LEBRA METHODOLOGY 2010-2011

1. Indicators: fish, hydrology and water quality

In 2010-2011, the 'no regrets' condition indicators, as chosen by the LEBRA Operations Group and endorsed by the LEB Oversight Group in November 2010, are hydrology, fish and water quality. These include focusing on the fish assemblage set combined with concurrent water quality sampling and ongoing hydrology monitoring as per Kiri-ganai's Implementation Plan. Hydrology monitoring is to be supplemented by the installation of additional water loggers (non-telemetered).

1.1. Draft Hypothesis and Thresholds of Potential Concern (TPC)

The draft hypotheses and TPCs (table below) were developed to help focus the 2011 sampling efforts, on the understanding that:

- they require further refinement and would be subject to change following the 2011 assessment, SAM outputs, and as we improve our knowledge of the LEB system;
- there are limitations to testing these hypotheses due to the fixed nature of the sites (see Sections1.2 and 1.4); and
- some need be more specific and/or rephrased (e.g. specific hypothesis for each fish species).

DRAFT LEBRA HYPOTHESES TABLE		
HYPOTHESIS **A healthy LEB aquatic system has:**	**Informed by:** * = wont be undertaken 10/11	**Possible Threshold of Potential Concern (general)**
Resilient fish populations with regular spawning and recruitment (species specific)	Fish spawning, age to spawning, length data, counts of each species, correlation curve between length and age*, genetic structure endemism*	Regular spawning and recruitment not detected (species specific within it's generation time – noting that spawning and recruitment in a healthy population need not be regular for all species) Loss of endemic fish species from any waterhole/site it was previously recorded
Wide range of fish size classes for each fish species	Fish length data, correlation between length and age*	Fish size is skewed (Species specific – noting that a healthy population could be skewed depending on the time scale and the longevity of the species. Need to check for an even distribution of strong cohorts, to confirm past breeding success and future capacity to respond).
Refugia '**Arks**' where all expected fish species can be found at all times	Fish assemblage data, fish species diversity, hydrology, waterhole persistence	Loss of (or impacts on) 'Ark' refugia
'Disco' refugia where fish populations can build during wet periods	Fish assemblage data, fish abundance, hydrology, waterhole persistence	Loss of 'Disco' refugia Fish not found in a reconnected waterhole after it was once dry (in line with resilience traits)
Periods of flood plain inundation	Hydrology, fish assemblages, event based sampling	Periods without flood inundation exceeds species longevity. Long extended periods (>5years) without flood inundation
Connectivity (in channel) most years	Hydrology, fish assemblages, fish movement tracking	Periods without in channel connectivity exceeds species longevity Systems remain unconnected for more than 2 consecutive years? (based on some zonation)
Rapid recolonisation of dry regions following drought	Fish assemblages	Slow recolonisation rates of dry regions following drought
Connectivity patterns that support slower migrants (i.e. 3 years of in channel flow)	Fish assemblages (long term), hydrology	Less than 3 years of in channel flow
Recovery from fish disease periods	Instances of diseased fish (long term)	Above average increase in the prevalence of disease and presence of new diseases Increase >20% in the prevalence of disease and presence of new diseases, diseases appearing outside on regular occurrence, i.e. after drying
Stable fish sex ratios	Sex of some fish species (where visual estimates are possible)	Fish sex ratios shift significantly, where one sex makes up >75% of population
A range of water quality to support tolerant and intolerant fish species	Water quality, fish assemblages, fish tolerances (EC, oxygen, temp, pollutants)*	Water quality parameters exceed fish species range of tolerance (note that juveniles probably are less tolerant that adults) The ratio of tolerant and intolerant species across the basin shifts significantly? Water quality monitoring detects worsening conditions
Low impact of terrestrial ferals (goats, camels, pigs etc)	Evidence of pugging and compaction of water banks and substrates, water quality, turbidity, damage to riparian vegetation	Increase in damage caused by feral animals and unrestricted stock access
Riverine and floodplain habitat that provide abundant food resources for fish in times of high flood/flow	Habitat characteristics, macroinvertebrates (bycatch)*, food chain isotope study*, fish diet*	Low fish abundance following high/flood flows
Low impact of alien fish	Presence and abundance of alien fish (new, current non-native, red claw etc)	Spreading and increased abundance of alien fish or high relative abundance of alien fish compared to native competitors. Appearance of new invaders
Low impact from cane toads	Cane toad presence/abundance in fish nets or spotted at night	Spreading and increased abundance of cane toads Fish assemblage or abundance changes in habitats where cane toads are present versus those where they are absent

Ark Refugia = Ark refugia, to describe waterbodies where conditions are appropriate for two of each species to survive drought disturbance, and that the resident individuals from a secure, viable complement of males and females in number sufficient to assure that there is capacity for survival, breeding, dispersal and recovery of a population. Ideally, the complement would also preserve most if not all of the regional genetic diversity typical of the species. In wetter areas, or in wet periods, many waterholes may serve as Ark refugia, but during drought, only a very few habitats may be available for all species to survive in. These are critical to protect so that species do not become locally extinct as a result of dry periods or over over-allocation of water resources away from the environment.

