Proposed Katherine to Gove Gas Pipeline
Draft Environmental Impact Statement

Appendix E

Aquatic Fauna

PACIFIC **ALUMINIUM**

KGGP Aquatic Fauna Report Final

Pacific Aluminium

(Alcan Gove Pty Limited)

2013

www.ecoz.com.au

Document Control Record

Prepared by:	William Riddell
Position:	Environmental Scientist
Signed:	
Date:	11/02/2013

Approved by:	Jeff Richardson
Position:	Principal Consultant
Signed:	
Date:	11/02/2013

REVISION STATUS

Revision No.	Description of Revision	Date	Comment	Approved
A	Internal review	31/01/2013		JS
0	First Issue	08/02/2013		JR

Recipients are responsible for eliminating all superseded documents in their possession.

Document No:	EZ12048-C0301-EIA-R-0001

Catalogue Number	D000029404

EcOz Pty Ltd.
EcOz Environmental Services
ABN: 81 143 989 039
Winlow House, 3rd Floor
75 Woods Street
DARWIN NT 0800
PO Box 381, Darwin NT 0800

Telephone: +61 8 8981 1100
Facsimile: +61 8 8981 1102
Email: ecoz@ecoz.com.au
Internet: www.ecoz.com.au

APPROVED COMPANY
ISO 9001 Quality Management Systems
QMS Certification Services

Executive Summary

The proposed Katherine to Gove Gas Pipeline (KGGP) will transverse 600km from Katherine to the Pacific Aluminium refinery on the Gove Peninsula in north-eastern Arnhem Land. In 2004 EcOz Environmental Services was contracted by Alcan Engineering Pty Ltd to undertake biological studies of the aquatic fauna in the areas along the proposed route. That work was previously submitted as part of an Environmental Impact Statement (EIS) in 2004.

In 2012 Pacific Aluminium requested that the environmental impact of the pipeline be re-examined. This report presents the methods and results of the 2004 field survey and a desktop survey done in 2013. Furthermore, this report examines the project proposal and considers mitigation measures to reduce impacts on threatened species and their habitat.

Within this report, species are considered as being of conservation significance if they are so listed under relevant Northern Territory or federal legislation.

Aquatic fauna surveys were conducted at 17 sites that will be crossed by the proposed pipeline. Twelve of these were surveyed in 2003 and five were surveyed in 2004. The purpose of the surveys was to:

- Ascertain what species are present in the river and creek systems that are to be crossed;
- Gain a wider understanding of the aquatic environments to be crossed by the pipeline so that the potential impacts can be assessed and appropriate management practices can be implemented to mitigate potential impacts; and
- Identify any threatened aquatic species along the pipeline route that require special protection.

A desktop literature review and consultation was undertaken to identify the range of fish species, habitat types and environmental constraints present in the river and creek systems traversed by the proposed KGGP route. Data sources included the Northern Territory Fauna Atlas, the Fish Atlas of Northern Australia and the Atlas of Living Australia.

A total of 47 species from 23 families were recorded during field surveys. A further 31 species from seven families were identified from the desktop survey. Overall a total of 78 species comprising 30 families are known from the aquatic systems that will be crossed by the proposed KGGP pipeline.

The Freshwater Sawfish *Pristis microdon*, listed as Vulnerable under the *Environment Protection and Biodiversity Conservation Act 1999* (*EPBC Act*) and the *Territory Parks and Wildlife Conservation Act* (*TPWC Act*), has been recorded from the KGGP project area. The species has been recorded in the Wilton River, though it is likely to occur in a number of creeks and rivers crossed by the project. Merten's Water Monitor (*Varanus mertensi*), which is listed as Vulnerable under the *TPWC Act*, was recorded at Mainoru River and Barmguerikba and Wonga Creeks. Persistence of these threatened species is dependent on retaining the health and extent of habitat.

The Freshwater Sawfish *Pristis microdon* is a diadromous species that typically occurs in the tidal areas of the large tropical rivers where high sediment loads are present as a result of the large tidal movement (Allen *et al*. 2002). Sawfish are susceptible to habitat change owing to their dependence on freshwater environments. Major changes to rivers and lake beds can readily exceed the tolerances of the species. Other threatening processes include commercial net fisheries, recreational line/net fisheries, aquarium collectors and trophy hunters (Peverell et al. 2004).

Increased sediment loadings or changes to water chemistry as a result of the construction and operation of the KGGP have the potential to impact on this species. However, such impacts from the project are anticipated to be minor and within the species threshold for change. Barriers to movement such as stream crossings, poorly designed culverts as well as gross water quality issues such as low dissolved oxygen levels present a much greater risk to this threatened species.

The following table provides a summary of the potential impacts of the pipeline project on aquatic fauna and aquatic habitats as well as recommended management practices to minimise any potential impacts.

Action	Potential Impact	Mitigation recommendations
Clearing of riparian vegetation	• Increased erosion, scouring and changes to channel morphology. • Increase in nutrient loadings and light penetration. • Increased proliferation of weeds. • Loss of species dependent on riparian habitat for shelter, breeding or feeding.	• Minimise the circumstances where excavation is carried out in water bodies or within riparian zones. • Remove the absolute minimum vegetation required and carry out clearing activities as early in the dry season as possible. • Hand clearing of bank slopes. • Minimise clearing of the outer bank. • Adhere to guidelines for the control of erosion and sedimentation at construction sites and NT soil conservation guidelines. • Rehabilitation works should be completed as soon as practical after disturbance.
Manufacturing processes and human activities	Impacts on water quality may include: • Increased in-stream water salinity. • High water turbidity and siltation. • Localised heavy metal pollution. • Cold-water pollution. • Increased siltation may result in smothering of riffle areas, fish eggs and macrophytes.	• Design and implement a water monitoring program based on the ANZECC 2000 guidelines. • Design and construct fuel and chemical storage and wastewater treatment facilities to comply with Australian regulations and ensure they are located away from any watercourses. • Discourage personnel from using personal toiletries in watercourses.
Pipeline laying and river crossings	• Fish passage. • Debris may block waterways. • Excessive flow through the low-flow pipe. • Inadequate flow depth over causeways. • Waterfall effect caused by excessive fall in water levels across a causeway or pipe outlet. • Sediment run-off from approaching road crossings.	• Conduct in-steam work during the driest part of the year and complete as soon as possible. • Remove any temporary infrastructure as soon as practical after completing the works. • Restore the streambed as near as possible to the original condition. • Avoid crossing waterways at riffle zones or near sharp bends or sections of unstable channel. • Avoid crossing over meandering waterways. • Avoid works that may change the frequency or spacing of an existing pool-riffle system.

		• Avoid disturbances to sections of a channel that has been identified as an area of high conservation value or where threatened species occur. • Avoid removal of essential shade trees. • Conduct a site assessment at each proposed crossing to decide on the appropriate crossing type. • Follow the recommended construction practices for the chosen crossing types.
Hydrostatic testing of the pipeline	• Translocation of fish species or other aquatic organisms. • Introduction of diseased organisms • Offence under the *Fisheries Act* if water is translocated from one waterbody to another.	• Dispose of wastewater from hydrostatic testing in accordance with regulatory and Traditional Owner requirements. • Surface water should be sterilised before release into another catchment. It should not be released into another watercourse.

Table of Contents

Tables

Figures

Appendices

1 Introduction

The proposed Katherine to Gove Gas Pipeline (KGGP) will transverse 600km from Katherine to the Pacific Aluminium refinery on the Gove Peninsula in north-eastern Arnhem Land. In 2004 EcOz Environmental Services was contracted by Alcan Engineering Pty. Ltd. to undertake biological studies of the aquatic fauna in the areas along the proposed route. That work was previously submitted as part of an EIS process in 2004.

In 2012 Pacific Aluminium requested that the environmental impact of the pipeline be re-examined. This report presents the methods and results of the 2004 field survey and a desktop survey done in 2013. Furthermore, this report examines the project proposal and considers mitigation measures to reduce impacts on threatened species and their habitat.

The assessment of aquatic fauna presented in this report is primarily concerned with documenting baseline information on the fish species that occur in the rivers and waterways that will be traversed by the proposed KGGP route, and assessing the potential impacts of disturbance of these river and creek systems as a result of clearing riparian vegetation and tunnelling under the waterways to construct the pipeline.

The aquatic fauna study was undertaken to satisfy the requirements of the Guidelines and more specifically to provide baseline information to guide an assessment of the potential impacts of the proposal and the development of appropriate management strategies for the project. This report documents the findings of field surveys, consultations with traditional owners and reviews of existing information and databases, and identifies the potential effects of the KGGP proposal on aquatic vegetation. Two freshwater fish specialists, Dave Wilson and Steve Brooks, undertook the field surveys and prepared this report.

2 Statutory Obligations

The KGGP proposal requires approval under the *Environmental Assessment Act* (NT) and *Environment Protection and Biodiversity Conservation* (EPBC) *Act 1999* (Cwlth). As part of this process the Northern Territory and Commonwealth Governments will set conditions of approval relating to the management of potential environmental impacts of the proposal. These conditions will be included in permit, lease or license conditions and in relevant management procedures (e.g. Environmental Management Plans) for the construction and operation of the project.

Other Northern Territory and Commonwealth legislation establishes statutory obligations for the protection of waterways and Threatened aquatic fauna. The implications of these Acts for the KGGP proposal are briefly discussed below.

The proposal has been declared a controlled action under the *EPBC Act* because it was considered likely to have significant impacts on listed threatened species and communities and listed migratory species. The proposal has also been declared as requiring assessment under the Northern Territory EAA. The *Guidelines for Preparation of an Environmental Impact Statement- Katherine to Gove Gas Pipeline* (NT Environment Protection Authority (EPA), January 2013) detail the specific requirements of the EIS document that is to be prepared for the KGGP proposal in accordance with Clause 8 of the Environmental Assessment Administrative Procedures of the EAA and Part 3 of the *EPBC Act*.

2.1 Territory Parks and Wildlife Conservation Act

Threatened wildlife are automatically given a protected wildlife status under the *Territory Parks and Wildlife Conservation* (TPWC) *Act*. Threatened species include those listed as either extinct in the wild, critically endangered, endangered or vulnerable. The *TPWC Act* requires a person to apply for a permit to take or interfere with these species.

2.2 Environment Protection and Biodiversity Conservation Act

The Australian Government mechanism for national environment protection and biodiversity conservation is the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). The *EPBC Act* provides for:

- identification and listing of Threatened Species and Threatened Ecological Communities;
- development of Recovery Plans for listed species and ecological communities;
- recognition of Key Threatening Processes; and where appropriate
- reducing these processes through Threat Abatement Plans.

The *EPBC Act* establishes lists of nationally threatened species and ecological communities which are Matters of National Environmental Significance protected by the Act.

2.3 Water Act

The *Water Act* (NT) regulates the restriction of water flows within a waterway. The provisions of the NT Water Act 2004 outline offences related to impeding water flows in a waterway. Persons are not permitted to obstruct the flow of water in a water way, take or use surface water except in accordance with a licence issued under the Act. The *Water Act* also provides for the investigation, allocation, use, control, protection, management and administration of water resources, and for related purposes.

If the construction of the KGGP uses surface waters for road dust control or testing pipe pressures it will invoke the provisions of the *Water Act*.

2.4 Fisheries Act

Water pumped from one catchment may be released in another, thus inadvertently translocating organisms from one location to another. A translocation of Aquatic Life will be an offence against the provisions of the *Fisheries Act* (NT).

3 Methodology

There are two approaches to understanding the aquatic flora and fauna along the pipeline route: desktop survey and field survey. The methodologies used in the assessment of aquatic fauna for the KGGP proposal were developed with the aim of adequately identifying and addressing the range of potential environmental issues associated with the proposal, and collating sufficient information to inform an assessment that satisfies the requirements of the EIS Guidelines. Areas of potential interest, namely those waterways where the fish fauna have not previously been surveyed and where listed Threatened species may occur, were identified in consultation with the NT Museum. Field survey methodologies were developed to focus on establishing a baseline knowledge of the fish fauna that occur in these waterways. The survey methodologies were developed by the Curator of Fishes at the NT Museum and were provided to the NT Office of Environment and Heritage (now the NT Environment Protection Authority (EPA)) for review and comment prior to field survey work being conducted. The key data sources utilised in conducting desktop reviews, the methodologies employed in the conduct of field surveys and the limitations of our approach are discussed below.

