internal report **443**

Monitoring of impacts of Ranger Uranium Mine on fish communities in shallow lowland billabongs in 2002

B Pidgeon, D Buckle,
C Humphrey, J Boyden
& R Luxon

June 2003

supervising scientist

Monitoring of impacts of Ranger Uranium Mine on fish communities in shallow lowland billabongs in 2002

B Pidgeon, D Buckle, C Humphrey, J Boyden & R Luxon

Environmental Research Institute of the Supervising Scientist
GPO Box 461, Darwin NT 0801

Registry File No. sg2001/0187

Australian Government
Department of the Environment and Heritage
Supervising Scientist

Contents

Monitoring of impacts of Ranger Uranium Mine on fish communities in shallow lowland billabongs in 2002

B Pidgeon, D Buckle, C Humphrey, J Boyden & R Luxon

Introduction

Shallow lowland billabongs and channel billabongs downstream of Ranger Uranium Mine (RUM) potentially can receive and accumulate mine related waste substances. The shallow billabongs are technically lagoons formed by levees at the confluence of the main creek channel with side streams. They receive water from the main channel at high (main channel) flows and flow back to the main stream at lower flows and hence are also termed back-flow billabongs. Some of these water bodies are important sources of food for traditional owners of the area as well as acting as dry season refuges for fish. Consequently, there is the potential for either direct toxicity (low risk) or bioaccumulation of wastes, especially metals, in these organisms and subsequent adverse effects on populations of some aquatic species. The risk of transfer of contaminants to human consumers, however, is regarded as small (Humphrey and Dostine 1994). It is likely that bioaccumulation would be a gradual process over many years and adverse effects on animal populations may occur only after harmful levels have been reached. Monitoring for detection of long-term effects on fish communities in these habitats is, therefore, important for the assurance of environmental health and management of the RUM.

Research by ***eriss*** on monitoring of fish communities in lowland billabongs began in 1979. Initially gill nets and seine nets were used for sampling. However, following the removal of feral water buffalo from the area during the mid 1980's these techniques were rendered ineffective in the shallow lowland billabongs due to increases in aquatic plant density (Pidgeon & Humphrey 1991). The composition of species in the fish community was also altered by the vegetation change and some larger growing fish species were excluded from the shallow reaches of billabongs where buffalo once wallowed and fed. This situation made it necessary to develop different methods for sampling fish in dense vegetation. After trialling a number of possible techniques, "pop-net" traps were found to be the most effective in shallow water and this technique is now used for monitoring this habitat.

The numbers of fish of different species present are used to determine the differences in fish communities amongst the billabongs and the change in fish communities over time. Natural changes are distinguished from change caused by mining or other human activities by: (1) the comparison of control sites (with no possible contamination from mining) with exposed sites (potentially exposed to mine wastes) and (2) the use of chemical and physical water parameters and a set of habitat structure variables as potential covariates of the fish community structure. Multivariate statistical analysis is used to compare the sites over time and to identify any environmental variables that correlate with the difference between sites and with any temporal changes in community structure.

The sampling technique – Pop-net traps

A quantitative sampling technique for monitoring fish communities in shallow billabongs has been developed using a trapping device called a "pop-net". The procedure has proven to be cost effective and to provide adequate representation of fish community structure in the shallow margins of the billabongs. Pop nets are essentially a trap that is set on the bottom within submerged vegetation and is manually triggered to suddenly enclose an area of vegetation from the bottom to the surface. Fish trapped within this enclosure are then removed by drag nets after first removing the vegetation.

The pop-nets used by ***eriss*** consist of a square wall of fine mesh netting (1.0mm diameter) attached to a bottom frame (2m x 2m) of heavy steel and a floating top frame of foam filled PVC pipe. The bottom frame also has chain attached and together these hold the trap wall on the bottom of the billabong while the floating frame holds the net wall on the surface. The top frame can be held on the bottom by Velcro straps wrapped around the bottom frame, net wall and top frame. In that arrangement the pop net is placed within the vegetation at randomly located sites at a suitable depth (<1.0m). The net is left overnight and the following morning the Velcro straps are released by pulling long ropes which are attached to them and extend to near the shore. The net rises quickly to the surface and encloses the vegetation and fish within an area of 4 m^2. Next the vegetation is removed by hand and collected for measuring its composition and biomass. The absence of vegetation then allows the fish to be collected using a fine mesh drag net which is used repeatedly until no more fish are collected. The fish are kept alive, identified and counted and then released.

As the operation of the pop net involves operators standing in the water there is a potential risk to operators from crocodile attack. Attempts have been made to modify procedures to minimise that risk. New safety procedures were trialled in the 2000 sampling operation. These procedures involve the use of barrier nets to exclude crocodiles from an area around the traps. The equipment and techniques have been further refined during 2001 and 2002. The use of an Argo amphibious vehicle has greatly assisted the deploying of the crocodile nets in a relatively safe manner. Review of safety procedures is ongoing and other refinements for safety will be included as they are identified. It is, however, important that the basic sample procedure remains unchanged to allow continued valid comparison with earlier data. The use of the crocodile nets has significantly increased the time involved in the sampling making it difficult to sample more than two billabongs in one week.

