A REVIEW OF AQUATIC, MANAGEMENT ISSUES AND NEEDS FOR

THE NORTHERN GULF NRM PLANNING REGION

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INTRODUCTION

Knowledge of the biodiversity and environmental values of freshwaters of the Northern Gulf region is limited compared to the knowledge base for marine and estuarine ecosystems, or of freshwaters elsewhere. Even basic information, such as a complete inventory of fish species and their distribution, is lacking let alone knowledge about ecosystem processes. Most of the limited aquatic environmental research that has been done has been driven by development issues. For instance, most of the marine research has resulted from the development of commercial fisheries in the Gulf of Carpentaria and currently, most riverine research is stemming from examining the impacts of existing irrigated agriculture in the upper Walsh catchment or proposals to develop new large dam and/or irrigation schemes.

This report provides a summary of the aquatic research and assessment work conducted to date in the Northern Gulf NRM region (Mitchell, Staaten, Gilbert and Norman catchments) of the Gulf of Carpentaria.

1.0 FRESHWATER AND RIPARIAN HABITATS

1.1 Importance of the Asset

Water provides the major connection between the uplands and the savanna lowlands and the coastal plains, wetlands and offshore habitats. Because of the variety of habitat types covered, from rainforests headwaters to savanna plains, basalt streams, sandstone gorges, to extensive coastal floodplain, wetlands and tidal forests and seagrass, the Northern Gulf rivers probably comprise some of the most diverse, but poorly known rivers systems in Australia. Because of the generally low levels of development across much of the region, the condition of many of these aquatic assets remains high, but still require active management to maintain their condition status and to manage existing and emerging threats.

The length of waterways in the Northern Gulf region is enormous. For instance, there are over 15,425km of major stream length in the Mitchell Catchment alone (Moller *et al.* 2002). Given that the Mitchell catchment represents approx. 36% of the Northern Gulf region, this could extrapolate to >45,000km of major stream length in the entire Northern Gulf planning region. Due to high rainfalls and extensive low gradient plains and floodplains, the waterways of the Northern Gulf region house thousands of permanent and semi-permanent waterbodies of considerable, but often understated, environmental value.

1.2 Freshwater Habitats With Formally Recognised Environmental Values

Although there are thousands of wetlands and waterbodies within the Northern Gulf region, probably the most widely recognised for their environmental values are the extensive coastal floodplain wetlands. These feature prominently in wetland assemblages listed in the Directory of Important Wetlands in Australia (ANCA 1996) and on the Register of the National Estate. The coastal freshwater wetland complexes have only recently been mapped by the EPA (see www.actfr.jcu.edu.au/sgeip). This mapping illustrates the variety of wetland types and their location and extent.

The upper rainforest-covered tributaries of the Palmer, Mitchell and Walsh rivers are the only streams within the Wet Tropics World Heritage Area (WTWHA) that flow into westward draining catchments (all the other streams are in catchment that discharge to the east coast of Queensland). These streams hold superlative natural heritage and conservation values, including several endangered frog species and other frog and crustacean species of considerable conservation value. An analysis of the conservation values of streams across the entire WTWHA (Pusey *et al.* 1999) found that those within the Palmer, Mitchell and Walsh catchments were of a generally equivalent environmental value to streams elsewhere within the WTWHA. These streams also provide very good quality water to downstream reaches, providing a buffer against water quality impacts from land uses in developed parts of the catchment.

1.2.1 Directory of Important Wetlands

The Directory of Important Wetlands in Australia (ANCA 1996) provides a list and description of wetlands considered to be of national importance. Within the Northern Gulf region, all of the wetlands listed in this directory are on the immense coastal floodplains. Other nationally important wetlands probably exist within the catchment but due to a lack of information, have not been able to be nominated for listing in the Directory. Currently listed wetlands from the Northern Gulf region are:

Dorunda Lakes
Is a large semi-abandoned riverine channel freshwater wetland complex covering 6,810 hectares. Dorunda Lake is a large, deep permanent riverine pool with a number of shallower permanent pools nearby. The site description claims this site to be one of the most pristine wetland sites in the Gulf Plains. This high profile wetland is also important for tourism.

Macaroni Swamp
This swamp of 258 hectares overflows into Macaroni Creek, a tributary of the lower Gilbert River. The lake is filled by a minor unnamed stream draining a localised catchment area. The swamp is freshwater but not permanent, with a maximum depth of ~1m. It has significant areas of aquatic plants, semi-aquatic and emergent plants. The site is described as a good example of a shallow, semi-permanent wetland and a significant habitat for waterfowl that is in good condition, including with minimal grazing disturbance. The establishment of ponded pastures would be detrimental to this site.

Mitchell River Fan Aggregation
This large freshwater wetland aggregation, located SE of Kowanyama, covers 714,886 hectares. It is up to 173km long and 73km wide. It is part of a huge alluvial fan bounded by the Mitchell River, Alice River and Yanko Creek to the north and the Nassau River and Sargents Creek to the south. It consists of a variety of wetland types, including permanent waterholes within streams, flooded depressions, levees and backplains. Contributing rivers include the Palmer, Mitchell and Lynd Rivers. The diverse range of wetland types vary in hydrological character, though most are less than 3m deep and the shallower wetland dry out during the dry season. The wetlands of this aggregation are important to Aboriginal people. Current disturbances include cattle grazing, feral animals, rubervine and water hyacinth.

Smithburne-Gilbert Fan Aggregation
This large freshwater wetland aggregation, located NW of Normanton, covers 250,320 hectares. It is up to 75km long and 60km wide. The aggregation is part of an alluvial plain incised by a

complex series of stream channels and braided streams, as well as shallow depression, levees and flooded plains, forming a very concentration of lagoon type wetlands. The main contributing river is the Gilbert River, with the Smithburne River being a major distributary. This aggregation is similar to that of the Mitchell River Fan Aggregation, but has less rainfall and waterholes have less permanency. There are many oxbows that retain water throughout most years. The shallow wetlands of the aggregation are thought to be the most important breeding area for sarus cranes in Australia. The wetlands are affected by cattle grazing feral pigs and rubbervine infestations.

Southeast Karumba Plain Aggregation
This large wetland aggregation, located SSE of Kowanyama, covers 336,233 hectares between the Smithburne and Gilbert Rivers. It is up to 238km long and 20km wide. The area is dominated by estuarine wetlands such as marine intertidal flats, beach dunes, and saline clay plains, and is subject to extensive seasonal freshwater flooding during flood events. The wetlands of the aggregation are fed by the Smithburne, Gilbert, Staaten and Nassau Rivers and numerous coastal streams. The area supports significant populations of many waterbird and wader species and includes two Declared Fish Habitat Areas – based on the Nassau River and the Staaten-Gilbert River estuaries. Wetlands within the aggregation are very important for aboriginal people. Disturbances include cattle grazing, feral pigs and rubbervine infestations.

Southern Gulf Aggregation
This very large wetland aggregation is up to 262km long and 30km wide, covering an area of 545,353 hectares. Most of the aggregation is within the Southern Gulf Catchments planning region, but it also includes significant sections of the Norman and Smithburne rivers. The area is dominated by estuarine wetlands such as marine intertidal flats, beach dunes, and saline clay plains, and is subject to extensive seasonal freshwater flooding during flood events. This aggregation is the largest continuous estuarine wetland aggregation of its type in northern Australia and one of the three most important shorebirds areas in Australia (Watkins 1993). The wetlands of the aggregation are very important for tourism and recreational fishing. Disturbances include cattle grazing, feral pigs and rubbervine infestations.

Stranded Fish Lake
This 67 hectare wetland is 2km by 500m, and located 41km SW of Karumba on the western edge of the Northern Gulf NRM planning region. It is a hollow formed between the eroded remnants of an old beach and is not connected to a particular catchment, being filled by either very high tides or localised freshwater run-off. Marine fish can migrate into this wetland but would become stranded and usually die there due to naturally poor water quality. The lake is essentially devoid of flora, being located on a salt clay plain and thus has no grazing in adjacent areas.

1.2.2 Register of the National Estate

The Register of the National Estate is compiled by the Australian Heritage Commission and recognises sites of environmental, cultural, social or historical significance. Listing provides formal recognition of the values of listed sites and places some onus on the Commonwealth not to take actions to adversely affect those values, but does not involve any change in management and places no constraints on owners. Few locations within the Northern Gulf region relevant to aquatic values are recognised on the Register of the National Estate. These are:

Mitchell River-Nassau River area

Nominated for its landform and extensive floodplain wetland ecosystems, but has not yet been formally registered on the estate list. It overlaps extensively with the Mitchell River Fan Aggregation as listed in the Directory of Important Wetlands (see above).

Mutton Hole Wetlands, Normanton
The Mutton Hole wetlands represent a diverse array of estuarine and freshwater wetlands and form part of the Southern Gulf Aggregation as listed in the Directory of Important Wetlands (see above). Its nomination has not yet been formally registered on the estate list.

Inkerman-Galbraith Area
This area covers the Staaten River estuary and coastal areas north to Salt Arm Creek. It is listed because of its floodplain landforms and its variety of coastal freshwater and estuarine and wetlands. Rubbervine is apparently widespread on the coastal dunes and swales of the area, forming large, dense stands in some locations. Its nomination has not yet been formally registered on the estate list.

Southern Gulf Plains
This site covers a wide variety of land and wetland habitat types from the coastal environments of Nicholson catchment to the coastal environments of the Norman and Smithburne Rivers. This site overlaps extensively with the Southern Gulf Aggregation and the Southeast Karumba Plain Aggregation as listed in the Directory of Important Wetlands (see above).

Staaten River National Park
This site is already protected by its National Park status. It is listed mainly because of its size, which makes it a valuable flora and fauna reserve. Aquatic values were not specifically included in its nomination, but this is more likely due to lack of available information.

1.2.3 Fish Habitat Areas

In Queensland, Fish Habitat Areas can be declared under the Fisheries Act (1994). These declared Fish Habitat Areas to enhance current and future fishing activities and to protect important habitat for fishes and other aquatic fauna. Legal forms of fishing or collecting are not restricted in declared Fish Habitat Areas, with most protection revolving around restrictions on development that result in habitat disturbance. Fish Habitat Areas may be declared in one of two management categories ‘A’ or ‘B’, with the former having the greater status and being reserved for the most important habitats. Across Queensland, there are 79++(1995 figure) (website says 68???) declared Fish Habitat Areas (ref for current number), all of which are in coastal environments. The legislation does not adequately allow for the declaration of freshwater Fish Habitat Areas, due to greater complexities of surrounding land tenure and other management issues. There are only two declared fish habitat areas within the Northern Gulf NRM planning region, both of which are in management category ‘A’ (DPI 1997). These are the Staaten-Gilbert Fish Habitat Area and the Nassau River Fish Habitat Area.

The Staaten-Gilbert Fish Habitat Area was declared in May 1990 and covers 10,175 hectares from 1km south of the Gilbert River mouth to 8km north of the Staaten River mouth. In the Gilbert River, the declared Fish Habitat Area extends only a short distance upstream. In the Staaten River, it extends up to the lower reaches of the Staaten River main channel, Staaten North Branch and Vanrook Creek. The Nassau River Fish Habitat Area was declared in May 1990 and covers 4,970 hectares. The declared area extends up the Nassau River to also include the lower reaches of Scrutton Creek. It also extends along southward the coast between the low and high water marks crossing the mouths of Rocky and Cattle creeks, extending as far south as the northern boundary of the Alma Holding.

1.2.4 Priority Freshwater Habitats Throughout the Region

There is very little recognition of values of most of the freshwater habitats of the Northern Gulf region. Even the recognition that the upland streams of the Mitchell catchment and its major tributaries contain many superlative values of the Wet Tropics World Heritage Area, are not as widely recognised as other Wet Tropics streams. The values of the coastal wetland aggregations are well known and recognised in the Directory of Important Wetlands, on the Register of the National Estate or as declared Fish Habitat Areas, and even in the minds of most stakeholders. However, these are all predominantly coastal and floodplain habitats. Apart from streams within the WTWHA, there is very little formal recognition of any kind for freshwater habitats in most other parts of the region. There is no standard basis across the region or its catchments, for recognising those waterbodies that may hold special values. Individual waterbodies would be recognised as important by those that have had associations with them, but this does not enable their importance to be evaluated in a regional context.

