Marine and Freshwater Research, 2018, **69**, 1092–1109
https://doi.org/10.1071/MF16175_AC

Supplementary material

Vulnerability of fish and macroinvertebrates to key threats in streams of the Kakadu region, northern Australia: assemblage dynamics, existing assessments and knowledge needs

Chris L. Humphrey[A,D], *Keith A. Bishop*[B] *and Peter L. Dostine*[C]

[A]Supervising Scientist Branch, Department of the Environment and Energy, GPO Box 461, Darwin, NT 0801, Australia.

[B]Aquatic Ecologist, 122 Sugar Creek Road, Bungwahl, NSW 2423, Australia.

[C]Department of Environment and Natural Resources, PO Box 496, Palmerston, NT 0831, Australia.

[D]Corresponding author. Email: chris.humphrey@environment.gov.au

http://dx.doi.org/10.1071/MF16175_AC

Table S1. Estimated surface area of major freshwater habitats at the end of the dry season in Magela Creek downstream of the Arnhem Land plateau

Estimations are based on the examination of a Google Earth photo mosaic dated 18 November 2015

Habitat (upstream to downstream)	Area (ha)	Percentage of all major habitats
Escarpment main-channel water bodies	6.3	0.7
Escarpment perennial springs	1.6	0.2
Lowland sandy creek pools	0.3	0.03
Lowland backflow billabongs	7.2	0.8
Channel–corridor water bodies	24.5	2.8
Total floodplain	843.9	95.5
Upper floodplain	99.8	15.1
Middle floodplain	96.1	11.3
Lower floodplain	648	73.3
All major habitats above	883.8	100

http://dx.doi.org/10.1071/MF16175_AC

Table S2. Differences in among-habitat dispersion of macroinvertebrate assemblages in multivariate space using PERMDISP routine in PRIMER

Habitat (Group) codes are as follows: UPF, upland riffles of permanent flow; USF, upland riffles of seasonal flow; LSS, lowland stream channels of seasonal flow with sandstone escarpment headwaters; LSL, lowland stream channels of seasonal flow with lowland headwaters; SLB, shallow lowland billabongs; CB, channel billabongs; FB, floodplain billabongs; and FP, seasonally inundated floodplain

Group	Size	Average dispersion	s.e.
SLB	33	42.9	1.8
CB	13	33.2	3.0
FB	2	23.8	0.0
FP	3	8.3	0.9
UPF	33	31.2	2.1
USF	4	26.7	2.0
LSS	240	38.8	0.6
LSL	32	45.0	2.2

http://dx.doi.org/10.1071/MF16175_AC

Table S3. Common fish species or genera sampled in Magela Creek 1978–79

Code	Scientific name	Common name
AL	*Neoarius leptaspis*	Salmon catfish
AM	*Ambassis* spp.	Macleay’s glassfish
AP	*Amniataba percoides*	Banded grunter
CM	*Craterocephalus marianae*	Mariana’s hardyhead
CS	*Craterocephalus stercusmuscarum*	Fly-specked hardyhead
DB	*Denariusa bandata*	Penny fish
GA	*Glossamia aprion*	Mouth almighty
HF	*Hephaestus fuliginosus*	Sooty grunter
LU	*Leiopotherapon unicolor*	Spangled grunter
MN	*Melanotaenia nigrans*	Black-striped rainbowfish
MS	*Melanotaenia splendida inornata*	Chequered rainbowfish
NA	*Neosilurus ater*	Black catfish
NE	*Nematalosa erebi*	Bony bream
NH	*Neosiluris hyrtlii*	Hyrtl’s catfish
OL	*Oxyeleotris lineolata*	Sleepy cod
PM	*Pingalla midgleyi*	Black-anal-fin grunter
PT	*Pseudomugil tenellus*	Delicate blue-eye
PR	*Porochilus rendahli*	Rendahl’s catfish
SK	*Strongylura krefftii*	Longtom
SB	*Syncomistes butleri*	Sharp-nosed grunter
TC	*Toxotes chatareus*	Archer fish

Table S4. Assessment forms for assessing literature and other information on change in Kakadu National Park

Signal summary identified for the threat denoted in red shading

Threat	1. Climate change | 1. Sea-level rise | 1. Inundation across floodplain – fish 1. Climate change | 1. Sea-level rise | 2. Salinity incursions across floodplain – fish			
Reference	National Environmental Research Program, Northern Hub (2015). Freshwater fishes of Kakadu National Park and the impact of sea-level rise. Available at http://www.nespnorthern.edu.au/wp-content/uploads/2015/10/3.3_kakadu_freshwater_fishes_fact_sheet_web.pdf (accessed 4 September 2016) + B. Pusey, pers. comm.			
Signal summary	Unknown	Neutral	Loss response	Gain response
Nature of predicted change (if any)	Fourteen species (6 classed highly vulnerable and 8 moderately vulnerable) could lose access to >10% of the catchment area they currently occupy. Similarly, 13 species (5 highly vulnerable and 8 moderately vulnerable) could lose access to <10% of their catchment area. (In all, 11 of 62 species in Kakadu have 15–40% of their overall distribution in Kakadu.)			

