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Wetland Biodiversity and Water Quality Surveys, Violetvale Station

Brendan C. Ebner and James A. Donaldson

Report No. 15/78

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A Report for Cape York NRM

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Centre for Tropical Water & Aquatic Ecosystem Research (TropWATER)
James Cook University
Townsville
Phone : (07) 4781 4262
Email: TropWATER@jcu.edu.au
Web: www.jcu.edu.au/tropwater/

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For further information contact:
Brendan Ebner
Centre for Tropical Water & Aquatic Ecosystem Research (TropWATER)
James Cook University
brendan.ebner@csiro.au
PO Box 780, 47 Maunds Road , Atherton QLD 4883

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EXECUTIVE SUMMARY

This report documents the findings from a five day field trip to Violetvale Station in the Normanby drainage basin of eastern Cape York. In anticipation of large scale fencing-off of wetlands, the main focus of this study was to document aquatic biodiversity, primarily fishes, and to a lesser extent crustaceans, aquatic reptiles and waterbirds. The study also served to provide some context in terms of basic water quality records from the wetlands on the property.

Surveys targeted four large wetlands across Violetvale Station in the Saltwater Creek catchment, but also included opportunistic surveys at a further seven sites (comprising small in-channel waterholes and floodplain wetlands) on the property. Across the eleven sites surveyed, a total of 19 fish, 2 aquatic reptiles, 8 aquatic macroinvertebrate and 16 waterbird species were observed. Estuarine crocodiles were recorded from each of the large wetlands, with a maximum count of two individuals in the most downstream of the large wetlands. Juvenile barramundi were caught in low numbers and in good condition at three of four main wetlands. Turtles were not caught at any sites, although the shell of a turtle was found on an earlier pilot study. Large aquatic beetles (Dysticids) were found in high abundance in all four large wetlands.

By way of relevant observations, wild pigs were observed at wetland edges and feral cattle were occupying edge and wetland habitat. Signs of trampling and diggings from these mammals were evident around the edges of the large wetlands. There is scope for fencing stock and pigs from these wetlands and determining potential shifts in aquatic and semi-aquatic (e.g. turtle) biodiversity using this report as a baseline.

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1 INTRODUCTION

Pastoral grazing represents a major contributor to the economy of northern Australia and is central to large scale food production for humans (McKeon *et al.* 1990, Bortolussi *et al.* 2005, MacLeod & McIvor 2006). However, these large mammals also influence catchment processes directly in terms of plant composition and primary production, nutrient and moisture uptake and release, soil erosion and landscape drainage, and indirectly by shaping biotic community composition. In this regard there can be negative impacts on native ecosystems including streams, wetlands and aquatic biota (Dodds *et al.* 2015) and balancing production in a sustainable manner is not easily achieved (MacLeod & McIvor 2006).

Wetlands are ecosystems that support high levels of biodiversity and perform essential ecosystem services. Importantly, they serve as nursery and refuge habitat for commercially, culturally and recreationally significant fish species including barramundi, sleepy cod and tarpon. The wetlands of Cape York are of high conservation value and provide habitat for a large number of plant and animal species (EHP, 2012). Some of the wetland systems along the expansive Eastern Cape York Peninsula of Australia have been surveyed for fishes (e.g. Herbert & Peters 1995, Kennard 1995, Pusey *et al.* 2000). However, riverine and wetland fish communities of Eastern Cape York have not received the level of survey effort afforded in more southern parts of the east coast of Australia, undoubtedly in part due to the relative inaccessibility of the most northerly systems in Queensland.

This lack of a strong research base or monitoring of fish and aquatic ecosystems inhibits the sustainable management of ecosystems in the region, including the vast wetland complexes typifying the greater Laura-Normanby catchment. These wetland ecosystems are vulnerable to degradation by feral herbivores such as cattle, pigs and horses as well as invasion by semi-aquatic and aquatic weeds (e.g. Doupé *et al*., 2009). It is important to establish a baseline inventory of species inhabiting these wetlands to monitor changes associated with management actions such as destocking, exclusion fencing and weed removal on cattle properties and in national parks. Arguably, the large national parks and cattle properties of the Cape provide the most pragmatic unit for environmental management in view of irregular government funding.

At the request of the property owners and with funding and facilitation by the regional Natural Resource Management (Cape York NRM) body, we aimed to document the aquatic fauna and compare the condition of wetlands on Violetvale Station based on rapid assessments. The focal taxa were fish, crustaceans, turtles and crocodiles in providing an indication of the inherent biodiversity value of the wetlands and to serve as baseline data to monitor future management actions, and specifically fencing-off of wetlands. To our knowledge, this was the first study to document the aquatic fauna and water quality of the expansive floodplain wetlands on Violetvale Station.

2 METHODS

2.1 Study sites

Violetvale Station, located just east of Musgrave, on Eastern Cape York Peninsula, Queensland, hosts a large number of floodplain wetlands in the Saltwater Creek catchment nested within the Normanby drainage basin. Four large wetlands were selected (Figure 1) on the basis of relatively large size, accessibility and overall spacing across the property. Sites were chosen to represent a range of proximities to the ocean since this can influence the community composition of diadromous species (species migrating between freshwater and sea during their complete life cycle) in wetlands (Ebner *et al*., unpub. data). These wetlands were dominated by thick stands of waterlilies and mud/silt bottom and had minimum widths of hundreds of metres. The four large wetlands surveyed in the current study were all floodplain wetlands dominated by grass, sedges and herbs. Additionally, a further seven small wetland sites including ephemeral and permanent pools in creeks and river beds and along oxbows were surveyed opportunistically to encompass a wide range of aquatic habitats in an effort to maximise the diversity of aquatic biota encountered. These smaller wetlands had minimum widths in the order of tens of metres or less, and were variable in dominant substrate with some being rock and sand dominated and others mud/silt) (Figure 1). All surveys were completed from 13th – 17th of July, 2015 (early-mid dry season).