Monitoring design

Following some technique development in 1992 and 1993, monitoring of fish communities in shallow billabongs with pop-nets began in 1994. The billabongs studied included control sites on catchments not associated with RUM, and sites potentially exposed to mining waste. Initially ten lowland billabongs, were chosen for the monitoring program (Table 1). Sites potentially exposed to the uranium mine in the Magela Creek catchment included Georgetown, Djalkmara and Coonjimba adjacent to Ranger mine and Gulungul and Corndorl Billabongs well downstream below the water quality compliance point at the end of the Ranger mine lease. Djalkmara billabong is no longer studied as it is now isolated from Magela Creek by the operation of Ranger Pit No. 3 and will soon disappear. Gulungul Billabong, and to a much lesser extent Corndorl Billabong, may also be influenced from waste arising from the Jabiru township. Consequently, Baralil Billabong is included in the design to act as the control for effects of Jabiru town because it is exposed to the township but not to the mine. Buba and Sandy Billabongs, located in the Nourlangie Creek catchment of the South Alligator River system, act as controls, as does Winmurra billabong on the Wirnmuyurr Creek tributary of the Magela Creek floodplain and Cathedral Billabong on an un-named tributary of the East Alligator River (Fig.1). Whilst the structure of fish communities changes naturally, both seasonally and from year to year, an impact of the mine would be inferred when the fish community in an exposed site changed in a different manner to control sites and/or the sites well downstream from the mine.

For logistic reasons Corndorl, Sandy, Winmurra and Cathedral billabongs have been omitted from the study in some years.

Table 1 Catchment and function of different lowland billabong sites used for monitoring effects of Ranger Uranium Mine

Function	Catchment	Site Name
Control	Nourlangie Creek	Buba Billabong
"	Nourlangie Creek	Sandy Billabong
"	East Alligator River	Cathedral Billabong
"	Magela Creek	Winmurra Billabong
Exposed to mine - adjacent	Magela Creek	Georgetown Billabong
"	Magela Creek	Djalkmara Billabong
"	Magela Creek	Coonjimba Billabong
Exposed to mine and Jabiru town - downstream	Magela Creek	Gulungul Billabong
"	Magela Creek	Corndorl Billabong
Exposed to Jabiru town	Magela Creek	Baralil Billabong

Sampling strategy

Bishop et al (1990) demonstrated considerable seasonal variation in fish community structure in lowland billabongs. As a result, measurements made at different seasons in the year cannot be used to obtain temporal replication for statistical inference in monitoring. Consequently, the sampling is carried out only once per year at the end of the Wet season in May when the billabongs become accessible by land. Other rationale for this timing are:

- Resident fish population abundances can be measured more effectively as emigration and immigration from Magela Creek has ceased;
- Cumulative effects of any release of mine water during recent wet season should be apparent (Humphrey et al. 1990);
- Earlier studies suggest that at this time fish species richness and abundance are greatest (Bishop *et al* 1990);
- Environmental conditions can be more readily standardised from year to year.

At each billabong ten pop-net samples are taken in water less than 1.0 m deep. Preliminary analysis of these data indicated that ten samples are adequate to detect most of the species present and for distinguishing fish community structure differences amongst billabongs.

