Status of the Gunbower Island Fish Community, June 2005

Including Recommendations for Future Monitoring

Adam Richardson, Shaun Meredith, Anthony Conallin and Clayton Sharpe

....

November 2005

Murray–Darling Freshwater Research Centre
P.O. Box 991
Wodonga VIC 3689

An MDFRC Consultancy Report
for the North Central Catchment
Management Authority
628–634 Midland Highway
Huntly VIC 3500

Status of the Gunbower Island Fish Community, June 2005.

A report prepared for the North Central Catchment Management Authority by the Murray-Darling Freshwater Research Centre.

For further information contact:

Adam Richardson* or Shaun Meredith‡

*Murray-Darling Freshwater Research Centre
PO Box 991 Wodonga VIC 3689
Ph (02) 60582300
Fax (02) 60597531

‡ Murray-Darling Freshwater Research Centre
PO Box 3428, Mildura VIC 3502

e-mail: Adam.Richardson@csiro.au
Shaun.Meredith@csiro.au
Anthony.Conallin@csiro.au
Clayton.Sharpe@csiro.au

November 2005

EXECUTIVE SUMMARY

Gunbower Island State Forest (Gunbower Forest) represents the Victorian component of the Gunbower and Koondrook–Perricoota Forests Significant Ecological Asset (SEA) — SEAs as identified in the Living Murray initiative. It is a floodplain system of almost 20 000 ha that includes a range of forest types and permanent and semi-permanent wetlands. The wetlands are of international significance (Ramsar listed) and are valued particularly for their genetic and ecological diversity — part of this diversity is described by the fish fauna present. Gunbower Island is bounded by the River Murray to the north-east, and an anabranch, Gunbower Creek, to the south-west. It is broadly accepted that the reduction in flooding extent and duration on Gunbower Island, as a result of regulation of the River Murray, has substantially altered the composition of the fish fauna on the island. In an attempt to halt, and where possible reverse, this process, the North Central Catchment Management Authority (CMA) is managing 'The Flooding Enhancement of Gunbower Forest' project. A key component of this project is the introduction of a flooding regime that will be beneficial to the fish fauna of Gunbower Forest and Gunbower Creek.

The key aims of this report were to develop an appropriate and repeatable sampling methodology for monitoring the fish fauna of Gunbower Island (wetlands and Gunbower Creek), to undertake sampling in accordance with this methodology, and then to report on collected data and the sampling program. The sampling program used was developed from the ecological objectives for fish monitoring listed in *A Monitoring System for the Gunbower Forest* (Crome 2004). Focused heavily on the relative abundances and evidence for breeding of a number of individual species, these ecological objectives guided the identification of targeted species and the development of testable hypotheses.

Sampling consisted of a one-off survey conducted in June 2005 at 12 wetland and creek sites suggested by the North Central CMA. The majority of fish sampling was undertaken using large and small fyke nets because low water levels and steep unstable banks in the Gunbower system prevented effective electrofishing (except at one site in Gunbower Creek). Recommendations for a future monitoring program of fish fauna of Gunbower Island were largely based on the results of the one-off survey.

Eight native fish species and five exotic fish species were collected in the survey. Carp gudgeons were the most abundant native species (13 865 fish), followed by Australian smelt (157), flathead gudgeon (126) and flyspecked hardyhead (120). Crimson-spotted rainbowfish (26) and golden perch (7) were much less abundant and only one Murray cod and one dwarf flathead gudgeon were captured. Gambusia was the most abundant exotic species (1290), followed by common carp (36), goldfish (9), redfin (2) and weatherloach (1).

Significantly greater numbers of fish were collected in wetlands (13 879 fish) compared to creek sites (1762 fish). This was due primarily to the large numbers of the small-bodied carp gudgeons and gambusia collected from wetlands. Of the exotic species captured using fyke nets, most were from wetlands: all goldfish, weatherloach and redfin, 94% of total common carp catch and more than 99% of gambusia.

Despite these differences in abundances, multivariate analysis did not reveal a difference in community composition between wetland and creek sites.

For the large-bodied native species, Murray cod and golden perch, there was no clear evidence of a recent breeding event. No juvenile Murray cod were collected and the smaller golden perch collected may have been stocked. In the absence of a readily accessible and inexpensive technique for discerning stocked fish in the field, this will remain a limitation to assessing evidence for breeding of important angling species. A sampling methodology that targets larval fish on Gunbower Island may overcome the above limitation.

In contrast, there was clear evidence of breeding by most of the small-bodied native fish collected on Gunbower Island. Length-age analyses of fish collected indicated that Australian smelt, flyspecked hardyhead, crimson-spotted rainbowfish, flathead gudgeon and carp gudgeon (complex) spawned and successfully recruited during the previous breeding season.

Three of the native species collected in the present survey are currently listed as 'threatened' under the Victorian *Flora and Fauna Guarantee Act (1998)*: flyspecked hardyhead, crimson-spotted rainbowfish and Murray cod. Both flyspecked hardyhead and crimson-spotted rainbowfish were collected in reasonable abundance and demonstrated evidence for breeding, suggesting that Gunbower Island may be an important habitat for mid-Murray populations of these threatened species.

Power analysis indicated that the monitoring system applied in this survey was not suitable for testing hypotheses that describe changes in the abundance of individual fish species. In the vast majority of cases, a reasonable increase in sampling effort (i.e. netting effort and number of sites surveyed) is not expected to improve total catch consistency or abundances such that power estimates are substantially increased. We recommend, therefore, that the ecological objectives for fish monitoring contained in Crome (2004) be altered so that the effects of a modified flow regimes on the fish fauna of Gunbower Island can be ascertained. We suggest that the ecological objectives should be broadened to consider: a) all small-bodied fish species as one group, b) total native fish abundance and species richness, c) total exotic fish abundance and species richness, and d) using a weighted 'fish index' as the basis for hypothesis testing.

It is also recommended that future sampling efforts are conducted late in the fish breeding season (ideally March) so that evidence for breeding can be more accurately detected using larval and early juvenile sampling techniques. We also recommend that small fyke nets and boat electrofishing are the most appropriate techniques for sampling small and large fish, respectively.

This report describes fully the adaptive management of a hypotheses-based fish monitoring program. Incorporation of suggested changes into a long term monitoring program will provide a sound basis for the assessment of changes in the abundance and breeding activity of the native and exotic fish fauna of Gunbower Forest.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

1 INTRODUCTION

1.1 The Living Murray and Gunbower Island

The Murray–Darling Basin Ministerial Council (MDBMC) established *The Living Murray* initiative in 2002, with the aim of returning the River Murray to a healthy river. To achieve this, the 'first step' decision in November 2003 committed $500 million and 500 GL of water to maintain or improve the social, economic, cultural and environmental values of the River Murray and its associated floodplains. To maximise the benefit, this investment has been targeted to six Significant Ecological Assets (SEAs) (Figure 1).

Figure 1: Six Significant Ecological Assets (SEAs) established by the Murray Darling Basin Commission (MDBC) under *The Living Murray* initiative (MDBC 2005). Figure reproduced with permission from MDBC.

Gunbower Island State Forest (Gunbower Forest) represents the Victorian component of the Gunbower and Koondrook–Perricoota Forests SEA. Gunbower Forest is a floodplain system of 19 450 ha that includes permanent and semi-permanent wetlands, the second largest red gum (*Eucalyptus camaldulensis*) forest in Victoria, and black box (*Eucalyptus largiflorens*) and grey box (*Eucalyptus microcarpa*) woodlands (Cooling *et al.* 2001). The forest is a Ramsar-listed wetland of international significance, particularly valued for its genetic and ecological diversity (Environment Australia 2001), and is currently utilised for timber production, recreation, wildlife conservation, grazing and flood mitigation (North Central Catchment Management Authority [CMA] 2005).

Gunbower Forest occupies most of Gunbower Island: an island bound by the River Murray to the north-east and Gunbower Creek, an anabranch of the River Murray, to the south-west (Cooling *et al.* 2001). The balance of land on Gunbower Island comprises small pockets of freehold land. Major towns in the region are Koondrook (at the western end of the island), Cohuna and Gunbower (along Gunbower Creek), and Echuca (east of the island).

Flooding of Gunbower Forest depends primarily on the height of the River Murray downstream of Torrumbarry Weir (Cooling *et al.* 2001). Flows into Gunbower Forest are delivered by floodrunners (e.g. Yarran Creek) when flows in the River Murray reach between13 700 and 15 000 ML day^{-1}. Although the natural flooding regime of Gunbower Forest is difficult to ascertain (Gippel and Blackham 2002), regulation and diversion of flow in the River Murray has reduced the frequency and duration of floods in Gunbower Forest. The following alterations to natural hydrological patterns have been observed (Gippel and Blackham 2002):

- Under natural conditions, flows of at least 15 000 ML day^{-1} occurred in the River Murray near Gunbower Forest for 5.8 months each year, but flows of this magnitude occur, on average, for only 2 months each year under regulated conditions.
- Inflows to Gunbower Forest (based on flows of 15 000 ML day^{-1} or more in the River Murray) occurred, under natural conditions, in 98% of years, but occur in only 57% of years under regulated conditions.

As a result, the altered flooding regime of Gunbower Forest has led to a decline in the extent of wetlands important for colonial waterbird breeding, and black box woodland has encroached onto areas that naturally flooded frequently and contained red gum forest (Cooling *et al.* 2001; Gippel and Blackham 2002).

Flow from the River Murray into Gunbower Creek is controlled by a regulator on the National Channel: the conduit between the creek and the river. Increased water levels in the River Murray, created by the pool upstream of Torrumbarry Weir, gravity feed into the National Channel and, when the regulator is open, flow into Gunbower Creek. High water levels are usually maintained throughout the irrigation season as Gunbower Creek is used to deliver water (Cooling *et al.* 2001).

Gunbower Creek is considered an option for the delivery of environmental flows into Gunbower Forest (Gippel and Blackham 2002). According to the 'Index of Stream Condition', based on an assessment of hydrology, water quality, streamside zone, bed and bank condition, instream habitat and aquatic life, Gunbower Creek is in 'moderate' (Department of Sustainability and Environment [DSE] 2005a).

The most recent survey of fish fauna in the Gunbower region occurred in Gunbower Creek in 1998 and 14 species of fish, including nine native and five exotic species, were collected (Douglas *et al.* 1998). This survey concluded that the Gunbower Creek fish community was dominated by large exotic species and that the smaller populations of large native species were maintained mostly by stocking and did not, therefore, represent viable populations (Douglas *et al.* 1998).

1.2 Monitoring and The Living Murray

Currently, through *The Living Murray* initiative, a number of ecological objectives have been (or are being) developed at each Significant Ecological Asset (SEA). These objectives are linked to flow requirements, and it is these flow requirements that will determine the regime for delivery of the 500 GL of new environmental water prescribed by the first step decision.

A critical part of *The Living Murray* initiative is the monitoring of ecological objectives that underpin the environmental water delivery decision making process. A monitoring program that incorporates a broad range of biotic (e.g. red gums, fish, macroinvertebrates) and abiotic (e.g. groundwater and surface water quality) indicators will provide a measuring stick of the success, or otherwise, of the initiative. The monitoring program will also provide the basis for an adaptive management approach to the delivery of environmental flows and, in doing so, will ensure that the ecological benefit of those flows are maximised. Such monitoring (and adaptive management) will most likely be undertaken at three different scales (from Scholz *et al.* (2005):

- Systems (or Basin) scale — all SEAs along the River Murray will be monitored and the results aggregated at the broadest (not replicated) scale to provide an overview of the success, or otherwise, of *The Living Murray* initiative.
- Whole-of-Asset scale — each individual SEA (again, not replicated due to broad-scale biological and geographical differences between SEAs) will be monitored to assess temporal changes in environmental condition resulting from water delivery.
- Intervention scale — ecological variation resulting from targeted flow manipulations (e.g. installation of a regulator) within individual SEAs will be monitored extensively (replicated and/or BACI type experimental design) to examine cause and effect responses of biota to water delivery.

The Murray–Darling Freshwater Research Centre (MDFRC) is in the process of developing a monitoring program at the 'Whole-of-Asset' scale for the Hattah Lakes and Barmah Forest (Victorian) component of the Barmah–Millewa Forest SEAs. The MDFRC has previously developed a monitoring program at the 'Intervention' scale for the Lindsay and Wallpolla islands component of the Chowilla/Lindsay/Wallpolla Islands SEA (Scholz *et al.* 2005). The monitoring presented in this report represents an extension of this work, and aims (in part) to standardise the monitoring approach being undertaken as part of *The Living Murray* initiative.

1.3 Flooding Enhancement of Gunbower Forest

'The Flooding Enhancement of Gunbower Forest' project is being managed by the North Central CMA. The overarching objective of the project is:

> *To enhance the ecological communities of Gunbower Forest by providing a flooding regime, based on pre- and post- river regulation flooding patterns, focusing on priority areas where enhanced flooding would be environmentally beneficial and physically feasible.*

There are eight implementation stages to the Flooding Enhancement of Gunbower Forest project:

Stage One: Project Set Up

Stage Two: Scoping and Information

Stage Three: Investigation of Priority Options

Stage Four: Monitoring, Approvals and Agreements

Stage Five: Summary of Report and Entire Process

Stage Six: Development of Water Management (Operational) Plan

Stage Seven: Implementation and Construction

Stage Eight: Evaluation and Review.

The Scoping Study of environmental water requirements and water management options was completed in 2001 (URS 2001). The Investigation of Priority Options was completed in two parts (A and B) in 2004 to identify priority water management options (Ecological Associates 2003, 2004). An overall system for monitoring was developed in 2004 to assess whether the implementation of water management options would improve the environmental condition of Gunbower Forest and whether the ecological objectives would be achieved (Crome 2004).

1.4 Scope and objectives of this report

A Monitoring System for the Gunbower Forest (Crome 2004) was developed for monitoring a series of 27 ecological objectives at the 'Whole-of-Asset' scale. Crome (2004) derived the 27 ecological objectives from a set of 22 'targets', and following this, 18 Programmed Monitoring Activities (PMAs) were designed to collect data to inform a tier of 50 'indicators' below these ecological objectives. 'Indicators' are then used to assess trends in a meaningful way and inform the ecological objectives.

The MDFRC was engaged to implement the fish component of the monitoring system developed by Crome (2004). The aim of this part of the project is to assess the fish fauna of Gunbower Forest by:

- Defining a sampling methodology to provide a representative sample of the fish fauna populations likely to be present.
- Undertaking field work to collect fish community composition, abundance and richness data for Gunbower Forest and any other pertinent environmental information.
- Analysing and reporting on collected data (North Central 2005).

