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A Biological Condition Gradient Model Approach for Fish-Based Ecological Condition Monitoring in the Western Mount Lofty Ranges, South Australia.

Rupert Mathwin, Dale McNeil and David Schmarr

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SARDI Aquatics Sciences
PO Box 120 Henley Beach SA 5022

April 2014

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South Australian Research and Development Institute
SARDI Aquatic Sciences
2 Hamra Avenue
West Beach SA 5024

Telephone: (08) 8207 5400
Facsimile: (08) 8207 5406
http://www.sardi.sa.gov.au

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Author(s): Rupert Mathwin, Dale McNeil and David Schmarr

Reviewer(s): Peter Goonan (EPA) and Rehanna Halfyard (DEWNR), Phillipa Wilson (SARDI) and Nick Whiterod (Aquasave)

Approved by: Assoc Prof Qifeng Ye
Science Leader – Inland Waters & Catchment Ecology

Signed:

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EXECUTIVE SUMMARY

This report outlines the application of a Biological Condition Gradient (BCG) modelling approach (Davies and Jackson 2006) to the assessment of a fish-based condition assessment in the Western Mount Lofty Ranges (WMLR), South Australia. This method uses expert assessment of field monitoring data to score biotic and abiotic attributes of the site along a gradient of increasing degradation.

The BCG approach was trialled using data from a 2011 fish survey encompassing 64 riverine sites across the Adelaide plains and Fleurieu Peninsula (McNeil *et al.,* 2011a). The data from this survey were previously used to develop the Fish Health Index (FHI), a fish-based condition assessment method. The FHI approach was deliberately ichthyocentric and scored fish community dynamics such as recruitment, predation, species composition and invasive species presence to generate an overall score and 'traffic light' indicator.

Recently, the South Australian Environment Protection Authority (EPA) have adopted the Biological Condition Gradient (BCG) model approach (Davies and Jackson, 2006) for assessing ecosystem condition, based on freshwater macroinvertebrate and vegetation survey data, supplemented by water quality, sediment and habitat data. If applicable, the assessment of fish monitoring data using the same approach will provide a consistent framework for assessing ecological condition in areas where a diverse range of biological data exists. This will provide a consistent approach to condition assessments to support NRM and water management objectives.

The fish based BCG assessments were largely comparable to the 2011 FHI assessments (R^2=0.66), with the majority of the sites scoring similarly using both approaches. Some specific discrepancies were identified, largely based on the incorporation of broader catchment condition and habitat connectance in the BCG approach and the high emphasis on exotic fish impacts in the FHI. In general, the BCG approach was found to be an acceptable approach to assessing fish based ecological condition both in the WMLR and, more broadly, across the State. The advantage of utilising a common framework for fish and other biological indicator groups is that it presents a more integrated approach to the ecological condition of freshwater ecosystems. A series of guidelines and recommendations are included to standardise future implementation of the BCG.

1. INTRODUCTION

1.1. Background

The protection of aquatic ecosystem health is central to a broad range of State and Commonwealth natural resource management (NRM) issues. In the Western Mount Lofty Ranges (WMLR), near Adelaide in South Australia, this includes the protection of native aquatic biodiversity, the identification of environmental water requirements to underpin water resource management and the planning and delivery of environmental water provisions to deliver specific aquatic ecosystem benefits. There is a legislative responsibility to protect the health and biodiversity of aquatic systems and this is underpinned by a number of policies and legislation. For example, in the WMLR this includes maintaining aquatic biodiversity via the provision of environmental flows (*Water Resources Act* 1997, *State Water Plan* 2000, *Natural Resource Management Act* 2004). Currently there are many different ways in which ecosystem health is assessed (Rapport *et al.* 1998, Burkhard *et al*. 2008) and these utilise a number of different approaches such as scale, gear type, species, etc. Therefore, there is a need to develop a consistent approach for measuring conditions to allow for comparable reporting against environmental targets and objectives. The development of an effective and consistent approach to measuring the condition of ecosystem components (e.g. macroinvertebrates and fish) is important to support the reporting of ecosystem condition against various NRM targets or objectives. Several approaches to assessing aquatic ecosystem health have been developed, many of which vary significantly in their approach, the diversity, scale and focus of data, and the use of expert opinion.

A recent approach to assessing aquatic ecosystem condition has been adopted by the South Australian Environment Protection Authority (EPA). This approach uses the 'Biological Condition Gradient (BCG) model' to rate environmental condition and using macro-invertebrate monitoring data. This model was developed by the United States Environmental Protection Agency (USEPA) (Davies and Jackson, 2006) and uses monitoring data and expert opinion to score various aspects of aquatic ecosystems. Utilisation of this model has enhanced reporting to State agencies in the USA and it has been suggested that this model be considered for use by others in the ecological field (Goonan *et al*. 2012). The nonspecific nature of this tool allows multimetric data from any riverine taxa to be deconstructed into a common currency for communication between fields, agencies and States, and should enable integrated reporting on river health.

The rating system requires the application of a consistent six tier classification to ten different ecosystem attributes. The six tiers represent a clearly defined level of ecosystem condition ranging from natural to severely impacted and are applied consistently to each of the ten attributes. The tier definitions are as follows:

1. Natural or native condition.
2. Minimal changes in structure of biotic community; minimal changes in ecosystem function.
3. Evident changes in structure of biotic community; minimal changes in ecosystem function.
4. Moderate changes in structure of biotic community; minimal changes in ecosystem function.
5. Major changes in structure of biotic community; moderate changes in ecosystem function.
6. Severe changes in structure of biotic community; major loss of ecosystem function.

A key aspect of the rating system is that scoring outputs place monitoring sites on an axis of biological condition versus stressor gradient (Figure 1). The six tiers are used to score each of ten ecosystem attributes:

Attribute I Historically documented, sensitive, long-lived, or regionally endemic taxa

Attribute II Sensitive-rare taxa

Attribute III Sensitive-ubiquitous taxa

Attribute IV Taxa of intermediate tolerance

Attribute V Tolerant taxa

Attribute VI Non-native or intentionally introduced taxa

Attribute VII Organism condition (especially of long-lived organisms)

Attribute VIII Ecosystem function

Attribute IX Spatial and temporal extent of ecosystem disturbance

Attribute X Ecosystem connectance

The scoring of each attribute into the six tiers is complex and requires careful consideration of the detail presented in Davies and Jackson (2006). A panel of experts is used to rate each site, based on historical records and monitoring data. The combination of scientific expert opinion and field data provides a hybrid approach to condition assessment that allows monitoring outputs to be assessed and applied into a consistent framework.

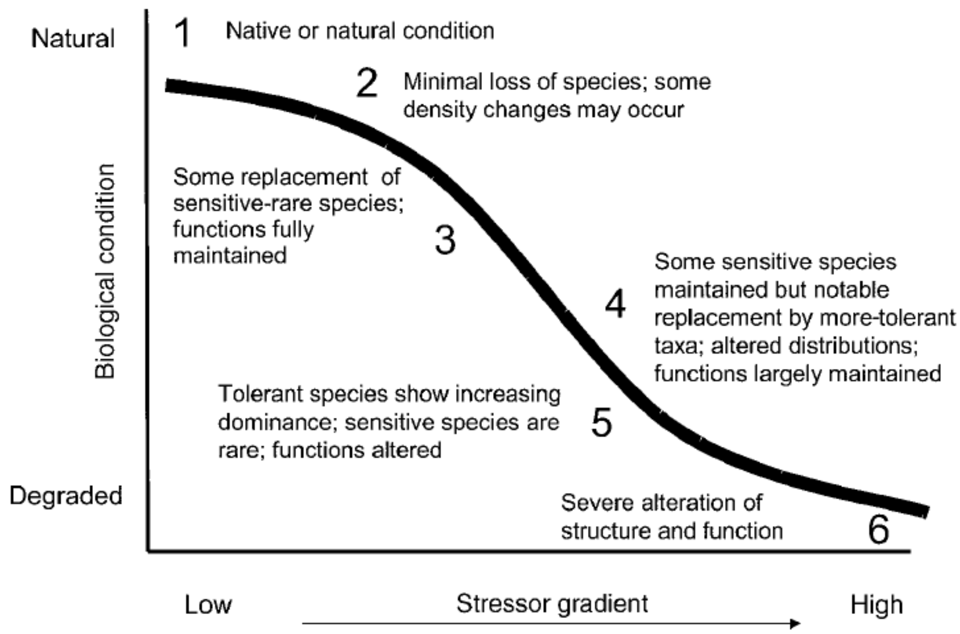

Figure 1. The Biological Condition Gradient (BCG) model scores ten attributes along a scale of increasing environmental degradation tiers. Tier 1 represents an unaltered habitat whilst tier 6 represents the most highly altered habitats. Reproduced from Davies and Jackson (2006).

