Fish Theme Summary of Pilot Audit Technical Report

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Preface

The Sustainable Rivers Pilot Audit (2002-2003) was set up to develop and agree on indicators and analytical procedures and identify costs and logistics of implementing a Basin-wide Sustainable rivers Audit. The Pilot project was completed at the end of 2003. The outcomes of the Pilot Audit are reported in 5 technical reports covering the major groups of indicators trialed in the Pilot Audit: fish, macroinvertebrates, hydrology, physical habitat and water processes.

This document is the Executive Summary only of the fish technical report from the Pilot Sustainable Rivers Audit. The full technical report is available on CD by contacting the office of the Commission on 02 62790100. Copies of the reports can also be loaned from public libraries throughout the Basin.

This summary outlines the major conclusions and recommendations for the fish theme. Subsequent to the Pilot Audit, partner governments to the Murray-Darling Basin Commission agreed to implement a Basin-wide Sustainable Rivers Audit from 2004/05 to 2010/11 with the following elements:

Three groups of indicators ("themes") for immediate implementation:

- Fish: 13 indicators derived from fish field sampling to be carried out once every 3 years in each of 23 valleys in the Basin;
- Macroinvertebrates: 3 indicators would be derived from field sampling once every 2 years in a single season in the 23 valleys of the Basin.
- Hydrology: 12 indicators to be derived from long term modeling sequences for modeled (largely regulated) areas only in each of the 23 valleys in the Basin, once each 6 years.

Three groups of indicators ("themes") for further development:

- Physical Form
- Riparian vegetation
- Floodplain ecosystems

Further information on the design and roll out of the Basin-wide Sustainable Rivers Audit will be released in the second half of 2004.

Background

Murray-Darling Basin water reforms were introduced to improve water use efficiency and to provide protection for aquatic ecosystems across the Basin. The most significant reform, the introduction of the Cap on diversions, sought to balance protection of the riverine environment with the need for consumptive water use. In 2000, the Murray-Darling Basin Ministerial Council noted the absence of a long-term Basin-wide assessment that could determine the effectiveness of current management practices, including the Cap, in sustaining river health. They agreed to initiate the development of a Sustainable Rivers Audit (SRA) that would assess river health using five themes: macroinvertebrates, fish, water quality, hydrology and habitat.

The primary aim of the SRA would be to provide consistent Basin-wide information on the health of rivers (through a rigorous systematic monitoring program) to drive high level, sustainable land and water management decisions. In 2001, the Cooperative Research Centre for Freshwater Ecology developed a framework for assessing the health of the Basin's rivers with the active involvement of jurisdictional representatives (Whittington *et al.*, 2001). However, before the SRA could be implemented on a Basin-wide scale, it was agreed that a Pilot SRA be conducted in four catchments in 2002/03 (Condamine, Lachlan, Ovens and Lower Murray) to trial and refine indicators and methods, and to identify logistical constraints and indicative costs.

Fish provide ideal assessment tools for a long-term, broad-scale monitoring program such as the SRA as they are easily identified, relatively abundant, valued by the general community and sensitive to a range of changes in river health. Impacts on fish communities are long lasting and the existing communities show the net effects of environmental factors over a period of years, effectively summarising the recent history of the stream. Fish also have a high public profile, with significant recreational, economic, social and cultural values.

Until recently, there had been few attempts in Australia to use fish for bioassessment, and no standardised sampling methodology or analysis framework had been accepted and applied to fish communities in the Basin. The primary aim for the fish theme of the Pilot SRA was to establish and trial standard methods for fish bioassessment to provide informative and comparable results across the Basin.

Design and methods

A referential framework has been adopted for the SRA. The aim is to express current river health relative to 'natural' condition (defined as 'the condition that would exist now in the absence of human influence experienced during the past two centuries'). This 'natural reference condition' is used to facilitate comparisons across the Basin. It is used as a standardisation tool and does not equate with the objective of returning rivers to a natural condition. While 'natural' is the condition with the highest ecological integrity, it should not be construed as being the 'optimum' or 'desired' condition as we often accept a departure from natural as a necessity to securing other important social and economic values.

