internal report 425

Sampling and design options for monitoring freshwater fish: Potential strategies for the Darwin Harbour catchment

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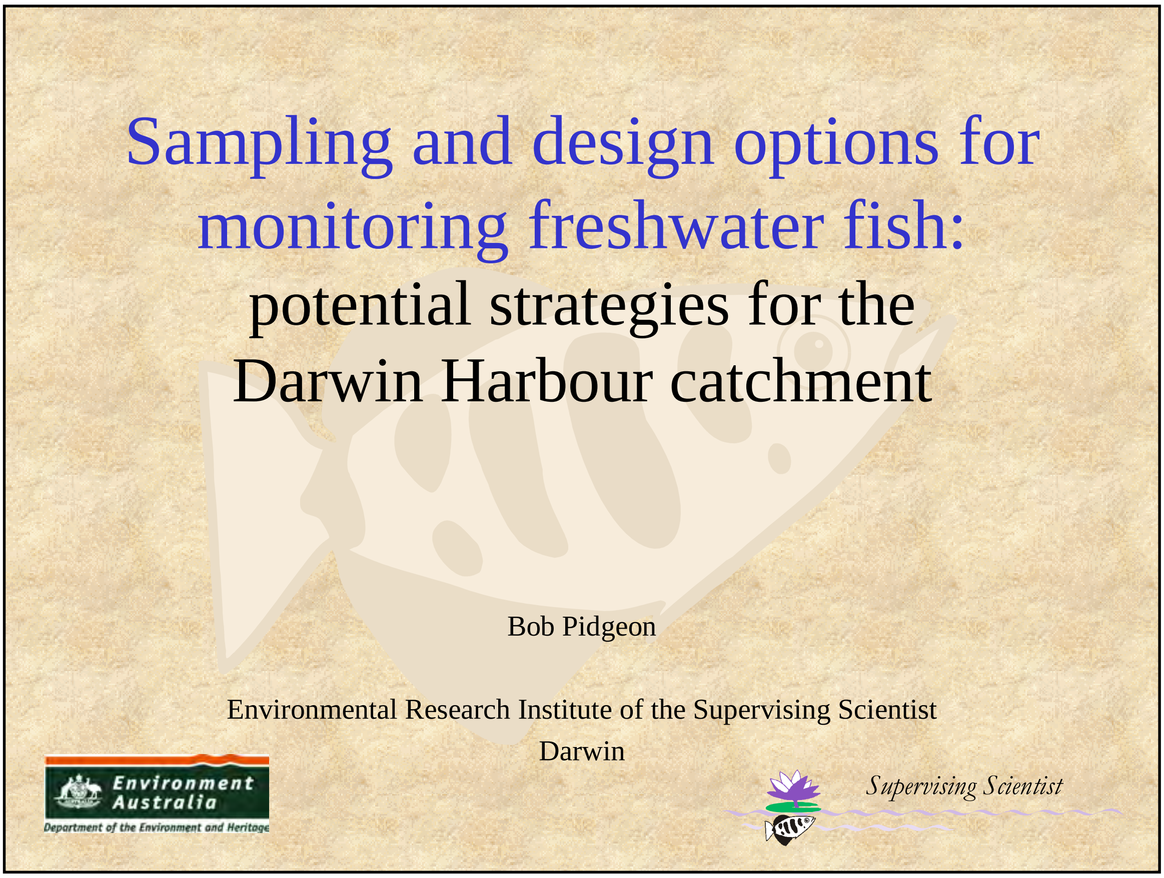
supervising scientist



This talk was presented to the Department of Infrastructure, Planning and Environment, Water Monitoring Branch, in May 2003. It deals with the options for monitoring of freshwater fish in the Darwin Harbour catchment as part of a comprehensive environmental management program for Darwin Harbour being planned by DIPE. It accompanies a report prepared as part of a consultancy by the Environmental Research Institute of the Supervising Scientist to the Department of Infrastructure, Planning and Environment, June 2003.

Background

- Plans by DIPE to begin monitoring freshwater fish as part of a comprehensive environmental management strategies for Darwin Harbour catchment
- Why monitor fish?
  - Important role in determining structure of aquatic ecosystems
  - Sensitive to pollution, habitat change and altered hydrology – useful indicators of ecosystem health
  - High profile of conservation of biodiversity and food and recreation values
  - Concerns about contamination and human health

Freshwater fish monitoring in the NT

- Not widespread
- Most extensive studies are in relation to uranium mining:
  - in Magela Creek & South Alligator River -Ranger mine;
  - Finnis River - Rum Jungle mine
- Taxonomy is now well known and basic biology and ecology known for many species – good basis for use in monitoring and assessment*
- Fisheries research focused on barramundi

*The research on fish ecology and reproductive biology by the Office of the Supervising Scientist in 1978-79 (Bishop et al 1986, 1990 & 2002) provides a good basis for the evaluation of impacts on freshwater fish that might be detected in monitoring programs.