Whilst the BCG modelling approach has been applied to the assessment of ecological condition in the WMLR using macroinvertebrate and vegetation data, fish based assessments have been developed using alternative approaches (McNeil *et al.* 2011a). The fish condition index approach produced a 35 point Fish Health Index (FHI) score, which was expressed in a three point *traffic light* condition rating. FHI scores were comprised of a score for:

- Native fish biodiversity;
- Exotic fish biodiversity;
- Native fish dominance (based on abundance and population dynamics).

The FHI ratings were based on the assessment of monitoring data outputs for fish assemblage structure (i.e. species composition, abundance, size class distribution, competition and predation), spawning condition and recruitment success, and fish health. Site condition, water quality and threatening processes were also recorded as part of the monitoring program; however, only fish data were used to calculate condition scores for the FHI.

1.2. Objectives

The principal objective of this study was to assess the utility of the BCG model approach for assessing the ecological condition of freshwater sites, based on fish communities in the WMLR. To this end, the 2011 fish survey conducted by the South Australian Research and Development Institute (SARDI) was used as a test case, and a BCG model developed based on the data from that survey (reported in McNeil *et al.* 2011a), as well as expert opinion and historical information on freshwater fish in the WMLR.

As this survey was also used as the basis of the FHI condition assessment, this approach will allow a comparison of these two methods for assigning condition ratings. Any modifications to the BCG model, tiers or attributes that will improve the applicability of the approach to freshwater fish communities, as well as any optimisations that might result from combining aspects of the two approaches, is discussed.

Finally, this report makes recommendations about the scope and utility of a fish based BCG model applied under a common framework with the EPA’s invertebrate and plant-based assessments. This includes suggestions for:

- standardised procedural approaches for sampling;
- rewording of the model to better account for WMLR fish metrics;
- standardised geographic definitions for Attributes IX-X;
- improving data management.

2. METHODS

The BCG methodology from Davies and Jackson (2006) was adopted and any deviations from set definitions or terminology used in that paper were recorded. Data from the 2011 fish condition monitoring report (McNeil *et al*. 2011a) was used to populate the BCG models for 40 sites. Time constraints precluded the assessment of all of the 64 sites assessed in that survey.

Sites were assessed using a combination of data collected for the FHI, including fish abundance, length frequency, spawning and reproductive status and disease prevalence, as well as physical habitat, water quality, land use and identified threats that were recorded during the survey but not used to determine the original FHI scores. Population structure data for each species and site were used to determine recruitment and longevity metrics. Historical data and distribution patterns previously published for the WMLR were also used to determine expected distributions, historical records, assemblage and biological information (Hammer 2001, Hammer 2002, Wedderburn and Hammer 2003, Hammer and Walker 2004, Hammer 2005, Hammer 2006, McNeil and Hammer 2007, McNeil and Wilson 2008, McNeil *et al.* 2009, McNeil *et al.* 2010, Bice *et al.* 2010, McNeil *et al*. 2011a, McNeil *et al*. 2011b, Waterwatch 2011).

A consensus was reached to assign each fish species known in the study area to an attribute from I to VI (Table 1). For future application of the BCG in the WMLR these classifications should be considered static and adjustments carried out cautiously with expert justification. Estuarine specialist species (e.g., *Atherinosoma microstoma* and *Aldrichetta forsterii*) were excluded from the assessment due to the number of extra species that this would add to the analysis, coupled with uncertainties about the known distribution and attributes of these species.

To encourage consistency and clarify ambiguous tier descriptors, members of the panel were required to modify wording of the BCG (outlined in Davies and Jackson 2006) to allow direct application to WMLR fish metrics. Modifications were conservative and enable consistency for this and future applications (Appendix 1).

Guidelines were adopted to encourage logical consistency in scoring specific attributes. These included:

- Attribute VI (non-native and introduced taxa) was determined to include Murray-Darling translocations (e.g *Melanotaenia fluviatilis* and *Tandanus tandanus* in the Torrens catchment). Where records of exotics exist in the catchment but were not identified at the site, this attribute was scored a tier 1 to highlight absence.

- When scoring attribute VII (Organism condition) the condition of non-native and introduced taxa (attribute VI) was not considered.

Table 1. Designation of attribute groups to known fish species used in the formulation of the BCG for WMLR sites. Note estuarine specialist species are not considered.

Scientific Name	Common Name	Attribute (I – VI)	Notes
Ambassis agassizii	Agassiz's glassfish	I	Anecdotally documented
Anguilla australis	Short finned eel	I	Diadromous, rare, historically rare, possible range extension, life history sensitivities
Carassis auratus	Goldfish	VI	Intentionally introduced taxa
Cyprinus carpio	European carp	VI	Intentionally introduced taxa
Gadopsis marmoratus	River blackfish	I	Anecdotally documented
Galaxias brevipinnis	Climbing galaxias	II	Diadromous, sensitive and rare, cooler reaches, life history sensitivities
Galaxias maculatus	Common galaxias	III	Diadromous, tolerant to salinity, common in downstream reaches, rare in upland reaches
Galaxias olidus	Mountain galaxias	III	Sensitive to WQ and predation, common
Gambusia holbrooki	Eastern gambusia	VI	Intentionally introduced taxa
Geotria australis	Pouched lamprey	I	Diadromous, historically common, now rare
Hypseleotris spp.	Carp gudgeon	VI (*V)	Murray Darling translocation, biological pollution, *considered endemic in the Finniss River

Scientific Name	Common Name	Attribute (I –VI)	Notes
Melanotaenia fluviatilis	Murray River Rainbowfish	VI (*V)	Murray Darling translocation, biological pollution, *considered endemic in the Hindmarsh River
Mogurnda adspersa	Purple spotted gudgeon	I	Historically documented, regionally extinct?
Mordacia mordax	Short-headed lamprey	I	Diadromous, historically common, now rare
Oncorhynchus mykiss	Rainbow trout	VI	Intentionally introduced taxa
Perca fluviatilis	Redfin perch	VI	Intentionally introduced taxa
Phalloceros caudimaculatus	Speckled livebearer	VI	Intentionally introduced taxa
Philypnodon grandiceps	Flatheaded gudgeon	V	Tolerant to wide range of impacts including low flow, WQ
Philypnodon maculatus	Dwarf flatheaded gudgeon	V	In the Onkaparinga and Torrens it is unclear if this species is endemic or a River Murray translocation
Pseudaphritis urvillii	Congolli	II	Diadromous, more commonly found in coastal reaches
Pseudogobius olorum	Western blue spot goby	II	Amphidromous, sensitive to disturbance, sensitivities not well documented, reliance on rocky interstices, rare
Salmo trutta	Brown trout	VI	Intentionally introduced taxa
Tandanus tandanus	Murray River catfish	VI	Murray Darling translocation, biological pollution, but protected
Tinca tinca	Tench	VI	Intentionally introduced taxa, not necessarily harmful to native fishes

- Attribute VIII (Ecosystem functions) was not scored due to a lack of available limnology data for this catchment at the time of the study.
- For some attributes, notably attribute X (Ecosystem connectance), information was sometimes insufficient to determine a single tier value. When data were unavailable to confidently assign a tier, a range of tiers was assigned rather than a single value.