Disco Refugia = Disco refugia become active during good times, especially during recovery from drought. They protect fish through dry seasons, but dry out completely during long periods of drought. As such they are waterholes where fish migrate to, access booming resources, meet partners and reproduce to rebuild populations following drought. Disco waterholes are critical to build resilience between drought periods. From McNeil and Schmarr (2011).

Polo Refugia = Harsh waterholes (i.e. very saline) where only a select group of species can tolerate conditions. Most species cannot persist in these habitats during drought, but may be able to move in during wetter periods where water quality may improve due to fresh inflows. These waterholes are very important for those tolerant species that use them as they can build up populations without competition and predation from weaker species.

1.2. Sites

The reference to 'fish sampling sites' includes hydrological and water quality indicator sites.

The Operations Group discussed the merits of the different fish sampling site selection methods and, based on the objectives of LEBRA, decided that random site selection, such as used by the Murray Darling Basin Authority's *Sustainable Rivers Audit*, was not a practical option because it would be too resource-intensive to ensure sufficient statistical power (i.e. to ensure that significant differences could be detected, if they exist). Instead, the preferred option was to select a smaller number of sites based on criteria such as: good spatial distribution in the Basin (stratified sampling, where numbers of sites correspond to environmental or habitat characteristics), against a gradient of identified disturbance (if possible), use of significant/high conservation value sites, permanent as well as temporary waterholes and refugia type (see below hypotheses table for explanation of refugia types). It was also decided that use of a set of 'fixed' sites as well as some 'opportunistic' or 'back-up' sites would provide the most useful information. Due to the 2010-2011 resource constraints limiting sample numbers, only fixed sites were chosen.

The number of sites is limited by the budget (refer to Appendix A for list of sites and Appendix B for map of sites).

In 2010-2011 the fish sites were selected based on:

- Recommendations in Kiri-ganai reports
- Spatial spread and geomorphic diversity where possible (include sampling at representative reaches covering the whole Basin)
- Ability to elucidate the hypotheses
- The refugia type (Ark, Polo or Disco)
- Site permanency.

Sites where only the hydrological (not fish) data are collected were selected depending on where existing gauging stations or data loggers are present.

1.3. Methods

Refer to:

- Appendix C: Proposed Guidelines for Fish Monitoring of the Ops Group Proposal
- Appendix D: Bathymetric survey of waterholes.
- Appendix E: Installation of processing of Data Loggers
- Kiri-ganai 2009 methods report p 46- 52
- *"Martin Thoms, Samantha Capon, Richard Price, Doug Watkins (2009) Lake Eyre Basin Rivers Assessment Implementation Plan Project Milestone 2 Report: Proposed LEB Rivers Assessment Methodology, Table 4.".*

Ideally, sites would be assessed in spring and autumn each year. However in 2011, due to flooding and extended rain periods, some sites planned to be sampled in autumn (May 2011) may not be sampled until spring 2011.

Each site should be sampled at the end of the dry season, to provide maximal detail on refugia and potentially-limiting thresholds (i.e. climatic tolerance and water quality), and in the following wet season, to allow the assessment of connectivity, fish movement and recolonisation. Sampling twice a year in this way will allow the assessment of catchment-scale range expansions and contractions, and inform on the impact of climatic extremes on the. Understanding these extremes under natural variability will also allow assessment of river health trajectories and inform on indicators of river health.

At each fish sampling site information will be collected to determine:
Fish specific

- Species Richness,
- Abundance
- Abundance of alien species
- Recruitment
- Migration
- Population size and structure
- Prevalence of disease
- Presence of threatened species
- Sex ratios
- Presence of predators (e.g. piscivorous waterbirds)

Water quality

- Conductivity (EC loggers),
- pH,
- Dissolved oxygen (diel range),
- turbidity,
- water temperature (diel range)

Hydrology

- Water depth (depth loggers and telemetered depth loggers) – Appendix E
- Waterhole persistence
- In channel flow and flow regime (gauging stations)
- Bathymetry (once every 10yrs or so) – Appendix D
- Floodplain inundation

Habitat

- Refuge type (Ark, Polo, Disco)
- Substrate complexity
- Woody debris
- Macrophytes
- Erosion
- State of riparian vegetation
- Presence of pest plants and animals and unrestricted stock (e.g. cane toads, evidence of pugging)

The addition of extra waterloggers is aimed at improving fish trajectory modeling and is expected to greatly enhance Thresholds of Potential Concern assessments by linking waterhole hydrology to catchment hydrology, providing information on waterhole antecedent condition and persistence.

