krefftii, Emydura subglobosa subglobosa* and *Emydura subglobosa worrelli* occur in Cape York Peninsula, although all of these species also occur in other regions (Pusey *et al*., in press b). The New Guinea painted turtle *Emydura subglobosa subglobosa* is the most restricted of the species occurring in freshwater habitats of Cape York Peninsula, being limited to only the Jardine river and the Jacky Jacky basin. It also occurs in southern Papua New Guinea and is another example of a species, such as those fish species discussed above, that occurs only in these two regions.

Spatial patterns in freshwater turtle species richness and endemism is displayed in Figure 4.13. Most of northern Australia's turtles are widespread, consequently richness at the basin scale tends to be relatively uniform. The Daly and South Alligator River basins in the Top End each contain the highest number of turtle species (eight) in northern Australia. Species present here include the Pignosed turtle (*Carettochelys insculptus)* and the sandstone longnecked *Chelodina burrungandjii* which occurs only in freshwaters of sandstone massifs and escarpments. Basins of Western Cape York Peninsula contain six species each whereas those of eastern Cape York Peninsula tend to contain 1 species fewer. Across northern Australia, with the exception of those basins draining into the Coral Sea, high species richness is correlated with high taxonomic endemism. On the east coast, species richness is lower but some basins such as the Jacky Jacky basin (see above) and the Normanaby River basin are distinguished by relatively high rates of endemism. In the case of the Normanaby River basin, this reflects the northern most distribution of Kreffts river turtle *Emydura macquarii krefftii* (Fig 4.13a). These patterns were similar when turtle endemism was mapped at the sub-basin scale (Fig. 4.13b).

Sandy river banks are important habitats for nesting for freshwater turtles and riparian vegetation is an important source of fallen fruits that supplement the diet of freshwater turtles, based predominantly on aquatic plants, stream invertebrates and fish. The timing, duration and magnitude of river flow may determine dispersal and breeding patterns of freshwater turtles and sustain their food resources and habitats. This in turn may be a key factor allowing multiple species of turtle to coexist (Georges *et al*., 1993).

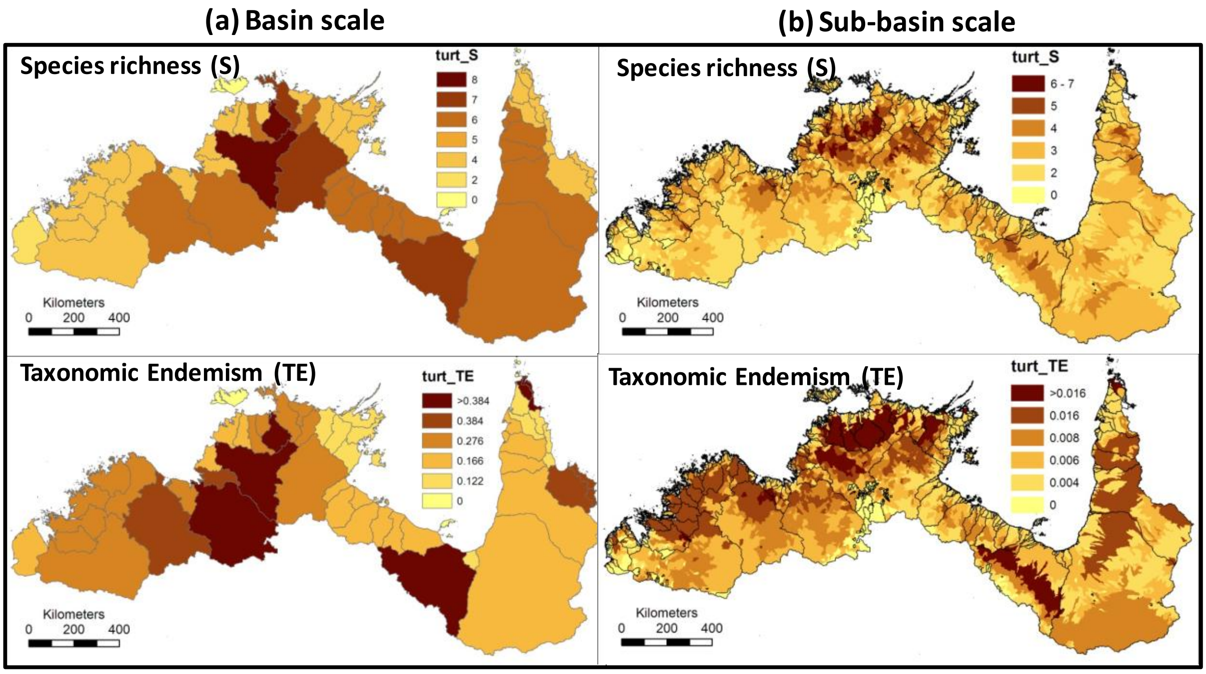

Figure 4.13. Spatial variation in turtle species richness and endemism across northern Australia at two spatial scales: (a) entire river basins and (b) sub-basins (Source: Kennard 2011).