Feature assessed	Quality/sensitivity rating with reasoning (none, low, medium, high)	Score[A]
Quality of abiotic-change characterisation	Low: only 1 m rise in sea level considered with no consideration of salinity structure dynamics	1
Quality of biotic-response characterisation	Low: (1) only areal distribution from broad-scale mapping, (2) no Kakadu-specific verification of mapping results, (3) no consideration of surface-water availability across the landscape	1
Sensitivity in relation to the consideration of key 'constrictions'	Low: no consideration of the changed availability of dry-season refuges across the landscape	1
Quality of consideration of the interaction with other threats	Low: rising temperatures was incidentally mentioned	1

[A]Score: 0, none; 1, low; 2, medium; 3, high.

Total score	4
Percentage of the maximum possible (12)	33%

Table S4. (*Continued*)

Threat	1. Climate change | 1. Sea-level rise | 1. Inundation across floodplain – macroinvertebrates and ecological processes 1. Climate change | 1. Sea-level rise | 2. Salinity incursions across floodplain – macroinvertebrates and ecological processes			
References	Macroinvertebrates: (1) Finlayson *et al*. (2006). Biodiversity of the wetlands of the Kakadu region, northern Australia. *Aquatic Sciences* **68**, 374–399. (2) AECOM (2010). Research of Key Knowledge Gaps in the Ecological Character of the Cobourg Peninsula Ramsar Site, Northern Territory: Aquatic Flora and Fauna and Physicochemical Assessment. Prepared for the Australian Government, Canberra Ecological processes: Junk *et al*. (1989). The flood pulse concept in river floodplain systems. *Canadian Special Publication of Fisheries and Aquatic Sciences* **106**, 110–127.			
Signal summary	Unknown	Neutral	Loss response	Gain response
Nature of predicted change (if any)	Macroinvertebrate taxon number reduced in brackish–saline habitats compared with freshwater habitats. However, no freshwater macroinvertebrate species yet recorded is unique to this habitat (minimal conservation-value loss). Absence of floodplain drying phase would result in a significant loss of (seasonal) secondary production to higher trophic levels			

Feature assessed	Quality/sensitivity rating with reasoning (none, low, medium, high)	Score[A]
Quality of abiotic change characterisation	Low: no hydrodynamic modelling available to better predict flow and inundation patterns with sea-level rise	1
Quality of biotic response characterisation	Medium: conservation assessment and general species loss based on local published information.	2
Sensitivity in relation to the consideration of key ‘constrictions’	Low: no consideration of the changed availability of dry-season refuges across the landscape	1
Quality of consideration of the interaction with other threats	Low: unknown	1

[A]Score: 0, none; 1, low; 2, medium; 3, high.

Total score	5
Percentage of the maximum possible (12)	42%

Table S4. (*Continued*)

Threat	2. Flux of invasive species | 2. Invasive fauna | 3. Cane toads – fish and macroinvertebrates			
Reference	van Dam *et al*. (2002). A preliminary risk assessment of cane toads in Kakadu National Park. Supervising Scientist report 164. Supervising Scientist, Darwin. Bishop (2014). Opportunistic diver-based mid-dry-season recensusing of freshwater fish assemblages in two streams within Kakadu National Park: is there any evidence of impacts arising from cane toads? Report to Parks North (Kakadu National Park) and the Environmental Research Institute of the Supervising Scientist (Commonwealth Department of the Environment), November 2014. Supervising Scientist (2005). Annual report 2004–2005. Supervising Scientist, Darwin; Section 3.6.2. Woinarski and Winderlich (2014). A strategy for the conservation of threatened species and threatened ecological communities in Kakadu National Park 2014–2024. Charles Darwin University, Darwin.			
Signal summary	Unknown	Neutral	Loss response	Gain response
Nature of predicted change (if any)	van Dam *et al*. (2002) suggested an unknown to neutral response while Woinarski and Winderlich (2014) listed competition with cane-toad tadpoles (e.g. dissolved oxygen depletion) at high tadpole densities as among plausible threats to endemic plateau shrimp populations. None of these threats has been realised yet (includes site visits to shrimp sites post-toad invasion).			