Taxonomy follows Last and Stevens (1994) for shark and ray species and Allen *et al*. (2002) was used for all other freshwater fish species.

3.1 Desktop Survey

A desktop literature review and consultation was undertaken to identify the range of fish species, habitat types and environmental constraints present in the river and creek systems traversed by the proposed KGGP route.

The data sources reviewed were:

- EPBC Act Protected Matters Search Tool (accessed January 2013) (http://www.environment.gov.au/epbc/pmst/index.html). This database provides a list of species under the provisions of the *EPBC Act* that occur, or are likely to occur, in the project area
- Northern Territory Fauna Atlas, managed by Department of Land and Resource Management (as at January 2013)
- Atlas of Living Australia (http://www.ala.org.au) (accessed January 2013)
- Fish Atlas of Northern Australia (accessed January 2013)(http://www.jcu.edu.au/archive/actfr_old_Projects/FishAtlas/Index.htm)
- Search of the Museums and Art Gallery Database and review of published and unpublished literature including other surveys and field work within the rivers of the Northern Territory.
- Search of the records of the Australian and New Guinea Fishes Association.

Literature to support regional species assemblage included: Midgley (1980) and Midgley (1983).

Results of desktop searches of the Atlas of Living Australia and Fish Atlas of Northern Australia databases are provided in Appendix 1.

3.2 Determining Likelihood of Freshwater Sawfish *Pristis microdon* Occurrence

A literature review was used to establish criteria to determine likelihood of presence of Freshwater Sawfish at waterway crossings along the KGGP. These criteria are:

- Estuarine influence. A crossing point must be at, or connected to, an estuary for Freshwater Sawfish to occur
- Presence of floodplain habitat surrounding the crossing point. This is good refuge habitat for juvenile and sub-adult sawfish
- Presence of billabongs upstream of crossing point providing suitable habitat for juveniles and sub-adults
- Volume of water at the crossing. Perennial freshwater rivers and creeks are more likely to hold Freshwater Sawfish.

Analysis of the KGGP route (Pipeline Alignment Division 5) on Google Earth revealed that a total of 19 points occur where potential Freshwater Sawfish habitat is traversed. At each crossing point the criteria were used to determine the likelihood of Freshwater Sawfish occurrence.

The likelihood of Freshwater Sawfish occurring along the KGGP project area is discussed further in Section 5.2.1.

3.3 Field Surveys

Surveys were conducted at 17 sites that are crossed by the proposed pipeline route (Table 1). Twelve sites were surveyed in October and November 2003 whilst the remaining five sites were surveyed, once accessible after the wet season, in June 2004.

The purpose of the surveys was to:

- Ascertain what species are present in the river and creek systems that are to be crossed
- Gain a wider understanding of the aquatic environments to be crossed by the pipeline so that the potential impacts can be assessed and appropriate management practices can be implemented to mitigate potential impacts
- Identify any threatened aquatic species along the pipeline route that require special protection.

Table 1: Aquatic fauna survey sites along the KGGP route

Waterway	General Description of survey site	Latitude	Longitude
Mainoru River	Middle reach river with long quiet tree lined pools connected by short runs of faster water.	S13.95133	E133.96333
Krabakuk	Middle reaches of small seasonal creek, comprised of small drying waterholes. Rock and clay substrate. Tributary of Mainoru R.	S14.06662	E134.05246
Wilton River	Middle reach river with long wide pools connected by short sets of rapids.	S13.75333	E134.46000
Jasper Creek	Lower reaches, small pools connected by long slow runs, silt and boulder substrate.	S13.88600	E134.46150
Goyder River	Middle reach river with long wide tree lined pools connected by short sets of rapids.	S13.02800	E134.97667
Rocky Bottom Creek	Fast flowing stream with rock and sand substrate.	S12.90083	E135.01533
Barmgueikba Creek	A small fast flowing creek with some still pools between runs. Sandy substrate with some boulders.	S14.24900	E133.52767

Waterway	General Description of survey site	Latitude	Longitude
Chambers River	Upper reaches of river surrounded with non-permanent waterholes. River contains small non-permanent waterholes. Muddy substrate with discoloured very turbid water. Flat plains with open woodland.	S14.53867	E133.31883
Dook Creek	Small stream dropping through low rock escarpment area onto flat plain. Boulders and sand substrate.	S14.47767	E132.97683
Maiwok Creek	Non-flowing small sandy creek with high banks flowing in a low hilly area. Flat black soil plains adjacent the creek.	S14.27817	E133.68400
King River	Long, wide deep pools with small fast runs at the ends. A substratum of sand and mud with the occasional boulder. Surrounded by low hills and open woodland.	S14.51017	E132.63500
Giddy River	A small river flowing across a sand substrate, a long deep pool at sample site but mostly narrow sandy river with a swamp upstream from site and another downstream from sample site.	S12.36330	E136.70960
Wonga Creek	Headwaters stream comprising of several large waterholes with fast water running over rock and waterfall approx. 3 metres high. Sloping ground with open woodland.	S12.45295	E136.57870
Cato River	Low hilly area with open woodland areas of monsoon forest along river at sample site. Long wide deep pools with wide shallow slow flowing areas between sandy substrate. Small swampy areas in the monsoon forest near river.	S12.41967	E136.38380
Richard River	A small upland stream with occasional long shallow pools with small runs and riffles. Running through open woodland with grass and sandpalm understorey plants.	S12.70038	E136.09697
Habgood River	Long deep pools with a sandy substrate punctuated by rocky barriers creating sets of rapids; the river flows through open woodland in sandy country.	S12.52405	E135.89987
Buckingham River	Short deep pools with an earthen substrate, plant-lined trickle at ends of the pools. The river flows through open woodland in low hilly sandy country.	S12.68638	E135.69038

3.3.1. Site Selection

The waterways surveyed were selected following consultations with the Curator of Fishes at the NT Museum. Once in the field, local conditions and accessibility determined the actual site location on each of the waterways. Consultation with traditional owners or their representative was required at each site to ensure that no culturally sensitive areas were entered or disturbed during the surveys.

Sample sites did not necessarily correspond exactly with the proposed pipeline crossings. At times larger water bodies near the proposed crossing of the pipeline were selected if there were no major barriers to fish movement between the sample site and the crossing. These sites were identified as areas likely to contain the most number of fish species as well as the species of interest such as the Freshwater Sawfish and Freshwater Whipray.

3.3.2. Survey Techniques

Survey site localities were recorded using a hand-held GPS. Water temperature, dissolved oxygen and conductivity were recorded by a YSI model 30 system, while pH was recorded using a TPS FL90 water quality meter as well as reagent test kits and alkalinity by an Aquasonic test kit. The maximum water depth was recorded for each site. Turbidity was recorded using a Secchi disk, or by observation. Each site was described with the nature of watercourse, substrate, banks and aquatic vegetation. Also, a photograph of each sampling site and a brief description of surrounding country was recorded (Appendix 1).

Sampling was undertaken by two people using a range of techniques which included: multi-panel gill-nets, fine-mesh seine, scoop-nets or push-nets, hook and line, dip-net and torch at night, and sight observations from the bank or by snorkelling. Each site was sampled for a day and night for accurate census of aquatic fauna, unless the waterbody was small and clearly not worthy of intensive sampling (e.g. a shallow creek). The existence of estuarine crocodiles in some waterbodies prevented snorkelling methods being used.

The two multi-panel gillnets are each 35 m long, with a drop of 2 m, and seven 5 m long panels each of a different mesh size: 26, 44, 58, 76, 100, 126, and 150 millimetres, knot to knot. Gillnets are considered to be the most efficient method for surveying for sawfish according to *Survey Guidelines for Australia's Threatened Fish* (SEWPaC 2011). The differing mesh sizes allowed sampling of a wide range of fish species and sizes (e.g. from small rainbow fish to adult barramundi). Wherever possible, the nets were set so that one was at a right angle to the bank, and one was parallel to the bank to capture fishes travelling down the centre of the waterbody as well as those moving along the bank close to shelter. The nets were tied or anchored and buoyed (working from a small dinghy) so that they remained stationary, and were left for approximately an hour in the afternoon, then re-set for another hour in the evening, with sunset occurring during the latter set, where possible. Gillnets were normally set for one hour, to prevent drowning any crocodiles and to minimise fish mortalities. The pattern and timing of deployment of the nets depended upon the topology of the water-body. Fish captured were identified, counted and released, with voucher material of each species being retained when possible. A permit from the Department of Business, Industry and Resource Development Fisheries Division (now called Department of Primary Industry and Fisheries) was obtained to operate nets to collect samples (licence number 17901).

Sampling with push scoops was undertaken at each site through the in-stream habitat such as microphytes and undercut banks. Additional sampling with scoop nets and small aquarium dipnets was carried out at each locality at night. This enabled observation and capture of nocturnally active fish species such as eel-tailed catfish, and made capture of many other species less difficult.

Voucher specimens were euthanased with an overdose of anaesthetic then placed in a drum with formalin or 100% ethanol, preserved, labelled and deposited to the Museum and Art Gallery of the Northern Territory, Darwin (MAGNT), where they were sorted and their identification confirmed. They were then deposited as vouchers in the MAGNT reference collection. Specimens deposited in the collection will be registered, and habitat and physical data included in the MAGNT database.

Informal interviews with Traditional Owners and Pastoralists were conducted to ascertain their knowledge of species of fish that were present in the various rivers sampled. Field guides were provided to Traditional Owners to assist in the recognition of various species. The information gained from these interviews was used to supplement the information collected during the short survey periods and to identify species that are likely to occur in each waterway.

3.3.3. Assessment of Conservation Significance

The conservation significance of aquatic fauna was assessed with reference to the following:

- Species classified as Threatened and\or protected in accordance with the *Territory Parks and Wildlife Conservation Act 2000.*
- Species classified as threatened in accordance with the *Environment Protection and Biodiversity Conservation Act 1999.*
- Near-threatened and regionally endemic species.
- Habitats of threatened species and habitats with outstanding biodiversity values.

The conservation significance of aquatic fauna in the waterways crossed by the KGGP route is discussed in Section 5.

4 Results

The following summarises the results of both the field and desktop surveys.

4.1 Fishes

A total of 47 species from 23 families were recorded during field surveys. A further 31 species from seven families were identified from the desktop survey. Overall a total of 78 species comprising 30 families are known from the aquatic systems that will be crossed by the proposed KGGP pipeline (Table 2).

The family Terapontidae (grunters) is represented by more species (nine) than any other recorded, closely followed by the gudgeons (family Eleotridae) and Rainbowfish (Melanotaeniidae) represented by seven species. The fork tailed catfish (family Ariidae) are represented by six species.

Species diversity is dependent on a great range of factors including distance from the sea, size of river and catchment, permanency, habitat, water quality, presence of barriers to fish movement and season. Bishop and Forbes (1991) suggested that species diversity in monsoonal rivers varies dramatically over time, with species diversity in any one habitat decreasing as the dry season progresses. Given that these surveys were based on a single sampling event at a single site it is unlikely that all species likely to be present will be recorded. Herbert *et al*. (1995) considered that it would be unrealistic to expect that any survey group would catch all species of fish in a river system, as species composition varies diurnally and seasonally.

The waterway with the lowest number of species was the seasonal Krabakuk Creek, a tributary of the Mainoru River, where only two species of fish were identified. The highest number of species recorded during the 2004 survey occurred on the Cato River with 24 species followed by 20 species on the Goyder and Habgood Rivers. Though in stating this we must be careful to take into consideration the greater effort expended on both the Goyder and the Mainoru Rivers. Several days were spent at both of these sites awaiting the necessary approvals to continue.

The survey was notable due to the discovery of species previously unrecorded from the Northern Territory, significant range extensions for several species and other yet undescribed species. The Aru gudgeon *Oxyeleotris arvensis* located in the Cato River was a range extension known previously only from Aru Island near Southern New Guinea and the eastern side of the tip of Cape York, Queensland. Two further species of gobies were collected in the Cato River that were previously unrecorded from the region. One was identified as *Glossogobius concavifrons* by MAGNT (Helen Larson pers. comm.). This species has previously been known from the Fly-Strickland system of Papua New Guinea and the northern region of Cape York Peninsula (Allen 1991). The second species of goby is an undescribed species of *Glossogobius* known commonly as Munro's Goby or *Glossogobius sp 2* (Allen *et al*. 2002). The observation of the Freshwater Whipray *Himantura chaophraya,* also in the Cato River, represents the first record of this species in Arnhem Land. This species was previously only recorded from South Alligator and Daly Rivers in the NT (Midgley 1980; Allen *et al.* 2002). Further range extensions were recorded for the Exquisite Rainbowfish *Melanotaenia exquisita* in Dook Creek, and Butler's Grunter *Syncomistes butleri* in the Goyder River and Rocky Bottom Creek. This is discussed further along with species of significance in Section 5.2.