Numerous species of lizard have strong habitat associations with riparian zones on Cape York Peninsula, including species within the families Agamidae (dragons), Scincidae (skinks) and Varanidae (goannas, known also as monitors). The agamid eastern water dragon *Physignathus lesueurii* is rarely found distant from water. It occurs widely in eastern Australia but its distribution in northern Australia is limited to eastern Cape York Peninsula south of the Normanby River (Cogger 2000). At least four species of varanid are associated with aquatic habitats in northern Australia: *Varanus panoptes, V. mertensi, V. indicus* and *V. semiremex.* The latter two species are more common in lowland and mangrove sections of rivers. *Varanus panoptes* is an important predator of the eggs of turtles (both marine and freshwater) whereas *V. mertensi* is the most aquatic of species including fish and prawns in its diet.

Similarly, many species of snake are commonly found in riparian zones of Cape York Peninsula, and three aquatic species are known; one distributed throughout Cape York Peninsula, Macleay's water snake, *Enhydris polylepis*, and two distributed only on the western side; *Cerberus rynchops*, and the file snake, *Acrochordus arafurae*.

Two species of crocodile occur in Cape York Peninsula; the freshwater crocodile, *Crocodylus johnstoni*, and the estuarine crocodile, *Crocodylus porosus*. Hydrologic processes may play important roles in growth of crocodiles, with most growth occurring during the wet season. Large permanent pools are important dry season refugia for crocodiles, especially *C. johnstoni*. Freshwater crocodiles build nests in sandy river banks, similar to freshwater turtles, whereas estuarine crocodiles construct nests from vegetation. Incubation temperature for both species determines the gender of the hatchling, with higher temperatures producing females.

4.3.4 Macroinvertebrates

The freshwater-dependent ecosystems of Cape York Peninsula contain numerous macroinvertebrate species from several phyla, including Arthropoda (insects, crustaceans and arachnids), Mollusca (snails), Annelida (worms) and Porifera (sponges). Commonly encountered taxa include immature stages of aquatic insects belonging to the orders Ephemeroptera (mayflies), Trichoptera (caddis flies), Odonata (damselflies and dragonflies) and Diptera (true flies), and various families of decapod crustacean, including atyid shrimp (Atyidae) and river prawns (Palaemonidae) (Garcia *et al*., in press). The family composition of the aquatic invertebrate fauna across northern Australia is relatively uniform at the river basin scale (see Cook *et al*., 2010), with the Jardine River in the north of Cape York Peninsula being a notable exception, containing some fauna associated with the Wet Tropics region that have not been reported elsewhere in the wet–dry tropics, including the only species stone fly (order Plecoptera) in the Wet-Dry tropics (see Garcia *et al*., in press),

Various species of freshwater crayfish, genus *Cherax* have narrow distributions on Cape York, such as C. *cartalacoolah*, found only sand dune and coastal creek habitats in the Cape Flattery area, and *C. wasselli* and *C. rhynotus* both restricted to the northern tip of Cape York Peninsula (Munasinghe *et al*., 2004). Freshwater crabs belonging to the genus *Austrothelphusa* contain many undescribed species (P. Davie, pers. comm.), many of which are recoded only from Cape York Peninsula, and it is possible that endemic undescribed species of atyid shrimp, genus *Caridina*, occur on Cape York Peninsula (T. Page, per. Comm.). A recent molecular study has demonstrated that the riffle shrimp *Australatya striolata* from north-eastern Australia (eastern Cape York Peninsula to Proserpine) are a distinct species from their southern counterparts (Cook *et al*., unpublished data).

4.3.5 Hydrophytes

Freshwater-dependent plant communities (hydrophytes) include aquatic and semi-aquatic plants that grow in surface waters, areas that fringe surface waters (i.e. the riparian zone), and on river floodplains. These plant communities may also be phreaphytic, meaning that they rely on groundwater, particularly during the dry season. Plant community structure and patterns of species distribution are dependent on hydrological processes, and in savanna regions where limited available moisture limits plant productivity, rivers and waterholes represent localised hotspots of high productivity (Pettit *et al*., in press). Fringing vegetation around waterbodies provide refugia for remnant tropical rainforest species in some parts of Cape York Peninsula.