Feature assessed	Quality/sensitivity rating with reasoning (none, low, medium, high)	Score[A]
Quality of abiotic change characterisation	Human-disturbed waterbodies in Kakadu noted to have seasonally high densities of toads	1
Quality of biotic response characterisation	Medium	2
Sensitivity in relation to the consideration of key 'constrictions'	n.a.	
Quality of consideration of the interaction with other threats	Low (mine-disturbed sites on the Ranger uranium mine lease with seasonally high densities)	1

[A]Score: 0, none; 1, low; 2, medium; 3, high.

Total score	4
Percentage of the maximum possible (9)	44%

Table S4. (*Continued*)

Threat	2. Flux of invasive species | 2. Invasive fauna | 3. Cane toads – fish			
Reference	van Dam *et al*. (2002). A preliminary risk assessment of cane toads in Kakadu National Park. Supervising Scientist report 164. Supervising Scientist, Darwin.			
Signal summary	Unknown	Neutral	Loss response	Gain response
Nature of predicted change (if any)	(98 species uncertain status: 3 fish spp. high priority, 4 fish spp. moderate priority) (31 species unlikely: 4 fish spp., thus, low priority)			

Feature assessed	Quality/sensitivity rating with reasoning (none, low, medium, high)	Score[A]
Quality of abiotic change characterisation	n.a.	
Quality of biotic response characterisation	Medium	2
Sensitivity in relation to the consideration of key 'constrictions'	Medium	2
Quality of consideration of the interaction with other threats	None	0

[A]Score: 0, none; 1, low; 2, medium; 3, high.

Total score	4
Percentage of the maximum possible (9)	44%

Table S4. (*Continued*)

Threat	2. Flux of invasive species | 2. Invasive fauna | 3. Cane toads – fish			
Reference	Supervising Scientist (2005). Annual report 2004–2005. Supervising Scientist, Darwin; section 3.6.2			
Signal summary	Unknown	Neutral	Loss response	Gain response
Nature of predicted change (if any)	No evidence of a decline in any fish trophic groups following toad arrival in Magela and Nourlangie lowland backflow billabongs.			

Feature assessed	Quality/sensitivity rating with reasoning (none, low, medium, high)	Score[A]
Quality of abiotic change characterisation	n.a.	
Quality of biotic response characterisation	Medium	2
Sensitivity in relation to the consideration of key ‘constrictions’	Medium	2
Quality of consideration of the interaction with other threats	None	0

[A]Score: 0, none; 1, low; 2, medium; 3, high.

Total score	4
Percentage of the maximum possible (9)	44%

Table S4. (*Continued*)

Threat	1. Climate change | 3. Increase in frequency of stronger La Niña events | 1. Increased suspended sediment transport 3. Mining and other impacts | 1: Mining | 3. Turbidity and bedload changes associated with landform erosion			
Reference	Supervising Scientist (2013). Annual report 2012–2013. Supervising Scientist, Darwin; Section 4.3.			
Signal summary	Unknown	Neutral	Loss response	Gain response
Nature of predicted change (if any)	Primary productivity shows decline after 50–70 nephelometric turbidity unit (NTU) in billabong. Macroinvertebrate losses in a sandy creek by 30 NTU. Major loss in a sandy creek microphagic carnivore, *Craterocephalus marianae*, at 60 NTU and possibly lower. Many complicating factors to be considered to resolve direct effects (and indirect effects such as settling and bedload changes, not considered).			

Feature assessed	Quality/sensitivity rating with reasoning (none, low, medium, high)	Score[A]
Quality of abiotic change characterisation	Medium	2
Quality of biotic response characterisation	Medium	2
Sensitivity in relation to the consideration of key 'constrictions'	Medium	2
Quality of consideration of the interaction with other threats	None	0

[A]Score: 0, none; 1, low; 2, medium; 3, high.

Total score	6
Percentage of the maximum possible (12)	50%

Table S4. (*Continued*)

Threat	1. Climate change | 3. Increase in frequency of stronger La Niña events | 1. Increased suspended sediment transport 3. Mining and other impacts | 1. Mining | 3. Turbidity and bedload changes associated with landform erosion 3. Mining and other impacts | 1. Mining | 4. ‘Terrestrialisation’ of lowland backflow billabongs			
Reference	Supervising Scientist (2007). Annual report 2006–2007. Supervising Scientist, Darwin; fig. 2.18.			
Signal summary	Unknown	Neutral	Loss response	Gain response
Nature of predicted change (if any)	High aquatic-plant densities preclude large-bodied fish species, and small-bodied species if plant densities are very high			

Feature assessed	Quality/sensitivity rating with reasoning (none, low, medium, high)	Score[A]
Quality of abiotic change characterisation	Medium	2
Quality of biotic response characterisation	Medium	2
Sensitivity in relation to the consideration of key ‘constrictions’	Medium	2
Quality of consideration of the interaction with other threats	None	0

[A]Score: 0, none; 1, low; 2, medium; 3, high.