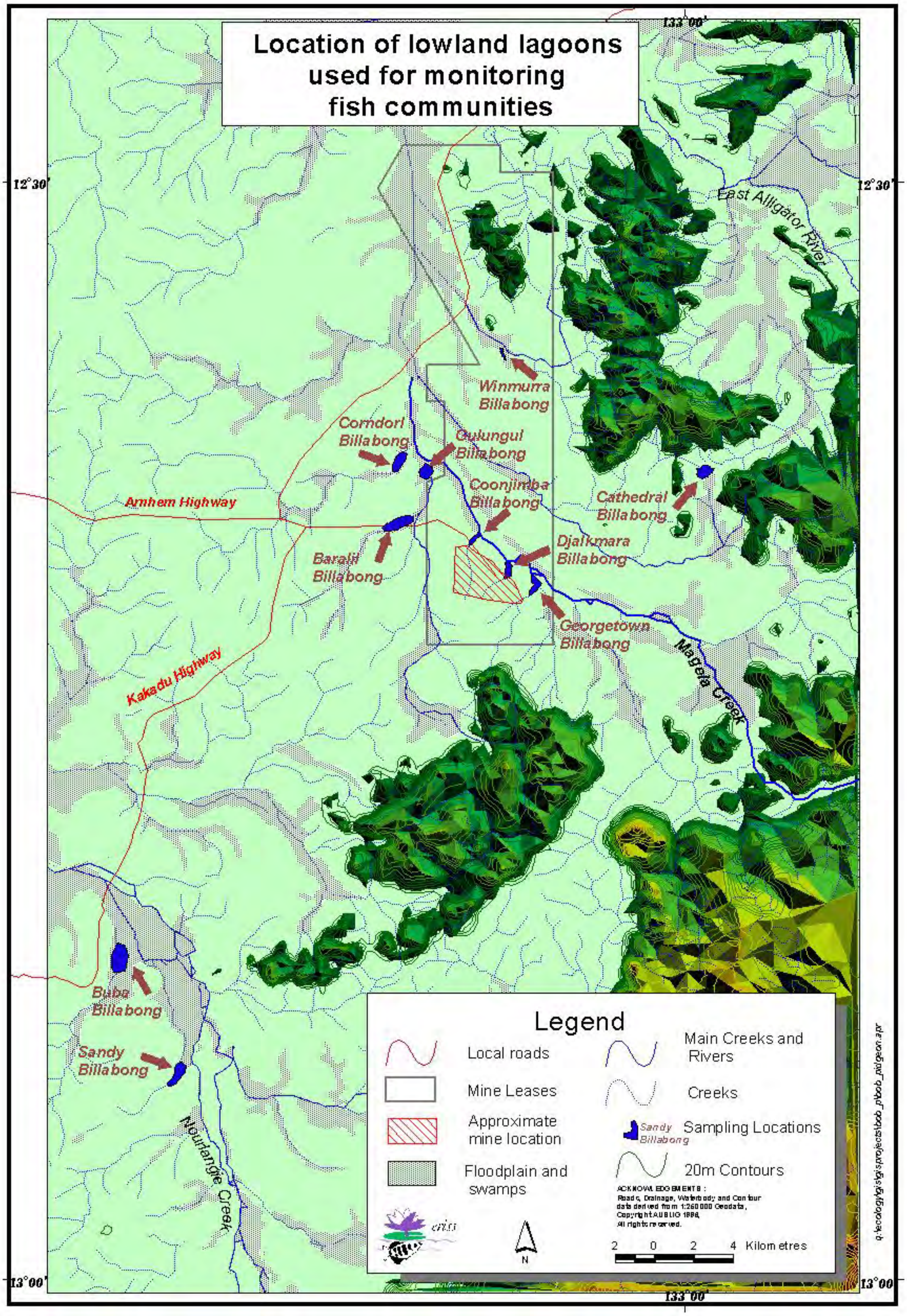

Figure 1 Location of shallow lowland billabongs used for monitoring fish community structure

General fish community structure in shallow lowland billabongs

The pop-netting procedure samples the shallow margins of billabongs that are typically densely vegetated. This habitat is characteristic of large areas of many of these billabongs and the fish community inhabiting it is dominated by smaller-growing species. The other habitat that influences fish occurrence is the area of open water. This habitat allows larger and more active fish species to inhabit these billabongs. As the amount of open water varies enormously among billabongs and between different years, the relative abundance of these larger-growing fish would also change. The pop-net program does not attempt to sample this, presumably more variable, component of the fish assemblage in shallow billabongs.

The average composition of the fish community sampled over all sites and all years (1994-2002) is shown diagrammatically in Table 2. This shows that 3 small-growing species, sail-fin perchlet (na-rranggi), Pennyfish (na-rranggi) and chequered rainbowfish (Dilebang), comprise around 80% of all fish in the shallow margins. Six other small-growing fish make up a further 9%. Nine species of larger-growing fish have been captured over the five year period and together these make up only 11% of the total. The most abundant of these larger-growing fish, Rendahl's catfish (Binjdjarrang), is not really very large (up to 25 cm long) and comprises 5% of the fish community.

Table 2 Composition of fish fauna sampled in shallow billabongs by pop-nets from 1994 to 2002

Common name	Gunjehmi name	Scientific name	Percentage of total catch
*Small fish**			
Sail-fin perchlet	Na-rrangi	Ambassis agrammus	48.14%
Penny fish	Na-rrangi	*Denariusa bandata*	21.66%
Chequered rainbowfish	Dilebang, Dohlbo	*Melanotaenia splendida inornata*	10.85%
Dwarf gudgeon	?	*Oxyeleotris nullipora*	2.54%
Fly-specked hardyhead	Dilebang, Dohlbo	*Craterocephalus stercusmuscarum*	2.05%
Delicate blue-eye	Dilebang, Dohlbo	*Pseudomugil tenellus*	1.97%
Black-striped rainbowfish	Dilebang, Dohlbo	*Melanotaenia nigrans*	1.70%
Spotted blue-eye	Dilebang, Dohlbo	*Pseudomugil gertrudae*	0.21%
Carp gudgeon	Bigodjmalemale	*Hypseleotris compressus*	0.14%
Total small fish			**89.26%**
*Large fish***			
Rendahl's catfish	Binjdjarrang	*Porochilus rendahli*	5.00%
Mouth -almighty	Na-rrangi, Djabelh	*Glossamia aprion*	2.31%
Sleepy cod	*Djurludj*	Oxyeleotris selheimi	1.84%
Purple-spotted gudgeon	Djagolk, Gomboh	*Mogurnda mogurnda*	0.71%
One-gilled eel	?	*Ophisternum gutterale*	0.54%
Hyrtl's catfish	Binjdjarrang	*Neosiluris hyrtlii*	0.17%
Spangled grunter	Burd	*Leiopotherapon unicolor*	0.11%
Salmon catfish	Gonggonj, Al-makkawarri	*Arius leptaspis*	0.02%
Saratoga	Yinmamarra, Guluibirr	*Scleropages jardinii*	0.02%
Total large fish			**10.72%**

* 'Small fish' are those species typically growing to <10cm; ** 'Large fish' are those growing to > 10cm

An illustrated list of fish sampled from pop-nets and their various names (Gunjeihmi, common English and scientific names) are shown in Appendix 1.

Monitoring results for 2002

Personnel

It is important to compress as much as possible the time taken to sample all the billabongs in order to minimise the risk of changes in fish communities that might occur from natural temporal effects during the sampling period rather than mining activities. In order to do this, a team of at least 8 people is required each day to operate the sampling protocol. In 2002 the following people were involved in this work: Duncan Buckle, Rob Luxon, James Boyden, Bob Pidgeon, Matt Daniel, Don Elphick, Alistair Cameron from ***eriss***; Colin Liddy, Wilson Douglas, Andrew Moore, from Gunjehmi Aboriginal Corporation; Alex Mountain and Emlyn Samuel from Conservation Volunteers Australia; and also Paul Stevens, Brett Payne, Warren Baird, Rocky Cahill, Lassymn Shiosaki and Anthony Sullivan from the Jabiru area.