Note: In this report, Gunbower Island replaces Gunbower Forest in the above aim. Gunbower Forest includes only 'wetlands' whereas Gunbower Island includes 'wetlands' and Gunbower Creek. The established ecological objectives specify 'targets' in Gunbower Creek, wetlands in Gunbower Forest, or both (Crome 2004: Section 2.1). A definition of key terms used in Crome (2004) is given in Section 2.1.1.

To design the monitoring program for Gunbower Island, we applied the following seven step process (Scholz *et al.* 2005). This process was developed to ensure the design of effective adaptive management-based monitoring programs for monitoring previously undertaken by the MDFRC as part of *The Living Murray* initiative:

1. Define key ecological objectives and management priorities.
   Identify ecological objectives and define key terms used in ecological objectives.

2. Develop a conceptual model for the system in question.
   A simple conceptual model for an ecological objective facilitates an understanding of causal factors linked to the response variable. This can result in the simultaneous collection of field data critical for the interpretation of monitoring results over time.

3. Define specific testable hypotheses.
   Specifying testable questions increases the ability to feed collected data back into an adaptive management process.

4. Select variables and indicators for measuring.
   The generation of hypotheses based on the conceptual model will assist in the identification of key response variables. Indicators should directly assess progress toward an ecological or management objective.

5. Develop a program design.
   Collecting data to detect the presence or measure the size of key indicators requires careful design of the sampling program. The focus at this stage of the monitoring program design would include an analysis of existing sampling methodologies (e.g. Sustainable Rivers Audit), their applicability to selected response variables, the repeatability of sampling methods (for future sampling); the seasonality of targeted fish species, their sizes, life stages, behaviour and 'catchability'.

6. Optimise sampling effort and statistical power.
   The aim is to design a sampling regime that provides the most efficient (in terms of resources) and precise estimates of ecological response variables. Major consideration needs to be given to the type of spatial and temporal sampling (random, stratified, systematic) and to power analysis: power analysis provides a measure of the confidence of conclusions reached for a given sampling effort.

7. Feed-back of monitoring data into the adaptive management process.
   The periodic review of monitoring data, and its interpretation in terms of the conceptual model and management targets, is integral to the adaptive management process. From the point of improved knowledge of an ecosystem, changes in management responses may be identified, and the conceptual model and hypotheses may be modified.

In this report, steps 1–4 are considered in Section 2 and assist in the development of methods for an initial assessment of fish fauna on Gunbower Island (step 5 detailed in Section 3). Steps 6 and 7 are addressed and discussed in Section 4 and inform 'Recommendations for Future Monitoring' (Section 5).

2 DEVELOPMENT OF MONITORING PROGRAM

Aquatic ecosystems are complex and often unpredictable; thus, the imposition of planned human intervention on these systems lends itself well to an adaptive management approach (Panel of Adaptive Management for Resource Stewardship 2004). Such an approach regards unanticipated ecosystem responses as new knowledge; this new knowledge is then fed directly into previously defined conceptual models of ecosystem function to generate improved management strategies and/or operational rules (Scholz *et al.* 2005). In addition to improving the efficacy of management decisions, adaptive management adds value to hydrological manipulations by increasing scientific knowledge — site specific and extrapolative to other systems — whilst adding flexibility to management policies (Lee 1999).

Monitoring is the process that provides management with new knowledge (Finlayson and Mitchell 1999) — for example, expected trends and unanticipated ecosystem responses. A critical phase in the development of monitoring programs is the establishment of sound ecological objectives (see stage 1 in Scholz *et al.* 2005). These objectives must be clear, concise and detail specifically what is to be achieved (ANZECC and ARMCC 2000) because they are used to form the conceptual model and testable hypotheses — central components of an adaptive management-based monitoring program.

Crome (2004) based a monitoring system around a set of ecological objectives — developed by the North Central CMA specifically for Gunbower Forest — that aimed to describe the effects of future changes to water management on birds, fish, amphibia and invertebrates. Here, we focus on the ecological objectives included in Crome (2004) for native fish (see Section 2.1). In their original form, these objectives provide a valuable basis for the development of a fish monitoring program. They do, however, require refining and accurate definitions ascribed to terms before appropriate conceptual models and testable hypotheses can be generated. In this report, we delineate habitat types, define key terms and specify fish species referred to in Crome (2004) and, as a result, generate a total of 37 measurable and testable hypotheses linking ecological response to hydrology.

2.1 Ecological objectives

The ecological objectives and suggested endpoints for management interventions are taken directly from Crome (2004) and presented in Table 1. To expand these objectives, we have considered the spatial unit over which the objectives are applicable, the species we consider to be included/affected by the objective, and the response variable that is measurable as part of a monitoring program.

Table 1: Ecological objectives from Crome (2004), expanded to define a spatial unit, species considered and measurable response variable.

Indicator (Crome 2004)	**Ecological Objective**	**Suggested Endpoint**	**Spatial unit**	**Species considered**†	**Measurable**
F1	Restore populations of cod and perch by providing opportunities for floodplain access.	Number of native species should increase each audit up to maximum possible.	Whole of Island: Wetlands and Gunbower Creek	Golden perch, Macquarie perch, Murray cod, trout cod and silver perch.	Relative abundance (CPUE‡) of individual species
F2	Restore populations of cod and perch by providing opportunities for floodplain access.	Number of species with evidence for breeding should increase each audit.	Whole of Island: Wetlands and Gunbower Creek	Golden perch, Macquarie perch, Murray cod, trout cod and silver perch.	Relative abundance (CPUE‡) and size class distribution of individual species$^{\Omega}$.
F3	Restore self-sustaining populations of cod and perch in Gunbower Creek.	A size range of each species that indicates breeding has occurred should occur in the creek.	Gunbower Creek	Golden perch, Macquarie perch, Murray cod, trout cod and silver perch.	Presence/absence of 0+ (larval and/or juvenile) individuals of each species.
F4	Restore self-sustaining populations of pygmy perch, gudgeons and other small indigenous fish.	Number of species should increase with each audit up to the maximum possible.	Wetlands	Bony bream, Murray jollytail, Australian smelt, Murray hardyhead, flyspecked hardyhead, crimson-spotted rainbowfish, southern pygmy perch, flathead gudgeon, dwarf flathead gudgeon and carp gudgeon complex.	Relative abundance (CPUE‡) of individual species
F5	Restore self-sustaining populations of pygmy perch, gudgeons and other small indigenous fish.	Number of native species breeding.	Wetlands	Bony bream, Murray jollytail, Australian smelt, Murray hardyhead, flyspecked hardyhead, crimson-spotted rainbowfish, southern pygmy perch, flathead gudgeon, dwarf flathead gudgeon and carp gudgeon complex.	Relative abundance (CPUE‡) and size class distribution of individual species$^{\Omega}$.

†See text for species names ‡Catch Per Unit Effort $^{\Omega}$see also definition for 'self-sustaining population' (Section 2.1.1)

2.1.1 Defining key terms in the context of ecological objectives

- Restore — Return to an original or target condition.
- Cod and perch — For the purposes of this study, 'cod' and 'perch' are fish belonging to either Family: Percichthyidae or Family: Terapontidae, and not the pygmy perches (Family: Nannopercidae) nor the freshwater perches (Family: Percidae). Species with distributions that include Gunbower Island (McDowall 1996) are golden perch (*Macquaria ambigua*), Macquarie perch (*Macquaria australasica*), Murray cod (*Maccullochella peeli peeli*), trout cod (*Maccullochella macquariensis*) and silver perch (*Bidyanus bidyanus*).
- Evidence for breeding — According to Crome (2004), breeding is demonstrated by the presence of 'pregnant'[sic] females, recently hatched fish, eggs, and analyses of length-frequency distributions indicating that a cohort of young fish is present. Because the current sampling was undertaken in June, and not during the normal breeding season for most Australian freshwater fish (≈ September–March), and because otolith studies are destructive and expensive, length frequency distributions were considered the most appropriate measure of breeding evidence. In future, however, larval and early juvenile fish might be targeted with sampling during the breeding season.
- Self-sustaining population — A self-sustaining fish population is considered here to:
    - Contain a spread of life stages including juvenile and adult fish.
    - Display evidence for breeding (see above).

  Although a self-sustaining population of fish would also contain a population density/abundance sufficient for the interaction of a suitable number of breeding pairs, determination of what constitutes a 'sufficient' density/abundance is neither possible nor measurable to a satisfactory level. Estimates of population density/abundance are not considered, therefore, as a meristic of 'self-sustaining population.'
- Pygmy perch — Southern pygmy perch (*Nannoperca australis*)
- Gudgeons — Gudgeons with distributions that include Gunbower Island (McDowall 1996) are flathead gudgeon (*Philypnodon grandiceps*), dwarf flathead gudgeon (*Philypnodon* sp.) and carp gudgeon species complex (*Hypseleotris* spp.) — there is debate as to the current taxonomic status of carp gudgeons (Bertozzi *et al.* 2000)
- Other small indigenous fish — Other small native species with distributions that include Gunbower Island (McDowall 1996) are bony bream (*Nematalosa erebi*), Murray jollytail (*Galaxias rostratus*), Australian smelt (*Retropinna semoni*), Murray hardyhead (*Craterocephalus fluviatilis*), flyspecked hardyhead (*Craterocephalus stercusmuscarum fulvus*) and crimson-spotted rainbowfish (*Melanotaenia fluviatilis*).
- Gunbower Island — All creeks, wetlands and floodplain between Gunbower Creek and the River Murray. For the purposes of this study, Gunbower Creek is considered part of Gunbower Island.

2.2 Conceptual model

The ecological objectives listed in Table 1 (F1–F5, from Crome [2004]) all link an increase in fish abundance and reproductive effort to the frequency and extent of floodplain and wetland inundation. A single conceptual model that links overbank flows to fish production is therefore required to fulfil the third step of the seven step process derived by Scholz *et al.* (2005).

Under natural conditions, Australian rivers are amongst the most hydrologically variable in the world (Puckridge *et al.* 1998). However, as a result of regulation and extraction, the River Murray and its floodplain experience reduced seasonal flow variability and reduced annual volumes of flow (Finlayson *et al.* 1994; Maheshwari *et al.* 1995). The most common consequence for floodplain wetlands and ephemeral creek systems is reduced flood frequency and duration of inundation.

Floodplains and their wetlands are naturally diverse and productive habitats that often experience a decline in environmental condition when natural flow patterns are altered (Kingsford 2000a, 2000b). For the maintenance of ecosystem integrity in floodplain wetlands, both wet and dry periods are critical because they drive aquatic and terrestrial successional processes and they promote the exchange of abiotic and biotic material between the floodplain and riverine environments (Junk *et al.* 1989; Scholz *et al.* 2005).

The flood pulses that cause floodplain inundation provide a dual mechanism for increasing the production and recruitment of Australian native fish:

1. <u>Inducement of spawning</u> — It is generally agreed that flood pulses at the appropriate time of year provide a spawning cue for golden perch and silver perch — two native fish species expected to occur on Gunbower Island (Humphries *et al.* 1999; Koehn and O'Connor 1990). Most other native species relevant to this monitoring program have demonstrated spawning patterns independent of specific flow events and do not require a flood to spawn (Humphries 2005; Humphries *et al*. 2002; Meredith *et al*. 2002). Recent evidence, however, shows that some increases in flow do elicit spawning responses from most species likely to occur on Gunbower Island (Meredith and McCasker, unpublished data).
2. <u>Increased recruitment</u> — Periodic floodplain and wetland inundation results in increased aquatic habitat extent, diversity and availability (Bowen *et al.* 2003), and an increase in the abundance of food resources (e.g. zooplankton) for larval and juvenile fish (Junk *et al.* 1989). Use of the inundated floodplain for recruitment purposes is likely to vary among native fishes: according to King *et al*. (2002), Macquarie perch, trout cod, Australian smelt and flathead gudgeon are the species most likely to utilise the floodplain for recruitment. There is some conjecture about the relationship between overbank flows and recruitment success for golden perch and silver perch (Harris and Gehrke 1994; Mallen-Cooper and Stuart 2003), but it is generally accepted that year-class strength is strongly related to flooding for most Australian native fish. As a spring flood pulse subsides, water on Gunbower Island will concentrate into the floodrunners (e.g. Yarran Creek) and wetlands; these areas will become important sites for native fish recruitment as they are likely to contain high densities of suitably sized prey (Humphries *et al.* 1999).

This fish monitoring program for Gunbower Island includes the regulated Gunbower Creek and permanent and semi-permanent wetlands of Gunbower Forest. The water requirements to achieve ecological objectives have been identified for wetlands (Ecological Associates 2004), but, as of yet, not for Gunbower Creek. The water requirements recognise the variability of natural flow patterns by indicating that permanent wetlands may undergo a drying phase once every ten years, and semi-permanent wetlands occasionally remain inundated for a full year (Table 2).

Table 2 Flow objectives required to achieve ecological objectives (Ecological Associates (2004).

Water Regime Class	Frequency	Duration	Flood Timing
Permanent wetlands	10 years in 10	9–12 months	Late winter/spring persisting for 12 months in nearly all years
Semi-permanent wetlands	6–9 years in 10	5 months	August/September to January/February persisting for 12 months in many years

It is reasonable to expect that attainment of the flow objectives in Table 2 would stimulate an increase in the abundance and production of native fish on Gunbower Island. The major assumptions are, given the flow objectives, that periodic inundation of the floodplain and floodrunners that deliver water to many of the wetlands will occur. Also, there will be, at least, periodic wetting and drying of the littoral zone of wetlands.

To measure the extent of this expected ecological response — native fish abundance and production — and to determine which species will be most affected by such a hydrological change, individual hypotheses have been developed below.

2.3 Testable hypotheses

2.3.1 Gunbower Island (creek and wetlands)

The following hypotheses are derived from ecological objective F1 (Crome 2004):

H1 The relative abundance of golden perch will increase on Gunbower Island following managed (intervention) overbank flows.

H2 The relative abundance of Macquarie perch will increase on Gunbower Island following managed (intervention) overbank flows.

H3 The relative abundance of Murray cod will increase on Gunbower Island following managed (intervention) overbank flows.

H4 The relative abundance of trout cod will increase on Gunbower Island following managed (intervention) overbank flows.

H5 The relative abundance of silver perch will increase on Gunbower Island following managed (intervention) overbank flows.

The following hypotheses are derived from ecological objective F2 (Crome 2004):

H6 The relative abundance of golden perch occupying different juvenile year classes will increase on Gunbower Island following managed (intervention) overbank flows.