Total score	6
Percentage of the maximum possible (12)	50%

Table S4. (*Continued*)

Threat	1. Climate change | 3. Increase in frequency of stronger La Niña events | 1. Increased sediment inputs 2. Flux of invasive species | 2. Invasive fauna | 2. Buffalo habitat damage 3. Mining and other impacts | 1. Mining | 3. Turbidity and bedload changes associated with landform erosion 3. Mining and other impacts | 1. Mining | 4. 'Terrestrialisation' of lowland backflow billabongs			
Reference	Humphrey *et al*. (1990). Use of biological monitoring in the assessment of effects of mining wastes on aquatic ecosystems of the Alligator Rivers region, tropical northern Australia. *Environmental Monitoring and Assessment* **14**, 139–181. Bishop (1987). Dynamics of the freshwater fish communities of the Alligator Rivers region, tropical northern Australia. Ph.D. Thesis, Macquarie University, Sydney.			
Signal summary	Unknown	Neutral	Loss response	Gain response
Nature of predicted change (if any)	Very high plant densities (e.g. from sedimentation) preclude large-bodied fish species – loss in this context, but gain in relation to buffalo influence, where plant densities are reduced. Mine-related sedimentation may infill backflow billabongs (habitat loss).			

Feature assessed	Quality/sensitivity rating with reasoning (none, low, medium, high)	Score[A]
Quality of abiotic change characterisation	Medium	2
Quality of biotic response characterisation	Medium	2
Sensitivity in relation to the consideration of key 'constrictions'	Medium	2
Quality of consideration of the interaction with other threats	Low	1

[A]Score: 0, none; 1, low; 2, medium; 3, high.

Total score	7
Percentage of the maximum possible (12)	58%

Table S4. (*Continued*)

Threat	2. Flux of invasive species | 1. Invasive flora | 2. Spread of Para grass and its impacts			
Reference	Douglas *et al*. (2001). Weed management and the biodiversity and ecological processes of tropical wetlands. Draft final report to National Wetlands R & D Program Environment Australia & Land and Water Australia.			
Signal summary	Unknown	Neutral	Loss response	Gain response
Nature of predicted change (if any)	Fish and aquatic invertebrate communities appear to be largely insensitive to native versus introduced (para grass) habitat type. Some limited impacts on food web but with caveats.			

Feature assessed	Quality/sensitivity rating with reasoning (none, low, medium, high)	Score[A]
Quality of abiotic change characterisation	n.a.	
Quality of biotic response characterisation	Medium	2
Sensitivity in relation to the consideration of key ‘constrictions’	Medium	2
Quality of consideration of the interaction with other threats	None	0

[A]Score: 0, none; 1, low; 2, medium; 3, high.

Total score	4
Percentage of the maximum possible (9)	44%

Table S4. (*Continued*)

Threat	1. Climate change | 3. Increase in frequency of stronger La Niña events | 1. Increased sediment inputs			
Reference	Nanson *et al*. (1990). Quaternary evolution and landform stability of Magela Creek catchment near the Ranger uranium mine, northern Australia. Open file record 63. Supervising Scientist for the Alligator Rivers region, Canberra.			
Signal summary	Unknown	Neutral	Loss response	Gain response
Nature of predicted change (if any)	Mudginberri Billabong infilling predicted at 7.5 m per year longitudinally, thus filled in 125 years from 1990 (i.e. ~2115). With more inputs, the filling time will shorten.			

Feature assessed	Quality/sensitivity rating with reasoning (none, low, medium, high)	Score[A]
Quality of abiotic change characterisation	Medium	2
Quality of biotic response characterisation	n.a.	0
Sensitivity in relation to the consideration of key 'constrictions'	High	3
Quality of consideration of the interaction with other threats	None	0

[A]Score: 0, none; 1, low; 2, medium; 3, high.

Total score	5
Percentage of the maximum possible (9)	56%

At the downstream end of the Magela Creek sand channel, in the vicinity of Mudginberri Billabong, the Mangela's infilled trench extends more than 10 m below present sea level; ^{14}C dates indicate that it filled fluvial sand at the time when there existed a deep-water estuarine environment at the site, probably by advance of a sand delta. From aerial photograph analysis there is evidence that a sand delta is presently advancing into the upstream end of Mudginberri Billabong at a rate of ~7.5 m per year. An extrapolation of this rate means that Mudginberri Billabong will be infilled with sand in ~125 years, although more detailed work on sediment yields by Roberts *et al*. (in prep.) will refine this estimate.

