Characterisation of the Impacts of Pre- and Post- Remedial Contaminant Loads from Rum Jungle on Riparian Vegetation and Fishes of the Finniss River System

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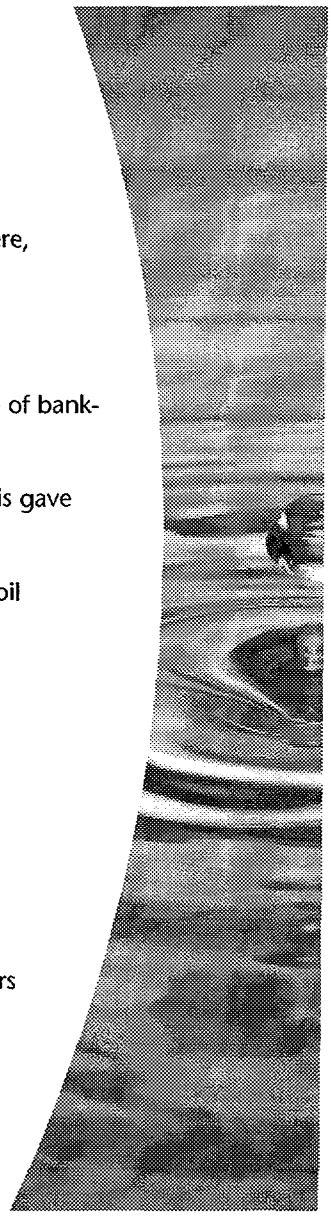
Introduction

The status of the riparian vegetation and fish biodiversity in the Finniss River (FR) system is compared before and after remediation at the Rum Jungle (RJ) mine site with the following datasets:

- Riparian vegetation in the East Branch (EB): (a) still colour transparencies and recorded observations of obvious detriment in 1974 (Jeffree and Williams, 1975, 1980); and (b) aerial photography and quantitative analysis using the E-RMS Geographical Information System (GIS) for the years 1941 (pre-mining), 1963 (during mining), 1978 (post-mining and pre-remediation) and 1990 (8 years after remediation began) (Stratford, 1994).

- Observations in the FR on fish diversity and abundances in pre-remedial (1974) and post-remedial (1992-1995) periods for (a) quantitative abundances of seven species and species groups, based on effort-corrected numbers caught in a suite of enmeshing nets (Jeffree et al., 2001), and (b) presence/absence data for 17 species or species groups caught in the same nets (Jeffree, in prep.).



Riparian vegetation

Whereas observations recorded during pre-remedial field studies in 1974 indicate no obvious effects of mine effluents on the riparian vegetation in the FR, the impacts in the EB were severe, as summarised in the following recorded observations (Jeffree and Williams, 1975, 1980):

- No rooted or submerged plants.
- Live bankside Pandanus were rare, although dead stumps were common.
- Shallow gullying, gently sloping banks and sand deposits were associated with the absence of bank-side roots.

The quantitative analysis of the EBs riparian vegetation by aerial photography and GIS analysis gave the following results (Stratford, 1994):

- Whereas the canopy of riparian vegetation in 1941 virtually covered the EB, areas of bare soil increased by factors of 35 in 1963 and by 47 in 1978.
- Since remediation at RJ there has been some improvement in riparian vegetation as well as reduction in the areas of bare soil, but its factor of increase compared with 1941 was still ca. 30, based on 1990 data.
- Regeneration of riparian species was also observed in the 1994 dry season.

Fish biodiversity

Pre-remedial studies in the FR showed an appreciable decline in fish diversity and abundance for at least 15 km downstream of the confluence with the EB, during dry season sampling (**Figure 1**) and also following the fish-kills observed at the beginning of two wet seasons. Sites in the FR immediately downstream of the confluence with the EB showed lower numbers of species and individuals than those upstream, or further downstream. There was a gradual recovery in both the number of species and individuals in the FR with increasing distance downstream of the confluence with the EB (Jeffree and Williams, 1975).