Fish abundance and species diversity

The average number of species present over the sampling period(1994-2002) is quite similar in all billabongs and has ranged from 8.7 in Coonjimba to 11.6 in Buba Billabong (Table 3). Species richness (number of species sampled) in different years is shown in figure 2. These graphs show there has also been little variation in species richness from year to year and no evidence of a decline over time in any of the billabongs close to the mine. An exception to this was a decline by 50% at one control site, Sandy Billabong, in 2002 and in Corndorl Billabong, well downstream from the mine, in 1996 and 2002. It is difficult to explain this change in Sandy Billabong. However, in Corndorl Billabong it is most likely related to the much lower numbers of fish sampled (Fig. 3). Corndorl has usually been the last billabong sampled each year. In 2002 this was in early June, nearly four weeks after the first billabong, and by then the water levels had declined to levels that made sampling difficult. This situation was the combined result of an early end to the Wet season rains in 2002 and a more protracted sampling period (caused by the new safety procedures). Consequently, the validity of the data for Corndorl in 2002 is questionable. If the lower than normal fish catch in Corndorl was related to mining effects it would be expected that this would be repeated in other billabongs upstream and closer to the mine. This did not occur and provides support for attributing the low Corndorl catch to natural causes.

In contrast to species richness, there is considerable variation in average fish abundance among different billabongs (Table 3). Values range from an average of 7.1 fish /m^2 in Cathedral Billabong to 31.4 fish/m^2 in Winmurra. There is also considerable year to year variation in total abundance of fish sampled in different years in most billabongs since 1994 (Fig. 3). With the exception of Coonjimba Billabong, the temporal pattern of change in abundances in billabongs downstream from Ranger mine has been quite similar indicating a quite uniform response of the fish communities in these water bodies to inter-annual variation in environmental conditions. One of the control sites, Sandy Billabong, also displays a similar temporal pattern to the Magela sites indicating that the variation observed is related to natural environmental factors and is not related to mining activity.

However, the temporal pattern in the other control site, Buba Billabong, is more similar to that in Coonjimba Billabong where similar low abundances have been observed amongst years (Fig. 3).

The low number of fish observed in these billabongs could significantly influence the temporal pattern displayed here. It is, however, possible that these differences in fish abundance are related to some natural differences in environmental factors such as hydrological regime, water quality (especially dissolved oxygen) and vegetation patterns. This possibility will be examined by further analysis of environmental and habitat data for these waterbodies. It is certainly not possible at this stage to ascribe the different temporal pattern and lower abundance in Coonjimba Billabong to an effect of mining activity.

Table 3 Average species richness (number of species) and average total abundance of all fish species in different billabongs between 1994 and 2002

Billabong	**Average species richness (no. spp.)**	**Average total abundance (no./m²)**
Coonjimba	8.67	7.9
Cathedral	9.00	7.1
Corndorl	9.29	23.1
Djalkmara	9.33	17.7
Georgetown	9.43	16.9
Baralil	9.88	22.4
Winmurra	10.25	31.4
Gulungul	10.89	14.2
Sandy	11.00	16.7
Buba	11.57	10.1

