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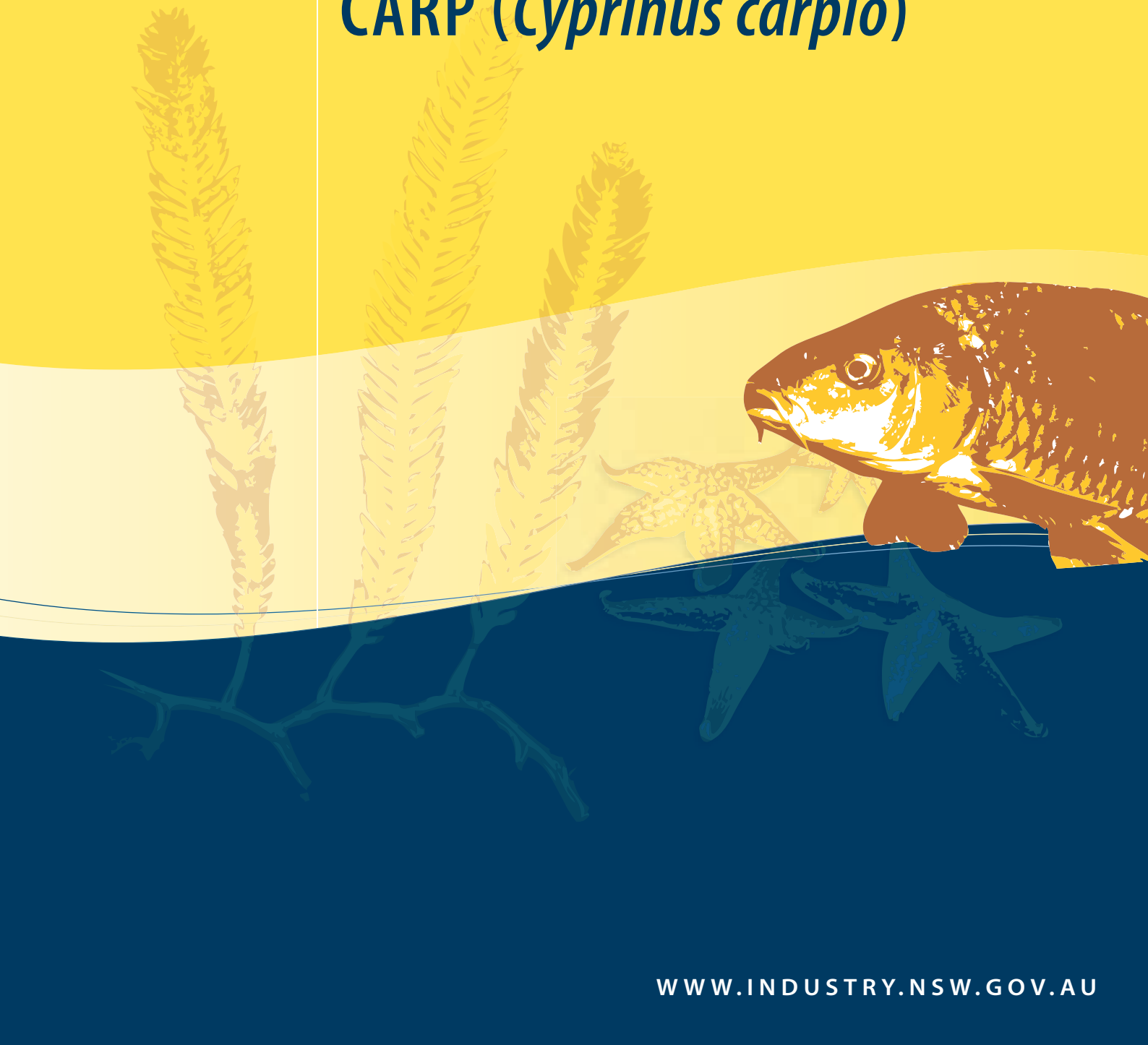
NSW CONTROL PLAN for the NOXIOUS FISH CARP (*Cyprinus carpio*)



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NSW Control Plan for the noxious fish carp
Cyprinus carpio

Carp image by Pat Tully.

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NSW CONTROL PLAN FOR THE

NOXIOUS FISH CARP *Cyprinus carpio*

NOVEMBER 2010

NSW GOVERNMENT | Industry & Investment

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SUMMARY

Carp are an introduced freshwater pest fish now widespread throughout most of NSW, particularly in the Murray-Darling Basin and the river systems of the Mid NSW Coast and Tablelands. In many areas they dominate the fish biomass at the expense of native species. Their range is expanding to include an increasing number of coastal catchments, particularly on the NSW North Coast.

The reported impacts of carp include increased turbidity, algal blooms, riverbank damage and destruction of aquatic vegetation. Although domesticated koi carp are a popular ornamental fish in NSW (they are prohibited in all other states except Western Australia), wild carp are generally unpopular and have been the focus of considerable control efforts – by both governments and communities – for many decades.

Traditional methods of controlling carp have involved mainly physical removal, for example through netting or angling. However, these generally have little long-term impact on the carp population, as carp are prolific breeders with strong migratory behaviour and can quickly repopulate areas where their numbers have been depleted. Consequently, research and management are increasingly focusing on 'smarter' ways of controlling carp, for example by exploiting unique aspects of their behaviour or targeting areas where they aggregate to breed. Some novel genetic and biological control methods are also being investigated, but they offer little hope in the short to medium term.

Given the scale of the carp problem in NSW, it is important to have a coordinated and targeted approach in order to maximise the environmental and community benefits that can be achieved from the limited resources available. This Control Plan aims to provide a framework for carp management in NSW by outlining what is already being done, what is feasible, and what additional actions might be most valuable.

Following a Background Section (1) and an outline of the goals and scope of the Control Plan (2), Sections 3 to 7 deal with actions under the following five areas:

- coordination
- vector management
- control and impact reduction
- education and community involvement
- research, surveys and monitoring.

At the end of Sections 3 to 7 a list of 'Goals' for future action can be found. These goals will require resources to be identified and may be addressed by Industry & Investment NSW (I&I NSW), other government agencies, Catchment Management Authorities, councils, community groups and/or other local or regional organisations as resources allow.

SECTION 1: BACKGROUND

The common carp *Cyprinus carpio* is the largest member of the family Cyprinidae present in Australia. The Cyprinidae are one of the most species-rich families of freshwater bony fishes in the world, comprising around 20 000 described species, none of which is native to Australia.

Other cyprinids that have established feral populations in Australia include the goldfish *Carassius auratus*, crucian carp *Carassius carassius* – which were confirmed in the Campaspe River in Victoria in 2006 (Raadik 2007), tench *Tinca tinca*, roach *Rutilus rutilus* and white cloud mountain minnow *Tanichthys albonubes*.

1.1 DESCRIPTION

Common carp are similar in appearance to goldfish and crucian carp, but are distinguished by the presence of two pairs of barbels (whiskers) at each corner of their mouth. They have thick lips, a forked tail and a single dorsal (top) fin with a strongly serrated first spine. Carp have an elongated body and may reach up to 120 cm in length and 60 kg in weight (Brumley 1996). However, wild carp in NSW are usually smaller, most commonly ranging from 50 g to 5 kg in weight and up to about 85 cm in length (Koehn *et al.* 2000).

The common carp *Cyprinus carpio* Photo: Gunther Schmida

Carp colouring is variable. In the wild, most carp are bronze or olive-gold on their backs (dorsally), with light bronze or olive-gold graduating to pale yellow or white on either side and on their bellies (ventrally) (Koehn *et al.* 2000). Koi (or Japanese) carp are domesticated ornamental varieties of common carp and show a much broader range of colours and colour patterns, with various combinations of white, black, red, yellow, blue and orange markings. Scale variations, including large shiny scales either scattered or in a line along the flanks ('mirror carp') or an absence of scales ('leather carp') are also common in ornamental and wild fish.

Koi carp *Cyprinus carpio* Photo: Gunther Schmida

Genetically, carp show a great deal of regional variation across their geographic range, and they can be divided into two different subspecies (Haynes 2008), as well as the innumerable strains developed as a result of selective breeding for aquaculture and ornamental purposes. Regardless of their colouring, scale type, body shape or common names (e.g. European, koi, common, mirror or leather carp), all strains belong to the same species, *Cyprinus carpio*.

1.2 DISTRIBUTION

Worldwide distribution

Carp are native to Asia and Eastern Europe, with a natural distribution extending from Japan in the east to the River Danube (which flows through Europe into the Black Sea) in the west (Balon 1995). However, carp have long been used and domesticated by humans for food and ornamental purposes, and these activities have introduced carp into many new waterways throughout Europe, Asia, Africa, the Americas, Oceania, Australia and New Zealand (Koehn 2004). As a result, carp are now one of the world's most broadly distributed freshwater fish species.

In Europe and Asia, both wild-caught and cultivated carp are an important food source for human consumption. In China and Japan, carp have been domesticated for centuries for display because of their colour, beauty and longevity (Koehn *et al.* 2000). This genetic strain, known as koi carp, is a popular fish in backyard ponds.

Introduction to NSW

Carp – along with other species such as goldfish, tench and roach – were first introduced into Australia to establish food and sport fisheries (Brumley 1991). However, the exact history of where and when carp were introduced is not clear, with the timing of introductions and the origin of fish often going unrecorded.

The earliest known introductions of carp into NSW waterways occurred around Sydney in 1865. In the early 1900s, carp fingerlings of unknown origin were used to establish several wild populations in the Sydney area, including in Prospect Reservoir (where they still persist); these are referred to in the scientific literature as the 'Prospect' strain.

In the Murray-Darling Basin there is some dispute as to the timing of the first introductions, but carp have been established since at least the 1920s, with early records describing low numbers being caught in both NSW and Victoria (Clements 1988). Early records of translocation from Sydney (Rolls 1969), together with recent genetic evidence (Haynes 2008) suggest that these early populations were derived at least in part from Prospect carp. Another distinctive orange-coloured strain of carp, the 'Yanco' strain, became established in the Murrumbidgee Irrigation Area sometime between 1910 and 1950 (Shearer & Mulley 1978, Haynes 2008).

Until the 1960s, carp were, although widespread in the Basin, still relatively uncommon, except in some irrigation canals and other slow-moving waters (Weatherly & Lake 1967). However, during the 1970s carp underwent a rapid population expansion, colonising many new areas and greatly increasing in abundance. This has been attributed to a combination of the release of a new strain (known as the 'Boolarra' strain after the fish farm in Victoria that bred and distributed them), together with widespread flooding in 1974 and 1975, which provided access to many previously isolated areas of habitat (Shearer & Mulley 1978, Koehn *et al.* 2000). Haynes (2008) also identified another distinct ('Burrinjuck') strain of carp in Wyangala Dam in the Lachlan River and Burrinjuck Dam in the Murrumbidgee River; the dissimilarity of this strain to populations in adjacent rivers suggested human introduction from another source. Data on commercial harvests of carp indicate that carp numbers in the Murray-Darling Basin peaked in 1977–78 and subsequently declined and stabilised.

In coastal NSW, carp from Prospect Reservoir were distributed around the Sydney Basin in the early 1900s (Clements 1988), becoming established in areas such as the Hawkesbury-Nepean and Parramatta rivers. Introduction to the Hunter catchment north of Sydney occurred much later, probably sometime between 1980 and 1985 (Battaglene 1985). The introduction of carp to coastal waterways has continued unabated, with populations (mainly of koi) being recorded in an increasing number of rivers on the NSW North Coast in recent years (page 6). Koi is also now the dominant strain in the Parramatta River. This suggests that deliberate introduction and/or accidental release or escape of ornamental fish from backyard ponds are major vectors for the ongoing spread of carp.