Attributes were allocated to a tier value independently by each expert and the final condition score for each site was rated by consensus from all experts (Appendix 2). Condition scores for sites using the BCG and FHI approaches were compared for the 40 sites where both assessments were conducted. This included an assessment of the comparative index scores (1 to 6 for the BCG and -19 to +15 for FHI), as well as the final three point *traffic light* condition score of each site. Under this approach a ‘green light’ (best condition) was awarded to scores of 1 and 2 (BCG) and 5+ (FHI); amber was awarded to 3 and 4 (BCG) and -4 to 4 (FHI); and red light (worst condition) attributed to 5 and 6 (BCG) and < -5 (FHI). Final ratings were compared to highlight discrepancies between the approaches.

3. RESULTS

BCG scores were successfully generated for 40 sites. A detailed list of attribute scoring is included in Appendix 2. Traffic light ratings were largely comparable between the two approaches (Table 2) with some notable differences.

Table 2. Scoring for BCG Attributes (I-X) for a selection of MLR fish sites used in the FHI showing final BCG ratings as well as FHI scores attributed previously in McNeil *et al*. (2011a).

Site Name	I	II	III	V	VI	VII	IX	X	BCG Consensus	Fish Health Index
Back Valley		5		4	1	5	5	4	4	3
Bartletts		6	6				5	5	6	-5
Cherry Plantation			2		1	3	5	4	3	6
Commercial Rd		4	6		6	5	5	4	5	-10
Cootamundra Reserve		1	1	1		2	4	2	2	15
Corkscrew Bridge		6			6		3	2	4	-19
Cox Creek		5	1-2		1	2	3	4-5	3	9
Dog Trap Creek		6	5		6		5	4	5	-11
Field		2	2		1	3	5	3	3	11
Gawler Dam			2	4	4	2	5	5	4	1
Glacier Rock		4			5	5	5	4	5	-6
Guaging Station		5	5	4	5	6	5	4	5	-11
Hay Flat		2	2			2	5	3	3	8
Hindmarsh Falls		1	1		1	1	4	2	2	11
Ingalalla Falls		4			3	2	4-5	4	4	-3
Light Ford			5	5	4-5	2	4	3-5	4	3
Marrabel			2	6	4-5	2	4	3-5	3-4	-2
Moculta		6		6			5	5	6	-5

Site Name	I	II	III	V	VI	VII	IX	X	BCG Consensus	Fish Health Index
Mt Crawford		4		4	2	5	5	5	4	-1
Mt McKenzie		6		6	6		5	5	6	-13
Myponga Township		5	6		6		5	3-5	5	-13
Nashwauk		4	4		5	2	6	4	4	-1
Nuriootpa		6		6	6		6	5	6	-8
Pages Flat		3	6		4	2	5	3-5	4	0
Patawolonga	2	3	4		4	4	5	4	4	2
Pony Club		4	3	3-4	5	1	4	4	4	-3
Portuguese Bridge		6		6	6		5	5	6	-11
Railway Dam			5		1	5	5	4	4	3
Rockies			3	5	4-5	5	5	3-5	4-5	1
Sawpit Rd		2	1		1	1	4	3	2	13
Scott Creek Conservation			6		1		5	4-6	3-4	-5
South Rd		2	2			2	5	3	3	11
Stornoway		1			2	3	3	5	3	0
Sturt Creek Tributary			2		1	2	5	4	2-3	9
Tunkalilla		1				2	4-5	3 - 5	2-3	9
Victoria Creek		1			1	1	5	2	2	9
Washpool		2	3			2	2	2	2	8
Willow Glen			6		6		4	4	5	-11
Yaldara		3	3	4	5	3	5	5	4	-5
Yankalilla Rec Centre		4	3		5	2	5	3	4	2

Three sites (Rockies, Sturt Creek Tributary and Tunkalilla) scored BCG consensus scores that were inappropriate for conversion to *traffic light* values. These sites had BCG values presented as a range that straddled two of the three categories (e.g. the Rockies site BCG consensus was 4 – 5 placing it between the 'amber' and 'red' score ranges) and were excluded from the similarity analysis.

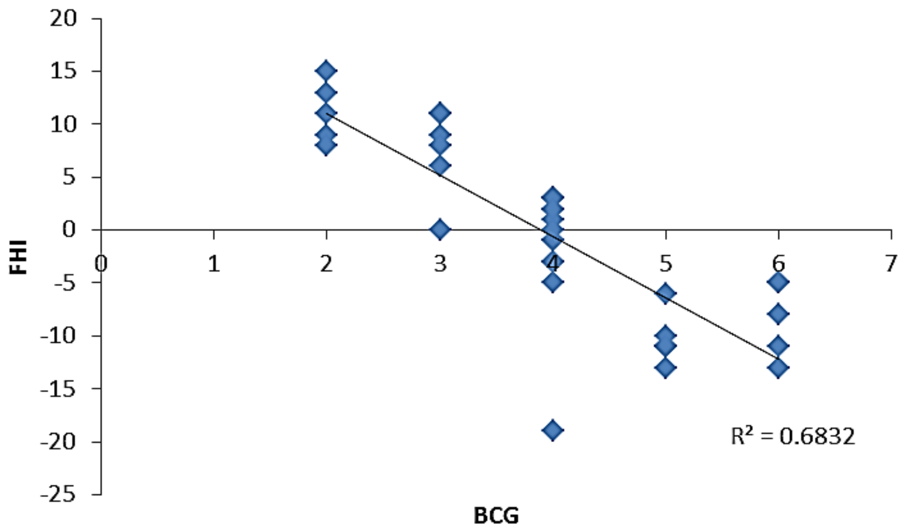

Figure 2. Sites were plotted on a scale of increasing degradation to compare the FHI and BCG scores. Sites are overlaid and outliers described in the text.

Table 3. Five sites were scored lower (more degraded) by the Biological Condition Gradient than the FHI. These sites typically contained strong native fish population in highly urbanised environments.

Site	BCG	FHI	Reason
Cherry Plantation	3	6	Strong fish population (*Galaxias olidus*), altered landscape
Cox Creek	3	9	Strong fish population (*Galaxias olidus*), altered landscape
Field	3	11	Strong fish population (Diadromous), altered landscape
Hay Flat	3	8	Strong fish population (Diadromous), altered landscape
South Rd	3	11	Strong fish population (Diadromous), altered landscape

Following conversion of BCG values into the three tier *traffic light* system, 29 of the 37 sites examined were consistent between the two approaches (Figure 2). The remaining eight were scored inconsistently by the two approaches. Five sites scored lower (more degraded) and three sites scored higher (less degraded) by the BCG. Of the five sites scored higher by the BCG (Table 3), all five contained strong native fish populations in an absence of exotic species, in highly altered (typically urbanised) environments (Table 4).

Table 4. The Biological Condition Gradient considered three sites to be less degraded than the Fish Health Index. These sites typically had fish communities devoid of native fish value in less degraded environments.

Site	**BCG**	**FHI**	**Reason**
Corkscrew Bridge	4	-19	Only exotic predators present
Scott Creek Conservation	3-4	-5	No fish
Yaldara	4	-5	Community dominated by exotics

4. DISCUSSION

The application of the BCG model to assess the ecological condition of aquatic ecosystems using fish metrics developed for the WMLR, demonstrated that the approach provides an acceptable method for translating fish monitoring data, historical information and expert opinion into a meaningful condition rating output. Generally, the BCG modelling approach and structure outlined in Davies and Jackson (2006) was transferable, with very little modification required to accommodate the specifics of freshwater fish in an Australian setting where fish species diversity is extremely low compared to areas of the U.S. in which the initial approach was developed.

A number of modifications were required to optimise the structure of attribute specific tier descriptions. Changes were predominantly rewordings to allow for explicit distinction between tiers. Additional alterations excluded invertebrate concepts of replacement. This phenomenon is atypical of the WMLR's depauperate fish community, which has a limited capacity for redundancy. Attribute VII (Organism condition) was broadened to accept metrics that reflect local population breeding success (spawning condition and complex size distribution) and homozygosity (congenital abnormalities). These changes did not alter the spirit of the model, but optimised cohesion between the BCG wording and the dynamics observed in WMLR fishes.