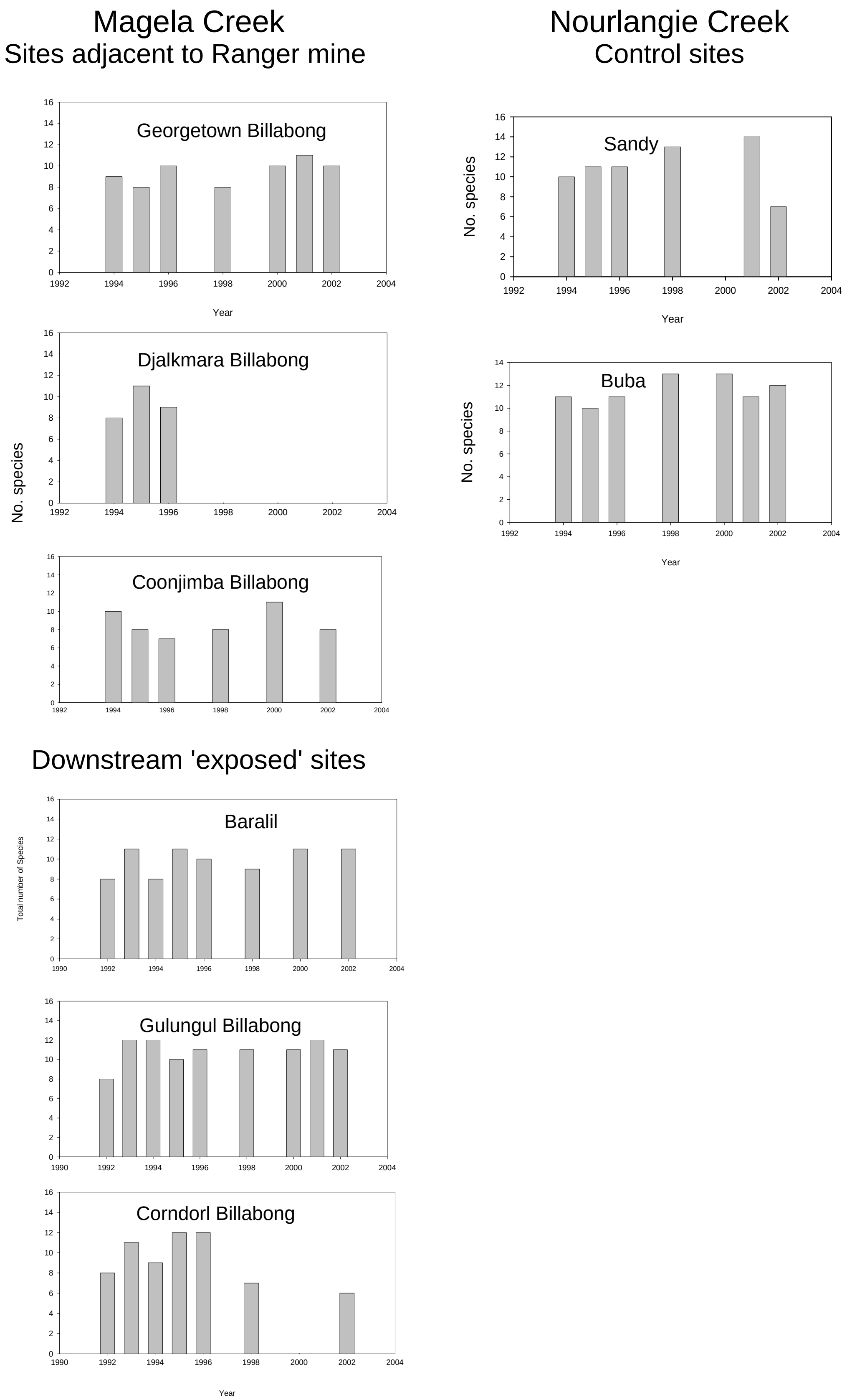

Figure 2 Fish species richness (number of species) in shallow billabongs in Magela Creek exposed to Ranger mine and in billabongs on control streams

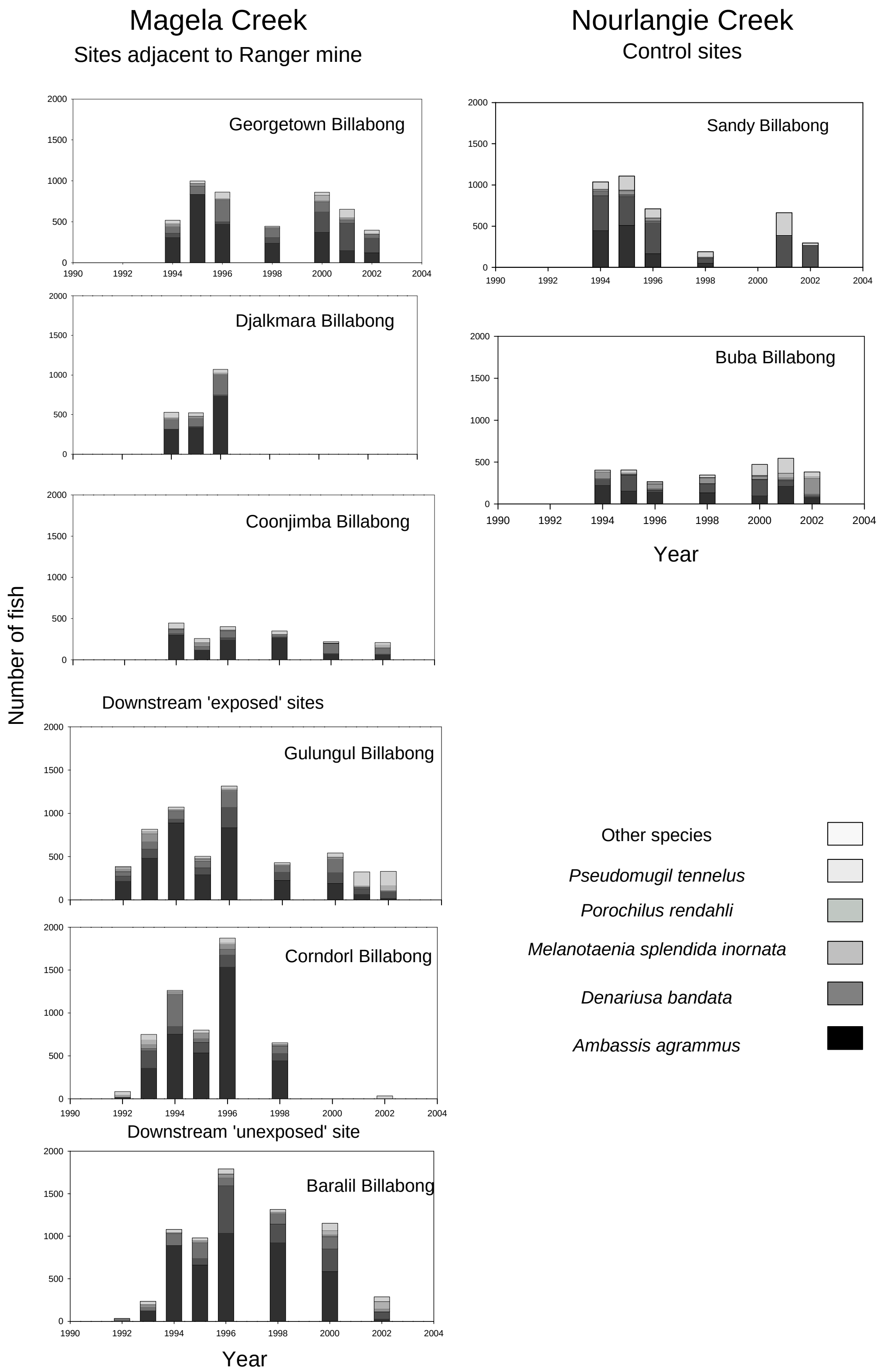

Figure 3 Abundance of fish in shallow billabongs in Magela Creek exposed to Ranger mine and in billabongs on control streams

Shading indicates the relative abundance of the 5 most abundant species. Fish numbers are the total catch per billabong (no./40m^2).