Research into carp population genetics by Haynes *et al.* (2010) in three coastal drainages in NSW (Hunter River, Hawkesbury/Nepean rivers and Sydney Basin) has found koi carp to be the dominant strain in the Sydney Basin, with all fish caught in this catchment showing some koi ancestry. The Hunter and Hawkesbury/Neapean rivers were found to have a common origin based on the original Prospect strain, but with some signs of interbreeding with koi.

Current distribution

Carp are widespread in many parts of Australia, including NSW (Figure 1), Victoria, the Australian Capital Territory, South Australia and in more restricted areas of Tasmania (see Case Study 4), south-west Western Australia and Queensland.

Carp are thought to be present throughout the Murray-Darling Basin, except where limited by unsuitable habitat (e.g. high altitude areas), natural barriers (e.g. waterfalls) or artificial barriers (e.g. large dams in catchment headwaters). Areas of the Basin currently believed to be carp-free (Graham *et al.* 2005) include:

- **New England area**: upper MacIntyre and Severn rivers, Gwydir River upstream of Copeton Dam, MacDonald River above Woolbrook, and upper reaches of the Namoi River
- **Central Tablelands**: Cudgegong River upstream of Windamere Dam near Rylstone, Winburndale Rivulet and Reservoir on the upper Macquarie River, Fish River above and including Lake Oberon, and part of the upper Lachlan catchment
- **Southern Tablelands**: upper Queanbeyan River (including Googong Reservoir), Swampy Plain River above Khancoban, and storage lakes and headwaters of other rivers in the higher altitudes of the Snowy Mountains.

Despite some evidence that their numbers have fallen in the Murray-Darling Basin (perhaps partly in response to drought), carp still make up a substantial proportion of the fish biomass, including about 87% in the Murrumbidgee catchment and about 49% in the lower Murray-Darling catchment (Gilligan 2005a,b). In some areas they have been recorded at densities of more than 11 000 fish per hectare (Reid *et al*. 1997).

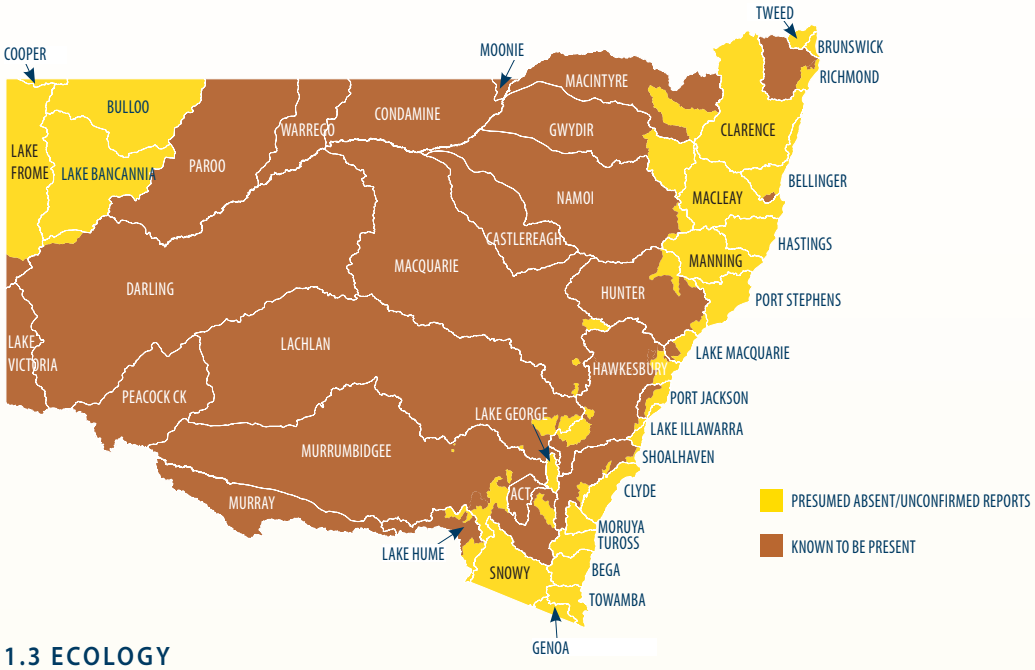
Carp are also widespread in many coastal catchments, particularly in the central section of NSW from the Hunter in the north to the Shoalhaven (including the Southern Highlands and Tablelands) in the south. Populations of carp – many of them koi – are also being reported in increasing numbers from the North Coast of NSW, including in some areas reported by Graham *et al.* (2005) as carp-free; these areas are asterisked in the list below. As of mid-2010, North Coast catchments known or believed to contain carp (noting that some reports are anecdotal and unconfirmed by scientific sampling) include:

- **Tweed**: Oxley River near Eungella*
- **Richmond**: Iron Pot Creek (west of Kyogle in the upper catchment); Horseshoe Lagoon near Casino; Richmond River downstream from Tatham (including tributaries such as Pelican Creek and Bungawalbin Creek) as far as Broadwater; Emigrant Creek near Ballina (markedly increased reports since the 2008 floods)
- **Clarence**: Clarence River near Harwood*
- **Bellinger**: Bellinger River; Warrell Creek (a tributary of the Nambucca River)
- **Macleay**: from Kempsey upriver to Georges Junction near the Wild Rivers National Park (reported as unconfirmed by Graham *et al.* 2005)
- **Hastings**: Hastings River at Beechwood; Cowarra Dam near Wauchope*; Wrights and Mimosa Park Creeks in Port Macquarie
- **Manning**: Manning River*

- **Port Stephens – Great Lakes**: Wallamba River (dams on upper river, dams near Darawank, Tallwoods Village sub-catchment, creek at Pipers Bay south of Forster); Karuah River near Booral
- **Central Coast**: Wyong River near Wyong.

On the South Coast, carp have been reported only from Long Swamp near Bermagui and the Towamba River near Towamba (west of Eden) (Graham *et al.* 2005).

Figure 1. Distribution of carp in NSW by catchment (catchment boundaries indicated by white lines)



1.3 ECOLOGY

Carp are ecological generalists. They tolerate poor water quality, including low oxygen levels, high turbidity, moderate salinities and high levels of toxicants (Koehn 2004). They prefer warm, slow-flowing rivers and still waters (such as lakes and billabongs), particularly at lower altitudes, but can also be found in some cooler, higher-altitude areas such as around Cooma. Their broad environmental tolerances have allowed them to invade from relatively pristine waterways through to highly degraded ones.

Carp are bottom feeders, sucking up sediments with their mouths and expelling indigestible material through the gills.

Under suitable conditions, carp are highly prolific. They mature early (as early as 1 year for males and 2 years for females), and females produce large numbers of sticky eggs (around 80 000 for fish of 1.25 kg, and up to 1.5 million for fish of 6 kg; Hume 1983 *et al.*). Carp migrate to and from breeding grounds during the breeding season, sometimes travelling hundreds of kilometres (Balon 1995, Stuart & Jones 2006). Egg and larval mortality is extremely high, with the number of eggs surviving to the adult population dependent on environmental conditions and available resources. Flood conditions appear to be especially favourable for carp breeding, providing abundant food for both adults and juveniles.

1.4 IMPACTS

Carp are viewed as undesirable ecological pests in Australia and many other countries where they have been introduced (Lamarra 1975, Cooper 1987, Koehn *et al*. 2000), with reports of detrimental impacts on vegetation, native fish and water quality. Although they are an important food source in Asia and Europe, in Australia they are generally considered too bony, with unpalatable ('muddy') flesh.

The bottom-feeding behaviour of carp has led to them being widely blamed for environmental problems such as increased turbidity, algal blooms, damage to riverbanks and loss of aquatic vegetation. Carp are also thought to be indirectly responsible for declines in native fish populations. However, the effects of carp are difficult to separate from other factors such as river regulation and land clearing. Agricultural runoff, uncontrolled stock grazing, salinity, drought, thermal pollution, heavy rain periods and water regulation were all implicated in the decline of native fish species well before the explosion of carp numbers in the 1970s. Gilligan *et al*. (2010) reported a weak relationship between carp biomass and poor ecosystem health in the lower Lachlan catchment. This research found no significant relationships between carp density and turbidity, nutrient concentrations within the water column, stream bank erosion, macrophyte cover, macro-invertebrate diversity, native fish diversity or total native fish biomass.

Previous studies on carp impacts have been primarily undertaken in closed lentic ecosystems. Gilligan *et al*. (2010) suggests that carp impacts in river ecosystems may not be as extreme as those in lentic ecosystems. Alternatively, aquatic ecosystems may shift to an alternative stable ecological state some time after carp establishment, where the relationships with aquatic habitat variables are harder to define. If this is the case, the true impacts of carp on the environment may only be discernible when extensive data-sets are available for aquatic ecosystem condition prior to the establishment of carp populations. These datasets generally do not exist in Australia. However, it is possible that factors other than carp or a combination of factors could be responsible for the observed degradation in river ecosystems. Scientific work to better understand wild carp populations and quantify their impacts is continuing.

1.5 VECTORS

A 'vector' is an activity or process that facilitates the spread of a pest such as carp.

Following the first releases of carp into NSW river systems, carp have spread extensively, largely by natural dispersal (migration along watercourses) helped by floods that carry the carp into areas normally isolated from the main river system, such as billabongs. Other natural vectors, such as transportation of the sticky eggs on the feet of waterfowl, may also have contributed to their wide dispersal.

Human-mediated dispersal has also played a significant (and ongoing) role in the spread of carp, especially into new catchments. Carp may be spread through deliberate (illegal) introduction in an attempt to establish new recreational fisheries, illegal use as live bait, or the accidental or deliberate release of ornamental koi. The significance of these human-mediated vectors is shown by the existence of carp populations in many large impoundments (which are too large to be drowned out in floods) and the discovery of koi in an increasing number of coastal waterways.

Management of these vectors to prevent further spread of carp is discussed in Section 4.

1.6 LEGAL STATUS

In NSW carp are listed as a Class 3 Noxious Fish under the *Fisheries Management Act* 1994. This permits their sale and possession. This listing recognises the fact that wild carp are a commercial fisheries species and koi carp are a popular ornamental fish in NSW, but it aims, through education and awareness-raising, to discourage further spread of carp. It is not illegal for recreational fishers to immediately return carp to the water where they are captured; however, I&I NSW strongly encourages fishers to retain and utilise them.

1.7 BRIEF HISTORY OF CARP MANAGEMENT

Carp have been recognised as a significant problem, particularly in the Murray-Darling Basin, for several decades, and various initiatives have been undertaken to address the problem. Some of these are briefly outlined below.

In 1999 the NSW Government launched a $1 million Carp Assessment and Reduction Program (CARP). This program was established to manage the impact of carp on the state's inland waterways in the lead-up to the release of the federally funded National Management Strategy for Carp Control (see below) in 2000. NSW funding was principally directed toward research on carp impacts and control methods, including commercial harvesting techniques; the development of a viable commercial fishery and associated industries based on carp and carp products; and community education and the promotion of recreational carp fishing opportunities.

In 1999 the Carp Control Coordinating Group (CCCG) was established by the former Murray-Darling Basin Commission following an agreement between several state, territory and federal government bodies. In 2000 the CCCG released the **National Management Strategy for Carp Control 2000–2005**, supported by a strategic research plan – **Future Directions for Research into Carp** – and a document called **Ranking Areas for Action: A Guide for Carp Management Groups**.

The former Murray-Darling Basin Commission also developed the **Native Fish Strategy for the Murray-Darling Basin 2003–2013 (Native Fish Strategy)**, with the goal of rehabilitating native fish communities in the Basin back to 60% of their estimated pre-European settlement levels after 50 years of implementation. One of the Native Fish Strategy's 13 objectives relates to alien fish.

The Murray-Darling Basin Authority (formerly Commission) has been instrumental in encouraging progress in carp research and control initiatives through the CCCG and Native Fish Strategy and through funding of the Invasive Animals Cooperative Research Centre (Invasive Animals CRC). The Murray-Darling Basin Authority (the Authority) and the Invasive Animals CRC continue to support a number of important projects, including research into carp population dynamics and migrations, identification of reproduction hotspots, carp attractants, development of carp separation cages, and biological controls. The Authority is also currently developing a **Basin Alien Fish Plan**.