Table S4. (*Continued*)

Threat	All listed threats			
Reference	Winderlich and Woinarski (2014). Kakadu National Park landscape symposia series. Symposium 7: conservation of threatened species, 26–27 March 2013, Bowali Visitor Centre, Kakadu National Park. Internal report 623, June, Supervising Scientist, Darwin.			
Signal summary	Unknown	Neutral	Loss response	Gain response
Nature of predicted change (if any)	There are no listed threatened bony fishes in Kakadu National Park. However, the freshwater and estuarine bony fish community of the Park requires some consideration here. There are several range-restricted freshwater fishes with a large proportion of their range in Kakadu National Park, such as Midgley's grunter (*Pingalla midgleyi*), Magela hardyhead (*Craterocephalus marianae*) and Barraway's gudgeon (*Hypseleotris barrawayi*). For other freshwater species (i.e. *Mogurnda* spp. and *Melanotaenia* spp.), taxonomic resolution is required and may result in new species with restricted ranges. Elasmobranchs mentioned.			

Feature assessed	Quality/sensitivity rating with reasoning (none, low, medium, high)	Score[A]
Quality of abiotic change characterisation	None	0
Quality of biotic response characterisation	None	0
Sensitivity in relation to the consideration of key 'constrictions'	None	0
Quality of consideration of the interaction with other threats	None	0

[A]Score: 0, none; 1, low; 2, medium; 3, high.

Total score	0
Percentage of the maximum possible (12)	0%

Table S4. (*Continued*)

Threat	3. Mine closure | 2. Changes to water quality (chemistry) | 1. Toxicity and loss of connectivity in Magela Creek sand channels as a result of saline ($MgSO_4$) groundwater plumes 3. Mine closure | 2. Changes to water quality (chemistry) | 2. Other water quality changes (localised acid sulfate conditions, elevated ammonia/nutrients, metals including manganese and uranium)			
Reference	ERA (2014). 'Ranger 3 Deeps Draft Environmental Impact Statement. Appendix 9. Solute Egress Modelling for ERA Ranger 3 Deeps Mine Closure.' (Energy Resources of Australia: Jabiru, NT.) Available at http://www.energyres.com.au/uploads/general/Appendix_09_Solute_Egress_Modelling_for_ERA_Ranger_3_Deeps_mine_closure.pdf (Accessed 31 March 2016) R. Bartolo, A. Harford, S. Iles and R. van Dam (unpubl. data)			
Signal summary	Unknown	Neutral	Loss response	Gain response
Nature of predicted change (if any)	Large-scale use of waste rock will be used as capping for the final landform of the Ranger uranium mine rehabilitated site. This waste rock will generate significant loads of magnesium sulfate ($MgSO_4$) salts to surface runoff and shallow groundwaters, dispersing to adjacent Magela Creek very shortly after mine-site closure (ERA 2014). Effects of this solute egress on groundwater-dependent and surface-water ecosystems of the creek are currently being identified, modelled and assessed. This assessment includes potential impacts to ecological connectivity (e.g. fish migration, macroinvertebrate drift). Modelling has indicated that post-closure concentrations of other mine-derived chemical contaminants to offsite receiving waters will likely be below locally derived, water-quality closure criteria.			

Feature assessed	Quality/sensitivity rating with reasoning (none, low, medium, high)	Score[A]
Quality of abiotic change characterisation	Medium	2
Quality of biotic response characterisation	Medium	2
Sensitivity in relation to the consideration of key 'constrictions'	Low	1
Quality of consideration of the interaction with other threats	Low	1

[A]Score: 0, none; 1, low; 2, medium; 3, high.

Total score	6
Percentage of the maximum possible (12)	50%

Table S4. (*Continued*)

Threat	1. Climate change | 4. Temperature rise | 1. Increase water temperature extremes 1. Climate change | 2. More, stronger El Niño | 1. Dry-season refuge quantity and quality reduced			
Reference	Woinarski and Winderlich (2014). A strategy for the conservation of threatened species and threatened ecological communities in Kakadu National Park 2014–2024. Charles Darwin University, Darwin.			
Signal summary	Unknown	Neutral	Loss response	Gain response
Nature of predicted change (if any)	Small, groundwater-dependent waterbodies on the sandstone plateau harbour endemic, palaemonid shrimps. These surface waters may be at risk of drying or over-heating with more protracted or hotter dry seasons. Similar risks to other dry-season refuges require assessment.			