H7 The relative abundance of Macquarie perch occupying different juvenile year classes will increase on Gunbower Island following managed (intervention) overbank flows.

H8 The relative abundance of Murray cod occupying different juvenile year classes will increase on Gunbower Island following managed (intervention) overbank flows.

H9 The relative abundance of trout cod occupying different juvenile year classes will increase on Gunbower Island following managed (intervention) overbank flows.

H10 The relative abundance of silver perch occupying different year classes will increase on Gunbower Island following managed (intervention) overbank flows.

2.3.2 Gunbower Creek

The following hypotheses are derived from ecological objective F3 (Crome 2004):

H11 The relative abundance of 0+ golden perch in Gunbower Creek will increase following managed (intervention) overbank flows.

H12 The relative abundance of 0+ Macquarie perch in Gunbower Creek will increase following managed (intervention) overbank flows.

H13 The relative abundance of 0+ Murray cod in Gunbower Creek will increase following managed (intervention) overbank flows.

H14 The relative abundance of 0+ trout cod in Gunbower Creek will increase following managed (intervention) overbank flows.

H15 The relative abundance of 0+ silver perch in Gunbower Creek will increase following managed (intervention) overbank flows.

2.3.3 Wetlands of Gunbower Forest

The following hypotheses are derived from ecological objective F4 (Crome 2004):

H16 The relative abundance of bony bream will increase in wetlands following managed (intervention) flooding of Gunbower Forest.

H17 The relative abundance of Murray jollytail will increase in wetlands following managed (intervention) flooding of Gunbower Forest.

H18 The relative abundance of Australian smelt will increase in wetlands following managed (intervention) flooding of Gunbower Forest.

H19 The relative abundance of Murray hardyhead will increase in wetlands following managed (intervention) flooding of Gunbower Forest.

H20 The relative abundance of flyspecked hardyhead will increase in wetlands following managed (intervention) flooding of Gunbower Forest.

H21 The relative abundance of crimson-spotted rainbowfish will increase in wetlands following managed (intervention) flooding of Gunbower Forest.

H22 The relative abundance of southern pygmy perch will increase in wetlands following managed (intervention) flooding of Gunbower Forest.

H23 The relative abundance of flathead gudgeon will increase in wetlands following managed (intervention) flooding of Gunbower Forest.

H24 The relative abundance of dwarf flathead gudgeon will increase in wetlands following managed (intervention) flooding of Gunbower Forest.

H25 The relative abundance of carp gudgeons (complex) will increase in wetlands following managed (intervention) flooding of Gunbower Forest.

H26 The relative abundance of small indigenous fish will increase in wetlands following managed (intervention) flooding of Gunbower Forest.

The following hypotheses are derived from ecological objective F5 (Crome 2004):

H27 The relative abundance of 0+ bony bream will increase in wetlands following managed (intervention) flooding of Gunbower Forest.

H28 The relative abundance of 0+ Murray jollytail will increase in wetlands following managed (intervention) flooding of Gunbower Forest.

H29 The relative abundance of 0+ Australian smelt will increase in wetlands following managed (intervention) flooding of Gunbower Forest.

H30 The relative abundance of 0+ Murray hardyhead will increase in wetlands following managed (intervention) flooding of Gunbower Forest.

H31 The relative abundance of 0+ flyspecked hardyhead will increase in wetlands following managed (intervention) flooding of Gunbower Forest.

H32 The relative abundance of 0+ crimson-spotted rainbowfish will increase in wetlands following managed (intervention) flooding of Gunbower Forest.

H33 The relative abundance of 0+ southern pygmy perch will increase in wetlands following managed (intervention) flooding of Gunbower Forest.

H34 The relative abundance of 0+ flathead gudgeon will increase in wetlands following managed (intervention) flooding of Gunbower Forest.

H35 The relative abundance of 0+ dwarf flathead gudgeon will increase in wetlands following managed (intervention) flooding of Gunbower Forest.

H36 The relative abundance of 0+ carp gudgeon (complex) will increase in wetlands following managed (intervention) flooding of Gunbower Forest.

H37 The relative abundance of 0+ small indigenous fish will increase in wetlands following managed (intervention) flooding of Gunbower Forest.

3 METHODS FOR FISH SURVEY

Although the Gunbower Island Fish Survey presented here is a one-off sampling event, it is important that data is collected in a way that permits comparisons with future surveys. The methodology described here provides an assessment of fish presence/absence and instantaneous abundance estimates, and will be comparable with future sampling efforts — this will facilitate the detection of temporal changes in fish abundances at an appropriate scale.

Another key objective of the survey is to adopt a sampling technique that allows comparisons of the fish communities within and between sites in Gunbower Creek and wetlands on Gunbower Island. The shallow depths of most wetlands, noted during the initial site visit/inception meeting, make it impossible to launch and adequately survey with an electrofishing boat. Similarly, it was noted during the initial site visit that the use of a backpack electrofisher will yield inconsistent results due to large discrepancy in turbidity, substrate type and water depth among wetlands and creek reaches. Consequently, the adoption of the Sustainable Rivers Audit (SRA) protocol was not recommended to meet the above key objective. The MDFRC proposed to use two types of nets in both the wetlands and creek sites — this technique is most likely to capture a diverse range of fish species and life history stages, and also allow the direct comparison of the fish communities between and within wetland and creek sites.

Another objective of the survey was to collect data to allow comparisons of the fish community in Gunbower Creek with other areas within the Murray-Darling Basin. The most effective method for doing this is to sample (at least) one representative reach in Gunbower Creek with an electrofishing boat using SRA protocols.

3.1 Location of sites

Six 'sentinel' wetlands and six reaches of Gunbower Creek were sampled for fish (Figure 2): water quality measurements and rapid habitat assessment were undertaken at all twelve sites. The six sentinel wetlands, selected following the inception meeting, were:

- Little Reedy Lagoon
- Reedy Lagoon
- Yarran Creek
- Green Swamp
- Little Reedy Lagoon
- Black Charlie Lagoon

Four weirs divide Gunbower Creek into five reaches: the River Murray to Koondrook Weir, Koondrook Weir to Cohuna Weir, Cohuna Weir to Thompsons Weir, Thompsons Weir to Gunbower Weir, Gunbower Weir to the River Murray. At least one site was sampled within each section with equal effort (Figure 2).

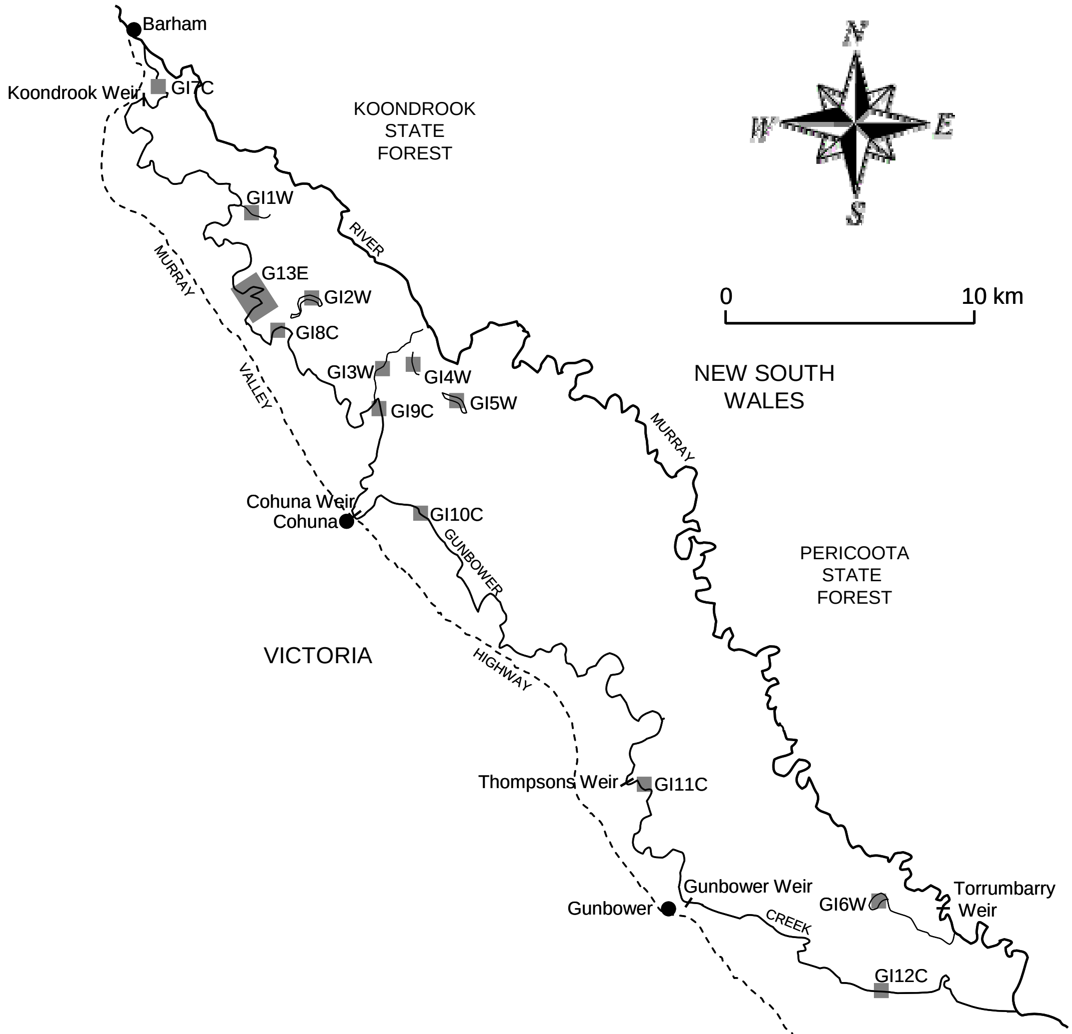

Figure 2 Location of wetland and Gunbower Creek sampling sites.

Table 3 Site codes and site names for sampling sites on Gunbower Island

Site code	Site name
GI1W	Little Gunbower Creek
GI2W	Reedy Lagoon
GI3W	Yarran Creek
GI4W	Green Swamp
GI5W	Little Reedy Lagoon
GI6W	Black Charlie Lagoon
GI7C	Downstream of Koondrook Weir
GI8C	Scout Camp
GI9C	Yarran Creek regulator
GI10C	Cohuna Island Road Reserve
GI11C	Upstream of Thompsons Weir
GI12C	Downstream of National Channel
GI13E	Koondrook Track jetty

3.2 Sampling methods

3.2.1 Habitat assessment and water quality

General habitat assessments were made qualitatively at each site (wetland and creek). Parameters such as substrate type, percent and type of instream cover, water levels and level of disturbance were visually assessed and estimated following a protocol for assessment of physical stream and wetland condition used in programs such as AusRivAS (Parsons *et al.* 2002). Water level was a relative assessment according to bank height and/or watermark, and disturbance level related to visible human disturbance (e.g. rubbish, clearing of riparian vegetation, pumps, etc). Water quality measurements were made at each site (two at GI3W and GI13E and four at every other wetland and creek site); pH, electrical conductivity (μS cm^{-1}), turbidity (NTU), temperature ($^{\circ}$C) and dissolved oxygen (mg L^{-1}) levels were recorded with a Horiba U–10 Water Quality Checker between 1200–1700 hrs.

3.2.2 Fyke netting

The fish communities at each site (wetland and creek) were sampled with large fyke nets and small fyke nets between 6 June and 17 June 2005. Four replicates of one small fyke net and one large fyke net were used for sampling at each site: the exact locations of replicates are given in Appendix II. Nets were set to ensure a diversity of aquatic habitats was sampled at each site: for example, open water, amongst or against vegetation and woody material. Large fyke nets (LFN) had a central wing (8 m × 0.65 m) attached to the first supporting hoop (Ø = 0.55 m) with a mesh entry of 0.32 m and a stretched mesh size of 28 mm. Small fyke nets (SFN) had dual wings (each 2.5 m × 1.2 m), the first supporting hoop (Ø = 0.4 m) was fitted with a square entry plastic grid (0.15 m × 0.15 m) with rigid square openings (0.05 m × 0.05 m). Each SFN had a stretched mesh size of 2 mm. Fyke nets were set in the afternoon and retrieved the following morning. Set and pull times were recorded but actual fishing times of nets varied minimally (1–2 hrs).

3.2.3 Boat electrofishing (SRA protocol)

A total of twelve boat electrofishing runs (90 second machine time) were completed at one representative site in Gunbower Creek, in accordance with the SRA protocol (MDBC 2004) on 15 June 2005. In addition, ten bait traps were set for approximately two hours during the electrofishing survey. Bait traps had a funnelled opening at each end (0.22 m × 0.22 m × 0.4 m) and were set unbaited in the littoral zone close to emergent vegetation, submerged macrophytes and woody debris to sample fish normally associated with such structures.

3.2.3 Identification and measurement

Fish were identified in the field according to McDowall (1996); owing to current taxonomic uncertainty at the species level, carp gudgeons were only identified to genus (Bertozzi *et al.* 2000). From each replicate net, a maximum of 25 of each species — up to 100 of each species per site — were measured (fork length and total length for large fish; total length for small fish) to the nearest millimetre. Large fish were weighed individually to the nearest gram and small fish were batch weighed to the nearest tenth of a gram. Native fish were returned to the habitat from which they were captured, exotic species were euthanised and buried. By-catch (e.g. turtles and yabbies) were identified according to Williams (1980) and Cogger (1999), counted and returned to the creek or wetland unharmed.

3.2.5 Data analysis

Water quality parameters were converted to means for each wetland and creek reach. Comparisons among wetlands and creek reaches was tested for significance at the 5% level using two tailed t-tests assuming unequal variance (Microsoft Excel 2002).

Fish abundances were standardised to catch per unit effort (CPUE)net^{-1} instead of (CPUE)time^{-1} because of minimal variation in deployment time among nets. Because fish catch data were strongly heteroscedastic (unequal variances), differences in small fish, large fish and total fish abundances between wetlands and creek sites were examined using the non-parametric Kruskal-Wallis test. Fish community data — mean abundance and presence/absence — were analysed using Primer Version 5 (Primer-E 2000). Fish abundance data were 4th-root transformed to reduce the influence of individual taxa and to increase analytical robustness of zero values before calculating Bray-Curtis similarity coefficients. Non-metric multi-dimensional scaling (NMDS) was then used to graphically display the relative similarities of fish communities among all sites. Analysis of similarities (ANOSIM) was used to determine whether significant differences in fish communities existed between wetlands (combined) and Gunbower Creek sites (combined): R-values indicate the degree of similarity (maximum separation when R=1).