The main groups of hydrophytes found in Cape York Peninsula are algae, aquatic plants, riparian vegetation, floodplain vegetation, and mangroves (Pettit *et al*., in press). Algae are important because they form the basis of most aquatic food webs. Whilst many thousands of algal names are reported from Australia, they are poorly known with respect to species diversity and distribution (Pettit *et al*., in press). It is likely that few would be endemic to Cape York Peninsula, although tropical algal communities in northern Australia have significantly different species composition when compared to temperature communities in southern Australia (Pettit *et al.*, in press). Aquatic plants may be either fully aquatic (i.e. the entire life cycle is in or on the water) or semi-aquatic, with the latter surviving and growing while seasonally inundated but continue to survive out of the water during the dry season. Aquatic plants can be found in most freshwater-dependent ecosystems across Cape York Peninsula, including streams, rivers, waterholes and floodplains, although few (e.g. *Vallisneria nana*) species have adaptations for flowing waters. By contrast, the diversity of aquatic plants in lacustrine and palustrine hydrosystems is much higher (Pettit *et al*., in press). Most aquatic plants in northern Australia are also found in other tropical regions of the world, and it is likely that Cape York Peninsula has very few, if any, species that are endemic to the region.

Riparian vegetation across Cape York Peninsula is dominated by only a small number of tree species, including river red gum (*Eucalyptus camaldulensis*), pandanus (*Pandanus aquaticus*), various paperbark species (Melalueca spp.), she-oak (*Casuarina cunninghamiana*), and swamp box (*Lophostemon grandiflorus*) (Pettit *et al*., in press). Some riparian zones contain relicts of rainforest species, including Leichhardt tree (*Naulcea orientalis*), stem-fruited fig (*Ficus racemosa*), cathormion (*Cathormion umbrellatum*), terminalia (*Terminalia microcarpa*) and strychnine tree (*Strychnos lucida*). Floodplain vegetation communities are dominated by grasses, with open perennial and annual swamps and billabongs having vegetation communities dominated by broadleaved paperbark (*Melaleuca* spp.) forests and sedge herbfields (Pettit *et al*., in press). Finally, mangroves occur in the lower reaches of riverine hydrosystems and throughout estuarine hydrosystems, with about 41 species known from northern Australia, and one species (*Avicennia integra*) being endemic to northern Australia (Pettit *et al*., in press). Mangrove species diversity is higher on the eastern coastline than on the western coastline.

4.4 Aquatic food webs and connectivity

Food webs describe the feeding relationships and the flow of energy throughout the ecosystem (Pusey & Kennard, 2009). Food webs generally start with primary producer organisms (e.g. plants and algae), which are then eaten by primary consumers animals which are in turn eaten by secondary and higher order consumers (predators). Energy flow can be a simple food chain from primary producer to primary consumers to higher order consumers but more often is more complex and the term food web is a more appropriate description of this energy pathway. For example, food webs often contain omnivores which consume both primary and secondary production.

Freshwater food webs are predominantly based on a combination of energy sources from within the water body (autochthonous) and subsidies from riparian and terrestrial (allochthonous) sources. Algae tend to form a more important source of carbon in aquatic food webs compared to other primary producers (e.g. aquatic macrophytes). However, other sources of carbon derived from the terrestrial environment may become significant at certain times of the year. For example, during the wet season, when high flows can increase turbidity thereby decreasing light penetration and primary production, terrestrial vegetation, insects and even vertebrates inundated by floodwaters become an important food source for some species. During the dry season when river flows are low or when pools become isolated and contract in size, terrestrial inputs of tree seeds, fruits and insects may become a very important food source for some species. Non-aquatic consumers such as waterbirds, riparian birds and snakes may add additional complexity to aquatic food webs (Fig. 4.14).