Koi carp are just one of a large number of ornamental fish species kept and traded in NSW. To address the significant aquatic biosecurity (pest and disease) risks associated with the escape of ornamental fish nationally, **A Strategic Approach to the Management of Ornamental Fish in Australia** was developed and approved by the Natural Resource Management Ministerial Council in 2006. This strategy provides for new arrangements for regulation of the ornamental fish industry, including the development of a national noxious fish list, which is being progressively implemented in NSW from 2010.

This Control Plan also complements other existing strategies such as the **Australian Pest Animal Strategy**, the **NSW Invasive Species Plan 2008–2015** and the **2007 NSW Department of Primary Industries Biosecurity Strategy**.

SECTION 2: ABOUT THIS PLAN

2.1 RISK ASSESSMENT

There are many constraints to the effective management of carp in NSW, including the very large geographic area affected, the lack of effective control or eradication options, the limited resources available to deal with this pest, and limited scientific information on the impacts of carp or the effectiveness of control measures. These constraints make it vital to have a risk-based approach, based on the best available information, to ensure that limited resources are used to maximum effect.

A preliminary risk assessment has been developed (see Appendix) to identify the main vectors that risk spreading carp into new areas, the costs and effectiveness of available control measures and the shortcomings in current knowledge to identify priority areas for action under this Control Plan (see Sections 3 to 7).

Because this Control Plan is intended to be adaptive, new information will be incorporated into the risk assessment as it becomes available, and the results will be used to refine the management response as necessary.

2.2 OBJECTIVES

This Control Plan aims to provide a framework for the management of carp in NSW that can be used by local communities, councils, environmental organisations, government agencies and funding bodies. The overall objectives are to:

- minimise the further spread of carp across NSW and maintain existing 'carp-free' catchments
- ensure that resources for carp-control are used in the most effective and cost-efficient way, by using best available methods and targeting priority areas such as reproduction 'hotspots' and environmentally significant sites
- increase community understanding of the impacts of carp and the community's role in management strategies
- encourage further scientific investigation of the biology, population dynamics and environmental impacts of carp in NSW waters
- encourage the development of more effective and efficient control techniques
- encourage an integrated approach to river rehabilitation that includes actions to improve fish habitats and support native fish populations, in addition to carp-control techniques.

2.3 SCOPE

This Control Plan summarises the actions taken to date to manage carp in NSW and sets out key goals for future work. These are divided into the following areas:

- coordination
- vector management
- control and impact reduction
- community involvement and education
- research, survey and monitoring.

SECTION 3: COORDINATION

3.1 IMPORTANCE OF COORDINATION

As discussed in Section 1.7 (Brief history of carp management), many different organisations are involved in carp management, education and research, particularly in the Murray-Darling Basin, which crosses several state borders. These include federal, state and regional bodies such as the Murray-Darling Basin Authority (the Authority), I&I NSW, Victorian Department of Primary Industries, South Australian Research and Development Institute (SARDI), and the various Catchment Management Authorities (CMAs) and city and shire councils.

The involvement of so many organisations has led to some exciting collaborative projects, particularly under the Invasive Animals CRC which is funding a range of carp research and control projects. However, inter-agency and inter-jurisdictional coordination is vital to avoid overlap, inconsistency or provision of conflicting advice.

3.2 EXISTING COORDINATION ARRANGEMENTS

A range of coordinating arrangements is already in place. For example, the Authority has several panels and working groups, including a Native Fish Strategy Advisory Panel and Basin Alien Fish Plan Task Force. Although the Carp Control Coordinating Group is no longer functional, there are still mechanisms for coordination of carp management, for example through Ministerial Councils and Standing Committees.

3.3 WHAT I&I NSW IS CURRENTLY DOING

I&I NSW currently:

- is represented on relevant Murray-Darling Basin committees, including the Native Fish Strategy Advisory Panel and Basin Alien Fish Plan Task Force
- maintains research partnerships with other agencies through involvement in collaborative projects funded by the Invasive Animals CRC (see Section 5 – Control and Impact Reduction – and Section 7 – Research and Monitoring)
- is contributing to the development of other strategies and documents relevant to carp management in NSW (e.g. Basin Alien Fish Plan, educational materials).

3.4 PRIORITIES FOR FUTURE COORDINATION

Ongoing coordination of carp management and research activities, and communication among all stakeholders, are important ongoing priorities.

GOAL: Coordination and communication

3A Continue to develop and strengthen relationships with national, state and local stakeholder groups in regards to carp management.

SECTION 4: VECTOR MANAGEMENT

4.1 IMPORTANCE OF VECTOR MANAGEMENT

Although carp are widespread in most of NSW, there are still some areas believed to be free of this pest (see 'Current distribution' in Section 1.2). Given the difficulty (or impossibility) of eradicating carp once they are established, it is of paramount importance to prevent their spread into new areas.

4.2 EXISTING VECTOR MANAGEMENT METHODS

Table 1 lists some of the known or potential vectors for the spread of carp (discussed briefly in Section 1.5) and the methods available to manage them.

Table 1. Carp vectors, significance and management options

VECTOR	SIGNIFICANCE	MANAGEMENT OPTIONS
Natural flood and high water and the delivery of environmental flows	Apparently a major factor in spread of carp in 1970s. May allow carp to spread into areas normally isolated from the main watercourse. Provides important habitat for breeding.	Few methods available (difficult to manage). Encourage the use of carp information (distribution and abundance) during the development and delivery of environmental contingency allowances and water sharing plans. Note: Sampling of larval fishes dispersing during floods has been used to locate the point sources of carp reproduction in inland rivers, i.e. breeding hotspots.
Natural migration (including through fishways)	Important for breeding, as carp migrate to reach suitable breeding grounds. In some areas, installation of new fishways could allow access to areas from which carp are currently excluded.	Avoid installing fishways on barriers to carp migration, or fit carp separation devices (e.g. Williams cages) designed to capture carp and automatically release native fish. Carp-exclusion devices (fish screens) on wetland inlets.

VECTOR	SIGNIFICANCE	MANAGEMENT OPTIONS
Escape or release of ornamental koi	Key source of new populations in previously carp-free areas.	Education. Enforcement of existing legislation.
Deliberate introductions to establish recreational fisheries	Source of new populations in previously carp-free areas.	Education. Enforcement of existing legislation.
Illegal use as live bait	Possible source of new populations in previously carp-free areas.	Education. Enforcement of existing legislation.
Stocking or translocation of contaminated batches of native fish	Possible source of new populations in previously carp-free areas.	Implementation of Hatchery Quality Assurance Program for hatcheries producing fingerlings for stocking, to reduce the risk of unwanted species or diseases being released. Stocking permits.
Accidental translocation via gear and boats	Possible source of new populations in previously carp-free areas.	Education.
Accidental translocation of eggs by waterbirds	Possible source of new populations in previously carp-free areas.	No management options available.

Natural flood distribution and the delivery of environmental flows

Natural flooding events are important for the entire river ecosystem. Large floods reconnect previously isolated aquatic habitats such as wetlands and billabongs with the main river channel. They replenish the river system with organic materials and hence improve the river's productivity. Higher flows allow for the movement of aquatic organisms from drought refuges (such as deep river pools) to inundated habitats.

As well as providing rejuvenated habitat for native fish, flooding greatly benefits carp populations because of the increase in inundated vegetated habitat crucial for spawning. The large flooding events of the mid-1970s aided a massive carp dispersal to many reaches of the Murray-Darling Basin, with further floods in 1993 helping to extend their range even further.

There are very few options available to manage floods or to limit the boost to carp populations that flooding provides. Further river regulation to limit flooding is not desirable, because flood events also provide so many ecological benefits to native fish populations. No interruption to natural flooding cycles (e.g. to prevent carp from entering new areas) should be considered unless the benefits can be shown to far outweigh any potential loss to native fish recruitment success. In any case, such activities are carefully regulated and there are a range of offences under the *Fisheries Management Act* 1994 and the *Water Management Act* 2000 for dredging and reclamation, obstructing fish passage or modifying instream structures without a permit, or constructing or using water supply, drainage or flood works without appropriate approval.

The delivery of environmental flows can simulate natural flooding events in some cases. Information on distribution and abundance of carp should be carefully considered during the development and delivery of environmental contingency allowances and water sharing plans to minimise the benefits to carp populations of environmental flows.

Natural migration of carp (including through fishways)

Carp exhibit strong migratory behaviour. Natural migration (aided by floods) has allowed carp to colonise virtually the entire Murray-Darling Basin.

Regulatory structures such as dams and weirs, of which there are over 2000 in inland NSW, impede fish migration. A current initiative focusing on fishway construction aims to allow native species unobstructed access to spawning grounds and preferred habitat. Around 32 of the major weirs or water diversions across NSW are already fitted with carefully designed fishways.

However, fishways also allow the passage of alien or pest species such as carp. In fact, because of their highly migratory behaviour, carp often dominate the biomass using fishways (Stuart *et al*. 2006). To mitigate this, specialised carp separation devices have been developed and installed on some fishways (see 'Fishway carp separation devices' in Section 5.2 for more details).

If a fishway is proposed for a barrier above which carp are currently absent, the potential for the fishway to allow carp access to new areas upstream needs to be considered as part of the environmental impact assessment.

Escape or release of ornamental koi

Koi carp, along with goldfish (*Carassius auratus*), are popular ornamental fish for backyard ponds. However, they are also potential sources of new carp populations, particularly in many coastal waterways. Some of these populations may be derived from fish that have escaped from backyard ponds during heavy rainfall or floods. However, others occur at isolated sites and are clearly the result of deliberate dumping, perhaps in the belief that it is a more humane option for unwanted pets than euthanasia.

In the wild, koi populations may revert to the common colouring through interbreeding with other strains or selective predation of brighter, more ornamental individuals over several generations.

It is important that koi are kept in secure ponds to prevent escape into the wild.
Photo: Melissa Walker I&I NSW

The release of domestic koi carp and goldfish has the potential to introduce new diseases and pathogens into the wild, some of which may be damaging to native fish populations. There is also the potential for interbreeding between the two species: hybrids of varying ancestry have been found in the wild, and Haynes (2008) found that 5.3% of the genetic diversity of carp in the Murray-Darling Basin is derived from goldfish. This interbreeding could further contribute to the invasiveness or adaptiveness of carp, for example by introducing genetic components that make them more resistant to disease, and it could reduce the effectiveness of emerging species-specific biological controls such as daughterless gene technology or introduced diseases (see 'Daughterless carp' and 'Koi herpesvirus' in Section 5.2).

Although the Class 3 Noxious Fish listing for carp permits sale and possession in NSW, existing management arrangements focus on education programs to reduce the risk of further spread of the species.

I&I NSW has developed educational materials ('Don't dump that fish!' bookmark, brochure and poster) that highlight the illegality and environmental consequences of releasing aquarium or pond fish into the wild. These have been widely distributed to pet/aquarium shops, hobbyists and to the public at information days.

Deliberate introductions to establish recreational fisheries

Because of carp's fighting ability some anglers consider this species a worthwhile target. At some sites, such as large impoundments in the headwaters of some catchments, there are carp populations that could not have become established by natural dispersal and show no genetic links to ornamental strains, or even to populations in adjacent waterways. This has led both anglers and scientists to suspect that carp have been deliberately transferred to establish new recreational fishing opportunities (Koehn *et al.* 2000, Haynes 2008).

Under the NSW *Fisheries Management Act* 1994 it is illegal to introduce any live fish into any public NSW waterway without a permit (with the exception of immediate re-release of fish at the site where they were captured). Public advice on this issue is regularly provided via fishing outlets, fishing clubs, I&I NSW Fisheries Officers, and Fishcare Volunteers trained and supported by I&I NSW.