Four species of native fish (Australian smelt, flyspecked hardyhead, flathead gudgeon and carp gudgeon spp.) were sampled in abundances sufficient for the generation of meaningful length-frequency histograms. For three of these species, separate length-frequency histograms were generated for wetland and creek sites, but flyspecked hardyhead occurred in sufficient abundance in creek sites only. The exotic species gambusia was also sampled in sufficient abundances in wetlands to produce a meaningful length-frequency histogram.

To determine required sampling effort in any future monitoring programs on Gunbower Island, power analysis was conducted on fish abundance data according to the following equation:

$$Power \propto \frac{ES\alpha\sqrt{n}}{\sigma}$$

In this equation described by Quinn and Keough (2002, p.164), power equals $(1-\beta)$, where β is the risk of making a Type II error. The power of a test is proportional to effect size (ES), sample size (n), variance (σ^2) and significance level (α). This survey provided estimates of variance for each species from wetland (n=6) and creek sites (n=6), and Gunbower Island (wetland and creek: n=12). The values of α and β were set by conventional standards of 0.05 and 0.80, respectively (Quinn and Keough 2002). Effect size (ES) refers to the size of change in fish abundances to be detected and, for the power analysis, 50% difference was considered the minimum ES. The number of sample sites is the calculation of interest for this report. Power analysis was conducted on transformed (4th-root) data using SYSTAT (v. 10.2).

4 RESULTS

4.1 Habitat assessment and water quality

All sampled wetlands were classified as billabong/swamp with no flow, with eucalypt forest on both banks (Appendix II). Water levels were low or very low at nearly all wetlands: GI1W and GI6W were at medium levels. Substrate consisted of silt and clay at all wetlands except GI3W (fine sand and clay) and GI5W (silt only). Instream fish habitat varied among wetlands: most contained a combination of logs, branches, organic debris (leaves), overhanging terrestrial vegetation and aquatic vegetation. Notably, GI2W contained only aquatic vegetation, much of which was filamentous algae. Most wetlands contained emergent and submerged aquatic vegetation, but floating vegetation was most common at GI4W. Riparian vegetation consisted mostly of native trees and human disturbance levels at all wetlands was low–moderate.

All sites in Gunbower Creek were pools with low or very low water levels, except GI11C which was a pool at medium water level. As with wetlands, the predominant substrate types were silt and clay, although coarse sand was present at GI2C and GI9C. Eucalypt forest occurred on both banks at most sites, but agricultural land abutted both banks at GI10C and GI11C. The combinations of instream fish habitat were similar to those in wetlands (logs, branches, organic debris, overhanging terrestrial vegetation and aquatic vegetation), but urban rubbish (garbage) was present at GI7C. The dominant aquatic vegetation varied among sites: none at GI10C, only submerged at GI7C, and only algae at GI12C. Native trees were the most common type of riparian vegetation at all sites, except GI8C and GI10C where sedges/rushes were more common. Disturbance levels ranged from very low at GI9C to very high at GI7C, GI11C and GI12C.

Water quality parameters for each site are presented in Table 4. The only parameter significantly different between wetland and creek sites was conductivity ($t=-2.881$, $df=10$, $p=0.016$).

Table 4 Water quality (mean) at sample sites on Gunbower Island.

Site	pH	Conductivity ($\mu S\ cm^{-1}$)	Turbidity (NTU)	Dissolved oxygen ($mg\ L^{-1}$)	Temperature (˚C)
GI1W	6.86	105	10	5.01	12.1
GI2W	9.27	146	15	12.62	13.1
GI3W	7.64	76	180	12.93	11.4
GI4W	8.13	114	158	12.13	10.4
GI5W	9.57	189	81	15.30	14.0
GI6W	6.66	105	28	6.11	11.5
GI7C	7.57	64	54	8.10	13.1
GI8C	7.24	64	49	10.24	10.7
GI9C	7.23	64	82	9.07	10.9
GI10C	7.65	83	42	11.27	11.7
GI11C	7.74	103	20	10.00	12.1
GI12C	7.35	33	33	10.06	11.7
GI13E	6.60	68	35	6.55	10.9

4.2 *Fish*

Presence/absence, abundances, community assemblages and length frequency fish data is presented below for fish caught by large and small fyke nets (LFN and SFN, respectively). Fish caught by boat electrofishing are presented in Section 3.2.6.

4.2.1 Presence/absence

A total of 15 641 fish of 13 species (eight native and five exotic) were captured in fyke nets on Gunbower Island (Table 5). Native fish captured were Australian smelt, flyspecked hardyhead, crimson-spotted rainbowfish, golden perch, Murray cod, flathead gudgeon, dwarf flathead gudgeon and carp gudgeons. Exotic species captured were goldfish (*Carassius auratus*), common carp (*Cyprinus carpio*), weatherloach (*Misgurnus anguillicaudatus*), gambusia (*Gambusia holbrooki*) and redfin (*Perca fluviatilis*).

4.2.2 Abundances

Carp gudgeons were the most abundant native species (13 865 fish), followed by Australian smelt (157), flathead gudgeon (126) and flyspecked hardyhead (120). Crimson-spotted rainbowfish (26) and golden perch (7) were much less abundant and only one Murray cod and one dwarf flathead gudgeon were captured. Gambusia was the most abundant exotic species (1290), followed by common carp (36), goldfish (9), redfin (2) and weatherloach (1).

Many more fish were caught in SFNs (15 586 fish) compared with LFNs (55) and a different suite of species was sampled by each method (Figures 3 and 4). The small-bodied Australian smelt, flyspecked hardyhead, crimson-spotted rainbowfish, flathead gudgeon, dwarf flathead gudgeon, weatherloach and gambusia were caught only in SFNs, and the larger species, golden perch, Murray cod, goldfish, common carp and redfin were caught only in LFNs.

Many more fish were collected from wetlands (13 879 fish) compared to sites in Gunbower Creek (1762). Mann-Whitney U test comparison of fish abundances in wetland and creek sites showed a significantly greater number of fish were collected in wetlands than in creek sites ($U = 5.00$, $df = 6,6$, $p = 0.037$). Small fish, particularly carp gudgeons and gambusia, accounted for much of this large difference in fish abundances (Figures 3 and 4); Mann-Whitney U test comparison showed that small fish were more abundant in wetland sites compared to creek sites ($U = 5.00$, $df = 6,6$, $p = 0.037$). Statistically, there was no difference between the catch of large fish at wetland or creek sites at the $\alpha = 0.05$ level ($U = 6.5$, $df = 6,6$, $p = 0.059$). Several native species were more abundant in wetlands than in creek sites: 69% of all Australian smelt collected were in wetland samples, as were 71% of golden perch, 64% of flathead gudgeons and 89% of carp gudgeons. Only one flyspecked hardyhead was collected from wetlands, compared with 119 from creek sites, whilst crimson-spotted rainbowfish only occurred in creek samples. The single Murray cod and dwarf flathead gudgeon collected were from Gunbower Creek. Of the exotic species captured, most were from wetlands: all goldfish, weatherloach and redfin, 94% of total common carp catch and more than 99% of gambusia.

GI5W had the greatest abundances of Australian smelt, carp gudgeons and gambusia: 18, 1645 and 274 fish net^{-1}, respectively (Appendix III). Of all the Gunbower Creek sites, the furthest upstream site (GI12C) had the greatest abundances of Australian smelt (10 fish net^{-1}), fly-specked hardyhead (22 fish net^{-1}), crimson-spotted rainbowfish (5 fish net $^{-}$1), flathead gudgeon (11 fish net^{-1}) and carp gudgeons (213 fish net^{-1}). Goldfish were most abundant at GI2W (1.5 fish net^{-1}) and common carp were most abundant at GI4W (7 net^{-1}).

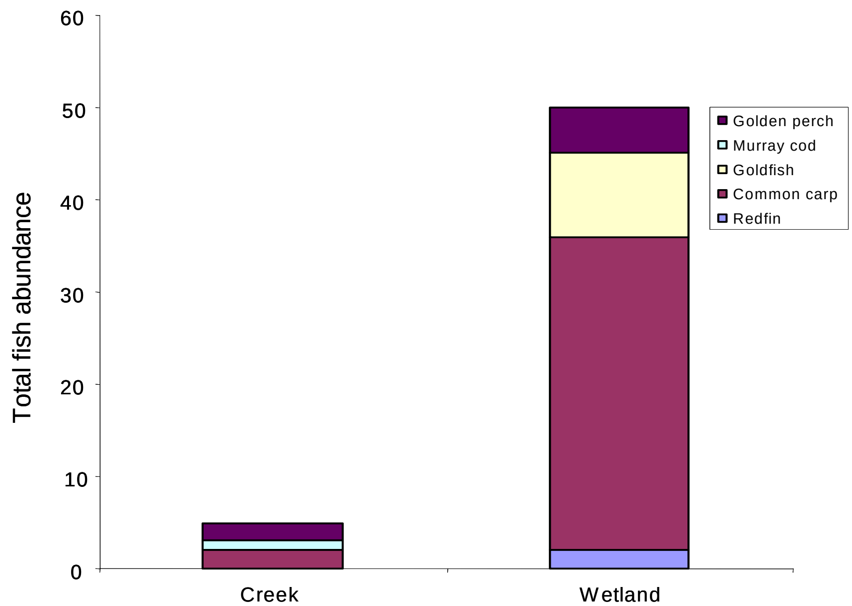

Figure 3 Total abundance of fish caught using large fyke nets in creek and wetland sites on Gunbower Island.

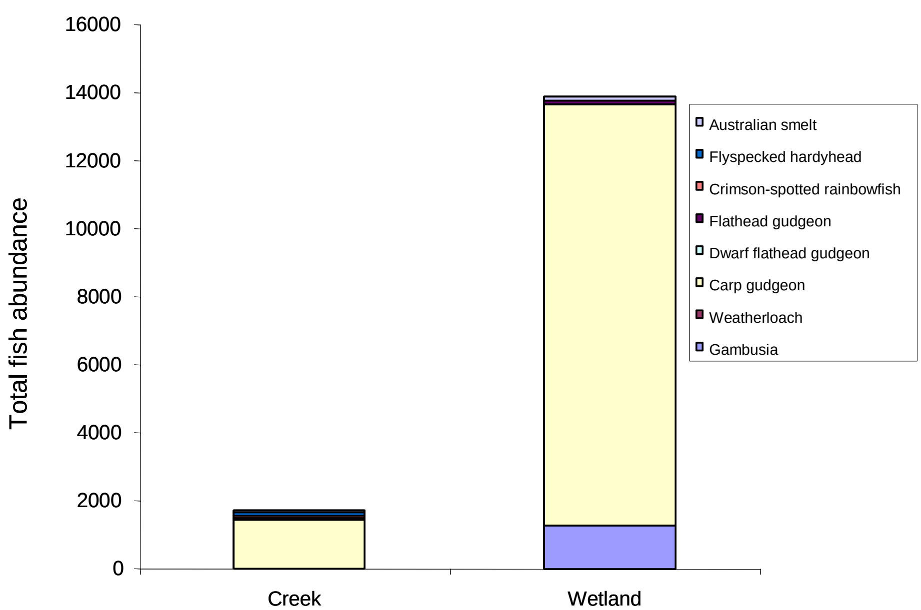

Figure 4 Total abundance of fish caught using small fyke nets in creek and wetlands sites on Gunbower Island.

Table 5 Total numbers of fish caught on Gunbower Island using all sampling methods: large fyke nets, small fyke nets and boat electrofisher — exotic species on grey background.

Site code	Site name	Sampling method	Fish species: Australian smelt	Flyspecked hardyhead	Crimnson-spotted rainbowfish	Golden perch	Murray cod	Flathead gudgeon	Dwarf flathead gudgeon	Carp gudgeon spp.	Goldfish	Common carp	Weatherloach	Gambusia	Redfin
GI1W	Little Gunbower Creek	LFN	0	0	0	0	0	0	0	0	0	0	0	0	0
		SFN	0	0	0	0	0	0	0	295	0	0	1	2	0
GI2W	Reedy Lagoon	LFN	0	0	0	0	0	0	0	0	6	0	0	0	0
		SFN	1	0	0	0	0	6	0	3360	0	0	0	0	0
GI3W	Yarran Creek	LFN	0	0	0	5	0	0	0	0	0	4	0	0	0
		SFN	17	1	0	0	0	0	0	489	0	0	0	0	0
GI4W	Green Swamp	LFN	0	0	0	0	0	0	0	0	0	27	0	0	0
		SFN	20	0	0	0	0	16	0	1637	0	0	0	186	0
GI5W	Little Reedy Lagoon	LFN	0	0	0	0	0	0	0	0	0	0	0	0	1
		SFN	70	0	0	0	0	8	0	6579	0	0	0	1094	0
GI6W	Black Charlie Lagoon	LFN	0	0	0	0	0	0	0	0	3	3	0	0	1
		SFN	0	0	0	0	0	51	0	38	0	0	0	3	0
GI7C	Downstream of Koondrook Weir	LFN	0	0	0	2	0	0	0	0	0	1	0	0	0
		SFN	3	0	0	0	0	0	0	68	0	0	0	0	0
GI8C	Scout Camp	LFN	0	0	0	0	0	0	0	0	0	0	0	0	0
		SFN	0	0	0	0	0	0	0	33	0	0	0	0	0
GI9C	Yarran Creek regulator	LFN	0	0	0	0	1	0	0	0	0	0	0	0	0
		SFN	1	0	0	0	0	0	0	280	0	0	0	0	0
GI10C	Cohuna Island Road Reserve	LFN	0	0	0	0	0	0	0	0	0	0	0	0	0
		SFN	0	0	1	0	0	0	0	213	0	0	0	0	0
GI11C	Upstream of Thompsons Weir	LFN	0	0	0	0	0	0	0	0	0	1	0	0	0
		SFN	4	31	4	0	0	3	0	21	0	0	0	2	0
GI12C	Downstream of National Channel	LFN	0	0	0	0	0	0	0	0	0	0	0	0	0
		SFN	41	88	21	0	0	42	1	852	0	0	0	3	0
	Total fish catch in nets		**157**	**120**	**26**	**7**	**1**	**126**	**1**	**13865**	**9**	**36**	**1**	**1290**	**2**
GI13E	Koondrook Track Jetty	Electroboat	12	94	2	0	0	0	0	0	1	15	0	2	0

4.2.3 Communities: assemblages and biomass

Although a total of ten species (native and exotic) were recorded in each habitat type, the diversity of native fish was greater in Gunbower Creek (eight species) than in wetlands (five species). Five species of exotic fish were recorded in wetlands compared with only two species (common carp and gambusia) in creek sites. A total of seven species were recorded at each of the furthest upstream Gunbower Creek sites (GI11C and GI12C), whilst only one species was collected at GI8C. Of the wetlands, GI6W was the most diverse (six species); only three species were recorded at GI1W, the least for any of the sampled wetlands (Table 5)

By abundance, fish assemblages at most wetland and creek sites were dominated by carp gudgeons — the only exceptions were at GI6W and GI11C, where flathead gudgeon (52%) and fly-specked hardyhead (47%), respectively, constituted a greater proportion of the catch than any other species (Figure 5a). By biomass, carp gudgeons were the largest proportion at only six of the twelve wetland/reaches (Figure 5b). Common carp constituted the greatest biomass at GI3W (54%), GI4W (95%) and GI6W (84%). Sixty-five percent of the catch, by weight, at GI7C was golden perch; Murray cod accounted for 98% of sampled biomass at GI9C, and flyspecked hardyhead had the greatest biomass of all fish at GI11C (36%).