If resource/time permits, some key photo points may be established.

1.4. Analysis

(Note: One of the Delivery Agency outputs in the Project Plan is for the Delivery Agencies to undertake the data analysis and interpretation, including justifications and rationales behind choice of statistical methods and analysis techniques used.)

Due to the nature of the LEB environment, random site selection was deemed not practical (see Section 1.2), and this limits the use of some kinds of parametric methods. In addition, many of the sampled data will be spatially and temporally related (i.e. not independent), and this further limits the scope for analyses using either parametric or non-parametric methods.

Ordination methods are an alternative approach that is free of many restrictive assumptions. These are multivariate techniques which display multi-dimensional data in two-dimensional space, potentially revealing similarities and differences and relationships between samples and environmental variables (e.g. Pielou, 1984). Basically, similar species and samples are plotted close together, and dissimilar species and samples are placed far apart. There are many ordination techniques, all with particular strengths and weaknesses; they include principal components analysis (PCA), non-metric multidimensional scaling (NMDS), correspondence analysis (CA) and its derivatives (detrended CA (DCA), canonical CA (CCA)), Bray–Curtis ordination and redundancy analysis (RDA), among others.

Ordination methods are used to explore complex data sets. They can be used to test certain kinds of hypotheses, and to compare categories of data, but their principal value is as a means to detect relationships and thereby generate hypotheses. Subsequently, these hypotheses can be tested using conventional statistical methods. Ordination methods are widely used in ecological research, and there are several excellent Internet sites, text books and supporting software (e.g. http://online.sfsu.edu/~efc/classes/biol710/ordination/ordination.htm, accessed 30 March 2011)

Another technique under consideration for the future includes Bayesian models (sometimes referred to as Bayesian Belief Networks), wherein conceptual models based on presumed or speculative relationships can be constructed and tested against empirical data. Again, Bayesian methods are widely-used in research, and there are abundant resources as Internet sites, texts and software.

Ordination and Bayesian methods have several inherent advantages and lend themselves to exploratory data analyses, developing hypotheses and models. Even if there were sufficient resources to implement a full sampling program, this would be a prudent beginning.

1.5. Reporting

This is covered in the Project Plan, page 7, under ‘Output 3’.