Illegal use as live bait

The discovery of established carp populations in isolated locations may also be attributable to the use of small carp as live bait. Although this practice is now illegal in NSW and Victoria, small live carp have, in the past, been used as bait for catching larger species such as Murray cod (*Maccullochella peelii peelii*), throughout the Murray-Darling Basin (Koehn *et al.* 2000). The presence of carp in Leigh Creek Dam in the Lake Eyre Drainage Basin and the Onkaparinga River in South Australia has been attributed to either use of the species as live bait by anglers or to deliberate release (Brown 1996).

Stocking or translocation of contaminated batches of native fish

To enhance recreational fishing opportunities I&I NSW manages a number of native fish stocking programs across the state, primarily for Murray cod, golden perch and silver perch in the Murray-Darling Basin and Australian bass in coastal drainages. Permits are issued to both government agencies and stocking groups, with fingerlings sourced from either government or privately operated hatcheries. There is a risk that carp could contaminate batches of fingerlings, resulting in inadvertent release of the carp into previously carp-free areas.

It is thought that carp were first introduced into the ACT as a contaminant of releases of native fish. This may also have occurred elsewhere, which could explain why carp now occur in many large impoundments in NSW. To improve the quality of stocked fish I&I NSW has developed a Hatchery Quality Assurance Program, whereby all hatcheries wishing to produce fingerlings for stocking must be accredited to ensure they have appropriate quality control procedures to prevent unwanted species or diseases being accidentally released with the fingerlings.

A separate, but related issue is the rescue and translocation of native fish populations from drying water bodies during times of drought. These operations carry a risk of introducing carp to new areas if the rescued population contains carp and the destination is carp-free. As any introduction of fish to public waters requires a permit from I&I NSW, the majority of these operations will be covered by permits, which may impose measures to minimise the risk of carp transfer.

4.3 WHAT I&I NSW IS CURRENTLY DOING

I&I NSW currently:

- assesses new fishway proposals to ensure that the potential impacts of providing access of carp to new areas are properly considered and mitigated
- distributes pest fish educational materials to the aquarium industry and hobbyists
- informs the public that release or translocation of live fish without a permit and the use of live bait are illegal, and enforces this as part of compliance operations
- implements the Hatchery Quality Assurance Program and undertakes regular compliance checks of government and privately operated hatcheries to ensure standards are implemented
- implements permit conditions for fish stocking or rescue operations to minimise the risk of introducing carp (or other exotic fish species) to new areas.

4.4 PRIORITIES FOR FUTURE VECTOR MANAGEMENT IN NSW

Preventing further spread of carp into areas currently believed to be 'carp-free' is one of the highest priorities of this Control Plan. However, since most ongoing introductions are the result of actions by individuals (sometimes acting illegally), there is little direct action that can be taken to stop them. Instead, efforts to stop further spread will need to focus on education, awareness-raising and compliance to reduce undesirable behaviours. These efforts will be supported by ongoing research into carp migrations and impacts (Section 7).

GOALS: Vector management

4A Continue to develop advisory material specifically for the ornamental industry and hobbyists, with information on the impacts of dumping and advice on secure fish pond design to minimise escape. Continue to distribute the materials widely, especially within 'carp-free' areas.

4B Ensure information on carp distribution and abundance is used during the development and delivery of environmental contingency allowances and water sharing plans.

4C Ensure that where feasible, existing and future fishways incorporate carp separation cage technology.

SECTION 5: CONTROL AND IMPACT REDUCTION

5.1 IMPORTANCE OF CARP CONTROL

It is not feasible to attempt a comprehensive eradication program for carp in NSW. They are too widespread, well-established and abundant, and there is a lack of effective control techniques. Smith (2005) also noted that carp were resilient to control work in various locations, even where control efforts were repeated and extensive.

Nonetheless, localised efforts to reduce carp numbers, for example through fishing, are popular in many parts of NSW. There is some anecdotal evidence that they may help to keep carp numbers under control, especially when repeated over a period of time. However, there is currently limited scientific evidence to support the value of very localised, ad-hoc or one-off carp removal events. Because only a proportion of the carp population is removed with each attempt, and because carp generally have a very high population recovery rate, carp numbers can quickly return to their original levels. In addition there is always the potential, in interconnected waterways, for carp to move in from surrounding areas.

Often, the main argument for removing carp is to provide some respite to aquatic habitats and native species. When integrated with habitat rehabilitation efforts, a reduction in carp numbers can give native species the opportunity to become re-established. Efforts to control carp numbers and limit their spread could also prove important in the success of emerging control techniques (see Section 5.2). The size of the standing population of carp at the time when a new control technique is introduced is likely to affect the degree and rate of success of the technique.

Many projects are underway to improve the management of carp, for example by combining a range of techniques in the one location (integrated carp management) and by targeting high-priority areas such as carp breeding 'hotspots' (see Section 5.3).

5.2 EXISTING AND POTENTIAL CONTROL METHODS

Various methods for controlling carp numbers have been investigated in NSW and elsewhere. Primarily these have involved physical removal (e.g. netting, angling, trapping) or poisoning. All of these methods have advantages and disadvantages relating (for example) to their effectiveness, ease of use, size specificity (some remove only adult carp), impacts on non-target organisms, and cost (Table 2).

The high costs of eradication and control techniques must be taken into consideration when planning carp management programs. For example, Gilligan *et al*. 2010 estimates a cost of $1.15 million to eradicate carp from an area in the Bland Creek – Lake Cowal sub-catchment in the lower Lachlan catchment.

Several new technologies proposed as potential carp-control methods are currently under investigation. Although some show great promise, as yet the most ambitious ('daughterless carp' and koi herpesvirus) are still a long way from field trials, let alone implementation.

These existing and potential control methods and their feasibility and limitations on use are summarised in Table 2 and discussed in greater detail on the following pages.

Table 2. Carp-control or impact-reduction methods used, trialled or under investigation in Australia

EFFECTIVENESS (IMPACT ON CARP POPULATION)	SIZE SPECIFICITY	IMPACTS ON NON-TARGET ORGANISMS	COSTS/RESOURCES	FEASIBILITY/LIMITATIONS ON USE
COMMUNITY CARP FISHING COMPETITIONS / MUSTERS / FISH-OUTS (ANGLING)				
Potential to remove large numbers of carp from localised area. Currently little scientific evidence for long-term impact on carp population.	Size specific – generally targets larger fish, not juveniles.	Non-target species can be released, although not all survive.	Human resource intensive; however, events are often independently organised by community groups.	High interest from community groups in conducting these types of events. Increases community awareness. Ineffective in reducing population numbers or removing residual carp from waterways.
COMMERCIAL HARVESTING (HAULING / NETTING / TRAPPING)				
Potential to remove large quantities of carp quickly in specific locations. Probably little long-term effect on population.	Dependent on mesh size.	Some by-catch of non-target species.	Self-funding, but only if carp populations and market price allow for a viable, self-sustaining industry. Otherwise fee-for-service.	Requires consistent supply of large quantities for market to remain viable. Market returns justify effort only under specific conditions (high carp biomass, proximity to markets, minimal obstructions such as snags). Currently low viability because of low market price and high costs of fishing. Not viable for removal of residual carp populations in connected waterways. Judas carp technique (where males are radio-tagged and act as 'tracker' fish) may enhance effectiveness and efficiency of commercial harvest by targeting spawning or winter aggregations; this would require commitment to a long-term control program.

EFFECTIVENESS (IMPACT ON CARP POPULATION)	SIZE SPECIFICITY	IMPACTS ON NON-TARGET ORGANISMS	COSTS/RESOURCES	FEASIBILITY/LIMITATIONS ON USE
ROTENONE				
Potential to kill discrete populations of carp quickly.	Not size specific.	Broad-scale application kills virtually all non-target species as well as carp. Rotenone baits have been trialled but tended to be rejected by carp; the rotenone may also leach out and thus affect non-target species.	Human resource intensive (planning, application and removal/ disposal of large quantities of carp). Moderate costs.	Illegal to use except in accordance with Australian Pesticides and Veterinary Medicines Authority (APVMA) permit issued to I&I NSW. May be feasible to eradicate small, discrete populations under specific circumstances (e.g. new populations) where benefits clearly outweigh harm to native species. Not suitable for broad-scale use because of impacts on non-target organisms. Use of baits is not currently feasible without further improvement.
FISHWAY CARP SEPARATION CAGES				
Potential to remove large quantities of carp and, in some circumstances, eliminate carp from stretches upstream of cages. Effectiveness depends on how much of carp population is static vs. migrating. This is unknown for many sites.	Size specific – generally capture larger carp (>250 mm).	Minimal – designed to release native fish and vertebrates.	Installation cost ranges from $15,000 to $45,000 (or more) per fishway. Ongoing maintenance is human-resource intensive; requires regular checking and disposal of captured carp.	Highly feasible where suited to existing fishways, or where new fishways are being designed. Lack of carp-disposal options may limit feasibility at some sites. Fish composting technology may be an effective utilisation and disposal method (where feasible and based on resources available from local agencies/ groups).
CARP-EXCLUSION DEVICES (E.G. MESH SCREENS, 'FINGER TRAPS') FITTED TO WETLAND REGULATORS				
Can prevent access of mature carp to wetlands or other spawning grounds. Potential to substantially reduce carp populations if breeding hotspots are targeted.	Size specific – generally exclude only larger carp.	May affect native fish recruitment by also excluding native species from spawning grounds.	Relatively inexpensive. Requires supporting infrastructure and ongoing maintenance.	Already installed at many sites in the Murray-Darling Basin. For maximum effectiveness, requires ecological research to identify recruitment areas for carp and native species. 'Finger traps' may be more effective but are still at the prototype stage.

EFFECTIVENESS (IMPACT ON CARP POPULATION)	SIZE SPECIFICITY	IMPACTS ON NON-TARGET ORGANISMS	COSTS/RESOURCES	FEASIBILITY/LIMITATIONS ON USE
DAUGHTERLESS CARP TECHNOLOGY				
In theory could eventually provide total eradication, but effects would not be seen for several to many decades (at least). Effectiveness would depend on many factors, including heritability; fitness of 'daughterless' males; size of carp population at time of release; and number of modified fish released.	Not size specific.	None – species-specific technology.	Very expensive technology, still under development, total costs unknown.	Unclear. Still many technical hurdles to overcome before ready for laboratory or field trials. Would initially require stocking of large numbers of genetically modified fish. Would require integrated implementation with other initiatives. Risk of public non-acceptance of intentional release of genetically modified pests into natural environment; requires extensive public consultation.
KOI HERPESVIRUS				
Causes mass mortalities of carp – potential to substantially reduce populations (at least until resistance develops).	Not size specific although juveniles may be more susceptible.	Believed to be species-specific (even closely related cyprinid species are unaffected); potential impacts on native species not yet fully understood. Mass mortalities over large geographic areas could have water quality impacts detrimental to native species.	Unknown; still under investigation.	Unclear; Still under investigation. Interbreeding between goldfish and carp could reduce effectiveness, as goldfish are resistant to koi herpesvirus. Risk of public non-acceptance of intentional release of exotic disease agent into the environment and public resistance because of the potential impacts on the ornamental koi carp industry in NSW; requires extensive public consultation.

Community carp fishing competitions

Carp fishing competitions, commonly known as carp fish-outs or musters, are popular in many communities. Large quantities of carp biomass may be removed from an area, although research and anecdotal evidence suggest that this reduction may be only a short-term outcome that does not result in a lasting reduction in carp numbers. For example, researchers from the Queensland Department of Employment, Economic Development and Innovation (Primary Industries and Fisheries) are evaluating the impact of carp fishing competitions in the Albert-Logan River catchment in south-east Queensland under a project funded by the Invasive Animals CRC. Pre- and post- competition surveys of several events suggest that angling pressure has had only a minimal impact on local carp numbers. For example, an event at Goondiwindi in 2007 attracted 169 participants, but the average population reduction per site as a result of angling was estimated at only 0.5%. Studies of fishing events in NSW by I&I NSW have found similarly low proportions of the carp biomass are removed (D. Gilligan I&I NSW pers. comm. 2009).