2.2 Survey methods

At each of the four large wetland sites (sites 6, 7, 8, 10) a standard survey procedure was applied;

- 10 baited bait traps (deployed overnight)
- 4 single-wing fyke nets (deployed overnight)
- 2 multi-panel gill nets (deployed overnight)
- Early evening spotlighting for crocodiles
- Water quality measurements

Each of the remaining sites was surveyed opportunistically using a suite of techniques tailored to the specific site as a function of pool size, depth, water clarity and time constraints (see Appendix 1). It included use of fyke nets, bait trapping, snorkeling, above water observation, baited cameras and dip netting. Captured fish were measured to the nearest millimeter for fish less than 100 mm total length and 10 mm for larger fishes. Fishes were identified using Allen *et al.* (2002) and crabs by (Riek, 1951).

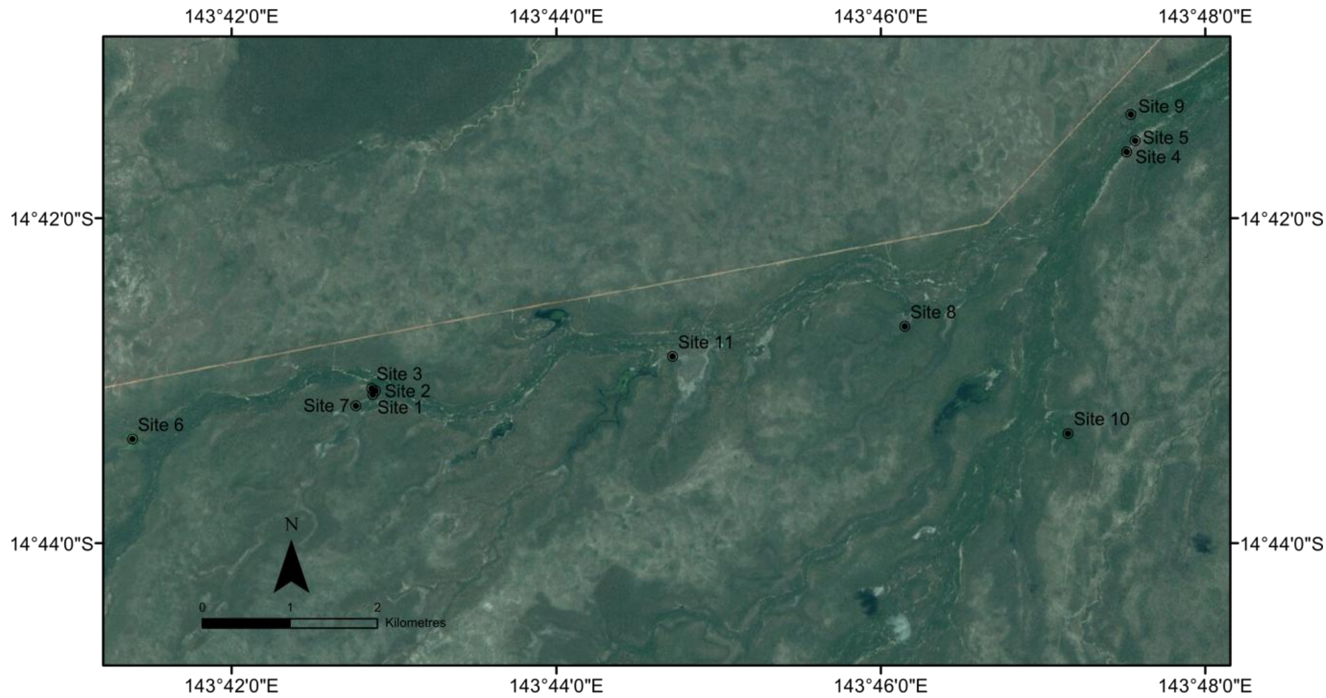

Figure 1. Map of study sites, Violetvale Station, Cape York, Australia.

Figure 2. A dinghy was used to deploy nets at each of the four main wetland sites.

2.2.1 Netting

Gill nets, fyke nets, dip nets and frame nets were used to sample fish community composition in this study. Two gill nets were used simultaneously to target medium-large fish species and were deployed in the afternoon from a boat (figure 2) and checked every hour until night fall, to gauge likely catch rates in each large wetland and minimise distress to entangled individuals. These 20 m length gill nets were comprised of multi-panel meshes with alternating four by 5-metre panels of 2 and 3 inch mesh. However, the gillnets varied in their depth with one being 1-metre deep and the other 2-metres deep. Accordingly, nets were positioned to accommodate depth of fishing capacity, though in reality, depths of greater than 1.5 m were not encountered.

Fyke nets were used to target fish across a range of size classes and were used in all large wetlands and in one of the smaller wetlands where it was possible but unlikely that an estuarine crocodile could be present (low visibility) and active techniques such as dip-netting were initially not appropriate. We used fine-mesh (3-mm stretched mesh) fyke nets with a single 5 metre wing and 'D-shaped' mouth of 530 x 600 mm (Figure 3). These nets were usually tied to a tree over-hanging the water.

Dip nets and frame nets were primarily used at the opportunistic sites, typically for between 5 and 20 minutes depending on the size of the water body and the structural complexity of habitat (essentially a function of how confident we were that we had recorded fish species richness comprehensively).