Advantages of monitoring fish

- Relatively small number of species – only 20-30 at one location, often less
- Most species easy to identify*
- Little laboratory time involved in processing samples
- Large body size of many is useful for sampling tissue for levels of contaminants

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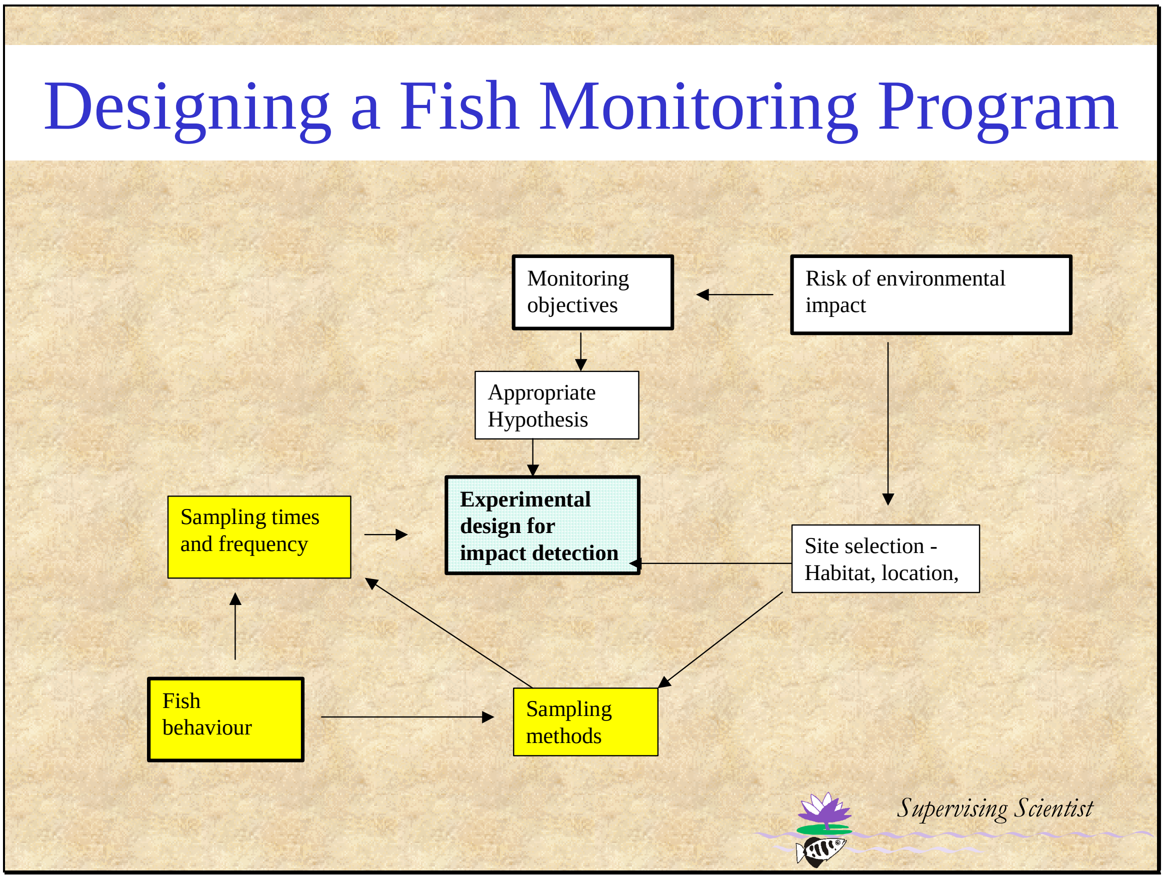
* There is little difficulty in identifying larger individuals of most species. However, the juveniles and smaller sizes of some species groups can be difficult to separate. This can be a problem when a number of these species are known to occur in the one river system. The main groups where this problem occurs are the eel-tailed catfish (*Neosiluris* and *Porochilus* spp) and some rainbowfish (*Melanotaenia splendida* sub spp, *M. australis and M. solata)*.

Disadvantages of monitoring fish

- Mobility - movement along waterways means different locations cannot be strictly independent in statistical analyses
  - upstream-downstream comparison invalid
  - Control sites should be on different stream systems
- Mobility makes capture difficult→ many different sampling methods
  - **Sampling bias** in most methods
- Schooling- can result in species being under-represented
- Natural Fish kills – common in NT & potential confounding effect for impact detection



The experimental design of a fish monitoring program is a result of the interaction of a number of different influences. The most important drivers are the behaviour of the fish and the perceived sources and scale of risk of environmental impacts.

The latter determines both the objectives of the monitoring program (and appropriate hypothesis to be tested) and the selection of habitats and sites that are important to monitor.

Fish behaviour can have a major influence on the capture methods necessary to sample them and on the appropriate times and frequency to sample.

The final experimental design will consider these parameters in a model that can test the hypotheses posed. Power analysis can be used to evaluate the level of effects that can be detected by the model.