2. Appendix

CATCHMENT	WATERCOURSE	WATERNAME	STATE	SAMPLE DETAILS	REFUGIA TYPE
Diamantina	Scattery Creek (Farrars)	Palparara WH	Qld	Fixed site: Fish, water quality and hydrology (depth/EC logger)	Arc
Georgina	Georgina River	Little Wanderer WH	Qld	Fixed site: Fish, water quality and hydrology (depth/EC logger)	Disco
Georgina	Georgina River	Lake Francis	Qld	Fixed site: Fish, water quality and hydrology (depth/EC logger)	Disco
Cooper	Kyabra Creek	One Mile Waterhole	Qld	Fixed site: Fish, water quality and hydrology (depth/EC logger)	Arc
Cooper	Barcoo River	Unknown	Qld	Fixed site: Fish, water quality and hydrology (depth/EC logger)	Disco
Cooper	Nutting Creek	Unknown	Qld	Fixed site: Fish, water quality and hydrology (depth/EC logger)	Disco
Cooper	Towehill Creek	Unknown	Qld	Fixed site: Fish, water quality and hydrology (depth/EC logger)	Arc
Cooper	Thomson River	Bogewong Garden Hole	Qld	Fixed site: Fish, water quality and hydrology (depth/EC logger)	Arc
Cooper	Barcoo River	Killman WH	Qld	Fixed site: Fish, water quality and hydrology (depth/EC logger)	Arc
Cooper	Cooper Creek	Tea-tree holes	Qld	Fixed site: Fish, water quality and hydrology (depth/EC logger)	Arc
Diamantina	Farrars Creek	Unknown	Qld	Fixed site: Fish, water quality and hydrology (depth/EC logger)	Disco
Georgina	King Creek	Cluny Waterhole	Qld	Fixed site: Fish, water quality and hydrology (depth/EC logger)	Arc
Diamantina	Diamantina River	Windmill/Town Waterhole	Qld	Fixed site: Fish, water quality and hydrology (depth/EC logger)	Arc
Diamantina	Diamantina River	Unknown	Qld	Fixed site: Fish, water quality and hydrology (depth/EC logger)	Disco
Cooper	Cooper Creek	Didhelginna Waterhole	Qld	Fixed site: Fish, water quality and hydrology (depth/EC logger)	Arc
Georgina	Linda Ck	Toko Gorge	Qld	Fixed site: Fish, water quality and hydrology (depth/EC logger)	Arc
Cooper	Darr River	Darr Waterhole	Qld	Fixed site: Fish, water quality and hydrology (telemetered depth logger/gauging station)	Arc
Cooper	Cooper Creek	Nappa Merrie Waterhole	Qld	Fixed site: Fish, water quality and hydrology (telemetered depth logger/gauging station)	Arc
Diamantina	Diamantina River	Wongaree	Qld	Fixed site: Fish, water quality and hydrology (telemetered depth logger/gauging station)	Arc
Georgina	Burke River	Burke Waterhole	Qld	Fixed site: Fish, water quality and hydrology (telemetered depth logger/gauging station)	Disco
Georgina	Georgina River	Smokey Waterhole	Qld	Fixed site: Fish, water quality and hydrology (telemetered depth logger/gauging station)	Arc
Georgina	Eyre Creek	Glengyle Station WH	Qld	Fixed site: Fish, water quality and hydrology (telemetered depth logger/gauging station)	Arc
Georgina	Mills Creek	Oondooroo GS	Qld	Fixed site: Fish, water quality and hydrology (telemetered depth logger/gauging station)	Arc
Cooper	Cornish Creek	Bowen Downs GS	Qld	Fixed site: Fish, water quality and hydrology (telemetered depth logger/gauging station)	Disco
Cooper	Thomson River	Longreach WH	Qld	Fixed site: Fish, water quality and hydrology (telemetered depth logger/gauging station)	Arc
Cooper	Alice River	Barcaldine GS	Qld	Fixed site: Fish, water quality and hydrology (telemetered depth logger/gauging station)	Arc
Cooper	Barcoo River	Blackall GS	Qld	Fixed site: Fish, water quality and hydrology (telemetered depth logger/gauging station)	Arc
Cooper	Thomson River	Stonehenge GS	Qld	Fixed site: Fish, water quality and hydrology (telemetered depth logger/gauging station)	Arc
Diamantina	Diamantina River	Birdsville Gauging Stn	Qld	Fixed site: Hydrology (gauging station)	
Georgina	James River	Big Ranken Waterhole	NT	Fixed site: Fish, water quality and hydrology (depth/EC logger)	Arc?
Georgina	Georgina River	Eight Mile Waterhole	NT	Fixed site: Fish, water quality and hydrology (depth/EC logger)	Arc?
Sandover (Georgina)	Sandover River or tributary	Landerandera Waterhole	NT	Fixed site: Fish, water quality and hydrology (depth/EC logger)	Disco
Sandover (Georgina)	Ooratippra Creek	Ooratippra Waterhole	NT	Fixed site: Fish, water quality and hydrology (depth/EC logger)	Arc?
Finke	Finke River	Two Mile Waterhole (above Glen Helen Gorge)	NT	Fixed site: Fish and water quality	Arc/Polo
Finke	Jay Creek	Fish Hole (Jay Creek Fish Hole)	NT	Fixed site: Fish and water quality	Arc?
Finke	Finke River	Boggy Hole	NT	Fixed site: Fish and water quality	Arc
Finke	Finke River	Snake Hole	NT	Fixed site: Fish and water quality	Arc?
Finke	Finke River	Running Waters	NT	Fixed site: Fish and water quality	Arc
Neales	Neales	Hookeys/	SA	Fixed site: Fish and water quality	Disco
Neales	Neales	Stewarts	SA	Fixed site: Fish and water quality (telemetered depth logger planned 2011)	Disco
Neales	Neales	Algebuckina	SA	Fixed site: Fish and water quality (telemetered depth logger planned 2011)	Arc