Sampling for the Pilot focussed on the main river network, actively excluding two important components of riverine ecosystems: aquatic habitats on the floodplain and ephemeral systems. Whilst these are very important aquatic environments in the Basin, they were excluded as robust assessment of these environments at a scale appropriate to the Basin was not considered to currently be technically feasible and would have made the initial Audit too ambitious. It is expected that these systems will be considered for inclusion in the full SRA given their importance to fish and macroinvertebrate communities.

The four river valleys were divided into three valley process zones (VPZ's) based on geomorphic characteristics. These were zones of: sediment source; sediment transfer; and sediment deposition. The Lower Murray, which strictly should be classified entirely within the sediment deposition zone, was divided into three surrogate zones for the fish theme (Murray mouth to Mannum, Mannum to Overland Corner, Overland Corner to Wentworth). These zones were also based on geomorphologic considerations.

The total number of sites was based on the need for adequate reporting at the valley scale. Results can be reported at finer resolutions but with lower confidence. The number of sites allocated to each zone was based on the area of the zone. Sites were located at random within a zone to ensure that the sampling was unbiased and measurements could therefore be combined to infer the condition of the entire valley. Where possible, sites for fish sampling were also used in the macroinvertebrate water processes and physical themes.

The number of 'assessment' sites sampled in the Pilot Audit in each valley process zone is shown in *Table 1*. Sampling was also carried out at 88 'best available' sites chosen to be as close as possible to natural condition. Due to the scarcity of suitable sites with the Murray-Darling Basin, these sites were not restricted to the four Pilot valleys.

Table 1: *The number of fish assessment sites within each zone of each valley for the Pilot SRA.*

	Source	**Transport**	**Deposition**	**Total**
Condamine	3	6	12	21
Lachlan	5	5	16	26
Lower Murray	0	0	24	24
Ovens	7	7	7	21

Three different approaches to establishing reference condition were investigated: prediction of historical species occurrence, comparison with best available sites, and an internal reference which benchmarked site results against the entire sampling dataset.

In three of the four valleys, sampling of assessment sites was conducted between March and May 2002. Most of the 'best available' sites were also sampled during this period. The Lower Murray was sampled as soon as possible after the irrigation flows ceased. The remaining 'best available' sites were sampled between October and December 2002. A variety of active and passive sampling gear-types were trialled including boat and backpack electrofishing, fyke nets and bait traps.

The primary variables for fish measured at each site were:

- species identity
- number of each species caught
- lengths of individual fish (if necessary, a sub-sample of 50 fish per site/ per species/ per method was measured)
- health and condition of individuals (parasites, lesions, diseases, and abnormalities (sub-sampled where necessary).

To enable the use of native/alien biomass ratios as an indicator, the weight of individual fish was calculated using existing length: weight relationships.

The 29 indicators considered in the Pilot are listed in *Table 2*.

Table 2. *Fish indicators considered in the Pilot SRA.*

Concept/Class	**Metric**
Abundance	1) Total abundance per unit effort
Biomass	2) Total biomass per unit effort
Native fish biodiversity	3) Number of native species 4) Evenness of native species
Aliens	5) Biomass 6) Abundance 7) Biomass as proportion of all fish 8) Abundance as proportion of all fish
Habitat guilds	Number of species (including aliens) that are: 9) Benthic 10) Pelagic 11) Riffle dwelling 12) Floodplain dwelling
Trophic guilds	Number of species (including aliens) that are: 13) Macrophagic carnivores 14) Microphagic carnivores 15) Omnivores
Reproductive guilds	Number of species (including aliens) that are in: 16-19) Reproductive strategy 1, 2, 3a or 3b (Humphries *et al*. 1999)
Migratory guilds	Number of species (including aliens) that migrate at: 20) Basin scale 21) Audit river valley scale 22) Local (reach) scale
Tolerances	Average scores across all species for: 23) FSI (water quality) 24) FSI (migration) 25) FSI (general) *sensu* Chessman (in prep.)
Abnormalities	Number of individuals (including aliens) that have: 27) Visible abnormalities 28) Parasites
Size distribution	Number of individuals (list aliens separately) that are: 28) Adult, or 29) Sub adult.