Outputs from the BCG were highly consistent (r^2=0.66) with assessment of the same sites using the fish-based FHI approach (McNeil *et al*. 2011a). Both approaches utilised data on assemblage structure whilst relying on expert interpretation of abundance, population structure, disease impacts and broader biological factors. Accordingly, there was a high level of agreement between the two approaches, especially once ratings were distilled into three-point *traffic light* condition ratings.

Where variance was observed, the source was usually an artefact of differential emphasis. In particular, the BCG utilised broader catchment, habitat and connectivity information that was not scored in the FHI approach (although relevant data were collected during monitoring to inform the BCG assessment). As such, the BCG placed proportionally larger emphasis on broader catchment condition compared to biotic information when rating overall site condition. This contributed to scoring populations of exotic predators or sites without fish higher than the FHI, and downgrading strong native populations of fish where they were observed in degraded environments.

Conversely, the FHI approach did not account for site metrics like connectance and disturbance but emphasised the interspecific dynamics of competition and predation to produce a condition score for the fish community in isolation. In this way the FHI emphasised the negative impact of exotic (and especially predatory) fish species, and did not account for catchment level impacts.

These differences have important repercussions when applying aquatic condition scores for NRM purposes. For example, the application of condition ratings to inform flow provisions for native fish under water allocation planning, may be better informed by a fish based assessment with lesser emphasis on catchment conditions beyond the ability to manage through flow provision. Alternatively, sites that score high on native fish values, but exist within denuded or highly impacted catchments, may be at higher risk to land use impacts and may be areas where targeted restoration activities may enjoy optimised NRM outcomes due to the value of the assets.

For general assessment purposes it is undesirable to over-estimate the condition of a given site by ignoring the landscape context. It is noted, however, that by incorporating expert opinion and robust discussion into the process, the BCG approach sets a framework within which concerns can be raised about specific site or attribute scores and their interpretation. It is hoped that expert discussion will allow for sites without fish or with only exotic fishes present to be scored down which would account for the main flaw in the BCG approach.

A key advantage to using the BCG approach to assess monitoring outputs in the WMLR and across South Australia is its consistency with current macroinvertebrate and physical habitat based monitoring conducted regularly across the State by the EPA. The addition of fish monitoring outputs into this approach as a common framework for assessing ecological condition leads to a more robust and reliable resource for the State. Consistent with this is the increased power that condition assessments and therefore monitoring programs will have in informing key water and biodiversity management programs, where fish and macroinvertebrate data are often difficult to bring together into consistent application (Van Laarhoven and van der Wielen, 2009). Therefore, it is recommended that the co-ordination of regional fish monitoring programs and other biotic monitoring programs under an approach of BCG modelling be considered by regional NRM bodies and State agencies as a way of optimising the utility of ecological condition assessments for aquatic ecosystems and catchments.

The trial conducted for the present study revealed a slight (although perhaps intentional) anomaly with the usual linear approach to condition gradients. The varying weight of biotic and ecosystem tier scores across the condition gradient is an inherent part of the BCG structure as it exists. Whilst the biotic condition tiers sit along a clearly linear gradient of condition from natural to highly modified, the ecosystem function scores are non-linear in that tiers one to four all relate to unmodified ecosystem functions, whilst tiers five and six represent an incredibly sharp drop in condition (Figure 3). The result is that tiers one to four are made solely on biotic aspects, whilst five and six represent a combined impact on biota and catchment processes. In our experience, this anomaly resulted in a large number of tier five scores being allocated to attributes IX and X due to the highly developed nature of the WMLR region. As a result, the majority of assessments were being pulled in the direction of the tier five score based on the exceptionally strong influence of attributes IX and X. It is possible that the tier descriptors as stated in Davies and Jackson (2006) may be further modified to bring biotic and catchment gradients into line with each other. In the interest of consistency and comparability further changes to the BCG model are not recommended for application in the WMLR.

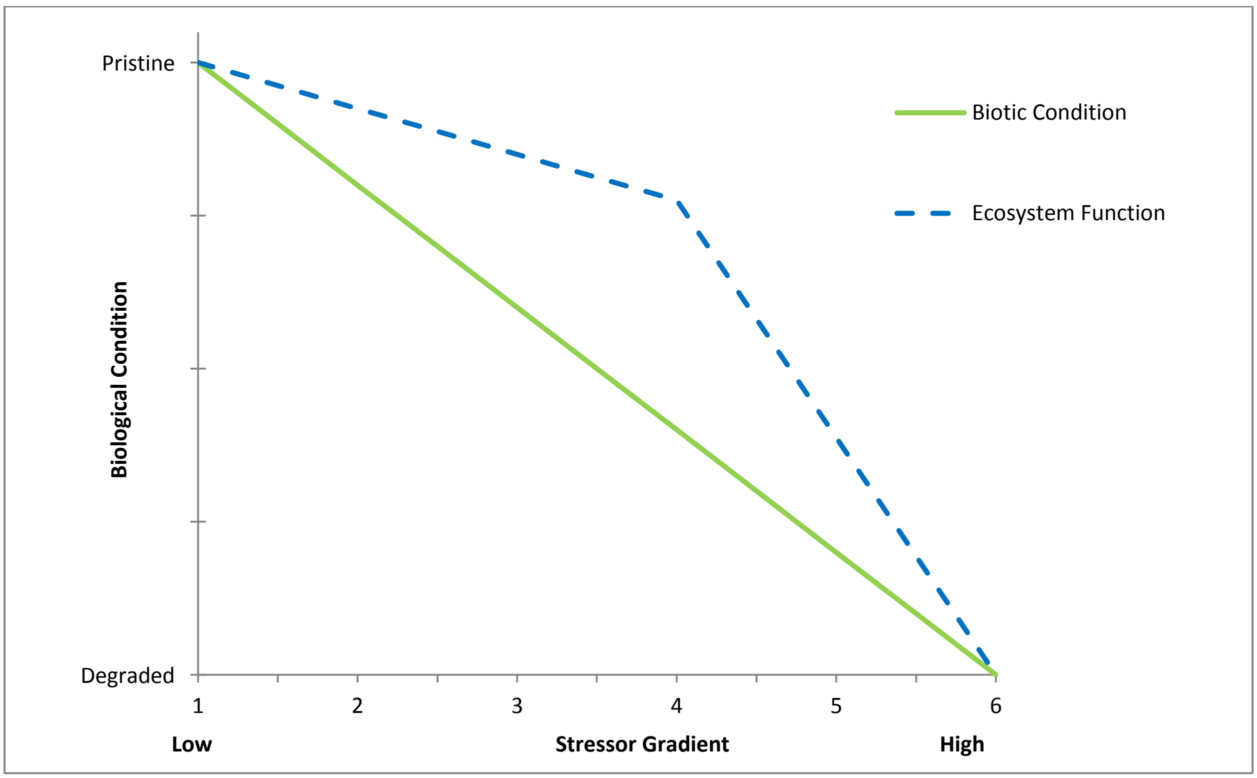

Figure 3. Conceptual comparison of condition gradients between biotic condition tiers (Attributes I-VII) and ecosystem function tiers (Attributes IX and X).

5. RECOMMENDATIONS

5.1. Fish Sampling

It is recommended that a standardised sampling approach be applied to condition assessment of fish communities in the WMLR through the BCG model. This technique is designed to sample all fish species present at a site and should provide adequate data to inform BCG assessment. The following method has been developed by SARDI and may be adapted to most habitats in the WMLR. The approach uses two net types; double-wing small fykes (2 x 5 m wing, 4 mm mesh, 3 m funnels, 0.6 m high) and small fykes (3 m wing, 4 mm mesh, 3 m funnel, 0.6 m high). Double-wing small fykes should be deployed at the upstream and downstream ends of each pool, opening away from the pool. A minimum of two double-wing nets should be set at each site. For very large pools additional double wing fykes may be deployed to a maximum of four. Small fykes should be deployed to target diverse fish microhabitats within the pool. As a guide, proximity should be such that when swung through a full arc no small fyke could touch any other small fyke (Figure 3). A total of six small fykes should be deployed wherever possible.