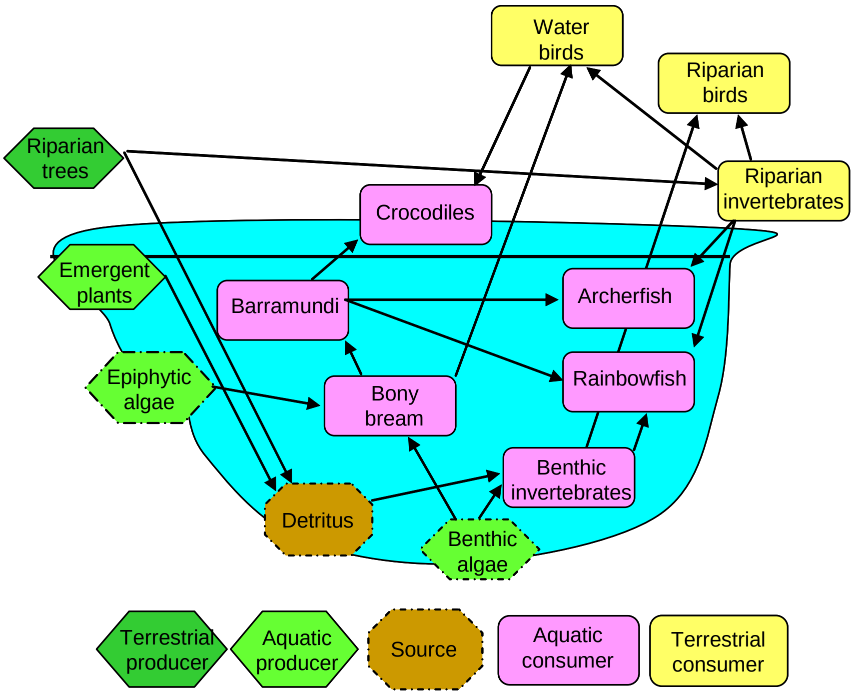

Figure 4.14. Conceptual diagram of a possible food web in a northern Australian river. Arrows represent pathways of organic material and energy. Major food sources are denoted by the broken lines around each food source. Not all possible pathways are presented (Source: Pusey & Kennard 2009).

Hydrological connectivity facilitates the movement of organic material and biota and this is critical for maintaining food web dynamics and ecosystem function at a range of spatial scales. In addition to small-scale lateral transfers between a river and its riparian zone, larger scale lateral transfers between the river and its floodplain also occur during the wet season. Given the enormous comparative differences in area (floodplains *vs* river), the transfer of material and energy between these two habitats may be enormously important for river function and ecological integrity.

Longitudinal fluxes of organic material are also a distinctive feature of riverine food webs, with fluxes occurring between headwater streams, main channel reaches and even estuaries and the near-shore marine environment. This movement may be passive (i.e. algae, detritus and invertebrates are moved downstream in the flow) or active, involving the upstream and downstream migrations of fish and invertebrates such as freshwater prawns. Seasonal differences between the wet and dry seasons have a large influence on the distribution and productivity of biota within the river as well as connectivity with the adjoining floodplain and the waterholes within the floodplain. This strong interconnection of aquatic habitats highlights the dependence of food webs on the river flow regime and the critical role played by the strong seasonality in tropical Australian rivers.

Douglas *et al*. (2005) proposed five general principles to characterise the food webs and ecosystems processes in northern Australia. These are: (1) seasonal hydrology is a strong driver of ecosystem processes and food web structure; (2) hydrological connectivity is important for terrestrial-aquatic food web subsidies; (3) river and wetland food webs are strongly dependent on algal production; (4) a few common macroconsumer species have a strong influence on benthic food webs; and (5) omnivory is widespread and food chains are short (i.e. there are only a few levels to the food web). These principles highlight the links between different parts of the riverine environment and the overriding influence of the natural flow regime. Food webs are the basis of natural communities and the best way to maintain that base is to protect the natural flow regime and connectivity.

5.0 Natural integrity of hydroecological features and threatening processes

The terrestrial, marine and freshwater ecosystems of northern Australia, including Cape York Peninsula, are regarded as some of the most extensive intact ecosystems in the world (e.g. Australian Tropical Rivers Group, 2004). Indeed, northern Australia has been heralded as one of the last major networks of free-flowing tropical rivers on Earth (Australian Tropical Rivers Group, 2004), with aquifers of the region being largely untapped (Pusey *et al*., in press c). The high integrity of aquatic ecosystems on Cape York Peninsula is a virtue of the overall low population density of people in the region and limited water resource development (Pusey *et al*., in press). The generally intact condition of ecosystems on Cape York Peninsula is recognised in the Queensland Government's draft biodiversity strategy, *Building Nature's Resilience: A Biodiversity Strategy for Queensland* (DERM, 2010a), with the Wenlock River regarded as 'one of the most pristine and highly biodiverse rivers in Australia'.

The Riverine Disturbance Index (RDI; Stein *et al*., 2002) is a metric that describes indirect measures of flow regime disturbance (e.g. impoundments, flow diversions and levee banks) and catchment disturbance (e.g. urbanisation, road infrastructure and land-use activities). The index quantifies disturbance for individual stream sections along a continuum from near pristine (very low scores, e.g. zero) to severely disturbed (high scores). Most of Cape York Peninsula has relatively low RDI scores (Fig. 5.1), indicating the generally good condition of freshwater-dependent ecosystems of the region. In contrast, some subcatchments in the upper Mitchell River (e.g. the Palmer and Walsh Rivers) have higher RDI scores because they have been impacted by past gold mining and overgrazing (see Pusey *et al*., in press c), and the Walsh River has been impacted by alterations to its flow regime (i.e. impoundments and inter-basin water transfers from the Baron River in the Wet Tropics region) and has elevated stream nutrient levels associated with localised irrigated agriculture (Pusey *et al.,* in press c). Estuaries and riparian vegetation ecotones are typically in good condition throughout Cape York Peninsula.