Risk of environmental impact on fish in Darwin Harbour catchment

- Risk Level is related to the extent of industrial and urban development and hence, proximity to Darwin and Palmerston.
- Water bodies could be classified into risk categories as different treatment levels in the experimental design. Four levels are suggested

4. Very high risk -	Darwin/Palmerston urban industrial streams and wetlands
3. Moderate-high risk	Inner rural areas – Howard river and Elizabeth river
2. Moderate –low risk	Outer rural areas – Darwin River and Blackmore River
1. Low risk	Remote rural areas – Small streams on Cox Peninsula, Gunn Point Peninsula, and Charlotte and Annie Rivers (Bynoe Harbour)

Whether this scheme is appropriate or not would be determined from more detailed knowledge of the developments in each catchment and the habitats present in the waterways. This knowledge would help in the identification of any potential point sources of impacts for consideration in the experimental design. Nevertheless, it will be important to identify any potential control streams that could be used in any design for a long term monitoring program. The low risk streams may be suitable for that purpose.

Monitoring objectives of a fish monitoring program

- Environmental protection - not fishery management
- Biodiversity conservation and ecosystem health
  - Fish community structure indicators
  - Species of conservation significance (not an issue for DH)
  - Measures of fish health
- Human health protection
  - Levels of contaminants in fish tissues

Fish species in NT museum records for Darwin Harbour catchment

Freshwater species	Catadromous or estuarine vagrants	Feral species
Ambassis agrammus		*Gambusia holbrooki*
A. Mulleri	**Catadromous species**	*Osphronemus goramy*
A. macleayi	*Lates calcarifer*	*Poecilia reticulata*
Denariusa bandata	*Meglops cyprinoides*	*Xiphophorus sp*
Craterocephalus stercusmuscarum		*Hemichromis bimaculatus*
Amniataba percoides	**Marine vagrants**	
Leiopotherapon unicolor	*Elops hawaiiensis*	
Hypseleotris compressa	*Hemigobius hoevenii*	
Mogurnda mogurnda	*Mugilogobius filifer*	
Oxyeleotris lineolata	*Mugilogobius wilsoni*	
Oxyeleotris selheimi	*Prionobutis microps*	
Oxyeleotris nullipora	*Pseudogobius sp2*	
Melanotania splendida inornata	*Pseudomugil cyanodorsalis*	
M. splendida australis	*Redigobius chrysoma*	
M. nigrans	*Scatophagus argus*	
Pseudomugil tennellus	*Selenotoca multifasciata*	
Pseudomugil gertrudae		
Strongylura krefftii		
Toxotes chatareus		
Nematalosa erebi		
Neosiluris hyrtlii		
Neosiluris ater		
Ophisternon gutterale		
Glossamia aprion		
Glossogobius giuris		
25 species	***12 species***	***5 species***

Notable absenses from this list of freshwater species are fork-tailed catfish (*Arius* spp), eel-tailed catfish of the genus *Porochilus* and sooty grunter (*Hephaestus fuliginosus*). This may be related to small catchment size of most streams. However, more intense sampling may find some of these species present. Sooty grunter are notoriously diffcult to catch in nets.

Measurable indicators of impacts on fish

- Biodiversity measures
  - Loss of species – decline in species richness
  - Decline in abundance
  - Change in community structure indices (based on relative abundance of species)
- Fish and human health indicators
  - Increase in disease indicators, decline in condition factors
  - Elevation of tissue concentration of contaminants (pesticides, metals, others)

Monitoring locations

- Major types of freshwater bodies are sufficiently different in structure to expect that their fish communities would also differ.
- Within each type some habitats that may require sampling by different methods
- *ephemeral wetlands* - difficult to monitor in a predictable manner.
- *medium sized rivers* Blackmore River, Darwin River, Elizabeth River and Howard River
- *small seasonal creeks* that discharge directly into the harbour
- *lagoons*, especially in the Howard River catchment - vary in the degree to which they dry out
- *extensive coastal wetlands* - Howard River only!

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Habitats

- Major habitat features influencing fish are water depth, the density of woody debris and aquatic vegetation.
- Sampling should include the range of habitats at a site
  - Streams - deep pools, shallow riffles and runs
  - Lagoons – littoral zone and open water if present
- These features also affect the performance of different sampling methods.

- Data on habitat parameters can be important covariates for distinguishing natural and anthropogenic causes of change in fish communities

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Sampling methods

Passive methods

- Gill nets
- Trammel nets
- Fish traps
  - Fyke nets
  - Trap nets
  - Minnow traps

Active methods

- Seine/Drag nets
- Trawls
- Electrofishing
- Poisons
- Visual census
- Pop-nets
- Drop and throw traps
- Cast net

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Passive methods are those that utilise the movements of fish tocatch themselves. They normally provide only catch per unit effort data unless a trap-out procedure is used.

Active methods persue the fish to capture them or otherwise detect their presence and identity (eg visual census and sonar). They can usually provide data on catch per unit of habitat (area or volume).

Gill netting

Pop-nets

You don’t need this!