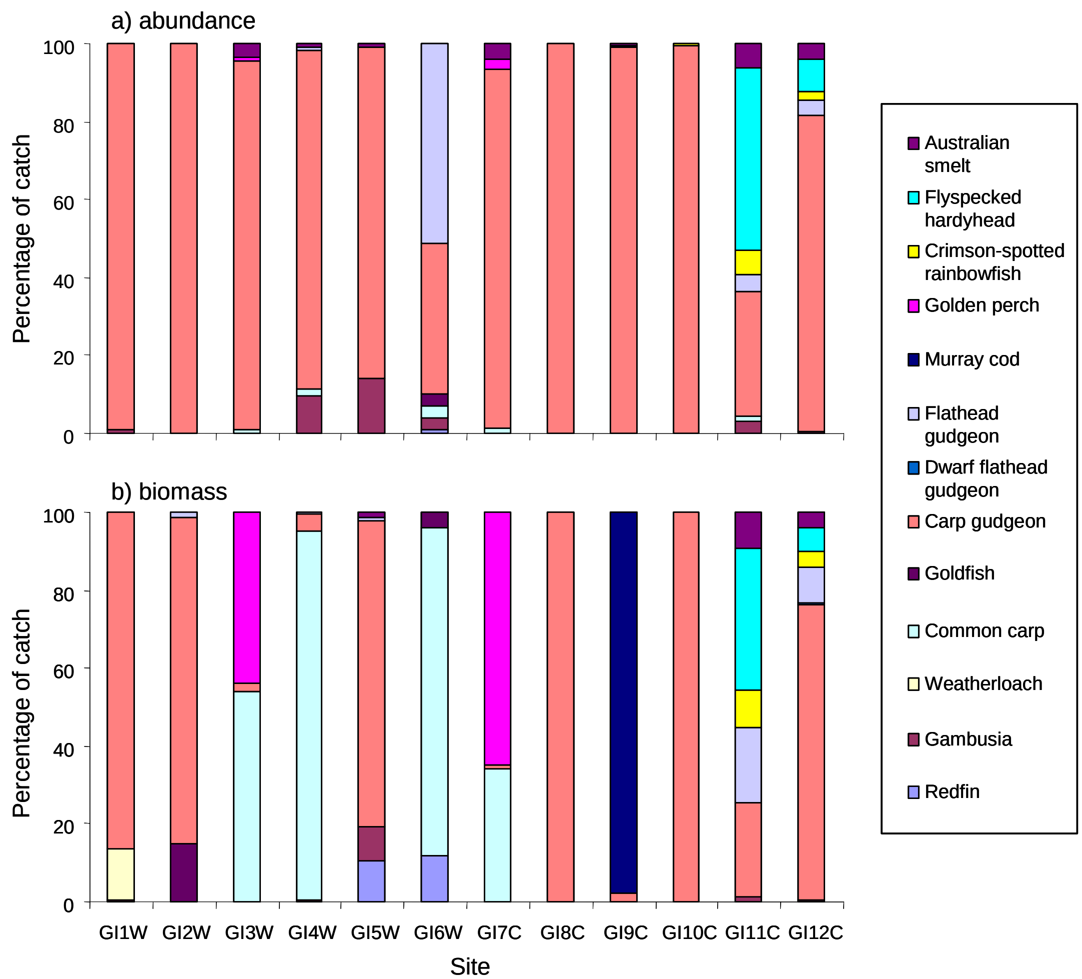

Figure 5 Proportion of catch at each site by a) abundance and b) biomass.

There was no clear separation or aggregation of sites according to the NMDSs based either on fish abundance (Figure 6) or fish presence/absence (Figure 7). ANOSIM analyses showed that there were no significant differences between the fish communities in wetlands (combined) and Gunbower Creek sites (combined), based on either abundances (R=0.161, p=0.102) or presence/absence (R=0.096, p=0.203).

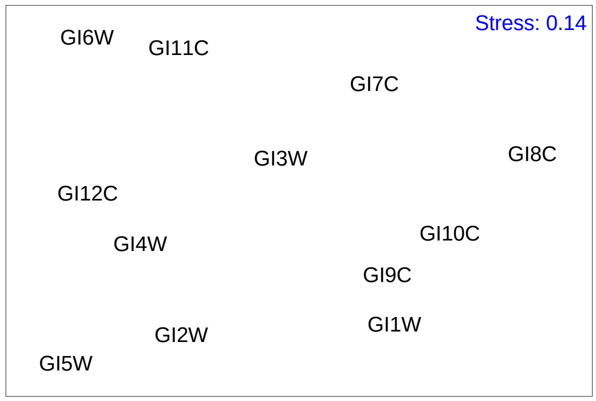

Figure 6 Non-metric multidimensional scaling (NMDS) ordination of fish community structure (abundance) for wetland and creek sites on Gunbower Island.

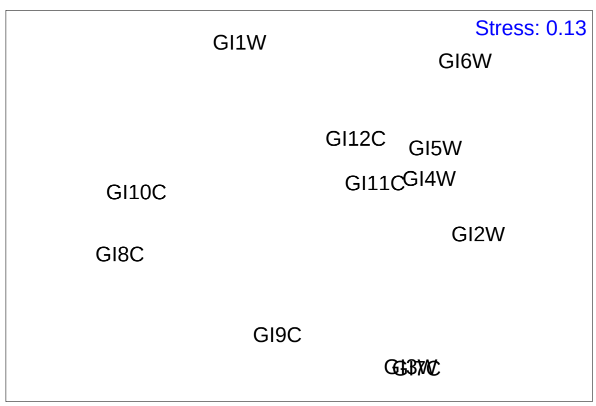

Figure 7 Non-metric multidimensional scaling (NMDS) ordination of fish community structure (presence/absence) for wetlands and creek sites on Gunbower Island.

4.2.4 Length frequency

Australian smelt in wetlands ranged in total length from 21 to 62 mm (n=73) compared with a length range of 25–50 mm (n=49) for Australian smelt collected from creek sites. The length-frequency histogram of Australian smelt in wetlands (Figure 8) was bimodal with peaks at 26–30 mm (n=24) and 41-45 mm (n=13). In Gunbower Creek, the Australian smelt population length-frequency histogram appeared normally distributed with a single modal peak at 41–45 mm (n=20). Flyspecked hardyhead length-frequency histogram also appeared normally distributed in creek sites, with a modal size class of 26–30 mm (n=35) and a size range of 18–47 mm (n=96). In wetlands, flathead gudgeons (Figure 10) ranged in total length from 15 to 83 mm (n=66) and in creek sites they ranged from 27 to 71 mm (n=45) total length. The modal size class in wetlands was 16–20 mm (n=17), but most individuals were more than 35 mm in total length. In creek sites, the modal size class was 36–40 mm (n=10) and over 90% of fish were between 31 and 55 mm in total length. The size ranges of carp gudgeons (Figure 11) were similar in both habitat types: 12–54 mm (n=493) total length in wetlands and 16–53 mm (n=381) in Gunbower Creek. The modal size class in each habitat type was also the same (31–35 mm).

The size range of the exotic species gambusia sampled in wetlands was 17–40 mm (n=175) total length. The length-frequency histogram for gambusia (Figure 12) was normally distributed with a modal size class of 25–28 mm (n=80)

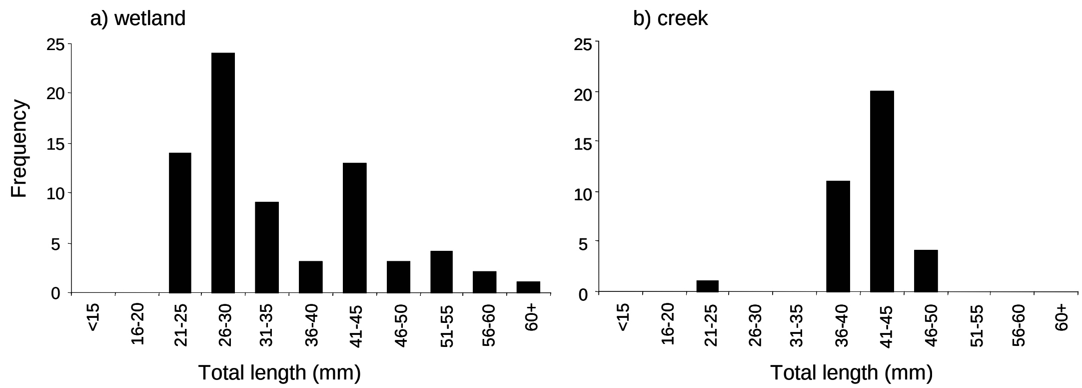

Figure 8 Length-frequency histograms of Australian smelt sampled at a) wetlands (n=73) and b) creek sites (n=49) on Gunbower Island.

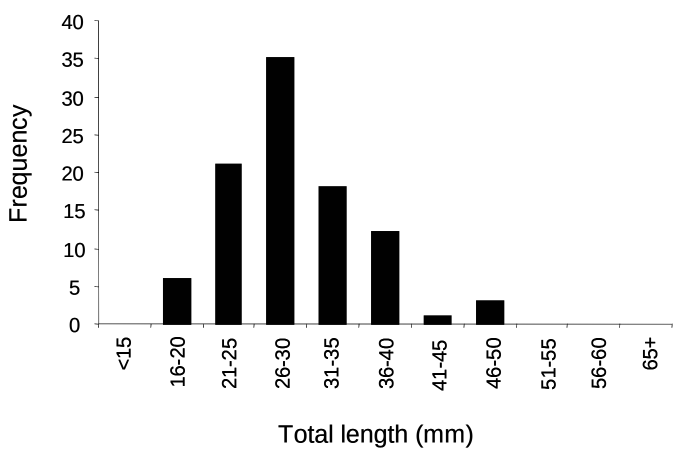

Figure 9 Length-frequency histogram of flyspecked hardyhead sampled in Gunbower Creek (n=96).

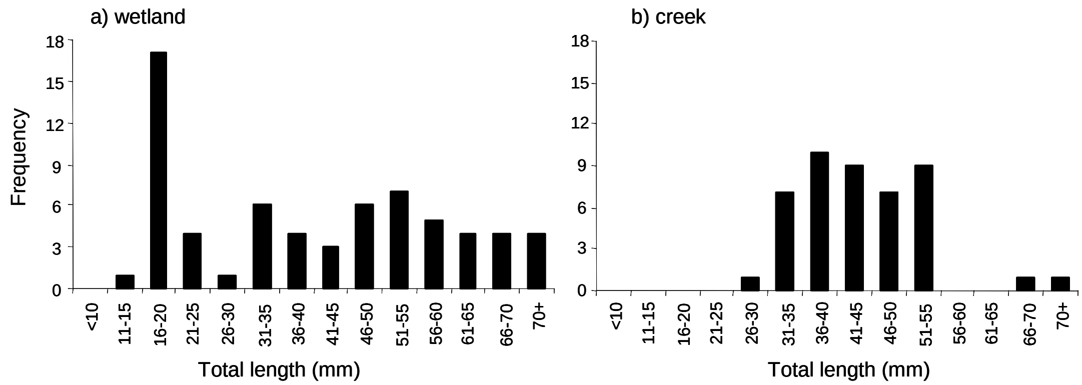

Figure 10 Length-frequency histograms of flathead gudgeon sampled at a) wetlands (n=66) and b) creek sites (n=45) on Gunbower Island.

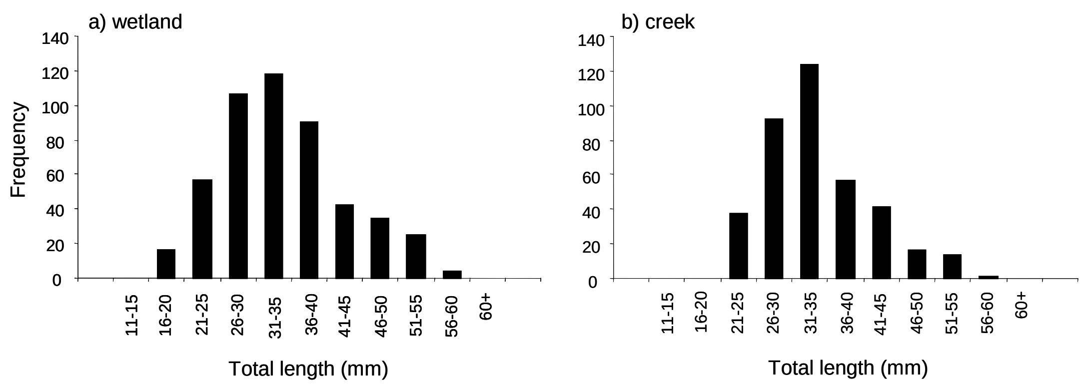

Figure 11 Length-frequency histograms of carp gudgeon spp. sampled in a) wetlands (n=493) and b) creek sites (n=381) on Gunbower Island.

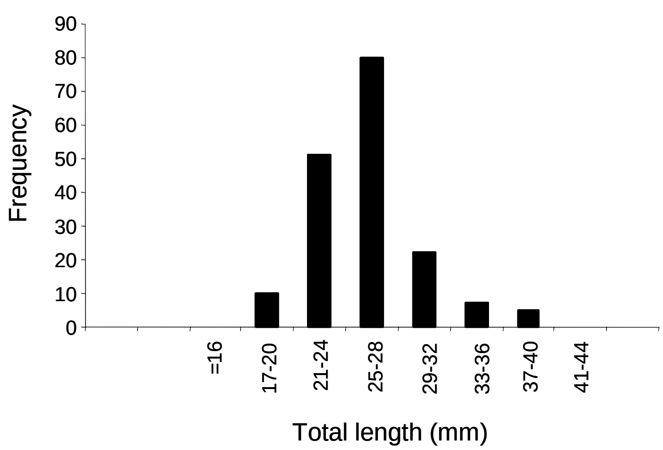

Figure 12 Length-frequency histogram of gambusia sampled in wetlands on Gunbower Island (n=175).