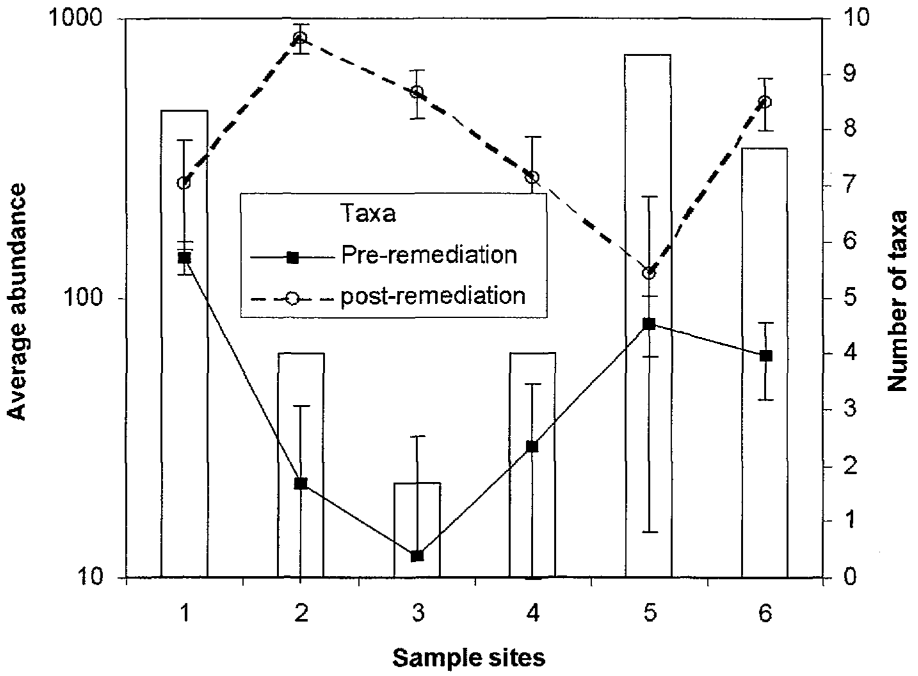


Figure 1. **Accumulated number of total species caught at each site during sampling periods prior to remediation, and average abundances of seven species during pre- and post-remedial sampling (from Jeffree et al., 2001).**

The effects of early wet season 'first flushes' from the EB on the fishes of the FR were also observed during 1973-74 and 1974-75. Fishes were recovered dead or moribund in the FR downstream of the EB junction (a) over a river length of 500 m during 1973-74 and (b) over a total distance of 4 km from observations made at points of access along the river. Following remediation at RJ, that began in 1981-82, the following changes to contaminant delivery to the FR were measured; (a) reductions of in situ contaminant water concentrations of various contaminants at the time of fish samplings in the dry season, and (b) reductions in annual-cycle contaminant loads of sulfate, Cu, Zn and Mn by factors of 3-7. Also, under intense observation, there was no fish-kill in the FR during the 1997-98 'first flush' (Jeffree et al., 2001).

The effects of varying pre- and post-remedial contaminant loads on the relative abundances of seven fish species were determined by non-metric multidimensional scaling, in combination with cluster-analysis and other non-parametric statistical techniques. These analyses showed that:

- Prior to remediation, the impacted region of the FR in 1974 showed significantly ($P < 0.001$) dissimilar and more heterogeneous fish communities, generally characterised by reduced diversity and abundance (cf. **Figure 1**), compared to sites unexposed to elevated contaminant water concentrations.
- Post-remediation, fish communities from the impacted region in both 1992 and 1995 were not dissimilar from those sampled at either contemporary ($P = 0.16$) or pre-remedial unimpacted sites, indicating their recovery. The species most important in discerning between samples from pre-remedial impacted sites and all others is shown in **Table 1**.

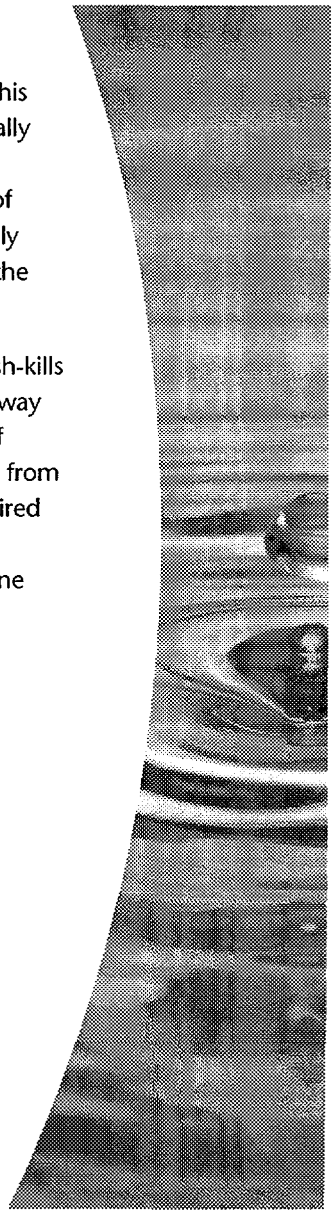
Table 1. *Average abundances of fish species and their percentage contribution to average dissimilarity measures between samples from pre-remedial impacted sites and all other samples (from Jeffree et al., 2001)*