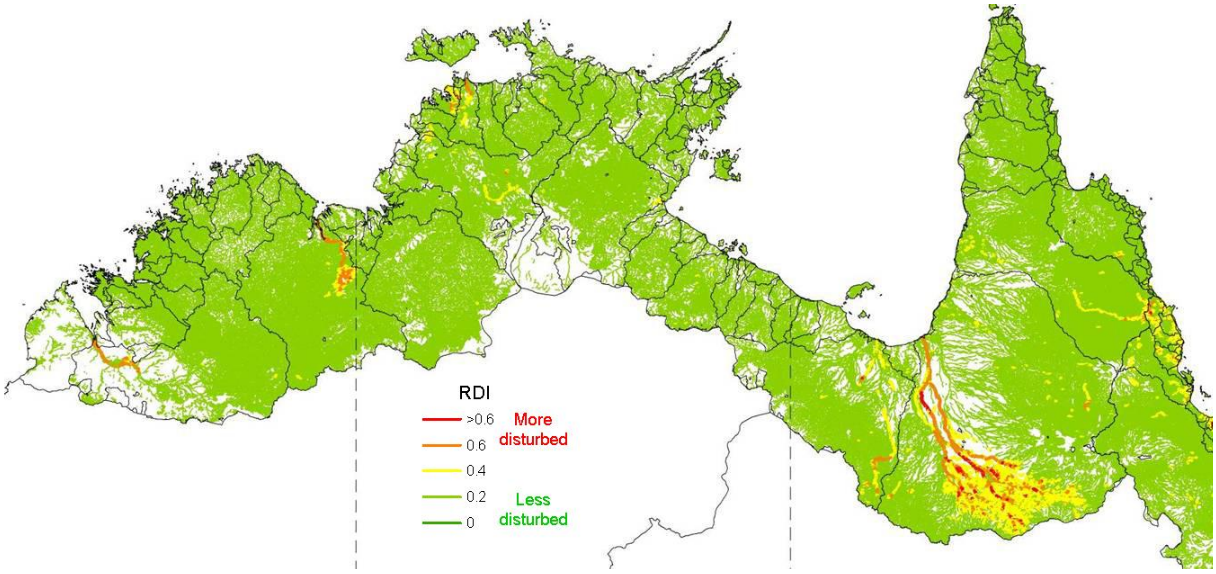

Figure 5.1. Riverine Disturbance Index (RDI) scores for hydrosystems of Cape York Peninsula.

The elevated RDI score in the upper Mitchell River area demonstrates that Cape York Peninsula is not a pristine landscape (Pusey *et al*., in press c). Various impacts and threats to freshwater-dependent ecosystems are known in Cape York Peninsula, and these a summarised in Table 5.1. This list of ecological threats to aquatic ecosystems on Cape York Peninsula could be used in future assessment of risk to their heritage values (see UNESCO, 2010). Despite these various and mainly localised pressures, the freshwater-dependent ecosystems of Cape York Peninsula are overall among the least impacted hydrosystems in the country (NLWRA, 2002) and globally (Vörösmarty *et al*., 2010). Consequently, these systems are ecological assets of global significance (Pusey & Kennard, 2009).

Table 5.1. Overview of ecological threats and impacts to freshwater-dependent ecosystem on Cape York Peninsula. Summarised from Pusey *et al*. (in press c).

Threat	Overview
Grazing	• Pastoralism is the dominant land use in northern Australia, although grazing pressure on Cape York Peninsula is lower than other regions; • Cattle aggregate in shady riparian zones; • Grazing results in increased soil erosion, increased soil compaction, more 'flashy river flows', reduced water quality and impacted in-stream biotic communities; • Impact or loss of springs, leading to major impacts to dry-season flows and water availability.
Invasive animals	• Feral horses may have similar impacts to pastoralism; • Localised occurrences of alien freshwater fish – guppies (*Poecilia reticulata*) in upper Walsh River and Mozambique tilapia (*Oreochromis mossambicus*) in the Endeavour River; • Feral pigs (*Sus scrofa*) consume a variety of aquatic and riparian biota (e.g. seedlings of riparian vegetation, freshwater invertebrates especially mussels, amphibians, and the eggs of ground nesting turtles, crocodiles and birds), and increase river bank erosion and sedimentation; • Cane toads (*Bufo marinus*) have led to declines of freshwater crocodiles and water monitors (*Varanus* spp.), although sooty grunter (*Hephaestus fuliginosus*) may be able to consume cane toads with no ill effects.
Invasive plants	• Sources of weeds include 'escaped' pastoral species, deliberately introduced species, or those introduced inadvertently via fishing equipment and boats; • Some terrestrial weeds (e.g. prickly mimosa *Mimosa pigra* and rubber vine *Cryptostegia grandiflora*) form dense thickets around waterholes, preventing access by wildlife and recruitment by native riparian vegetation; • Several aquatic weeds are reported from Cape York Peninsula, including *Salvinia molesta* and *Eichorna crassipes*, both of which can grow prolifically and are highly invasive. They may block