4.2.5 Lengths of other sampled fish

Native fish
Crimson-spotted rainbowfish ranged in total length from 22 to 62 mm (n=26). The size range of golden perch was 165–366 mm total length (n=7), with four individuals between 200 and 235 mm total length. The single Murray cod sampled was 577 mm total length and the dwarf flathead gudgeon was 38 mm in total length.

Exotic fish
Goldfish ranged in total length from 92 to 200 mm (n=9), common carp ranged from 134 to 649 mm total length (n=36), and the two redfin sampled were 236 mm and 408 mm total length.

4.2.6 Electrofishing

A total of 126 fish from six species (three native and three exotic) were collected by boat electrofishing at GI13E (Table 5). Of the native species, 12 Australian smelt, 94 flyspecked hardyhead and two crimson-spotted rainbow fish were collected. Of the exotic species, one goldfish, 15 common carp and two gambusia were collected. Common carp dominated the catch by biomass: the 15 individuals collected weighed a total of 27.86 kg, whilst all fish combined weighed a total of 28.5 g.

Carp gudgeons were the only taxa captured in bait traps at GI13E — 13 fish with a collective biomass of 2.0 g.

4.3 Other aquatic fauna

A total of two yabbies (*Cherax destructor*), 21 eastern long-necked turtles (*Chelodina longicollis*) and three Murray turtles (*Emydura macquarii*) were captured as bycatch in large fyke nets. Both yabbies were collected from Gunbower Creek at GI10C. Twenty of the eastern long-necked turtles were collected from wetlands including 12 from GI2W, six from GI4W and two from GI3W. Two Murray turtles were caught at GI2W and one was collected from Gunbower Creek (GI12C).

4.4 Power analysis

Power analysis was employed to determine the minimum sample size (number of wetland and/or creek sites) required to adequately detect a 50% change in the abundance of each species using the current sampling methodology. Raw catch data for all species was highly variable and non-normally distributed, thus power analysis was conducted on 4^{th} root transformed data. Calculations assumed power $(1 - \beta) = 0.8$ and $\alpha = 0.05$ and produced a power v. sample size relationship similar to that presented in Figure 12. Power calculations for both raw data and 4^{th} root transformed data are presented below (Table 6). The reduction in sample variance resulting from data transformation produces much smaller sample sizes than the raw data. For the purposes of this study, only 4^{th} root transformed data will be considered further.

Because of the relatively consistent large numbers of carp gudgeons collected in both wetland and creek sites, only eight, seven and 14 sites were needed to detect a 50% change in abundance of carp gudgeons in wetlands, Gunbower Creek and throughout Gunbower Island, respectively. By comparison, the number of sampling sites required to detect a 50% change in the abundance of each other species was considerably higher: for example, 27 sites for Australian smelt in wetlands and throughout Gunbower Island, and 414 sites for species collected only as single specimens (Murray cod, dwarf flathead gudgeon and weatherloach).

By considering an hypothesis that aims to detect a 50% change in the abundance of all small-bodied native fish using only small fyke nets (i.e. by lumping all small native fish together we exclude individual species differences), only eight, 20 and 12 sites would need to be sampled in wetlands, Gunbower Creek and throughout Gunbower Island, respectively. Similarly, detection of a 50% change in the abundance of all exotics would require that 29, 71 and 56 sites be sampled with both large and small fyke nets in wetlands, Gunbower Creek and throughout Gunbower Island, respectively.

Table 6 Power Analyses: the number of wetlands and/or creek sites on Gunbower Island that must be sampled to allow detection of a 50% change in fish abundances. Sample size calculations based on raw data and 4th root transformed data. Terms: SFN (small fyke net); LFN (large fyke net); Both (SFN and LFN); and, – denotes no fish collected from this habitat.

		Sample size (wetlands)		Sample size (Gunbower Creek)		Sample size (Island: wetlands and creek	
Species	**Method**	**Raw**	**4th root**	**Raw**	**4th root**	**Raw**	**4th root**
Australian smelt	SFN	73	27	126	29	90	27
Flyspecked hardyhead	SFN	185	185	104	80	216	126
Crimson-spotted rainbowfish	SFN	–	–	118	47	245	118
Golden perch	LFN	192	189	196	191	215	184
Murray cod	LFN	–	–	185	185	414	414
Flathead gudgeon	SFN	67	24	162	90	91	41
Dwarf flathead gudgeon	SFN	–	–	185	185	414	414
Carp gudgeon spp.	SFN	49	8	55	7	93	14
Goldfish	LFN	90	79	–	–	195	173
Common carp	LFN	112	45	80	80	208	61
Weatherloach	SFN	185	185	–	–	414	414
Gambusia	SFN	133	44	83	78	272	73
Redfin	LFN	80	80	–	–	167	168
All small native fish	SFN	49	8	60	20	89	12
All exotics	Both	254	29	96	71	510	56

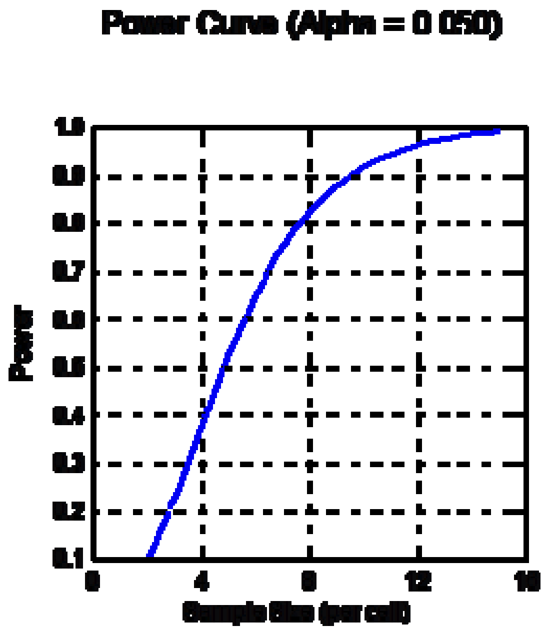

Figure 12 Power v. sample size for carp gudgeon spp. in wetlands of Gunbower Forest. When *α*=0.05, eight wetlands must be sampled to detect a 50% change in abundance with a power of 0.80.

5 DISCUSSION

5.1 General observations

5.1.1 Native fish

Three of the native species collected on Gunbower Island are currently listed as 'threatened' under the updated (February 2005) Victorian *Flora and Fauna Guarantee Act (1998)*: non-specked hardyhead [sic] (same species as flyspecked hardyhead), Murray rainbowfish [sic] (same species as crimson-spotted rainbowfish), and Murray cod (DSE 2005b). Given the relative abundance of flyspecked hardyhead (120) and crimson-spotted rainbowfish (26) and evidence for their breeding found in the current survey, Gunbower Island may be an important habitat for mid-Murray populations of these threatened species.

Douglas *et al.* (1998) collected one additional native fish species in Gunbower Creek — bony bream (*Nematalosa erebi*) — than we collected in the current study. The lack of bony bream in the current study is most likely due to the common mass mortality of this species as a result of low water temperatures during winter (Puckridge *et al* 1989). Also, Gunbower Island is near the southern distributional limit of bony bream (McDowell 1996). The current study collected dwarf flathead gudgeon, a species not collected in the Douglas *et al.* (1998) survey: we collected a single specimen only, however, which is unlikely to represent a significant change in the fish fauna of the area.

Fifteen species of native fish were considered to be directly relevant to the ecological objectives of the fish monitoring program and, as a consequence, were listed individually in the 'testable hypotheses' (Section 2.3). Seven of those listed species were not detected in the current survey. Four of the absent species — Murray hardyhead, Macquarie perch, trout cod and silver perch — are 'threatened' according to the Victorian *Flora and Fauna Guarantee Act (1998)* (DSE 2005), and their absence is likely to reflect the low abundances and restricted distributions expected of threatened species. Of the three other absent species, bony bream is more common in the River Murray further downstream, Murray jollytail is widely distributed but local and intermittent, and southern pygmy perch has suffered from habitat fragmentation and is now most common south of the Great Dividing Range in Victoria (McDowall 1996).

Relative abundance

This survey was an initial assessment of fish fauna on Gunbower Island and, unfortunately, an appropriate data set for comparison of relative abundances does not exist. However, recent surveys in other floodplain systems have reported similar catch patterns. King *et al.* (2004) surveyed the nearby Barmah–Millewa Forest and found that fish assemblages were strongly dominated by carp gudgeons and Australian smelt, and that flyspecked hardyhead were also abundant. Ellis and Meredith (2005) surveyed two wetland systems adjacent to the River Murray downstream of Mildura and found that carp gudgeons were clearly the most abundant species followed by flyspecked hardyhead; Australian smelt and flathead gudgeon were present but less abundant. Sharpe *et al.* (2003) surveyed Cardross Lakes and found similar relative abundances of carp gudgeon, Australian smelt and flathead gudgeon to the present survey. Gunbower Island can therefore be considered to have a relatively restricted fish fauna typical of Murray River floodplain and wetland systems.

Adult Murray cod were not collected in any of the above surveys. Adult golden perch were not collected by King *et al.* (2004) and in low numbers only by Sharpe *et al.* (2003) and Ellis and Meredith (2005). The low number of large native fish sampled at Gunbower Island may be due to the timing of the survey — early winter when water temperature is low. It has been suggested that when water temperatures are low the mobility of golden perch decreases (Crook 2004), an occurrence that may reduce the effectiveness of passive netting techniques during winter.

Evidence for breeding

There was broad-scale evidence for breeding of most of the short-lived small-bodied native fish across multiple sites sampled as part of the current survey. Juvenile fish (almost certainly young-of-the-year) of all small-bodied species were collected on Gunbower Island. For Australian smelt (which reach sexual maturity at approx 40 mm TL: Koehn and O'Connor 1990) and flathead gudgeon (which reach sexual maturity at approx. 25 mm TL: Koehn and O'Connor 1990; Pusey *et al.* 2004), many more young-of-the-year fish were collected in wetlands than in creek sites. It is likely, therefore, that recruitment of Australian smelt and flathead gudgeon following the most recent breeding season was more successful in wetlands than in Gunbower Creek. Flyspecked hardyhead can reach sexual maturity at approximately five months, or 32 mm standard length (SL) (McDowall 1996). As a large proportion of this species were less than 30 mm TL, it is likely that they were spawned the previous spring (Koehn and O'Connor 1990). Similarly, given its growth rate (Milton and Arthington 1984), the smallest crimson-spotted rainbowfish sampled (22 mm TL) are likely to be juveniles that were spawned the previous spring (Koehn and O'Connor 1990). Carp gudgeons do not reach reproductive size until at least 27 mm SL (Pusey *et al.* 2004); therefore, populations sampled in wetland and creek sites (Figure 9) included juveniles most likely spawned the previous spring/summer (Koehn and O'Connor 1990).

For the large-bodied species there was no clear evidence of a recent breeding event. For Murray cod, the single specimen collected was approximately five years of age (length-age curve in Anderson *et al.* 1992). For golden perch, two-thirds (four) of the individuals collected were aged 2–3 years, one was 1–2 years and the other was approximately five years old (based on length-age curves for golden perch collected at Torrumbarry: Mallen-Cooper and Stuart 2003). Although the above age classes may suggest the occurrence of a breeding event the last two years, it is possible that the individuals sampled were stocked. In the absence of a readily accessible and inexpensive technique for discerning stocked fish in the field, this will remain a limitation to assessing evidence for breeding of important angling species. A sampling methodology that targets larval fish on Gunbower Island may overcome the above limitation (see Section 6: Recommendations for Future Monitoring).

5.1.2 Exotic fish

Common carp and gambusia were the most common exotic species on Gunbower Island and both of these species occur throughout the MDB (McDowall 1996). By biomass, common carp dominated the total fish catch in half of sampled wetlands and the electrofished reach of Gunbower Creek. Gambusia occurred mostly in wetlands in conjunction with greater abundances of small native fish. Goldfish and redfin are also widespread throughout the MDB (McDowall 1996), but were not particularly abundant on Gunbower Island. Only one weatherloach was sampled on Gunbower Island (wetland). Weatherloach was not collected in the 1998 survey (Douglas *et al.* 1998) and this species has only occurred in the MDB since the mid 1980s (Koster *et al.* 2002). Weatherloach was relatively abundant in a recent survey of fish in the Barmah–Millewa Forest (King *et al.* 2004) and is considered a threat to native fish in the MDB (MDBC 2003). Future monitoring of this noxious fish on Gunbower Island is strongly recommended so that possible causal links with flow regimes and other environmental impacts may be identified.

Douglas *et al.* (1998) did find one additional exotic species, Tench (*Tinca tinca*). Failure to collect this species in the current study likely reflects its low abundance and gradual decline in most areas within the MDB.

5.1.3 Wetland and creek sites

Statistically, fish community composition on Gunbower Island did not differ significantly between wetlands and creek sites. The results indicated, however, that a much greater relative abundance of fish, particularly small-bodied native species, occurred in wetlands than in Gunbower Creek. Despite the possible confounding effects of minimal flow in Gunbower Creek on passive netting techniques (Hubert 1996), we consider these differences in relative abundance to be real and significant.

The greater abundance of fish in wetlands cannot be explained by routine water quality analyses. Electrical conductivity (EC) was the only significantly different factor between wetlands and creek sites, but the difference was at levels well below those likely to have an impact on fish abundances. The most likely reasons for the marked difference in relative abundance are probably related to the enhanced productivity of wetland systems (Mitsch 1995) and reduced bioenergetics (e.g respiration) demands placed on fish in non-flowing environments. In a temporal context, the increased suitability of low and non-flowing environments to (in particular) small-bodied fish forms the basis of the low-flow recruitment hypothesis (Humphries *et al.* 1999).

It is possible that the fish communities among wetlands and Gunbower Creek sites may be more patchily distributed and heterogenous than what they would be under more natural conditions. Predominantly low water levels in Gunbower Forest have reduced connectivity between wetlands, floodrunners, Gunbower Creek and the River Murray for longer periods than would naturally occur. Barriers and weirs may have had a similar isolating effect on the fish communities in the different sections of Gunbower Creek. The lack of 'disturbance', particularly in wetlands, is likely to interact with successional processes and result in one species (or functional group of species) dominating a particular site. A patchy pattern of fish distribution will most likely be altered significantly after a flooding event (managed or otherwise), whereby successional processes are effectively reset as a diversity of fish species are given access to previously isolated wetland and creek systems. Such a flooding event may result in reduced variation in fish catch between sites, and thus has implications for statistical power and sampling effort for future surveys.