Table 2: Fish Species in Catchments Traversed by the Proposed KGGP Route

Scientific Name	Common Name	Roper River	Koolatong River	Daly /Katherine Rivers	Mainoru River	Krabakuk Creek	Jasper Creek	Wilton River	Goyder River	Rock Bottom Creek	Dook Creek	Maiwok Creek	Barmguerikba Ck	Chambers River	King River	Giddy River	Wonga Creek	Cato River	Richard River	Habgood River	Buckingham River
Ambassis agrammus	Sailfin Glassfish			#				#								X			X		#
Ambassis macleayi	Reticulated Glassfish			#	X		X		X	X	X		X	X				X		X	X
Ambassis muelleri	Western Glassfish			#	X		X	X		X			X	X							
Ambassis sp. 1	Glassfish	#	#	#					#												#
Amniataba percoides	Barred Grunter	#	#	#	X		X	X	X	X	X	X	X			#		X		X	#
Anodontiglanis dahli	Toothless Catfish	#		#	X			#			X			X							
Arius berneyi	Berney's Catfish	#						#	X		#										
Arius graeffei	Lesser Salmon Catfish	#		#				#													
Arius leptaspis	Salmon Catfish	#		#	X			X	X	X								X			#
Arius midgleyi	Shovel-nose Catfish	#		#							X			X	X						
Arius sp.	Fork-tailed Catfish			#																	
Arrhamphus sclerolepis	Snub-nosed Garfish	#																			
Aseraggodes klunzingeri	Tailed Sole			#																	
Brachirus selheimi	Freshwater Sole	#		#			X		#												#
Caranx sexfasciatus	Bigeye Trevally																				#
Carcharhinus leucas	Bull Shark			#	*			#													
Carcharhinus sp.	Whaler Shark	#		#																	
Chanos chanos	Milk Fish	#																			
Cinetodus froggatti	Small-mouthed Catfish										#										
Craterocephalus marianae	Mariana's Hardyhead			#																	

		Roper River	Koolatong River	Daly /Katherine Rivers	Mainoru River	Krabakuk Creek	Jasper Creek	Wilton River	Goyder River	Rock Bottom Creek	Dook Creek	Maiwok Creek	Barmguerikba Ck	Chambers River	King River	Giddy River	Wonga Creek	Cato River	Richard River	Habgood River	Buckingham River
Scientific Name	**Common Name**																				
Craterocephalus stercusmuscarum	Fly-specked Hardyhead			#	X		X	X	X		X							X		X	X
Craterocephalus stramineus	Blackmast			#																	
Dasyatis sp.	Stingray			#																	
Denariusa bandata	Penny Fish		#	#					#									X			#
Gerres filamentosus	Whipfin Silverbiddy	#	#														X				#
Glossamia aprion	Mouth Almighty	#	#	#	X		X	X	X	X	#	X	X	X	X	X	X	X		X	X
Glossogobius aureus	Golden Goby			#				#													
Glossogobius celebius	False Celebes Goby																				#
Glossogobius giurus	Flathead Goby	#	#	#	X			#	X	X	#				X						
Glossogobius sp. 1	Munro’s Goby																	X			
Glossogobius concavifrons	Concave Goby																	X			#
Hephaestus carbo	Coal Grunter		#						X	X						X	X	X		X	#
Hephaestus fuliginosus	Sooty Grunter	#	#	#	X		X	#	X		X	X	X		X						#
Hephaestus jenkinsi	Western Sooty Grunter			#																	
Himantura chaophraya	Freshwater Whipray			#														X			#
Hypseleotris compressa	Carp Gudgeon			#												X					#
Hypseleotris sp.	Katherine Gudgeon			#																	
Iriatherina werneri	Threadfin Rainbowfish								#												
Kurtus gulliveri	Nursery Fish			#																	
Lates calcarifer	Barramundi	#	#	#	X		X	X	X		X		X		X	X	X	X		X	#
Leiopotherapon unicolor	Spangled Grunter	#	#	#	X		X	#	X	X	X	X	X	X	X	#	X		X	X	X
Liza alata	Diamond Mullet			#																	
Lutjanus argentimaculatus	Mangrove Jack															X					#

Scientific Name	Common Name	Roper River	Koolatong River	Daly /Katherine Rivers	Mainoru River	Krabakuk Creek	Jasper Creek	Wilton River	Goyder River	Rock Bottom Creek	Dook Creek	Maiwok Creek	Barmguerikba Ck	Chambers River	King River	Giddy River	Wonga Creek	Cato River	Richard River	Habgood River	Buckingham River
Megalops cyprinoides	Indo-pacific Tarpon	#	#	#					X				X	X		X	X	X		X	X
Melanotaenia australis	Western Rainbowfish		#	#											X						#
Melanotaenia exquisita	Exquisite Rainbowfish	#		#							X										#
Melanotaenia nigrans	Black-banded Rainbowfish			#					#							X		X	X	X	X
Melanotaenia trifasciata	Banded Rainbowfish		#	#					X							X	X	X	X	X	
Melanotaenia solata	Northern Rainbowfish		#						#												#
Melanotaenia splendida australis	Chequered Rainbowfish	#	#	#	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X
Mogurnda mogurnda	Purple Spotted Gudgeon	#	#	#	X	X	X	#	#		X	X	X			#	X	X	X	X	X
Nematalosa erebi	Bony Bream	#	#	#	X			X	X		#		X	X	X			X		X	#
Neosilurus ater	Black Catfish	#	#	#	X				X	X	X					X	X	X		X	X
Neosilurus hyrtlii	Hyrtles Catfish	#	#	#	X			#	#		#	X	X	X	X		X		X	X	#
Ophisternon gutterale	Swamp eel	#		#																	
Oxyeleotris arvensis	Aru Gudgeon																	X			#
Oxyeleotris lineolate	Sleepy Cod	#		#	X		X	X	#		#										
Oxyeleotris nullipora	Poreless Gudgeon								#							X		X			X
Oxyeleotris selheimi	Giant Gudgeon	#	#	#					#					X							#
Pingalla midgleyi	Midgley's Grunter			#																	
Porochilus obbesi	Obbes Catfish			#																	
Porochilus rendahli	Rendahl's Catfish	#		#					#					X							X
Pristis microdon	Freshwater Sawfish	#		#	*			#													
Pseudomugil gertrudae	Spotted blue-eye			#					#							X		X		X	#

Scientific Name	Common Name	Roper River	Koolatong River	Daly /Katherine Rivers	Mainoru River	Krabakuk Creek	Jasper Creek	Wilton River	Goyder River	Rock Bottom Creek	Dook Creek	Maiwok Creek	Barmguerikba Ck	Chambers River	King River	Giddy River	Wonga Creek	Cato River	Richard River	Habgood River	Buckingham River
Pseudomugil tenellus	Delicate Blue-eye			#																	
Redigobius chryosoma	Spotfin Goby																				#
Scatophagus argus	Spotted Scat			#																X	#
Scleropages jardinii	Gulf Saratoga	#	#		X				X									X		X	#
Scortum barcoo	Barcoo Grunter							#													
Scortum ogilbyi	Gulf Grunter	#			X								X	X							
Selenotoca multifasciata	Striped Scat	#		#																X	#
Strongylura krefftii	Freshwater Longtom	#	#	#	X		X	X	X		#			X				X		X	#
Syncomistes butleri	Butlers Grunter			#					X	X					X						
Thryssa scratchleyi	Freshwater Anchovy	#						X													
Toxotes chatareus	Common Archerfish	#	#	#	X		X	X	X	X	X	X	X	X	X			X			
Toxotes jaculatrix	Banded Archerfish																				#
Toxotes lorentzi	Primitive Archerfish			#																	
Zenarchopterus sp	Garfish	#																			
Total #		36	23	56	0	0	0	13	13	0	8	0	0	0	0	3	0	0	0	0	21
Total X		0	0	0	21	2	14	12	20	12	13	8	14	15	11	13	11	24	7	20	11
Total ALL		36	23	56	21	2	14	25	33	12	21	8	14	15	11	16	11	24	7	20	32

X Species recorded during 2004 field surveys

Species only recorded from river system in Museum, ALA or Fish Atlas of the Northern Territory records

* Landowners indicated presence in waterway but not recorded in current or previous surveys

4.2 Other Aquatic Fauna Species

4.2.1. Crustaceans

Five species of crustacean were recorded during the surveys (Table 3). Two species of *Macrobrachium* were not identified to species level during the survey. Voucher specimens for these were lodged with the Museum and Art Gallery of the NT for identification. These specimens remain unidentified.

Table 3: Crustacean species identified during the field survey

Common Name	Scientific Name	Locations Identified
Glass Shrimp	*Caradina sp*	Cato River
Redclaw	*Cherax quadricarinatus*	Mainoru River Wilton River Goyder River Dook Creek
Cherabin	*Macrobrachium rosenbergii*	Mainoru River Dook Creek King River
Freshwater prawn	*Macrobrachium sp1*	Krabakuk Creek Goyder River Dook Creek Maiwok Creek Chambers River
Freshwater prawn	*Macrobrachium sp2*	Wonga Creek

4.2.2. Amphibians

The aquatic survey encountered eight species of amphibians (Table 4) none of which are listed under NT or Commonwealth legislation. At the time of the survey the recording of *Sylvirana daemeli* at Cato River location represented a range extension for the species. This species is listed as Near-threatened under the *TPWC Act*.

The introduced Cane Toad *Bufo marinus* was also identified at various locations and this is discussed further in 4.3.

Table 4: Amphibian species recorded during the field survey

Common Name	Scientific Name	Locations Identified
Northern Dwarf Tree Frog	*Litoria bicolor*	Dook Creek Giddy River
Rockhole Frog	*L. meiriana*	Dook Creek
Rocket Frog	*L. nasuta*	Wonga Creek Cato River Richard River Habgood River
Red Tree-frog (Desert Tree Frog)	*L. rubella*	Chambers River (sugar bag waterhole)
Wotjulum Frog	*L. wotjulumensis*	Dook Creek Giddy River Wonga Creek Cato River Richard River Habgood River Buckingham River
Unidentified sp.	*Crinia sp.*	Cato River Goyder River
Wood Frog	*Sylvirana daemeli*	Giddy and Cato Rivers

4.2.3. Reptiles

Twelve species of reptiles were identified during the field surveys (Table 5). The Saltwater Crocodile *Crocodylus porosus*, which was spotted in the Habgood River and is likely to occur in all of the major waterways crossed by the pipeline route, is a listed migratory species and is protected under the *EPBC Act 1999*.

Merten's Water Monitor (*Varanus mertensi*), which is listed as Vulnerable under the *TPWC Act*, was recorded at Mainoru River and Barmguerikba and Wonga Creeks. This species occurs across most of the Top End and Gulf region and is seldom seen far from water. The species has experienced a decline in population since the field survey was conducted, largely due to the arrival and dispersal of Cane Toads *Bufo marinus* throughout the Top End (Griffiths & McKay 2005; Doody *et al.* 2009). The species is susceptible to Cane Toad toxin and monitors often die after eating a Cane Toad (Smith and Phillips 2006).