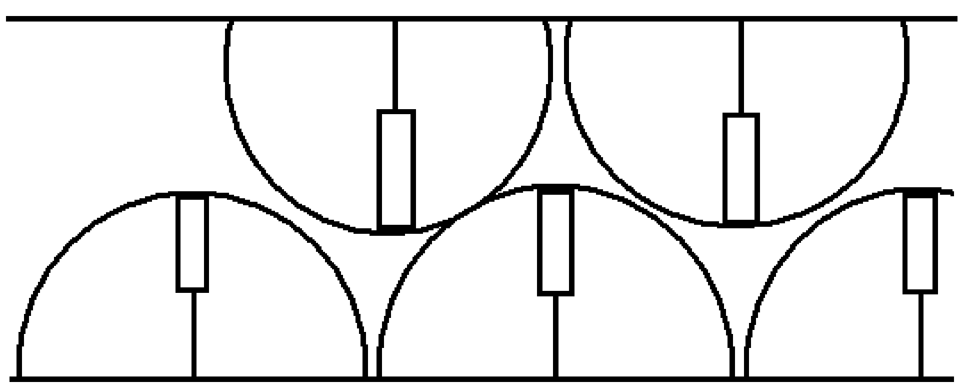

Figure 4. Small fykes should be deployed in such a manner that the arcs of each small fyke do not overlap. The above figure represents the maximum density of small fykes that may be deployed in a stream.

Fyke nets should be attached to the bank at the wing end(s) and be pulled taut. Nets should be anchored with stakes and/or weights to ensure they remain taut and static until processing. Two buoys should be added to the distal compartment of each cod end to minimise mortality of nontarget air-breathing taxa. Fyke nets should be set continuously along the substrate or water's surface with dramatic vertical kinks in the line of the net to be avoided. Sites should remain set for sufficient time to harness both a dusk and a dawn feeding period (e.g. approximately 15 hours).

The setting of fyke nets should comprise the bulk of sampling effort at a site. Where specific habitat characteristics preclude the effective use of fyke nets but require BCG assessment (eg shallow riffle habitats or deep areas) alternative techniques may be considered and might include electrofishing, bait traps, gill nets, dip nets, drum nets, angling, seine sweeps and visual surveys (including spotlighting). Comprehensive, best practice models of sampling should be used regardless of gear type. Sampling effort must be deployed with sufficient intensity that researchers are confident of identifying;

- all species present,
- size structure of those species,
- presence and proportion of gravid or diseased individuals within those species.

5.2. Processing Fish

Fish total lengths (TL) should be recorded such that an accurate distribution of lengths (as a representation of age structure) may be created for each species at each site. Analysis of historic SARDI data in the WMLR shows that 100 fish/species/site is a reliable dataset to confidently reflect population dynamics. Selecting samples to measure should account for potential in-net size bias. Fish that are not measured should be counted to create overall species counts for each site. Comprehensive records should be kept of diseased, spawning or gravid individuals. Example data sheets are included in Appendix 3.

5.3. Common Definitions for Common Attributes.

Normalising local definitions will improve accuracy within, and between, disciplines. By assigning WMLR fish species to attributes I - VI (Table 1) and subtly rewording tiers (Appendix 1) efforts have been made to normalise future scoring of BCG fish metrics. Perhaps less clear is the scoring of attributes IX (Spatial and temporal extent of detrimental effects) and X

(Ecosystem connectance). Frequently in this study experts were unable to confidently assign tiers to these attributes due to lack of detailed specific knowledge of rivers. These attributes (IX and X) deserve particular attention as they are common to all applications of the BCG regardless of taxa and are (relatively) temporally static.

It is a recommendation of this study that detailed transects be used to characterise rivers that require detailed study. An ideal party would involve experts from differing disciplines each of whom could highlight features important to their chosen taxa. In this way an informed consensus on attribute IX and X tiers could be assigned to stretches of each river. These values could then be disseminated to researchers for consistent future application. Standardising definitions of these values will improve the accuracy of reporting between taxa.

6. ENHANCING FUTURE APPLICATION THOUGH A NEW MODEL OF DATA MANAGEMENT.

The reference list used in this study provides a comprehensive guide to fish ecology in the WMLR. Its collation was carried out by experts in the field and was based on professional knowledge of the available published reports. This list is central to informing various aspects of the BCG but may suffer from publication bias. Here site assessments must be informed by the reported findings and cannot account for unpublished data. These may include observations of water quality, disease and spawning statistics which were insufficient to warrant publication. Using this classical approach to research, limitations are inherent.

It is anticipated that a database could be readily adapted or developed that incorporates comprehensive and diverse aquatic ecosystem data into a central queriable format. The goal would be to integrate past and future data from all State-funded fish surveys carried out in freshwater environments across South Australia. This approach would allow for currently unavailable levels of data extraction and analysis.

Through incorporation of past and future State-funded freshwater fish data into a single database, queries could be phrased to rapidly ask ecological and physiological questions, identify all historic data for catchments and accurately determine knowledge gaps therein. In this way novel management questions would be consistently framed in an historic context and newly generated data would continue to feed back into the process producing a system of continuous improvement.

7. REFERENCES

Bice, C., Hammer, M., Leigh, S. and Zampatti, B. (2010). Fish monitoring for the 'Drought Action Plan for South Australian Murray-Darling Basin threatened freshwater fish populations': summary for 2009/10. South Australian Research and Development Institute (Aquatic Sciences), Adelaide. SARDI Publication No. F2010/000647-1. SARDI Research Report Series No. 484. 156pp.

Burkhard, B., Müller, F. and Lill, A. (2008). Ecosystem health indicators. <u>Encyclopedia of ecology</u>. Editors-in-Chief: Sven Erik, J. and Brian, F. Oxford, Academic Press**:** 1132-1138.

Davies, S. P. and Jackson, S. K. (2006). The biological condition gradient: a descriptive model for interperating change in aquatic ecosystems. *Ecological Applications*. 16(4), 1251-1266.

Goonan, P., Gaylard, S., Jenkins, C., Thomas, S., Nelson, M., Corbin, T., Kleinig, T., Hill, R., Noble, W. and Solomon, A. (2012). The south australian monitoring, evaluation and reporting program (MERP) for aquatic ecosystems: Context and overview. Adelaide, South Australian Environment Protection Authority.

Hammer, M. P. (2001). Fish survey of selected sites in the Light River Catchment. Unpublished report to the South Australian Environmental Protection Agency, Adelaide.

Hammer, M. (2002). The South East Fish Inventory. Distribution and conservation of freshwater fishes of south east South Australia. Adelaide: Native Fish Australia (SA) Inc.

Hammer, M. and Walker, K. F. (2004). A catalogue of South Australian freshwater fishes, including new records, range extensions and translocations. *Transactions of the Royal Society of South Australia,* 128**,** 85-97.

Hammer, M. (2005). The Adelaide Hills Fish Inventory: Distribution and Conservation of Freshwater Fishes of the Torrens and Patawalonga Catchments, South Australia. Adelaide: Native Fish Australian (SA) Inc. Torrens Catchment Water Management Board Patawalonga and the Catchment Water Management Board.

Hammer, M. (2006). Report on Stage One of the Southern Fleurieu Fish Inventory. Adelaide, South Australia: Native Fish Australia (SA) Inc. Aquasave.

McNeil D. G and Hammer, M. (2007) Biological review of the freshwater fishes of the Mount Lofty Ranges. South Australian Research and Development Institute (Aquatic Sciences), Adelaide. 104pp., No. Publication number: F2006/000335 SARDI Research Report Series No. 188. 104pp.

McNeil D. G. and Wilson P. J. (2008). The speckled livebearer (*Phalloceros caudimaculatus*): A new alien fish for South Australia. South Australian Research and Development Institute (Aquatic Sciences), Adelaide. Publication number: F2008/000939-1. SARDI Research Report Series No. 316. 29pp.