CATCHMENT	WATERCOURSE	WATERNAME	STATE	SAMPLE DETAILS	REFUGIA TYPE
Peake	Peake	Peake	SA	Fixed site: Fish and water quality with proposed depth logger/gauging station	Polo
Peake	Peake	Baltacoodna	SA	Fixed site: Fish and water quality	Arc/Disco
Peake	Peake	Warrawarina	SA	Back-up or opportunistic site: Fish and water quality	Arc/Disco
Diamantina/Warburton	Diamantina River	Pandie Pandie	SA	Fixed site: Fish, water quality and hydrology (old depth data logger)	Arc
Diamantina/Warburton	Diamantina River	Goyders Lagoon	SA	Fixed site: Fish, water quality and hydrology (old depth data logger)	Disco
Diamantina/Warburton	Warburton Creek	Ultoomurra	SA	Fixed site: Fish and water quality (telemetered depth logger planned 2011)	Polo Club
Diamantina/Warburton	Warburton Creek	Kalamurina	SA	Fixed site: Fish and water quality	Disco/Polo
Diamantina/Warburton	Warburton Creek	Stony Crossing	SA	Back-up or opportunistic site: Fish and water quality	Disco
Diamantina/Warburton	Warburton Creek	Lower Warburton	SA	Fixed site: Fish and water quality	Disco
Cooper	Cooper Creek	Cullyamurra	SA	Fixed site: Fish, water quality and hydrology (depth/EC gauging station)	Arc
Cooper	Cooper Creek	Kudriemitchie	SA	Fixed site: Fish and water quality with SANTOS depth logger/gauging station	Arc?
Cooper	Cooper Creek	Coongie Lakes	SA	Fixed site: Fish and water quality (telemetered depth logger planned 2011)	Disco
Cooper	Cooper Creek	Lower Cooper	SA	Fixed site: Fish and water quality	Disco
Cooper	Cooper Creek	Embarka Swamp	SA	Fixed site: Fish and water quality with SANTOS depth logger/gauging station	Disco
Macumba River	Macumba R	Tupanna	SA	Fixed site: Fish and water quality	Polo/Disco
Macumba River	Macumba R	Adarranna	SA	Back-up or opportunistic site: Fish and water quality	Disco/Arc
Macumba River	Macumba R	Mongulina Waterhole	SA	Fixed site: Hydrology (telemetered gauging station)	
Nekeena Creek	Nekeena Ck	Winkies	SA	Fixed site: Fish and water quality	Disco
Wooldridge Creek	Wooldridge Ck	Murdarinna (WH/Dam)	SA	Fixed site: Fish and water quality	Disco
Lindsay River	Lindsay R	Eringa / Indeda	SA	Fixed site: Fish and water quality	Arc?
Stevenson's Creek	Stevensons Ck	Adnobangalina	SA	Fixed site: Fish and water quality	Polo/Disco
Hamilton Creek	Hamilton Ck	Ethawarra /	SA	Fixed site: Fish and water quality	Disco
Hamilton Creek	Hamilton Ck	Carpamoongana	SA	Back-up or opportunistic site: Fish and water quality	Disco/Arc
Finke	Finke River	Glen Helen Gorge Waterhole	NT	Back-up or opportunistic site: Fish and water quality	Arc
Finke	Ormiston Creek	Ormiston Gorge Waterhole	NT	Back-up or opportunistic site: Fish and water quality	Disco/Arc
Finke	Pioneer Creek	Pioneer Creek Mound Springs	NT	Back-up or opportunistic site: Fish and water quality	Polo
Finke	Ellery Creek	Ellery Creek Big Hole	NT	Back-up or opportunistic site: Fish and water quality	Arc
Finke	Tributary of Ellery Creek	Upper Serpentine Gorge - slot gorge and pool	NT	Back-up or opportunistic site: Fish and water quality	Arc
Finke	Tributary of Hugh River	Fringe Lilly Gorge Waterhole	NT	Back-up or opportunistic site: Fish and water quality	Arc
Finke	Illara Creek (tributary of Palm	Illara Rockhole	NT	Back-up or opportunistic site: Fish and water quality	Arc
Finke	Finke River	Main Camp Waterhole	NT	Back-up or opportunistic site: Fish and water quality	Arc
Finke River	Hugh River	South Road crossing	NT	Fixed site: Hydrology (telemetered gauging station)	
Finke River	Finke River	South Road crossing	NT	Fixed site: Hydrology (telemetered gauging station)	
Finke River	Palmer River	South Road crossing	NT	Fixed site: Hydrology (telemetered gauging station)	
Finke River	Finke River	Finke railway	NT	Fixed site: Hydrology (telemetered gauging station)	
Georgina River	Ranken River	Ranken Store	NT	Fixed site: Hydrology (telemetered gauging station)	
Hay River	Plenty River	Harts Range	NT	Fixed site: Hydrology (telemetered gauging station)	
Hay River	Unca River	Jervois Mine	NT	Fixed site: Hydrology (gauging station)	
Todd River	Trephina Creek	Trephina Gorge	NT	Fixed site: Hydrology (telemetered gauging station)	
Todd River	Roe Creek	South Road crossing	NT	Fixed site: Hydrology (telemetered gauging station)	
Todd River	Todd River	Wills Terrace	NT	Fixed site: Hydrology (telemetered gauging station)	
Todd River	Emily Creek	u/s Undoolya Road	NT	Fixed site: Hydrology (telemetered gauging station)	
Todd River	Todd River	Amoonguna Settlement	NT	Fixed site: Hydrology (telemetered gauging station)	
Todd River	Todd River	Near Rocky Creek	NT	Fixed site: Hydrology (telemetered gauging station)	
Todd River	Todd River	Wigley Gorge	NT	Fixed site: Hydrology (telemetered gauging station)	
Todd River	Charles River	Big Dipper	NT	Fixed site: Hydrology (telemetered gauging station)	
Todd River	Todd River	Heavitree Gap	NT	Fixed site: Hydrology (telemetered gauging station)	