A frame net with dimensions of 83 cm by 630 cm and a fine mesh of 2 mm (stretched) was used to collect small-bodied fishes and crustaceans particularly in dense macrophyte beds. Small fine mesh dip nets were also occasionally used off the side of the boat to confirm the identity of small bodied fishes that were observed including early juvenile phase hardyhead (*Craterocephalus stercusmuscarum*).

Figure 3. A fyke net deployed in shallow water in a wetland at Violetvale Station.

2.2.2 Spot lighting

A high-powered spotlight was used at each of the four main wetland sites to scan for crocodiles at 30 minute intervals (minimum of 2 scans). Eye shine was used to estimate the total number of crocodiles present in the wetland.

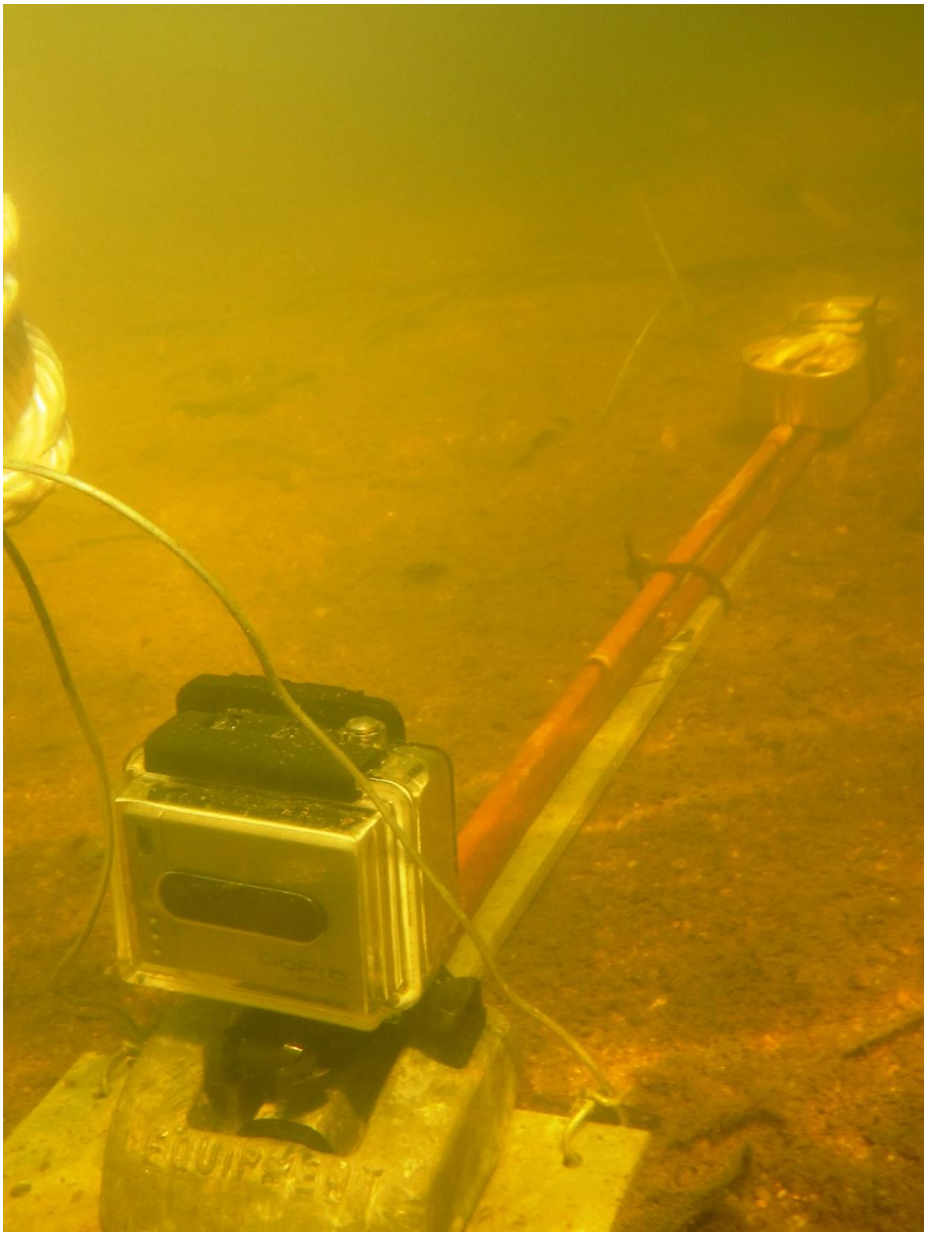

Figure 4. Baited Remote Underwater Video Stations (BRUVS) deployed.

2.2.3 Baited Remote Underwater Video Stations (BRUVS)

Baited cameras were used at two sites where water clarity was sufficient to permit their use (Figure 4). The apparatus used in the deployment of the cameras consisted of a t-shaped metal stake (450 mm x 150 mm) to which a single 1 kg lead dive weight and a GoPro camera (Hero2 model) in a dive housing were fixed at one end and two bamboo canes fixed at the other. Cameras were baited with tinned sardines and left for 1 hour. Video footage collected during deployments was viewed and analysed in VLC Media Player (version 2.0.4; VideoLAN, Paris, France).

2.2.4 Bait traps

Baited traps (500 x 200 x 200 mm) were deployed from a boat at each of the four main wetland sites (Figure 5). Each trap was baited with a small amount of sardine and deployed in two clusters of five traps across two disparate habitat types within the wetland. Traps were set in the afternoon and retrieved the following morning, giving a set time of 14–16 hours.

Figure 5. Deploying a bait trap from a boat.

2.2.5 Wetland birds

Wetland birds were observed and recorded opportunistically with the aid of binoculars at each of the four main wetland sites (e.g. Figure 6). No attempt to record abundance was made.

