Conceptual model to guide investments for restoring native fish in the Murray-Darling Basin

Report by the Expert Panel
convened by the Murray-Darling Basin Commission
Edited by Bill Phillips

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Executive summary

At the request of the Chief Executive Officer of the Murray-Darling Basin Commission (MDBC) an Expert Panel was formed to develop a conceptual model to assist the Commission and Ministerial Council with deliberations and future investment decisions in relation to its Native Fish Strategy.

The Expert Panel was comprised of:

- Dr John Harris, CRC for Freshwater Ecology;
- Mr. John Koehn, Arthur Rylah Institute, Victoria;
- Dr Peter Jackson, Queensland Department of Primary Industries:
- Dr Terry Hillman, CRC for Freshwater Ecology;
- Associate Professor Keith Walker, CRC for Freshwater Ecology, University of Adelaide; and
- Dr Mike Braysher, University of Canberra.

The first three names above are members of the MDBC's Fish Working Group.

The Expert Panel members met on 12 December 2001 for a full day workshop, having submitted in advance a lengthy questionnaire designed to prepare the way for their deliberations. Dr Bill Phillips (MainStream Environmental Consulting Pty Ltd) facilitated workshop preparation, process and reporting.

This Report presents the workshop deliberations of the Expert Panel, and should be considered as 'best guess' based on the combined expertise of the Panel members and the current state of knowledge about fish biology, ecosystem functioning, riverine ecology and restoration science.

The following seven strategic interventions were considered in the development of the conceptual model, as identified in the Project Brief:

- allocation of environmental flows;
- habitat restoration;
- abatement of cold water pollution;
- provision of fishways and fish passage;
- establishment of an aquatic reserve system;
- carp management; and
- management of other alien fish species that are threatening native fish.

The Expert Panel applied the conceptual model to the following four response variables:

- restoring native fish;
- restoring listed threatened fish and fish communities;
- reducing the impact of carp; and
- reducing the impact of other alien fish species that are threatening native fish.

The Expert Panel considered the seven strategic interventions for each 'measure of success' at the Basin-wide scale, and then subsequently for the lowland, upland, northern and southern parts of the Basin. Having established a view on the optimal combination of strategic interventions for each of the above situations, the Panel then considered how this could be integrated to provide an optimal blend of strategic interventions to achieve all four 'measures of success'.

Some **significant observations** made by the Expert Panel are summarised below

- None of the seven strategic interventions, if undertaken singly, is considered to have the capacity to recover the native fish of the Basin beyond 25 per cent of their pre-European level.

- The Expert Panel considers there is good evidence to believe that with all seven strategic interventions undertaken in an integrated way (and with appropriate levels of investment), the proposed target level of restoring native fish communities to 60 per cent of their pre-European level is achievable within a 50-60 year time frame.

- The Expert Panel acknowledged that threatened fish and fish communities are a sub-set of the broader native fish population, and the strategic interventions undertaken to see the Basin's native fish restored will also assist (at least in part) with the restoration of listed threatened fish and fish communities. However, the Panel believes that achieving this measure of success will be greatly accelerated if greater resources are allocated to developing a system of aquatic reserves and managing other alien fish species.

- The Panel noted that carp, now representing an estimated 80 per cent of the fish biomass across large parts of the Basin, were one of several 'threatening processes' which has seen native fish reduced to around 10 per cent of their pre-European levels. The Expert Panel acknowledged that through interventions such as the allocation of environmental flows and habitat restoration, native fish populations should begin to recover, and be better able to compete with carp. However, the Panel contends that unless directed actions are taken to reduce carp populations, and control their spread, carp will be a controlling or limiting factor in the efforts to see native fish restored. Of the other strategic interventions under consideration, it was the Panel's view that the abatement of cold water pollution and provision of fishways and fish passage were also important complementary actions.

- Also, under consideration at present is the so-called 'daughterless carp' technology (see main text). The Panel, while noting the potential this technology may offer as a control measure for carp, observed that the likely timeframe for seeing this technology refined and available was expected to be at least 30-40 years, added to which would be the logistical challenge of seeing the 'daughterless carp' themselves introduced across the Basin. The Panel urges careful consideration of this option, and if it is supported by expert opinion, to not place 'all the eggs in this basket' with respect to reducing the impact of carp. The Panel supported the implementation of the National Carp Management Strategy across the Basin as a necessary part of dealing with the carp problem.

- When considering the issue of other alien fish species that are having a negative impact on native fish in the Basin, the Panel concluded that there needs to be careful consideration and attention given to each, on a case-by-case basis. Not only do the threats posed by each alien species vary, but so also do the measures needed to reduce their impacts. It is important to note that, with the exception of environmental flows and habitat restoration, the interventions needed to reduce carp populations will not be likely to reduce the populations of other alien fish species.

- For the uplands (areas of the Basin above 300 metres ASL), the Panel recommended that habitat restoration combined with the provision of fishways and fish passage as the most valuable interventions for restoring native fish communities. The addition of aquatic reserves and interventions to reduce carp and other alien fish species will complement these actions.

- For the lowlands (areas at and below 300 metres ASL), the Panel concluded that the interventions needed are similar to those needed Basin-wide.

- For the northern Basin (from the Macquarie River and north), continuing vigilance is needed to prevent the spread of alien fish species from the southern rivers. Otherwise, it was the view of the Expert Panel that the strategic interventions needed are similar to those needed Basin-wide.

- For the southern Basin (south of the Macquarie River), the Panel concluded that cold-water pollution is a far greater problem than elsewhere in the Basin, and should be considered a priority intervention (in concert with the other interventions recommended for the Basin-wide perspective) to accelerate and optimise the restoration of native fish populations. This action should have major, immediate benefits to fish populations in the areas effected.

Strategic Interventions Plan

Key aspects of the proposed Strategic Interventions Plan, as summarised in Table 1 (below) and Table 3 (in the Report proper).

- The Expert Panel believes that an appropriate target for the Strategic Interventions Plan is to see native fish populations in the Basin returned to 60 per cent or better of their estimated pre-European levels after 50 to 60 years.

- To achieve this target it will be necessary to apply a strategy that involves, to some extent, all seven of the interventions considered by the Panel, as outlined further below. Investing in simply one or two will not allow this target to be achieved, or even approached within this timeframe.

- The Panel noted that some strategic interventions have more immediate impacts, while others will require a long lead-time before their impacts will be reflected in the native fish population.

- There are some differences in how the problem of the Basin's declining native fish communities need to be considered in the uplands, and in the northern and southern parts of the Basin. These differences need to be accommodated in the Strategic Interventions Plan (Table 1).

- The 'natural capital' upon which the native fish restoration effort will rely is presently being eroded at such a rate that it is not a wise strategy to only finance actions that will achieve their potential in 10 to20 years time. A balanced approach is needed that will see some short-term, quick return interventions undertaken, while also directing resources toward those that will provide returns in the longer term.

- By making some investment in the short-term interventions, the 'natural capital' in the system will be (at worst) maintained and will probably begin to recover. This will provide a stronger base for later interventions to build on.

Table 1: Priority immediate strategic interventions

Strategic interventions	Priority investment
Abatement of cold water pollution	Immediately design and implement the necessary engineering solutions and changes to operating protocols, or a combination of both, to see this threat largely removed from the Basin within 10 years.
Provision of fishways and fish passage	Significantly boost existing efforts to install fishways and provide for fish passage. Ensure efficient operation of fishways and provision of appropriate flows. Ensure that suitably designed carp traps are installed to operate at all, or most, flows.
Allocation of environmental flows	Invest in strategic flow allocations to benefit native fish communities in the short-term. Ensure medium and longer-term allocations take native fish restoration into consideration.
Habitat restoration	**Immediate investment in re-snagging of priority reaches.** Ensure that Federal and State/Territory natural resource management programs are prioritising habitat restoration for the rehabilitation of native fish populations..
Development of system of aquatic reserves	Review current situation with respect to reserves, identify gaps and develop a way forward for achieving a comprehensive, adequate and representative freshwater aquatic reserves system for the Basin.
Carp management	Escalate efforts to see the National Carp Management Strategy implemented across the Basin. Following suitable evaluation, invest in development of 'daughterless carp' technology as a longer-term complementary intervention.
Management of other alien fish which pose a threat to native species	Develop as necessary, specific measures to reduce the impacts of other alien fish species, in parallel with and complementary to the above interventions
Knowledge generation, communication, monitoring and evaluation	Invest in knowledge generation, communication, monitoring and evaluation to provide the basis for future adaptive management that has strong community support and accountability.
Establishment of 'demonstration sites/reaches'	Identify and develop 'demonstration sites/reaches' where multiple interventions are focused and intensified to show the broader community benefits to be gained from larger scale, multiple investments.

1. Introduction

At the request of the Chief Executive Officer of the Murray-Darling Basin Commission (MDBC) an Expert Panel was formed to develop a conceptual model that could assist the Commission and Ministerial Council with future investment decisions in relation to its Native Fish Strategy.