Table 5: Reptile species identified during the field survey

Common Name	Scientific Name	Locations Identified
Arafura File Snake	*Acrochordus arafurae*	Dook Creek
Brown Tree Snake	*Boiga irregularis*	Dook Creek
Skink sp.	*Carlia sp.*	Richard River
Freshwater Crocodile	*Crocodylus johnstoni*	Barmguerikba Creek Wilton River Moil River
Saltwater Crocodile	*C. porosus*	Habgood River Cato River
Common Tree Snake	*Dendrelaphis punctulata*	Richard River
Two-lined Dragon	*Diporiphora bilineata*	Buckingham River
Northern Snapping Turtle	*Elseya dentata*	Mainoru River
Yellow-faced Turtle	*Emydura sp.*	Habgood River
Northern Red-faced Turtle	*Emydura victoriae*	Chambers River (sugar bag waterhole)
Gilbert's Dragon	*Lophognathus gilberti*	Maiwok Creek Chambers River (sugar bag waterhole)
Merten's Water Monitor	*Varanus mertensi*	Mainoru River Barmguerikba Creek Wonga Creek

4.3 Introduced species

No introduced species of fish were found during the field surveys. No record of introduced fishes could be found at or from any of the study sites. There is a population of feral Guppies *Poecilia reticulata* and feral Platys *Xiphophorus variatus* (Axelrod *et al*. 1985) in the town billabong at Nhulunbuy which have been there since at least 1988 (Dave Wilson, personal observation).

The Cane Toad *Bufo marinus* was common at all the study sites from east of the King River to the Giddy River. On the sample sites at Maiwok Creek there were several dead toads in various states of decay. Cane Toad tadpoles were observed in a small swamp on the side of the Road a few kilometres east of the Mainoru River. According to the Mainoru Station owner, toads have been at that location since approximately 1999.

4.4 Aquatic flora

The ability of a waterway to support submerged aquatic plants depends on all the physical and biochemical properties that are necessary for plant growth being present under water. Some of the limiting constraints to submerged plant growth are physical such as low light caused by turbidity or thick streamside plant cover. Other limiting factors to plant growth can be chemical such as low amounts of carbon. The presence of inorganic carbon in the form of free dissolved carbon dioxide, carbonic acid, bicarbonates and carbonates influences submerged plant growth. Some species of local native aquatic plants such as Water Thyme *Hydrilla verticillata* have the ability to alter water quality by breaking the chemical bonds in calcium carbonate. This then drives the pH very high giving the species an advantage over other species such as *Eriocaulon setaceum* that do not do well in water with a high pH (Cronk and Fennessy 2001; Sainty and Jacobs 1988; Boyd 1995).

Plant communities in submerged environments are divided into two basic categories, those that live in waters with a high amount of dissolved solids, such as the Daly and Mainoru Rivers, and those that live in waters with very small amounts of dissolved solids. The majority of the waters to be crossed by the proposed pipeline route fall into this latter category.

Some species of submerged aquatic plants are difficult to identify without the presence of flowers and seed and have only been identified to a Genus level (Table 6).

Table 6: Aquatic flora recorded during the field survey

Waterway	Aquatic flora species identified
Mainoru River	*Chara sp* (algae), *Nitella sp* (algae), *Vallisneria nana* (ribbonweed), *Hydrilla verticillata* (water thyme, hydrilla), *Ottelia alismoides, Nymphaea violacea* (Blue flowering native water lily), *Triglochin sp* (water ribbons), *Schoenoplectus sp, Nelsonia campestris, Ceratopteris thalictroides* (native water sprite)
Wilton River	No submerged plants at sample site
Goyder River	*Aponogeton vanbruggenii* (NT lace plant)
Rocky Bottom Creek	*Vallisneria nana* (ribbonweed), *Nelsonia campestris, Limnophila brownii, Hygrophila angustifolia, Chara sp* (algae), Unidentified filament algae
Barmgueikba Creek	*Rotala occultiflora, Najas sp, Blyxa aubertii, Nymphaea violacea* (Blue flowering native water lily), *Limnophila aromatica, Hygrophila angustifolia*
Chambers River	*Nymphaea violacea* (Blue flowering native water lily), *Marsilea drummondii* (rainbow nardoo), *Najas sp*
Dook Creek	*Nymphaea violacea* (blue flowering native water lily), *Nymphoides indica* (snowflake lily), *Limnophila brownii, Rotala occultiflora*
Maiwok Creek	No submerged aquatic plants at sample site
King River	*Nymphoides spongiosa, Microcarpaea minima, Limnophila brownii, Staurogyne leptocaulis, Vallisneria nana*
Giddy River	*Blyxa aubertii, Limnophila fragrans, Chara sp.* (algae), *Eriocaulon setaceum, Utricularia fulva, Hygrophila angustifolia*

Waterway	Aquatic flora species identified
Wonga Creek	*Eriocaulon setaceum, Eriocaulon willdenovianum* *Chara sp* (algae) *Limnophila fragrans*
Cato River	*Nymphaea violacea* (blue flowering native water lily), *Limnophila aromatica, Eriocaulon setaceum, Eriocaulon willdenovianum, Blyxa aubertii, Limnophila fragrans*
Richard River	*Isachne sp, Microcarpaea minima, Xyris indica, Triglochin sp, Blyxa aubertii, Eriocaulon setaceum, Eriocaulon sp, Nelsonia campestris, Goodenia sp*
Habgood River	*Aponogeton sp, Limnophila chinensis, Limnophila aromatica, Isachne confusa, Utricularia fulva, Utricularia gibba, Utricularia australis, Hanguana malayana, Najas sp, Nymphoides sp* (yellow flower), *Nymphoides indica* (snowflake lily)
Buckingham River	*Nymphaea violacea* (Blue flowering native water lily), *Limnophila chinensis, Eriocaulon setaceum, Hygrophila angustifolia, Utricularia fulva, Utricularia sp, Triglochin sp, Eriocaulon sp* (small rosette growing submerse)

4.5 Water Quality

The physical and chemical qualities of water can be tested to give an indication of its suitability to support aquatic life. The qualities measured on the survey study sites were temperature, conductivity, pH, alkalinity, total hardness, dissolved oxygen and turbidity (Table 7).

Table 7: Water Quality Results

River Name	Date	Temp ºC	pH	DO Mg/l	Hardness ppm	Ec µS/cm	Alk ppm	Turb mtrs
Mainoru River	Oct /03	29	7.8	6.1	270	646	180	>3
Wilton River	Oct /03	23	8.4	7.5	180	506	140	1.2
Goyder River	Oct/03	27	8.1	6.1	120	455	100	>6
Rocky Bottom Creek	Oct/03	30	8.1	7.15	100	464	100	1.8
Barmgueikba Creek	Oct/03	30	7.0	6.1	20	69	20	1.5
Chambers River	Oct/03	34	8.1	7.5	10	67.8	10	<0.05
Dook Creek	Oct/03	30	7.1	5.91	10	29.1	10	2.3
Maiwok Creek	Oct/03	35	7.8	5.97	220	691	180	>0.3
King River	Nov/03	29	6.8	-	<10	-	<10	0.35

River Name	Date	Temp ºC	pH	DO Mg/l	Hardness ppm	Ec µS/cm	Alk ppm	Turb mtrs
Giddy River	Jul/04	27.7	7.43	6.62	<10	60.2	<10	2.8
Wonga Creek	Jul/04	29.8	5.32	7.72	<10	37	<10	3.2
Cato River	Jul/04	27	6.41	6.1	<10	36	<10	>3
Richard River	Jul/04	19.8	7.46	8.32	<10	36.5	<10	1.5
Habgood River	Jul/04	24.4	6.77	7.68	40	126.4	40	>5
Buckingham River	Jul/04	26.2	6.59	13.35	10	40.8	20	1.5

5 Conservation Significance

5.1 Habitats of ecological conservation significance

Across the Top End, aquatic ecosystems, and riparian zones in particular, are generally considered to be in good or fairly pristine condition with the main threatening processes being feral animals, grazing pressure and introduced weeds (ANRA 2002).

Herbert *et al.* (1995) concluded from an intensive three-year study on the freshwater fish and aquatic habitat of Cape York that perennial lagoons are crucial habitats for some species of fish, which appear to require aquatic vegetation. They are also important refuges in dry seasons and breeding grounds prior to floods. Lagoons are particularly crucial as refuges in the middle and upper reaches, where waterholes are few and far between. They are also known to harbour the complete diversity of aquatic plants in a catchment.

The Cato River is significant as it recorded the highest species diversity of the surveyed rivers and it yielded two species not previously recorded from the Northern Territory, the Aru Gudgeon *Oxyeleotris arvensis* and the Concave Goby *Glossogobius concavifrons* as well as a near-threatened (*TPWC Act*) amphibian, the Wood Frog *Sylvirana daemeli*. These species were all recorded from swamps within associated monsoon rainforest patches at the study site. The species composition of this river is not dissimilar to that of the Jardine River in northern Cape York, with 22 of the 24 fish species recorded during this survey also being found in the Jardine (Allen and Hoese 1980; Byron and Blake 1993; Allen *et al.* 2002). It is likely that other rivers within North Eastern Arnhem Land such as the Giddy, Goromuru and Habgood Rivers, will yield similar and additional new species with further sampling, extending the known ranges of many fish species in the Top End of the NT. Particular emphasis should be placed on areas that are surrounded by monsoon forest.

Extensive coverage of the aquatic plant *Hanguana malayana* was observed along the banks and across the surface of the water into the Habgood River. This macrophyte was not observed on any of the other waterways and created a complex habitat over some quite deep water and was exclusive to this river. The Gulf Saratoga *Scleropages jardinii* which has a preference for habitat with overhanging vegetation was extremely common at this site, most likely as a result of this habitat.

5.2 Aquatic Fauna of Conservation Significance

Species of conservation significance include those species that are classified as Threatened and\or protected under NT and Commonwealth legislation, and species that are regionally restricted in their distribution. The locations, attributes and significance of aquatic species in relation to the KGGP route are discussed below.

5.2.1. Freshwater Sawfish *Pristis microdon*

The Freshwater Sawfish *Pristis microdon* is listed as vulnerable under the *EPBC Act 1999* and the *TPWC Act*. The species is known from several drainages in northern Australia where it inhabits the muddy bottoms of embayments and estuaries. Juveniles and sub-adult Freshwater Sawfish predominantly occur in the freshwater reaches of tropical rivers, while large mature individuals occur more frequently in coastal and offshore waters up to 25 m depth (Kyne 2012, Stevens *et al*. 2005).

Most Freshwater Sawfish records come from large river systems such as the Roper, East Alligator, Adelaide and Daly Rivers. These river systems provide a variety of habitat types and access to large areas of upstream reaches and tributaries which can provide dry season refugial waterholes. In some instances juvenile Freshwater Sawfish occupy larger floodplain billabongs that reconnect with the main channel of the river during the dry season (Thornburn *et al.* 2003). Recent studies suggest that mature Freshwater Sawfish inhabit marine waters during the post wet season months and enter less saline waters inshore during the wet season months to pup (Whitty *et al*. 2008, Peverell 2005).

Surveys conducted by Thornburn *et al.* (2003) resulted in seven individual Freshwater Sawfish records across the Northern Territory. Survey locations included the Mainoru and Glyde Rivers that traverse the KGGP corridor, though Freshwater Sawfish were not recorded in these rivers during the survey. Several rivers in eastern Arnhem Land, including the Cato and Wilton Rivers, were not surveyed as traditional owners had closed the region at the time of the survey. One freshwater sawfish was recorded in the Roper River several hundred kilometres from the sea (Thornburn *et al.* 2003). While the KGGP route does not cross the Roper River, it does cross tributaries of the river, including Maiwok Creek and Flying Fox Creek. This record highlights the species ability to move far inland.

Thornburn *et al*. (2003) recorded Freshwater Sawfish in the main channel, larger tributaries and in backwaters, in lower, middle and upper riverine reaches. It was recorded from waters ranging in depth from 0.7 m to 6m in both tidal and non-tidal reaches with generally low flow rates. The species was commonly encountered over finer substrates, such as sand and silt, often in a deeper section of a river adjacent to a sand or silt shallow, such as a sandbar or shallow backwater. Freshwater Sawfish were mainly collected from fresh or low salinity water of less than 10 parts per thousand (ppt). The species was recorded in both turbid and clear water though capture sites were generally clear and had relatively high dissolved oxygen levels (Thornburn *et al.* 2003).

NT Museum records show that this species has been recorded in several of the larger rivers that will be crossed by the KGGP including the Wilton and Mainoru Rivers. Historically, this species has been reported in the lower reaches of several rivers in Eastern Arnhem Land including the Goyder and Cato Rivers. These records are from areas far downstream of the proposed KGGP route; however the species has been recorded several hundred kilometres inland (Thornburn *et al.* (2003). This record from the Roper River indicates that there is potential for the species to occur in most rivers and creeks crossed by the KGGP project.