Fish community structure

Impacts on community structure can occur without changing the species richness and overall abundance. This may happen in situations which cause change by depressing population abundances of only some of the species and/or enhancing those of others. However, such changes can also occur naturally and the challenge for monitoring is to distinguish natural and unnatural changes of this kind.

In this program it is assumed that the natural processes that operate to cause these changes apply equally to both control and exposed (potentially impacted) sites and, consequently, changes in fish community structure should be similar in the two groups. Consequently, an impact might be inferred when the control and exposed sites change in different ways. Multivariate analysis was used determine whether such changes have occurred.

Multivariate pattern analysis can be used to calculate a measure of the similarity of one sample of a community with another based on the species present and their abundance. When changes occur, this measure then allows us to determine how large the change has been over time. It can also indicate whether this change is a result of natural processes, or not, by seeing if similar changes have occurred in control sites.

The measure of similarity of the fish community between pairs of sites was the Bray-Curtis index of *dissimilarity*. This ranges in value from 0 (identical) to 1 (totally different). Figure 4 plots changes over time in the index of dissimilarity between the two control sites on Nourlangie Creek, Buba Billabong and Sandy Billabong. This shows that there has been a quite consistent difference between the two fish communities until 2002 when the difference increased substantially. The latter was probably related to the inexplicable reduction in species richness in Sandy Billabong in 2002.

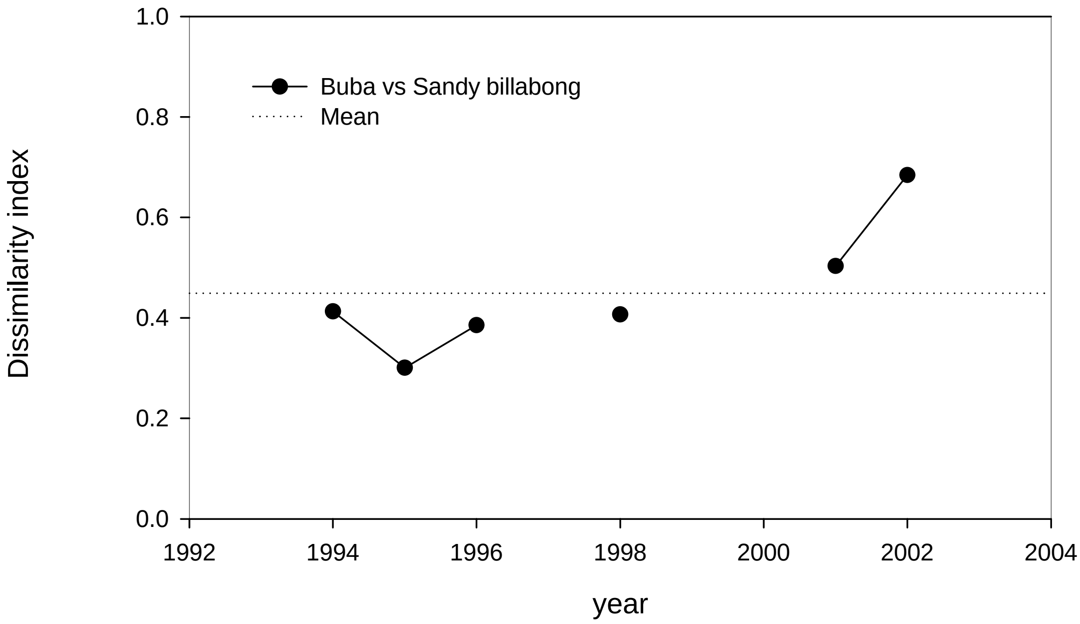

Figure 4 Dissimilarity index comparing the fish communities in two control sites on Nourlangie Creek, Buba and Sandy billabongs

The data for the two control sites were combined and used for comparison with six Magela Creek sites. The temporal pattern of the resulting dissimilarity shows that the difference between the control and exposed sites has remained fairly constant and around the same level as that calculated between the two control sites. The exception to this was Corndorl billabong where there was a large increase in the dissimilarity in 2002 which is probably related to the very low fish catch in that year.

The conclusion from this analysis is that, apart from the spurious result for Corndorl in 2002, there have been no significant differences between control and exposed sites in the year to year variation in their fish community structure (abundance of different species).