McNeil, D. G., Wilson, P. J., Fredberg, J. F. and Westergaard, S. (2010). Fish Passage at the Breakout Creek Fishway, River Torrens, South Australia. Report to the Adelaide and Mount Lofty Ranges Natural Resource Management Board. South Australian Research and Development Institute (Aquatic Sciences), Adelaide. Publication number: F2009/000409-1 SARDI Research Report Series No. 440. 25pp.

McNeil, D.G., Fredberg, J. and Wilson, P.J. (2009). Coastal Fishes and Flows in the Onkaparinga and Myponga Rivers. Report to the Adelaide and Mount Lofty Ranges Natural Resource Management Board. South Australian Research and Development Institute (Aquatic Sciences). Adelaide. Publication No. F2009/000410-1. SARDI Research Report Series No. 400. 76pp.

McNeil, D.G, Schmarr, D.W and Mathwin, R (2011a). Condition of Freshwater Fish Communities in the Adelaide and Mount Lofty Ranges Management Region. Report to the Adelaide and Mount Lofty Ranges Natural Resources Management Board. South Australian Research and Development Institute (Aquatic Sciences), Adelaide. SARDI Publication No. F2011/000502-1. SARDI Research Report Series No. 590. 65pp.

McNeil, D.G., Schmarr, D.W., Wilson, P.J. and Reid D. J (2011b). Fish Community and Flow Ecology in the Western Mount Lofty Ranges Environmental Water Provisions Trial Reaches. Final Report to the Adelaide and Mount Lofty Ranges Natural Resources Management Board and the SA Department for Water. South Australian Research and Development Institute (Aquatic Sciences), Adelaide. SARDI Publication No. F2011/000313-1. SARDI Research Report Series No. 581. 238pp.

Rapport, D.J., Costanza, R. and McMichael, A.J. (1998). Assessing ecosystem health. *Trends in Ecology & Evolution* 13(10): 397-402.

Waterwatch (2011). Adelaide and Mount Lofty Ranges Fish Monitoring Program, Survey Results Webpage. Accessed August 2012 http://waterwatchadelaide.net.au/index.php?page=fish-monitoring.

Wedderburn, S. and Hammer, M. (2003). The Lower Lakes Fish Inventory. Distribution and Conservation of Freshwater Fishes of the Ramsar Convention Wetland at the Terminus of the Murray Darling Basin, South Australia. Adelaide: Native Fish Australia (SA) Inc.

VanLaarhoven, JM and van der Wielen, M. (2009). Environmental water requirements for the Mount Lofty Ranges prescribed water resources areas. DWLBC Report 2009/29, Department of Water, Land and Biodiversity Conservation & South Australian Murray-Darling Basin NRM Board, Adelaide.

Appendix 1. Descriptions of the 10 attributes that distinguish the six tiers of the BCG modified for fish community assessment. Changes were conservative and have been underlined.

BCG Tier	Description
Attribute I	**Historically documented, sensitive, long-lived, or regionally endemic taxa (species with unpredictable occurrence are only scored if historical records exist for locality).**
Tier 1	<u>Present</u>
Tier 2	<u>Absent but known at the site (within the last 5 sampling events)</u>
Tier 3	<u>Absent but recolonisation possible</u>
Tier 4	<u>Absent due to global extinction</u>
Tier 5	<u>Absent due to regional extirpation</u>
Tier 6	<u>Absent</u>
Attribute II	**Sensitive-rare taxa (species with unpredictable occurrence are only scored if a historical record exist for locality).**
Tier 1	As predicted for natural occurrence, with at most minor changes from natural densities.
Tier 2	Virtually all are maintained with some changes in densities
Tier 3	Some loss, with replacement by functionally equivalent sensitive-<u>common</u> taxa
Tier 4	Present but markedly diminished
Tier 5	<u>Absent from catchment but likely to occur due to the presence of suitable habitats (supported by recent observation, anecdotal or otherwise from the catchment)</u>
Tier 6	Absent
Attribute III	**Sensitive Common Taxa**
Tier 1	As predicted for natural occurrence, with at most minor changes from natural densities
Tier 2	Present <u>with minor changes in expected density</u>
Tier 3	Common <u>in the catchment but much lower density than expected</u>
Tier 4	Present with reproducing populations maintained; some replacement by functionally equivalent taxa
Tier 5	Markedly diminished
Tier 6	Absent

Attribute IV	**Taxa of intermediate tolerance**
	(No WMLR fish species were assigned to Attribute 4 therefore wording preserved from Davies and Jackson, 2006)
Tier 1	As predicted for natural occurrence, with at most minor changes from natural densities
Tier 2	As naturally present with slight increases in abundance
Tier 3	Often evident increases in abundance
Tier 4	Common and often abundant; common abundance may be greater than sensitive-<u>common</u> taxa
Tier 5	Often exhibit excessive dominance
Tier 6	May occur in extremely high or extremely low densities; richness of all taxa is low

Attribute V	**Tolerant taxa**
Tier 1	As predicted for natural occurrence, with at most minor changes from natural densities
Tier 2	Present with a slight increase <u>or decrease in expected</u> abundance.
Tier 3	<u>May be common in catchment, but locally are either absent or do not exhibit significant dominance</u>
Tier 4	May be common in catchment, but do not exhibit significant dominance
Tier 5	<u>Common in catchment and exhibit significant dominance</u>
Tier 6	Comprise the majority of the assemblage <u>with very high densities</u>.

Attribute VI	**Nonnative or intentionally introduced taxa**
Tier 1	Nonnative taxa <u>not present</u>
Tier 2	Nonnative taxa may be present, but occurrence has a non-detrimental effect on native taxa
Tier 3	Sensitive introduced taxa dominate assemblage
Tier 4	<u>Diversity of non-native taxa dominate assemblage</u>
Tier 5	Fish assemblage is dominated by tolerant nonnative fish(es)
Tier 6	<u>Nonnative fishes are the only representatives of the fish taxa</u>

Attribute VII	**Organism <u>and population</u> condition <u>(disease, congenital abnormalities, reproduction)</u>**
Tier 1	<u>Anomalies not observed, multiple age classes apparent</u>
Tier 2	Any anomalies consistent with naturally occurring incidences and characteristics, <u>multiple age classes apparent</u>
Tier 3	Anomalies are infrequent
Tier 4	<u>Biomass reduced or anomalies common</u>
Tier 5	Biomass reduced and anomalies <u>widespread</u>
Tier 6	Long-lived taxa may be absent; biomass reduced; anomalies widespread and serious; minimal reproduction except for extremely tolerant groups.

Attribute VIII	**Ecosystem functions**
	This tier is not utilised in the current approach but has been retained to allow future integration of limnological data.
Tier 1	All are maintained within a range of natural variability
Tier 2	All are maintained within a range of natural variability
Tier 3	Virtually all are maintained through functionally redundant system Attributes; minimal increase in export except in high storm flows
Tier 4	Virtually all are maintained through functionally redundant system Attributes, although there is evidence of loss of efficiency (eg increased export or increased import)
Tier 5	Apparent loss of some ecosystem functions manifested as increased export or increased import of some resources and, changes in energy exchange rates (eg P/R, decomposition)
Tier 6	Most functions show extensive and persistent interruption

Attribute IX	**Spatial and temporal extent of detrimental effects**
Tier 1	Not applicable. Natural disturbance regime is maintained
Tier 2	Limited to small pockets and short durations
Tier 3	Limited to reach scale and/or limited to within a season
Tier 4	Mild detrimental effects may be detectable beyond the reach scale and may include more than one season
Tier 5	Detrimental effects extend far beyond reach scale leaving only a few islands of adequate conditions; effect extends across multiple seasons.
Tier 6	Detrimental effects may eliminate all refugia and colonisation sources within the catchment and affect multiple seasons.

Attribute X	**Ecosystem Connectance**
Tier 1	No alteration to natural connectance patterns in space or time
Tier 2	System is fully connected at least annually (longitudinally, laterally **and** vertically)
Tier 3	Slight loss of connectance but there are adequate local colonisation sources
Tier 4	Some loss of connectance but colonisation sources exist within the catchment
Tier 5	Significant loss of ecosystem connectance is evident. Recolonisation sources do not exist for some species
Tier 6	Complete loss of connectance lowers reproductive success of most groups. Frequent failures in reproduction and recruitment.