Nonetheless, community-based carp fishing activities can have important positive outcomes, by promoting community stewardship and providing a forum for awareness-raising on a variety of issues, such as aquatic habitat protection, threatened species recovery, the impacts of pests, and responsible fishing practices.

Although carp musters are often organised and funded by local community groups, I&I NSW's Aquatic Habitat Rehabilitation Unit manages various large-scale aquatic rehabilitation projects, funded by CMAs, including some community carp musters. In these cases, the musters provide an opportunity for I&I NSW and CMA staff to interact with the community and distribute information on other aquatic environmental issues and rehabilitation actions such as replanting of riparian vegetation, weed control, reintroduction of woody debris to waterways to improve fish habitat (re-snagging) and monitoring of fish populations (see Case Study 1).

CASE STUDY 1: COMMUNITY CARP FISHING COMPETITIONS AND AQUATIC HABITAT REHABILITATION

THE BREWARRINA DEMONSTRATION REACH PROJECT 2008

This is an ongoing project that involves re-snagging and on-ground riparian works with landholder participation in revegetation and erosion-control activities. Remediation and stabilisation projects have been completed within the reach, and fishways are being designed for weirs at Bourke and Brewarrina. An inland freshwater river health education program is currently being developed for implementation in local schools. Six carp musters have been held over 2007–08 as part of this important project, with a total of around 480 people attending the four events held during 2008.

NAMOI AQUATIC HABITAT INITIATIVE 2008

This is another demonstration reach project. It was launched in Narrabri in March 2008, coinciding with a carp muster event and community tree planting day attended by over 300 people. Again, this project has several on-ground components involving the local community, and carp musters are utilised to actively promote beneficial habitat rehabilitation initiatives while raising awareness of carp and other aquatic pests.

Carp collected during community carp muster 2009 Photo: Milly Hobson I&I NSW

Commercial harvesting

Commercial fishers have the capacity to remove large volumes of carp with minimal impact on native species. Commercial fishing has been shown to reduce carp numbers in lakes and enclosed water bodies such as sewage treatment ponds (Graham *et al*. 2005). However, as with other methods of carp removal, the benefits of reduction efforts are relatively short term, with carp populations quickly recovering.

Research conducted under the Carp Assessment and Reduction Program in NSW found that hauling was the most effective method of carp removal, but only in locations such as shallow lakes or dams where the lake bed is clear of obstructions. It was also found that mesh nets and traps, previously used in the inland native fish fishery, could be effective in carp removal.

The Judas carp technique (where males are radio-tagged and act as 'tracker' fish) may enhance effectiveness and efficiency of commercial harvest by targeting spawning or winter aggregations which contain populations of sexually mature carp (Gilligan *et al*. 2010). This method is being trialled in Lake Cargelligo in the lower Lachlan catchment as part of the River Revival – Lachlan River Carp Cleanup Project (see Case Study 3). The Judas method has been used with success in Tasmania (see Case Study 4).

From 1999–2001 the NSW Government offered incentive payments to commercial carp fishers in an effort to stimulate commercial carp fishing and the market for carp products. However, several factors have impeded the establishment of an ongoing, economically viable commercial carp fishery in NSW – in particular, the low market value of carp and the ongoing effects of the drought on carp populations. Only a small proportion of harvested carp is sold for human consumption, most being used as lobster bait or to produce low-value fishmeal, fish oil, pet feed, fertiliser and stockfeed. This means that the fishery is generally only viable under conditions that allow the removal of large volumes of carp at minimal cost. Nonetheless, some fishers have been active in developing new and more lucrative markets for carp products, including export for human consumption overseas.

Lower carp numbers (probably attributable to drought conditions) have resulted in very little activity in this fishery between 2001 and 2010. The exceptions are localised events where the draw-down of a regulated water body has created an opportunity to efficiently extract large volumes of carp (e.g. Moira Lake near Echuca on the Murray River – see Case Study 2), or where a contract for carp harvest or disposal has been entered into (e.g. Torrumbarry Weir fishway on the Murray River).

Although commercial carp fishing will undoubtedly continue on some scale as dictated by supply, market demand and/or contractual arrangements, it is unclear whether it is possible to establish a viable, self-sustaining carp fishery on a scale that could substantially reduce carp populations in NSW.

CASE STUDY 2: MOIRA LAKE REHABILITATION PROJECT

Moira Lake is part of an extensive system of forests and wetlands known as the Barmah-Millewa Forest, which covers about 66 000 hectares of floodplain on both sides of the mid-Murray River between Tocumwal, Deniliquin and Echuca. Moira Lake is located on the NSW side of the river and consists of two shallow, open freshwater lakes, totalling 1500 hectares.

In the past, Moira Lake supported large waterbird breeding colonies and was a major native fish breeding site for the central Murray region, particularly for Murray cod. However, with the completion of the Hume Dam near Albury in 1936, the natural pattern of periodic flooding (in winter/spring) and drying (in summer/autumn) was completely altered. For example, the river channel often runs at capacity over summer owing to the release of water for irrigation, giving connected wetlands no opportunity to dry out. This has changed the ecology of Moira Lake and created ideal conditions for pest species such as carp.

A rehabilitation plan for the Moira Lake wetland system was developed by the NSW Murray Wetlands Working Group in conjunction with Forests NSW (now part of I&I NSW) and the former Department of Infrastructure Planning and Natural Resources. First, a regulator – a gate across the river – was constructed to control water flows into and out of the lake. The regulator can be closed off to exclude water and enable the wetlands to dry out, or opened to reconnect the wetlands to the river. The first drying of the lake in 60 years occurred in the summer of 1997–98. It is now a regular event under the management plan for the Barmah-Millewa site prepared as part of the 'Living Murray' program (a river restoration program established as a partnership between the Australian, NSW, Victorian, South Australian and ACT governments).

Active management of water flows through the regulator has also provided an opportunity for carp-control. After flooding of the wetlands, the regulator is slowly and progressively opened. This draws carp towards the regulator, where they are harvested by a commercial fisher – mostly for export to Asia for human consumption or processing into garden fertiliser. Approximately 80 tonnes of carp was harvested in 2001, and nearly 40 tonnes in 2004. The regulator gates are then progressively opened to allow native fish to freely move between the river and the lake.

Restoration of more natural wetting and drying cycles and carp harvesting are being combined with other management actions, such as fencing to exclude stock, to gradually restore native fish and waterbird habitats.

Rotenone

Rotenone is a naturally occurring chemical, obtained from the roots of several tropical and subtropical plant species, which is widely used as an insecticide and pesticide. It also kills fish. However, it is not registered by the Australian Pesticides and Veterinary Medicines Authority (APVMA) for use on fish; hence it is illegal to use it for this purpose except as authorised under a specific permit issued by the APVMA.

I&I NSW was issued an APVMA permit on 4 October 2006 for the use of rotenone to control pest fish species. The permit is restricted to use by I&I NSW officers or others under their direct supervision, and operators must be trained in chemical handling. The permit also prescribes specific dosage rates and other conditions.

To date, I&I NSW has used rotenone (in accordance with the APVMA permit) to attempt to eradicate two freshwater pest species, speckled mosquitofish (*Phalloceros caudimaculatus*) and platys (thought to be a cross between *Xiphophorus maculatus* and *Xiphophorus variatus*). In both cases the target (pest) population had a very restricted distribution (in small ponds and a small drain, respectively). A great deal of planning was necessary to assess and mitigate environmental impacts, for example by delimiting the area and removing native species before treatment.

The use of rotenone to kill pest fish can be justified only in very limited circumstances, i.e. where eradication is feasible; where a review of environmental factors (REF) has identified that the benefits outweigh any impacts on native species or that impacts can be reduced to an acceptable level; and where there is no risk to the health of humans, stock or domestic animals through direct contact or contamination of drinking water.

In the past, I&I NSW also tested the use of floating pellet baits containing lethal doses of rotenone as a potential carp-control technique (Gehrke 2003, Gilligan *et al*. 2005), with the aim of developing a more targeted control technique than broad-scale application. However, the research returned mixed results, with few carp killed in some instances and large numbers of native Australian smelt killed in one case. When floating pellets were not removed from the water body, large numbers of non-target species were killed, suggesting that leaching of rotenone from uneaten pellets can affect non-target fish species. The outcome of this research suggested that further development and testing would be required (and a separate APVMA permit approved) before rotenone baits could be utilised to target carp populations.

Although it is a potential option to eradicate discrete new populations of carp in some limited circumstances, rotenone will not be used for carp-control on a large scale.

At the time of publishing this Control Plan, there is no other chemical that is legal to use to control pest fish in Australia.

Fishway carp separation devices

As discussed in 'Natural migration of carp (including through fishways)' in Section 4.2, carp are highly migratory and can use fishways designed for native fish passage. However, the bottlenecks created by fishways can also provide an important opportunity for carp-control. Some existing fishway designs provide an opportunity to manually separate and dispose of carp – for example, fish locks (which are similar to lifts) collect fish in a 'cage' for manual transport across the barrier. Separation and disposal of carp does occur at some major weirs on the Murray River, where migrating fish are trapped and counted each day as part of long-term monitoring (Stuart *et al*. 2006). However, it is clearly very labour intensive.

Observations of carp trying to jump out of fish traps – an escape behaviour not shown by native fish – led a Murray River weir-keeper to develop the concept of a carp-selective fish trap that would trap carp in a separate confinement area. The 'Williams Carp Separation Cage' was further developed and tested by Victorian researchers from the Arthur Rylah Institute and weir-keepers from Goulburn Murray Water, with funding and support from the Murray-Darling Basin Commission. Further research since 2002 has produced more sophisticated designs, the latest of which ('Mark V') traps carp while allowing automatic release of native fish. Testing of the Mark IV design at Torrumbarry weir on the Murray River found that it successfully captured 78% of adult carp, while more than 99.9% of native fish passed through (Stuart *et al*. 2006). Cages have now also been installed on fishways at Lock 1 and Lock 10 on the Murray River (I. Stuart pers. comm. 2009), and at several sites in the Lachlan River catchment under the River Revival – Lachlan River Carp Cleanup project (see Case Study 3 in Section 5.3).

However, arrangements for disposal of captured carp continue to be the major impediment to more widespread use of these cages. At Lock 1 on the Murray River, a commercial fisher has been engaged through competitive tender to process the carp, with a large freezer available on site to hold fish for collection. Other sites are not as suitable for such arrangements owing to the lack of commercial quantities of carp.

Jackson (2009) reports approximately 40–50 tonnes of carp per year are required to sustain a commercially viable business; therefore in some locations a commercial fisher will be required to harvest carp at multiple fishways or other sites, or retain carp in freezers until there are sufficient numbers for collection. Potential options for the commercial use of carp are limited to crayfish bait and fertilizer. Where commercial use of carp is not feasible other options include burial, cremation and composting, all of which require compliance with state and local environmental regulations (Jackson 2009).

Fish composting technology may be an effective option for carp disposal when utilising carp cages and exclusion devices. However this would require investigation by local councils, CMAs and/or community organisations into the feasibility of this composting method and also requires resources for ongoing maintenance.

Carp separation cages have not yet been trialled in any coastal catchments. It is unclear whether or how existing designs could be adapted for coastal use to prevent bycatch of native species which also show jumping or climbing behaviour (e.g. mullet, eels).

Carp-exclusion methods (e.g. screens)

In the warmer months, carp tend to migrate from the river channel into shallow wetland areas to spawn.