5.2 Sampling methodology and statistical power

The present survey was conducted in June (early winter), when flows are usually low, because it was thought that fish would be more concentrated in wetland and creek sites. Furthermore, access to most sites (particularly wetlands) would be virtually impossible during periods of high flow or when Gunbower Forest is being flooded. It is now clear, however, that low water levels preclude the use of several alternative sampling methods, most notably boat mounted electrofishing. Sampling in winter also reduces the likelihood of adequately addressing many of the testable hypotheses, particularly those relating to ‘evidence for breeding’.

Crome (2004) requires that a fish monitoring program collects data quantifying ‘evidence for breeding’ of a full range of species. Size-class methods used in this study are problematic because naturally spawned and stocked individuals cannot be separated and because of assumptions that link fish size to age — this is particularly relevant for the commercially important large species. The most effective and unambiguous method for determining successful breeding activity (spawning) is to target larval fish at an appropriate time of the year, usually between September and March (Koehn and O’Connor 1996), or following high flow events outside these times. In Australian freshwater systems, methods such as modified quadrafoil light traps, sweep net electrofisher, hand trawl and overnight drift nets have been used (e.g. Humphries *et al.* 1999; Meredith *et al.* 2000; King *et al.* 2004). Targeted sampling of larval fish at a more appropriate time of year using the above methods would more adequately quantify ‘evidence for breeding’, as required by Crome (2004).

For large bodied fish, boat-mounted electrofishing is likely to be considerably more efficient and yield more precise catch data than the large fyke nets used in this study. The single creek site sampled with a boat-mounted electrofisher yielded 88% of the total catch of carp in all creek sites combined. Murray cod and golden perch were not collected from the site sampled with the boat-mounted electrofisher; but this null catch is more likely to be due to extremely low abundances (or absences) of these species at this site as opposed to a limitation of technique. Murray cod and golden perch occurred infrequently in this, and previous surveys (Douglas *et al.* 1998), of Gunbower Creek, and boat electrofishing has proved to be an effective technique for sampling both these species in other floodplain systems (A. Conallin, unpublished data).

Power analysis indicated clearly that it is not practicable (or in some cases even possible) to test the individual species hypotheses (section 2.3) using the current sampling methodology. To address this, aspects of the monitoring design need to be modified to ensure that fish catches (i.e. relative abundances) are increased, and/or variability in catch within sites is minimised. This may be physically achievable by increasing the number of nets deployed per wetland/creek site, increasing the range of gear types and catch methods employed at each site, or increasing the frequency of sampling and ‘lumping’ temporal data. It may also be possible to reduce required sample sizes (number of sites to be sampled) by changing the nature of the hypotheses being tested. For example, by ignoring individual species hypotheses and focusing instead on hypotheses that examine 'all small-bodied indigenous fish' (see hypotheses H26 and H37: Section 2.3), the number of sites that need to be sampled to detect a 50% change in abundance is reduced substantially and becomes readily achievable.

This hypothesis modification approach has the disadvantage of obscuring data from rare and threatened species (e.g. pygmy perch). However, it may be possible (and sensible) to overcome this problem by adopting a weighting approach, whereby rarer and/or more desirable fish species are given an appropriate weighting. The weighting is applied to raw catch data and a 'fish index', which forms the basis of future hypothesis testing, is achieved.

6 RECOMMENDATIONS FOR FUTURE MONITORING

This report describes fully the adaptive management of a hypothesis-based fish monitoring plan. Changes to the existing monitoring program design and sampling methodology, to improve its efficacy and scientific credibility, have been suggested throughout this report. These changes form the basis for the recommendations summarised below:

Hypotheses and Objectives: Power analysis revealed that the current monitoring program was not suitable for testing hypotheses that describe changes in the abundance of individual fish species. In the vast majority of cases, a reasonable increase in sampling effort (i.e. netting effort and number of sites surveyed) is not expected to improve total catch consistency or abundances, such that power estimates are substantially increased. We recommend, therefore, that the ecological objectives for fish monitoring contained in Crome (2004) be modified so that the effects of a modified flow regimes on the fish fauna of Gunbower Island can be ascertained. We suggest that the ecological objectives should be broadened to consider: a) all small-bodied fish species as one group, b) total native fish abundance and species richness, c) total exotic fish abundance and species richness, and d) using a weighted 'fish index' as the basis for hypothesis testing.

Temporal scale for monitoring: Long term (several years) fish monitoring programs involving monthly sampling that targets a range of fish life stages are ideal and represent the most accurate and defensible fish data upon which management decisions can be based and assessed. Such programs, however, are expensive and in many cases not feasible.

Assuming that such a comprehensive monitoring program is not feasible for Gunbower Island, but that annual monitoring will continue, it is essential that future sampling collects data that adequately quantifies 'evidence for breeding' of key species (or groups of species). To achieve this, we suggest that any annual monitoring program should collect samples in March (or as close as possible), when the presence of larvae and/or juveniles of most species of interest should be present.

Sampling techniques: Small fyke nets were an effective method for collecting small fish in wetland and creek sites and we suggest that they are used in future surveys. Boat electrofishing in accordance with the Sustainable Rivers Audit protocol is probably the most effective method for sampling large fish on Gunbower Creek. Assuming that sampling in March allows for the launch and use of a boat at wetland and creek sites, we suggest that future monitoring programs employ a boat-mounted electrofisher at all sites.

Larval and early juvenile fish should also be targeted. As for other larval fish studies conducted in Australian freshwaters, a combination of passive (modified quadrafoil light traps) and active (drift nets, backpack electrofishing, night trawling) techniques is likely to provide the best assessment of the species present and breeding on Gunbower Island.

ACKNOWLEDGEMENTS

The authors would like to acknowledge the assistance of Brad Drust (North Central CMA) and Iain Ellis (MDFRC) for their efforts in establishing and running this project. We are also grateful to Dr. Bernard McCarthy (MDFRC) for insightful comments on the manuscript. All fish sampling was conducted under Victorian Fisheries research permit RP584.

REFERENCES

Anderson, JR, Morison, AK and Ray, DJ (1992), Age and growth of Murray cod, *Maccullochella peelii* (Perciformes: Percicthyidae), in the lower Murray–Daring Basin, Australia, from thin-sectioned otoliths, *Australian Journal of Marine and Freshwater Research*, 43, pp. 983–1013.

Australian and New Zealand Environment and Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand (2000), *Australian guidelines for water quality monitoring and reporting*, www.deh.gov.au/water/quality/nwqms/pubs/

Baldwin, DS, Nielsen, DL, Bowen, PM and Williams, J (2005), *Recommended Methods for Monitoring Floodplains and Wetlands*, MDBC Publication No. 72/04, MDBC, Canberra.

Bertozzi, T, Adams, M and Walker, KF (2002), Species boundaries in carp gudgeons (Eleotridae: Hypseleotris) from the River Murray, South Australia: evidence for multiple species and extensive hybridization, *Marine and Freshwater Research*, 51, pp. 805–815.

Bowen, ZH, Bovee, KD and Waddle, TJ (2003), Effects of flow regulation on shallow-water habitat dynamics and floodplain connectivity, *Transactions of the American Fisheries Society*, 132, pp. 809–823.

Cogger, HG (1999), *Reptiles and Amphibians of Australia*, Reed Books, Sydney.

Cooling, MP, Lloyd, LN, Rudd, DJ and Hogan, RP (2001), Environmental water requirements and management options in Gunbower Forest, Victoria, *Australian Journal of Water Resources*, 5(1), pp. 75–87.

Crome, F (2004), A monitoring system for the Gunbower Forest, report to the North Central Catchment Management Authority, Francis Crome Pty Ltd.

Crook, DA (2004), Movements associated with home-range establishment by two species of lowland river fish, *Canadian Journal of Fisheries and Aquatic Sciences*, 61, pp. 2183–2193.

Department of Sustainability and Environment (2005a), Victorian Water Resources Data Warehouse, visited 21 November at www.vicwaterdata.net/vicwaterdata/home.aspx

Department of Sustainability and Environment (2005b), Flora and Fauna Guarantee Act — Listed species, communities and threatening processes, visited 8 August at www.dpi.vic.gov.au/dse/nrenpa.nsf/FID/-EADA0F1874AF9CF24A2567C1001020A3?OpenDocument#comfish

Douglas, J, Gooley, G, Kemp, D and Ingram, B (1998), *An Ecological Survey of the Three Major Murray River Anabranches in North-Western Victoria With Reference to Ecosystem Condition Indices*, Marine and Freshwater Resources Institute Internal Report, Alexandra, Victoria.

Ecological Associates (2003), *Flooding Enhancement of Gunbower Forest — Investigations of Priority Options Part A*, Ecological Associates Pty Ltd report for North Central Catchment Management Authority.

Ecological Associates (2004), *Flooding Enhancement of Gunbower Forest — Investigations of Priority Options Part B*, Ecological Associates Pty Ltd report for North Central Catchment Management Authority.

Ellis, I and Meredith, S (2005), Aquatic fauna of wetlands 352 and 491 near Wentworth, South-West NSW, November 2004, MDFRC consultancy report for NSW Murray Wetlands Working Group, Technical Report 01/2005.

Environment Australia (2001), *A Directory of Important Wetlands in Australia*, third edition, Environment Australia, Canberra.

Finlayson, BL, Gippel, GJ and Brizga, SO (1994), Effects of reservoirs on downstream aquatic habitat, *Water*, August, pp. 15–20.

Finlayson, CM and Mitchell, DS (1999), Australian wetlands: the monitoring challenge, *Wetlands Ecology and Management*, 7, pp. 105–112.

Gippel, CJ and Blackham, D (2002), *Review of environmental impacts of flow regulation and other water resource developments in the River Murray and Lower Darling River Systems*, final Report by Fluvial Systems Pty Ltd, Stokton, to Murray-Darling Basin Commission, Canberra, ACT.

Harris, JH and Gehrke, PC (1994), Modelling the relationship between streamflow and population recruitment to manage freshwater fisheries, *Agricultural Systems Information Technology*, 6, pp. 28–30.

Humphries, P (2005), Spawning time and early life history of Murray cod, *Maccullochella peelii peelii* (Mitchell) in an Australian river, *Environmental Biology of Fishes*, 72, pp. 393–407.

Humphries, P, King, AJ and Koehn, JD (1999), Fish flows and flood plains: links between freshwater fishes and their environment in the Murray–Darling River system, Australia, *Environmental Biology of Fishes*, 56, pp. 129–151.

Humphries, P, Serafini, LG and King, AJ (2002), River regulation and fish larvae: variation through space and time, *Freshwater Biology*, 47, pp. 1307–1331.

Junk, WJ, Bayley, PB and Sparks, RE (1989), The flood pulse concept in river-floodplain systems, *Canadian Special Publication of Fisheries and Aquatic Sciences*, 106, pp. 110–127.

King, AJ, Humphries, P and Lake, PS (2003), Fish recruitment on floodplains: the roles of patterns of flooding and life history characteristics, *Canadian Journal of Fisheries and Aquatic Sciences*, 60, pp. 773–786.

King, A, Mahoney, J and Tonkin, Z (2004), Assessing the effectiveness of environmental flows on fish recruitment in Barmah-Millewa, 2003/2004 Annual Progress Report (BMF 2004.09), prepared by Arthur Rylah Institute for MDBC.

Kingsford, R. (2000a), Ecological impacts of dams, water diversions and river management on floodplain wetlands in Australia, *Austral Ecology*, 25, pp. 109–127.

Kingsford, R. (2000b), Protecting rivers in arid regions or pumping them dry? *Hydrobiologia*, 427, pp. 1–11.

Kingsford, RT, Brandis, K, Thomas, R, Knowles, E and Gale, E (2003), *The Distribution of Wetlands in New South Wales*, Natural Heritage Trust, NSW National Parks and Wildlife Service and MDBC.

Koehn, JD and O'Connor, WG (1990), *Biological Information for the Management of Native Freshwater Fish in Victoria*, Victorian Government Printing Office, Ivanhoe, Victoria.

Koster, WM, Raadik, TA and Clunie, P (2002), *Scoping Study of the Potential Spread and Impact of the Exotic Fish Oriental Weatherloach in the Murray-Darling Basin, Australia: a Draft Management Strategy*, Arthur Rylah Institute for Environmental Research, Heidelberg.

Lee, KI (1999), Appraising adaptive management, *Conservation Ecology*, 3(2), available at: www.ecologyandsociety.org/vol3/iss2/art3/inline.html

Maheshwari, BL, Walker, KF and McMahon, TA (1995), Effects of regulation on the flow regime of the River Murray, Australia,. *Regulated Rivers: Research & Management*, 10, pp. 15–38.

Mallen-Cooper, M and Stuart, IG (2003), Age, growth and non-flood recruitment of two potomadrous fishes in a large semi-arid/temperature river system, *River Research and Applications*, 19, pp. 697–719.

McDowall, R. (1996), *Freshwater Fishes of South-eastern Australia*, Reed Books, Chatswood, New South Wales..

MDBC (2003), *Native Fish Strategy for the Murray–Darling Basin 2003–2013*, Murray–Darling Basin Ministerial Council, Canberra.

MDBC (2004), Fish Theme Pilot Audit Technical Report — Sustainable Rivers Audit, Murray-Darling Basin Commisssion, Canberra.

MDBC (2005), Significant Assets, visited on July 15 at www.livingmurray.mdbc.gov.au/implementing/six_significant_ecological_assets

Meredith, SN, Gawne, B, Sharpe, C, Whiterod, N, Conallin, A and Zukowski, S (2002), 'Dryland Floodplain Ecosystems: Influence of Flow Pattern on Fish Production', report no. 1/2002 (MDFRC: Mildura, Australia).

Milton, DA and Arthington, AH (1984), Reproductive strategy and growth of the crimson-spotted rainbowfish *Melanotaenia splendida fluviatilis* (Castelnau) (Pisces: Melanotaeniidae) in south-eastern Queensland, *Australian Journal of Marine and Freshwater Research*, 35, pp. 75–83.

Mitsch, W.J. (1995), Restoration of our lakes and rivers with wetlands — an important application of ecological engineering, *Water Science and Technology*, 31, pp.167-177.

Hubert, WA (1996), 'Passive capture techniques', in Murphy, BR and Willis, DW (eds), *Fisheries Techniques* (2nd edition), American Fisheries Society, Bethesda, Maryland.