Appendix 2. Expert Panel site assessment ratings outlining attribute tiers for each of 40 fish monitoring sites and the factors contributing to those scores. Fish species are abbreviated using the first three letters of the genus and species name as follows; Gal bre - climbing galaxiid, Gal mac - common galaxiid, Gal oli - mountain galaxiid, Gam hol – eastern gambusia, Nan aus – southern pygmy perch, Onc myk – rainbow trout, Per flu – redfin perch, Phi gra – flathead gudgeon, Pse olo – western blue spot goby, Pse urv – congolli, Sal tru –brown trout. Exotic species listed in red.

Site Name	I	Reason	II	Reason	III	Reason	V	Reason
Back Valley			5	Nan aus absent, captured in previous site surveys (interpreted as failure to capture). Gal bre absent			4	Hyp spp not dominant
Bartletts			6	No fish	6	No fish		
Cherry Plantation					2	High abundance		
Commercial Rd			4	2 Pse urv found spread across multiple habitats	6	Gal mac absent		
Cootamundra Reserve			1	Pse urv as predicted for natural occurrence	1	Gal mac as predicted for natural occurrence	1	Phi gra as predicted for natural occurrence
Corkscrew Bridge			6	No Gal bre present				
Cox Creek			5	Gal bre absent possibly due to barriers downstream	1 or 2	Gal oli present with recent recruitment		
Dog Trap Creek			6	No Gal bre captured, previous recorded	5	No Gal oli, possibly should be there		
Field			2	Pse urv present in high abundance	2	Gal mac in high abundance		
Gawler Dam					2	Gal mac increasing in abundance, Gal oli absent	4	Common in the river, not dominant here
Glacier Rock			4	Markedly diminished Gal bre				Phi gra not present but not considered for this site, not previously recorded
Guaging Station			5	Pse urv absent, unclear about potential barriers.	5	Gal mac markedly diminished	4	Hyp spp not dominant
Hay Flat			2	Pse urv present in high abundance	2	Gal mac in high abundance		

Site Name	I	Reason	II	Reason	III	Reason	V	Reason
Hindmarsh Falls			1	Gal bre as predicted for natural occurrence	1	Gal oli as predicted for natural occurrence		
Ingalalla Falls			4	Markedly diminished				
Light Ford				No Gal bre records in the Light	5	Single Gal mac	5	Unusually high numbers
Marrabel				No Gal bre records in the Light	2	Very high abundance	6	No Phi gra observed
Moculta			6	Gal bre expected but absent			6	Phi gra expected but absent
Mt Crawford			4	Markedly diminished Gal bre			4	Phi gra not dominant
Mt McKenzie			6	Gal bre expected but absent			6	Phi gra expected but absent
Myponga Township			5	Gal bre absent , but seen further upstream	6	Gal oli absent, historic records		
Nashwauk			4	A single representative of Pse olo and Pse urv	4	Reproductive Gal mac population with expected density		
Nuriootpa			6	Gal bre expected but absent			6	Phi gra expected but absent
Pages Flat			3	Reduced number with replacement	6	Gal oli absent, historic records		
Patawolonga	2	First record of very rare species in this catchment	3	Two rare species, replacement by exotics probable	4	Reproductive but reduced Gal mac		No past records of Phi gra in Greater Patawolonga
Pony Club			4	Low abundance of Pse olo	3		3 or 4	Common in the river, not dominant here
Portuguese Bridge			6	Gal bre expected but absent			6	Phi gra expected but absent
Railway Dam					5	Markedly diminished		
Rockies				No Gal bre records in the Light	3	Gal mac common and abundant	5	Unusually high numbers
Sawpit Rd			2	Gal bre and Pse urv maintain possible lower density	1	Gal mac as predicted for natural occurrence		Phi gra present DS, not considered for this site
Scott Creek Conservation					6	Gal oli absent		
South Rd			2	Pse urv present in high abundance	2	Gal mac in high abundance		

Site Name	I	Reason	II	Reason	III	Reason	V	Reason
Stornoway			1	Good Gal bre population				
Sturt Creek Tributary					2	High numbers		
Tunkalilla			1	Predicted abundance				
Victoria Creek			1	Gal bre as predicted for natural occurrence				
Washpool			2	Small environment with near expected densities	3	Small environment		
Willow Glen					6	Absent in this stretch		
Yaldara			3	Low abundance of Pse olo	3	Gal mac common and abundant, Gal oli absent	4	Phi gra not dominant
Yankalilla Rec Centre			4	Decrease in abundance	3	Gal mac common and abundant		

Site Name	VI	Reason	VII	Reason	IX	Reason	X	Reason
Back Valley	1	No invasive species	5	Biomass reduced	5	Stock access, Off-channel Dams, High nutrient runoff, incised channel	4	Some loss of connectivity, recol sources for all taxa
Bartletts					5	Grazing and dairy upstream	5	Significant loss of connectivity, no major barriers identified
Cherry Plantation	1	Nil exotics	3	Nil disease but single size class	5	Islands of population	4	Upstream health population
Commercial Rd	6	Several pools contained Car aur	5	No reproduction, biomass reduced	5	Pools liable to turn toxic eliminating refuge	4	Ocean considered a site for recolonisation
Cootamundra Reserve		Mel flu present but considered possible native to this catchment	2	Complex population structure, no disease, abundance could be higher	4	Upstream farming/urban impacts, reasonable site habitat	2	Unimpaired connectance
Corkscrew Bridge	6	Dominated by Sal tru and Onc myk			3	Limited to reach	2	Unimpaired connectance
Cox Creek	1	No invasive species	2	Absence of disease	3	Weeds, Erosion limited to reach scale	4 to 5	Unknown?, Some or significant loss of connectance
Dog Trap Creek	6	Only representative of assemblage			5	Grazing upstream, land clearance, pine forest	4	Gal bre refugia may exist in catchment
Field	1	No invasive species	3	Complex pop structure, but some disease	5	Urban Runoff, High Nutrient Runoff, Invasive riparian zone	3	Some loss of connectance, refugia exist
Gawler Dam	4	Abundant and diverse nonnatives not dominating	2	No disease, complex pop structure, abundant species	5	?Barrier to movement, Grazing runoff	5	Significant loss of connectivity, recol sources for some taxa
Glacier Rock	5	Large Per flu dominating assemblage (prey species)	5	No complex population structure, no disease, biomass reduced	5	Litter, Invasive weeds	4	Some loss of connectivity, recol sources for all taxa
Guaging Station	5	Exotics dominating the system	6	Biomass reduced nil reproduction	5	Redfin, Invasive weeds, farming	4	Some loss of connectivity, recol sources for all taxa
Hay Flat			2	No disease, complex pop structure, abundant species	5	Urban Runoff, High Nutrient Runoff, Invasive riparian zone	3	Loss of lateral connectance
Hindmarsh Falls	1	No invasive species, trout stocking permitted	1	Complex population structure, no disease	4	Upstream farming impacts	2	Unimpaired connectance