The Expert Panel comprised three members of the MDBC's Fish Working Group: Dr John Harris from the CRC for Freshwater Ecology; John Koehn, from Victoria's Arthur Rylah Institute for Envieonmental Research; and Dr Peter Jackson from the Queensland Department of Primary Industries. These experts were joined by Dr Terry Hillman from the CRC for Freshwater Ecology, Associate Professor Keith Walker from the CRC for Freshwater Ecology at the University of Adelaide and Dr Mike Braysher of the University of Canberra.

The Expert Panel members met on 12 December 2001 for a full day workshop, having submitted in advance a lengthy questionnaire designed to prepare the way for their discussions. Dr Bill Phillips (MainStream Environmental Consulting Pty Ltd) facilitated workshop preparation, process and reporting.

The objectives of this exercise are outlined below.

- Produce a conceptual model that will enable prediction of the relative environmental benefits for the Basin's rivers that would result from rehabilitation programs focussed on the following topics: carp control (including the proposed "daughterless carp" technology); control of other alien fish; environmental flows; habitat restoration; fishway construction; abatement of coldwater pollution; and aquatic reserves.

- Illustrate the model's predictions in terms of the following response variables: native fish distribution and abundance; status of threatened aquatic species; carp distribution and abundance; and the distribution and abundance of other pest fish.

- Stratify the model by river type (upland and lowland) and by region (northern and southern portions of the Basin).

- Provide an emphasis on likely fish community responses to the cumulative effects of strategic interventions.

The product of the Panel's deliberations, as presented in this report, should be considered as 'best estimate' based on the combined expertise of the Panel members and the current state of knowledge on fish biology, ecosystem functioning, riverine ecology and restoration science. While the Expert Panel generated the views expressed in this report, it also calls upon the Commission and Governments of the Murray-Darling Basin to note knowledge gaps and research priorities. This conceptual framework needs to be fine tuned over time but will require urgent investment in R&D to fill the obvious gaps in our knowledge that made developing this conceptual framework a challenging task. Additional knowledge will allow refinement of the predicted outcomes of this model and restorative actions.

Expert Panels, like this one, provide a strategic overview to a problem by synthesising the best available information and knowledge. This helps to develop a predictive model that can point the way forward. The Panel recommends that the Strategic Interventions Plan for the Basin's native fish populations be accepted and acted on in full.

2. Strategic interventions

The development of the conceptual models that follow was undertaken giving consideration to the seven strategic interventions identified in the Project Brief. While many other interventions are identified in the Native Fish Strategy these seven are considered to be those with the greatest likelihood of delivering broad scale and significant improvements to the status of native fish in the Murray-Darling Basin.

The Expert Panel considered each possible strategic intervention and reached agreement that for this report they should be interpreted as meaning the following:

2.1 Allocation of environmental flows

The Panel is conscious that across the Basin, several jurisdictions and the Commission, are implementing changes to environmental flows and seeking to have further flows allocated. In the context of this Report, environmental flows mean allocations that specifically offer benefits for native fish. While it is probably true to say that any environmental allocation can be expected to offer some level of benefit for native fish communities, more tactical and strategic allocations could provide greater benefits. For example instances such as where environmental flows can re-establish connectivity with floodplain wetlands, reinstate semi to natural flow regimes (including wetting and drying cycles in wetlands), stimulate key physiological or behavioural processes, or allow fishways to operate more effectively.

It is also recognised that environmental flows are a key part of addressing the carp problem in the Basin (see consideration of the carp management intervention below) and for this Report, and in the conceptual model, it is assumed that the environmental flows intervention has this additional benefit. In this context it should be understood that environmental flows, while assisting to restore native fish populations, can also benefit carp. Environmental flows on their own do not offer a quick fix solution to the carp problem.

2.2 Habitat restoration

The Panel considers that this strategic intervention means a range of actions that will provide direct and more-or-less immediate benefits for native fish. This includes actions such as re-snagging, restoring or protecting riparian margins, restoring floodplain wetlands, and reducing catchment erosion and associated sedimentation and turbidity in rivers and streams. The Panel also notes that habitat restoration, as defined here, will yield even greater benefits for native fish if done in conjunction with environmental flow allocations.

2.3 Abatement of cold water pollution

Cold-water pollution is now acknowledged as impacting on thousands of kilometres of the Basin's rivers downstream of storages. The Panel considers that this strategic intervention refers both to the structural or engineering solutions available to abate cold-water pollution, and to solutions that can be implemented through changed operating procedures for storages. Undertaking this intervention to provide for a more natural temperature regime can give almost immediate results.

2.4 Provision of fishways

The Panel interprets this strategic intervention as meaning the installation of fishways on dams and weirs, as well as broader consideration of removing barriers to fish passage. The Panel also notes that such measures can serve to assist the movements of carp, and that fishways need to include carp traps that can prevent carp movements upstream of storages that may currently provide a barrier.

2.5 Establishment of aquatic reserve system

This intervention is taken to mean the very strategic development of a system of freshwater 'reserves' across the Basin. These 'reserves' can yield significant targeted benefits for biodiversity conservation, including native fish, as well as contributing to improvements to the overall 'health' of the Basin's riverine and floodplain ecosystems. The Panel understands the term "strategic development" of such an aquatic reserve system to mean translation of the concepts of

'comprehensive, adequate and representative' from terrestrial ecosystems into riverine and floodplain ecosystems. This would, it is assumed, give priority consideration to protecting vital fish habitats, and especially those of threatened fish species.

The Panel chose not to consider the term 'reserve' in the formal sense of a gazetted nature reserve or similar, but rather any area that is managed in a way sympathetic to biodiversity conservation, be it privately owned or managed by Government. Such 'reserves' may also, in appropriate situations, be areas that are exploited for their resources, providing such exploitation is ecologically sustainable. Examples cited are the Barmah-Millewa forest, Macquarie Marshes, Bookmark Biosphere Reserve and the Lower Gwydir Ramsar listed Wetlands of International Importance. In the following analysis an arbitrary level of 'reserves' constituting 5 per cent of river reaches and floodplains was assumed. While perhaps an ambitious target, it was the view of the Panel that this probably represented a minimum level to have any serious impact.

2.6 Carp management

This includes the range of interventions outlined in the National Carp Management Strategy, but not, in this context, environmental flows or habitat restoration designed specifically to disadvantage carp. Those two interventions are covered separately in this exercise (see above). The interventions that "carp management" includes are wetting and drying cycles for floodplain wetlands and the installation of screens to prevent adult carp migrations.

Also included under this strategic intervention is the proposed development of the so-called 'daughterless carp' technology that CSIRO is seeking to pursue. The Panel noted that considerably better information is required before this technique can be fairly assessed in comparison with other strategic interventions.

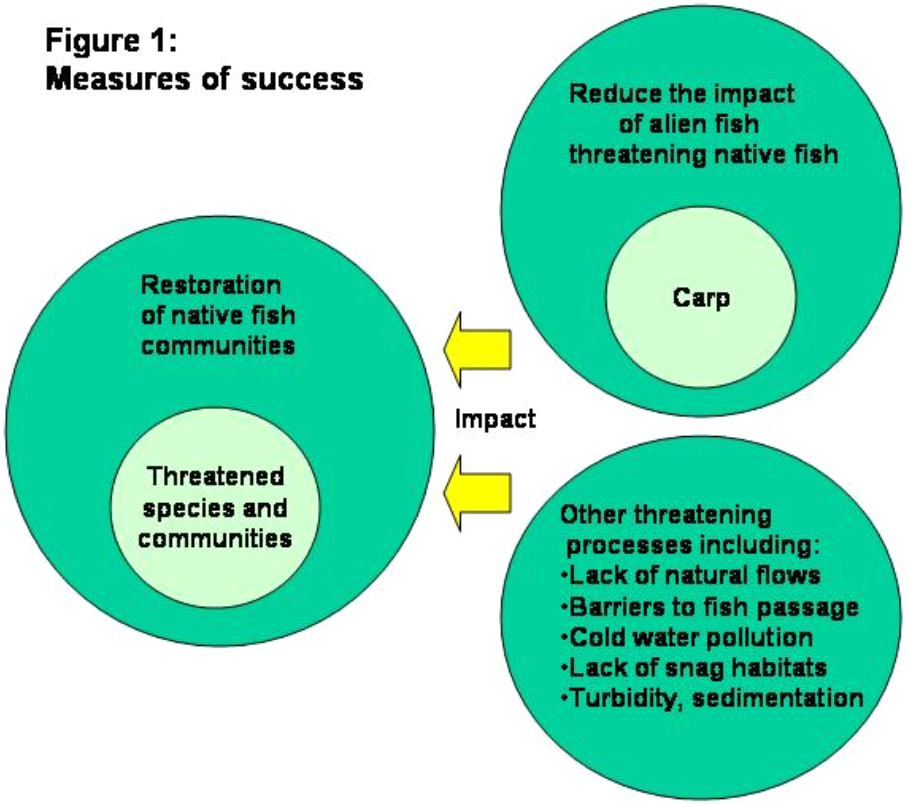
2.7 Management of other alien fish species which are threatening native fish communities

The Expert Panel recognises that the interventions needed to address the threats posed by other alien fish vary considerably depending on the species involved and level of threat they pose. There is a very strong view among Panel members that a vital part of this strategic intervention is education and awareness raising. Vigilance and actions to prevent the introduction of further alien fish species and the further spread of those introduced species already established in the Basin are also needed.