Figure 6. Plumed whistling ducks and green pygmy geese

2.3 Water quality sampling

Water quality measurements were taken at each of the four large wetland sites (Site 6, 7, 8, 10) and two additional sites (Site 9, 11) with permanent water; for a wide range of basic parameters specifically: water temperature, pH, turbidity, conductivity, dissolved oxygen, total dissolved solids, and salinity. Three replicate measurements were taken either from a boat (in large wetlands) or from the shore (site 9, 11) in areas clear of thick macrophytes. A calibrated Horiba U-52 (Horiba ltd. Kyoto, Japan) multiparameter water quality meter was used for obtaining all measurements. The dense water lily coverage of all four large wetlands surveyed, inhibited the use of an outboard motor and rowing. Push-poling with oars was used to manoeuvre the boat around the wetlands affording multiple opportunities to gauge the depth profile of these wetlands, partly in search of deeper sections for deploying nets. While depth profile data was not quantified we obtained a good qualitative understanding of the depth of these large wetlands which mostly exhibited gradual shifts in bathymetry.

3 RESULTS

3.1 Wetland fauna survey

A total of 19 fish species, 2 aquatic reptiles, and 8 aquatic macroinvertebrates were recorded (Table 1, Figure 7). Estuarine crocodiles were recorded from each of the main wetland sites with a maximum count of two individuals at Site 7. The other reptile encountered was a single Macleay's water snake in one of the large wetlands. No turtles were collected or observed in the survey.

Typically, the greatest number of fish species detected was in the four main wetland sites where the majority of the effort was applied (sites 6, 7, 8 and 10), with large volumes of water and therefore more expansive aquatic habitat present. Nevertheless, Site 11 (a small wetland) yielded the third highest species richness count across the sites despite the fact that many of the techniques used in the main wetlands were not applied there. Site 11 consisted of a narrow, but rather deep (1.5 m max depth) expanse of water and appeared to be the outflow of a large wetland. It also had comparatively high water clarity.

The most common species observed across all of the sites were the eastern rainbowfish (*Melanotaenia splendida splendida*), sailfin glass perchlet (*Ambassis agrammus*) and spangled perch (*Leiopotherapon unicolor*) (Table 1). Three recreationally and commercially important species were also recorded during the surveys (Table 1); barramundi (*Lates calcarifer*), tarpon (*Megalops cyprinoides*) and sleepy cod (*Oxyeleotris lineolata*) (Figure 8). A total of five juvenile barramundi (272 – 355 mm TL) were recorded from three sites (main wetland sites), a single tarpon was recorded (314 mm TL) and twenty-six sleepy cod from five sites (25 – 320 mm TL). Many of the latter were very small juveniles 25-50 mm TL.

Numerous fish species, including commercial and recreational fisheries species were collected as singletons or in very low number at sites (Table 1). For instance, two individuals of the eel *Anguilla* cf. *obscura* were collected in a single fyke net in one of the large wetlands, and pennyfish (*Denariusa australis*) were not recorded in abundance at sites where they were detected. It is possible that the *Anguilla* cf. *obscura* are *A. bicolor*, though vertebral counts were difficult to achieve from X-rays due to the small size of the posterior vertebrae. Teeth arrangements suggest the specimens are *A. obscura*.

Whilst macroinvertebrates other than crustaceans were not a focus of our surveys, exceptional numbers of water beetles were captured at each of the main wetland sites where bait traps were implemented (up to 603 from 10 bait traps at a single site)(Table 1). Crustaceans were infrequently encountered and the detection of prawns and shrimps was surprisingly low given the survey techniques used in the study (Table 1). While freshwater crabs (*Austrothelphusa* spp.) were not detected in the surveys, a number of individuals were collected during a pilot study approximately 1 month earlier at Site 11.

Sixteen wetland bird species were observed across the four large wetlands that we spent the majority of our time at over five days. The relevant presence-absence data is presented in Table 2. Given the propensity for high mobility of waterbirds between wetlands and long-range migratory capability of many species, and the poor temporal resolution of our surveys, no further detail is afforded this taxonomic group.

3.2 Water quality sampling

Measured water quality parameters at each of the six wetland sites were relatively similar with the exception of turbidity (Table 3). Temperature ranged from 20.8 – 23.5 ^{o}C, pH ranged from 5.3 to 6.9, conductivity ranged from 0.0 – 0.1 mS/cm, TDS ranged from 0.0 – 0.1 g/L and salinity was stable across all sites at 0.0 ppt. Three of the four large wetlands (Site 6, 7, 8) exhibited low visibility (typically 10–30 cm) and this was supported by turbidity readings (Table 3). The one large wetland where good visibility (in the order of 1–2 m in places) was observed (Site 10) had lower turbidity readings (6–7 NTU) than the aforementioned large wetlands (25–59 NTU) (Site 6, 7, 8). This coincided with substantial submerged macrophyte beds (aquatic plants) not present in the other three large wetlands. The atypical large wetland (Site 10) also had subtly deeper sections (1.0–2.0 m maximum depth) than the other large wetlands (0.6 – 1.2 m maximum depth). Most of the smaller wetlands that were opportunistically surveyed for fishes had clear water and the two of these sites sampled for water quality had low turbidity (Table 3).

Table 1. Total number of individuals sampled at each site and total number of species for fish, reptiles, invertebrates. The large wetland sites are highlighted in grey.