There are many criteria by which the importance of waterholes may be valued. The gorges of the Gilbert and Einasleigh catchments are important because of their uniqueness and also as tourist attractions, the upper Lynd catchment where major tributaries such as Fossilbrook Creek have numerous large waterholes, with this high level of baseflow maintained by groundwaters from shallow basalt aquifers, and the numerous floodpath overflow lagoons along the length of major rivers which are highly productive and greatly increase the variety of aquatic habitat present. Permanent waterholes in river reaches that are otherwise largely dry would also be important because of their importance as a refuge in that river reach. Other types of waterbodies may include those that harbour rare or unique species, those that represent unusual or rare habitat types and sustain important ecological processes. Even artificial waterbodies, such as the Mareeba Wetlands (formed by reception of urban runoff) have high environmental value and the protection of water quality is important for weirs that serve as town drinking water supplies. Some waterbodies may be socially important (eg, swimming holes) or culturally important to traditional owners.

Springs are small, but particularly important aquatic habitats. As many provide permanent water, they create distinctive aquatic habitat in otherwise dry environments. They may contain specialist spring animal and plant species and are often of great cultural and pastoral significance. Springs are particularly vulnerable to disturbance from livestock, feral pigs, ponded pastures, excavation and bore-drain construction. The Great Artesian Basin (GAB) underlies much of the Northern Gulf region and several major springs groups from this source are present. The EPA has mapped virtually all of the springs associated with the GAB in Queensland and undertaken a prioritisation process (Fensham and Fairfax 2003). They have also partly mapped springs not associated with the GAB (eg, basalt or sandstone associated springs). In the Northern Gulf, significant springs occur around the McBride Plateau (draining into the Einasleigh River), the granite springs near Georgetown, the Tallaroo hot springs, and the upper parts of the Norman, Gilbert, Staaten and Lynd rivers (R. Fensham pers. comm..). Throughout the GAB, the majority of formerly permanent discharge springs have become inactive due to loss of pressure created by excessive extraction, predominantly for pastoral uses. Several of the better remaining discharge springs occur within the Northern Gulf region (eg, Bulleringa National Park).

An inventory of most types of waterbodies is lacking for the catchment. A catchment wide program to inventory this would provide the basis for solid future planning. Such a program would involve determining the types of waterbodies present (ie, a classification scheme) and then identifying the number and location of waterbodies in each category. This type of information can be gained from topographic maps, aerial photos and local knowledge. Selected representative examples of each type of waterbody would be utilised for condition assessment. Despite the thousands of waterbodies present, this is an achievable task. The inventory would group waterbodies into aggregations of similar waterbodies in many instances. Given the size of such an undertaking, it could not be exhaustive, but should be sufficient to provide greater recognition of the values of these habitats and to underpin validation of condition trends as required in the NRM plan. The involvement of knowledgable community members with on-ground experience would greatly enhance this undertaking.

2.0 CATCHMENT CONDITION

The aquatic habitats of the Northern Gulf region are generally considered to be subject to low levels of disturbance. Mining was the first disturbance to the aquatic habitats of the region, beginning in Gilbert and Palmer catchments in the 1870's. Grazing followed shortly thereafter. Irrigated agriculture did not begin in any significant manner until the 1950's and fishing in the 1960's. Urban influences are present but remain limited and localised due to low population density. Toady, mining, grazing, urban, semi-rural, fishing and agricultural influences are all still increasing in influence.

2.1 Quantitative Riverine Condition Assessments

Within the Northern Gulf region, five studies have undertaken quantitative, repeatable, assessments of riverine condition, all of which were in the Mitchell catchment. The condition of rivers across the whole of the Mitchell catchment were assessed under the State of the Rivers program and as part of the National Land and Water Resources Audit. The condition of the upper Mitchell and Walsh Rivers were assessed as part of the Water Resource Plan for the Barron Catchment and again as part of a large Natural Heritage Trust project (Ryan *et al.* 2002). The condition of nine sites in the Palmer River sub-catchment were assessed as part of the CYPLUS program (Herbert *et al.* 1995). No other catchments within the Northern Gulf region have been subject to any systematic condition assessment.

The State of the Rivers is a state-wide program run by DNRME that reports on the condition of rivers at a catchment scale. It has been applied in at least 16 other catchments in Queensland since its inception in 1993. From August 1998 to August 1999, 88 sites in the Mitchell catchment were assessed under this program with the results reported in Moller *et al.* (2002). These included 21 sites in the Mitchell catchment itself, plus 17 in the Lynd, 11 in the Palmer, 19 in the Walsh catchment, 5 in Alice, 14 in the lower Mitchell plains. Each site is assessed in considerable detail, though on average, there is only one site for every 175km of stream length, so the geographic coverage is not extensive. It is considered to be a somewhat 'random' selection. Overall, 79% of stream lengths were considered to be subject to low to very low levels of disturbance, 13% to moderate levels of disturbance and only 8% to high or very high levels of disturbance. Sites with the greatest disturbance were located in the MDIA.

83% of stream length was rated as having very stable banks, 9% as stable and 8% as moderately stable to very unstable. Sites with the greatest level of instability were located along the main channel of the Mitchell River between Bellevue and Mt. Mulgrave and Brown Creek between ? and Gamboola and the Alice River upstream of its junction with Crosbie Creek. Further information on the distribution of bank erosion and instability should be available from the reports of the Technical Assessment Panel of the Gulf WRP, who undertook a survey and aerial inspection of much of the length of the Mitchell River and several main tributaries in March 2004.

Channel habitat diversity was low, with 66% of sites having low to very channel habitat diversity, 17% moderate and 17% had high to very high diversity. Diversity varies across the catchment but is generally highest in more upland reaches and lowest on floodplain reaches. This is counterbalanced though by the greater availability of off-stream habitats, such as floodplain lagoons, swamps and a wide variety of wetlands in the floodplain reaches that are not included in the State of the Rivers surveys which only include main channel habitats.

Riparian vegetation condition was good to very good at 82% of sites, moderate at 10% of sites and poor to very poor at 8% of sites. Sites where riparian vegetation was considered to be at its poorest were along Elizabeth Creek, Chillagoe Creek, Rocky Tate River, Fulford Creek (Lynd sub-catchment) and the upper reaches of the Lynd River. Exotic plants were present at 77% of sites, with rubbervine being the most common, being found at 64% of sites, including being abundant at 84% of those sites where it was present.

Aquatic habitat condition was rated as good to very good at 34% of sites, moderate at 28% of sites and poor to very poor at 38% of sites. Aquatic habitat condition was poorest at sites along Elizabeth Creek and Emu Creek (Walsh sub-catchments), the King River and the Palmer River above Maytown, the Palmer River from Strathleven to the junction with the Mitchell River, Brown Creek (Mitchell sub-catchment) and the Mitchell River around Bellevue and the St. George River, the lower Mitchell River (below the Palmer junction), the Scrutton River, from along Massie Creek (Lynd sub-catchment), the Tate River from Bolwarra to Torwood and the Lynd River from Torwood to the Mitchell River junction, and the upper Lynd River and tributaries.

The above analysis would indicate that in-stream disturbance are more prominent than disturbance to banks stability or riparian vegetation. The above summary is based on analysis across the entire catchment, which includes everything from rainforest to lowland savanna environments. Division into types of reaches (eg, rainforest, savanna etc.) would give a different impression of the data, though clearly, most sites, regardless of location, are in good condition.

Overall condition which combines the various previous attributes (and some additional attributes not discussed above) was considered to be good or very good at 85% of sites and moderate at 15% of sites, with no sites rating as poor to very poor. The moderate sites were in the Elizabeth Creek, Chillagoe Creek, Brown Creek (tributary of Mitchell River), Tate River, upper Lynd River, streams of the MDIA and parts of the upper Palmer River.

Table 1. Percentage of Sites Surveyed for the Mitchell Catchment State of the Rivers Study in Various Condition States

Sub-Catchment	Reach Disturbance			Bank Stability			Channel Habitat Diversity			Aquatic Habitat Diversity			Riparian Vegetation Condition			Riparian Vegetation Width		
	VP/P	M	G/VG	VP/P	M	G/VG	VP/P	M	G/VG	VP/P	M	G/VG	VP/P	M	G/VG	<10m	10-20m	>20m
Palmer	10	20	70	0	0	100	100	0	0	51	30	19	0	10	90	17	55	29
Upper Mitchell	5	14	81	11	0	89	71	14	15	18	25	57	0	0	100	27	30	34
Walsh	11	26	65	0	11	89	31	18	51	22	27	51	13	15	72	27	56	17
Lynd	0	0	100	0	2	98	57	20	23	60	39	0	23	23	53	9	42	49
Alice	17	0	83	17	0	83	55	45	0	29	0	71	0	0	100	0	54	46
Lower Mitchell	13	7	80	14	0	86	88	12	0	42	36	22	0	0	100	0	73	27
Overall	8	13	77	6	2	92	66	17	17	38	28	34	8	10	82	16	52	32

VP=very poor; P=poor; M=moderate; G=good; VG=very good

From Table 1, it can be seen that the Walsh sub-catchment as the greatest proportion of sites with significant signs of disturbance. Riparian vegetation condition was poorer in this sub-catchment than expected and riparian width was noticeably narrower than would be expected. Conversely, the Walsh sub-catchment had the highest results for channel habitat diversity and aquatic habitat diversity. The Palmer sub-catchment had the lowest scores for channel habitat and aquatic habitat diversity, possibly reflecting years of alluvial mining disturbance. The Lynd sub-catchment had the lowest scores for aquatic habitat diversity and riparian vegetation condition. Overall condition scores were provided in the State of the Rivers report, but analysis of the individual attributes are considered more informative. Attributes such as recreational/aesthetic and conservation value were not scored in the report, but the former was not considered relevant (due to low levels of human habitation, all sites rated well for this attribute anyway) and the latter scored with insufficiently robust or relevant criteria. Care should be taken when viewing the State of the Rivers analysis as there are too few sites in some sub-catchments (eg, only six sites in the Alice sub-catchment), each site represents a large length or river (175km each on average), only large tributaries are considered and only a small proportion of those. Additionally, even within sub-catchments, sites range from upstream tributaries to downstream large rivers are included together, when this is not really an appropriate means of combining sites. An analysis based on comparing headwater sites against tributaries and main lowland river sites may have been more useful for example to determine what type of sites have been most affected. Additionally, some criteria assume that more is best. For example, cover attributes assume that sites with greater cover are in riparian cover and with more aquatic macrophytes are in better condition, when low values for these attributes may be their natural condition. In this regard, site ‘condition’ is sometimes used when site ‘status’ is more appropriate. A large problem here is the lack of true reference sites against which expected condition for any given type of site can be compared.

The recent National Land and Water Resources Audit (NLWRA) undertook an assessment of Australia’s catchments, rivers and estuaries (NLWRA 2002), the first such national assessment of its kind. Assessments for catchment and river condition could only be undertaken in catchments where sufficient data was available, but estuarine condition assessments were undertaken for all estuaries. Of all the Gulf of Carpentaria catchments, only the Mitchell River catchment had sufficient available data for catchment and riverine condition assessments. Because no other Gulf catchment was included in the assessment, comparisons with them cannot be made, and are limited to dry savanna catchments in other parts of north Queensland (Burdekin, Fitzroy, upper Herbert and east coast of Cape York). Catchment condition was generally moderate or better and riverine condition was largely unmodified, with some sections considered to be only moderately unmodified. In general, these ratings ranked lower than most east coast Cape York catchments, similar to the upper Herbert catchment and better than the Burdekin catchment. All estuaries in the Gulf of Carpentaria were considered to be either near pristine or largely unmodified. Within the Northern Gulf region, the Mitchell, Nassau and Norman River estuaries were considered to be largely unmodified, with the remainder considered to be near pristine.

As part of the Barron WRP, in November and December 1998, 17 sites in the upper Walsh River and Emu Creek were assessed for evidence of hydraulic and/or geomorphological change following water resource developments there (this was in addition to 49 sites similarly assessed in the Barron catchment). Existing impacts from water resource development in the upper Walsh River were identified as follows:

- Collins Weir significantly affects hydraulic habitat and traps 25% of the incoming sediment load (noting that the sediment load may be higher than natural due to disturbance by mining in stream reaches above Collins Weir).