3. Measures of success

The Expert Panel was asked to develop the conceptual model for four response variables, as outlined below. These were also considered by the Panel as "measures of success" against which future strategic interventions could be measured. Figure 1 presents these measures of success graphically and illustrates how two of the "measures of success" (management of carp and other alien fish species) are means to achieving the two key outcomes of restoring native fish populations and conserving threatened fish species and communities.

Figure 1:
Measures of success



3.1 Restoring native fish

Implicit in this measure of success is that the distribution and abundance of native fish within the Basin will expand and increase (respectively) toward their pre-European status.

3.2 Restoring listed threatened fish and fish communities

Implicit in this measure of success is that the conservation status of those native fish species and communities listed under either Commonwealth or State/Territory legislation will improve, meaning they will start to trend back toward a 'secure' status. The Expert Panel acknowledges that this measure of success is in fact a sub-set of the first measure of success. However, it is retained as a discrete measure of success due to the special considerations necessary for restoring threatened species and communities, some of which are required by legislation.

3.3 Reducing the impact of carp

Implicit in this measure of success is that the distribution and abundance of carp, and presumably of their impact on native fish across the Basin will contract and decrease (respectively) to an acceptable level. This measure of success is included because of perceptions that carp are a major threat to the status of native fish. It should be noted that this threatening process is but one of many that are contributing to the decline of native fish communities. Further, this measure of success is, in principle at least, a sub-set of reducing the total threat from alien fish species (see below).

Carp reduction has been retained as a separate measure of success in the conceptual model as the Expert Panel believes that the strategic interventions required to reduce carp impacts are largely different from those needed to reduce the impact of the other alien fish species. However, it should be noted that in most cases the actions to reduce carp numbers can have a long-term effect only if they are combined with the interventions that will restore native fish habitat.

3.4 Reducing the impact of alien fish species which are threatening native fish communities

Implicit in this measure of success is that the distribution and abundance of alien fish species, and their impact on native fish across the Basin will contract and decrease (respectively) to acceptable levels. The Expert Panel believes that this measure of success needs to be applied to those alien fish species which already affect native fish in the Basin, and also those fish which if introduced, or allowed to spread further, could become significant threats. It is acknowledged that this category includes: redfin perch, the salmonids, gambusia, goldfish and oriental weatherloach, and that each poses a different level of threat to native fish in different areas that needs to be considered when strategic interventions are under consideration. The Panel also noted that, without due vigilance, there is potential for other alien fish (notably tilapia) to invade the waterways of the Basin.

4. Conceptual models

The approach taken by the Expert Panel was to consider the seven strategic interventions (see Section 2) for each of the four 'measures of success' (see Section 3). This was done initially for the Basin-wide scale, and then subsequently for the lowland, upland, northern and southern parts of the Basin.

Having established a view on the response curves for respective strategic interventions at the Basin-wide and other scales, the Panel then considered how these could be integrated to provide the optimal combination. From this, a Basin-wide conceptual model was developed and then presented as a Strategic Interventions Plan. The latter is given in Section 5.

There is an assumption implicit in all models, and the Strategic Interventions Plan, that other external factors that may impact on native fish populations (for example, outbreaks of fish diseases or over-exploitation by professional and/or recreational anglers) are not in play. It is important to recognise that such factors may significantly alter the response curves shown below, and accordingly, that these factors cannot be ignored in long-term planning and management to restore native fish populations.

4.1 Basin-wide response curves and conceptual models for each measure of success

In developing the response curves that follow it has been assumed that each strategic intervention was in place and taking full effect immediately. No allowance has been made in these figures for implementation time lags. For example, the time it would take to implement measures to remove cold-water pollution across the Basin, or remove major artificial barriers to fish passage. This means the response curves for each strategic intervention are directly comparable in terms of the relative impact that they would have on restoring native fish communities, reducing the impact of carp or whichever measure of success is under consideration.

4.1.1 Restoration of native fish communities

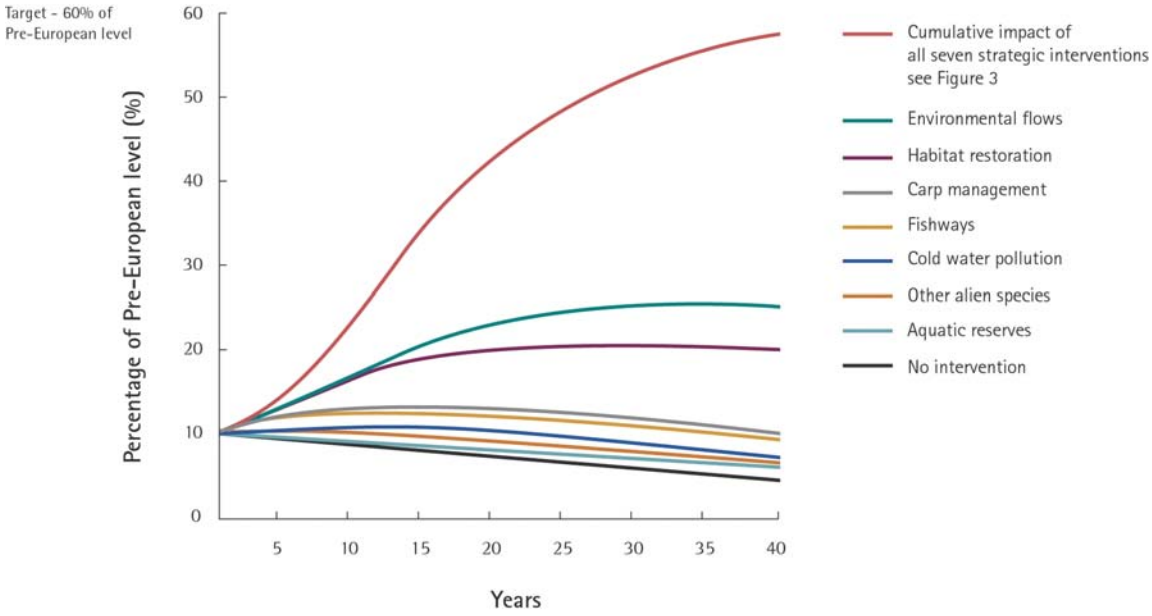
Figure 2 shows the individual response curves for each of the seven strategic interventions under consideration. The restoration target set here by the Expert Panel is to see native fish communities returned to 60 per cent of their pre-European level after 40 years of implementing the respective interventions. It is currently estimated that the level of the native fish community is 10 per cent of the pre-European level, and that without any interventions this is likely to fall to near 5 per cent over the coming 40 to 50 years. At these levels there is increased risk that individual species will be susceptible to extinction due to "under-population" effects from factors such as chance disease outbreaks.

Figure 2 reflects the Panel's view that the allocation of environmental flows, followed by habitat restoration are the most important interventions for restoring native fish populations in the medium to long-term (10 years and beyond).

The third most important intervention, especially over the medium to long-term, is carp management. Section 4.1.3 below looks in more detail at carp management response curves. Following these three interventions, in priority order, are: provision of fishways and fish passage; abatement of cold water pollution; management of other alien fish species; and establishment of an aquatic reserves system. While these latter four interventions are not considered able to deliver the same outcome with restoring native fish communities as environmental flows, habitat restoration and carp management, they have heightened importance when considering the other measures of success. In particular, abatement of cold water pollution is likely to have immediate and substantial benefits to native fish populations in areas where the pollution occurs.

Note that none of the strategic interventions, if undertaken singly, is considered to have the capacity to recover the native fish communities of the Basin beyond 25 per cent of their pre-European levels. In fact, 25 per cent is the maximum recovery level predicted, through the introduction of environmental flows, with all other interventions falling below this level of recovery.

Figure 2: Restoration of Native Fish Communities



Also shown on Figure 2 is the cumulative response curve generated when all seven strategic interventions are undertaken together. The Expert Panel considers there is good evidence to believe that with all seven strategic interventions undertaken in an integrated way (with suitable levels of investment) the proposed target level of restoring native fish communities to 60 per cent of their pre-European level is achievable. However, it must be stressed that the time frame for doing this is expected to be longer than 40 years when allowance is factored in for implementing the respective interventions. In some cases the time needed to introduce the intervention fully will be at least 10 to 20 years from now.

The Panel also notes that strategic interventions vary considerably in terms of their establishment phase. For example, abatement of cold-water pollution could (with sufficient funding) be largely achieved across the Basin within 5 to 10 years achieving benefits for native fish communities relatively soon. Significant fish passage could be restored and environmental flows allocated in this same period. In each case, the constraint is financial rather than a lack of understanding about how to fix the problem. The Strategic Interventions Plan provided in Section 5 returns to this important point.