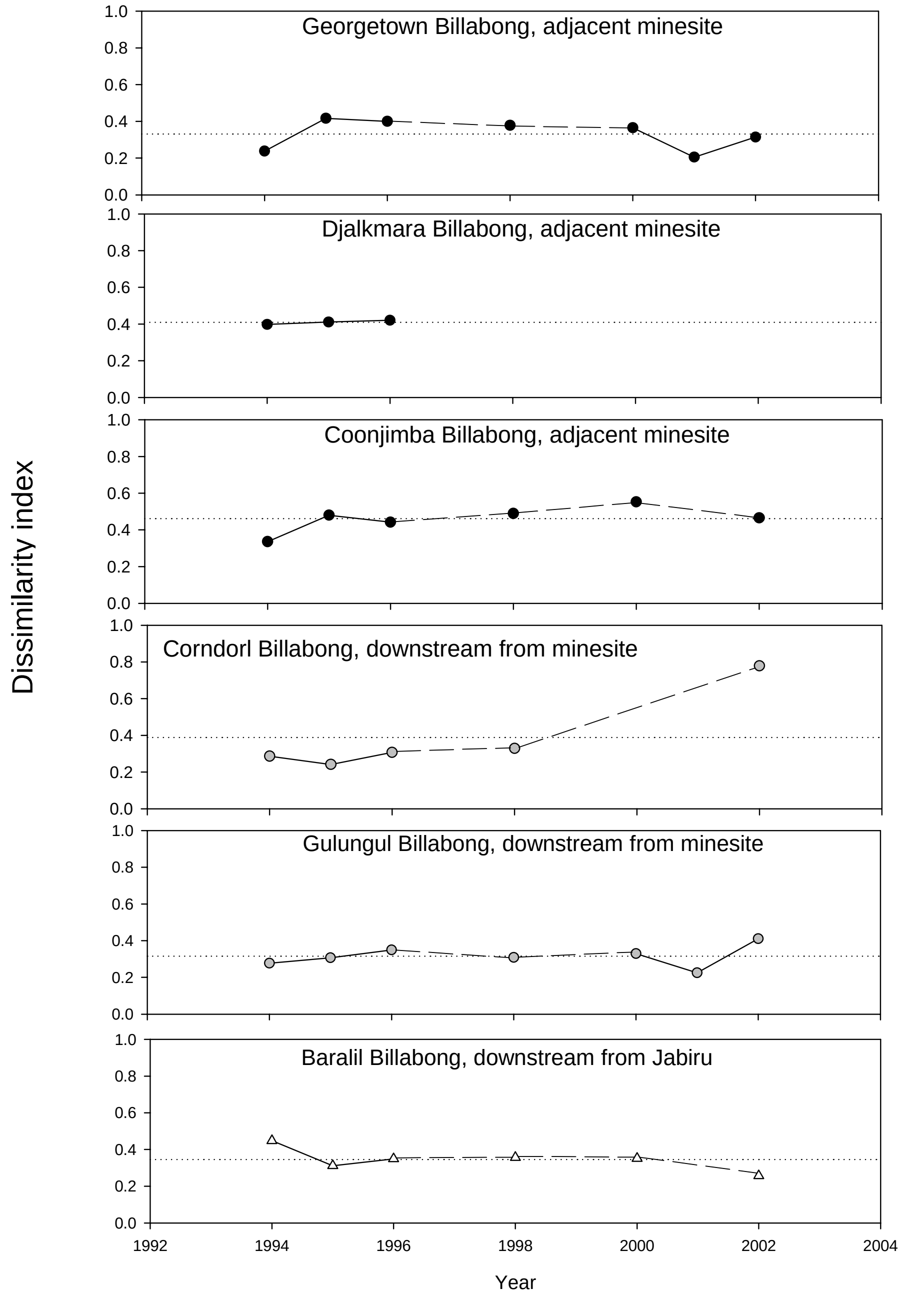

Figure 5 Dissimilarity index for fish communities of shallow billabongs on Magela Creek around Ranger Uranium Mine compared to the average of two control sites (Buba and Sandy Billabongs) on Nourlangie Creek

The dissimilarity index was also used in ordination pattern analysis to illustrate the relationships of the different fish samples by their position in "multi-dimensional ordination space". The more similar samples are, the closer together they are in this space. This technique was used to examine how the fish community structure has changed since mining at Ranger began. The patterns of relationships between sites for data collected in 1978, one year prior to mining, using gill nets and seine nets (Bishop et al 1990) is compared with the patterns derived from data collected by pop-nets in the periods 1993 to 1996 and 1998 to 2002. The control site on Nourlangie Creek in 1978 was Anbangbang Billabong. The control site for subsequent years was Buba Billabong. The results are shown in figure 7 where the sites are designated by three treatment types: *Control* (Buba), *Exposed* sites adjacent to the mine (Georgetown, Coonjimba and Djalkmara) and *Unexposed* sites downstream from the mine (Gulungul and Corndorl)[1]. The 1978 data included all the fish species in the billabongs and not just that component living in the vegetated littoral margins that is sampled by pop-net traps. Nevertheless, the three time periods show a very similar pattern of relationships between the fish communities in the different treatments.

There would be some evidence of mining impact in the Magela billabongs if, during mining, the 'exposed' sites were well separated from both the Magela 'unexposed' sites and the 'control' site relative to their respective positions in the ordination prior to mining. However, patterns shown in figure 7 suggest little change has occurred over the 24 year period. In particular the 'exposed' and 'unexposed' sites on the Magela have maintained a similar 'ecological distance' over time. If substantial mine-related effects were evident it would be expected that there would be divergence of these two groups in the ordination space over time. In support of the absence of such an effect, the mean dissimilarity index between exposed and unexposed sites for the three time periods (1978, 1993-96 and 1998-02) are near constant at 0.247, 0.275 and 0.269 respectively.

The lack of significant change in the ordination pattern before and after mining commenced indicates that the structure of the fish communities is more influenced by natural environmental factors than by effects of mining activity. These results provide reasonable assurance that changes to water quality downstream of Ranger as a consequence of mining in the period 1979 to 2002 are not sufficient to have resulted in major changes to fish communities.

Conclusions about impacts

Whilst there are no significant differences among lowland billabongs in their fish species richness, there are natural differences in their total fish abundance and the relative abundance of different species. These differences have been quite consistent over time providing a good basis for detecting adverse impacts of mining activities by Ranger uranium mine.