Lake Eyre Basin Rivers Assessment 2010/11

0 55 110 220 330 440

Kilometres

Towns
Roads
Rivers
Lakes
Inundation Areas
Lake Eyre Basin Agreement Area
Lake Eyre Basin
State Borders

LAKE EYRE BASIN MINISTERIAL FORUM

Data sources:

Lake Eyre Basin Boundary AWRC Drainage Divisions and Basins
© Commonwealth of Australia (Geoscience Australia), 1997.

Rivers, Roads, Towns and Waterbodies
© Commonwealth of Australia (Geoscience Australia), 2004

NT Government

SA Government (provided by SA Department of Water)

Neales River & Douglas Creek Catchment
© South Australia Department of Water, Land and Biodiversity Conservation, 2009

All data are presumed to be correct as received from data providers.

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Proposed Guidelines for Fish Monitoring

Lake Eyre Basin Rivers Assessment

7/4/2011

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Site selection

The Operations Group discussed the merits of the different types of site selection and, based on the objectives of LEBRA, decided that random site selection and having different sites for different times of sampling was not the most effective approach. Instead the preferred option was to select a set of fixed long-term monitoring sites based upon the following criteria:

- Good spatial distribution in the Basin (stratified),
- Against a gradient of identified disturbance (if possible),
- Representative of the surrounding landscape and hydrology,
- Use of significant/high conservation value sites,
- Permanent as well as temporary waterholes, and
- Legacy sites.

Some flexibility will be required in site selection depending upon the need to fill information gaps across the LEB or to address a specific management question (e.g. the influence of fishing pressure a specific waterhole). These sites would be sampled on as need basis and would be in addition to the fixed long-term monitoring sites.

Monitoring Timing

Fixed long-term sites will be assessed twice yearly in spring (end of dry season) and autumn (following the wet season). Sampling at the end of the dry season will provide maximal detail on refugia and potentially limiting thresholds (i.e. climatic tolerance and water quality). End of wet season sampling provides an assessment of connectivity, fish movement and recolonisation. Sampling twice a year in this way will allow the assessment of catchment

scale range expansions and contractions and inform on the impact of climatic extremes on the ecology of fish. Understanding these extremes under natural variability will also allow assessment of river health trajectories and inform on indicators of decline in river health.

Monitoring Equipment

Unpublished data from the Aridflo survey (Janet Pritchard unpublished data) indicates that overnight (<24 hour) sets of fyke nets, combined with seining for smaller or more cryptic species will provide the highest catches of all resident fish species. Fishing effort will vary amongst sites depending on the size of waterholes and time constraints at each site and spare nets are recommended to enable more extensive surveys of large sites. However, there will be a "standard" set of nets deployed (as above) at each site. For very large waterholes, additional survey days may be required (i.e. the set of nets may need to be repeated to effectively cover very large waterhole such as Algebuckina or Cullyamurra).

A netting efficiency study will be undertaken using the standard gear during the first round of monitoring. This will provide data about the catchability of various fish species using different gear types and will assist greatly with the analysis of presence absence, and standardised abundance estimates as well identifying the specific gear types that are best for particular species.

Each site will be sampled using twelve nets including three types of fyke nets and six runs using a small seine net:. Netting details for each site include:

- 6 x Fyke small meshed single-winged design (3 m wing, 4mm mesh, 3m funnel, 0.6m high) - these nets are effective at sampling smaller bodied fish in shallow water habitats along the banks.
- 4 x Fyke small meshed double-wing design (2 x 5m wing, 4mm mesh, 3 m funnels, 0.6m high) - these nets are effective at sampling smaller bodied fish in shallow water habitats.
- 2 x Fyke large hoop double-wing design (2 x 10m wing, 12mm mesh, 5 m funnels, 1.2m high) - these large fyke nets target large bodied fish and can be set in deeper waters.
- 1 x Seine Net (3m x 1.2m drop, 2mm mesh, in built collection bag, leaded rope on bottom) – seine nets are effective at targeting very small fish and benthic (less mobile) species such as desert gobies, which are generally hard to catch using other gear types.