Figure 3 shows how the cumulative native fish community response curve for all seven strategic interventions being implemented together (as shown in Figure 2) was derived. The approach taken was to plot the individual response curves for the two interventions considered likely to generate the greatest improvement in the status of native fish communities - environmental flow allocations and habitat restoration. The impact of the other five interventions was then progressively added to these curves. However, as outlined in the Strategic Interventions Plan (section 5) these curves ignore the time factors and scales that must be considered in devising the optimal combination of strategic interventions.

Figure 3 shows that with the combined impacts of environmental flow allocations and habitat restoration, native fish communities could be expected to reach levels approaching 50 per cent of their estimated pre-European levels. The addition of carp management to these two interventions could boost this a further 3 to4 per cent, the provision of fishways another 2 to 3 per cent, abatement of cold water pollution another 2 to 3 per cent, with the management of other alien fish and aquatic reserves each contributing another 1 to 2 per cent. However, it must be stressed that this model needs to be tempered with consideration of those developed for the other measures of success. As these show, if the desire is to see the other measures of success achieved, then the

combination of interventions chosen may warrant reconfiguration to place greater emphasis on certain strategic interventions.

Figure 3: Restoration of native fish communities – Cumulative impact of all interventions

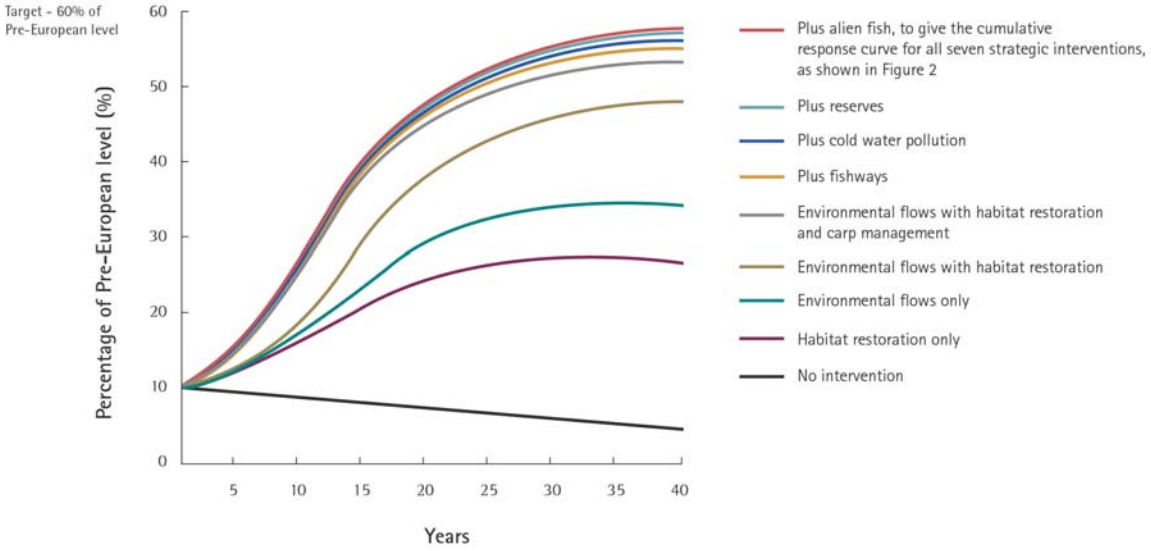
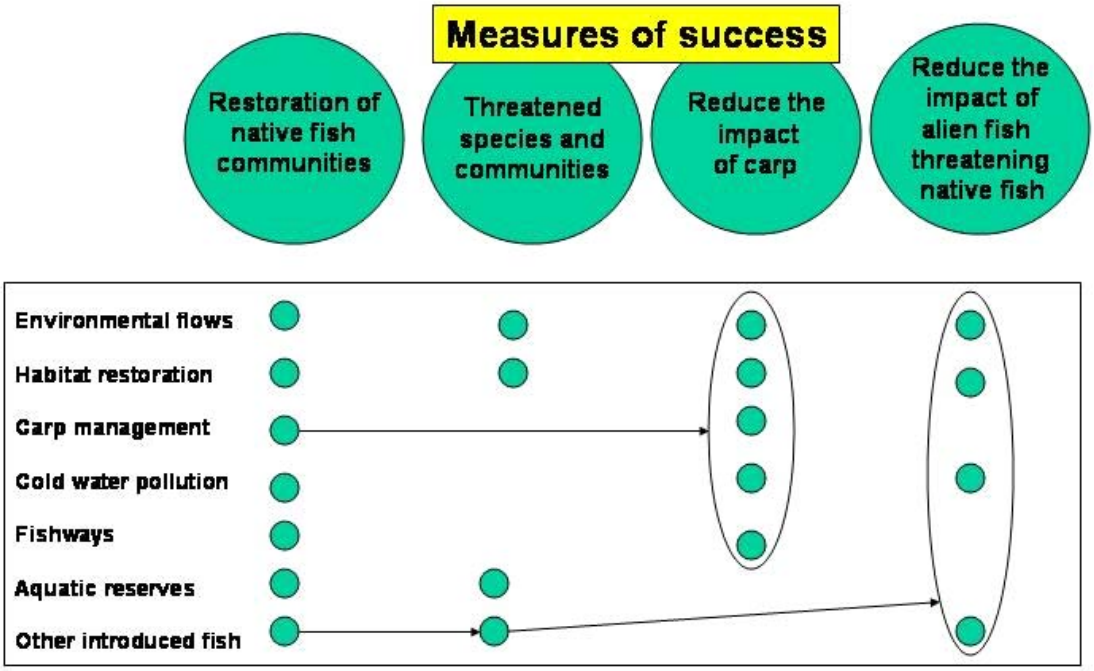


Figure 4 summarises the conclusions of the Expert Panel for this measure of success at the Basin-wide scale.

Figure 4: Priority strategic interventions needed to achieve the respective measures of success at the Basin-wide scale. See Sections 4 and 5 for explanation



4.1.2 Restoration of listed threatened fish and fish communities

The Expert Panel acknowledges that threatened fish and fish communities are a sub-set of the broader native fish community (see Section 3). It is also acknowledged that the strategic interventions undertaken for restoring the Basin's native fish will also assist with restoring threatened

fish and fish communities. However, the Panel believes that achieving this measure of success will be greatly accelerated if the strategic interventions of developing a system of aquatic reserves and the management of other introduced alien species gain greater priority.

The Panel believes that restoring threatened fish and fish communities will be significantly advanced through the development of an aquatic reserve system for the Basin - a system of freshwater refugia and habitats where threatening processes can be more closely managed. Likewise, it is acknowledged that certain alien fish species (such as gambusia, trout and redfin perch) are threatening some native fish species in some locations, as competitors and/or predators, and that control measures for these alien species will also assist efforts to restore threatened native fish and fish communities.

Figure 4 summarises the conclusions of the Expert Panel for this measure of success at the Basin-wide scale.

4.1.3 Reducing the impact of carp

In Section 3 of this report (and Figure 1) the Panel noted that carp, now representing an estimated 80 per cent of the total fish biomass in large areas of the Basin, were one of several 'threatening processes' that has seen native fish communities reduced to around 10 per cent of their pre-European levels. In terms of the overall restoration of native fish (Section 4.1.1) it was concluded that, after environmental flows and habitat restoration, reducing the impact of carp was the intervention likely to provide the next greatest benefits.

The response curve for carp management in Figure 5 shows that with no interventions the level of carp across the Basin is expected to continue to increase and expand northwards and upstream. The Expert Panel acknowledges that through interventions such as the allocation of environmental flows and habitat restoration, native fish populations should begin to recover and be better able to compete with carp. However, the Panel also contends that unless directed actions are taken to reduce the carp population and control the spread of the species, carp will be a controlling or limiting factor in the efforts to restore native fish communities.