Seine netting

Selection of sampling methods

- Most important decision for biodiversity measures
- Change of methodology can be costly – can invalidate temporal comparisons
- Most methods selective in size and species sampled
- Combination of methods is often used to maximise species array
- However, different methods may provide data in different measurement units – ecological relevance of combined datasets may then be limited
- OH&S, animal experimentation ethics and government regulations may also influence choice of method

Fish numbers detected by different sampling methods in Jim Jim Creek

Scientific Name	Gill-netting	Seine-netting	Visual count*
Neosilurus ater	92	0	25
Nematalosa erebi	76	0	6
Syncomistes butleri	24	0	35
Megalops cyprinoides	29	0	0
Scleropages jardini	27	0	0
Anodontiglanis dahli	25	0	44
Neosiluris hyrtlii	22	0	5
Hephaestus fuliginosus	5	0	38
Arius leptaspis	4	0	0
Lates calcarifer	3	0	11
Toxotes chatareus	4	0	0
Arius midgleyi	1	0	0
Pingalla midgleyi	64	2	45
Leiopotherapon unicolor	45	5	28
Amniataba percoides	122	17	45
Strongylura kreffti	23	1	2
Ambassis macleayi	8	5	0
Glossamia aprion	5	1	1
Melanotaenia splendida inornata	62	376	289
Craterocephalus marianae	0	2313	439
Melanotaenia nigrans	0	321	106
Craterocephalus stercusmuscarum	0	261	267
Ambassis agrammus	0	34	24
Glossogobius giuris	0	18	0
Mogurnda mogurnda	0	3	1
Pseudomugil gertrudae	0	3	7
Denariusa bandata	0	0	1
Total No. of Species	**19**	**14**	**20**

*only made before road opened

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This dataset shows fish sampled by 3 different methods in Jim Jim Creek near Jim Jim falls in Kakadu National Park. The gill nets and seine net procedures caught a very different array osf species. The visual count included species captured by both the other methods but did not detect the entire array of species present. Whilst the combination of gill nets and seine nets provided a reasonably comprehensive list of species combining data from the two methods as an indication of relative abundance requires rigid application of a standard sampling effort at each sampling to enable comparison between sites and times.

Recommended fish sampling methods for different habitats in Darwin Harbour catchment

Habitat	Deep open water	Bank Edge (root mat, debris, undercut)	Shallow open water	Shallow water macrophytes
Main-stem river	+	+	+	+
Small stream	?	+	+	
Lagoons	+		+	+
Sampling technique	Gill net or Electrofishing	Seine (scoop method) or Electrofishing	Seine, electrofishing	Seine, dredge or trawl; electrofishing

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Electrofishing is now one the most widely used methods for sampling freshwater fish for both biodiversity and population measurements. It involves the use of pulsed electric current to temporarily immobilize fish enabling their capture with a hand net as they come to the surface, or to cause fish to swim along a directional field towards one electrode (galvanotaxis) where they can be captured by a hand net.

Advantages: Can provide estimates of density. Can capture a wide range of fish sizes but catch biased towards larger fish. Fish canbe released alive. Relatively short sampling time. Easy to target specific habitats and times. Commercially available.

Disadvantages: Impact on fish unclear. Some evidence of injury to fish. Can be very expensive ($30,000 -$50,000 per unit) but small back-pack units are cheaper ($14,000) and can be hired. Difficult to use in dense emergent vegetation. Effectivesness reduced at very low temperatures and in high and low conductivity waters. Low conductivity can be a problem in the Top End. Boat based units powered by generators are useful only in larger streams and open water lagoons and billabongs. In smaller streams back-pack battery operated units are generally used but this involves entering the water and exposing operators to crocodile risk. Operators need to be well trained in use and safety procedures. High risk of electric shock. The need to wear insulating gloves and waders has the potential to cause rapid weight loss in operators in the tropics.

Variation in pulse structure is required to sample different size fish. The higher frequency required for smaller fish can kill larger fish. Multiple passes through fished areas using different pulse settings can reduce this risk (Pusey et al 1998).

Sampling costs

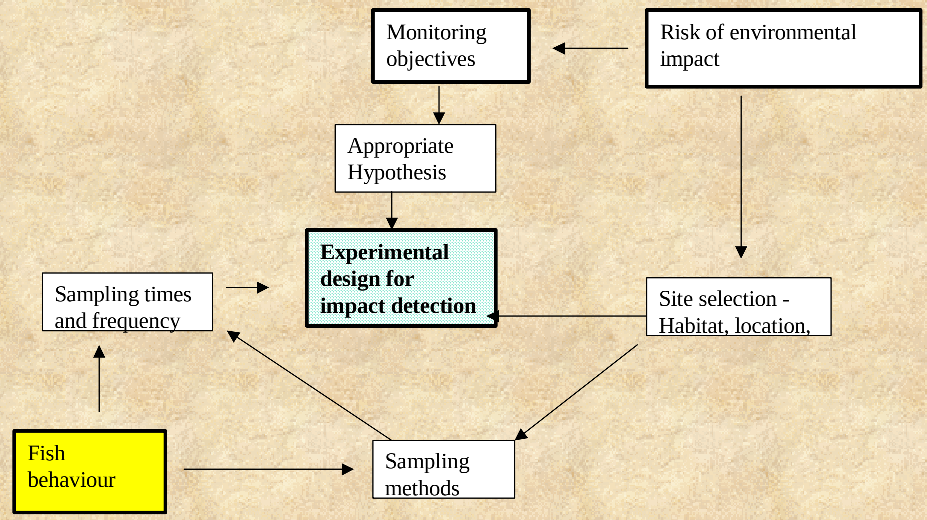
- **Personnel** – minimum of three people in field.
  - **Training** in fish identification and sampling methods