Likelihood of Freshwater Sawfish Occurring along the KGGP Corridor

Analysis of the KGGP route (Pipeline Alignment Division 5) on Google Earth revealed that a total of 19 points occur where potential Freshwater Sawfish habitat is traversed (Figure 1).

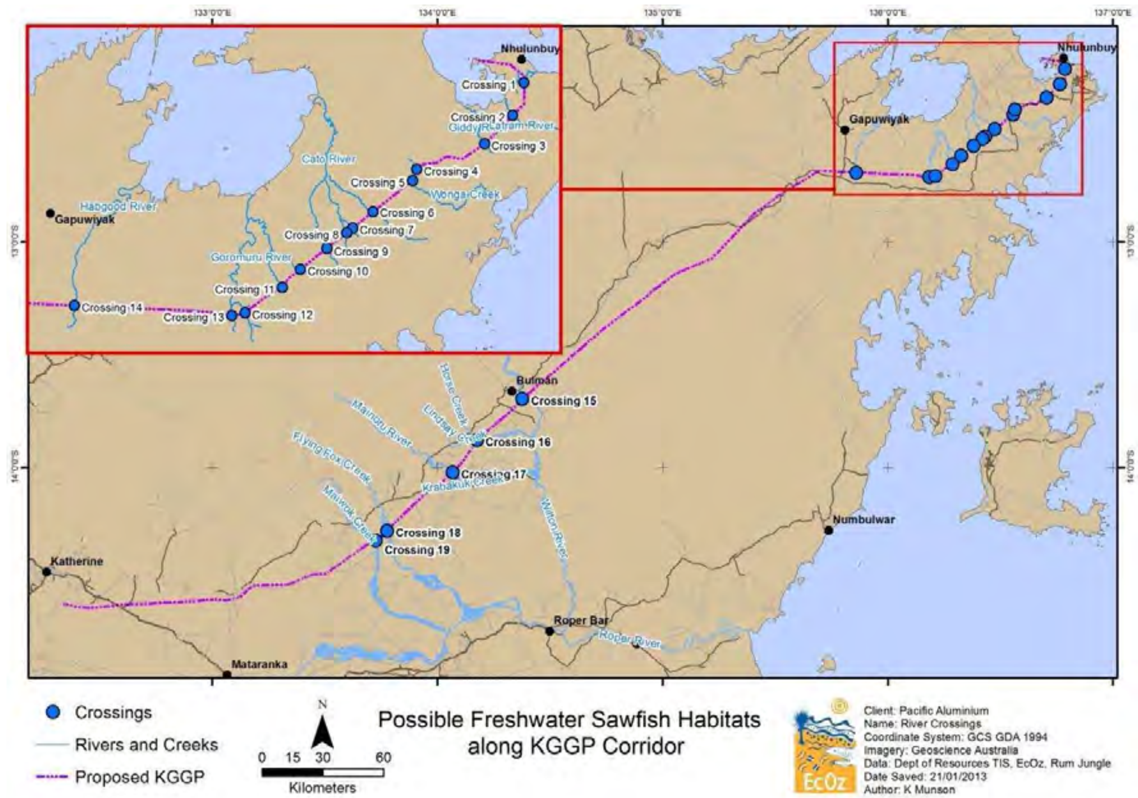


Figure 1: Possible Freshwater Sawfish habitat along the KGGP corridor

Table 8 shows the creek crossings traversed by the KGGP corridor and the likelihood of Freshwater Sawfish occurring at each crossing point.

Table 8: Creek/ River Crossings and Likelihood of Freshwater Sawfish Occurrence

Site	Location	Likelihood of Freshwater Sawfish	Notes
Crossing 1	-12.2334°, 136.7883°	Unlikely	Estuarine. Adults possibly occur. Too saline for juveniles and sub-adults.
Crossing 2	-12.3003°, 136.7653°	Possible	Latram River. Middle reaches of estuary. Possible juvenile and sub-adult refuge.
Crossing 3	-12.3594°, 136.7068°	Likely	Giddy River. Upper reaches of estuary. Freshwater, likely juvenile and sub-adult refuge.
Crossing 4	-12.4116°, 136.5671°	Likely	Numerous crossings of freshwater creek between Crossing 4 and Crossing 5. Upper reaches of estuary to provide refuge for juveniles and sub-adults in billabongs during the dry season.
Crossing 5	-12.4345°, 136.5586°	Likely	Upper reaches of estuary to provide refuge for juveniles and sub-adults in billabongs during the dry

Site	Location	Likelihood of Freshwater Sawfish	Notes
			season.
Crossing 6	-12.4993°, 136.4767°	Likely	Cato River. Upper reaches of estuary with large disconnected billabongs in the dry season. Likely juvenile and sub-adult refuge.
Crossing 7	-12.5327°, 136.4344°	Possible	Upper reaches of estuary. Possible juvenile and sub-adult refuge.
Crossing 8	-12.5424°, 136.4222°	Possible	Upper reaches of estuary. Possible juvenile and sub-adult refuge.
Crossing 9	-12.5745°, 136.3814°	Likely	Likely juvenile and sub-adult refuge due to presence of intermittent billabongs.
Crossing 10	-12.6176°, 136.3266°	Unlikely	Upper reaches of large river. Probably too far upstream and likely to be dry most of the year.
Crossing 11	-12.6554°, 136.2894°	Likely	Upper reaches of large river. Appears to have substantial freshwater that will become disconnected billabongs in the dry season. Good refuge area for juveniles and sub-adults.
Crossing 12	-12.7071°, 136.2124°	Possible	Upper reaches of large river. Appears to have substantial freshwater but is possibly too far upstream and may dry out in the dry season.
Crossing 13	-12.7129°, 136.1846°	Possible	Upper reaches of estuary. Appears to have substantial freshwater but is possibly too far upstream and may become dry.
Crossing 14	-12.6926°, 136.8606°	Possible	Upper reaches of estuary. May be too far upstream but freshwater pools occur further upstream so may be suitable refuge area.
Crossing 15	-13.6957°, 134.3781°	Possible	Wilton River. Upper reaches of large estuary. Appears to be suitable refuge area for juveniles and sub-adults though may be upstream of escarpment where sawfish are unlikely to pass through.
Crossing 16	-13.8768°, 134.1766°	Possible	Horse Creek. Upper reaches of estuary. Floodplain area. May be suitable habitat for juveniles and sub-adults.
Crossing 17	-14.0220°, 134.0686°	Possible	Mainoru River. Upper reaches of estuary. May be suitable refuge area for juveniles and sub-adults.
Crossing 18	-14.2790°, 133.7861°	Unlikely	Flying Fox Creek. Probably too far upstream of river. Likely to be an ephemeral freshwater creek.
Crossing 19	-14.3239°, 133.7269°	Possible	Maiwok Creek. Upper reaches of estuary. Possible juvenile and sub-adult refuge.

It should be noted that this assessment is based on a desktop review and a more accurate assessment can be carried out in the field. The analysis involves looking at images on Google Earth taken at varied times of the year. This is likely to influence the appearance of a creek crossing, particularly the volume of water that appears to occur within the creek.

5.2.2. Obbes' Catfish *Porochilus obbesi*

Obbes' Catfish *Porochilus obbesi,* which is currently listed as near-threatened under the *TPWC Act* prefers slow flowing streams, lagoons and shallow lakes with considerable macrophyte growth (Merrick and Schmida 1984; Herbert and Peeters 1995; Allen *et al.* 2002). This species is listed as uncommon by many authors (Merrick and Schmida 1984; Herbert and Peeters 1995; Allen *et al.* 2002) and has a rather disjunct distribution across Northern Australia. Given the largely cryptic nature of this species, it is likely that it will be found in many more rivers as further intensive sampling is undertaken throughout its known distribution. Along the KGGP route this species is presently only recorded from the Daly system in Yam Creek (Allen 1989). However, Peter Unmack (http://www.peter.unmack.net/biogeog/html/appendices/appendixiv.html) considers that this record to be incorrect as Yam Creek is now believed to be part of the Adelaide River drainage. If this is the case, then this species has not in fact been recorded in the Daly Catchment and therefore is not known to occur along the KGGP route.

5.2.3. Data Deficient Species

A search of the Atlas of Living Australia (ALA) and the Fish Atlas of Northern Australia database reveals that an additional eight fish species listed as Data Deficient under the *TPWC Act* occur in rivers and catchments that traverse the KGGP corridor. This includes the following:

- Barred Grunter *Amniataba percoides*
- Small-mouthed Catfish *Cinetodus froggatti*
- Fly-specked Hardyhead *Craterocephalus stercusmuscarum*
- Munro's Goby *Glossogobius Sp 2*
- Threadfin Rainbowfish *Iriatherina werneri*
- Northern Trout Gudgeon *Mogurnda mogurnda*
- Gulf Grunter *Scortum ogilbyi*
- Freshwater Anchovy *Thryssa scratchleyi*

The Data Deficient listing indicates that available information on the species' distribution and abundance is insufficient for a proper assessment of conservation status to be made.

5.2.4. Range Extensions and New Species

The identification of the Aru Gudgeon *Oxyeleotris arvensis* and Concave Goby *Glossogobius concavifrons* in the Cato River was an extension of the known range of these species only known from Southern New Guinea and the tip of Cape York Queensland. One further species of goby collected in the Cato River is presently undescribed but known commonly as Monroe's Goby *Glossogobius sp 2*. The observation of the Freshwater Whipray *Himantura chaophraya*, also in the Cato River, represents the first record of this species in Arnhem Land. This species was previously only recorded from the South Alligator and Daly Rivers in the NT (Midgley 1980; Allen *et al.* 2002).

The identification of Butler's Grunter *Syncomistes butleri* in the Goyder River and Rocky Bottom Creek was another range extension as this species. Previously it was known from Drysdale River in the west to the

Liverpool River in the east and is considered to be common in all the upper reaches of the larger rivers in this region (Allen *et al.* 2002).

The Exquisite Rainbowfish *Melanotaenia exquisita* is presently known from disjunct populations across northern Western Australia and the Northern Territory. This species is restricted to escarpment areas and within rivers that originate directly adjacent to waterfalls. This species was not previously known from the Roper catchment and was recorded in Dook Creek.

It would appear that few fish species in the Northern Territory are restricted or are endemic to single river systems. Unmack's (1999) thesis on the biogeography of Australian freshwater fish describes only 3% or one endemic species in both the Arnhem and Daly Provinces. These provinces were determined by Unmack based on combination of river catchments and biogeographical zones and incorporate all coastal drainages within the Northern Territory.

6 Potential Environmental Impacts and Management Recommendations

The aquatic ecosystems that will be crossed by the KGGP are considered on a national scale to be in relatively pristine condition. It is therefore imperative that the KGGP is constructed and operated in a manner that ensures minimal impact to these environments and those species listed as threatened under state and federal legislation.

6.1 Clearing of Riparian Vegetation, Erosion and Sedimentation

6.1.1. Impact

Riparian vegetation has been recognised as valuable habitat and vital to the functioning of stream ecosystems. The removal or modification of this can adversely affect every aspect of stream habitat. Riparian vegetation is in relatively good condition across the NT (ANRA 2002). Even so, the condition of riparian zones in the NT is declining because of damage associated with proliferation of weeds, feral pigs and buffalo, and (in some cases) unrestricted access by livestock (ANRA 2002).

Riparian vegetation is known to (Wager and Jackson 1993);

- maintain bank stability and channel morphology,
- provide a buffer which filters sediment, organic and inorganic nutrients from run off,
- provide in-stream habitat in the form of woody debris (snags), leaves and bark,
- maintain undercut banks by its presence,
- provide the major source of energy input in the form of vegetative material, terrestrial insects etc, and
- its removal often results in an increase in water temperatures and increased temperature fluctuation.

The clearing of riparian vegetation can result in increased erosion, scouring and changes to channel morphology. An increase in nutrient loadings and light penetration may result in unfavourable algal blooms and increases in water temperatures. Decreases in in-stream habitat may also occur with a loss of undercut banks, woody debris and leaves etc. Disturbance of riparian vegetation is also known to allow the proliferation of weed species. Arthington *et al.* (1983) have documented the adverse effects of Para Grass (*Brachiaria mutica*) on native fish habitats in streams around Brisbane after the loss of native riparian vegetation.