Mesh screens have been fitted on regulators (water inlets/outlets) at many wetlands in NSW, South Australia and Victoria to prevent access of carp to these areas for breeding. However, these screens may block the passage of native fish and fauna as well as carp. Scientists from SARDI have been evaluating the use of these screens and investigating alternative options. They have developed a 'finger' style pushing trap (Thwaites *et al*. 2007) that can be retrofitted on wetland inlets and outlets during the carp spawning season. Carp are so determined to enter the wetland that they will push through the swinging bars ('fingers') into the trap, whereas native fish remain in an outer cage and can be returned to the river. A combined jumping/pushing carp trap was trialled at Banrock Station wetland in South Australia in 2008; it captured 4 tonnes of carp in 4 weeks.

Carp separation cage at Island Bend on the Lachlan River. Photo: I&I NSW

Draining and drying

In private waterbodies (e.g. farm dams) and wetlands fitted with a regulator to control inflows and outflows, it may be possible to eradicate carp (at least temporarily) by draining and allowing the substrate to dry completely. However, there is always the likelihood of reinfestation if carp are present in surrounding areas. In regulated wetlands, carp populations can be minimised by combining periodic drying (at least every 3 years) with screening of the inlet during the filling phase. Screening prevents access of adult carp to spawn, while regular drying eliminates carp which may have entered as juveniles before they reach a reproductive age.

However, careful consideration needs to be given to the potential impact on native fish and other flora and fauna when implementing this method, especially in wetland areas and associated water bodies where acid sulphate soils are know to occur. Draining and drying may require the completion of a review of environmental factors (REF) and/or a permit; therefore local agencies must be consulted regarding any requirements before attempting this method.

Manipulation of water flows

Scientists from SARDI have found that, when a wetland is drained, native fish tend to leave before it is dry, whereas carp swim against the current of the out-flowing water, thus moving deeper into the drying wetland until they are stranded – a behaviour that could be exploited by manipulating water flows.

In Lake Crescent in Tasmania, water flows have been manipulated to maintain low and falling water levels during the carp spawning season to reduce the risk of spawning (see Case Study 4 in Section 5.3).

Stocking of native fish

Native fish may help keep carp populations under control through predation, particularly of larvae and juveniles; however, the extent of any impact is unknown. I&I NSW already supports several departmental and community fish stocking programs through research and the Dollar for Dollar Native Fish Stocking Program (funded through the NSW Recreational Fishing Trust). Stocking activities are managed in accordance with the Freshwater Fish Stocking Fishery Management Strategy.

Native fish restocking after carp muster in Narrabri 2009. Photo: Anthony Townsend I&I NSW

Daughterless carp

'Daughterless Carp' is a collaborative project funded by the Invasive Animals CRC which aims to produce genetically modified carp that have only male offspring. The development of the genetic technology is being undertaken by CSIRO in Tasmania, with other participants, including I&I NSW, conducting supporting research. The concept is that large numbers of carp containing the modified gene would be bred in hatcheries and released into the wild. Over time, the gene would spread through the wild carp population, resulting in substantially fewer females and the eventual collapse of (or at least substantial reduction in) the carp population.

I&I NSW researchers are playing a key supporting role by investigating current carp recruitment and population dynamics; these findings should help to identify potential release sites for daughterless carp and ways to maximise the spread of the gene. For example, researchers are identifying important locations for carp spawning and recruitment ('hotspots') within the NSW portion of the Murray-Darling Basin, estimating the density of carp larvae and juveniles produced, and assessing the relationships between environmental factors and carp spawning success.

The advantages of this technology – if it is finalised – are that it would be species-specific (no impacts on native fish) and could potentially result in a substantial reduction in, or even eradication of, the carp population. However, it is a very long-term, high-risk and expensive technology, and it is still unclear when (or whether) it will reach the stage of field trials. Apart from the technical issues, there may be some other hurdles to overcome, including potential public resistance to the release of large numbers of a genetically modified pest organism. Even if the program is successful, it is likely that the impacts on carp numbers would not be seen for a considerable time (several to many decades). Consequently, it cannot be considered a viable control option, at least in the short- to medium-term.

Koi herpesvirus

Koi herpesvirus (KHV, sometimes also referred to as Cyprinid herpevirus-3, CyHV-3) is a disease that causes mass mortalities of common and koi carp. It broke out in several countries (including Germany, the UK, the Netherlands, Israel and USA) in 1997–98 and subsequently spread, devastating the carp and koi carp industries of South East Asia (Bretzinger *et al*. 1999). It has not been detected in Australia.

KHV/CyHV-3 is currently being assessed by researchers at the Australian Animal Health Laboratory for possible use in controlling carp numbers in Australia. One potential advantage of this virus is its specificity to carp; even related cyprinids such as goldfish and grass carp (*Ctenopharyngodon idella*) are not affected and do not act as carriers (Haynes 2008). However, its potential impacts on Australian native species are not fully understood and given the level of interest in ornamental koi by aquarium hobbyists in NSW, any potential future use of the virus would be subject to extensive community and industry consultation.

The extent of interbreeding between carp and goldfish in the Murray-Darling Basin (Haynes 2008) also poses some potential problems for the use of this virus as a control agent. If released, fish carrying genes for KHV resistance inherited from goldfish ancestors could gain a selective advantage, increasing the prevalence of disease resistance in the carp population and hence negating any long-term impact of the disease (Haynes 2008). Goldfish are resistant to a number of other carp viruses (Hedrick *et al*. 2006) and could act as genetic reservoirs of resistance to a whole range of potential disease controls (Haynes 2008).

5.3 IMPROVING THE EFFECTIVENESS OF CARP CONTROL

Several research projects are currently underway in an effort to give us a better understanding of the behaviour and population dynamics of carp, and hence to improve the efficiency of carp-control programs. For example, researchers are looking at carp sex pheromones and environmental and sensory attractants such as water flow, temperature gradient, and food, plant and soil odours. Use of such attractants could increase the success of existing control methods such as trapping.

In Tasmania, the Inland Fisheries Service (IFS) has found that capturing, radio-tagging and releasing carp to act as 'tracker' or 'Judas' fish allows them to identify the location of carp aggregations which can then be targeted using traditional harvesting methods.

I&I NSW researchers have been using larval drift studies and electrofishing (use of electricity to stun fish for capture, without killing them) to identify carp reproduction 'hotspots'. These 'hotspots' can then be targeted by using a suite of control measures to limit the success of carp spawning events. The effectiveness of such an approach is currently being tested in the lower Lachlan catchment, under a project involving a wide variety of stakeholders, including the Invasive Animals CRC and the Lachlan CMA (see Case Study 3, below).

CASE STUDY 3: RIVER REVIVAL – LACHLAN RIVER CARP CLEANUP PROJECT

The lower Lachlan catchment provides a unique opportunity for implementation of a carp-control program in the Murray-Darling Basin. The population density of carp in the Lachlan catchment is the highest of any catchment in NSW. The carp population in the lower Lachlan is supported by two known and two potential carp recruitment 'hotspots': Lake Cargelligo and Lake Cowal (known) and the Great Cumbung Swamp and Lake Brewster (potential). The Lachlan is largely isolated from the remainder of the Murray-Darling Basin and only ever connects with the Murrumbidgee River during periods of very high flow (1-in-20-year floods). As a result, the carp population within the lower Lachlan catchment is not exposed to continual immigration from carp populations in other catchments.

The River Revival – Lachlan River Carp Cleanup project aims to reduce the overall numbers of carp in the lower Lachlan through identifying and eliminating access to recruitment hotspots. The project began in 2007 and is a collaboration between the Lachlan CMA, Invasive Animals CRC, I&I NSW, SARDI, Victorian Department of Sustainability and the Environment, Kingfisher Research Pty Ltd, K. & C. Fisheries Global Pty Ltd, the NSW State Water Corporation and the Lachlan catchment community (e.g. shire councils, indigenous groups, recreational fishing clubs, Landcare or Rivercare groups and Fishcare Volunteers).

The initial 2 years of the project focused on benchmarking the status of the carp population and the aquatic ecosystem in the lower catchment, including carp population size and recruitment levels, water quality, riverbank stability, aquatic vegetation cover and macroinvertebrate and native fish community composition, as well as social attitudes towards carp. The benchmarking phase was also used to trial carp removal options in preparation for the implementation phase, including carp separation cages within the inlet and outlet channels at Lake Brewster, as well as on the inlet channel to Lake Cargelligo and on the Lachlan River upstream of the Great Cumbung Swamp. The benchmarking phase found a weak relationship between carp biomass and these ecosystem variables indicating that carp removal may be unlikely to result in rapidly improved ecosystem health (Giilligan *et al*. 2010). Research and monitoring will continue to assess impacts of carp during the implementation phase.

Carp removal activities implemented from 2009 onwards (the implementation phase) will focus on recruitment hotspots and will include: 1) exclusion of adult carp from hotspot locations; 2) trapping of carp dispersing from hotspot locations; 3) removal of migrating carp in riverine fishway traps; 4) removal of carp from freshwater lakes by using attractants/traps; 5) commercial harvesting from freshwater lakes; 6) recreational harvesting through community-based carp fish-out competitions; 7) implementation of daughterless carp gene technology when/if it becomes available for field application; and 8) any other control options provided through the freshwater products and strategies program of the Invasive Animals CRC.

After 2011, the intention is to source funding to continue the control program until 2035.

Commercial carp fishing (K&C Fisheries) in Lake Cargelligo. Photo: I&I NSW

In Tasmania, the IFS is attempting to eradicate carp from two large lakes in central Tasmania through a combination of containment and fishing effort (see Case Study 4).

CASE STUDY 4: ERADICATION OF CARP FROM LAKE CRESCENT AND LAKE SORELL, TASMANIA

Carp were first discovered in a number of farm dams in north-west Tasmania in 1975 and again in 1980. These populations were eradicated by using rotenone. In early 1995 carp were again discovered, this time in the popular recreational trout waters of lakes Crescent and Sorell in central Tasmania. The size of the lakes (2305 and 5310 ha, respectively), as well as environmental issues, prevented the use of rotenone, so the IFS embarked on a program to first contain, then eradicate, the populations through targeted fishing. Containment was achieved by placing a weir with a series of mesh screens at the outlet of the downstream lake, Lake Crescent. Lake Sorell was also isolated from Lake Crescent with a fine-mesh screen structure. The mesh sizes were small enough to prevent escape of eggs and juveniles. The lakes were also closed to anglers to reduce the risk of further translocations. Despite extensive surveys no carp have been found downstream of the lakes.

Initially, water levels in Lake Crescent were manipulated to maintain low and falling water levels during the carp spawning period to reduce the risk of spawning and to prevent the migration of carp downstream in case of a flood. Initially carp numbers in Lake Sorell were low. Spawning has occurred sporadically over the past 15 years despite extensive efforts to prevent this from occurring. Marsh areas have been fenced off to prevent carp accessing preferred spawning sites with some success.

A variety of fishing techniques have been used to reduce the carp population (fyke nets, seine nets, gill nets, traps, barrier nets, backpack electrofishing, boat electrofishing and pheromone attractants), targeting areas favoured by carp. From 1997, the IFS began to radio-tag and release males to act as tracker or 'Judas' fish to identify aggregations that could be fished down and to help understand carp habitat preference and behaviour. Subsequently, the goal of total eradication was refined to the intermediate goal of eradicating female carp, because of their high fecundity. Capture mark recapture techniques have been used to obtain population estimates in Lake Crescent and more recently catch per unit effort (CPUE) data has been used to estimate population size in Lake Sorell.