Fish	Common Name	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7	Site 8	Site 9	Site 10	Site 11
Ambassis agrammus	Sailfin glass perchlet	31	51	31	0	36	404	177	165	17	158	326
Amniataba percoides	Barred grunter	1	1	0	0	34	0	3	0	0	0	0
Anguilla cf. obscura	Eel	0	0	0	0	0	2	0	0	0	0	0
Anguilla reinhardtii	Longfin eel	0	0	0	0	0	4	2	0	1	2	0
Craterocephalus stercusmuscarum	Fly-specked hardyhead	0	0	0	51	205	0	1	0	0	25	113
Denariusa australis	Pennyfish	0	1	0	0	0	1	0	0	7	1	0
Glossamia aprion	Mouth Almighty	0	0	0	0	0	1	2	0	2	5	4
Lates calcarifer	Barramundi	0	0	0	0	0	1	3	0	0	1	0
Leiopotherapon unicolor	Spangled perch	1	1	0	12	69	0	0	12	0	1	64
Melanotaenia splendida	Eastern rainbowfish	201	201	201	51	129	18	23	5	9	6	316
Mogurnda sp.	Purple-spotted gudgeon	11	0	0	0	0	1	18	0	0	0	90
Nematalosa erebi	Bony herring	0	0	0	0	0	0	14	2	0	4	0
Neosilurus ater	Black catfish	0	0	0	0	0	0	1	4	0	0	0
Neosilurus hyrtlii	Hyrtl's tandan	0	0	0	0	0	1	0	0	0	0	0
Oxyeleotris nullipora	Poreless gudgeon	0	0	0	0	0	12	32	2	0	0	5
Oxyeleotris selheimi	Giant gudgeon	0	0	0	0	0	0	1	0	0	0	0
Oxyeleotris lineolata	Sleepy cod	0	0	0	0	0	5	0	0	0	0	0
Oxyeleotris spp.	Gudgeon species	0	1	0	0	0	2	11	4	0	0	2
Porochilus rendahli	Rendahl's catfish	0	0	0	0	0	10	6	1	0	5	2
Toxotes chatareus	Seven-spot archerfish	0	0	0	0	17	0	0	0	0	0	1
Total species		**5**	**6**	**2**	**3**	**6**	**12**	**13**	**8**	**5**	**10**	**10**
Reptiles												
Crocodylus porosus	Estuarine crocodile	0	0	0	0	0	1	1	2	0	2	0
Pseudoferania polylepis	Macleay's water snake	0	0	0	0	0	0	1	0	0	0	1
Total species		**0**	**0**	**0**	**0**	**0**	**1**	**2**	**1**	**0**	**1**	**1**

Aquatic invertebrates	Common Name	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7	Site 8	Site 9	Site 10	Site 11
Dytiscid sp.	Water beetle	0	0	0	0	0	337	181	603	9	371	3
Cherax quadricarinatus	Redclaw crayfish	0	0	0	0	0	3	0	0	0	0	0
Gastropod sp.	Aquatic snail	0	0	0	0	0	0	20	0	0	1	0
Austrothelphusa sp.	Inland freshwater crab	1	0	0	1	0	0	0	0	0	0	0
Palaemonid sp.	Freshwater shrimp	0	0	0	0	1	0	0	0	0	0	0
Macrobrachium sp.	Freshwater prawn	0	0	0	0	0	0	0	0	0	1	0
Hirudinea sp.	Leech	0	0	0	0	0	0	0	0	0	1	0
Total species		**1**	**0**	**0**	**1**	**1**	**2**	**2**	**1**	**1**	**4**	**1**

Table 2. Total number of individuals sampled at each site and total number of species wetland birds at each site. The large wetland sites are highlighted in grey.

Wetland birds	Common Name	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7	Site 8	Site 9	Site 10	Site 11
Grus rubicundus	Brolga	No bird survey	No bird survey	No bird survey	No bird survey	No bird survey	x	x		No bird survey		No bird survey
Anhinga melanogaster	Australian darter						x		x		x	
Todirampus macleayii	Forest kingfisher						x					
Irediparra gallinacean	Jacana						x		x		x	
Dendrocygna eytoni	Plumed whistling duck						x				x	
Threskiornis spinicollis	Straw-necked ibis						x					
Anseranas semipalmata	Magpie geese							x				
Platalea regia	Royal spoonbill							x				
Ardea ibis	Cattle egret							x				
Ardea alba	Great egret							x	x		x	
Nettapus pulchellus	Green pygmy goose							x	x			
Pelecanus conspicillatus	Australian pelican								x		x	
Fulica atra	Eurasian coot								x		x	
Tadorna radjah	Rajah shellduck								x			
Haliaeeyus leucogaster	White-bellied sea eagle								x			
Egretta garzetta	Little egret										x	
Total species							6	6	8		7	

Figure 7. Images of fish species from surveys of the wetlands on Violetvale Station; a) Longfin eel (*Anguilla reinhardtii*), b) eel (*Anguilla cf. obscura*), c) poreless gudgeon (*Oxyeleotris nullipora*), d) purple-spotted gudgeon (*Mogurnda* sp.), e) Rendahl's tandan (*Porochilus rendahli*), f) black catfish (*Neosilurus ater*), g) Hyrtl's tandan (*Neosilurus hyrtlii*), h) mouth almighty (*Glossamia aprion*), i) barred grunter (*Amniataba percoides*), j) bony herring (*Nematalosa erebi*), k) sailfin glass perchlet (*Ambassis agrammus*), l) seven-spot archerfish (*Toxotes chatareus*), m) spangled perch (*Leiopotherapon unicolor*), n) eastern rainbowfish (*Melanotaenia splendida*), o) pennyfish (*Denariusa australis*), p) fly-specked hardyhead (*Craterocephalus stercusmuscarum*).