Erosion and sedimentation modifies the morphology of channels and banks and increases the sediment load. Increased sediment loading may have a variety of effects including infilling of holes and channels, smothering of riffle areas and the associated invertebrate fauna, smothering of macrophytes, and smothering of fish eggs deposited in gravel substrates or attached to underwater surfaces (Wager and Jackson 1993). Hall (1991) found that 80% of freshwater fish species in Victoria produce eggs, which are susceptible to smothering by fine sediments. Despite very different species being identified during this survey, they represent a similar range of families and therefore fine sediments may impact on a similar proportion of the species diversity.

Culverts and crossings that restrict stream flow (thereby increasing water velocity) may also cause scouring of the stream bed and erosion of adjacent banks if the outlet or downstream is inadequately protected (Cotterell 1998).

6.1.2. Management

In order to limit the detrimental effects on rivers and streams, it is recommended that construction attempts to minimise the circumstances where excavation is carried out in water bodies or within riparian zones. Where it is required, the absolute minimum should be removed and clearing of riparian vegetation should be carried out as early in the dry season as possible to allow for sufficient revegetation. Hand clearing of bank slopes at the site minimises erosion and the need for rehabilitation. If possible, work to the outer bank should be minimised, as these are usually the most unstable bank and prone to erosion. Where vehicle traffic is expected in these zones, ‘roadways’ should be covered in gravel, particularly entry and exit areas. All works should adhere to guidelines for the control of erosion and sedimentation at construction sites and NT soil conservation guidelines. Rehabilitation works should be completed as soon as practical after the disturbance. Care should be taken not to establish weeds.

6.2 Water Quality

6.2.1. Impact

Water picks up minerals from the surfaces it passes over or through (Reid 1972). It also picks up organic materials from biological activity. In areas of human habitation and agricultural activities it picks up waste materials from those activities. Threats to water quality in Australia's inland fresh waters include:

- Increasing in-stream water salinity
- Nutrient enrichment and eutrophication
- High water turbidity and siltation
- Pesticide contamination of water and sediments
- Localised heavy metal pollution
- Increasing acidity of inland waters
- Cold-water pollution.

The threats to water quality are likely to result from manufacturing processes and human activities. These may include silting, spills of potentially hazardous and dangerous chemicals such as fuels and oils, and wastewater (camp and hydrostatic testing) disposal. The greatest risks to water quality include increased sediment loading and change of physiochemical properties of wastewater from both the camps and the hydrostatic testing of the pipeline.

Increased sediment loading may have a variety of effects including infilling of holes and channels, smothering of riffle areas and the associated invertebrate fauna, smothering of macrophytes, and smothering of fish eggs deposited in gravel substrates or attached to underwater surfaces (Wager and Jackson 1993). Berkman and Rabeni (1987) showed that silt affected the composition of fish assemblages, interfered with feeding of algivorous fish, and lowered the reproductive success of some spawning guilds (substrate and macrophyte spawners).

Biotic factors (morphology, competition, predator-prey interactions and resource partitioning) and habitat complexity influence distributions of animals in benign environments, but in harsh environments, the ability of the organism to tolerate or avoid physiochemical stress may be more critical to their success (Matthews 1998). Monsoonal rivers are considered harsh environments and many species other than the generalists will have difficulty coping with further physiochemical changes during the dry season, or low flow periods which may ultimately lead to their death.

6.2.2. Management

A water monitoring program based on the ANZECC 2000 guidelines should be established to assess ecosystem integrity throughout the construction period and during the first few years of operation to ensure nil to minimal impact of the crossings. This will involve the:

- Defining of water quality objectives
- Selection of appropriate trigger values for selected indicators
- Establishment of a water quality monitoring program.

Design and construction of fuel and chemical storage, and wastewater treatment facilities should comply with Australian regulations and be located appropriate distances from any watercourses. Personnel should be discouraged from using personal toiletries in any watercourse or from swimming whilst wearing sunscreen and insect repellent.

Disposal of wastewater from hydrostatic testing should be undertaken according to regulatory and Traditional Owner requirements. In particular, water drawn from a marine source should only be disposed of to an ocean outfall. If surface water is used, it should be sterilised before release into another catchment. Under no circumstances should this water be released into a watercourse.

6.3 Fish Passage

6.3.1. Impact

Many fish species travel up and down waterways as evidenced by huge aggregations of various species that can be observed at natural and un-natural barriers in rivers before, during and especially after the wet season (D. Wilson personal observation). Fish move for a range of reasons including feeding, breeding, escaping predators or dispersal. Many tropical freshwater fishes migrate up-river as the water level rises in the wet season and undergo lateral movements out onto the floodplains when conditions permit (Lowe-McConnell 1975). Some species are renowned for their ability to travel. One of the most widespread native fish, the Spangled Perch *Leiopotherapon unicolor* has a reputation for moving long distances upstream in a short time during periods of high rainfall to both breed and to disperse (Allen *et al*. 2002). Other species recorded during this survey, such as Barramundi *Lates calcarifer*, Spotted Scat *Scatophagus argus,* Striped Scat *Selenotoca multifasciata*, Indo-pacific Tarpon *Megalops cyprinoides*, and Mangrove Jacks *Lutjanus argentimaculatus* need to move downstream into saltwater to breed. The adults and juveniles of most of these species then return to freshwater (Allen *et al.* 2002).

Whilst there has been concern over the effects of dams and weirs on fish movements, simple structures such as road crossings also have significant effects. A poorly designed or installed culvert can affect the fish stocks of an entire drainage basin (Cotterell 1998). If a crossing or culvert is designed such that the channel width is restricted or a drop is created, the velocity of flowing water will be increased. Whilst fish are stimulated to move in response to floods, the water velocity in culverts or at crossings under flow conditions may exceed the swimming ability of many fish, therefore excluding these from upstream habitat that many species require.

Although usually low cost, causeways result in many problems for fish passage including:

- Debris blockage of the pipe;
- Excessive flow velocities through the low flow pipe;
- Inadequate flow depth over the causeway during minor stream flows;
- Excessive fall in the water level across the causeway or at the outlet of the low flow pipe creating a waterfall effect; and
- Sediment runoff from the approach roads (Fairfull and Witheridge 2003).

The NT *Water Act 2004* regulates the restriction of water flows within a waterway. The provisions of the NT *Water Act* establishes offences related to impeding water flows in a water way.

6.3.2. Management

As discussed in Section 6.1.2, all in-stream work should be conducted during the driest part of the year and completed as quickly as possible. All temporary in-stream structures such as temporary crossings and bund walls should be removed as soon as practical after the works are completed and the streambed restored to as near as possible original condition. It is recommended that design and construction of any stream crossings follow the guidelines produced by Cotterell (1998), Witheridge (2002) and Fairfull and Witheridge (2003).

Each waterway proposed to be crossed by the KGGP will require a site assessment in order to determine the most appropriate crossing for the site. It should be a primary objective to minimise the number of crossings that will be required. In addition, the following 5 principles should be followed (from Fairfull and Witheridge 2003):

1. Avoid crossing waterways at or near sharp bends, sections of unstable channel or major 'riffle' zones.
2. Avoid locating crossings over meandering waterways where such meandering is likely to continue in the future and may cause damage to the structure, erosion of the channel or misalignment with the channel in the future.
3. Avoid works that may change the frequency or spacing of an existing pool-riffle system.
4. Avoid disturbances to sections of a waterway channel or its associated bank vegetation, particularly those identified as areas of high conservation value or where threatened species are known to occur.
5. Avoid removal of essential shade trees, especially where there has already been a loss of natural vegetation cover.

Following the site assessment, consideration should be given to the most appropriate crossing type. Table 9 details the recommended crossing types for various classifications of fish habitat (from Fairfull and Witheridge 2003).

Table 9: Recommended crossing types for various classifications of fish habitat (from Fairfull and Witheridge 2003).

Classification	Characteristics of Waterway Type	Recommended Crossing Type in preferred order.
Class 1 – Major fish habitat	Major permanently or intermittently flowing waterway (e.g. river or major creek), habitat of a threatened fish species.	Bridge Arch structure Tunnel
Class 2 – Moderate fish habitat	Named permanent or intermittent stream, creek or waterway with clearly defined bed and banks with semi-permanent to permanent waters in pools or in connected wetland areas. Freshwater aquatic vegetation is present. Known fish habitat and/or fish observed inhabiting the area.	Bridge Arch structure Culvert (high priority should be given to a high flow design) Ford.

Classification	Characteristics of Waterway Type	Recommended Crossing Type in preferred order.
Class 3- Minimal fish habitat	Named or unnamed waterway with intermittent flow and potential refuge, breeding or feeding areas for some aquatic fauna. Semi-permanent pools form within the waterway or adjacent wetlands after a rain event. Any minor waterway that interconnects with wetlands or recognised aquatic habitats.	Culvert (high flow or medium flow designs should be given priority where affordable) Ford
Class 4 – Unlikely fish habitat	Named or unnamed waterway with intermittent flow following rain events only, little or no defined drainage channel, little or no flow or free standing water or pools after rain events. No permanent aquatic flora present.	Culvert Causeway Ford

If an access track is to traverse the length of the pipeline, then structures will be required for river and creek crossings. Depending on the most appropriate structure decided upon for each crossing, the construction practices recommended in Table 10 should be followed.

Table 10: Recommended construction practices for various types of water way crossings (from Fairfull and Witheridge 2003).

Crossing type	Recommended construction practices
Ford	• The deck of the ford should follow the natural bed elevation. • Where concrete is used, the surface will need an artificial roughness, at least along the lowest section of the crossing. Grouted rocks may be used instead of the concrete pad. • Do not use exposed-aggregate concrete finishing as its preparation can pollute.
Causeway	• Minimise the use of causeways where migratory fish species have been identified. • Construct the deck to follow the stream's natural cross section to achieve variable flow depths over the causeway. • Give appropriate consideration to fish passage and install low-flow pipes or boxes to carry the normal dry-weather flow.
Culvert	• Align the culvert with the downstream channel to minimise bank erosion. • Minimise the changes to the natural flow of the waterway through the culvert's wet cells. These should have a minimum depth of 0.2-0.5 m to encourage fish passage. • Designed to maximise the geometric similarities of the natural channel profile from the bed of the culvert up to a flow depth of 0.5 metres. • If a smooth bed is required, flow velocities for water depth up to 0.5 m should be no more than 0.3 m/s. • In sand and gravel-based streams, natural bed material should be placed along the bed of the wet cells or allowed to deposit in these cells. • In clay-based streams that do not experience movement of bed load sediment, artificial roughness can be created by grouting rounded stone across the bed of the wet cells.

Crossing type	Recommended construction practices
	• Consideration should be given to adding artificial sidewall roughness along the walls immediately adjacent to the channel banks. • Construct pools at the inlet and outlet of the culvert. • Ensure the low-flow channel extends across the inlet and outlet aprons. • Use debris deflector walls to reduce blockages. • Maximise light penetration within the wet cells. • Avoid the formation of a perched culvert or damage to the stream bed, control erosion using rock protection or with a stabilised energy dissipation pool.
Bridges and Arch structures	• Avoid locating bridge piers or foundations within the main waterway channel. • Design and orientate bridge piers to avoid the formation of large-scale turbulence or erosion of the bed and banks. • Give appropriate consideration to fish passage requirements along floodplains. Locate bridge abutments away from the channel banks and consider the possibility of installing floodplain culverts adjacent to the main crossing. • Maximise light penetration under the bridge or arch to encourage fish passage. • Maximise bed and bank erosion control measures.

During construction and operation, all measures should be taken to minimise the restrictions of fish passage, the release of sediment into freshwater creeks or rivers and damage to or the removal of bank vegetation, particularly vegetation that shades the low-flow channel in the system (Fairfull and Witheridge 2003).

During operation of the pipeline, it is imperative that all waterway crossing structures be inspected and maintained on a regular basis. All in-stream maintenance should be scheduled for times of the year that will ensure a minimal environmental impact (Fairfull and Witheridge 2003). The dry season would be best for such activities as this should avoid critical periods of fish passage and seasonal high flows.

6.4 Translocation

6.4.1. Impact

The translocation of fish and other aquatic organisms may have a range of adverse effects. These include the introduction of diseased organisms, disturbance of ecosystems, loss of biogeographic information and loss of genetic diversity (Wager and Jackson 1993).