- **Duration of sampling**
  - one site per day with netting option as it includes sampling at diurnal peak of fish mobility after sunset
  - Possibly 2 sites per day with electrofishing

- **Sampling frequency**
  - frequent repeat sampling could adversely affect fish
  - One sampling per year probably sufficient

- **Number of sites**
  - determined by risk assessment, impact detection strategy and funding

Designing a Fish Monitoring Program



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Fish behaviour and sample times

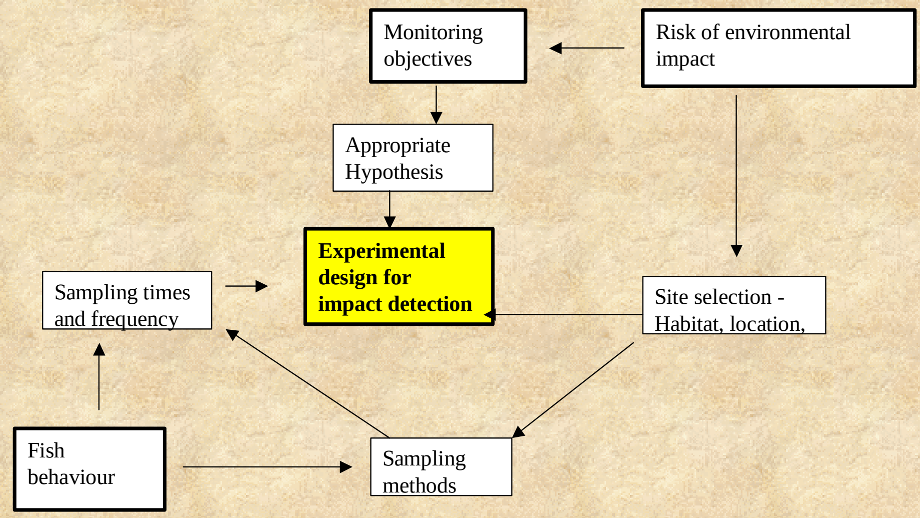
- ***During the wet season*** there is extensive dispersal of fish along river channels and across wetlands. Best, and often only, time to sample many wetlands.

  Access to riverine sites is difficult during wet.

- ***End of wet- early dry season*** - fish diversity is high and access becomes possible. Optimal time for sampling riverine locations

- ***Mid –late dry season*** – fish diversity and abundance declines. Can be relevant time to sample for bioaccumulation of contaminants, but not for biodiversity

Designing a Fish Monitoring Program



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Experimental design and sampling program

- Design based on method of impact detection
  - ➢ **Control chart** approach – acceptable level of change
  - ➢ **Indicator species** approach - Not developed in Australia for fish
  - ➢ **Change in community indices**, preferably in comparison to reference (control) sites eg BACI designs
- Inclusion of **control** sites/streams if possible is very beneficial
- **Power analysis** of designs after initial sampling help to refine sampling effort and may improve ability to detect change

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Experimental design and sampling program

- Change in community parameters in comparison to reference (control) sites - BACIP designs
  - **B**efore – **A**fter - **C**ontrol –**I**mpact-**P**aired difference
  - Important assumption is that there will always be some difference between any two sites.
  - That difference should remain relatively constant, as both sites should change in same way in relation to natural variation in environmental parameters.
  - Can be used with univariate and multivariate parameters.

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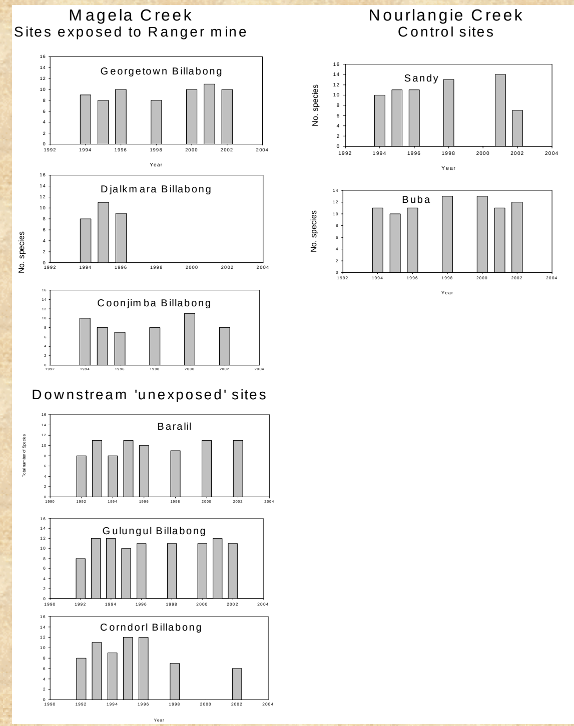
Some examples of the use of fish community structure indices from Kakadu