- Immediately below Collins Weir, bed erosion is leading to a decrease in stream sediment and armouring of the bed (ie, loss of sediment covering the harder underlying bedrock)
- Reduced availability of aquatic habitat below Collins Weir due to trapping of stream flow within Collins Weir.
- Channel morphology near the Nullinga gauging station has been significantly altered by instream sand and gravel extraction
- Below Springmount Weir, stream baseflow is elevated due to inputs of irrigation water diverted from Tinaroo Dam
- Paragrass infestations below Springmount Weir are facilitated by the altered flow regime, have implications for sediment erosion, deposition and channel morphology as well as aquatic habitat and faunal communities
- Although Bruce and Leafgold weirs do not trap sediment during floods, they still significantly alter hydraulic habitat during low to medium flow conditions
- There was no significant impact on channel morphology in Emu Creek due to limited water resource development

The same 17 sites were also assessed for riparian vegetation condition as part of the Barron WRP. Riparian vegetation in the upper Walsh River and Emu Creek was generally considered to be in good to excellent condition, except for localised disturbance and in parts of the MDIA were paragrass is present. Immediately downstream of Collins Weir, because of the weir trapping water and reducing baseflow, especially during the dry season, the riparian vegetation has become disconnected from the low flow channel and cannot migrate further into the channel due to bed armouring that has occurred there. This effect persists for only a short distance downstream of the weir however. Paragrass is much more abundant in the supplemented reach of the Walsh River below Springmount Weir, than in the unsupplemented reach above the weir.

Additional habitat assessments have been undertaken at 44 sites in the Walsh and upper Mitchell catchments by Ryan *et al.* (2002) and by the QDPI long-term monitoring program at their seven annual sampling sites on the Mitchell River. In their study, Ryan *et al.* (2002) assessed the habitat condition of their sites with the rapid assessment pro-forma utilised by Herbert *et al.* (1995) in the CYPLUS study (which also included nine sites on the Palmer River). This form is similar to that utilised by Russell *et al.* in fish habitat reports for various Wet Tropics catchments, including the Barron catchment (Russell *et al.* 1998). This all provides considerable uniformity for the habitat assessment methods. The methods are based on the channel morphology, substrate composition, instream habitat and riparian vegetation composition. Because of the quantitative nature of the assessment methods, these can be repeated in the future to check for changes in habitat condition over time. In the Mitchell catchment, sites upstream of Mt. Carbine had greater levels of disturbance (several with high to very high levels of disturbance) than sites downstream of Mt. Carbine (none with more than moderate levels of disturbance). Of the 19 sites assessed in the upper Mitchell catchment, two had very high levels of disturbance (these being the Mitchell River at Adil Road and at Pickford Road), four had high levels, eight moderate, four low and one (Mitchell River at Nychum crossing on Karma Waters station) had very low levels of disturbance. They felt that the Rifle Creek sub-catchment was under increasing pressure from erosion and agriculture runoff. Of the 25 sites assessed in the Walsh River, three had very high levels of disturbance (these being Dingo Creek, Cattle Creek and the MDIA channel inflow point on the Walsh River), two had high levels of disturbance, 17 had moderate levels of disturbance, two were low and only one (in the Mt. Baldy state forest) had very low levels of disturbance. All sites with high or very high disturbance ratings are within the MDIA.

2.2 Mine Disturbance and Runoff

The catchments of the Northern Gulf region are highly mineralised. There are few mines within the region that are currently operating and hence subject to modern standards of environmental management. In contrast, there are thousands of abandoned mines and mine workings within the region that existed prior to any standards of environmental management or knowledge of impacts thereupon, were known. All the major tributaries of the Mitchell (Palmer, Walsh, Hodgkinson and Lynd) and much of the Gilbert catchment, have been extensively mined, particularly during the period 1870-early 1900's.

The Palmer River has been highly disturbed by mining. The area supported a population of up to 35,000 people (ref) living in very basic conditions and also living off the land in many ways. Alluvial gold mining was so extensive during the boom gold rush days of the 1870's and early 1880's, that the alluvial sands of the entire river bed over a significant length of the river (from near its headwaters down to Strathleven, a distance of approximately ? km) may have been worked over. Natural flood events also cause substantial reworking of the river sands, but the alluvial mining may have caused the loss of instream islands, alluvial terraces and associated riparian vegetation. Herbert *et al.* (1995) assessed the river during the CYPLUS project and considered it to be the most disturbed river on Cape York. They found scattered patches of gallery forest on the main river and several tributaries and speculated that along with other elements of the riparian vegetation, these may have once been more common, but extensive alluvial mining over many years along most of the rivers length has resulted in their loss and the scouring of alluvial sand down to bedrock, thus preventing any recolonisation. Any decrease in the extent and abundance of riverine vegetation would have a significant negative impact on fish populations, as well as bank erosion and water quality. Herbert *et al.* (1995) also reported elevated turbidity downstream of existing alluvial mine workings. Other rivers systems such as the Hodgkinson, tributaries of the Walsh River such as Emu and Eureka creeks, and various rivers in the Gilbert catchment were also extensively mined and disturbed during mining rushes of last century, but there are no condition assessments of those systems.

Abandoned mines and mine workings pose a significant threat to the health of nearby aquatic habitats. Apart from physical disturbances mentioned above, mines disturb soil layers that are heavily laden with metals. Acid mine drainage (AMD) and high concentrations of heavy metals in runoff from abandoned mine sites are particularly important sources of impact to water quality. Visible signs of AMD include reduced riparian or instream flora and fauna diversity and development; discoloured waters, the presence of precipitated salts, sulphur odours and unsuccessful colonisation of waste dumps by vegetation. Metals are either attached to sediment particles or are dissolved in the water. Those attached to sediment particles and may be transported during runoff events to downstream environments before being deposited. Heavy metals are more commonly associated with the finer sediment particles rather than coarser particles, and are therefore not evenly distributed throughout any receiving waters. Finer sediment particles are more mobile and remain suspended in the water column longer. Thus they may be dispersed further downstream. Dissolved metals are available for uptake by animals and plants, becoming deposited in their tissues, resulting in bioaccumulation up the food chain.

Mine impacts vary considerably depending on the type of workings. Some mining areas such as the Palmer, were mainly alluvial, whereas others such as Chillagoe and Irvinebank were predominantly shafts. Tailings and waste rock have a lower potential for contamination because of the lower quantities of sulphidic substances compared to other sources.

The DNRME mineral occurrence datasheet recognises 3069 mines in the Mitchell River catchment alone, with about 12% of these showing high concentrations of sulphidic minerals associated with ore and waste dumps (Bartareau *et al.* 1998). There is a real paucity of data on this topic. Bartareau *et al.* (1998) form the most comprehensive study of water and sediment quality from abandoned mines in the region. They initially examined 56 abandoned mine sites for obvious ‘aesthetic’ signs of mine impact. From this, they selected 10 sites in the Mitchell/Walsh catchment, covering a range of levels of suspected contamination, for further examination. They assessed water quality upstream and downstream of these abandoned mines in Nov-Dec 1995 (dry season) and April 1996 (end of wet season). They noted elevated metals concentrations in water and sediment samples from the vicinity of those mines and up to 2km downstream of the input point. Some of the reported metals concentration were very high compared to trigger values accepted for the protection of ecosystem values, suggesting a high probability of environmental harm.

Given the high potential for environmental harm, this issue rates as a high priority. However there are thousands of abandoned mines and a strategic approach is required for this task. Rapid risk assessments of the larger and more obviously impactful mines are required to find out where high risk sites are, in terms of risk of contaminant losses and potential for exposure of aquatic ecosystems to toxicants. This would also involve consideration of the value of likely receiving environments for environmental and human (eg, drinking water) values and hydrological considerations such as the dilution from non-exposed stream flows. Because metals accumulate in bottom sediments, a broad sub-catchment level stream sediment survey, incorporating extra effort at high risk and valuable sites would be a rapid means where problems might be occurring. Stream sediment data collected by exploration companies may also be useful to collate and analyse in this regard. The Statewide Abandoned Mines Land Program through the Regional Mining Industry Liaison Unit of DNRME have the largest database on the existence of abandoned mines, risk assessments, data on potential impacts from some abandoned mines (including within the Northern Gulf region) and experience in mine site rehabilitation and would be important partners in any such project.

2.3 Water Resource Development

The construction of water storages and the resultant land uses changes, such as irrigation development are key issues for future development and management of aquatic resources in the Northern Gulf region. The Gulf of Carpentaria catchments have very high runoff (Table 2), the greatest proportion of rainfall to runoff in Australia and despite their isolation, are becoming increasingly targeted for further water resource development. There are proposals to construct new impoundments, or enlarge existing ones, in the Gulf rivers, especially the Mitchell, Walsh and Gilbert systems. However, at this stage, these are just proposals and none have been moved to the next stage of assessment. All catchments in the Northern Gulf region deliver large volumes of freshwater to the Gulf of Carpentaria. Currently, <1% of the mean annual runoff the Northern Gulf is captured, but there are other issues besides this to consider.

Table 2. Mean Annual Discharge From the Four Main Northern Gulf Catchments

Catchment	Area (km^2)	Mean Annual Discharge (ML)
Mitchell	71,000	12,000,000
Staaten	25,700	6,851,000
Gilbert	46,400	4,375,000
Norman	50,500	2,346,000

The Mareeba-Dimbulah Irrigation Area (MDIA) was established in 1958 to provide water security to irrigated farms and the developing tobacco industry. It supplies 95,000 ML of water annually for 16,000 hectares of irrigated crops (mostly sugar cane, mangoes, maize, tobacco, peanuts and a range of other crops on 840 farms ranging in size from 40ha to 200ha (Hyder 1998). The more recent change from tobacco to other crops and the development of a sugar industry has meant the demand for irrigation water has increased. Plus there is additional land suitable for irrigation not yet receiving any water. Thus the future demand for water is anticipated to increase. The likely requirement for the provision of environmental flows, being developed as part of the Barron WRP (DNR 1999) also represent a consumptive use of the available water. Irrigation takes approximately half of the available water supply (Hyder 1998), with that proportion likely to increase. Urban demand is also increasing but not so much in the Northern Gulf part of the area.

Most of the water for the MDIA is fed by the Walsh Bluff Main Channel from the Barron River (below Tinaroo Dam) into the Walsh River. Three additional creeks within the Walsh catchment (Walsh River, Eureka Creek and Murphys Creek) are also supplemented by Tinaroo dam water. There are four weirs within the Walsh catchment part of the MDIA. Collins Weir is upstream of the point where water from the Barron catchment enters and is thus trapping only Walsh River water which is distributed to farms via the South Walsh main Channel. Solanum Weir performs a similar function on Eureka Creek, a tributary of the Walsh River. Two other weirs, (Leafgold and Bruce) would capture some local runoff but store mostly Barron River water. In the Mitchell catchment, only Two Mile Creek is supplemented from the MDIA, however, overflows can occur into the Mitchell River, Four Mile, Sandy, Sorensen, Boyle, Douglas, Podargus, Owl and Marianne Creeks (DNR 1999). In 1997/98, approximately 80,000ML or 7% of the mean annual flow of the Barron River was diverted into the Walsh and Mitchell Rivers (Hyder 1998).

There are already two existing dams, eight significant weirs and numerous smaller weirs (mainly from old mines) in the Northern Gulf catchments. The Kidston dam was built on the Copperfield River (Gilbert Catchment) at Kidston for the Kidston gold mine in 1984. The mine ceased operations in 2002 but the dam remains. It has the potential to be used for irrigation and/or tourism and there have been calls to raise the dam wall even further to increase its utility for irrigation. MacKinnon (1998) undertook a feasibility study for aquaculture development, and Kilpatrick (1998) for soil, crop and irrigation suitability, in the Kidston area.

A dam was built on the Little Mitchell River between Mareeba and Mt. Molloy (visible on the left side of the highway when travelling north) in 1989. It is variously known as Lake Mitchell, Lake Southedge or 'Quaid's Dam'. It has a large surface area, and large shallow areas and a storage volume of 130,000ML (Hyder 1998), making it the 6th largest dam in north Queensland. It was reputedly built with the idea of developing a large satellite city around it (ie, a satellite city of Cairns), but this has not progressed and the dam remains idle). There are proposals to double the dam volume, and any such proposal would have to be considered as part of the Mitchell and Gulf WRP's and subject to an Environmental Impact Assessment. The dam is heavily impacted by exotic weeds such as water lettuce, paragrass and hymenachne. Many shallow dams across the country are recognised as environmentally important habitats, particularly for waterbirds and this dam may have similar values. There are no studies on the values or impacts of this dam.

The eight significant weirs in the catchment include six on the upper Walsh River to support irrigation activities of the MDIA, Glenore Weir on the Norman River which supplies tow water to Normanton and Belmore Weir on Belmore Creek at Croydon which supplies water for that town. In addition, there are numerous smaller weirs around the catchment, most are historical remnants associated with either mining or irrigation.