Sampling Protocols

The following outlines the process which will be undertaken in setting and retrieving the fyke and seine nets.

1. An assessment of the physical structure of the waterhole, including identification of all major habitat types and depth profiles, will be undertaken to determine the most appropriate location for net deployment
2. Small single fykes will be set with the wing (leader) perpendicular to the bank and extend the net towards the centre of the river. The cod end will be pulled tight and straight, with no gaps underneath (Figure 1a). Small fykes should be set at relatively shallow locations allowing the leader to remain in contact with the substrate. If the site is too deep for small fyke nets, the buoy at the cod end will pull the cod end vertical and prevent effect catching (Figure 2a). For steeper banks, angle the net in relation to the bank to ~ 45° to reduce the drop off under the net leader (Figure 2b).

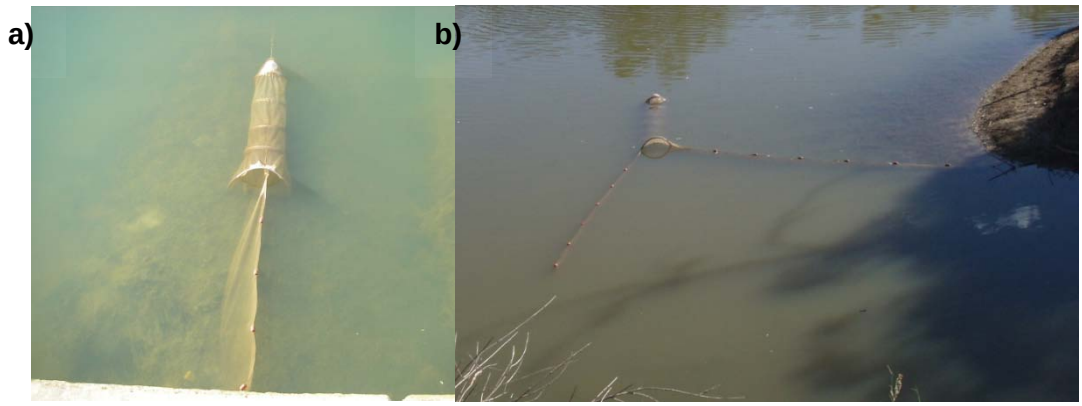

Figure 1. a) Small fyke set perpendicular to bank (can be set <45° to bank) with leader at bank and cod end (with buoy) floated towards the centre of the waterbody and b) 2 winged fyke set on point of anabranch/backwater.

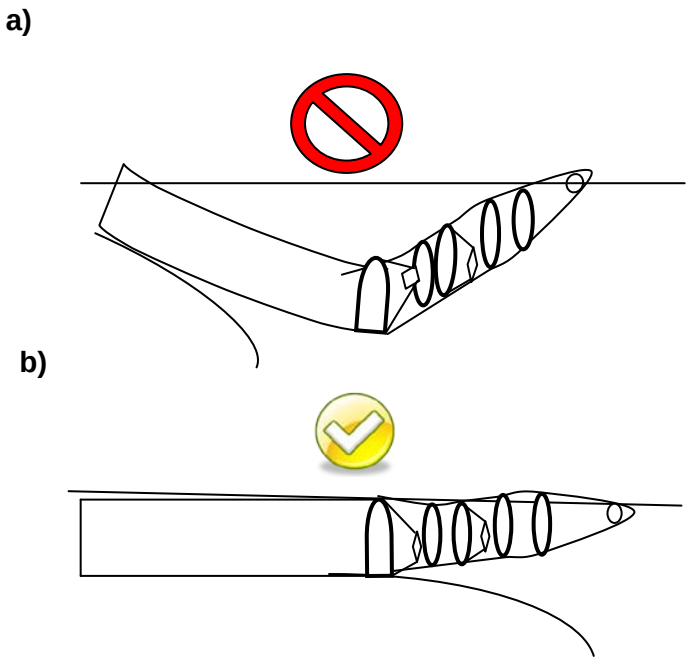

Figure 2, Side of single wing small fyke a) set incorrectly on steep bank and b) set correctly with leader flush to the benthos between the bank and the entrance.