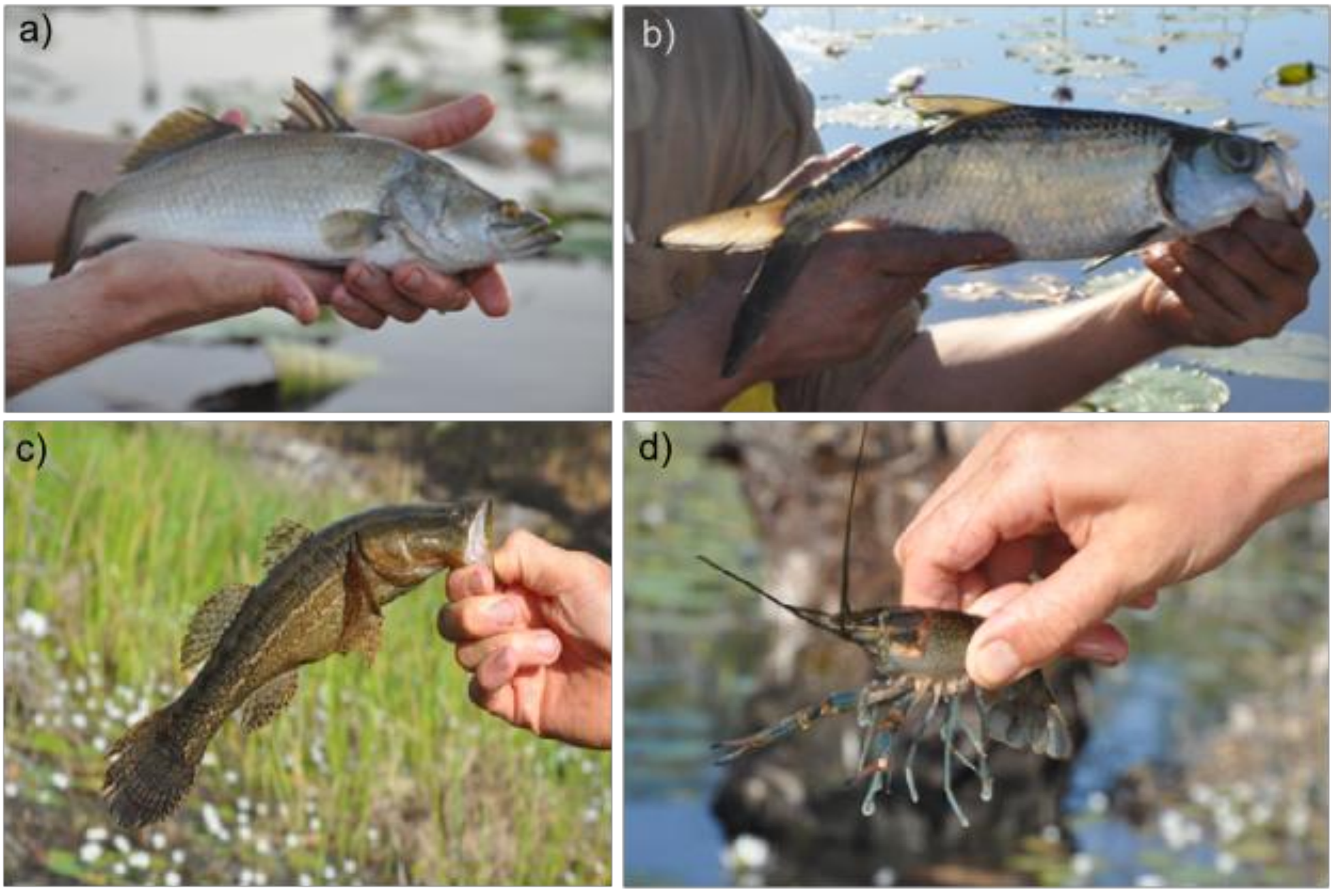

Figure 8. Recreationally, commercially and culturally important species; a) barramundi (*Lates calcarifer*), b) tarpon (*Megalops cyprinoides*), c) sleepy cod (*Oxyeleotris selheimi*) and d) redclaw crayfish (*Cherax quadricarinatus*).

Table 3. Water quality measurements taken at each of the wetland sites.

Date	Time	Site	Rep.	Temp. (^{o}C)	pH	Conductivity (mS/cm)	Turbidity (NTU)	DO (mg/L)	DO (%)	TDS (g/L)	Salinity (ppt)
13/07/2015	16:20	6	1	22.5	6.2	0.1	25.6	3.1	37.2	0.1	0.0
			2	22.5	6.1	0.1	25.2	3.7	43.8	0.1	0.0
			3	22.5	6.2	0.1	25.6	3.8	44.3	0.1	0.0
			Average	**22.5**	**6.1**	**0.1**	**25.5**	**3.5**	**41.8**	**0.1**	**0.0**
14/07/2015	16:00	7	1	23.6	5.3	0.1	56.0	1.6	19.2	0.0	0.0
			2	23.6	5.3	0.1	54.9	1.5	18.5	0.0	0.0
			3	23.3	5.3	0.1	58.8	1.6	19.2	0.0	0.0
			Average	**23.5**	**5.3**	**0.1**	**56.6**	**1.6**	**19.0**	**0.0**	**0.0**
15/07/2015	16:40	8	1	20.9	5.8	0.1	55.2	3.5	39.5	0.0	0.0
			2	20.7	5.7	0.1	48.3	3.4	38.8	0.0	0.0
			3	20.8	5.7	0.1	49.5	3.4	39.8	0.0	0.0
			Average	**20.8**	**5.8**	**0.1**	**51.0**	**3.4**	**39.4**	**0.0**	**0.0**
17/07/2015	11:30	9	1	21.4	6.9	0.1	12.8	7.8	89.1	0.1	0.0
			2	21.5	7.0	0.1	12.8	7.5	87.0	0.1	0.0
			3	21.5	7.0	0.1	13.3	7.4	85.0	0.1	0.0
			Average	**21.5**	**6.9**	**0.1**	**13.0**	**7.5**	**87.0**	**0.1**	**0.0**
16/07/2015	16:15	10	1	22.9	5.7	0.1	6.0	4.1	48.2	0.0	0.0
			2	22.7	5.7	0.1	6.9	4.2	49.7	0.0	0.0
			3	22.3	5.6	0.1	6.9	4.2	48.7	0.0	0.0
			Average	**22.6**	**5.7**	**0.1**	**6.6**	**4.2**	**48.9**	**0.0**	**0.0**
17/07/2015	13:30	11	1	22.6	6.6	0.0	6.6	6.5	77.2	0.0	0.0
			2	22.3	6.5	0.0	5.4	6.2	72.0	0.0	0.0
			3	22.3	6.5	0.0	5.9	6.2	73.8	0.0	0.0
			Average	**22.4**	**6.5**	**0.0**	**6.0**	**6.3**	**74.3**	**0.0**	**0.0**