Feature assessed	Quality/sensitivity rating with reasoning (none, low, medium, high)	Score[A]
Quality of abiotic change characterisation	None	0
Quality of biotic response characterisation	None	0
Sensitivity in relation to the consideration of key ‘constrictions’	Medium	2
Quality of consideration of the interaction with other threats	Low	1

[A]Score: 0, none; 1, low; 2, medium; 3, high.

Total score	3
Percentage of the maximum possible (12)	25%

http://dx.doi.org/10.1071/MF16175_AC

Table S4. (*Continued*)

Threat	1. Climate change | 2. More, stronger El Niño | 2. Flow persistence reduced			
Reference	Dostine and Humphrey (2012). Macroinvertebrate responses to reduced baseflow in a stream in the monsoonal tropics of northern Australia. National Water Commission, Canberra.			
Signal summary	Unknown	Neutral	Loss response	Gain response
Nature of predicted change (if any)	Dostine and Humphrey (2012) observed significant declines of flow-dependent macroinvertebrate taxa as base flow in a perennial section of the upper South Alligator River (SAR) declined over a several-year period (1990–94). A return to high-rainfall wet seasons lead to responses largely unrelated to flow and unpredictable, particularly for previously dominant taxa. However, no local taxon losses were observed and associated with such extended periods of drought. More and stronger La Niña events associated with climate change would presumably re-charge aquifers responsible for dry-season stream flows, so possibly no long-term loss of perenniality in key refuge areas. In the period 1987–92, there was considerable damage to riparian vegetation caused by buffalo over-stocking in the upper SAR. Localised sedimentation and habitat loss were observed, but were not widespread.			

Feature assessed	Quality/sensitivity rating with reasoning (none, low, medium, high)	Score[A]
Quality of abiotic change characterisation	High	3
Quality of biotic response characterisation	High	3
Sensitivity in relation to the consideration of key ‘constrictions’	Low	1
Quality of consideration of the interaction with other threats	Low (e.g. El Niño-related fires destroying riparian vegetation)	1

[A]Score: 0, none; 1, low; 2, medium; 3, high.

Total score	8
Percentage of the maximum possible (12)	66%

Table S4. (*Continued*)

Threat	1. Climate change | 2. More, stronger El Niño | 3. Increased fires and damage to riparian vegetation 1. Climate change | 3. Increase in frequency of stronger La Niña events | 3. Increased cyclone and flood damage to riparian vegetation
Reference	Andersen *et al*. (2005). Fire frequency and biodiversity conservation in Australian tropical savannas: implications from the Kapalga fire experiment. *Austral Ecology* **30**, 155–167.
Signal summary	Unknown | Neutral | Loss response | Gain response
Nature of predicted change (if any)	Experimentally burnt catchments resulted in greater inputs of solar radiation, sediment and nutrients to streams compared to unburnt catchments and streams, the greater productivity enhancing macroinvertebrate taxon richness. This indicates a short-term gain or enhancement for biota; however, depletion of nutrients and increased erosion, could reverse those gains, i.e. longer-term loss. Riparian-dependent fish species would likely decline through either direct (food-source loss) or indirect (pool shading loss increasing temperatures and evaporation) mechanisms, although short-term gains could occur for a range of small-bodied fish species if macrophytes increased with increased light.

Feature assessed	Quality/sensitivity rating with reasoning (none, low, medium, high)	Score[A]
Quality of abiotic change characterisation	Medium	2
Quality of biotic response characterisation	Medium	2
Sensitivity in relation to the consideration of key ‘constrictions’	Low	1
Quality of consideration of the interaction with other threats	None	0

[A]Score: 0, none; 1, low; 2, medium; 3, high.