Threat	Overview
	sunlight to aquatic ecosystems, reduced dissolved oxygen, reduced abundance and diversity of native aquatic plants, and reduced habitat quality for fish and other aquatic biota; • Escaped pastoral species, including *Hymenachne amplexicaulis*, *Urochloa mutica* and *Andropogon gayanus*, can choke aquatic ecosystems and riparian zones, and increase fine fuel loads that lead to intensive fires.
Altered fire regime	• Shift from small-scale early dry-season burns, to large scale intensive burns; • Intensive late dry-season burns encroach on riparian vegetation, which is not as resilient to fire as savanna vegetation; • Secondary impacts to in-stream ecosystems, including greater sediment loads, greater solar radiation, and altered aquatic plant and faunal composition.
Horticulture	• Restricted to upper Mitchell River area (see Fig 5.1). Impacts may include increased sediment and nutrient loads and contamination with biocides.
Tourism	• Recreational fishing is the largest tourism-based activity in Cape York Peninsula, with barramundi (*Lates calcarifer*) being prized angling species. Impacts may include localised overfishing (and secondary impacts to food webs) and impacts from boating (e.g. increased erosion from wash, hydrocarbon contaminants); • Other impacts associated with water-oriented tourism include addition of nutrients from human waste, litter and detergents, and impacts associated with roads, access and 4WD use.
Industrial, mining and urban developments	• Abandoned gold mines in the Palmer River (upper Mitchell River) continue to contaminate water and sediments.
Altered flow regimes	• Flow regimes on Cape York Peninsula are mostly in a natural condition, however any future proposal for significant water extraction has potential to adversely affect the biodiversity and ecology of freshwater-dependent ecosystems of the region.
Physical barriers to movement	• These include dams, weirs, tidal barrages, road crossings; all of which constrain movement by aquatic animals through river networks; • Many species migrate between freshwater sections of rivers and estuaries or even the sea (e.g. barramundi), and several species require access to brackish water for early larval development to complete the life cycle (e.g. cherabin). Such species are known to become locally extinct if significant barriers prevent both downstream and upstream migration by these species; • Other species migrate within freshwater sections of rivers; for example catfish and sooty grunter move into headwater streams for reproduction.
Climate change	• Climate change predictions for Cape York Peninsula include increases in high, mean and low temperatures, greater evaporation rates, and greater intensity and frequency of extreme events (i.e. severe storms, tropical cyclones and drought); • High elevation aquatic species, such as in the upper Mitchell River, may at risk from increasing temperatures, as shown for terrestrial species in the region (Williams *et al*., 2003); • River levels may be lower more often, thus reducing critical habitat for aquatic biota, and dry-season refugia may be fewer and smaller, and thus under greater pressure; • Floodplain inundation may reduce in magnitude and duration, having implications for maintenance of river morphology, biotic dispersal, and reproduction and recruitment by aquatic biota; • Low-lying coastal wetlands and their unique biota may be at risk by rising sea levels.

6.0 Preliminary assessment of the national and international natural heritage significance of hydroecological features of Cape York Peninsula

A preliminary assessment of the national and international natural heritage significance of hydroecological features and processes of Cape York Peninsula was undertaken by the project team according to the National Heritage and World Heritage criteria that relate to natural heritage (Table 6.1). This assessment used both available data and expert judgment to assess the natural heritage values. We include justification for listing hydroecological features in the table and provide comparative assessments to illustrate heritage values.

We identified 11 hydroecological features as potentially having natural World Heritage and/or National Heritage significance. This short list is not a final determination of freshwater-dependent ecosystems of Cape York Peninsula for future National Heritage or World Heritage listing. The data and expertise was not comprehensive and more information may be required to establish the natural heritage values of aquatic ecosystems of Cape York Peninsula. We recognise that consultation would need to be undertaken with owners, occupiers and those with Indigenous rights or interests before any of the identified hydroecological features are added to either the National Heritage or World Heritage list.