4 DISCUSSION

Survey methods and detection of aquatic taxa

This study has established baseline data for aquatic biodiversity and water quality for wetlands on Violetvale station using repeatable scientific methods. A total of 19 fish, 2 aquatic reptile, 8 aquatic macroinvertebrate and 16 waterbird species were recorded. These data will serve as a reference to gauge the efficacy of changes in future land management practices and specifically to provide before-data in relation to large-scale fencing of wetlands to exclude cattle and direct culling of feral pigs.

The fish assemblage data set provides a key baseline for monitoring these wetlands. It should prove sensitive to major shifts in recruitment of different species. In this case the surveys detected recent breeding of sleepy cod (*Oxyeleotris* spp.) since several small juveniles were collected (although, length frequency data are not provided in this report). The fish fauna across the wetlands comprises at least 19 species, however, many of these species were detected in very low numbers indicated that in future surveys no less survey effort should be applied if several of these species are to be detected assuming similar fish densities and surface water availability. In fact increased survey effort would probably be valuable for increasing the detection of a number of fish species (and potentially species not detected in the current survey). This logic extends to getting a better estimate of barramundi density and size distribution. Applications of gill and fyke nets provide useful means of surveying barramundi; however, both are passive techniques which rely on the mobility of the fish. It is possible that barramundi were inactive during the survey period and thereby netting-data provided a poor indication of abundance. The obvious alternative would be to conduct boat-electro-fishing surveys; however, this latter method is unlikely to be effective in these large wetlands due to the extreme density of waterlilies and problems with obstruction to the outboard motor and the challenges of penetrating the water with electrodes.

Although this section of the Normanby catchment has not been previously surveyed to the best of our knowledge, the bulk of the fish species recorded were typical of the nearby region (Herbert & Peters 1995, Kennard 1995, Allen *et al*. 2002). Two eels that were collected appeared to be *Anguilla bicolor* but inspection of teeth in the laboratory was indicative of *Anguilla obscura* and X-rays of the skeleton did not elucidate vertebral counts (due to the small size of posterior most vertebrae of specimens). Genetic testing is required to confirm the identity of these specimens; however, they are mostly likely *A. obscura*. This warrants clarification as the known Australian distribution of *A. bicolor* is confined to the Pilbara and Kimberley regions of Western Australia (Morgan *et al.,* 2014), despite being more widely found in the Indian Ocean and the Indonesian Seas rather than eastern Australia (Watanabe *et al.* 2014). However, Herbert and Peeters (1995) recorded *Anguilla reinhardtii* and *Anguilla obscura* and acknowledged that *Anguilla bicolor* may be present on Cape York.

Despite being large-bodied, freshwater eels can be difficult to identify to species levels owing to a combination of the fact that they have few obvious external morphological attributes and because of the challenges of capturing and handling live eels. The individuals collected in the current survey have been retained as voucher specimens, and we recommend more specimens be retained in future surveys to gain a more accurate view of the eel species present along Eastern Cape York.

We in no way claim to have sampled macroinvertebrates comprehensively, and only three of our survey techniques (bait traps, fyke nets and frame nets) were likely to detect macrocrustaceans (prawns, shrimps, crabs). However, these techniques are effective at detecting these macrocrustaceans when these taxa are abundant. Therefore, our survey design and baseline data should be useful in subsequent monitoring for inter-annual shifts in macrocrustacean composition. Prawns and shrimps can undergo short-term boom and bust (at about monthly or seasonal scales) and can show major inter-annual shifts in abundance (e.g. Novak *et al.* 2015). At times they are conspicuous in large water bodies and comprise an important component of fish diets, particularly early in the dry season (Jardine *et al.* 2012). In contrast, in north Queensland rivers and streams, freshwater crabs are often cryptic, living in burrows and under rocks, often in shallow ephemeral waters and additionally can be very seasonal in their activity and susceptibility to detection at different times of year (Ebner, pers. obs.). This may explain why they were detected in the pilot study and not during the subsequent and more intensive current survey. The finding of redclaw, *Cherax quadricarinatus* is significant in that it is an alien species to the Eastern Cape York Peninsula catchments (cf. Baker *et al.* 2008).