Figure 5: Reduce Carp

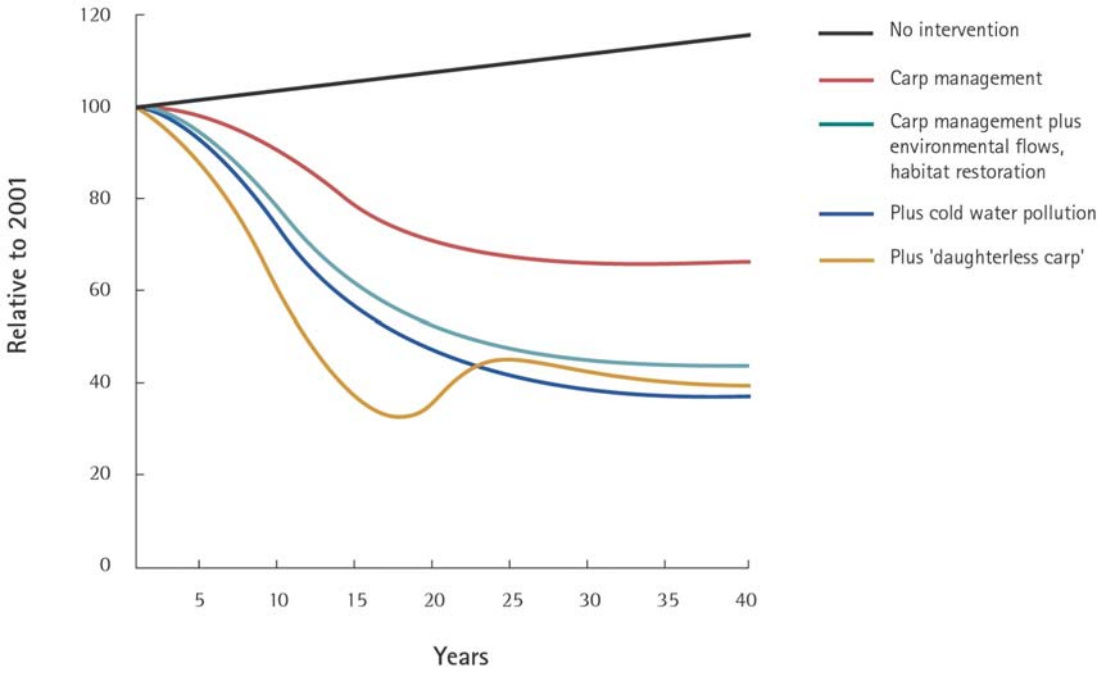


Figure 5 shows the response curves anticipated with various scenarios of carp management. The National Carp Management Strategy sets down a comprehensive program for addressing the carp problem. This includes, among a wide range of actions, the allocation of environmental flows and

habitat restoration measures that will disadvantage carp and enhance the capacity of native fish to compete with carp.

Also under consideration at present is the so-called 'daughterless carp' technology which would, if successful, over several generations see the carp population become male dominated with fewer and fewer females available for breeding. The Panel, while noting the potential this technology may offer as a control measure for carp, felt insufficiently informed to make especially strong declarations about its possible impact on the carp population. It was also observed that the likely timeframe for seeing this technology refined and taking effect was expected to be at least 10 to15 years. This is exacerbated by the logistical challenge of introducing the appropriate numbers of 'daughterless carp' across the Basin.

The 'best estimates' of the Panel in terms of the response curves for reducing the impact of carp are as shown in Figure 5. It shows that 'carp management' (that is, implementing the National Carp Management Strategy minus its environmental flows and habitat restoration elements – see Section 2.6), could reduce the carp population quite markedly. If this is done in conjunction with suitable environmental flows and habitat restoration, then this impact could be sharply increased by advantaging native fish predators that could help to limit recruitment into the adult carp population.

Of the other strategic interventions under consideration, it was the Panel's view that abatement of cold-water pollution and provision of fishways and fish passage were important complementary actions. In the case of cold-water pollution, it was noted that it provides carp with ideal habitats for up to hundreds of kilometres below many major storages, while at the same time grossly disadvantaging native fish in these same reaches. The net result is to reduce the predation and competition pressures on carp that native fish could otherwise apply. It was also observed that providing fishways could, in a few cases, become a 'mixed blessing' when attempting to control carp that can also use such structures. However, fishways can be fitted with traps that will allow for the capture and removal of carp to overcome this risk.

In Figure 5 the Panel has shown a response curve for the possible impact that 'daughterless carp' could have on the overall carp population of the Basin. As indicated above, the Panel did not feel sufficiently well informed to be definite in this area. The curve shown is based on 'gut feeling' and experience with the introduction of other control ('silver bullet') measures for pest species. The Panel expects that, like all similar 'silver bullet'-style pest control measures, the population effects of the method may attenuate over time resulting in the recovery of carp numbers in the absence of other control measures.

The curve labelled 'daughterless carp' in Figure 5 reflects the expected outcome from the combined impact of other interventions referred to, plus the introduction of 'daughterless carp' into the population. This assumes widespread introduction of the 'daughterless carp' across the Basin which would, it is believed, see the marked additional reduction in carp numbers as shown in Figure 5 over a 30 to 40 year period. It is expected that this would be followed by a recovery period, the extent of which may be determined by the scale of other actions being undertaken to assist native fish. This recovery in the carp population results from the selective advantage for remnant 'wild type' females, which have very high fecundity, and will occur whether or not releases of modified fish continue over time.

In summary, 'daughterless carp' may provide a useful tool to assist broader and longer-term efforts to see the species reduced across the Basin. The impact of 'daughterless carp', if proven to be workable, is likely to be maximised if the other strategic interventions considered here are implemented as per the Strategic Interventions Plan (section 5).

In conclusion, while the Panel can see the potential that the 'daughterless carp' technology may offer, it urges against 'placing all the eggs in this basket' with respect to reducing the impact of carp. Best results from the 'daughterless carp' technology would most likely be generated if in advance of its introduction, carp populations could firstly be reduced through the combination of actions set down in the National Carp Management Strategy.

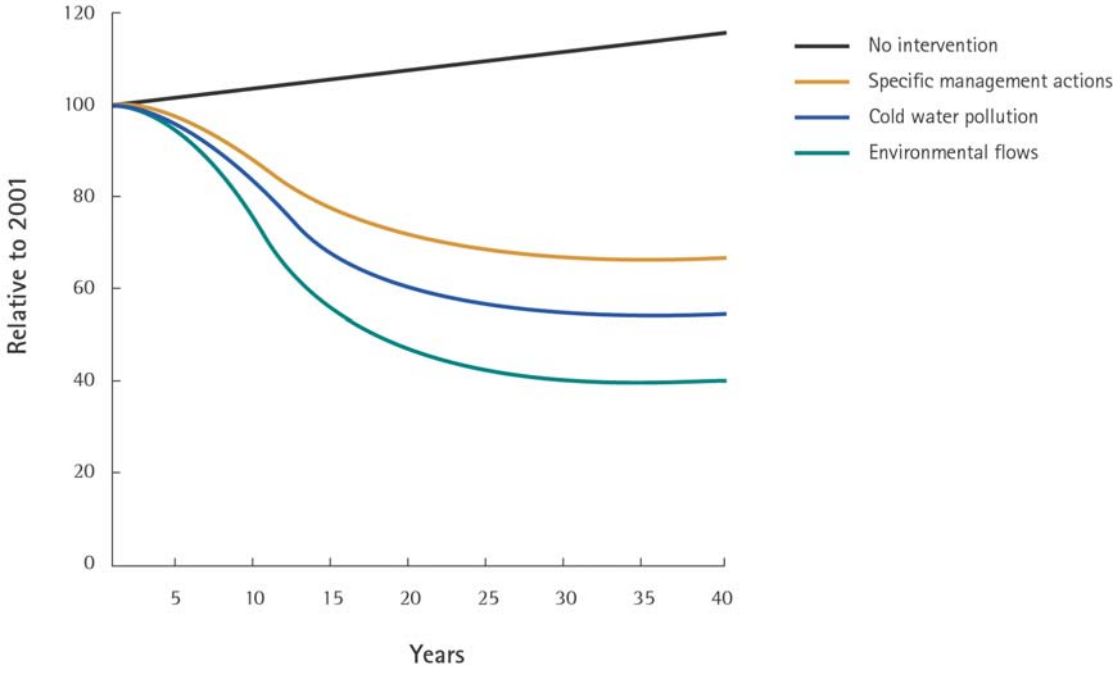
Figure 4 summarises the conclusions of the Expert Panel for this measure of success at the Basin-wide scale.

4.1.4 Reducing the impact of alien fish species that are threatening native fish communities

When considering the issue of the other alien fish species that are threatening native fish in the Basin, the Panel concluded that there needs to be careful consideration and attention given to each on a case-by-case basis. Not only do the nature and severity of the threats posed by each vary, but also the measures needed to reduce their impacts are different. It is important to note that, with the exception of environmental flows and habitat restoration, the interventions needed to control carp will not significantly reduce the populations of the other alien fish species which are of greatest concern in this context.

Figure 6 shows the response curves anticipated if specific interventions were taken to reduce the threats from these other alien fish species. As indicated in Section 3.4, the species considered priorities here are redfin perch, the salmonids, gambusia, goldfish, oriental weatherloach and tilapia. Of the salmonids, trout are acknowledged as having, in some situations, a negative impact on threatened species and fish communities.

Figure 6: Reduce alien fish species other than carp



The Panel's conclusion was that through specific management actions there could be reductions in the populations of these alien fish species. Abatement of cold water pollution is considered an important intervention here as the colder environments created below storages are providing refuges for these alien fish, from which they can disperse to colonise other reaches. Restoring more natural temperature regimes will serve the dual purposes of disadvantaging alien species and assisting native populations to re-establish and expand.

Environmental flow allocations are also important for combating alien fish, disadvantaging these species, while making the native population more competitive. Environmental flows give the native fish more of a 'fighting chance' than they have at present.

Figure 4 summarises the conclusions of the Expert Panel for this measure of success at the Basin-wide scale.

4.2 Considering all measures of success at the Basin-wide scale

Section 4.1 considered the four 'measures of success' established by the Expert Panel against the strategic interventions, but did so in isolation from one another. While this assists in gaining an understanding of how the different strategic interventions can help to achieve different outcomes, the Panel also looked across its conclusions from the preceding analysis to offer an optimal combination of strategic interventions.