As of early 2009, over 11 000 carp had been removed from the two lakes and estimates of remaining carp numbers were fewer than five (possibly none) in Lake Crescent and fewer than 50 in Lake Sorell. However, in late 2009 juvenile carp were detected in Lake Sorell. Favourable spawning conditions as a result of a wet winter and spring prompted the IFS carp team to mount an intense response by installing additional barrier netting and traps to prevent carp from reaching spawning areas. However the rise in lake levels enabled some carp to jump over the barrier nets resulting in a spawning event and successful recruitment. IFS estimates that this recruitment event was limited to less than 20 000 fish. To date over 14 000 of these new juveniles have been caught and removed. Early population estimates indicate that this is over 75% of the new cohort. Although this is a significant setback IFS has reported what appears to be the successful eradication of carp from Lake Crescent. The program will increase both fishing effort and measures to restrict access to spawning areas. An intensive operation for summer 2010 is planned to prevent further spawning in Lake Sorell and further reduce the juvenile population. To date the Carp Management Program has cost the Tasmanian Government approximately $7 million.

Another tool that may help to assess the likely effectiveness of control strategies before their implementation in future is **CarpSim**, interactive software developed by the Victorian Department of Primary Industries in collaboration with the Invasive Animals CRC. It is designed to help researchers and natural resource managers evaluate the effectiveness of potential carp-control strategies in a range of situations. This software can be used to simulate the likely outcomes of carp management activities with varying degrees of size- or sex-selectivity, including netting, trapping, cages, angling, piscicides (fish poisons) or daughterless carp technology. The software is downloadable from the Victorian Department of Primary Industries (DPI) website.

5.4 WHAT I&I NSW IS CURRENTLY DOING

I&I NSW is currently:

- promoting its aquatic pest fish reporting program [24-hour recorded hotline (02 4916 3877) and e-mail (aquatic.pests@industry.nsw.gov.au)] on pest advisory materials and signs
- undertaking active surveillance for early detection of carp via native fish surveys and passive surveillance through the aquatic pest reporting program
- following up reports of carp in new locations to obtain positive verification
- undertaking research (e.g. on reproduction 'hotspots') as the basis for developing more effective, integrated control programs
- combining community-based carp fishing competitions with aquatic rehabilitation at a range of demonstration reach sites
- contributing to the implementation of a range of carp-control measures (including the use of separation cages) in the Lower Lachlan catchment
- encouraging and supporting local councils, CMAs and community groups' participation in aquatic rehabilitation works to improve habitat for native species.

Aquatic revegetation at the Namoi River. Photo: Milly Hobson I&I NSW

5.5 PRIORITIES FOR FUTURE CONTROL WORK IN NSW

As previously discussed, the lack of any cost-effective large-scale control techniques means that a comprehensive carp eradication program for NSW is not currently feasible. Ad-hoc or opportunistic attempts to reduce carp numbers in small areas (e.g. where carp are aggregating below instream barriers) are difficult to justify, given their expense and limited effect on the carp population. Instead, resources need to be directed towards carefully planned, targeted and integrated control programs, focusing on areas that are of key importance to the carp population (e.g. reproduction 'hotspots') or environmentally significant areas where carp-control can be combined with other forms of aquatic habitat rehabilitation.

On the basis of the preliminary risk assessment in the Appendix, I&I NSW has identified the following priorities for carp-control in NSW (Table 3).

Table 3. Priorities for future carp-control work in NSW

TYPE OF CONTROL WORK	CONDITIONS
PRIORITY 1: NEW OUTBREAKS IN PREVIOUSLY CARP-FREE AREAS	
Containment or eradication (e.g. through the use of barriers to movement, rotenone and/or physical removal), combined with public education to reduce the risk of re-release.	Containment or eradication is feasible. Benefits outweigh potential impacts on native species, including threatened species. Little or no potential for re-establishment by natural migration. Resources available.
PRIORITY 2: CARP BREEDING / RECRUITMENT HOTSPOTS	
Variety of methods, including exclusion devices (to limit access of carp) and/or physical removal to reduce size of breeding population.	Area identified as a carp breeding/recruitment hotspot. Benefits of action outweigh potential impacts on native species (e.g. loss of access to breeding sites). Local or regional funding available.
PRIORITY 3: HIGH- CONSERVATION-VALUE AREAS OR DEMONSTRATION REACHES	
Physical removal or exclusion, combined with other habitat rehabilitation actions such as revegetation, re-snagging, mitigation of thermal pollution from dams, restoration of environmental flows, water regime management (periodic drying) of wetlands and lakes and/or protection and enhancement of populations of Murray cod (a predator of carp) or other native fish which prey on carp eggs and larvae.	Carp-control has been identified as contributing to broader goals for aquatic habitat rehabilitation and native fish replenishment. Aquatic rehabilitation works are conducted on localised scales by councils, CMAs and community groups and this will continue to be encouraged and supported by I&I NSW. Part of a funded rehabilitation project.
PRIORITY 4: FISHWAYS	
Installation of carp separation devices on new or modified fishways.	Installation of a separation device is feasible. Arrangements can be made for ongoing maintenance and removal of carp. Cost can be incorporated into fishway funding agreements or externally funded.

These priorities do not preclude other organisations from undertaking carp-control works. However, I&I NSW has limited capacity to support, or help with, work outside these priority areas. For example:

- Where there is substantial local concern about carp, local community groups may wish to organise **carp fishouts** or **carp musters**. Subject to availability of resources, I&I NSW recreational fishing, compliance and/or extension officers may attend these events to promote good fishing practices and awareness of a range of issues. However, it is important for participants to understand the limited scope for long-term reduction of carp numbers through such efforts alone.
- Where councils or individuals wish to undertake carp-control in **privately owned** or **managed water bodies**, either themselves or by contracting commercial fishers on a fee-for-service basis, I&I NSW may provide general information and advice but is unable to provide financial or physical resources.

GOALS: Control work

5A Promote the aquatic pest reporting program [24-hour recorded hotline (02 4916 3877) and e-mail (aquatic.pests@industry.nsw.gov.au)] in 'carp-free' areas, targeting recreational fishers and farmers, to encourage early reporting of new populations.

5B Develop targeted surveys to regularly monitor 'carp-free' areas, with the aim of identifying new populations.

5C Where new carp populations are identified in previously 'carp-free' areas, assess the feasibility, costs and benefits of eradication and, where appropriate, attempt eradication.

5D Build partnerships to develop, fund and implement integrated carp-control programs for identified reproduction 'hotspots'.

5E Integrate carp-control measures (including community involvement) into new aquatic habitat rehabilitation and demonstration reach projects, where feasible.

5F Identify opportunities to install carp separation cages on existing or new fishways and develop arrangements for ongoing maintenance and disposal of harvested carp.

5G Encourage councils, CMAs and/or community organisations to investigate the potential to use fish composting technology as an option for carp utilisation when using carp cages and exclusion devices.

5H Trial and implement new carp control technologies to enhance the effectiveness of existing methods.

SECTION 6: EDUCATION AND COMMUNITY INVOLVEMENT

6.1 IMPORTANCE OF EDUCATION AND COMMUNITY INVOLVEMENT

Awareness of the pest status of carp is generally high, especially in rural and regional NSW, where there is a great deal of concern about carp and support for carp management. However, some barriers to effective management remain. They include:

- widespread but sometimes ill-founded beliefs about the impacts of carp, which may overemphasise the role of carp relative to other causes of riverine degradation
- unrealistic expectations about the potential to control carp numbers or eradicate carp populations
- continuing illegal or ignorant behaviours (such as dumping / translocation) which undermine control efforts
- alternative views among some (minority) sectors of the community who value carp and oppose control measures.

Because of the scale of the carp problem and the role individual actions play in its spread, it is vital for the community to be aware and informed about carp, involved where appropriate in control and habitat rehabilitation programs, and compliant with current laws prohibiting release of live fish or use of live bait.

6.2 EXISTING EDUCATIONAL INITIATIVES

Existing educational and community involvement projects designed to raise awareness of carp or increase compliance are summarised in Table 4.

Table 4. Existing community education and awareness initiatives

ADVISORY MATERIALS
• In 2003, NSW Fisheries (now part of I&I NSW) produced a 'Fishnote' on carp. It described the biology and impacts of carp and the control programs of the department and was circulated to various interest groups. • The same information, in summary form, is available on the I&I NSW website. In addition, in 2010 the I&I NSW carp webpages were expanded to include information for specific groups on carp control and the humane utilisation of carp with links to recipes and information on using carp as fertiliser. • In 2004 a booklet titled '*Aliens in the basin: an introduction to alien fish in the Murray-Darling Basin*' was prepared by the Murray-Darling Association and the National Carp and Pest Fish Task Force. This replaced the previous '*CARP: Villains or Victims?*' brochure. • I&I NSW produced a '*Don't dump that fish!*' bookmark, brochure and poster, which have been circulated to aquarium and pet stores throughout NSW. The brochure highlights the risks associated with escape of ornamental fish – including carp – into the wild. In 2010 the '*Don't dump that fish!*' bookmark and brochure was translated and printed in 5 languages to better target stakeholder groups. • In 2010 I&I NSW developed a freshwater pest fish Primefact which contains information on how to prevent the spread of pest fish. This Primefact notes it is illegal to use live fish as bait in freshwater and that it is also illegal to release live fish (including for cultural purposes) without a permit due to pest and disease risks.

COMMUNITY EVENTS
• Community carp 'fish-outs/musters' have been held in local communities across the state, both independently of, and in conjunction with, I&I NSW. The department's Aquatic Rehabilitation Unit has integrated many successful carp fishing events into its aquatic habitat rehabilitation projects (see Case Study 1).
DIRECT COMMUNICATION
• Local Fisheries Officers provide an important information contact point in regional areas for various biosecurity and aquatic conservation issues including carp information. • I&I NSW trained Fishcare Volunteers play an important role in disseminating information to the public about a wide range of issues, including carp. This is done through community events such as agricultural shows, advisory field events and casual liaison at popular recreational fishing spots. • I&I NSW representatives have conducted a series of general aquatic habitat conservation workshops, where carp impacts were discussed, in south and north-west NSW as part of the Fish Friendly Farms program, a I&I NSW program that encourages farmers to protect fish habitat on and off their properties through sustainable agricultural practices. • I&I NSW Native Fish Strategy coordinators communicate directly with the community through school and community workshops to highlight the threats to native fish, including the impact of carp, and discuss the benefits of improving aquatic habitat for native fish.
COMMUNITY MONITORING AND REPORTING
• The I&I NSW Aquatic Pests Hotline (02 4916 3877) is a 24-hour telephone message system that allows members of the public to report sightings of new infestations of alien or pest species. • Pest reporting is also available via e-mail at aquatic.pests@industry.nsw.gov.au and through the I&I NSW website. • Local reports of carp were used in the preparation of a carp distribution geographic information system (on which the map in section 1.2 is based).

Carp fishing events can help raise awareness of pest species, promote aquatic habitat rehabilitation programs and generate a sense of stewardship for the environment. Photo: Milly Hobson I&I NSW

6.3 WHAT I&I NSW IS CURRENTLY DOING

I&I NSW is currently:

- updating website information as new information becomes available
- assisting community-organised 'carp musters' by providing information on responsible and ethical fishing practices, conservation issues and the broader issues associated with carp management
- providing general advice on control options, costs and benefits and feasibility for individuals or organisations wishing to undertake localised carp-control
- providing information on pests, including carp, as part of Fishcare Volunteers training.

6.4 PRIORITIES FOR FUTURE EDUCATION AND COMMUNITY INVOLVEMENT

A continuing focus on education and awareness-raising is important to ensure dissemination of accurate information and encourage behavioural change to prevent further human-mediated spread of carp. Information needs to be regularly reviewed and updated to ensure that it is accurate, and redistributed to maintain awareness of the issues.

GOALS: Education and community involvement

6A Enhance the existing educational program through cooperation with other groups and organisations, including Fishcare Volunteers, the Native Fish Strategy and associated education programs.

6B Continue to improve and disseminate educational materials (based on available behavioural and demographic information) to better target and inform different stakeholder groups on the risks associated with carp and encourage its humane utilisation.