Total score	5
Percentage of the maximum possible (12)	42%

Fish species/taxa	Longitudinal arrays of habitats								Percentage of total lost if floodplain lost
	EMW	EPS	LSC	LBB	CW	UFB	MFB	LFB	
Melanotaenia nigrans	6.3	194.4	16.2	0.0	0.0	0.0	0.0	0.0	0
Pingalla midgleyi	0.0	32.8	0.0	0.1	0.0	0.0	0.0	0.0	0
Hephaestus fuliginosus	6.3	20.8	0.0	0.0	0.0	0.0	0.0	0.0	0
Syncomistes butleri	3.2	0.0	0.0	0.0	6.1	0.0	0.0	0.0	0
Neosiliurus hyrtlii	0.0	80.0	9.0	0.4	0.0	0.0	0.0	0.0	0
Craterocephalus marianae	431.6	0.0	896.4	0.3	0.0	0.0	0.0	0.0	0
Leiopotherapon unicolor	0.0	40.8	27.0	0.5	122.5	0.0	0.0	0.0	0
Glossogobius giurus	6.3	0.0	16.2	0.1	36.8	0.0	16.0	0.0	21.3
Strongylura krefftii	6.3	0.0	57.6	0.4	0.0	49.9	16.0	0.0	50.7
Toxotes chatareus	6.3	0.0	0.0	0.1	61.3	99.8	0.0	0.0	59.6
Scleropages jardinii	6.3	1.6	3.6	0.0	0.0	25.0	16.3	0.0	78.2
Lates calcarifer	0.0	0.0	0.0	0.0	6.1	0.0	31.7	0.0	83.8
Craterocephalus stercusmuscarum	85.1	4.0	72.0	0.1	330.8	1347.3	272.0	972.0	84
Neosilurus ater	28.4	2.4	0.0	0.0	275.6	474.1	208.5	972.0	84.4
Amniataba percoides	59.9	0.0	28.8	0.1	73.5	573.9	0.0	324.0	84.7
Mogurnda mogurnda	0.0	6.4	12.6	0.8	0.0	124.8	31.7	0.0	88.8
Nematalosa erebi	9.5	0.0	7.2	1.5	49.0	399.2	175.9	0.0	89.6
Melanotaenia splendida inornata	6.3	0.0	187.2	1.0	281.8	3992.0	833.2	648.0	92
Ambassis spp.	3.2	0.0	55.8	12.0	2431.6	37574.7	38312.2	53460.0	98.1
Neoarius leptaspis	10.5	0.0	0.0	0.5	79.6	1172.7	929.3	3240.0	98.3
Glossamia aprion	0.0	0.0	0.0	0.6	49.0	4141.7	192.2	324.0	99
Denariusa bandata	0.0	0.0	16.2	1.9	30.6	4366.3	672.7	0.0	99
Megalops cyprinoides	0.0	0.0	0.0	0.0	18.4	249.5	223.9	1944.0	99.2
Oxyeleotris spp.	0.0	0.0	0.0	0.9	0.0	49.9	0.0	972.0	99.9
Hypseleotris compressa	0.0	0.0	0.0	0.0	6.1	49.9	208.2	7776.0	99.9
Porochilus rendahli	0.0	0.0	0.0	1.2	0.0	25.0	31.7	2916.0	100
Pseudomugil tenellus	0.0	0.0	0.0	0.1	0.0	124.8	656.4	0.0	100
Ophisternon gutterale	0.0	0.0	0.0	0.0	0.0	25.0	0.0	0.0	100
Neoarius graeffei	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1296.0	100
Liza alata	0.0	0.0	0.0	0.0	0.0	74.9	0.0	648.0	100

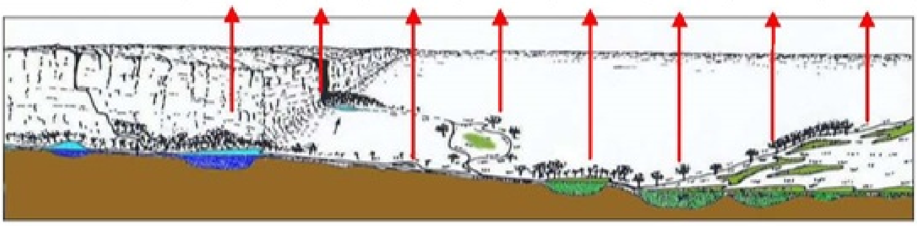

Fig. S1. Estimates of the percentage of late-dry season refuge habitat lost in Magela Creek for a range of fish species if all freshwater floodplain habitat is lost with future sea-level rise. The values given per habitat are the product of the late dry-season surface area of the habitats (see Table S1) and the mean late dry-season abundance of the species from Bishop *et al*. (1990). By including the species abundance in the calculation, the apparent relative importance of each habitat is factored in. Grey shading indicates species either known to breed in estuaries or frequently found therein. EMC, escarpment main-channel waterbodies; EPS, escarpment perennial springs; LSS, lowland sandy creeks; SLB, shallow lowland billabongs; CB, channel or corridor billabongs; UFB, upper floodplain billabongs; MFB, middle floodplain billabongs; LFB, lower floodplain billabongs.

References

AECOM (2010). 'Research of Key Knowledge Gaps in the Ecological Character of the Cobourg Peninsula Ramsar Site, Northern Territory: Aquatic Flora and Fauna and Physicochemical Assessment.' (Prepared for the Australian Government: Canberra, ACT, Australia.)