Results

Of the 29 indicators originally proposed for evaluation in the Pilot, eight were eliminated because of lack of an appropriate conceptual model, insufficient species in the Basin on which to base the indicator, or lack of agreement or knowledge with which to classify species into functional groups. Two of the eight were recommended for further investigation.

Both the prediction of historical species occurrence and the use of internal benchmarking were assessed as suitable approaches to determining reference condition. The approach of sampling 'best available' sites proved impractical due to the difficulty in finding suitable unimpacted sites. Reference condition for the Pilot was constructed from expert knowledge, previous research, museum collections and historical data. The result of this process ('PERCH': **P**re-**E**uropean **R**eference **C**ondition for fis**H**) is used in the calculation of a number of the indicators. Due to the broad spatial and temporal scales of fish communities, PERCH is applicable at the zone not site scale.

A total of 13,952 fish from 27 species (20 native, 7 alien) were caught from assessment sites using all methods in the Pilot. The largest number of individuals was captured in the Condamine valley, followed by the Lachlan, Lower Murray and Ovens respectively. The most abundant species were carp gudgeons and bony herring comprising 37% and 24% of the catch respectively. The most abundant alien species were eastern gambusia and carp comprising 6% and 4% of the catch respectively. An estimated total of 895 kilograms of fish were collected using all gear types, comprising 214 kg of native species and 681 kg of alien species.

The iconic Murray cod was surprisingly scarce with only 13 individuals recorded from five assessment sites, none of which were in the lower Murray. The species was recorded at one of the 'Best Available' sites on the lower Murray (3 individuals captured) and an individual was observed but not captured at one of the Lower Murray sites. The failure to capture Murray cod from randomly selected sites indicates that this once abundant and widespread species is now scarce over much of its former range, although localised populations still occur and are well known by local communities and anglers. The contribution of continued stocking of hatchery-reared fish to some populations is unknown.

Almost 10,000 fish were observed at assessment sites during sampling but not captured. Carp gudgeons, bony herring, Australian smelt and eastern gambusia dominated the species that were observed. The majority of the carp gudgeons observed were in the Lachlan, with bony herring commonly observed in the Condamine and Lower Murray, Australian smelt in the Ovens and eastern gambusia commonly observed in the Condamine and Lachlan valleys. These four species comprised 83% of all fish observed but not caught. Assessment of fish community health is based on captured fish only because of higher data reliability and the ability to calculate biomass from the length measurements.

On a community-composition basis, results from using electrofishing alone generally provided good estimates of the fish community at a site relative to using all gear-types. Whilst electrofishing failed to capture some of the rare and smaller species, the financial benefits of being able to sample more than a single site per day with electrofishing outweighs the cost of losing some information on rare species. Because electrofishing under-represented several rare (few individuals per site) and small (in length) fish species, there is potential for improving representation of these fish at some sites by setting bait traps for a short period. The detectability of some species in deep-water environments also needs further investigation.

Analysis of the Pilot data showed that 12 electrofishing shots per site and 7 sites per zone are recommended to return the full species list for the purposes of applying the PERCH method. Sample size calculations based on proportion native biomass gave much more variable results with a prohibitively large number of samples being required for a relatively modest improvement in terms of power.

Recommendations

A full list of recommendations is provided in the technical report. Thirteen indicators were recommended for inclusion in the full SRA (*Table 3*). The value of additional indicators such as reproductive and migratory guilds, size structure and sensitivity/tolerance guilds should be investigated.