SECTION 7: RESEARCH, SURVEILLANCE AND MONITORING

7.1 IMPORTANCE OF RESEARCH, SURVEILLANCE AND MONITORING

Continuing research is critical to satisfy gaps in our knowledge of carp impacts, population dynamics and behaviour. The effects of carp on the native biota in NSW waterways remain largely speculative. Further research will help to reveal how much degradation is attributable to carp, and hence to determine the likely benefits of control efforts. Research into population dynamics and behaviour will provide valuable information to help target vector management and control work in the most effective way, for example by targeting breeding aggregations in 'hotspot' areas. New research findings will continue to be incorporated into the adaptive carp management strategy as they become available.

Native fish surveys are valuable as a way of detecting new pest fish populations. Ongoing monitoring of NSW waterways is a valuable tool for providing long-term observations of population dynamics, particularly in the face of increasing environmental pressures. In addition to this active surveillance, I&I NSW undertakes passive surveillance through the aquatic pest reporting program (24 hour recorded telephone hotline, email address and web reporting form).

7.2 COMPLETED AND CURRENT RESEARCH

I&I NSW has already concluded a number of carp research projects and trials, some in collaboration with the commercial fishing sector and partner organisations such as CMAs and the Murray-Darling Basin Authority.

Initial research was largely geared toward developing a baseline understanding of the NSW carp problem, assessing various control methods and investigating constraints to the establishment of a viable commercial carp industry. For example, research undertaken by NSW Fisheries (now part of I&I NSW) as part of the Carp Assessment and Reduction Program (1999–2002) and under Water Management Fund programs in the Murray and Murrumbidgee rivers included assessments of:

- small-scale fishing methods, such as electrofishing, various net configurations and traps
- large-scale commercial fishing methods (cost effectiveness, effect on native species, efficiency, and ease of use)
- by-catch reduction devices
- other control methods, in particular oral rotenone baits (effectiveness and impacts on aquatic biodiversity)
- methods of small-scale carp removal by local communities
- state-wide distribution and abundance of carp.

Primary research into the biology, recruitment dynamics, genetic diversity, and environmental tolerances (altitude, temperature, turbidity, nutrients, salinity) of carp has also been completed.

A number of collaborative research initiatives focusing on control technologies or improving the efficiency of control programs are currently being funded by the Murray-Darling Basin Authority and the Invasive Animals CRC. These include investigations into 'daughterless carp', reproductive 'hotspots', migrations, koi herpesvirus and various attractants, including sex pheromones and sensory or environmental attractants. As discussed in Section 5.2, some of these are emerging technologies which have potential for long-term suppression of carp populations.

Ecological work being undertaken by I&I NSW to support possible future implementation of the 'daughterless carp' technology (but with broader relevance) includes:

- providing DNA samples for the assessment of population genetics of carp throughout the Basin
- assessing the relationships between environmental factors and carp recruitment (necessary to calculate the required stocking rates of hatchery-produced 'daughterless' carp)

- quantifying a baseline sex ratio of carp populations across NSW (necessary so that the spread of the daughterless gene through wild populations can be monitored)
- assessing the movement and dispersal of carp through NSW waterways by tagging studies.

As described previously (see Section 5.3), I&I NSW has undertaken larval sampling and electrofishing across the Murray-Darling Basin to locate carp breeding and recruitment 'hotspots'. This work found that carp do not reproduce throughout entire river systems, and that a vast majority of recruitment occurs at a relatively small number of locations. In the Basin, these locations include important wetlands like the Macquarie Marshes, Namoi wetlands, Gwydir wetlands and Barmah-Millewa Forest.

I&I NSW researchers, together with a team of Invasive Animals CRC partners, are also installing and monitoring Williams Carp Separation Cages at three fishways on the Lachlan River. They are also developing and testing carp exclusion devices and traps at identified breeding areas (wetlands and storages).

Following the completion of the NSW Rivers Survey in 1997, freshwater fish diversity surveys have continued as components of a number of different projects. Such surveys assess the presence or absence of carp and their local abundance and have provided information on several new populations in previously 'carp-free' areas.

I&I NSW researcher tagging carp as part of carp tag-out week, 2008 Hillston Show. Photo: I&I NSW

7.3 WHAT I&I NSW IS CURRENTLY DOING

I&I NSW is currently:

- collating data collected during I&I NSW freshwater fish sampling projects to maintain up-to-date records of fish distributions (including carp)
- continuing research on the biology and ecology of carp (including migrations and spawning) and its impacts on native biota as a basis for carp management, through ongoing partnerships between I&I NSW, the Victorian DPI and the Invasive Animals CRC
- monitoring the outcomes of research and development into new and improved control techniques (e.g. improved trap and cage designs, attractants and long-term control options)
- undertaking a variety of freshwater fish sampling programs and incorporating the results (including carp records) in the freshwater fish database.

7.4 PRIORITIES FOR FUTURE RESEARCH IN NSW

GOALS: Research

7A Identify funding sources and partners for further collaborative research.

7B Develop, trial and implement new carp management technologies.

7C Investigate spawning inhibitors.

7D Investigate carp migration and reproduction in coastal NSW catchments, to identify key spawning sites and barriers to migration.

SECTION 8: IMPLEMENTATION AND REVIEW

8.1 IMPLEMENTATION

Implementation of this Control Plan is the responsibility of I&I NSW and of other agencies and groups with an interest in natural resource management at a regional or local level, particularly CMAs, local councils and other important stakeholders in the general community including anglers, Indigenous groups and relevant interest groups.

Time frames for implementation have not been provided; key actions are to be completed as resources permit.

8.2 REVIEW

The Control Plan will be reviewed within 5 years of the date of the final plan.

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APPENDIX: PRELIMINARY RISK ASSESSMENT

This preliminary risk assessment has been developed to identify (A) the risks associated with vectors that may spread carp into new areas, and hence the additional priority areas for action under this plan; and (B) the risks and benefits associated with carp-control work, and hence the priority scenarios under which control work can be justified under this plan.

(A) Risks of translocation of carp to new areas by vector

RISK	EXISTING/ONGOING MANAGEMENT ACTIONS	RESIDUAL RISK	NEW GOALS (UNDER THIS PLAN)
NATURAL DISPERSAL, E.G. DURING FLOODS AND THROUGH FISHWAYS			
High. Once carp are introduced to a waterway, floods can drown out barriers and connect previously isolated habitats (e.g. pools) allowing access to new areas.	• Few options – difficult to manage. • Installation of carp separation devices. • Careful assessment of new fishway proposals at limits of carp distribution.	High. Separation cages on fishways can be effective where installed, but they are likely to be a feasible way of minimising spread at a only small number of locations.	• Research on carp migration and reproduction in coastal areas. • Greater use of separation cages, screens and traps to minimise spread. • Encourage the use of carp information (distribution and abundance) during the development and delivery of environmental contingency allowances and water sharing plans.
DELIBERATE INTRODUCTION OR USE AS LIVE BAIT (RECREATIONAL FISHERS)			
Medium. Although it is currently illegal in NSW to release live carp or use them as bait, these activities may continue to contribute to the spread of carp into new areas.	• Education and compliance checks.	Medium. Education may reduce behaviour due to ignorance but is unlikely to substantially reduce deliberate illegal behaviour.	• Enhancement of existing educational program, including greater collaboration with Fishcare Volunteers and Fisheries Officers.
ESCAPE OR DELIBERATE RELEASE OF KOI (ORNAMENTAL FISH HOBBYISTS)			
High. Koi are popular in backyard ponds, and populations now exist in many coastal waterways.	• Education (e.g. '*Don't dump that fish!*' bookmark, brochure and poster).	Medium. Education may reduce behaviour due to ignorance but is unlikely to substantially reduce deliberate illegal release of fish.	• Targeted education campaign for koi industry and hobbyists.
CONTAMINATION OF NATIVE STOCK RELEASES			
Medium. Freshwater native fish-stocking programs were probably responsible for some past introductions but are unlikely to contribute substantially to further spread unless stocking begins in new areas.	• Hatchery Quality Assurance Program. • Hatchery accreditation schemes. • Stocking permits.	Low	

RISK	EXISTING/ONGOING MANAGEMENT ACTIONS	RESIDUAL RISK	NEW GOALS (UNDER THIS PLAN)
RECREATIONAL/ COMMERCIAL FISHING GEAR			
Low. Egg clutches are extremely sticky and could be transferred to new areas on boats or fishing gear; however, they become non-viable in a short time once exposed to air.		Low	• Enhancement of existing educational program, including greater collaboration with Fishcare Volunteers and Fisheries Officers.

(B) Risks and benefits of control work by location/circumstance

AIM AND APPROPRIATE CONTROL METHODS	RISKS	BENEFITS	PRIORITY UNDER THIS PLAN
NEW POPULATIONS IN AREAS PREVIOUSLY CONSIDERED 'CARP-FREE'			
Attempt eradication using rotenone, netting, trapping, electrofishing or a combination of methods.	• May be feasible only in very limited circumstances. • Costly, labour-intensive. • Fairly high chance of failure.	• May help maintain the 'carp-free' status of these catchments. • Increases awareness of the carp problem and may discourage human-mediated spread.	High
CARP BREEDING/RECRUITMENT HOTSPOTS			
Limit spawning success through exclusion of adults and/or physical removal to reduce breeding population.	• Removal techniques are costly and labour-intensive. • May affect native species as well as carp. • Intensive efforts may be required to substantially affect spawning outcomes.	• May reduce carp populations by limiting new recruitment. • Limited numbers of sites need to be targeted.	High
HIGH-CONSERVATION-VALUE AREAS OR DEMONSTRATION REACHES			
Support aquatic rehabilitation programs and native fish recovery by reducing carp biomass through angling, netting or the use of exclusion devices.	• Harvesting may have limited effect on carp population. • Benefits of carp removal on aquatic environment are not well quantified. • Labour intensive.	• Increases awareness of issues and promotes stewardship of aquatic environment. • Integrated approach to rehabilitation is likely to be of greatest benefit to native fish. • Volunteer labour (inexpensive).	Medium
FISHWAYS			
Reduce riverine populations through removal of migrating fish in separation cages.	• Limited number of locations may be suitable because of disposal issues. • Ongoing disposal arrangements may fail. • Allows passage of smaller carp.	• May reduce carp populations upstream of devices. • Automated operation possible (apart from carp disposal). • Minimal impact on native species. • Removal of substantial biomass possible for relatively little effort.	Medium

AIM AND APPROPRIATE CONTROL METHODS	RISKS	BENEFITS	PRIORITY UNDER THIS PLAN
AGGREGATIONS, e.g. BELOW IN-STREAM BARRIERS			
Reduce carp biomass through commercial netting or other forms of physical removal.	• One-off, ad-hoc carp-control actions are unlikely to have a substantial ongoing effect on the carp population. • Opportunistic approach (no prioritisation of sites) means that resources may be expended for little environmental benefit.	• Aggregations may be of a size that makes harvesting commercially viable without the need for additional payment.	Low
LOCATIONS OF CONCERN TO LOCAL COMMUNITIES			
Reduce carp biomass through angling (carp musters/fish-outs).	• Angling unlikely to substantially reduce population or have lasting effects. • Benefits of carp removal for the aquatic environment are not well quantified.	• Increases awareness of issues. • Opportunity to promote responsible fishing practices and introduce newcomers to the sport.	Low
PRIVATE WATER BODIES			
Reduce carp biomass through fishing or eradicate through draining and drying.	• If eradication is incomplete or if the water body is connected to other waterways (irrigation systems or natural waterways) infested with carp, the population will rapidly return to pre-harvest levels. • Costly and labour-intensive. • No wider benefit (no effect on riverine populations).	• Discrete water bodies (e.g. drainage ponds, farm dams) are among the best opportunities for complete eradication. • Removal may be necessary for operational reasons.	Low for I&I NSW or the public. Land-owners need to decide for themselves.

NSW CONTROL PLAN for the

NOXIOUS FISH CARP (*Cyprinus carpio*)

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