The construction of large water storages has long been talked of for the gulf rivers. In recent years, there have been feasibility studies undertaken for a number of sites. In the Mitchell catchment, these include Nullinga Dam on the Walsh River and the Pinnacles Dam at AMTD 410km on the Mitchell River (upstream of the Bellevue Road crossing, near the old OK bridge crossing Vallance *et al.* 2000). In the Gilbert catchment, the potential dam sites include Green Hills at AMTD on the Gilbert River, North Head at AMTD 398km on the Gilbert River, a dam at Bundock Creek, raising the existing Kidston Dam on the Copperfield River. These sites are discussed in more detail in a scoping study commissioned by DNRM (about to be released). In addition to this scoping report which covers the amounts of water and irrigable land available for each proposal, Vallance *et al.* (2000) provide a report on aspects of freshwater fisheries associated with these potential dam sites. For each potential dam site, weirs may also need to be constructed further downstream to regulate released water and to act as pumping pools for irrigation water.

In Queensland, planning for water resource developments is done on a catchment-wide basis using Water Resource Plans. These are being developed progressively for catchments throughout the state. Water Resource Plans currently exist for the Fitzroy, Burnett, Condamine-Balonne and Pioneer catchments and are underway or nearing completion for the Barron, Burdekin, Georgina-Diamantina catchments. The Barron Water Resource Plan also includes part of the upper Walsh River and Leadingham Creek because of their direct connection as part of the MDIA with water use from Tinaroo Dam on the Barron River. Issues associated with water allocation, environmental flows, and future water storage developments such as the proposed Nullinga Dam, are dealt with in that WRP (DNR 1999).

Recently, DNRM have just begun developing a Water Resource Plan for the Gulf rivers. This plan covers all rivers within the Northern Gulf region, plus all rivers east to the Northern Territory border. Because of the large area to be covered and the low demand for large levels of water extraction, most watercourses will not be dealt with specifically. Only reaches with existing and/or with some potential for water extraction in the near future are being considered. These include: the Mitchell River from the Pinnacles Dam site to its junction with the Lynd River; the upper Lynd River; most of the upper Einasleigh River and its major tributary the Copperfield River; and most of the Gilbert River. All remaining rivers such as the Alice, Palmer, Hodgkinson, Tate, Staaten and Norman are not being dealt with specifically, being a priori allocated no increase in water extraction allowed, except for stock and domestic purposes.

Even if no new large water storages are built, there may be increased water extraction from rivers that needs to be considered under water allocation planning. In some catchments, water harvesting, whereby water from rivers is pumped into offstream storages (eg, earthern dams) and later used for irrigation are becoming more popular as a means of more intensively utilising existing land resources. Water harvesting can also extract large amounts of water from rivers and the timing and volume of extraction are controlled by licences and under the provision of the relevant Water Resource Plan.

In 1997, the water Infrastructure Taskforce presented a broad strategy for water resource development throughout Queensland. The development of a Atherton Tableland/Cairns Regional Water Planning Study was one of the recommended options. This study was completed in 1998 (Hyder Environmental 1998) and included parts of the Barron, Mulgrave, North Johnstone, Walsh and upper Mitchell catchments. That study investigated 11 options for new water storages. Four of these options are within the Northern Gulf region:

- Raising Collins Weir on the Walsh River
- Nullinga Dam on the Walsh River (AMTD 259.6km)

- Dam at AMTD 11km on Leadingham Creek;
- Dam at AMTD 18km on Leadingham Creek;
- Dam on Rifle Creek at AMTD 5.5km

The Nullinga option (with the possible construction of a supplementary storage on Leadingham Creek) emerged from the study as the preferred option. The Nullinga Dam sites is only 10km downstream of Collins Weir and would inundate this weir most of the time. The wall would be built between Mt. Masterton and Wog Hill. Nullinga Dam was first conceived as part of the original MDIA scheme, but was dropped in favour of Tinaroo Dam. The site has a potential capacity of 440,158 ML, but the modelled dam was based on a storage volume of 292,200 ML, inundating 1,850hectares of land (Hyder 1998).

The irrigation suitability of soils in the Georgetown, Einasleigh and Flinders Rivers were assessed in 1999 (An Assessment of Agricultural Potential of Soils in the Gulf Region, North Queensland).

2.4 Grazing Management

Grazing is the dominant land use in the Northern Gulf region. In hot dry climates, riparian environments provide some of the better grazing country. Thus although overall livestock number may be low compared to other regions, livestock can concentrate around aquatic habitats, especially during the late dry season when waterbodies are most vulnerable to water quality declines. Two aspects of livestock management in riparian zones have emerged in recent years. This first is wet season spelling to allow palatable native perennial grasses to set seed and increase biomass. By wet season spelling, greater utilisation rates can occur later in the year. Although this concept was not developed for riparian pastures specifically, it is directly applicable. Even within paddocks, maintaining greater grass cover is critical to reducing sediment loss to aquatic environments. The A,B,C,D land condition framework would seem a suitable vehicle for promoting this goal. Sediment losses increase below 70% ground cover (condition 'A') and become particularly serious below 40% cover (condition 'B'). Thus, maximal protection of aquatic environments would require that surrounding lands are in condition 'A', or upper level condition 'B'

The second aspect of livestock management is that cattle can directly foul waterholes via defecation and disturbance of the substrate, especially during the dry season, when they tend to congregate there and when the waterholes are naturally vulnerable to disturbances and water quality decline. Riparian fencing projects in other regions (eg, Burdekin catchment) have shown that riparian fencing can allow wet season spelling and dry season spelling to protect the water quality for vulnerable waterholes (not the entire watercourse, just the waterholes). Other advantages include being able to build up higher fuel loads to use fire to control weeds such as rubbervine. Where fencing is not applicable, other approaches to managing cattle access to sensitive waterhole and riparian areas may be available (eg, installing offstream water points, conservative grazing during sensitive periods). Programs to assist landholders with means to better manage cattle access to key waterbodies, despite some early reservations, have had a high level of uptake by landholders in other catchments. Such riparian management approaches may not be considered practical in situations and some may not even require it. Assessments of which waterbodies would most benefit from such management arrangements could be included in the classification and inventory program proposed as part of the overall framework on freshwater habitat inventory and water quality monitoring. Such approaches would also enable more strategic use of on-ground funds by utilising them in locations where they would have the greatest environmental benefit.

3.0 AQUATIC FAUNA AND FLORA

3.1 Importance of Asset

The freshwater fish community of the Gulf of Carpentaria rivers form a biogeographically and evolutionary distinctive grouping. Russell *et al.* (2003) show that the fish community composition of the upper Walsh and upper Mitchell Rivers are significantly different to that of the adjacent but easterly draining, Barron River. It has been suggested that because the land between the upper Mitchell headwaters and the Barron River (just north of Mareeba) is low-lying and subject to inundation during flood events, that transfer of fishes may occur across this pathway. However, the available data do not indicate that this is a significant movement pathway.

Even where the same fish species do occur in both systems, they may have very distinctive genetic composition. For instance, preliminary genetic analyses of sooty grunter and barred grunter from the upper Gilbert River catchment and the upper Burdekin catchment (separated by the Great Dividing Range) has found large genetic differences suggesting that the populations have been separated for several million years. Red claw crayfish across the Gulf of Carpentaria rivers have been shown to have significant genetic differences, a trait being used through cross-breeding, to improve their aquaculture potential. Similar research into other species may reveal this to be a more common occurrence. Within the Wet Tropics, large differences in genetic structure of many fish and crustacean species between different adjoining catchments and different parts of the same catchments, have been shown to be common.

As for most of the Gulf of Carpentaria streams, there is a very large gap in our knowledge of what fish species are present and their distribution. For instance, even large, recreationally popular fish species such as grunter (*Scortum* spp.) and black bream (*Hephaestus fuliginosus*) have a confused taxonomy and/or poorly documented distribution. The distribution and abundance of species of high conservation value such as the freshwater sawfish, freshwater whipray and the lake grunter are also very poorly known.

The only river systems in the Northern Gulf region adequately surveyed for fish are the Palmer, Mitchell and Walsh rivers, although particular habitat types within those rivers may be underrepresented in fish surveys (ie, most work has focused only on the main river channel). Only minor survey has occurred in some parts of the Gilbert catchment and there have been no fish surveys from the Alice, Lynd, Staaten, Nassau, Smithburne and Norman catchments and other coastal catchments. Freshwater fish surveys in the Northern Gulf region are represented by four main documents – Ryan *et al.* (2002), Vallance *et al.* (2000), Herbert *et al.* (1995), and the DPI long-term monitoring program which include the Mitchell River.

Ryan *et al.* (2002) sampled fish at 25 sites in the upper Mitchell and upper Walsh Rivers on four occasions, as part of a program looking at water quality and fish communities in these catchments. Additional sites were sampled opportunistically. This study is the only such published study of sufficient rigour in any part of the Northern Gulf region to provide a good indication of its ecological status. A total of 36 and 33 fish species were found in the Mitchell and Walsh rivers respectively, a significant diversity. However, because the two catchments have so many species in common, the combined total was only 36 species (all 36 were present in the Mitchell River). With two additional species expected to be found but that were not found (northern saratoga and freshwater sole) the total species number is 38. The highest diversity at any individual site was 19 species found in the Walsh River at Trimble Crossing (the most downstream sites sampled - near the junction with the Mitchell River) and near Chillagoe, 16 species in Rifle Creek (at Font Hills) and 15 species in the Mitchell River (also at Font Hills). The maximum number of species likely at any one site is 34 (Ryan *et al.* 2002). In the Mitchell River, the most diverse sites were upstream whereas in the Walsh River, there greatest number of species were found in the most downstream site with decreasing number of species progressing upstream.

The statewide Long-Term Monitoring Program for freshwater fisheries, run by QDPI, includes seven sites on the Mitchell River sampled for fish each spring since 2000. This sampling is replicated on nine other rivers throughout the state (including the Gregory River in the southern gulf region). Although extra effort is focused on key species such as barramundi, this program collects data on all fish species present in freshwaters. Within the Mitchell River, the seven monitoring sites are spread along the length of the main river, from between Hurricane and Bellevue down to below the Koolatah road crossing. The data from 2000 and 2001 has been summarised in a report (Jebreen *et al.* 2002) which is also available on the DPI website. No trends can be interpreted from the data thus far, except to note the significant inter-annual variability, including for key species such as barramundi, sooty grunter and catfish. Given this kind of variability, it will require many years of data to detect changes in populations of key species.

The work reported in Vallance *et al.* (2000) was commissioned by DNRME as part of preliminary environmental investigations into potential dam sites within the Mitchell and Gilbert catchments. In October 1998, they sampled fish at four sites associated with the North Head Dam site on the Gilbert River, three sites in the Copperfield River associated with the Kidston dam, and four sites in the Einasleigh River (including Bundock Creek) associated with potential dam sites there.

As part of the CYPLUS study, Herbert *et al.* (1995) found 24 fish species at nine sites on the Palmer River and associated waterbodies from March-June 1993. Adding six fish species reported to occur in the river system (Herbert *et al.* 1995), this brings the total to 30 known species. Major tributaries of the Palmer such as King River remain unsampled for fish, although the species composition is unlikely to be very different to that of the Palmer. Herbert *et al.* (1995) considered the King River to be a sandy bottomed river with no permanent waterholes, although they did observe juvenile sooty grunter there when river flow was present.

Other smaller studies of fish distribution have occurred. In the Mitchell catchment, Hogan and Vallance (1997) briefly sampled fish in the inundation area of the proposed Nullinga dam site on the upper Walsh River, Vallance and Hogan (2001) sampled five sites in the Julatten/Mt. Molloy area associated with the upper Mitchell River stock routes and the fishes of the Mareeba wetlands have also been surveyed. Leggett (1990) briefly collected six fish species from the McLeod River. In the Palmer River, Macleay (1882) described a catch of seven fish species and Midgley (1988) collected 15 fish species at the King Junction waterhole in 1988. In the Copperfield River (Gilbert catchment), Tait (1998) noted the presence of six fish species in the Kidston River below the mine road bridge and 16 species in the Copperfield River gorge. Barlow (1987) undertook a fisheries survey of Kidston Dam. Additional sources of freshwater fishery data include the post-stocking surveys of Glenore Weir and Belmore Weir, both stocked with hatchery-reared fish (predominantly barramundi from the Karumba hatchery). The purpose of these surveys are to determine the growth rates and survival of the stocked fish in these artificial impoundments. Castelnau (1878) provided notes on some fishes from the Norman River, including describing new species, though these were more estuarine, than freshwater.