North Central Catchment Management Authority (2005), *Flooding Enhancement of Gunbower Forest Project Monitoring Program Implementation: Fish Surveys*, North Central CMA, Bendigo.

Panel of Adaptive Management for Resource Stewardship (2004), *Adaptive Management for Water Resource Planning*, National Academies Press, Washington DC.

Parsons, M, Thoms, M and Norris, R, (2002), *Australian River Assessment System: AusRivaAS Physical Assessment Protocol,* Cooperative Research Centre for Freshwater Ecology, Monitoring River Health Initiative, report number 22, Environment Australia, available at: www.ausrivas.canberra.edu.au/Geoassessment/Physchem/Man/Protocol

Primer-E Ltd (2000), Primer for Windows Version 5.2.4, Plymouth, UK.

Puckridge, JT, Sheldon, F, Walker, KF, and Boulton, AJ (1998), Flow variability and the ecology of large rivers, *Marine and Freshwater Research*, 49, pp. 55–72.

Pusey, B, Kennard, M and Arthrington, A (2004), *Freshwater Fishes of North-eastern Australia*, CSIRO Publishing, Collingwood.

Quinn, GP and Keough, MJ (2002), *Experimental Design and Data Analysis for Biologists*, Cambridge University Press, United Kingdom.

Reid, MA and Brooks, JJ (2000), Detecting effects of environmental water allocations in wetlands of the Murray–Darling Basin, Australia, *Regulated Rivers : Research and Management*, 16, pp. 479–496.

Scholz, O, Meredith, S, Suitor, L, Keating, R and Ho, S (2005), Living Murray icon site wetlands within the Mallee CMA region: monitoring program designs and 2004–05 monitoring results, report for the Mallee Catchment Management Authority and the Murray-Darling Basin Commission, Murray-Darling Freshwater Research Centre Lower Basin, report no. x/2005, 139p.

Sharpe, C, Conallin, A, Meredith, S and Roennfeldt, B (2003), Status of the Cardross Lakes Fish Community, April 2003, a CRC for Freshwater Ecology consultancy report for the Mallee Catchment Management Authority, technical report N39/2003.

Streever, WJ (1997), Trends in Australian wetland rehabilitation, *Wetlands Ecology and Management*, 5, pp. 5–18.

URS (2001), *Flooding Enhancement of Gunbower Forest — Scoping Study*, consultancy report prepared for the North Central Catchment Management Authority, Bendigo.

Williams, W.D. (1980), *Australian Freshwater Life*, Macmillan, South Melbourne.

APPENDIX I

Site Code	Name	Habitat	Method	Set	Coordinates	
					Easting	Northing
GI1W	Little Gunbower Creek	Wetland	LFN, SFN	A	0244245	6045951
				B	0244276	6045893
				C	0244352	6045841
				D	0244419	6045827
GI2W	Reedy Lagoon	Wetland	LFN, SFN	A	0247382	6042365
				B	0247397	6042409
				C	0247342	6042501
				D	0247321	6042544
GI3W	Yarrein Creek	Wetland	LFN, SFN	A	0249969	6039850
				B	0249916	6039706
				C	0249905	6039649
				D	0264987	6039604
GI4W	Green Swamp	Wetland	LFN, SFN	A	0250852	6039262
				B	0250917	6039181
				C	0250988	6039119
				D	0251034	6039072
GI5W	Little Reedy Lagoon	Wetland	LFN, SFN	A	0252732	6038358
				B	0252753	6038348
				C	0252772	6038327
				D	0252823	6038319
GI6W	Black Charlie Lagoon	Wetland	LFN, SFN	A	0270419	6018215
				B	0270375	6018268
				C	0270649	6018256
				D	0270182	6018040
GI7C	Downstream of Koondrook Weir	Creek	LFN, SFN	A	0270183	6014442
				B	0270023	6014467
				C	0269953	6014469
				D	0269739	6014466
GI8C	Scout Camp	Creek	LFN, SFN	A	0245823	6041384
				B	0246016	6041272
				C	0246114	6041289
				D	0245732	6041408
GI9C	Yarrein Creek regulator	Creek	LFN, SFN	A	0250180	6037805
				B	0250318	6037641
				C	0250280	6037771
				D	0250095	6037805
GI10C	Cohuna Island Road Reserve	Creek	LFN, SFN	A	0251924	6033302
				B	0251938	6033246
				C	0251976	6033157
				D	0252059	6033098
GI11C	Upstream of Thompsons Weir	Creek	LFN, SFN	A	0260702	6022604
				B	0260873	6022708
				C	0260931	6022797
				D	0261040	6022924
GI12C	Downstream of National Channel	Creek	LFN, SFN	A	0270183	6014442
				B	0270023	6014467
				C	0269953	6014469
				D	0269739	6014466
GI13E	Koondrook Track Jetty	Creek	Electro – fish	S	0244542	6042664
				F	0245274	6042009

APPENDIX II

Wetlands: summary of habitat assessments

<u>Little Gunbower Creek (GI1W)</u>
Waterbody type — billabong/swamp
Flow type — pool/backwater
Flow level — medium
Substrate — 50% silt, 50% clay
Instream cover — 60% organic debris, 30% log jams, 10% logs
Aquatic vegetation — 80% emergent, 20% submerged
Riparian vegetation — 80% native trees (>30 m), 20% native trees (<30 m)
Land type/use — left bank: eucalypt forest (State Forest), right bank: eucalypt forest (State Forest)
Disturbance — low

<u>Reedy Lagoon (GI2W)</u>
Waterbody type — billabong/swamp
Flow type — 100% backwater (disconnected)
Flow level — low
Substrate — 95% silt, 5% clay
Instream cover — 100% aquatic vegetation
Aquatic vegetation — 75% submerged, 25% emergent
Riparian vegetation — 40% native trees (<30 m), 40% sedges/ rushes, 20% grasses
Land type/use — left bank: eucalypt forest, right bank: eucalypt forest
Disturbance — low

<u>Yarran Creek (GI3W)</u>
Waterbody type — stream channel/billabong/swamp
Flow type — 100% backwater (disconnected)
Flow level — very low
Substrate — 40% fine sand, 60% clay
Instream cover — 75% branches, 10% branch piles, 10% organic debris, 5% aquatic vegetation.
Aquatic vegetation —90% emergent, 10% submerged
Riparian vegetation — 100% native trees (>30 m)
Land type/use — left bank: eucalypt forest (State Forest), right bank: eucalypt forest (State Forest)
Disturbance — moderate

<u>Green Swamp (GI4W)</u>
Waterbody type — billabong/swamp
Flow type — 100% backwater (disconnected)
Flow level — very low
Substrate — 60% silt, 40% clay
Instream cover — 80% logs, 10% branches, 10% aquatic vegetation
Aquatic vegetation — 90% floating, 5% submerged, 5% filamentous algae
Riparian vegetation — 100% native trees (>30 m)
Land type/use — left bank: eucalypt forest, right bank: eucalypt forest

Disturbance — moderate

Little Reedy Lagoon (GI5W)
Waterbody type — billabong/swamp
Flow type — 100% pool
Flow level — very low
Substrate — 100% silt
Instream cover — 50% aquatic vegetation, 20% overhanging vegetation, 10% organic debris, 10% branch piles, 10% branches
Aquatic vegetation — 50% emergent, 45% filamentous algae, 5% submerged
Riparian vegetation — 70% native trees (>30 m), 20% native trees (<30 m), 10% sedges/rushes.
Land type/use — left bank: eucalypt forest (State Forest), right bank: eucalypt forest (State Forest)
Disturbance — low

Black Charlie Lagoon (GI6W)
Waterbody type — billabong/swamp
Flow type — 100% pool
Flow level — medium
Substrate — 50% silt, 50% clay
Instream cover — 80% aquatic vegetation, 10% logs, 5% overhanging vegetation, 5% organic debris
Aquatic vegetation — 50% emergent, 40% floating, 10% submerged
Riparian vegetation — 40% native trees (>30 m), 10% native trees (<30 m), 30% native shrubs, 20% sedges/rushes
Land type/use — left bank: eucalypt forest, right bank: eucalypt forest
Disturbance — low

Creek reaches: summary of habitat assessments

Downstream of Koondrook Weir (GI7C)
Waterbody type — river (width >5m)
Flow type — pool
Flow level — very low
Substrate — 10% silt, 90% clay
Instream cover — 30% logs, 20% branch piles, 20% organic debris, 25% urban rubbish, 5% aquatic vegetation
Aquatic vegetation — 100% submerged
Riparian vegetation — 60% native trees (>30m), 20% native trees (<30m), 20% native shrubs
Land type/use — left bank: eucalypt forest, right bank: eucalypt forest
Disturbance —very high

Scout Camp (GI8C)
Waterbody type — stream (width <5 m): weir pool
Flow type — pool
Flow level — very low
Substrate — 75% silt, 25% clay

Instream cover — 75% logs, 10% log jams, 5% organic debris, 5% overhanging vegetation
Aquatic vegetation — 85% emergent, 15% submerged
Riparian vegetation — 40% native trees (<30 m), 60% sedges/rushes,
Land type/use — left bank: 50% agriculture, 50% eucalypt forest (State Forest), right bank: 50% agriculture, 50% eucalypt forest (State Forest)
Disturbance — high

Yarran Creek Regulator (GI9C)
Waterbody type — river (width >5 m)
Flow type — pool
Flow level — very low
Substrate — 40% silt, 40% clay, 20% coarse sand
Instream cover — 60% logs, 20% overhanging vegetation, 20% aquatic vegetation
Aquatic vegetation — 40% floating, 30% emergent, 30% algae
Riparian vegetation — 60% native trees (>30 m), 10% willows, 30% sedges/rushes
Land type/use — left bank: eucalypt forest, right bank: eucalypt forest
Disturbance — very low

Cohuna Island Road Reserve (GI10C)
Waterbody type — river (width >5 m)
Flow type — pool
Flow level — very low
Substrate — 50% silt, 50% clay
Instream cover — 75% logs, 15% branches, 5% overhanging vegetation
Aquatic vegetation — none
Riparian vegetation — 50% sedges/rushes, 30% native trees (>30 m), 20% native trees (<30 m), 5% willows
Land type/use — left bank: agriculture, right bank: eucalypt forest
Disturbance —high

Upstream of Thomsons Weir (GI11C)
Waterbody type — river (width >5 m)
Flow type — pool
Flow level — medium
Substrate — 50% silt, 50% clay
Instream cover — 30% logs, 20% organic debris, 20% overhanging bank, 10% overhanging vegetation, 20% aquatic vegetation
Aquatic vegetation — 80% submerged, 10% floating, 10% emergent
Riparian vegetation — 50% native trees (>30 m), 10% native trees (<30 m), 30% willows, 10% sedges/rushes
Land type/use — left bank: agriculture, right bank: agriculture
Disturbance — very high

Downstream of National Channel (GI12C)
Waterbody type — river (width >5m)
Flow type — pool
Flow level — very low
Substrate — 10% silt, 10% coarse sand, 80% clay
Instream cover — 15% logs, 80% log jams, 5% aquatic vegetation

Aquatic vegetation — 100% algae
Riparian vegetation — 60% native trees (>30 m), 30% native trees (<30 m), 10% exotic shrubs
Land type/use — left bank: eucalypt forest, right bank: eucalypt forest
Disturbance —very high

Koondrook Track jetty (GI13E)
Waterbody type — river (width >5 m)
Flow type — pool
Flow level — low
Substrate — 20% silt, 80% clay
Instream cover — 20% logs, 20% log jams, 5% organic debris, 5% overhanging vegetation, 50% aquatic vegetation
Aquatic vegetation — 75% emergent, 20% floating, 5% algae
Riparian vegetation — 20% native trees (>30 m), 10% native trees (<30 m), 70% sedges/rushes
Land type/use — left bank: eucalypt forest (State Forest), right bank: eucalypt forest (State Forest)
Disturbance — moderate

APPENDIX III

Mean abundances (± se) of all fish caught on Gunbower Island in wetlands and Gunbower Creek reaches.

		Wetland/Reach											
Species	**Total**	**GI1W**	**GI2W**	**GI3W**	**GI4W**	**GI5W**	**GI6W**	**GI7C**	**GI8C**	**GI9C**	**GI10C**	**GI11C**	**GI12C**
Australian smelt	157	0	0.25 ± 0.25	4.25 ± 1.55	5.00 ± 1.47	17.50 ± 1.89	0	0.75 ± 0.48	0	0.25 ± 0.25	0	1.00 ± 0.41	10.25 ± 5.95
Flyspecked hardyhead	120	0	0	0.25 ± 0.25	0	0	0	0	0	0	0	7.75 ± 3.47	22.00 ± 8.50
Crimson-spotted rainbowfish	26	0	0	0	0	0	0	0	0	0	0.25 ± 0.25	1.00 ± 1.00	5.25 ± 0.25
Golden perch	7	0	0	1.25 ± 1.25	0	0	0	0.5 ± 0.29	0	0	0	0	0
Murray cod	1	0	0	0	0	0	0	0	0	0.25 ± 0.25	0	0	0
Flathead gudgeon	126	0	1.50 ± 0.65	0	4.00 ± 1.47	2.00 ± 0.82	12.75 ± 7.82	0	0	0	0	0.75 ± 0.75	10.50 ± 3.57
Dwarf flathead gudgeon	1	0	0	0	0	0	0	0	0	0	0	0	0.25 ± 0.25
Carp gudgeon spp.	13865	73.75 ± 31.72	840.00 ± 170.76	122.25 ± 69.89	409.25 ± 168.21	1644.75 ± 289.32	9.50 ± 4.48	17.00 ± 4.02	8.25 ± 1.70	70.00 ± 25.90	53.25 ± 27.77	5.25 ± 4.31	213.00 ± 56.08
Goldfish	9	0	1.5 ± 0.96	0	0	0	0.75 ± 0.48	0	0	0	0	0	0
Common carp	36	0	0	1.00 ± 0.71	6.75 ± 3.62	0	0.75 ± 0.48	0.25 ± 0.25	0	0	0	0.25 ± 0.25	0
Weatherloach	1	0.25 ± 0.25	0	0	0	0	0	0	0	0	0	0	0
Gambusia	1290	0.50 ± 0.50	0	0	46.50 ± 25.56	273.50 ± 72.68	0.75 ± 0.75	0	0	0	0	0.50 ± 0.29	0.75 ± 0.48
Redfin	2	0	0	0	0	0.25 ± 0.25	0.25 ± 0.25	0	0	0	0	0	0