Table 6.1. Preliminary assessment of the natural heritage values of hydroecological features and processes of Cape York Peninsula in relation to the World Heritage and National Heritage Criteria (see body of report for more details on heritage features). Hydroecological features considered by the project team to potentially qualify under each criterion are indicated with Y (note that some areas could not be assessed with certainty to incomplete information and would require additional expert panel assessments). World Heritage Criteria: vi – beauty; vii – earth history; ix – (hydro)ecological processes; x – conservation. National Heritage Criteria: a – course of natural history; b – uncommon elements of natural history; c - potential to yield information to contribute to understanding of natural history; d - has characteristics of a particular class of natural environments.

Hydroecological feature	**World Heritage Criteria**				**National Heritage Criteria**				**Significance of natural values**	**Comparative assessment**
	vi	Vii (a)	ix	X (b)	a	b	c	d		
1. Jardine River	Y		Y	Y	Y	Y	Y	Y	• Strong biotic affinities with PNG [fish and invertebrates – AHC, 1995)] – legacy of former connectivity during glacial phases. Affinities also at molecular level - *Denariusa bandata* from the Jardine river shows close genetic relationships with populations from the Fly River (PNG). • Likely a long-term refugium – high endemism including cryptic endemics (e.g. endemic taxon within *M. maccullochi*). • Presence of relict populations of freshwater fish with fragmented distributions indicative of former widespread distributions and connectivity to Papua New Guinea; • The catchment was formerly a shallow sea, hence it has a unique sandstone lithology; • Unique hydroecology for a tropical river – oligotrophic, extremely low solute concentrations, low pH, sandstone geology/aquifer; • Highly distinctive flow regime type, typified by perenniality; • High diversity of other freshwater-dependent habitat types, including freshwater wetlands and swamp systems, forested wetlands, mangrove forests, salt flats, and sedgelands. Probably diversity in swamp development ages. Floating vegetation communities present (AHC 1995). • A large proportion of the diversity in this river occurs in perennial spring fed swamp habitats adjacent to the river, this pattern in contrast to that observed elsewhere. • Highly diverse and distinctive freshwater fish fauna – endemic fauna and transitional fauna (i.e. elements of eastern and western CYP and PNG fauna, e.g. *Neosilurus brevidorsalis*). The Jardine River shows up as being a separate group from other Northern Aus rivers • Large parts of the region are already protected and are relatively undisturbed; • Jardine Swamps contains features associated with prograding coastline including beach ridges and relic delta.	• No comparable legacy of former Australia-New Guinea connections; • Relict populations also occur in Jardine River and Wet Tropics, but for some species, strong genetic differentiation makes these places not comparable. • No comparable water quality parameters exist elsewhere; • Only one other small stream in Arnhem Land has similar flow regime; although with the Jardine being a much larger system, they are not highly comparable. • The Jardine River is possibly incomparable with other rivers - perhaps Olive River (smaller scale, Wenlock River, Jacky Jacky Creek, Jackson River)
2. Escape River Estuary						Y		Y	• Sequence of many marine inlets, including an extensive low-gradient estuarine complex at the mouth of Escape River composed of recent sediments that have been colonised by mangroves; • These are amongst the most diverse and well-developed mangroves in	• The Scarden River in PNG could be considered similar, but there are no Australian examples.

Hydroecological feature	World Heritage Criteria				National Heritage Criteria				Significance of natural values	Comparative assessment
	vi	Vii (a)	ix	X (b)	a	b	c	d		
									Australia, with the extent and structure being exceptional at the national level, including some of the tallest mangrove forests in Queensland (AHC 1995). *Rhizophora stylosa* (red mangrove) often completely dominates, forming an even, closed canopy (5-30m tall); • There are some saline intertidal and supra-tidal flats within in the complex and some associated with the complex. • A distinctive feature is the relative rarity of salt flats in the marine-terrestrial transition area. There are about 2,000 ha of salt flats on the site but most of them are located in the middle of mangrove islands.	
3. Olive River					Y	Y	Y		• High diversity of small coastal streams, with a reduction in diversity from north to south along coast; • Rainforest rivers with perennial flow regime located in an area otherwise characterised by wet/dry tropical savannah. • Contains remnant rainforest riparian vegetation, indicative of more extensive past distributions of rainforest communities • Unusual freshwater fish assemblage - high diversity for a relatively small systems, mix of east and west CYP fauna, also having biotic affinities with the Wet Tropics and the Jardine River and Fly River (PNG) – indicative of former connectivity,	• Similar transitional fauna to Jardine, Pascoe and Lockhart Rivers and to rivers in the Wet Tropics and smaller rivers around Shelburne Bay.
4.Normanby River floodplain									• High diversity of flow regime classes across the catchment, highly productive system; • Important waterbird habitat, very high number and high diversity of lacustrine and palustrine habitats in a relatively small area; • Extensive inter-tidal flats; • important breeding location for estuarine crocodiles; • Contains a species otherwise limited to west of the GDR (*Neoarius paucus* formerly known as *N. midgelyi*) • 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) • Extensive mud flats • Important estuarine Crocodile breeding ground • Important site of mollusc fossils	• Possibly has similar characteristics to lower reaches of some Gulf of Carpentaria rivers (e.g. Mitchell River)
5. Dune lake systems: 5a. Cape York Peninsula dune lakes (Lake Bronto, Lake Wichera); 5b Hammer Creek,	Y	Y	Y	Y	Y	Y	Y	Y	• Rare sand dune geomorphology, spectacular extensive white sand dune formations – internationally significant; • Presence of relict populations of freshwater fish indicative of former connectivity, often have unusual assemblages of freshwater fishes • High diversity of hydrosystem types, including perched and window lakes, acidic coastal streams, 'black water' estuaries, dun lake systems typically contain very large numbers of individual aquatic habitats;	• Relict populations of freshwater fish also occur in Jardine River and Wet Tropics, but for some species, strong genetic differentiation makes these places not comparable. • Wallum dune systems near Cairns (Cowley)