Sampling by electro-fishing is recommended as a cost effective means of obtaining adequate data for the purposes of the SRA. Supplementation with bait traps should be trialled and evaluated to improve representation of some species.

Table 3. *Fish indicators recommended for inclusion in the full SRA (abbreviation for indicator shown in brackets).*

Indicator	What is it?
observed to expected ratio (OE)	This value is a comparison of the native species predicted to occur in that VPZ with the species actually caught **at a site** during the SRA Pilot sampling. The total number of native species predicted to occur in the VPZ is corrected downwards for species believed to be rare and unlikely to be caught in sampling.
observed to predicted ratio(OP)	This value is a comparison of the native species predicted to have occurred (pre-European) **in a zone** (without correction for rarity) against the native species actually caught across all sites in that zone during the SRA Pilot sampling.
proportion native biomass (prop_N_biom)	This value represents the proportion of the total biomass (weight) caught that has been contributed by native species of fish.
total species richness (sp_rich)	This indicator compares the total species richness (native and alien) at each site to a predicted maximum species richness (native and alien), where the predicted maximum species richness is based on current condition (i.e. not pre-European).
benthic species richness (benthic)	This indicator compares the species richness of benthic (bottom-dwelling) fishes (native and alien) at each site to a predicted species richness based on current condition.
pelagic species richness (pelagic)	This indicator compares the species richness of pelagic (mid-water) zone fishes (native and alien) at each site to a predicted species richness based on current condition.
intolerant species richness (intol)	This indicator compares the occurrence of native and alien species known to be intolerant to various disturbances (e.g. low water quality, sediment, cold-water pollution, migration barriers) to a predicted number of species at each site.
proportion native abundance (prop_N_abund)	This indicator is the proportion of individual fish caught in each site that were native species.
proportion native species (prop_N_sp)	This indicator is the proportion of fish species in each site that were native species.
proportion macrocarnivores (macro)	This indicator is the proportion of individual fish (native and alien) in each site that were macro-carnivores (i.e. eat prey <15mm length).
proportion mega carnivores (mega)	This indicator is the proportion of individual fish (native and alien) in each site that were mega-carnivores (i.e. eat prey above 15mm length
total abundance (T_abund)	This indicator is the total number of fish (native and alien) caught in each site compared to the predicted number expected in a good site occurring at the same altitude.
fish with abnormalities (abnorm)	This indicator is the **inverse** median score of fish (native and alien) at a site that had diseases, parasites or abnormalities, across all sites in that VPZ (i.e. the higher the score the healthier the site).

The Pilot succeeded in developing an analytical framework for fish that was not previously available. The framework, incorporating the PERCH method for constructing reference condition and the method for aggregating indicators, is recommended for the full SRA.

Results from the Pilot will inform the overall audit design in terms of site layout, number of sites required and sampling frequency. Sites sampled for fish should continue to be overlapped as much as possible with site locations for other themes. Sites should be laid out in a stratified random approach and fixed for the first six years with a review thereafter. Seven sites per zone should be sampled to report with confidence at the zone scale. Fish communities should be sampled at every site in the Basin once every three years with one third of the valleys sampled in any one year.

Aggregation of indicators

Expert rules were developed for combining the recommended indicators into one score to make a summary assessment of the fish community (Sustainable Rivers – Fish Index, SR-FI). This expert system technique provides an objective way of capturing the complex relationships between the indicators and fish community health that cannot be expressed by a simple weighted sum.

The 13 indicators were first grouped into three sub-indices:

- $SR\text{-}FI_e$ – expected species richness: Indicators that contain information on species richness relative to reference condition (OE, OP, sp_rich)
- $SR\text{-}FI_n$ - 'nativeness': Indicators that contain information on the proportion of biomass and abundance that is native rather than alien (prop_N_biom, prop_N_abund, prop_N_sp)
- $SR\text{-}FI_d$ - 'diagnostic': Indicators that are considered of lesser importance in elucidating river health but that may be useful in diagnosing why poor river health may be evident (benthic, pelagic, intol, macro, mega, intol, abnorm).