Section 3 of this report, and Figure 1, emphasised that the restoration of native fish, including the restoration of threatened fish species and communities, is the fundamental measure of success (or goal) of the Native Fish Strategy. The Strategy states: "*The improved status of native fish in the Murray-Darling Basin will be the key criterion by which the public will judge the success of the Strategy.*" The Native Fish Strategy considers a range of 'threatening processes' and these are summarised in the Table below.

Table 2: Main threats to native freshwater fish in the Murray-Darling Basin.

Threat	Threatening process
Flow regulation	Loss of water to other uses, critical low flows, loss of flow variation, loss of flow seasonality, loss of low to medium floods, permanent flooding and high water, increased periods of no flow
Habitat degradation	Damage to riparian zones, removal of in-stream habitats, sedimentation
Lowered water quality	Increased nutrients, increased turbidity, sedimentation, salinity, artificial changes in water temperature, pesticides, and other contaminants
Barriers	Impediments to fish passage resulting from the construction and operation of dams, weirs, levees, culverts, etc., and non-physical barriers such as increased velocities, reduced habitats, water quality and thermal pollution (changes in water temperature)
Alien species	Competition and/or predation by carp, gambusia, oriental weatherloach, redfin perch and trout
Exploitation	Recreational and commercial fishing pressure on depleted stocks, illegal fishing
Diseases	Outbreak and spread of EHNV (Epizootic Haematopoietic Necrosis Virus) and other viruses, diseases and parasites
Translocation and stocking	The loss of genetic integrity and fitness caused by inappropriate translocation and stocking of native species

It is notable that the Strategy places carp and other alien fish among this range of threats to native fish. It is important in recommending a Strategic Interventions Plan (see Section 5) to keep this in mind.

When the outputs from Sections 4.1.1 – 4.1.4 are drawn together, as in Figure 4, it reveals that the allocation of environmental flows (noting as was done in Section 2.1 that this is taken to mean strategic or tactical allocations that can assist native fish) and habitat restoration are the interventions considered by the Expert Panel as providing the best long-term return for investment irrespective of the measure of success being applied.

The Panel accepted that carp pose a major threat to native fish in the Basin, and that without reducing their impact the responses from other strategic interventions will be limited (meaning unable to achieve the target proposed here of returning native fish to 60 per cent of pre-European levels). The Panel supported carp management and observed that, in addition to the strategic interventions of environmental flows and habitat restoration, reducing the impact of carp can be optimised if done in concert with the abatement of cold water pollution and the provision of fishways equipped with suitably designed carp traps.

The Panel concluded that, in the special case of threatened fish species and communities, the priority interventions are environmental flows and habitat restoration. However, an aquatic reserve system and measures to reduce the impact of other alien fish species need to be added so that responses can be optimised. The Panel also considered that fishways/fish passage and the abatement of cold-water pollution are important elements of an integrated approach.

These conclusions are considered further in Section 5 where a Strategic Interventions Plan is described.

4.3 Modifying the formula of strategic interventions for the lowlands and uplands and the northern and southern parts of the Basin.

Having developed a view on the optimal strategic interventions at the Basin-wide scale, the Expert Panel then considered how this model would vary for each of the situations - lowlands and uplands and the northern and southern parts of the Basin. The conclusions are provided below.

4.3.1 Uplands

For the purposes of this report the uplands are defined as areas of the Basin above 300 metres ASL. The conclusions are the same as for the uplands, environmental flows are less of an issue, although this should not be interpreted as meaning they are inconsequential. In the uplands carp are not yet as problematic as they are in the lowlands. For this reason they are not included as a priority intervention for restoring native fish communities in the uplands. Equally, cold water pollution is not considered such an issue in the uplands despite there being several structures above 300 metres ASL in the Basin. The Panel considered that in the uplands the cause of restoring threatened fish species and communities will be accelerated through the provision of fishways in appropriate locations, and controlling the impacts of alien fish species other than carp. It is noted that this needs to be considered on a case-by-case basis as in some locations the retention of barriers to trout migration upstream may be beneficial for some threatened species (for example, galaxiids).

To summarise, in comparison with the Basin-wide situation, the uplands native fish communities face fewer threats. Habitat restoration combined with fishways and controlling the impacts of alien fish species other than carp are considered the most valuable interventions for restoring native fish communities. The addition of aquatic reserves will provide the ideal formula.

4.3.2 Lowlands

For the lowlands, defined as areas at and below 300 metres ASL, it was concluded that the interventions needed were as for the Basin-wide perspective. This is not surprising given that most of the Basin is lowlands.

4.3.3 Northern Basin

For the purposes of this report the northern Basin is defined as the area north from the Macquarie River, and is differentiated from the Southern Basin because it is fed by summer rainfall events rather than the winter rain and snow melt which drives southern streams. The Expert Panel concluded that in this part of the Basin, alien fish species that are threatening native fish are of less concern than in the south, but vigilance is needed to prevent the spread of these species from the southern rivers. Special care is needed to prevent the introduction of tilapia from eastern Queensland rivers. Otherwise, it was the view of the Expert Panel that the strategic interventions needed in the northern part of the Basin were as for the Basin-wide model.

4.3.4 Southern Basin

The southern Basin is defined as the area south of the Macquarie River. The primary conclusion was that many of the storages responsible for cold-water pollution occur in this zone and mitigation of this impact should be considered a priority intervention (along with the others proposed at the Basin-wide scale) to accelerate and optimise the restoration of native fish.

4.4 Summarising the differences between upland, lowland, northern and southern parts of the Basin

The preceding analysis indicates that the model for optimal strategic interventions for the lowlands is similar to that for the Basin-wide view. The uplands, being less modified by comparison with the lowlands, have fewer threats to native fish and provide refugia for some species. Habitat restoration and provision of fishways are priority interventions in the uplands. Alien fish species are less prevalent in the northern part of the Basin, but maintaining this situation will require vigilance. In the southern region, cold water pollution associated with dams requires attention.

5. Strategic Interventions Plan

The Chief Executive Officer of the Murray-Darling Basin Commission indicated that this Report would be used to guide future Ministerial Council investment decisions about native fish restoration in the Basin. As a response to this need, the Panel has applied its conclusions within a Strategic Interventions Plan. This takes into consideration a range of factors beyond simply those that will yield the best long-term results for native fish. In doing this, the Panel recognised that this level of analysis approaches areas peripheral to the fields of expertise from which most members were drawn. However, these suggestions are based on the Panel's best assessment of the potential efficacy of the various management options, the likely time-scale of their actions, and their value in terms of other river health issues. The Panel was not in a position to consider details of cost, competing demands for management resources, or "non-scientific" aspects of achievability.

The Panel concluded during their deliberations that the seven strategic interventions under consideration would differ greatly in terms of their capacity to deliver against the four measures of success that were applied. It was also evident that some strategic interventions have more immediate impacts, while others require long lead-times before their impacts are reflected in improved native fish population. Some interventions are recognised as yielding wider benefits to the ecosystems and overall 'health' of the Basin, whereas others are directed primarily at restoring healthy fish populations. It is also true to say that there are some differences in how the problem of the Basin's declining native fish communities needs to be considered in the uplands, and in the northern and southern parts of the Basin.

The key questions in determining a strategy for the interventions needed to see native fish restored across the Basin are "what is the target being sought ?" and "how quickly do we wish to achieve it ?". The more modest the target, the easier it will be to reach (in theory). The longer the time frame available for reaching the target, then the smaller the level of annual investment required. Applying such logic to the situation of native fish communities in the Basin is fraught with dangers, for the longer the delays in making significant investment, the more difficult restoration will be. The 'natural capital' upon which such a restoration effort will rely is being eroded at such a rate that it is not a wise strategy to be financing just those actions that will begin to achieve their potential in 10 to 20 years time. Instead, a balanced approach is needed that will see some short-term quick return interventions undertaken while also directing some resources toward the long–term (a superannuation plan as it were!). By making some investment in the short-term interventions, the 'natural capital' in the system will be (at worst) maintained and will probably begin to recover. This will provide a stronger base for later interventions to build on. To use financial sector jargon – the compounding interest will see stronger returns from investment in later years by taking very directed, low-risk interventions now.

This is the philosophy behind the following Strategic Interventions Plan.

The Expert Panel believes that an appropriate target for such an investment plan should be to see within 50 to 60 years, native fish populations in the Basin returned to 60 per cent or better of their estimated pre-European levels.

Recommended short-term investments

The following (as shown in Tables 1 and 2) are recommended as immediate investment priorities that are designed to 'hold the line', or better, in terms of restoring native fish populations (including threatened species) and laying the necessary foundations for those interventions with longer time frames.