In freshwaters, the DPI post-stocking surveys at Glenore Weir and Lake Belmore are the only freshwater fish surveys ever conducted in the entire Norman catchment, though various surveys have occurred in the lower reaches around Normanton. Other major sub-catchments have also never been sampled for fish. These include the Alice River (except for one site on one occasion), Staaten River, Hodgkinson River, Lynd River, Tate River, Nassau River, Smithburne River and the lower Gilbert catchment. Even some catchments which have been sampled are represented by limited sampling effort. For example, the entire Gilbert catchment has been sampled at only seven sites on one occasion and this only involved brief visits. Similarly, the entire Palmer River has only been sampled at nine sites on one occasion. Only the Mitchell River and upper Walsh rivers have been sampled over significant stream lengths and on multiple occasions, to provide reliable data on their fish faunas.

3.1.1 Significant Fish Species of the Northern Gulf Region

From a conservation perspective, probably the most significant freshwater fish species in the Northern Gulf region is the freshwater sawfish *Pristis microdon*, the largest freshwater fish in Australia. This sawfish is listed as *Vulnerable* under the commonwealth EPBC Act. They are also listed as *Endangered* on the 2000 IUCN Red List of Threatened Species and *Critically Endangered* in SE Asia. It has recently been nominated for listing as 'Vulnerable' under the Queensland Nature Conservation Act (I. Briezze QEPA pers. comm.). Due to their saw-shaped rostrum, they are easily identified by non-experts, although there are a number of sawfish species and the taxonomy of individual species remains uncertain. The freshwater sawfish is known from at least 15 rivers across northern Australia as well as many parts of SE Asia and India. The records for the Northern Gulf NRM planning region include specimens from the Mitchell, Lynd, Gilbert, Norman and Staaten rivers, and reports from the Palmer and Walsh rivers.

Pristis microdon (also referred to as *Pristis pristis* in many previous reports) is the most freshwater adapted of the sawfish species and may even be able to breed in freshwater (Pogonoski *et al.* 2002). Although often caught in estuaries, only a few specimens are reported from offshore areas. Freshwater sawfish can grow up to seven metres in length, though Australian specimens are generally only up to two metres long (Last and Stevens 1994) with the largest known being 6 metres long (S. Peverell).

Within the northern Gulf region, sawfish records are known from approx. 300km upstream in Palmer and Mitchell Rivers. Allen *et al.* (2002) report it from Lynd Station on the Lynd River, approx. 500km upstream. Given their size and the unwieldy saw-shaped rostrum, it is unlikely that sawfish would be able to negotiate instream passage barriers as well as other fish. Weirs and dams would be likely to impede, and at baseflows, completely halt, instream movements. Nothing is known about the movement patterns or preferences of freshwater sawfishes. However, given that they are common in both freshwaters and estuaries, movements between those environments may be important and any artificial passage barriers may have a significant effect. Even low level weirs that drown out during flooding (eg, Glenore Weir at Normanton) may pose movement problems. Being large predators, they may also be subject to declining habitat condition along rivers in the catchment and be affected by droughts. They feed on benthic animals such as crustaceans and molluscs and also upon fish. Relatively little is known of their biology or habitat requirements. Because of their large size and slow reproductive rate, populations will recover more slowly than other fish species.

At least four other species of sawfish occur in the marine (and sometimes estuarine) waters of the Gulf of Carpentaria. They are all similarly threatened as the freshwater sawfish. All sawfish species are susceptible to fishing pressures being targeted for their fins, getting caught in nets and also being caught by line fishing. They are caught in the commercial by-catch of the Gulf of Carpentaria and NE Qld, the NT shark fishery and in beach protective shark nets in the Qld

Shark Control Program (Pogonoski *et al.* 2002). Stobutski *et al.* (2000) considered the by-catch of sawfishes in the northern prawn trawl fishery (does not include *P. microdon*) as least likely to be sustainable, due to their benthic nature making them more susceptible to capture. DPI are working with commercial fishers to reduce incidence of by-catch.

All known populations of *P. microdon* and indeed all sawfish species worldwide, have undergone serious population declines (Pogonoski *et al.* 2002). Research into this species is currently ongoing and the Commonwealth Department of Environment and Heritage is preparing a recovery plan at present.

There are many anecdotes about how the various sawfish species used to be more abundant than they currently are and that their range has declined. There is however, a lack of data upon which to substantiate these statements, so it cannot be fully verified. There are numerous rivers in the Gulf and on Cape York for which reliable anecdotal reports of freshwater sawfish, but no formal records are known. Given the size and distinctive shape of freshwater sawfish, anecdotal reports should be reliable (at least for identification). Collection of such anecdotal information would provide significant valuable information on the distribution (current and historical) of this species and be a valuable resource for planning and management purposes.

Other potentially significant fish species are also likely to be present in the Northern Gulf rivers, as they are relatively unsurveyed. The first comprehensive surveys of the Wet Tropics and Cape York (both in 1992-1993) revealed many new species and extended the known distributions of many others. There is little doubt that a comprehensive fish survey of the Gulf rivers would reveal a similar level of new information. The Fly River garfish (*Zenarchopterus novaeguineae*) is abundant within southern New Guinea, but within Australia, is currently only known from the Wenlock and Mitchell Rivers (Herbert *et al*. 1995, Allen *et al.* 2002). It occurs in estuaries and lowland rivers and tributaries. The blueblack blue-eye (*Pseudomugil cyanodorsalis*) is known from four widely separated estuarine areas (near Broome, Wyndham, Darwin and near Normanton) (Allen *et al.* 2002). It is likely to be more widespread but lives in brackish to hypersaline waters in mangroves and mangrove creeks. These habitats are not often sampled. Further data on this species is unlikely to come to light in general surveys unless its usual habitats are specifically targeted.

Like the freshwater sawfish, the giant freshwater whipray, *Himantura chaophraya*, is poorly known but similarly threatened. It can grow up to 200cm disc width and weigh up to 600kg, although the largest recorded Australian specimen was 160cm disc width and 120kg (Last 2002). In Australia, it is only known from the Daly and Alligator rivers (NT), the Pentecost and Ord Rivers (WA) and the Gilbert River in Qld, but as it also occurs in PNG and SE Asia, it may, with further survey, be found in more northern Australian rivers (Pogonoski *et al.* 2002). This species is listed as *Vulnerable* under the 2000 IUCN Red List (*Critically Endangered* in Thailand). Like *P. microdon*, this species is vulnerable to fishing as prey and bycatch, drought and fish passage barriers. The speartooth shark, *Glyphis* sp. A is only known from the Alligator River in the Northern Territory and the Bizant River in Queensland (Pogonoski *et al.* 2002), but a specimen identified as *Glyphis* sp. has been recently collected from the Ducie River on Cape York (S. Peverell pers. comm.). This distribution suggests that with further effort, it may be found to occur in the Northern Gulf waters. *Glyphis* sp. A occurs in estuarine and freshwaters, feeding upon fish. It is listed as *Criticially Endangered* under the federal EPBC Act and has been nominated for listing as *Endangered* under the Qld Nature Conservation Act.

Currently, there is only one fish species known to be restricted to the Northern Gulf region, this being the Lake Grunter, *Variichthys lacustris*, which, in Australia, is only known from Twelve Mile Lagoon in the Mitchell Catchment (Allen *et al.* 2002). It does however, also occur in the

Fly River delta of southern Papua New Guinea. This gap in its distribution suggests either that this population is a remnant of its former distribution, or that it occurs in more as yet undiscovered locations on Cape York and in the Mitchell catchment. Given its very restricted distribution outside of any protected area, this species warrants receiving a high formal conservation status. Further sampling effort targeting habitats similar to Twelve-Mile Lagoon, and a genetic investigation comparing it with specimens from PNG, are urgently required.

There are several fish species whose known distributions within the Gulf of Carpentaria drainages is limited and patchy. It is most likely that this is due to insufficient survey effort and that increased effort will find these species in additional catchment from where they are not currently recorded. In addition, further survey, genetic and taxonomic work would reveal much new information about Northern Gulf fish communities. For instance, freshwater grunters (*Scortum* spp.) are common large fishes in the Gulf catchments. Allen *et al.* (2002) only recognise one species – *Scortum ogilbyi* as occurring in all of the Gulf and cape York rivers. However, various surveys (eg, Herbert *et al.* 1995 and Vallance *et al.* 2000) have claimed other *Scortum* species as being present. Preliminary genetic and taxonomic evidence indicates that sooty grunter (also known as black bream) in the Gulf rivers are a different species to sooty grunter in the east coast drainages, and that there is considerable genetic differences in barred grunter as well (Pusey pers. comm.).

Fish species diversity generally decreases with increasing distance upstream. This decrease is usually gradual unless abruptly punctuated by fish passage barriers such as dams or weirs and natural barriers such as waterfalls. Some river reaches above major waterfalls, may have no fish species present (eg, Picanniny Creek in the Palmer catchment above Picanniny Falls – Herbert *et al.* 1995). In the Mitchell River, the Mitchell Falls (downstream of Mt. Mulgrave) act as a natural fish passage barrier to estuarine-breeding species such as tarpon, mullet, river whalers and barramundi. Although they did not find any barramundi above the Mitchell Falls, Ryan *et al.* (2002) report that barramundi have been caught above these falls, indicating that passage over these falls may be possible when they are drowned out during flood events. The flat nature of the Northern Gulf rivers enables many estuarine species to travel considerable distances upstream, much further than occurs for other rivers elsewhere. Several weirs (eg, Glenore Weir and the Walsh River weirs) and dams (eg, Kidston Dam) may act as either full or partial fish passage barriers. Any new dam would also act as a fish passage barrier to restrict movement. Lake Mitchell would also act as a fish passage barrier, except during flood events. Vallance and Hogan (2001) identified several fish passage barriers (as road crossings and culverts) on streams of the Julatten/Mt. Molloy area.

In the Walsh River, impediments to fish migration that might influence within catchment fish distributions include relatively steep rapids near Wrotham Park and Flat Rock plus four weirs. The largest weir, Collins weir, is also the most upstream weir and is likely to be a significant barrier to movement. The other weirs drown out during flood events and like are unlikely to act as barriers to fish movement during those times, but would restrict movements at other times. The impact on fish populations and productivity of these passage barriers is at this stage, uncertain.

3.1.2 Introduced and Translocated Species and Fish Stocking

The guppy, *Poecilia reticulata*, found in the upper Walsh River, is the only exotic fish species in the Northern Gulf region. Ryan *et al.* (2002) believe that this fish must have entered Two Mile Creek (upper Mitchell River tributary) and the upper Walsh River via irrigation channels from the Barron catchment. **T**here is substantial concern that tilapia and other fishes may move to the Gulf drainages via the same pathway. A screen to exclude fish and their eggs is to be installed on the irrigation delivery system later this year. Rainbow trout were introduced into Picaninny Creek above the falls in the 1970's (Hogan 1995, Herbert *et al.* 1995). They apparently survived and grew but were unable to reproduce and the population thus died out.

The restricted distribution patterns of several aquatic species in limited parts of the upper Walsh and upper Mitchell rivers, compared to their wider distributions in the Wet Tropics, indicate that either they are unusual natural occurrences and thus requiring special management, or that they may be more recent arrivals from adjoining catchments. Apart from the exotic guppies mentioned above, these include the eastern rainbowfish, *Melanotaenia splendida splendida*, and purple-spotted gudgeons (*Mogurnda adspersa*). Ryan *et al.* (2002) suggested that the translocated eastern rainbowfish were hybridising with the local subspecies (*Melanotaenia splendida inornata)*, though further analysis is required to confirm this. Such movements between closely located rivers could be via the MDIA irrigation channels or intentional releases by people (eg, from aquaria). The cause of such unusual species occurrences needs to be investigated. Whether they are natural or unnatural occurrences, the first requirement is to obtain a greater knowledge of their distribution. Where required, genetic techniques can be used to determine their uniqueness and the likely naturalness of their presence.

Limited artificial stocking of fishes has occurred in the Northern Gulf region. Sooty grunter occur naturally throughout the Mitchell catchment but their populations have been augmented by stocking fish into the Walsh River at Dimbulah and the Mitchell River at Julatten (Hogan 1995). Sleepy cod have also been stocked into the Walsh River to augment the naturally occurring populations there. Glenore Weir (Normanton) and the Norman River have been stocked with barramundi, and Lake Belmore (Croydon) has been stocked with barramundi, sooty grunter and striped sleepy cod, to enhance the naturally occurring populations there (Hollaway and Hamlyn 2001). Red claw crayfish are possibly the aquatic species most commonly translocated by people in Queensland, although they are native to the Northern Gulf catchments. Selective breeding and cross-breeding of red claw crayfish is being used to produce strains with superior growth rates and other traits desirable for aquaculture. Escape of these enhanced-strain crayfish to natural waters pose a threat to local faunas and genetic populations. Public awareness and education is the most important method for preventing the un-permitted introduction and spread of exotic and translocated native species. Monitoring would also be required to detect any new occurrences of any species (exotic or native) outside of its natural range.