Site Name	VI	Reason	VII	Reason	IX	Reason	X	Reason
Ingalalla Falls	3	Dominance by sensitive non-native taxa - Sal tru	2	Multiple size classes present	4 or 5	Multiple impacts occur in continuum along the catchment	4	Some loss of connectance
Light Ford	4 - 5		2	Multiple size classes, no disease noted	4	Farming impacts	3 to 5	Unknown
Marrabel	4 - 5	Huge numbers of exotics replace Phi gra	2	Nil disease	4	Farming impacts	3 to 5	Unknown
Moculta					5	Grazing, high nutrient runoff	5	Significant loss of connectivity, recol sources for some taxa
Mt Crawford	5	Per flu present	5	No complex population structure, no disease	5	Forestry, nutrient runoff, reduced flow	5	Significant loss of connectivity, recol sources for some taxa
Mt McKenzie	6	Only invasives present			5	Grazing, high nutrient runoff	5	Significant loss of connectivity, recol sources for some taxa
Myponga Township	6	Only representative		Exotics not considered	5	Extensive grazing	3 to 5	Poorly known strong Gal bre upstream
Nashwauk	5	Gam hol dominant	2	Nil abnormalities detected	6	Pool liable to turn toxic eliminating refuge	4	Ocean considered a site for recolonisation
Nuriootpa	6	Only invasives present			6	Weeds, Poor flow and anoxic conditions, Leaf Litter	5	Significant loss of connectivity, recol sources for some taxa
Pages Flat	4	Replacement apparent	2	Breeding and no disease	5	Extensive grazing	3 to 5	Poorly known
Patawolonga	4	Some replacement with diverse exotics	4	Reduced biomass, reproductive Gal mac	5	Extensive habitat alteration, habitat islands	4	Oceanic connectance good, upstream issues
Pony Club	5	Dominated by nonnative taxa	1	No disease, complex population structure	4	Invasive riparian plants	4	Some loss of connectance, refugia exist
Portuguese Bridge	6	Only invasives present			5	Grazing, high nutrient runoff	5	Significant loss of connectivity, recol sources for some taxa
Railway Dam	1	Anecdotal report of Per flu, not identified	5	Biomass reduced, nil reproduction	5	Islands of population	4	Upstream health population

Site Name	VI	Reason	VII	Reason	IX	Reason	X	Reason
Rockies	4 - 5		5	Native biomass reduced dramatically	5	Channelation, farming and tourism impacting heavily	3 to 5	Unknown
Sawpit Rd	1	No invasive species, trout stocking permitted	1	Complex population structure, no disease	4	Upstream farming impacts	3	Slight loss of connectance through tributary damming
Scott Creek Conservation	1	No invasive species		Nil fishes	5	Upstream nutrient input, logjams	4 to 6	Unknown,? Some or significant loss of connectance
South Rd			2	No disease, complex pop structure, abundant species	5	Urban Runoff, High Nutrient Runoff, Invasive riparian zone	3	Loss of lateral connectance
Stornoway	2	Very low Per flu abundance	3	Complex pop structure, no recent recruitment (0+ fish)	3	Per flu in dam upstream, farming upstream	5	Loss of connectance, no other source populations
Sturt Creek Tributary	1	Salmoniids have not penetrated these pools	2	Multiple size classes, no disease	5	Islands of recolonisation potential	4	Unknown probably slight
Tunkalilla		Not known in this catchment	2	Complex size classes, nil disease	4 or 5	Extensive cropping and forestry	3 - 5 ?	Unknown
Victoria Creek	1	No invasive species	1	Complex population structure, no disease	5	Nutrient runoff, urban development	2	Unimpaired connectance
Washpool			2	Nil abnormality detected	2	tiny catchment, low rates of urbanization	2	Tiny Catchment, unimpaired connectance
Willow Glen	6	Complete replacement by Sal tru		Don't consider exotics in Attribute VII	4	Mild	4	Unknown probably slight
Yaldara	5	Dominated by non-native taxa	3	Some complex population structure, no disease.	5	High nutrient runoff, riparian clearing	5	Significant loss of connectivity, recolonisation sources for some taxa
Yankalilla Rec Centre	5	Gam hol dominate according to visual observation	2	No disease, complex pop structure, abundant species	5	Urban Runoff, High Nutrient Runoff, Invasive riparian zone	3	Loss of lateral connectance

Appendix 3A. Site Coversheet (Front and Rear) used by SARDI Inland Waters, Climate and Catchment Ecology Group (October 2012).

SARDI Field Sampling

Catchment:	Site Name:	Season:	Date Set:	Date Pulled:

Land Use:		Observers:				

Operation Data

Set:	:
Pulled:	:
Site	**Weather**
Private	Sunny
Public	Cloudy
Parks	Rainy
Govt	Windy

Hydrology

Water Quality			
Time:	:		
Max Depth:	cm		
Connectivity	**Flow**		
Connected	Low	Mod	High
Isolated	Still		

Habitat

Flora	Emergent	Submerged	Riparian
Percent Cover:	%	%	%
Percent Native:	%	%	%
Dominant Species:			
Snags	**Large complex**	**Large simple**	**Small complex**
Number of Snags:			

%Subst (mm)	
<1	%
1-5	%
5-10	%
10+	%
Bedrock	%

SKETCH: show habitat features, phytes, rock features, snags riparian trees etc, estimated length/width, e-fish areas & all nets. **FLOW DIRECTION, PHOTO+WQ POINTS**

GEAR #	DW1	DW2	SF1	SF2	SF3	SF4	SF5	SF6		
MacroHabitat										
Wing Depth										
Set Off										
MicroHabitat										

Methods, Keys & Additional Data

Habitat

Emergent	Emergent Veg eg. Typha (or innundated shrub)
Submerged	Submerged Veg eg. Fillamentous Algae
Riparian	Veg cover up to 10m from bank, along SAMPLE area
Percent Cover	Only estimate cover WITHIN or ALONG sampling area Aquatic cover = relative to total waterbody of SAMPLE
# of Snags	Number of snags VISIBLE: LC= Large, multi branched LS= Large, singular trunk SC= Small, multi branched

Hydrology

Water Quality	Time & max depth recorded
Flow	Flow rate (Please Circle)
Connectivity	Hyrological connection between sample site and river
%Subst (mm)	Percentage cover of substrate sizes in sample site
Unknown="?"	

Operation Data

Set/Pulled	Time (24hr) eg. 17:00
Site (Type)	Management of the land. (Please Circle)
Weather	Choose either sunny OR cloudy (>50%) Rainy/Windy can be additional
Land Use:	Major land uses in area (eg. Pastoral)
Observers:	Names of participants (eg. J. Bloggs)

Comments: Note any limitations, errors or interesting observations etc.

Gear Habitat Data

From the keys below select the:

Macro Habitat = that best describes the area the net is set

Wing Depth = that best describes the level of wing floats

Set Off = habitat that the net is set off

Micro Habitat = that best describes/specifies the habitat the wing is targeting

Macro Habitat	Description
Main Channel	In main channel
Inlet	Embayment off main channel
Lake	Large, flat waterbody
Spring	Natural spring
Bore Drain	Man made bore

Wing Depth:	Description
Above Surface	All floats above surface
Below Surface	All floats below surface

Set Off	Description
Overhanging	Vegetation hanging into/above water
Emergent Veg	Typical emergent semi aquatic plants
Rock	Rocks emerging/surrounding water body
Snag	Snags within/emerging from water body
Bank	Bank surrounding water body
Across Inlet	Across embayment (perpendicular to inlet)
Structure	Man made object (board walk)
Mid Stream	Set within the middle of the water body
Along Inlet	Along Embayment (parallel to inlet)
Submerged Veg	Typical submerged aquatic plants
Off Inlet	Near the mouth of an inlet in main channel

Micro Habitat
Emergent Veg
Hanging Veg
Emergent Rock
Rock Face
Shallow Open Water
Large Complex
Large Simple
Small Complex
Bare Bank
Grassy Bank
Rocky Bank
Roots on Bank
Boardwalk/Jetty
Open Water
Submerged Veg
Riffle
Weir/Dam
Bridge/Pylon
Culvert

FAUNA		Genus	Species		Genus	Species
	SP1			SP5		
	SP2			SP6		
	SP3			SP7		
	SP4			SP8		

Mood:

Appendix 3B. Data entry sheets used by SARDI Inland Waters, Climate and Catchment Ecology Group (October 2012).

SARDI LEBRA FISH DATA

Page ____ of ____.

Date:	Catchment:	Site:

	Gear No.	Genus	Species	Fish No.	TL mm	Comments		Gear No.	Genus	Species	Fish No.	TL mm	Comments
1							51						
2							52						
3							53						
4							54						
5							55						
6							56						
7							57						
8							58						
9							59						
10							60						
11							61						
12							62						
13							63						
14							64						
15							65						
16							66						
17							67						
18							68						
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48							98						
49							99						
50							100						

If found please contact SARDI Aquatic Sciences, Tel (08) 8207 5400 or return to PO Box 120 Henley Beach SA 5022