Andersen, A. N., Cook, G. D., Corbett, L. K., Douglas, M. M., Eager, R. W., Russell-Smith, J., Setterfield, S. A., Williams, R. J., and Woinarski, J. C. Z. (2005). Fire frequency and biodiversity conservation in Australian tropical savannas: implications from the Kapalga fire experiment. *Austral Ecology* **30**, 155–167. doi:10.1111/j.1442-9993.2005.01441.x

Bishop, K. A. (1987). Dynamics of the freshwater fish communities of the Alligator Rivers region, tropical northern Australia. Ph.D. Thesis, Macquarie University, Sydney, NSW, Australia.

Bishop, K. A. (2014). Opportunistic diver-based mid-dry-season recensusing of freshwater fish assemblages in two streams within Kakadu National Park: is there any evidence of impacts arising from cane toads? Report to Parks North (Kakadu National Park) and the Environmental Research Institute of the Supervising Scientist (Commonwealth Department of the Environment), November 2014, Supervising Scientist, Darwin.

Bishop, K. A., Allen, S. A., Pollard, D. A., and Cook, M. G. (1990). Ecological studies on the freshwater fishes of the Alligator Rivers region, Northern Territory. Research report 4, Vol. II. Synecological studies. Supervising Scientist for the Alligator Rivers region. Australian Government Publishing Service, Canberra, ACT, Australia.

Dostine, P. L., and Humphrey, C. L. (2012). 'Macroinvertebrate responses to reduced baseflow in a stream in the monsoonal tropics of northern Australia.' (National Water Commission: Canberra, ACT, Australia.)

Douglas, M. M., Bunn, S. E., Pidgeon, R. J. W., Davies, P. M., Barrow, P., O'Connor, R. A., and Winning, M. (2001). Weed management and the biodiversity and ecological processes of tropical wetlands. Draft final report to National Wetlands R & D Program Environment Australia & Land and Water Australia, Canberra, ACT, Australia.

ERA (2014). 'Ranger 3 Deeps Draft Environmental Impact Statement. Appendix 9. Solute Egress Modelling for ERA Ranger 3 Deeps Mine Closure.' (Energy Resources of Australia: Jabiru, NT, Australia.) Available at http://www.energyres.com.au/uploads/general/Appendix_09_Solute_Egress_Modelling_for_ERA_Ranger_3_Deeps_mine_closure.pdf [Verified 31 March 2016]

Finlayson, C. M., Lowry, J., Bellio, M. G., Nou, S., Pidgeon, R., Walden, D., Humphrey, C., and Fox, G. (2006). Biodiversity of the wetlands of the Kakadu region, northern Australia. *Aquatic Sciences* **68**, 374–399. doi:10.1007/s00027-006-0852-3

Humphrey, C. L., Bishop, K. A., and Brown, V. M. (1990). Use of biological monitoring in the assessment of effects of mining wastes on aquatic ecosystems of the Alligator Rivers region, tropical northern Australia. *Environmental Monitoring and Assessment* **14**, 139–181. doi:10.1007/BF00677914

Junk, W. J., Bayley, P. B., and Sparks, R. E. (1989). The flood pulse concept in river floodplain systems. *Canadian Special Publication of Fisheries and Aquatic Sciences* **106**, 110–127.

Nanson, G., East, T., Roberts, R., Clark, R., and Murray, A. (1990). Quaternary evolution and landform stability of Magela Creek catchment, near the Ranger uranium mine, northern Australia. Open rile record 63. Supervising Scientist for the Alligator Rivers region, Canberra, ACT, Australia.

National Environmental Research Program, Northern Hub (2015). Freshwater fishes of Kakadu National Park and the impact of sea level rise. Available at http://www.nespnorthern.edu.au/wp-content/uploads/2015/10/3.3_kakadu_freshwater_fishes_fact_sheet_web.pdf [Verified 11 December 2015].

Supervising Scientist (2005). Annual report 2004–2005. Supervising Scientist, Darwin, NT, Australia.

Supervising Scientist (2007). Annual report 2006–2007. Supervising Scientist, Darwin, NT, Australia.

Supervising Scientist (2013). Annual report 2012–2013. Supervising Scientist, Darwin, NT, Australia.

van Dam, R. A., Walden, D. J., and Begg, G. W. (2002). A preliminary risk assessment of cane toads in Kakadu National Park. Supervising Scientist report 164. Supervising Scientist, Darwin, NT, Australia.

Winderlich, S., and Woinarski, J. (Eds) (2014). Kakadu National Park landscape symposia series. Symposium 7: conservation of threatened species, 26–27 March 2013, Bowali Visitor Centre, Kakadu National Park. Internal report 623. Supervising Scientist, Darwin, NT, Australia.

Woinarski, J. C. Z., and Winderlich S. (2014). A strategy for the conservation of threatened species and threatened ecological communities in Kakadu National Park 2014–2024. Charles Darwin University, Darwin.