The comparison of univariate and multivariate measures of fish community structure in control and exposed billabongs showed no evidence of adverse effects of Ranger mine activities.

---

[1] In earlier phases of mining it was assumed most contaminants would enter Magela Creek via creeks and billabongs adjacent to the mine on the west bank of Magela Creek and very little via Gulungul Creek. Consequently Gulungul billabong would have received contaminants mainy by backflow during flood events and so would have lower exposure than billabongs adjacent to the mine. More recently there is concern about possible direct contamination via Gulungul Creek which would place Gulungul Billabong at risk of higher contaminant levels than Corndorl Billabong. The term 'unexposed' is no longer appropriate.

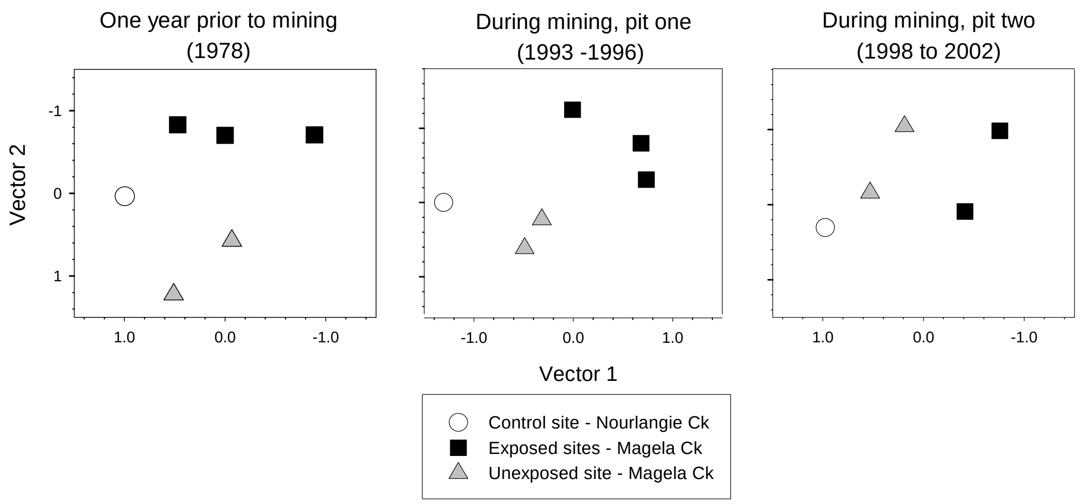

Figure 6 Ordination analysis of fish community structure at different phases of mining at Ranger

Exposed sites are those adjacent to the mine; Unexposed sites are well downstream from the mine

Future plans for the program

The pop-net procedure continues to be an OH&S concern in relation to exposure of personnel to risk of crocodile encounter. The present use of barricade nets and an amphibious all-terrain-vehicle for their deployment appears to provide reasonable safety for operators. Further improvements to safety procedures may be evaluated and included in the future.

The increased time of the sampling procedure resulting from the enhanced safety procedures remains a problem as it extends the duration of the sampling period at a time when water levels are rapidly declining. In 2003 organisation strategies to enable the sampling of at least 3 billabongs per week, instead of only two as in most of the 2001-02 sampling, will be attempted.

Acknowledgements

The pop-net procedure requires input in the field from a lot of people each year. ***eriss*** would like to thank people from Gunjehmi Aboriginal Corporation, Gagadju Association and Conservation Volunteers Australia who have assisted in this program in this and previous years. We are most grateful for their contribution to the work and the pleasure of their company in the field.

Special thanks to James Boyden who was involved in this program for the last time in 2002. James has been involved in the pop-netting project since its beginning in 1992 and has played a major role in the development of all aspects from field sampling to data analysis and reporting. His effort is greatly appreciated and his experience, advice and humour will be missed in future years.

References

Bishop KA, Allen SA, Pollard DA & Cook MG 1990. *Ecological studies on the freshwater fishes of the Alligator Rivers Region, Northern Territory. Volume II Synecology*. Research report 4 (ii), Supervising Scientist for the Alligator Rivers Region, AGPS, Canberra.

Humphrey CL & Dostine P 1994. Development of biological monitoring programs to detect mining waste impacts upon aquatic ecosystems of the Alligator Rivers Region, Northern Territory, Australia. *Proceedings of Conservation and Management of Tropical Inland Waters: Problems, Solutions and Prospects,* Conference. University of Hong Kong. *Mitteilungen Internationalis Vereinigung Limnologiae* 24, 293–314.

Humphrey CL & Dostine P 1994. Development of biological monitoring programs to detect mining waste impacts upon aquatic ecosystems of the Alligator Rivers Region, Northern Territory, Australia. *Proceedings of Conservation and Management of Tropical Inland Waters: Problems, Solutions and Prospects*, Conference. University of Hong Kong. *Mitteilungen Internationalis Vereinigung Limnologiae* 24, 293–314.

Humphrey CL, Bishop KA & Brown VM 1990. Use of biological monitoring in the assessment of effects of mining wastes on aquatic ecosystems of the Alligator Rivers Region, tropical northern Australia. *Environmental Monitoring and Assessment* 14, 139–181.

Pidgeon R & Humphrey C 1991. Structure of fish communities in billabongs for detection of longer-term effects in Magela Creek. *Annual Research Summary 1990-91*. Supervising Scientist for the Alligator Rivers Region, AGPS, Canberra.