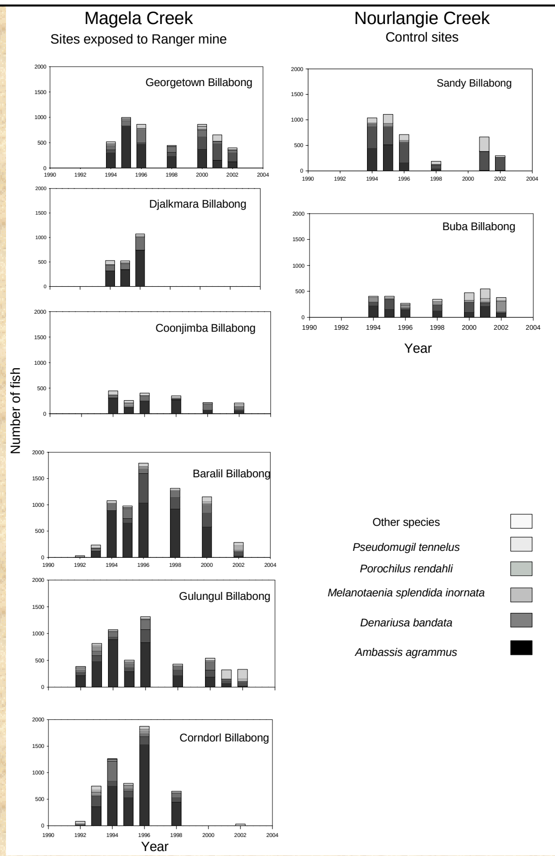
Fish species richness (number of species) in shallow billabongs adjacent to Magela Creek exposed to Ranger mine and in billabongs on a control stream, Nourlangie Creek



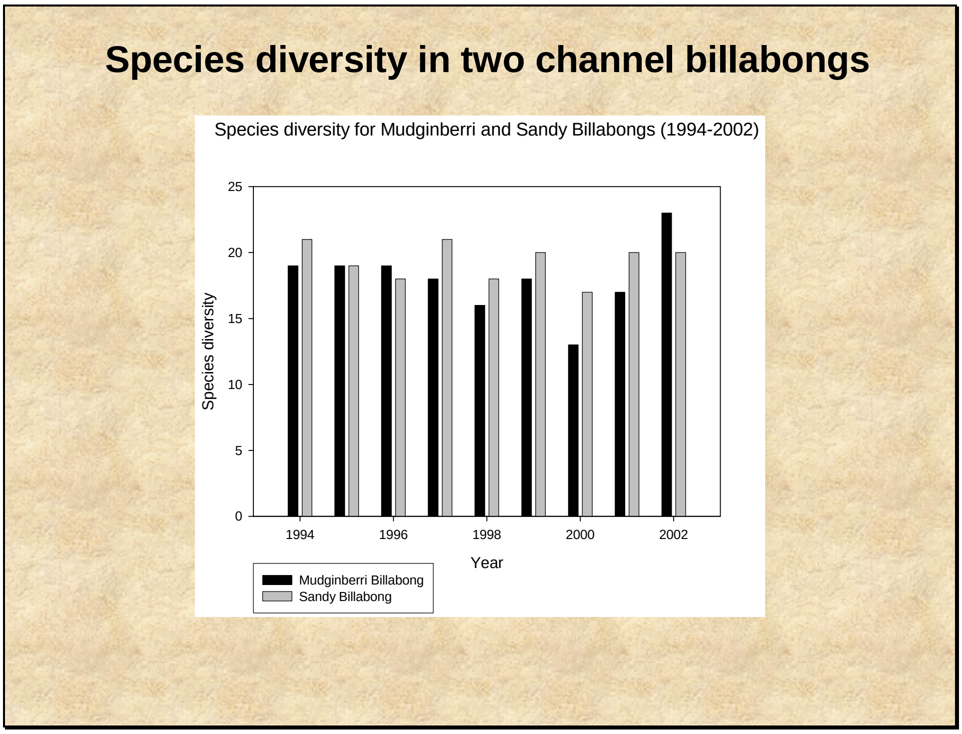
This figure shows the results of smpling fish in shallow billabongs in Kakadu using pop-net traps. There is little year to year variation in fish species richness in each billabong and little difference between billabongs. The decline in Corndorl billabong is probably related to low water levels and the presence of *Salvinia* at the time of sampling.