3.2 Aquatic Invertebrates

Aquatic invertebrates include faunal groups such as insects, crustaceans, worms and molluscs. Relatively little is known about the aquatic invertebrates of much of the Northern Gulf region. There have been no studies that have compiled even a moderately comprehensive species list for the region. This reflects the lack of taxonomic knowledge of the region and the common usage of only identifying invertebrates to family, not species, level in most studies. In the upper rainforest tributaries, there would be numerous new species to be found.

The study of Pearson and Christidis (1998) is the only study with sites located within the Northern Gulf region to have identified macroinvertebrates any further than family level, and even then, this was not done for all faunal groups and most identifications were done to morphospecies (ie, recognising that species are different but without being able to give them their proper name). This outcome is largely because of the predominance of rapid assessment procedures which only require identification to family level, the poor taxonomic state of the fauna in northern Australia, and the very high proportion of undescribed species found in northern Australian streams. Thus the species-level fauna and species richness of macroinvertebrates the region is mostly unknown. Hundreds of samples do exist however, preserved and stored in laboratories, from which a more extensive species-level faunal list could be derived.

The diversity of aquatic macroinvertebrates in the Wet Tropics is among the highest recorded in the world (Pearson *et al.* 1986). Pearson and Christidis (1998) sampled for aquatic invertebrates from riffle habitats at 74 sites in rainforest streams of the Wet Tropics region between 1993 and 1996. Nine of these sites were in the upper Mitchell catchment and one in the upper Walsh catchment. These sites were also sampled for water quality at the same time (reported in Butler and Pearson 1998). The purpose of the project was to describe the invertebrate fauna of Wet Tropics streams and to look for patterns in their distribution across the region. Analysis of the Oct-Nov 1993 data from 20 sites (including two from the upper Mitchell), reported in Pusey and Pearson (1999) did not reveal any patterns related to latitude, though altitude and substrate type strongly correlated with community composition and that variation in species richness was best explained by variation in abundance (ie, samples with greater numbers of individuals also had more species present).

The most common use of aquatic invertebrates is as biological indicators of aquatic ecosystem health. A methodology known as AUSRIVAS is a national standard for such monitoring and has been used as part of nation-wide assessments of river health. Within Queensland, these programs were, and still are, run by DNRME. A total of 42 sites, all at existing gauging stations, have been sampled in the Northern Gulf region (and by way of comparison, 39 sites in the Southern Gulf region) under these programs. Only one site was sampled in the Norman catchment (two occasions only) and two sites in the Staaten catchment (sampled on two occasions each) (Table 3). A total of six sites have been sampled in the Gilbert catchment (none sampled on more than five occasions) and 33 sites in the Mitchell catchment (Table 3). The greatest amount of replication has also occurred in the Mitchell catchment where 29 sites have been sampled at least 9 times, and 8 of these at least 13 times, between 1994 and 2000 (Table 3), making it the most intensively sampled catchment draining into the Gulf of Carpentaria.

Three sites (one sample at each) in the upper Walsh catchment and five sites (totalling 12 samples) in the upper Mitchell catchment (indicated in Table 3) were analysed as part of the Barron WRP (Choy *et al.* 1999). Little can be said about the data. Aquatic invertebrate data from below Lake Mitchell are only slightly different in species richness and health to sites in the Barron catchment. Sites in the upper Walsh catchment have less PET taxa than sites in Cattle Creek (Choy *et al.* 1999). Riffle habitats in the Walsh and Mitchell catchments support fewer species than riffles in the Barron catchment which may be because they occasionally dry out. The results from samples collected three times each year for three years (1998-2000) for the NHT-funded Mitchell River Catchment Study were analysed by Thomson *et al.* (2000). They found that the macroinvertebrate fauna of edge habitats (the only habitat type consistently sampled on all sampling occasions) at all sites were in equivalent to reference condition, indicating no obvious impact. Other metrics did indicate some impairment of the macroinvertebrate community at a few sites.

In total, 276 of the 345 sampling occasions where aquatic macroinvertebrate data collected by DNRME under AUSRIVAS methodologies, have been analysed, with 276 of these included in the Mitchell River catchment Study report (Thomson *et al.* 2002) and 15 for the Barron River WRP (Choy *et al.* 1999). None of the 25 samples collected from the Staaten, Gilbert and Norman catchments have even been analysed, though they would not provide much information at this stage, given the low level of replication.

Ongoing sampling under the Ambient Monitoring program involves sampling twice per year at selected sites. Future site selection in the ongoing ambient monitoring program is to be based on random stratified sampling. Thus the sites to be sampled on any occasion will be randomly selected from a pool of sites and the data reported on a reach or river scale rather than as long-term changes at individual sites (hence the use of different sites rather than using the same sites every time).

Table 3. List of Sites Sampled for Aquatic Macroinvertebrates by DNRME in the Northern Gulf Catchments

GS Number	Site Name	Latitude (S) Degree	Longitude (E) Degree	MRHI1- Oct-94	MRHI2 - May-95	MRHI3 - Sep-95	MRHI4 - Jun-96	MRHI5 - Dec-96	FNARH1 - May-97	FNARH2 - Nov-97	FNARH3 – May-98	FNARH4 – Nov-98	FNARH5 – May-99	FNARH6 – Oct-99	AM01/1 – May-01	AM01/2 – Oct-01	AM02/1 – May-02	AM02/2 – Oct-02	AM03/1 – May-03	MRCS (9 runs: 1998-2000)
	Norman Catchment																			
916004A	Walker Creek at Maggieville	17°28'23"	141°10'49"								+	+								
	Staaten Catchment																			
918002A	Mentana Creek at Mentana Yards	16°22'35"	142°05'54"										+	+						
918003A	Staaten River at Dorunda	16°32'05"	142°03'39"								+	+								
	Gilbert Catchment																			
9170006	Gilbert River at Stirling	17°10'18"	141°45'56"								+	+					+	+	+	
917001D	Gilbert River at Rockfields	18°12'10"	142°52'28"										+							
917008A	Little River at Inournie	18°16'13"	142°40'30"										+	+	+	+			+	
917102A	Einasleigh River at Carpentaria Downs	18°43'43"	144°18'42"														+	+		
917106A	Einasleigh River at Einasleigh	18°30'07"	144°05'42"										+							
917107A	Elizabeth Creek at Mt Surprise	18°08'02"	144°18'17"	+	+	+	+												+	
	Mitchell Catchment																			
9190002	Bushy Creek at Julatten	16°36'34"	145°20'08"												+	+				
9190003	Fossilbrook Creek at Vince Ray Causeway	17°48'59"	144°23'19"						+											+
9190006	Luster Creek at road crossing	16°39'37"	145°14'54"	+	+	+	+													
9190007	Lynd River at Mitchell Junction	16°27'55"	143°18'26"																	+
9190011	Mitchell River at Mt Mulgrave	16°22'35"	143°58'29"	+	+	+	+													+
9190016	2 mile Creek at Broad-McGrath Boundary	16°56'08"	145°23'47"														+	+		
919001C	Mary River at Mary Farms	16°34'07"	145°11'32"						+	+										+
9190030	Healeys Lagoon at Healeys Yard	16°04'14"	142°37'25"																	+
9190031	Longreach Lagoon at Western Fence	16°31'47"	143°24'19"																	+
9190032	Mitchell River at Font Hills	16°41'46"	145°12'18"																	+
919003A	Mitchell River at OK Bridge	16°28'29"	144°16'19"																	+

919004A	Tate River at Ootann	17°28'30"	144°35'54"										+
919005A	Rifle Creek at Font Hills	16°40'48"	145°13'39"	+	+	+	+						+
919006A	Lynd River at Torwood	17°26'03"	143°49'18"										+
919009A	Mitchell River at Koolatah	15°56'54"	142°22'36"	+	+	+	+						+
919010A	Lagoon Creek at Rutland Plains	15°38'14"	141°49'21"										+
919011A	Mitchell River at Gamboola Rd	16°32'12"	143°40'36"	+	+	+	+			+	+	+	+
919013A	McLeod River at McLeod	16°29'56"	145°00'03"					+	+				+
919014A	Mitchell River at Cooktown Crossing	16°33'58"	144°53'21"					+	+				+
9191001	Alice River at Pormpuraaw Road Crossing	15°22'46"	142°01'23"										+
9192002	Palmer River at Palmerville	15°59'55"	144°04'09"	+	+	+	+	+	+				+
9192004	Glenroy Creek at Palmerville Rd	15°55'20"	144°05'13"	+	+	+	+						
919201A	Palmer River at Goldfields	16°06'27"	144°46'42"										+
919204A	Palmer River at Drumduff Crossing	16°02'36"	143°02'07"	+	+	+	+					+	+
919205A	North Palmer River at Maytown	16°00'44"	144°17'25"										+
9193005	Chillagoe Creek at Chillagoe	17°09'10"	144°31'08"										+
9193030	Chillagoe Ck, downstream end of airstrip	17°08'03"	144°31'35"										+
9193033	Walsh River at Collins Weir	17°16'13"	145°17'18"	+	+	+	+						+
9193050	Cattle Creek at Walsh Junction	17°07'29"	145°15'16"					+					+
919309A	Walsh River at Trimbles Crossing	16°32'40"	143°46'59"										+
919310A	Walsh River at Rookwood	16°58'56"	144°17'11"	+	+	+	+						+
919311A	Walsh River at Flatrock	17°10'58"	144°53'57"					+					+
919312A	Elizabeth Creek at Greenmantle	16°39'14"	144°06'13"										+

Ryan *et al.* (2002) recorded 11 crustacean species as part of their survey in the Mitchell and Walsh Rivers. These included two species of widely distributed *Caridinia* shrimps, three species of *Macrobrachium* prawns, two *Cherax* crayfish species and four freshwater crab species, one of which is a new, undescribed species. The red claw crayfish, *Cherax quadricarinatus*, also very popular as a food species, is widely distributed throughout the catchment. The crayfish, *Cherax wasselli*, occurs in east coast Wet Tropics catchments but within the Northern Gulf, is only known from Mitchell River tributaries above Mt. Carbine (Ryan *et al.* 2002). All four freshwater crab species showed a patchy, and sometimes limited, distribution, with two species only being known from individual locations (Elizabeth Creek and Wrotham Park). The freshwater crab, *Holothuisiana agazizzii*, was found by Ryan *et al.* (2002) at several sites within the supplemented sections of the Walsh River. It is also known from the Barron River and Ryan *et al.* (2002) speculated that it may have transferred via the MDIA irrigation channels.

The spiny crayfish, *Euastacus fleckerii*, is known only from high altitude (>1000m) streams on Mt. Lewis (including Leichhardt Creek tributaries), near Mt. Molloy and on Mt. Spurgeon (including Roots Creek and the headwaters of the Mossman River) near Mt. Carbine (Morgan 1988). Logging has historically occurred in areas inhabited by this crayfish but its high altitude distribution within the Wet Tropics World Heritage Area should ensure that it no longer suffers any form of direct habitat disturbance. At least ten other *Euastacus* species are also only known from very restricted distributions on high altitude mountain streams in Queensland. Their distribution pattern suggests that they are relicts from previous geological periods which were wetter and/or cooler. Like most other mountain species, they are thus likely to be highly susceptible to changes in climate (ie, the climate becoming drier and hotter).

3.3 Other Aquatic Fauna

Saltwater crocodiles are reported as far upstream as King Junction Waterhole on the Palmer (Herbert *et al.* 1995) and the Mitchell River Falls below Mt. Mulgrave. Freshwater crocodiles occur throughout much of the region, including the upper reaches of major streams (eg, at least as far as Mt. Carbine on the Mitchell River – Ryan *et al.* 2002).

For the most part, frogs of the Northern Gulf NRM planning region are generalist species typical of open forest and drier regions of Australia. The only species of conservation concern would occur in the upper reaches of tributaries surrounded by rainforest. The upper tributaries of the Mitchell and Walsh river contain five frog species of conservation concern, plus an unknown number of significant and undescribed invertebrate species. Similar values probably also occur in the upper tributaries of the Palmer River.

The saw-shelled turtle, *Elseya latisternum*, occurs throughout the Mitchell and Walsh catchments (Ryan *et al.* 2002). A recently descried turtle species, *Emdyura tanybaraga*, is only known from the Mitchell catchment within Queensland, although it also occurs in the Daly and East Alligator rivers of the Northern Territory (Cann 1998). Its known distribution within the Mitchell catchment includes the middle reaches of the Mitchell River (eg. Mt. Mulgrave) and lagoons in the Mt. Molloy area (Ryan *et al.* 2002).