3. Double winged small fykes can be set in a variety of ways, either as a pair (as in Figure 3) to determine directional movement or singly (Figure 1b) to target fish moving through or around significant habitat features such as backwaters, anabranch entrances, snags, overhangs, banks or macrophyte beds.
4. Large double winged fykes will be set in the middle of the channel where possible in areas less than 2m deep. Wings will open upstream and downstream directions with the buoyed cod ends meeting or crossing in the centre.
5. All fyke nets will be set overnight for approximately 15 hours.
6. Six Seine sweeps will be made along a 10m stretch of the bank with the bank –end operator moving only a short distance, whilst the deep end operator moves in an arc with the seine extended , and returning to the bank ten metres from the start point (Figure 4 & 5). Moving from a downstream-upstream direction is recommended in flowing conditions but is not relevant for isolated waterholes.

Figure 3. A pair of double winged large fykes sampling in an upstream and down-stream direction on Aridflo sampling trip (courtesy of J. Pritchard)

Figure 4. Seine sweep; the bank operator remaining at the waters edge whilst deep end operator moves in an arc along a 10m bank length

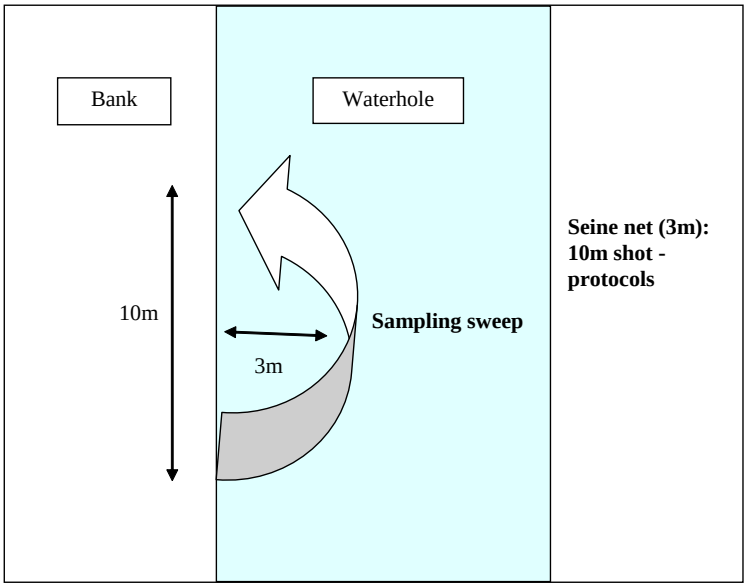

Figure 5. Diagrammatic representation of a 10m seine shot using a 3m long seine.

Sample processing

The following outlines the fish processing procedures:

1. All fish will be identified using well-known keys (Allen, Midgley and Allen, 2002; Wager & Unmack, 2000; J. Pritchard, unpublished data)
2. All specimens from each taxon will be counted
3. The lengths of at least 100 individuals of each taxon will be measured. Note that in some instances where very large numbers of fish are captured, sub-sampling may be employed at the discretion of the researcher, providing that a random subsample of fish is taken.
4. Measured fish will also be visually inspected for signs of disease and spawning condition, and all will be returned to the water at the point of capture. Voucher specimens may be kept for any fish where identification is uncertain.
5. Further samples of fish populations may be collected to answer specific questions about a species such as population genetics or age structure.
6. When moving between catchments, all nets will be soaked in a mild bleach solution for a minimum of one hour to disinfect the nets and prevent transfer of pathogens and pest plant and animal species. Within catchments, nets will be thoroughly emptied and dried at each site to prevent movement of pest species within the catchment.
7. To determine weight/length/age relationships, it is recommended that a specific focus study be conducted at the beginning of the monitoring program using fish collected from initial monitoring surveys. This will require that initially, weights must be taken in the field and specimens then preserved; the analysis of age should be conducted in the laboratory using otolith aging techniques. These are very well developed methodologies that can be carried out in the laboratory at SARDI. This aging study will require additional funding but will produce weight/age/length curves that can be used for the remainder of monitoring and the study will not need to be repeated unless there are concerns about seasonal variation in curve characteristics.
8. Water quality parameters, including temperature, dissolved oxygen, pH, conductivity and turbidity will be measured at each site during each survey using a multi-station water quality meter. Water quality will be measured at the surface and at 0.5 m depth intervals to detect stratification. If a turbidity sensor is not available, a standard Secchi disc can be used to assess water clarity as a proxy for turbidity.

9. Observations of the dominant substrate types, in-stream macrophytes and riparian vegetation will also be recorded at each site. Standard site description datasheets and fish measurement datasheets will be distributed to all participating research organisations to ensure data consistency.
10. Every effort should be made to photograph each site on each sampling occasion from set photo points to allow visual presentation of sites from season to season.