The three indices were then combined using expert rules to give an overall measure of fish community health (SR-FI) for each valley zone and for each valley. The scores are expressed on a scale from 0 to 1, with 1 representing natural condition. To aid interpretation, scores can be described as a departure from natural with 0 to 0.2 described as 'extreme modification', 0.2 to 0.4 as 'major modification', 0.4 to 0.6 as 'moderate modification', 0.6 to 0.8 as 'minor modification' and 0.8 to 1 as 'at or near natural condition'. However, it should be noted that the boundaries for these classes do not represent any known thresholds in river condition and rigid categories can lead to misleading interpretations when considering values near the boundary cut-offs (i.e. 0.59 and 0.61 fall in different classes but would not represent different fish community health. As such, interpretation on a continual scale is more appropriate (see *figures 19-34*).

Fish Community health assessments

All fish community health assessments are based on electrofishing results only. The values of each of the three sub-indices and the SR-FI are shown by zone in *Table 4* and by valley in *Table 5*. *Figure 1* also shows SR-FI scores for each valley. The longevity and relatively high mobility of fish means that they are integrators of river health over time and space. Results at the valley scale have a greater level of confidence associated with them than results within each zone. Results for individual sites have relatively low confidence.

It is apparent that of the four Pilot valleys the Condamine has the highest level of expected species present, along with high levels of nativeness. There were relatively few alien species recorded in the Condamine (goldfish, carp, eastern gambusia) compared to other valleys with two of the three species being smaller species, which did not contribute heavily to the total biomass.

In contrast to the Condamine, the Lachlan had low proportions of the expected native species and high proportions of aliens, which resulted in the lowest Fish Index score. This suggests that native species thought once to be widespread are now rare or patchily distributed. This result is dominated by results from the two lower zones of the Lachlan. The source zone of the Lachlan catchment returned a high river health score due largely to the abundance of mountain galaxias in the smaller source streams.

Fish Index scores for the lower Murray and Ovens lay in between the other two valleys with the lower Murray having a relatively high nativeness score moderated by a somewhat lower score for species richness. In the Ovens, the high nativeness score in the transport VPZ was outweighed by low scores in the source and depositional zones.

Table 4. *Sustainable Rivers – Fish Index scores by zone from the Pilot SRA.*

Valley	Zone	Expected species richness	Nativeness	Diagnostic	Overall
Condamine	Depositional	0.50	0.84	0.10	0.55
Condamine	Transportational	0.63	0.80	0.10	0.65
Condamine	Source	0.89	0.90	0.64	0.89
Lachlan	Depositional	0.28	0.39	0.41	0.33
Lachlan	Transportational	0.13	0.33	0.61	0.19
Lachlan	Source	0.41	0.78	0.10	0.48
L. Murray	Depositional	0.38	0.58	0.60	0.47
L. Murray	Transportational	0.45	0.84	0.44	0.59
L. Murray	Source	0.41	0.62	0.20	0.44
Ovens	Depositional	0.34	0.36	0.10	0.33
Ovens	Transportational	0.37	0.83	0.61	0.57
Ovens	Source	0.43	0.32	0.41	0.42

Table 5. *Fish community health scores by valley from the Pilot SRA.*

Valley	Expected species richness	Nativeness	Diagnostic	Overall	
Condamine	0.57	0.84	0.11	0.61	Minor modification
Lachlan	0.28	0.4	0.4	0.33	Major modification
L. Murray	0.42	0.76	0.28	0.51	Moderate modification
Ovens	0.38	0.45	0.39	0.44	Moderate modification