During the study no turtles were caught or observed. The only evidence of turtles at any of the sites was observed on a two-day pilot study prior to the commencement of the main surveys, in the form of an intact shell (Figure 9). TropWATER freshwater turtle specialist, Jason Schaffer, analysed a photo of this shell and concluded it was most likely from the yellow-faced turtle (*Emydura tanybaraga*). The apparent low densities of turtles in wetlands on Violetvale Station may be attributable to seasonal inactivity and/or may reflect the impact of predation by pigs or loss of suitable nesting areas due to soil compaction by large feral herbivores (Fordham *et al*., 2008; Burrows *et al*., 2010; Doupé *et al*., 2009, 2010). Increased turbidity can also affect the respiration rates of bimodally respiring freshwater turtles (Schaffer *et al*., 2015). Pig exclusion fencing has been shown to ease pressure on wetlands in terms of enabling macrophyte colonisation, reduced nutrient loading and increased water clarity, however there are substantial initial outlays and maintenance costs involved with effective fencing (Burrows *et al*., 2010; Doupé *et al*., 2009, 2010).

Figure 9. A freshwater turtle shell found during pilot study next to wetland. Likely a yellow-faced turtle (*Emydura tanybaraga*) (Jason Schaffer pers. Comm.)

Several fyke nets were also damaged by estuarine crocodiles in the large wetlands. It would be useful to undertake trials to minimise damage to fyke nets by crocodiles by testing different modifications (e.g. float characteristics: size, colour, camouflaging floats; and concealing the catch in the cod-end) as there are few alternatives for surveying fish assemblages in these wetlands.

Baited remote video has been used in a number of tropical rivers and waterholes to survey fish, aquatic reptiles and crustaceans (Ebner *et al.* 2014). Underwater video was used sparingly in this study mostly because of high turbidity and poor water clarity in the large wetlands. This technique may become more relevant post fencing of wetlands should water clarity improve, including later in the dry season than was achieved in this case. Certainly, underwater video would not have been compromised by water clarity in a number of the small wetlands during the recent survey. However, a baseline arising from techniques that do not require good water clarity was the priority in the context of surveying the Violetvale wetland complexes. Conversely, above water video or time-lapse photography may prove informative in understanding behaviour of cattle, pigs, waterbirds, turtles, crocodiles and even changes to vegetation and edge-habitat as adaptive management (e.g. wetland fencing) progresses on Violetvale Station.

Currently there are no Queensland Water Quality Guidelines (QWQG) for any of the eastern Cape York drainage basins with which data from this study can be directly compared. The Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC, 2000) however can be used as an interim guide. According to the guidelines for tropical Australia, the water quality data collected across each of the sites achieves a mixed scorecard. At three of the six sites at which water quality was measured, pH readings were generally within the acceptable range (pH 6.0-8.0), conductivity for all sites was within the 'acceptable' range (90–900 μScm^{-1}), as was turbidity for all sites (2–200 NTU), with most being at the lower end of this range.

Adaptive management

Wetland ecosystems of the vast tropical Australian Savannah country are vulnerable to a combination of threatening process including alien species, human land and water use and climate change. Importantly, on properties where maintaining agriculture productivity is a major consideration, sustainable solutions to protecting wetlands are rarely cheap and are most likely to come from collaboration between government and on-ground action by property owners and managers (MacLeod & McIvor 2006). The current baseline survey work and the large-scale fencing of wetlands that has followed while this report has been drafted, represent this type of collaboration and action at the property scale.

Small and large wetlands exist on Violetvale Station during the dry season. Accordingly, this presents different scales of management option as a function of alien species control or exclusion. The new exclusion fences are designed to manage cattle, including cattle access to wetlands and riparian areas and the intention is to control pig damage via direct culls (Figure 10; Michael Goddard, Cape York NRM, pers. comm.). The aquatic surveys performed in the current study have also served to identify opportunity for small-scale fencing of certain areas in the future. It would be informative to test small-scale replicated trials of cattle versus pig-cattle exclusion at a number of sites to quantify protection of aquatic fauna and flora, realising the high cost of pig exclusion fencing. This might include fencing of small wetlands, and also extend to partial fencing of small sections of larger wetlands. It is also possible to use above water time-lapse photography and video surveillance to better track the interactions among cattle, pigs and wetland systems in such an experimental process.

Figure 10. Pig damage at a wetland on Violetvale Station.

The deepest of the four large wetlands surveyed also coincided with good water clarity and substantial submerged aquatic plant beds relative to the other three large wetlands surveyed. This may be a function of subtle differences in cattle access to the wetland since the entire wetland was not of wade-able depth. The largest saltwater crocodile observed on the trip was also present in the deepest wetland, and the impact of this individual on cattle behaviour in the wetland is unknown. Depth is potentially a factor worthy of scrutiny in future plans to manage, fence and monitor wetland condition.

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A APPENDICES

A.1 Survey effort applied at each site

	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7	Site 8	Site 9	Site 10	Site 11
Bait trap						x	x	x		x	
Gill net						x	x	x		x	
Fyke net		x				x	x	x	x	x	
Spotlight						x	x	x		x	
Frame net	x	x	x	x	x				x		x
Dip net				x	x						x
BRUVS					x						x
Above water observation					x						x

A.2 GPS locations for each site surveyed

Code	Latitude	Longitude
Site 1	-14.7181	143.7145
Site 2	-14.7177	143.7148
Site 3	-14.7174	143.7144
Site 4	-14.692	143.7928
Site 5	-14.6932	143.7919
Site 6	-14.7226	143.6898
Site 7	-14.7192	143.7127
Site 8	-14.7111	143.7691
Site 9	-14.6894	143.7923
Site 10	-14.7221	143.7859
Site 11	-14.7142	143.7453

A.3 X-ray image of skeletal structure of *Anguilla* specimens retained from the study. A represents *Anguilla* cf. *obscura*, whereas, B represents *Anguilla reinhardtii*.