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

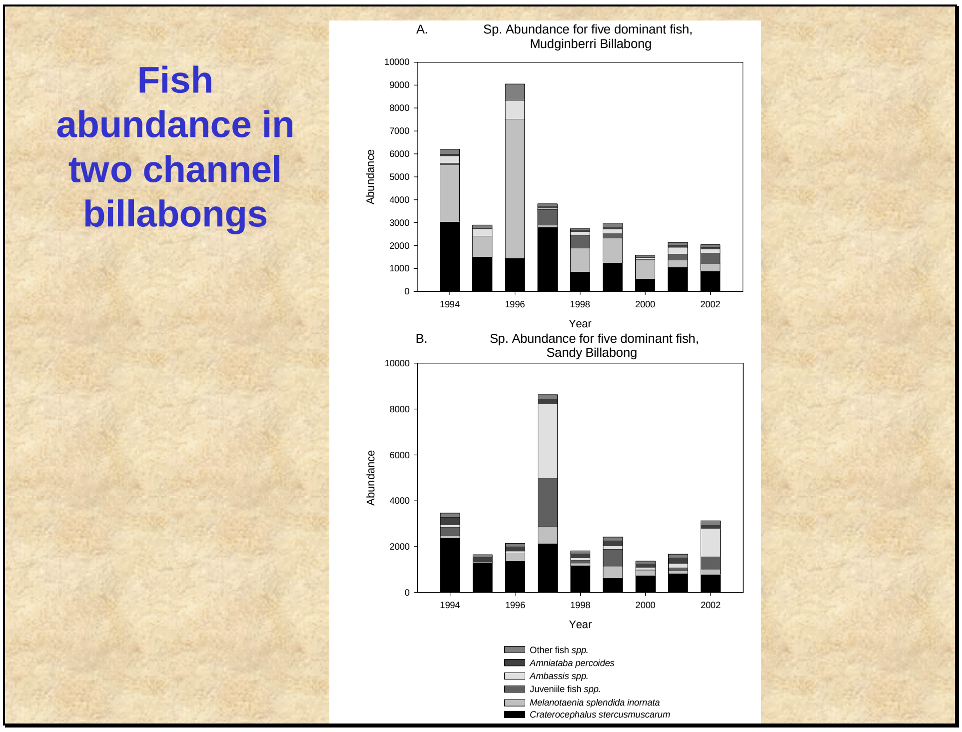
Shading indicates the relative abundance of the 5 most abundant species. Fish numbers are the total catch per billabong (no./40m2).



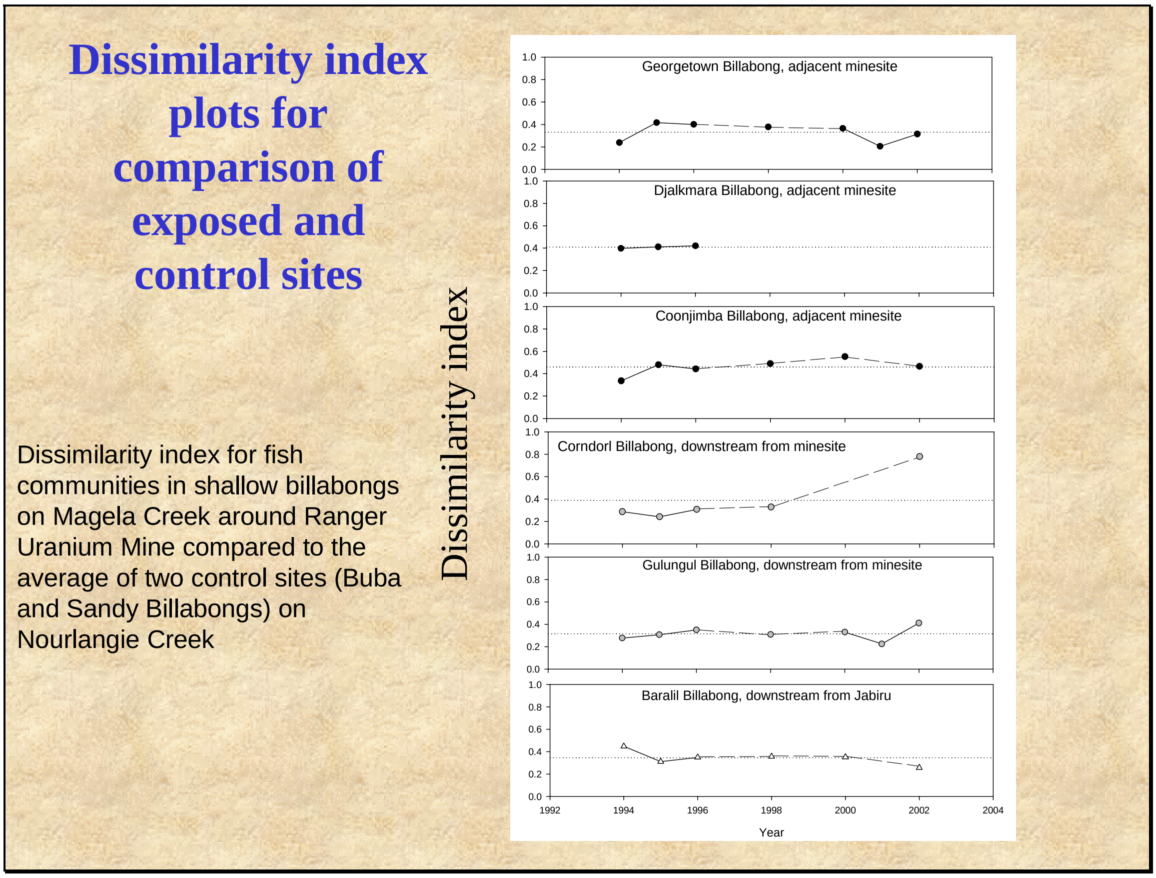
The numbers of fish captured in pop-net traps show a much greater variation from year to year within billabongs than species richness. This has happened in similar ways in control sites as well as sites exposed to mine influence enabling the conclusion that the changes are not related to mining activities.