Water transferred from one catchment to another during the hydrostatic testing of the pipeline may carry biological material. In addition, machinery and equipment used in a watercourse may carry material into the next. It is an offence under the Fisheries Act to translocate aquatic life.

6.4.2. Management

Water used during hydrostatic testing should be disposed of as described in accordance with the requirements set out in section 6.3.2. All machinery and equipment that will be submersed or used in a waterway should be washed down and decontaminated before the next catchment, river or waterway.

6.5 Impacts on Aquatic Fauna of Conservation Significance

6.5.1. Impacts

The pipeline crosses various rivers known to contain threatened and data deficient fish species. The literature review and interviews conducted with landholders and traditional owners determined that the Freshwater Sawfish *Pristis microdon* is known to occur in the Daly, Wilton and Mainoru River catchments on the KGGP route.

The Freshwater Sawfish *Pristis microdon* is a diadromous species that typically occurs in the tidal areas of the large tropical rivers where high sediment loads are present as a result of the large tidal movement (Allen *et al*. 2002). Due to their biology pristid sawfish have exhibited an inability to adapt to changes in their environment. Their dependence on predominantly freshwater environments makes them vulnerable to habitat loss or degradation. Freshwater environments are generally less stable than marine equivalents and are prone to fluctuations in temperature, oxygen level, mineral content, turbidity and water flow. Major changes to river and lake beds can readily exceed the tolerances of pristid sawfish (Peverell *et al*. 2004).

Other threatening processes include commercial net fisheries, recreational line/net fisheries, aquarium collectors and trophy hunters. The shallow water coastal distribution and the teethed rostrum of Freshwater Sawfish makes them particularly vulnerable to capture in gill nets (Peverell *et al*. 2004).

Increased sediment loadings or changes to water chemistry as a result of the construction and operation of the KGGP have the potential to impact on this species. However, such impacts from the project are anticipated to be minor and within the species threshold for change. Barriers to movement such as stream crossings, poorly designed culverts as well as gross water quality issues such as low dissolved oxygen levels present a much greater risk to this threatened species.

Many of the species listed as data deficient will be similarly impacted upon by the above activities. For example, the Barred Grunter (*Amniataba percoides*) inhabits still pools to fast-flowing streams in clear or turbid water. It is able to adapt to a wide range of temperature, pH (4.5-6.6) and salinity (fresh to brackish) conditions. The Gulf Grunter (*Scortum ogilbyi*) occurs in both turbid and clear waters while the Fly-specked Hardyhead (*Craterocephalus stercusmuscarum*) is able to survive in both slow moving and fast flowing creeks in temperatures ranging from 9 °C to 29 °C (Allen *et al.* 2002).

6.5.2. Management

Impacts on threatened species or those of conservation significance will be minimised if the management recommendations in sections 6.1.2, 6.2.2, 6.3.2 and 6.4.2 are implemented.

7 References

Allen, G. R. (1991) *Field Guide to the Freshwater Fishes of New Guinea*. Christensen Research Institute, Madang, Papuae New Guinea.

Allen, G. R. (1989) *Freshwater Fishes of Australia*. T.F.H., New Jersey.

Allen, G.R. and Hoese, D.F. (1980) A Collection of Fishes from Cape York Peninsula, Australia. *Journal of the Royal Society of Western Australia 63: 2: 53-61.*

Allen, G.R. Midgley, S.H. Allen, M. (2002) *Field Guide to the Freshwater Fishes of Australia*. West Australian Museum, Perth, Australia.

Arthington, A.H., McKay, R.J., Milton, D.A. (1983) Effects of Urban Development and Habitat Alteration on the Distribution and Abundance of Native and Exotic Fish in the Brisbane Region, Queensland. *Australian Journal of Ecology 8:87-101*.

Australian Natural Resource Atlas (ANRA). (2002) *National Land and Water Resources Audit*. Available online at <http://www.anra.gov.au/topics/publications/final-report/index.html>. Commonwealth Government of Australia, Canberra.

Axelrod, H.R. Burgess, W.E. Pronek, N. Walls, J.G. (1985) *Atlas of Freshwater Aquarium Fishes*. TFH, New Jersey.

Berkman, H.E. and C.F.Rabeni, (1987) Effect of Siltation on Stream Fish Communities. *Env. Biol. Fish. 18:285-95.*

Boyd, C.E., (1995) *Bottom Soils, Sediment, and Pond Aquaculture*. Chapman & Hall , New York.

Bishop, K.A and Forbes, M.A. (1991) The freshwater fishes of northern Australia In*:* Haynes, C.D., Ridgpath, M.G. and Williams, M.A.J. (eds) *Monsoonal Australia. landscape, ecology and man in the northern lowlands*. *pp 79-107*. A. A. Balkema: Rotterdam.

Byron, G. and Blake, D. (1983) Distribution and Abundance of Freshwater Fish on Northern Cape York Peninsula. Cape York Peninsula Scientific Expedition 1992: Royal Geographical Society of Queensland.

Cadwallader, P.L and G.N.Backhouse, (1983) *A Guide to the Freshwater Fish of Victoria*. Victorian Government Printing Office, Melbourne.

Cogger, H.G., (1992) *Reptiles and Amphibians of Australia revised Edition*. Reed International Books, Chatswood NSW.

Cotterell, E. (1998) *Fish Passage in Streams – Fisheries Guidelines for Design of Stream Crossings*. Fisheries Group, Queensland Department of Primary Industries, Brisbane.

Cowie I., Short P.S., Osterkamp-Madsen M., (2000) *Floodplain Flora, a flora of the coastal floodplain of the Northern Territory, Australia*. Published by CSIRO, Canberra.

Cronk J.K., Fennessy M.S. (2001) *Wetland Plants, Biology and Ecology.* Lewis Publishers, London NewYork and Washington.

Department of Business, Industry and resource Development, Fisheries Division: fish kills [online]. <http://www.fisheries.nt.gov.au/>.

Department of Environment and Heritage list of threatened species [online]. Available at: <http://www.deh.gov.au/cgi-bin/sprat/public/publicthreatenedlist> downloaded 13 August 2004.

Department of Sustainability, Environment, Water, Populations and Communities (SEWPaC). (2011). *Survey guidelines for Australia's threatened fish Guidelines for detecting fish listed as threatened under the Environment Protection and Biodiversity Conservation Act 1999*. Commonwealth Government of Australia, Canberra.

Doody, J.S., Green, B., Rhind, D., Castellano, C., Sims, R. & Robinson, T. (2009). Population-level declines in Australian predators caused by an invasive species. *Animal Conservation*. 12:46-53.

Fairfull, S. and Witheridge, G. (2003) Why do Fish Need to Cross the Road? Fish Passage Requirements for Waterway Crossings. NSW Fisheries, Cronulla.

Frogwatch NT. [online] <http://www.frogwatch.org.au/index.cfm>.

Griffiths, A.D. & McKay, J.L. (2005). *Monitoring the freshwater goanna Varanus mertensi after the arrival of cane toads using site occupancy models*. Report to Parks and Wildlife Service NT. (Charles Darwin University, Darwin).

Herbert, B. and Peeters, J., (1995) *Freshwater Fishes of Far North Queensland*. DPI, Queensland.

Herbert, B.W., Peters, J.A., Graham, P.A. and Hogan, A.E. (1995). *Freshwater Fish and Aquatic Habitat Survey of Cape York Peninsula*. Cape York Peninsula Land Use Strategy, Office of the Co-ordinator General of Queensland, Brisbane, Department of the Environment, Sport and Territories, Canberra, Queensland Department of Primary Industries, Brisbane.

Hall. D.N. 1991 *Management Plan for Freshwater Fishes in Major Gippsland Rivers: Water Resources Requirements*. Arthur Rylah Institute for Environmental Research, Technical Report 107.

Jones, D. & Morgan, G., (1994) *A field guide to Crustaceans of Australian Waters*. Reed Publishing, Chatswood, NSW.

Last, P.R. and Stevens, J.D. (1994) *Sharks and Rays of Australia*. CSIRO Australia.

Larson, H. (2004) Personnel Communication.

Larson, H.K. & Martin, K.C., (1989) *Freshwater Fishes of the Northern Territory*. Northern Territory Museum of Arts and Sciences Handbook.

Lowe-McConnell, R.H. (1975) *Fish Communities in Tropical Freshwaters*. Longman, New York.

Matthews, W.J. (1998) *Patterns in Freshwater Fish Ecology*. Chapman & Hall. New York.

Merrick, J., Schmida, G. (1984) *Australian Freshwater Fishes, Biology and Management*. Griffin Press, Netley, South Australia.

Midgley, S.H. 1980. *The Daly River, Katherine River, King River, Dry River, Flora River, Fergusson River, Fish River, Douglas River in the Northern Territory. A biological resource study of fresh waters conducted during August-September 1980*. Unpublished report to NT Fisheries.

Midgley, S.H. 1983. *The rivers of Arnhem Land and the Towns River. An account of a biological resource study of fresh waters conducted during July to August 1983*. Unpublished report to NT Fisheries.

Peverell, S., Gribble, N., and Larson, H. (2004). Sawfish. In *Description of key species groups in the Northern Planning Area*. pp, 75-83. (National Oceans Office, Hobart.)

Peverell, S.C. (2005). Distribution of sawfishes (Pristidae) in the Queensland Gulf of Carpentaria, Australia, with notes on sawfish ecology. *Environmental Biology of Fishes.* 73: 391–402.

Reid K. (1972) *Fresh Water*. Aldus Books, London.

Sainty G.R., Jacobs S.W.L. (1988) *Waterplants in Australia*. Published by CSIRO Division of Water Resources, Australia.

Sattler, P. and C. Creighton (eds). 2002. Terrestrial Biodiversity Assessment 2002. National Land and Water Resources Audit, Canberra [online] Available from; <http://audit.ea.gov.au/anra/vegetation/docs/biodiversity/bio_assess_contents.cfm> Accessed 2004 September.

Smith, J.G., and Phillips, B.L. (2006). Toxic tucker: the potential impact of cane toads on Australian reptiles. *Pacific Conservation Biology*. 12, 40-49.

Stevens, J.D., R.D. Pillans & J. Salini (2005). *Conservation Assessment of Glyphis sp. A (Speartooth Shark), Glyphis sp. C (Northern River Shark), Pristis microdon (Freshwater Sawfish) and Pristis zijsron (Green Sawfish)*. [Online]. Hobart, Tasmania: CSIRO Marine Research. Available from: <http://www.environment.gov.au/coasts/publications/pubs/assessment-glyphis.pdf>.

Thornburn, D., S. Peverell, J. Stevens, P. Last and A. Rowland. (2003). *Status of Freshwater and Estuarine Elasmobranchs in Northern Australia*. Department of Sustainability, Environment, Water, Population and Communities (SEWPaC), Commonwealth Government, Canberra.

Unmack P.J., (1999) *Biogeography of Australian Freshwater Fishes*. Masters thesis, Arizona State University

Wager, R and Jackson, P. (1993) *The Action Plan for Australian Freshwater Fishes*. ANCA, Canberra, Australia.

Whitty, J.M., Morgan, D.L., Thorburn, D.C., Fazeldean, T. & Peverell, S.C.1 (2008). Tracking the movements of Freshwater Sawfish (Pristis microdon) and Northern River Sharks (Glyphis sp. C) in the Fitzroy River. In J.M. Whitty, N.M. Phillips, D.L. Morgan, J.A. Chaplin, D.C. Thorburn & S.C. Peverell (eds). *Habitat associations of Freshwater Sawfish (Pristis microdon) and Northern River Shark (Glyphis sp. C): including genetic analysis of P. microdon across northern Australia*. Centre for Fish & Fisheries Research (Murdoch University) report to the Department of the Environment, Water, Heritage and the Arts, Australian Government.

Wilson, D.N. (1999) Freshwater Sawfish *Pristis microdon*. Australia & New Guinea Fishes Association' A-Z Notebook of native Freshwater Fishes. *ANGFA Bulletin 41*.

Wilson, D. (2004) Personnel Observation.

Wilson, S. and Swan, G. (2003) *A Complete Guide to Reptiles of Australia*. Reed, NSW.

Witheridge, G. (2002) *Fish Passage Requirements for Waterway Crossings- Engineering Guidelines*. Institute of Public Works Engineering, Brisbane.