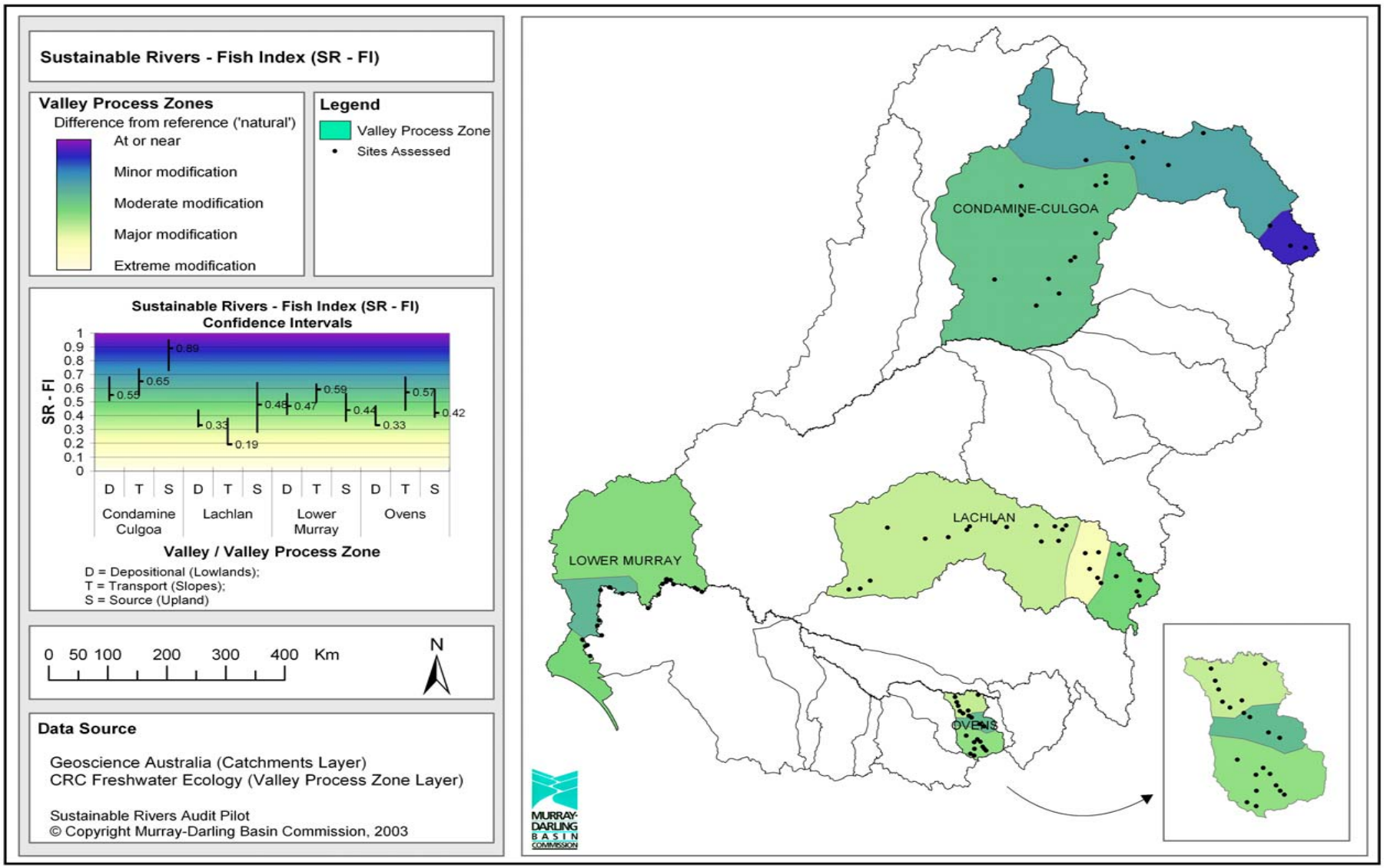

Figure 1. *Condition assessment of SR-FI in catchments assessed during the Pilot SRA (associated confidence in data displayed in legend). Colouring indicates the overall VPZ condition assessment.*