This figure shows results of monitoring fish by visual sampling in two channel billabongs, Mudginberri on Magela Creek downstream from Ranger mine and a control site, Sandy Billabong on Nourlangie Creek. Like the shallow billabongs shown earlier , there is little varaition in species richness from year to year. Sandy Billabong tends to have a slightly larger species array in keeping with its location on a stream with a larger catchement area.



Fish abundance in channel billabongs has also varied greatly in some years but it is generally more consistant than in the shallow billabongs. However, for some species large changes in their numbers of are not necessarily the same in each billabong.

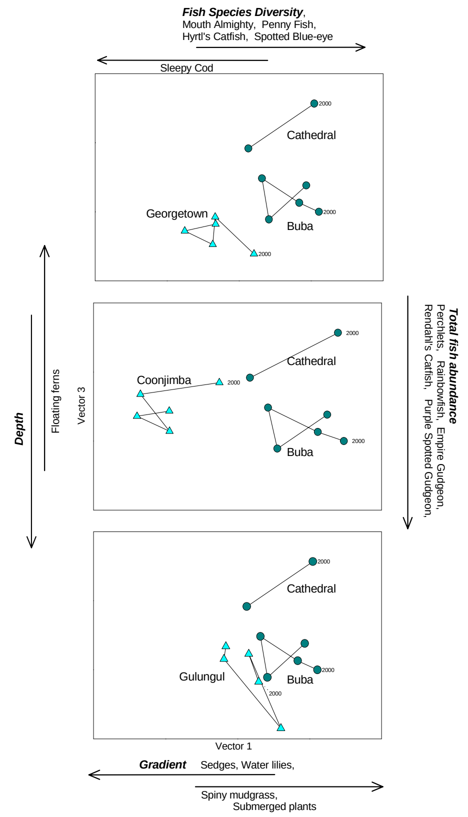


The use of multivariate analysis allows the calculation of measures of the similarity of different species assemblages that can take into account both the presence and abundance of different species. This figure is a plot of Bray-curtis dissimilarity measures between exposed shallow billabongs on Magela Creek and the average composition of the two control sites on Nourlangie Creek. Calculations were based on log transformed abundance data. With the exception of Corndorl billabong, the difference between control sites and exposed sites has remained reasonably constant over the sampling period indicating no detectable effects of mining activities.

There was a large increase in the dissimilarity between the fish communities in Corndorl and control sites in 2002. Corndorl billabong is the most downstream billabong from the mine and would be expected to have lower levels of contaminants (and hence fewer adverse effects) than sites closer to the mine. As mentioned earlier, the recent sampling at Corndorl has been associated with low water levels and the presence of *Salvinia* which may explain the very low numbers of fish present rather than an effect of mine influence.

Patterns of similarity of fish communities in shallow lowland billabongs comparing control sites (Cathedral and Buba) to sites exposed to Ranger Uranium Mine (3 dimensional HMDS ordination).

Lines sequentially join the position of each site in different years (1994 to 2000). Arrows indicate direction of influence of each vector for habitat and fish parameters that are statistically correlated with the ordination patterns.



Ordination analysis the graphic presentation of how similar fish communities are in different samples. The calculations are based on the dissimilarity index and can calculate positions using any number spatial dimensions. The results are easier to view in 2 dimensional plots shown above for fish in shallow billabongs in Kakadu. The closer two points are on this plot the more similar they are.

This figure plots the change in fish communities in each billabong over time. It shows that while the community in each billabong varies from year to year it tends to remain in the same general area of the ordination space calculated for all billabongs together. It would be expected that an impact would cause a significant sustained change to this pattern.

The influence of a range of other environmental variables can also be examined by calculating how well they are correlated with ordination pattern and the direction of their influence. In this figure the different variables that were shown to be significantly correlated with the ordination are shown on each axis together with the direction of that influence.

Conclusion

- A fish monitoring program based on low cost sampling equipment and biodiversity indicators can provide a useful tool for evaluating success of catchment management strategies

- Inclusion of suitable control streams and sites is extremely important

- Inclusion of measurement of bioaccumulation of contaminants will enhance the public assurance of good management.

- Any change to sampling methodology (eg. to electrofishing) should be made early in the development of the program

- Good Luck!