5.1 Abatement of cold water pollution

- **Immediately undertake the necessary engineering solutions, changes to operating protocols or a combination of both, to see this threat largely removed from the Basin within 10 years.**

The abatement of cold water pollution is a clearly definable, tangible and relatively low cost intervention. It could be completed for all the relevant storages of the Basin within 10 years, meaning that through either engineering solutions, changes to operating protocols or a combination of both, this threat could be largely removed from the Basin. This will provide a range of immediate benefits including helping to reduce the impacts of carp and other alien fish species along an estimated 4,000 kilometres of the Basin. This will also assist, along with other strategic interventions, to make these reaches suitable again for native fish breeding. While the cold water pollution problem is mostly found in the southern part of the Basin, investing in this intervention will have long term benefits for the whole Basin by seriously impacting on alien fish species that continue to move inexorably northward. In terms of the philosophy of this Strategic Interventions Plan, cold water pollution is an ideal early target that will at worst help to 'hold the line' until other interventions take effect.

5.2 Provision of fishways and fish passage

- **Significantly boost existing efforts to install fishways and provide for fish passage, and couple this with carp traps.**

The provision of fishways (passage, as interpreted here) is not quite as definable or tangible as the cold-water pollution problem, largely because it requires consideration of far more structures and situations across the Basin. However, as with mitigating cold-water pollution, the technology is known (although constantly evolving) so it is a relatively low risk intervention. Given that there are already significant efforts underway in the Basin to provide for fish passage, a 'ramping up' of these efforts would seem relatively simple and would offer further immediate (that is, within a 5-10 year timeframe) benefits for native fish populations. Importantly, it will allow for some native fish species to immediately expand their distributions back into their former habitats. When coupled with the installation of carp trap devices, the provision of fishways and fish passage will further reduce the impact of carp and begin to build a stronger more comprehensive program to combat the carp menace. The foregoing conceptual models (section 4.3.1) also identified the importance of fishways in the uplands as part of securing the future of threatened fish species and communities. The Panel believes that prudent (but significantly escalated) allocation of resources to provide for fish passage will provide more immediate benefits for native fish.

5.3 Allocation of environmental flows

- **Invest in strategic flow allocations to benefit native fish communities in the short-term and ensure medium and longer-term allocations take native fish restoration into consideration.**

The strategic allocation of environmental flows also offers the opportunity for relatively short-term rebuilding of the Basin's native fish communities. Assuming that native fish needs are factored into environmental flow determinations, the Panel believes this to be one of the most important short, medium and long-term investments needed to see native fish restored. Here again there are already moves across all jurisdictions of the Basin to see further environmental flows allocated. A stronger commitment to this could see major benefits to native fish delivered within 5-10 years.

5.4 Habitat restoration

- **Immediate investment in re-snagging of priority reaches, coupled with ensuring the range of Federal and State/Territory natural resource management programs are taking on board habitat restoration for native fish restoration as part of their priorities.**

The Expert Panel indicated that together with environmental flows, habitat restoration is the highest priority intervention needed to see native fish communities restored over the next 50-60 years. However, it also acknowledged that the rewards from making this investment are likely to be less immediate than the three investments indicated above. Habitat restoration, which includes actions such as re-snagging, the restoration or protection of riparian margins, restoration of floodplain wetlands, and the reduction of catchment-wide erosion and associated sedimentation, are not 'quick fix' options. They also require considerable capital outlay and to a large extent are reliant on strong catchment-based and community-supported efforts at the local level. Considerable investments have already been made (with the possible exception of re-snagging) through various State/Territory and Federal Government programs, and while more is warranted, it needs to be strategically coordinated to gain immediate and direct benefits for native fish. Despite these current levels of investment, habitat restoration remains a vital part of seeing native fish communities restored and it would seem there is a need to ensure that the current range of programs directing resources toward catchment-wide, floodplain and riverine restoration are doing so with full regard for how this can be undertaken to support native fish restoration.

There is an immediate need for greater investment in re-snagging along some key river reaches that would then provide a growing 'reservoir' from which native fish can begin to recolonise their former surrounding habitats once threats such as cold water pollution are removed, carp numbers begin to decline or fish passage becomes available again.

5.5 System of aquatic reserves

- **Review the current situation with respect to 'reserves', identify gaps and develop a way forward for achieving a comprehensive, adequate and representative freshwater system of 'reserves'**

The development of a system of aquatic reserves can also be considered as a medium to long-term investment. While today there are a reasonable number of 'protected areas' within the Basin, neither their collective contribution to biodiversity conservation nor their value for native fish conservation is known. The Expert Panel has noted this weakness in the current approach to Basin management. It urges immediate investment be made to understand the functions being carried out by the current freshwater 'protected areas' and 'reserves' of the Basin to identify gaps and weaknesses that can be addressed over time. It is noted that the concept of a reserve system that is comprehensive, adequate and representative is yet to be developed for aquatic ecosystems and this warrants high priority action.

In the preceding analyses, the Panel noted the importance of an aquatic reserve system from the perspective of restoring threatened fish species and communities, and here further stresses that investment in such a reserve system also has a potentially broader role in showing the products of river restoration to the community that must support these efforts. This issue is considered further below under Section 5.8 "Knowledge generation, communication, monitoring and evaluation".

5.6 Carp management

- **Escalate efforts to see the National Carp Management Strategy implemented in the Basin, and, if warranted based on further review, invest in development of 'daughterless carp' technology as a longer-term complementary intervention.**

Carp management can be considered to have short, medium to long-term elements, especially when this is taken to include the proposed development of the 'daughterless carp' technology. This technology is expected to take at least 10 to 15 years to be refined, before then beginning to take effect (assuming the technology is successful) within the next 20 to 30 years. As indicated in Section 4.1.3 the Panel strongly urges against responding to the threat posed by carp by 'placing all the eggs' in the daughterless carp technology. The conceptual model developed in Section 4.1.3 indicates that a combination of interventions (other than 'daughterless carp') can be expected to reduce carp numbers and distribution and presumably their impact on native fish populations. It is felt that the efficacy of special intervention such as 'daughterless carp' is most likely to be enhanced and extended if supported by other complementary measures such as integrated carp management, allocation of environmental flows, habitat restoration, abatement of cold water pollution and the provision of fishways. Such interventions would serve the dual purposes of helping to restore native fish populations, while depleting carp stocks.

5.7 Other alien fish that pose a threat to native species

- **Develop as necessary specific measures to reduce the impacts of alien fish species, in parallel with and complementary to the above interventions.**

The issue of reducing the impact of the other alien fish that pose a threat to native species has to a large extent been covered above. The Basin-wide model (Figure 4) indicates the special importance of addressing this threat in the interests of seeing threatened species and communities restored. Apart from targeted actions directed at certain of these alien species on a case-by-case basis, the Panel noted that the other interventions required to reduce this threat are primarily environmental flows, habitat restoration and the abatement of cold water pollution. Under this Strategic Interventions Plan these three interventions are recommended as immediate priorities as shown in Tables 1 and 2.

5.8 Knowledge generation, communication, monitoring and evaluation

- **Invest in knowledge generation, communication, monitoring and evaluation to provide the basis for future course corrections, gaining strong community support and accountability**

- **Identify and develop 'demonstration sites/reaches' where interventions are focused and intensified to show the broader community the benefits to be gained from larger scale investments.**

The Panel also noted that the implementation of this investment plan requires investment in:

- ongoing knowledge generation to see the conceptual models fine-tuned and adjusted over time;
- communication to ensure strong and growing support from the public and private sectors; and
- ongoing monitoring and evaluation to allow for feedback loops to operate, and to demonstrate successes and justify the investments made.

Part of this specialised knowledge generation will need to come from targeted hypothesis-based monitoring programs linking interventions with predicted outcomes to form adaptive management programs. Sections 6 and 7 of this report consider communication and knowledge generation, respectively.

It was also the view of the Panel that by showcasing restored or near pristine riverine ecosystems as 'demonstration sites' there is a unique opportunity to combine community education with the serious management task of conserving threatened fish species and communities. As was noted above with respect to re-snagging, a further advantage to be gained from an aquatic reserve system is that refuges are created throughout the system that can then act as 'reservoirs' for recolonising former habitats when other interventions reduce some of the threatening processes. This is now a commonly accepted approach to marine and coastal protected area management, where 'no go' zones are a fundamental component of maintaining healthy coastal fisheries. The development of the concept of 'demonstration sites or reaches' is a high priority.

This Strategic Interventions Plan is summarised in Tables 1 and 2 below.

Table 3: Priority immediate strategic interventions

Strategic interventions	Priority investment
Abatement of cold water pollution	Immediately undertake the necessary engineering solutions, changes to operating protocols or a combination of both, to see this threat largely removed from the Basin within 10 years.
Provision of fishways and fish passage	Significantly boost existing efforts to install fishways and provide for fish passage, and install suitably designed carp traps to operate at all, or most, flows.
Allocation of environmental flows	Invest in strategic flow allocations to benefit native fish communities in the short-term and ensure medium and longer-term allocations take native fish restoration into consideration.
Habitat restoration	Invest immediately in re-snagging of priority reaches, and ensure the range of Federal and State/Territory natural resource management programs are taking on board habitat restoration for native fish restoration as part of their priorities.
Development of system of aquatic reserves	Review current situation with respect to reserves, identify gaps and develop way forward for achieving a comprehensive, adequate and representative freshwater aquatic reserves system for the Basin.
Carp management	Escalate efforts to see the National Carp Management Strategy implemented in the Basin, and, following suitable evaluation, invest in development of 'daughterless carp' technology as a longer-term complementary intervention.
Management of other alien fish that pose a threat to native species	Develop specific measures to reduce the impacts of other alien fish species, in parallel with and complementary to the above interventions.
Knowledge generation, communication, monitoring and evaluation	Invest in knowledge generation, communication, monitoring and evaluation to provide the basis for future course corrections, gaining strong community support and accountability.
Establishment of 'demonstration sites/reaches'	Identify and develop 'demonstration sites/reaches' where interventions are focused and intensified to show the broader community the benefits to be gained from larger scale, multiple investments.