Hydroecological feature	World Heritage Criteria				National Heritage Criteria				Significance of natural values	Comparative assessment
	vi	Vii (a)	ix	X (b)	a	b	c	d		
Shelburne Bay, Cape Grenville; 5c Cape Flattery, Cape Bedford.									• High endemism, e.g. several frog and crayfish species; • Low visitation rates and high water purity • Relatively large area (several hundred sq kilometres) in an undisturbed condition. • Oligotrophic acidic stained dune lakes (both perched and window types) and stream systems linked to origins and adaptations of fauna. These oligotrophic, low pH dunes lakes; an uncommon feature elsewhere in northern Australia • Shelburne dune lakes are among best examples of their type in the world (AHC 1995). • Significant tropical woodland and heath vegetation communities, and high habitat diversity of other freshwater-dependent vegetation types	• Fraser Island WHA in S.E. Queensland, has comparable dune lakes but experiences much higher visitation rates and has impacted water quality; • Sand mining operation at Cape Flattery, similar operation on North Stradbroke Island
6. Bloomfield and Daintree Rivers									• Endemic species of spiny crayfish (*Euastacus robertsi*) and fish (Bloomfield River cod, *Guyu wujalwujalensis*), suggestive of long period of isolation. For example, the Bloomfield River Cod is 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. • Bloomfield is a rainforest river; has a waterfall close to river mouth. • Daintree river already in the wet tropics word heritage area	• Whilst there other high discharge rivers in the Wet Tropics, the Daintree is the best exemplar of this class of flow regime;
7. McIlwraithe and Iron Ranges, Pascoe River									• High endemism in frog species;	•
8. Cape Tribulation coastal streams									• Interesting fish, frog and crustaceans fauna, concentration of localised endemics, although more research is needed. • Recent discoveries several sicydine gobies, which may be more typical of species found on high tropical islands in the Pacific than of continental rivers; • High diversity of wetland types for a small area • Short catchments but high rainfall (up to and over 4 m per year), similar to river systems of tropical high islands;	• Possibly similar to the Lockhart River and to small rivers on the Hinchinbrook Island WHA; • Only other short-length perennial rivers in Australia occur in Tasmania.
9. Embley River / Ducie / Tentpole Creek etc & bays around Weipa									• No details	•
10. Wenlock (stronger claims) & Archer Rivers *(aggregation)*									• Connects rainforest of McIllwraith - Iron ranges and the smaller ranges on the west coast • Seasonal refugia • Rich freshwater fish fauna	

Hydroecological feature	World Heritage Criteria				National Heritage Criteria				Significance of natural values	Comparative assessment
	vi	Vii (a)	ix	X (b)	a	b	c	d		
									• Many endemic plant and animal species • High habitat diversity of wetlands types in a small spatial area • Junction of Archer-Coen provides excellent example of flood plain morphologies and environments	
11. Lower Mitchell River floodplain									• Presence of highly restricted terapontid grunter in Mitchell River (*Variichthys lacustris*) indicates former connection to southern PNG. • High area, density and connectivity of wetland features (lacustrine & palustrine) • Important waterbird habitat (e.g. Great billed heron abundant in these wetland types) • Diverse and extensive system of streams, closed depressions and open depressions, providing seasonal, semipermanent and permanent habitats for waterbirds, fish and other aquatic biota; • Mitchell River contains floodplain wetland systems with higher diversity in transparency/turbidity regimes – some are permanently turbid, others permanently clear whilst others change during the year. Such disparate wetland types may be found in very close proximity and impart diversity in wetland habitats over small spatial scales.	• Normanby River floodplain • Staatan/Gilbert floodplain • Flinders/Norman floodplain

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