Fish species	Average abundances		% contribution to
	Impacted, pre-remedial sites	All other sites	average dissimilarity
Nematalosa	3.1	216	28.2
Neosilurus	1.4	30.3	20.7
Amniataba	0	4.3	11.3
Megalops	12.9	30.3	10.8
Toxotes	0	5.8	10.0
Black bream	0.3	3.8	9.6
Melanotaenia	5.7	2.4	9.5

Comparable results were obtained from a similar set of analyses conducted on the presence/absence of 17 species or species groups (Jeffree, in prep.), that included the newly discovered species, and possibly new genus, of freshwater Teraponid (H. Larson, pers. comm.).

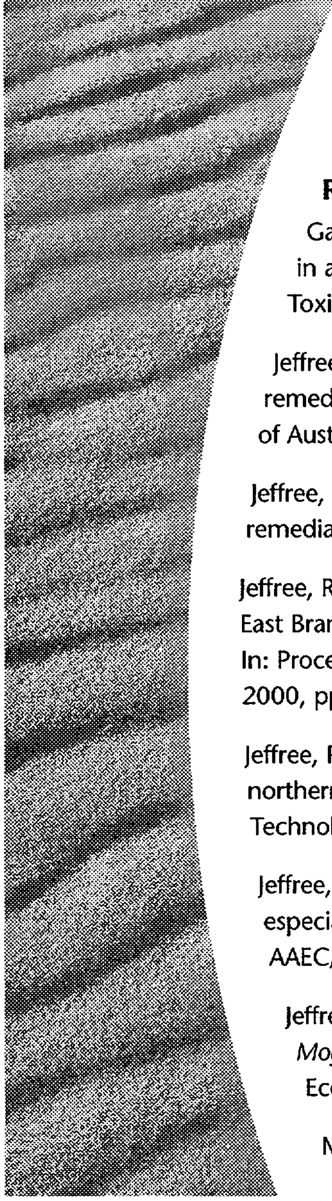
Even though considerable contaminant loads are still being delivered to the impacted region of the FR over the annual cycle, the recovery in fish abundance and biodiversity is consistent with:

- Reductions of in situ contaminant water concentrations at the time of fish sampling.
- Reductions in annual-cycle contaminant loads of sulfate, Cu, Zn and Mn by factors of 3-7.
- Greatly reduced frequencies of occurrence and magnitude of elevated contaminant water concentrations over the annual cycle, that was most pronounced for Cu.
- The absence of extensive fish-kills during the first-flushes of contaminants into the FR at the beginning of the wet season, that were observed prior to remediation.



The post-remedial recovery of fish biodiversity in the FR, as determined by two measures of community structure, indicates that mine site remediation has been of ecological benefit to this tropical freshwater system. The recovery in the FR, where no post-remedial impact is statistically discernible, is consistent with the post-remedial annual contaminant loads being ecologically sustainable by this aquatic system, as measured by fish biodiversity. Moreover, the presence of freshwater bivalves (*Velesunio angasi*) in the impacted region of the FR, that extend in age only back to the end of the remedial period (1986) (Markich et al., 2002), is also consistent with the post-remedial loads being ecologically sustainable.

If our interpretation of the major mechanism of detriment to fish biodiversity is correct, viz fish-kills during the 'first flush', then the temporal pattern of contaminant delivery to the FR, and the way remediation has greatly modified this pattern, are also important factors in the observation of sustainability in the face of still considerable annual contaminant loads. The broader message from these findings is that an understanding of the mechanism of detriment to biodiversity is required to more cost-effectively design remedial programs at mine sites, so as to reap the greatest ecological benefits (Jeffree, 2001). Similarly, the tolerance to Cu that has been measured in one fish species (Gale et al., submitted) suggests the possibility that the exposure of the fish community to contaminant loadings over more than four decades may have led to the development of tolerance that may also contribute to the ecological recovery that has been observed.



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