Appendix 1 – Aquatic Fauna Desktop Records

Species	Common name	Source*	Status# TPWC	Status# EPBC
Ambassis agassizii	Agassiz's Glassfish	ALA		
Ambassis agrammus	Sailfin Glassfish	Fish Atlas, ALA		
Ambassis macleayi	Macleay's Glassfish	Fish Atlas, ALA		
Ambassis sp.1	Glassfish	Fish Atlas		
Amniataba percoides	Barred Grunter	Fish Atlas, ALA	DD	
Anodontigglanis dahli	Toothless Catfish	Fish Atlas		
Arius berneyi	Berney's Catfish	Fish Atlas		
Arius graeffei	Lesser Salmon Catfish, Blue Catfish	Fish Atlas		
Arius leptaspis	Triangular Shield Catfish, Salmon Catfish	Fish Atlas		
Arius midgeleyi	Silver Cobbler, Shovel-nosed Catfish	Fish Atlas, ALA		
Arius sp	Fork-talked Catfish	Fish Atlas		
Arrhamphus sclerolepis	Snub-nosed Garfish	Fish Atlas		
Brachirus selheimi	Freshwater Sole, Selheim's Sole	Fish Atlas		
Caranx sexfasciatus	Bigeye Trevally	Fish Atlas		
Carcharinus sp	Whaler Shark	Fish Atlas		
Chanos chanos	Milkfish	Fish Atlas		
Cinetodus froggatti	Froggatt's Catfish, Small-mouthed Catfish	Fish Atlas	DD	
Craterocephalus marianae	Mariana's Hardyhead	Fish Atlas		
Craterocephalus stercusmuscarum	Fly-specked Hardyhead	Fish Atlas, ALA	DD	
Craterocephalus stramineus	Strawman, Blackmast	Fish Atlas		
Craterocephalus sp	Hardyhead	Fish Atlas		
Dasyatis sp	Stingray	Fish Atlas		
Denariusa bandata	Pennyfish	Fish Atlas		
Gerres filamentosus	Treadfin Silver Biddy	Fish Atlas		
Glossiama aprion	Mouth Almighty	Fish Atlas, ALA		
Glossogobius aureus	Golden Goby	Fish Atlas, ALA		
Glossogobius celebius	False Celebes Goby	Fish Atlas		
Glossogobius concavifrons	Concave Goby	Fish Atlas		

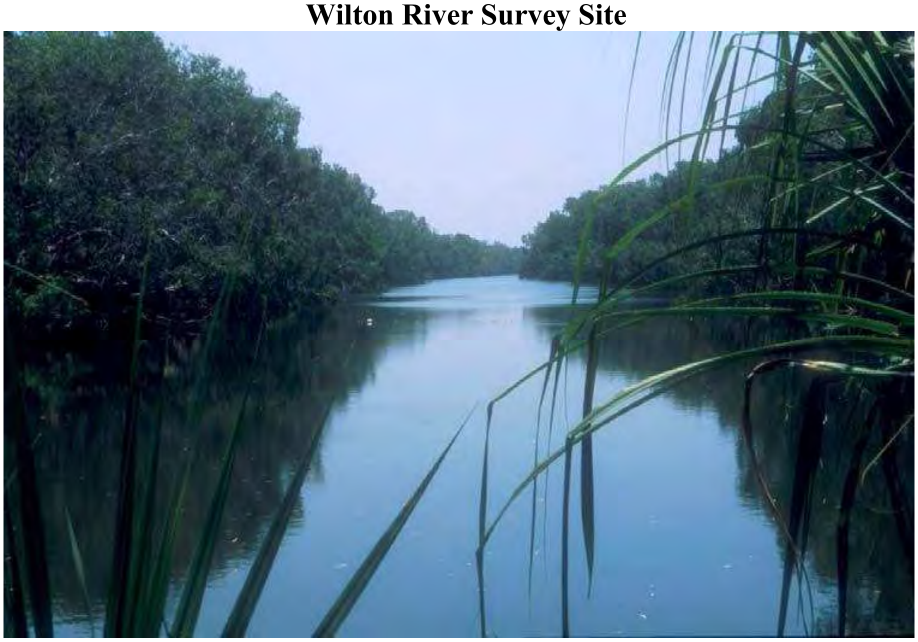
Species	Common name	Source*	Status[#] TPWC	Status[#] EPBC
Glossogobius giurus	Flathead Goby	Fish Atlas		
Glossogobius sp	Goby	Fish Atlas		
Glossogobius Sp 2	Munro's Goby, Square Blotch Goby	Fish Atlas	DD	
Hephaestus carbo	Coal Grunter	Fish Atlas		
Hephaestus fuliginosus	Sooty Grunter	Fish Atlas, ALA		
Hephaestus jenkinsi	Jenkin's Grunter, Western Sooty Grunter	Fish Atlas		
Himantura chaophraya	Freshwater Whipray	Fish Atlas		
Hypseleotris compressa	Empire Gudgeon	Fish Atlas		
Hypseleotris sp	Golden Gudgeon	Fish Atlas		
Iriatherina werneri	Threadfin Rainbowfish	Fish Atlas	DD	
Lates calcarifer	Barramundi	Fish Atlas, ALA		
Liza alata	Diamond Mullet	Fish Atlas		
Lutjanus argentimaculatus	Mangrove Jack	Fish Atlas		
Megalops cyprinoides	Oxeye Herring	Fish Atlas		
Melanotaenia australis	Western Rainbowfish	Fish Atlas		
Melanotaenia exquisita	Exquisite Rainbowfish	Fish Atlas		
Melanotaenia nigrans	Black-banded Rainbowfish	Fish Atlas, ALA		
Melanotaenia solata	Northern Rainbowfish	Fish Atlas		
Melanotaenia splen. australis	Western Rainbowfish	Fish Atlas		
Melanotaenia splen. inornata	Chequered Rainbowfish	Fish Atlas, ALA		
Melanotaenia trifasciata	Banded Rainbowfish	Fish Atlas		
Melanotaenia sp.	Rainbowfish	Fish Atlas		
Mogurnda mogurnda	Northern Trout Gudgeon	Fish Atlas, ALA	DD	
Nematalosa erebi	Bony Bream	Fish Atlas, ALA		
Neosilurus ater	Black Catfish, Butter Jew, Narrow-Fronted Tandan	Fish Atlas		
Neosilurus hyrtlii	Hyrtl's Tandan	Fish Atlas, ALA		
Neosilurus sp	Catfish	Fish Atlas		
Ophisternon gutturale	Swamp Eel	Fish Atlas		
Oxyeleotris aruensis	Aru Gudgeon	Fish Atlas		
Oxyeleotris lineolatus	Sleepy Cod	Fish Atlas, ALA		

Species	Common name	Source*	Status[#] TPWC	Status[#] EPBC
Oxyeleotris nullipora	Poreless Gudgeon	Fish Atlas		
Oxyeleotris selheimi	Giant Gudgeon	Fish Atlas		
Oxyeleotris sp	Gudgeon	Fish Atlas		
Pingalla sp	Grunter	Fish Atlas		
Porochilus rendahli	Rendahl's Catfish	Fish Atlas, ALA		
Pristis microdon	Freshwater Sawfish	Fish Atlas	V	V
Pseudomugil gertrudae	Spotted Blue-eye	Fish Atlas, ALA		
Pseudomugil tennellus	Delicate Blue-eye	Fish Atlas		
Pseudomugil sp	Blue-eye	Fish Atlas		
Redigobius chryosoma	Spotfin Goby	Fish Atlas		
Scatophagus argus	Spotted Scat	Fish Atlas		
Scleropages jardinii	Gulf Saratoga	Fish Atlas		
Scortum ogilbyi	Gulf Grunter	Fish Atlas	DD	
Selenotoca multifasciata	Banded Scat	Fish Atlas		
Strongylura krefftii	Freshwater Longtom	Fish Atlas		
Syncomistes butleri	Butler's Grunter	Fish Atlas		
Syncomistes sp	Grunter	Fish Atlas		
Thryssa scratchleyi	Freashwater Anchovy	Fish Atlas	DD	
Toxotes chatareus	Seven-spot Archerfish	Fish Atlas		
Toxotes jaculatrix	Banded Archerfish	Fish Atlas		
Zenarchopterus sp	Garfish	Fish Atlas		

Appendix 2 – Photos of Survey Sites

Mainoru River Survey Site

Wilton River Survey Site



Goyder River Survey Site

Rocky Bottom Creek Survey Site

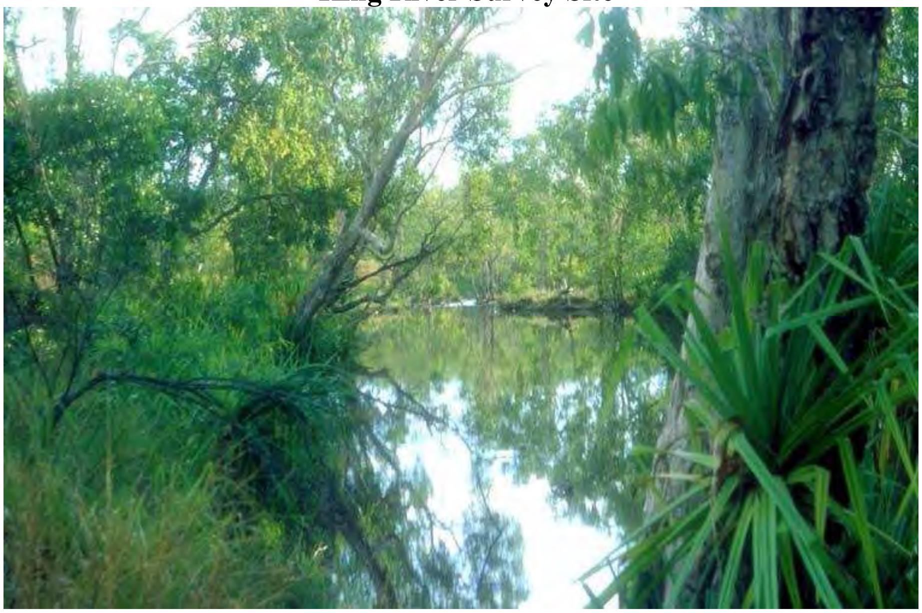
Barmgueikba Creek Survey Site

Chambers River Survey Site

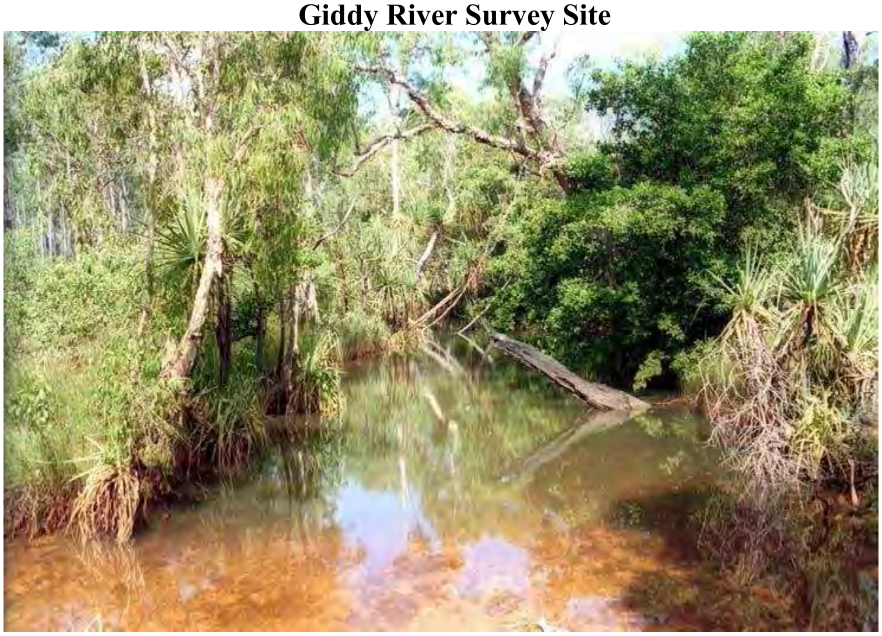
Dook Creek Survey Site

Maiwok Creek Survey Site

King River Survey Site



Giddy River Survey Site



Wonga Creek Survey Site

Cato River Survey Site

Richard River Survey Site

Habgood River Survey Site

Buckingham River Survey Site