There are a number of aquatic lizards and snakes within the planning areas, but all are widespread, preferring waterholes (usually larger ones) with good fish populations, and none are of particular significance (check Cogger and with Garry). Refer to the terrestrial biodiversity report (Alex).

Platypus and water rats occur within the planning area. Water rats are common and may occur throughout the area, whereas platypus will mainly be found in upstream reaches of streams. The Irrawaddy or river dolphin *Orcaella brevirostris*, classified as Rare in Queensland, may also be found in lowland portions of major rivers.

3.4 Aquatic Plants

The aquatic plant community includes phytoplankton such as algae, diatoms and cyanobacteria (also known as blue-green algae), periphyton (algae, moss and bryophytes growing on other surfaces such as rocks, as well as larger aquatic plants (termed macrophytes) such as lillies, and emergent grasses such as reeds and sedges. Ryan *et al.* (2002) found 34 species of native aquatic macrophyte and reed/sedges, and three species of exotic macrophytes, in their study of the Walsh and upper Mitchell catchments.

Phytoplankton are the most common and ubiquitous aquatic plants, although they are clearly not visible to the naked eye unless an algal bloom is occurring. Algae blooms result from an excess of nutrients but are enhanced by a number of other factors such as light availability, hydrological conditions. Larger aquatic macrophytes tend to be more patchily distributed throughout catchments. They are most common in stillwater habitats such as swamps and lagoons although they are also common in river channels in clearer, upper parts of catchments and reach high densities in reaches receiving elevated nutrient levels (eg, Two Mile Creek in the upper Mitchell River which receives sewage runoff from Mareeba – Ryan *et al.* 2002)

Paragrass is an exotic semi-aquatic grass species mainly found in upper catchment areas in disturbed riparian sites and any areas where there is a gap in the riparian vegetation. It is particularly abundant in the supplemented reaches of the Walsh River (DNR 1999). Paragrass has been shown to increase sedimentation and alter channel morphology, reduce water quality and flow rates, harbour exotic fishes and reduce habitat access for waterbirds. It provides very poor habitat for fish and are not incorporated into aquatic food chains. Hymenachne can be expected to show all these same effects. It is similar to paragrass in habit, growth form and preferred habitats, except that it grows larger and penetrates into deeper water and may outcompete paragrass where they occur together and has been named as one of Australia's top 20 worst weeds on the Weeds of National Significance (WONS) list. In coastal floodplains of east coast catchments, paragrass and hymenachne have caused massive environmental harm. They have been trialled for ponded pasture in several parts of the Northern Gulf region, though apparently with limited success. They will not establish along main watercourses, but prefer wetlands and other stillwater environments.

In the study of Ryan *et al.* (2002), hymenachne was found in the Mitchell River at Adil Road, Rifle Creek and Lake Mitchell in the Mitchell catchment and at Bontaba in the Walsh catchment. In east coast catchments where it is well established, it is a very serious environmental and agricultural weed. Although large areas of the Gulf catchment will be unsuitable for the establishment of this weed, there are many locations that are suitable and the distribution, abundance and environmental impact of this species is expected to expand considerably in the near future. It is already common in Lake Mitchell.

Three species of serious floating weeds – salvinia, water hyacinth and water lettuce, all occur in the Mitchell catchment. All are declared weeds under the Rural Lands Protection Act, requiring that they be controlled and salvinia is a WONS-listed species. Water lettuce is common in Lake Mitchell (Ryan *et al.* 2002, Werren 2000), water hyacinth currently infests streams and lagoons of the lower Mitchell River. Salvinia has previously been found in the Mitchell Catchment (in lagoons near Mt. Molloy – Room *et al.* 1984). These weeds can rapidly grow over an entire lagoon, blocking surface access and seriously altering aquatic habitat availability, quality and reducing water quality. Perna (2004) found that water hyacinth reduced oxygen levels in lagoons of the Burdekin floodplain (down to zero percent saturation in osme cases) and reduced the number of fish species normally found in those lagoons by more than half.

3.5 Riparian Vegetation

In headwater streams, surrounded by rainforest or wet sclerophyll forest, the distinction between the vegetation of the riparian zone and that of the surrounding landscape is minimal. Progressing downstream, this distinction becomes greater and in drier parts of the planning area, the riparian zone takes on tremendous importance in its role as refuge for terrestrial fauna during the dry season. Streams emanating from headwaters such as Rifle Creek, Mary Creek, McLeod River and tributaries of the upper Mitchell and Palmer River have dense rainforest elements along their riparian zones. In the remainder of the Northern Gulf NRM planning region, riparian vegetation is dominated by paperbark trees (*Melaleuca fluviatilis* and *M. leucadendra*) and river she-oaks (*Casuarina* spp.). Bottlebrushes (*Callistemon* spp.) and river mangroves (*Barringtonia acutangula*) are also common. Depressions associated with aquatic habitat often contain pandans (*Pandanus* spp.) and riverine floodplains and high river banks have either *Eucalyptus tereticornis* (forest red gum) in the wetter eastern parts and *Eucalyptus camaldulensis* (river red gum) in the drier western areas.

Riparian vegetation has mainly been disturbed by mining, weeds and agricultural development. Disturbance from mining is mainly historical and difficult to determine in the present context. Development is affecting riparian vegetation throughout the catchment. In areas like the upper Mitchell and MDIA, it is threatened by the effects of catchment development, such as clearing, weed invasion and altered flow regimes. Although disturbed by catchment development, riparian condition is generally better in the Mareeba-Dimbulah Irrigation Area than most other irrigation areas in north Queensland. This may be attributable to the soil types required for tobacco occurring further away from the river, the lack of pre-harvest burning (this being a major reason for the perilous condition of watercourses in most coastal agricultural catchments), and not all farm area has been cultivated.

The greatest threat to riparian vegetation throughout the region is weeds. The most widespread serious riparian weed is rubbervine, a native of Madagascar, that was introduced to Australia as an ornamental plant in the late 1800's. It can either grow as a free-standing multi-stemmed bush to 3m high or as a vine clambering up to 15m high and covering all the branches of large trees. Thus it can both dominate the understorey of riparian areas and kill the large trees. Dense rubbervine infestations can produce impenetrable thickets on the ground and eliminate most trees in the riparian zone. This destruction of the riparian zone would have serious impacts on terrestrial animals inhabiting the riparian zone, fish communities as they are very dependent on the riparian zone, and bank stability. Significant rubbervine infestations are present in many places throughout the catchment. A rust fungus, introduced as a biological control agent, is well spread throughout the region and is effective at reducing leaf production but is not enough to kill the plants. Fire has recently become a common management tool for controlling rubbervine. Riparian areas have to be spelled from cattle grazing for a period in order to build up a larger fuel load (understorey grasses) to create a sufficiently hot fire to kill the rubbervine plants. Ongoing research is being conducted into the effectiveness of fire as a control method and the indirect impacts to native plant regeneration and animals populations caused by this use of fire. A trial project using fire to control rubbervine has been undertaken at Wrotham Park station.

The distribution of rubbervine is often strongly associated with areas of human activity such as towns, camping areas and road crossings. Knowledge of the distribution and colonisation pathways and patterns of weeds like rubbervine will greatly aid in developing effective region-wide management strategies.

Other weeds in the region which can impact on the values and condition of aquatic and riparian habitats include giant rats tail grass, calotrope, castor oil bush, chinee apple, noogoora burr, parkinsonia, prickly acacia, sicklepod and bellyache bush. Recent discoveries of bellyache bush in the Palmer River should warrant a high priority for control.

3.6 Exotic Animal Pests

Feral pigs are common throughout the study region. They are particularly damaging to riparian and aquatic habitats. They predate upon eggs and small animals, uproot plants and greatly disturb soil, create erosion and foul water quality. They are most common in upstream areas of the Mitchell catchment (near Bushy Creek and Rifle Creek) and the upper Walsh River in the Herberton ranges (Ryan *et al.* 2002). They are more dispersed in drier areas but do congregate around waterholes, particularly swamps and off-river lagoons where they can be particularly destructive. Feral pigs can significantly degrade aquatic habitat and foul the water quality of many waterbodies throughout the catchment. Control methods such as baiting, trapping and shooting require significant effort and resources.

Cane toads were introduced to Queensland in 1935. They quickly dispersed along the NE coast of Australia and then moved inland across the Gulf catchments. They are very common around permanent and semi-permanent waterholes and may be numerically dominant there. As they have poison glands above their shoulders, they are poisonous to native animals that eat them and significant declines in the populations of many native animals have been recorded when cane toads first move into new areas. It is widely believed that many native animals have learnt to either avoid eating them or to avoid eating the poison glands, and their numbers may be recovering somewhat from the initial impacts. This effect also includes aquatic animals such as freshwater crocodiles, large fishes, aquatic snakes and water rats which fed upon cane toads. Cane toads can also out-compete native frogs and toads. They generally do not occur in habitats containing frog species of conservation concern as these are in cold, upland streams that cane toads cannot tolerate.

4.0 WATER QUALITY

Water quality is of central importance to all programs aimed at securing the health of aquatic ecosystems. Water quality data is collected by a large array of people for a wide variety of purposes, using a wide variety of field approaches, sampling designs and sampling and analytical methods. Thus water quality data consists of a large, but highly fragmented and poorly organised array of datasets.

The most significant water quality datasets available are those of Ryan et al. (2002), the Mitchell River Catchment Study and the DNRME gauging station and ambient monitoring network. Ryan *et al.* (2002) sampled for water quality (19 parameters) at 25 sites in the Walsh and upper Mitchell catchments, approximately monthly from November 1996 to June 1999. Not unexpectedly, the results varied considerably spatially and temporally. They found impacts on water quality due to agricultural land uses in the upper Walsh River catchment and to agricultural land use and sewage release in the upper Mitchell catchment, with elevated nutrient concentrations and low dissolved oxygen levels found below tributaries with significant agricultural and/or sewage releases.

In the upper Mitchell catchment, most sites had median conductivity values <100us/cm, which is very low and in the Walsh catchment, most sites had medians <150us/cm, which is also low. The highest individual conductivity readings were 878us/cm at Fisherman's Hole (Walsh River) and 636us/cm in the Mitchell River at Font Hills, both of which (probably along with most of the other high values) occurred at the end of the 1996 dry season (a low rainfall year). Higher conductivity values at Adil Road, Pickford Road and Font Hills were suggested to be due to sewage effluent and irrigation runoff (where does supplementation from the Barron come in). Saline groundwater in excess of 20,000us/cm (approximately one-third the strength of seawater) are close to the surface in the Dingo Creek area (Rose *et al.* 1996). However, the median conductivity at the Dingo Creek site was not noticeably higher than any other site and the highest reading recorded there (230us/cm in Sep 1997) is still a low reading by the standards of most rivers in north Queensland. Although conductivity readings in MDIA sections of the Walsh River had low conductivity readings in general, the poor correlation with chloride suggests that they may be influenced by irrigation runoff. The lower Walsh River reportedly has substantial saline springs. Conductivity readings at sites in the lower catchment were higher than for the upper catchment, but no more so than might be expected in the natural downstream progression, and were still not high by comparison with other north Queensland rivers.

In both catchments, the highest nutrient values were also consistently found at sites receiving irrigation and/or sewage runoff. Fish kills were associated with high ammonium levels (these are toxic to fishes) and low DO at Adil Road and Pickford Road in October 1998. Only summary statistics, not the actual raw data, are provided in their report. Given the size of the available dataset, more extensive analysis could be carried out, especially if it is combined with other data from the same catchment (eg, the Mitchell River Catchment Study and the gauging station data) , this being the most data available catchment in the region. In fact, some of the extra data are form the same sites sampled by Ryan *et al.* (2002), thus providing a longer term dataset than was available for analysis in their report.

In the Mitchell River Catchment Study, 29 sites were sampled nine times from 1998-2000. This data is on the DNRME HYDSYS database, but has not been analysed for any report as yet. The extensive dataset from the DNRME gauging station and ambient monitoring network has also never been analysed, although summaries are available on their Watershed website. This also includes summary data on streamflow for each gauging station. The DNRME gauging station data has traditionally collected data mainly on conductivity and salts in water, with the collection of environmentally relevant parameters such as nutrients only added in more recent years. Other important parameters such as chlorophyll are not sampled at all. Some analysis of trends in salinity and hardness data from gauging stations have been published (DPI 1994) and an overall report on water quality in Queensland “Testing the Waters’ has been published (DEH/DNR 1999).