Table 4: Investment plan - summary form

Strategic interventions	Short term investments (next 10 years)	Medium to longer term investments (10 – 50 years)
Abatement of cold water pollution	Definable, tangible and relatively low cost. Will yield immediate results. Contribute to restoration of native fish communities, especially in the southern part of the Basin. Helps to reduce impact of carp, and other alien fish species.	Some maintenance costs for minor engineering solutions over the long-term. Will contribute to the longer-term restoration of these reaches.
Provision of fishways and fish passage	Definable, and with immediate actions possible in many part of the Basin. Would be building on current initiatives. Allow a return of natural migration patterns, thus beginning to rebuild native fish stocks across the Basin. Will disadvantage carp, especially if carp traps are incorporated into fishways. Fishways important for threatened fish, especially in the uplands.	Given the number of structures and barriers, this will also require investments beyond a 10-year timeframe. Careful early planning will see major improvements in fish stocks sooner.
Allocation of targeted environmental flows	Targeted use of environmental flows could yield short-term results which would support all other interventions, including carp management and the conservation efforts for threatened species/communities	Allocation of environmental flows also a medium to long-term priority investment that can build on the strong base created by the short-term interventions.
Habitat restoration	Need to ensure existing Federal/State/Territory Government river and catchment-based restoration programs are also taking on board native fish restoration objectives and priorities. Short-term need to invest in re-snagging of high priority reaches to support recovery of native fish populations, including threatened species.	Habitat restoration is a medium and long-term priority investment that can build on the strong base created by the short-term interventions.
Development of system of aquatic reserve	Short-term goal of understanding the role of the current 'reserves' in the Basin, and designing a way forward in terms of achieving an aquatic reserve system that is comprehensive, adequate and representative. Where indicated, short-term action to establish new 'reserves' may be warranted in an effort to secure threatened species or communities.	Medium and longer term investments to see the aquatic reserve system put in place and offering: - havens/refugia for threatened species/communities; and - sources of fish stock for recolonising restored habitat areas
Carp management	In the short-term, primary carp management goals will be met through implementation of the National Carp Management Strategy and the above interventions.	Medium to longer term the development of 'daughterless carp' may assist to build on the results of the short-term interventions.
Management of	In the short-term, primary	Depending on impact of the above

other alien fish species	management goals will be met through the above interventions and their impacts on other alien species.	interventions, some targeted actions may be needed
Knowledge generation, communication, monitoring and evaluation	Knowledge gaps remain a constraint in guiding management action. Investment to fill these gaps is needed. Communication must form a key part of implementation, especially as so much will rely on local and catchment-based actions. Current systems for monitoring the status of fish populations and species are far from adequate to allow for evaluation. Development of 'demonstration sites/reaches' considered an immediate priority.	As for short-term.

6. Communicating conclusions and gaining community support for the actions taken

The Panel had little time to consider the question of how to communicate its conclusions to a wider audience. However it recognised that the effort to see native fish restored is one that will require considerable support and involvement from the community and private landholders.

Apart from providing this Report to the Commission and Ministerial Council for their consideration, the Panel also believes that it is vital that it be drawn to the attention of the Community Advisory Committee for their appropriate action.

Apart from the observations offered below, the Panel notes a need for a communications strategy to be developed and implemented. The development of such a strategy requires expertise in the fields of education, communication and community empowerment. This will ensure that the appropriate target groups are considered, and that delivery mechanisms used to convey key messages and information to these same groups are carefully formulated and effective.

Recognising that a number of the strategic interventions considered in this Report form part of broader river and aquatic ecosystem restoration efforts, the Panel believes it is important for all the relevant expert and advisory bodies operating under the umbrella of the Murray-Darling Agreement to receive and be asked to offer feedback and reaction to its contents. The Strategic Interventions Plan, as presented in section 5, draws attention to the need for these existing and related efforts to be better coordinated so they can deliver outcomes that can benefit native fish and help to reduce the impacts of alien fish, notably carp. It is important that this process of 'internal' consultation with these other advisory bodies be given a short timeframe in order that evolving and emerging programs of work are not done in isolation from the issues of native fish restoration and alien fish management.

The Expert Panel contends that native fish have enormous potential to be promoted as icons of the river restoration efforts within the Basin. Species such as Murray cod are icons of the rivers, are highly charismatic and could be used to draw community attention to the condition of the waterways and the plight of native fish. In the same way, carp have already gained considerable bad press and this needs to be built on to mobilise greater effort and resources to address this serious and immediate problem. Giving the program of actions proposed in the Strategic Interventions Plan, a banner like "Operation Fish Recovery" may also attract community and media attention.

Any communication effort will need to manage community expectations. For example, there is a danger that the public will see 'daughterless carp' technology as the sole solution to the native fish problem and question other investments. The 'daughterless carp' technology, if pursued, needs to be promoted as only one potential part of the answer to the problem. The communication strategy needs to stress an integrated approach to demystify issues and terms like cold water pollution, re-snagging and environmental flows. It also needs to provide clear messages about the implications of choosing the 'no intervention' options.

It is acknowledged that much has been done and is currently underway to help restore native fish populations. There are some 'good news' stories that should be used to highlight what local people and private landholders can do to make a difference. The careful use and placement of such good news stories, or case studies, in the media will help to build community support for this program.

Fishing is a very strong part of the Australian culture and the communication strategy developed to support this program needs to be pitched to appeal to that part of the psyche. Involvement of recognised advocates of sustainable fishing (for example, Rex Hunt) will give the program credibility, similar to the Coastcare and Landcare initiatives. Influential representative bodies are also needed as advocates and supporters. Among these are the bodies representing recreational and commercial fishing interests as well as Landcare Australia Limited, Greening Australia, World Wide Fund for Nature, the Australian Conservation Foundation and even the tourism sector.

Finally, the Expert Panel believes that the restoration of native fish in the Murray-Darling Basin will be greatly advanced through the immediate development of a network of 'demonstration sites or reaches' as proposed in the Native Fish Strategy. Such demonstration sites would provide the ideal way to showcase the improvements to river health, and native fish populations that can result from careful and strategic use of the appropriate interventions.

7. Knowledge needed to progressively fine tune the conceptual models

In the introduction to this Report, it was noted that the deliberations of the Expert Panel should be considered as 'best guess' based on the combined expertise of the Panel members and the current state of knowledge with respect to fish biology, ecosystem functioning, riverine ecology and restoration science.

The Expert Panel calls upon the Commission and Governments of the Murray-Darling Basin to note that there remain major gaps in our knowledge with respect to many aspects of fish management and these made developing the conceptual models and Strategic Interventions Plan very challenging.

The Panel took the opportunity to note areas of high priority requiring attention. These are given below. This list is not the product of a systematic and comprehensive review of research needs, and should not be seen as more than a collection of ideas and issues that came to the surface during the deliberations of the Panel.

Some priority knowledge gaps

- Life histories of species, and understanding their ecologies better. This is vital if future manipulations (environmental flow allocations, habitat restoration etc) are to be done with greater confidence.

- Recovery processes and predictive capacity. How will reaches, valleys, catchments respond when impacts such as cold-water pollution, sediment loads, carp numbers etc are reduced or abated?

- The relationships between flow regimes and native fish breeding success, recruitment etc.

- The interaction between native and alien fish species so that management actions can be appropriately tailored.

- The native and alien fish carrying capacities of different aquatic ecosystems.

- Habitat mapping for native fish species to better appreciate how to restore habitat most effectively.

- Methodology for building a comprehensive, adequate and representative system of aquatic 'reserves'.

- The broader impacts of fish barriers and fishways. How have barriers and fishways altered the ecology of rivers for other biota?

- Gaining baseline data on native fish population status. In other words, ensuring we have robust science and data to demonstrate success or failure of management actions.

A need for monitoring and review

The Expert Panel also noted that there is a need to improve the arrangements for ongoing review of performance in the area of fish management. For example, better data is needed at a Basin-wide scale on species' status, distribution, population size, habitat use and threat responses. Conceptual modelling exercises, such as this one, can then be based on far more robust data than was possible in this case. Such baseline data can also provide the benchmark against which management actions can be evaluated, and serve to identify those threatening processes that are not being adequately addressed. The development of a system of indicators for resource condition and implementation

should be a priority as the level of investment in restoring native fish in the Basin gains additional resources.