Apart from storm events and where streams are supplemented with irrigation water from Tinaroo Dam, surface water in most streams is maintained by subsurface groundwater and the quality of surface stream water is influenced by that of the underlying groundwater. Groundwater levels in the Cattle Creek catchment were first noticed to be rising in the late 1980’s and have continued to rise (Rose *et al.* 1996). Rising groundwater levels will mobilise salts stored in the soil which can enter the streams causing elevated stream conductivity. Ryan *et al.* (2002) suggested that the elevated conductivity they recorded in the Walsh River downstream of Cattle Creek, may have been due to the agricultural area, but the data are not conclusive about this. Jensen *et al.* (1996) found no salinity hazard in the Leadingham Creek area but that there was a significant salinity hazard in the Bibhoora area.

4.1 Water Quality Targets and Monitoring

The ANZECC guidelines recommend that water quality targets be derived from locally relevant conditions and situations. This requires that there be sufficient replication of water quality data from relevant types of waterbodies present in the region. To this end, water quality monitoring needs to be implemented. NRM maintains an ambient water quality network that could be used as a basis for assessing water quality and developing regional water quality guidelines. The utility of this dataset in performing this task is being reviewed by ACTFR.

Before undertaking any water quality program, one needs to ask what is the purpose of the monitoring? This question should be part of five steps.

First Step: Determine what assets and values need to be protected and monitored.
Second Step: Develop a conceptual model to predict drivers of condition in priority aquatic habitats
Third Step: Assessment of the likely effects of anthropogenic pressure on the above drivers
Fourth Step: Evaluate pressure, potential risks and possible outcomes
Fifth Step: Determine what, when and where to monitor (ie, select indicators that target the highest probability or most harmful outcome)

Water quality varies tremendously over the course of a year and between years. Measuring water quality during storm events with high flows requires different approaches and involves different issues to that occurring when ambient baseflow is predominant (ie, during the dry season).

4.2 Runoff Water Quality

Most areas in Australia have been shown to have greatly increased runoff of sediments and nutrients, compared to their natural condition, due to catchment development. This is largely due to reduced pasture grass cover, increased agricultural runoff and urban development. More recent research is also suggesting that these processes also increase peak event freshwater runoff. Because the Northern Gulf catchments are subject to high intensity rain events in the wet season, the potential for increased runoff is high if catchment condition is poor. No data on the quality of runoff water from any Gulf catchment has ever been published. DNRME staff from Mareeba have collected data from several wet season flood events from 1998-2000, but this data has not been written up as yet.

Brodie (2002) provides a brief review of water quality monitoring in coastal and marine waters of the southern Gulf of Carpentaria. Although average rainfall figures are generally low, intense rain events associated with cyclones and monsoons regularly result in significant flooding. Because the rivers of the Northern Gulf are braided and breakout to form vast inland seas that cross into adjacent catchments, it is very difficult to gauge flow volumes and to sample loads of sediment and nutrients carried in such flood flows. The most downstream gauging station in the Gilbert catchment is 200km upstream from the river mouth. In the Staaten and Norman rivers, the most downstream gauging stations are only 50 and 40 km upstream respectively. Because of the irregular flows of the rivers, and that during any one flow, discharge may have originated form different sub-catchments, reliably detecting trends in discharge concentrations of contaminants such as sediments, nutrients and metals will probably take decades. Because of this, in most areas of Australia, modeling approaches have been used to predict based on proxy indicators, the amount of sediment loss from catchments. The most widely applied of these models, as used in the NLWRA, is SEDNET. SEDNET was not applied to the Gulf catchments, because of the poor input data available and the difficulty in modeling vast floodplains where water travels widely and crosses into different catchments.

Despite the difficulties in measuring and modeling large event runoff, there are a number of indicators and actions closely related that can be taken. Indicators of runoff include:

1.) Grass cover and pasture condition – Below 70% grass cover, rainfall infiltration begins to decrease noticeably and below 40%, it increases significantly. The ABCD Land Condition Index currently being promoted by DPI rates land with >70% cover as condition 'A' and land with 40-70% cover, condition 'B'. Other recommended sustainable management guidelines for the northern beef industry, such as the Ecograze project (Ash *et al.* 2001) are built around maintaining high grass cover.

2.) Tree Cover and Riparian Condition – both of these indices are important input data parameters in assessing runoff in models.

3.) Bank erosion and damage – these are important indices used in runoff models. Data on these can be generated by various means, including aerial photos analysis

4.) Fertiliser and Pesticide Use – A considerable proportion of nutrients and fertiliser applied to land is lost to groundwaters and surface waters. Monitoring the amount of these chemicals applied to farms and the runoff from those farms would be a good indicator of this issue.

5.) Other indices such as stock numbers, riparian fencing and sewage effluent release may also be useful proxy indicators.

Condition indicators such as monitoring seagrass extent and health, the turbidity and chlorophyll of receiving waters, and deposition of terrestrial derived sediment in Gulf waters, would also indicate if runoff was affecting receiving water bodies. Research had shown that lead isotope ratios and rare earth element composition of sediments in the southern Gulf are specific to the catchments from which they came. Long-term chlorophyll monitoring, using a monthly sampling program along transects running perpendicular to the coastline, is used as a means to detect changes in nutrient status of the Great Barrier Reef lagoon. The same methodology could be applied to Gulf waters. Additionally, as occurs along Queensland north-east coast, aerial surveys of the extent and movement of flood plumes during major flow events would greatly aid in understanding where flood waters move.

4.3 Ambient Water Quality

Ambient water quality monitoring can be undertaken for many reasons such as:

1.) To develop regionally-relevant water quality guidelines
2.) To ensure the protection of high value sites and sensitive species (beside sites of environmental value, this could include tourist sites, town water supplies, sites of cultural importance.
3.) To assess impacts of high risk sites and on aquatic environments (eg, abandoned mines, agriculturally impacted sites)
4.) To assess the improvement or degradation resulting from changed land use and/or improved land use practices (eg, from improved grazing and/or farm runoff management practices).
5.) To monitor drinking water supplies
6.) For research purposes (eg, developing appropriate environmental flows)

Each of these six reasons are valid and require different approaches. There may be some overlap (ie, some sites may fit into more than one category and such sites should be sought out). For instance, the first task requires that all of the aquatic environments in the region be classified into suitable categories that can be expected to naturally have very different water qualities. For each category, several sites in 'good condition' should be chosen for regular water quality sampling in order to develop the guidelines against which other sites in the region can be compared against. The short list of the type of categories that could be included would be:

- upland rainforest and thick forest tributaries and tributaries formerly surrounded by such forests
- midland savanna streams (eg, to act as controls for Cattle Creek)
- supplemented streams (eg, Walsh River between Collins Weir and Flat Rock)
- midland rivers
- lowland tributaries (ie, lower order streams)
- lowland rivers (dominated by surface water or groundwater)
- overflow lagoons
- seasonal floodplain lagoons
- shallow vegetated wetlands
- estuarine waterways
- spring-fed tributaries with permanent flow (eg, Fossilbrook Creek)
- water storages (eg, weirs)

To undertake this task, there needs to be a classification system designed and an assessment of a majority of waterbodies in the catchment to determine what waterbodies fit into what categories and how many there are in each category and which ones would be most representative of each category and thus be included in the data collection program aimed at developing guidelines. Classification categories with low numbers of representation may not need to be included. This should be a priority task for the first year of the regional investment strategy and result in the development of a water quality monitoring program for subsequent years. Such a system would also link to programs undertaking inventory and classification for identifying important waterbodies in the region.

Other considerations are that water quality data is being collected in other regions and these may include sites that are comparable to sites in the Northern Gulf region. That is, the regionally relevant water quality data required may be at least partly obtained from appropriate sites in other north Queensland NHT regions. This obviously requires coordination with these other regions. The DNRME ambient water quality network would be of some use in this regard except that it is confined to instream freshwater channels (ie, does not include offstream lagoons, floodplains lagoons, vegetated wetlands or estuarine waters) and even within streams, it may not include all of the categories of stream and waterbody types. In addition, some key water quality parameters have not been included in this network (eg, dissolved oxygen). It should be remembered that the ambient water quality network is based on gauging stations, and the sites were not selected for their usefulness as water quality sites. These were set up to monitor stream flow of selected waterways and are based on locations with stable cross-sectional geomorphology. It is unrealistic to expect this network to cover too many of the data requirements for developing water quality targets, except with respect to certain waterbody types (eg, main stream channels)

4.4 Intensified Land Uses

Whilst much attention is focused on large-scale individual developments, such as the prospect of new large dams, in many locations, the intensity of land use is gradually, but inexorably increasing. This occurs in many forms. Irrigated pastures involve extraction of water from local sources of harvesting of water during peak flows into offstream storages. This is likely to be a popular alternative to large-scale irrigation development as it is particularly suited to low-gradient, low bank streams, and requires less capital investment. Ponded pastures are another means of extracting greater productivity. The extent of ponded pasture development in the Northern Gulf is limited compared to its extensive occurrence on east coast floodplains such as such as the Burdekin and Fitzroy catchments. Ponded pastures generally involve the use of exotic pastures species such as paragrass, olive hymenachne or aleman grass, all of which can be serious weeds when uncontrolled. These have caused extensive environmental damage along the east coast, though their ability to do so in the Gulf plains in uncertain. Their current distribution in the Northern Gulf appears to be limited. The construction of bund walls on floodplains to create ponded pastures can also impact on the environment. These may block tidal flows, altering the nature of the floodplain environment, and restricting fish and crustaceans access to important supratidal habitats. Bund walls are common on the east coast, but less common on the Gulf plains. The location of bund walls should be carefully considered in relation to tidal flows and fish passage requirements.

Increasing development in areas such as Julatten and Mt. Molloy is also resulting in land clearing and conversion to intensive land uses, loss or degradation of the riparian zone, and likely greater sediment and nutrient runoff. The more intensively developed areas of the MDIA have traditionally been the greatest focus for these type of issues. Because of its perennially-flowing rainforest-covered headwaters, water quality emanating from this area should be good and probably even dilute poorer quality water emanating from the Two-Mile creek system. Further developments that reduce the quality of water from this region may negate this benefit to some extent. The aquatic values of streams in the Julatten-Mt. Molloy area are high. This area deserves special attention in regards to planning to ensure that the environmental values of the area and the ecosystem services (eg, clean water) it provides to downstream habitats are maintained.

5.0 HISTORICAL CONTEXT OF LANDSCAPE CHANGES

Often, one of the large stumbling blocks to improved NRM is recognising or agreeing whether change has occurred, and if so, what sort of change. The motivation to alter practices is often based on recognising that undesirable change has occurred. Many projects already have elements of historical change included within them. Water quality, riparian habitat condition programs aim to detect changes in the status of those assets. This report has indicated that historical information on the distribution of freshwater sawfish would be very useful to its management. Historical information underpins the basic data collection of many projects. For example, information on how recent bank erosion occurred, how often do particular waterholes go dry, other historical land uses such as mining are all key components of many other projects. Rarely is such information drawn together to create a better understanding of change.

Research into historical change is also enlightening views on issues where change has not previously been recognised, usually because it occurs gradually, occurred before the current generation and was not documented at that time or where the significance of the change is only recognised at larger scales (eg, the widespread loss of great Artesian Basin springs – Fairfax and Fensham 2002). Lewis (2002) provides a good example of how historical change can be useful for shedding light on previously unrealised aspects of change and providing a basis for future NRM management. That publication, ‘Slower Than the Eye Can See’, used a combination of explorers diaries, written records of early settlers, historical photographs and oral history interviews to highlight several issues that were otherwise unrecognised by scientists and the general community. These included gradual increases in tree density, particularly along riparian watercourses, the loss of mangrove vegetation in lower reaches and the widespread loss of particular aquatic species (eg, bankside reeds) when grazing was first introduced. Publications and studies such as this can be very powerful for obtaining widespread community agreement of otherwise controversial issues. Such studies contribute to capacity building and NRM adoption as they often generate considerable community interest. Indeed, community members are essential participants in many projects of this type, where their combined knowledge becoming core data. Methods for assessing historical changes can vary from oral history projects with long-term residents and comparing old photographs, to modern methods with high level of technical equipment (eg, isotopes to measure sedimentation or change in tree density).

Changes (or lack thereof) to the condition and status of riparian environments, the distribution of key fish species and the permanency and inundation frequency of aquatic environments are of particular interest to aquatic targets proposed. The coastal environment is very dynamic, especially on the low gradient plains of the Gulf catchments, and changes in the distribution of coastal communities such as mangroves, saltpans and adjoining freshwater habitats are amenable to such methods and would be very illuminating for NRM.

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