1. 4. Carp management objectives and preliminary life history and conceptual models for carp habitat use

4.1 Objectives

Carp are very efficient invaders and colonisers and have established themselves in river systems all over the world (Mussared, 1997). They can survive a wide range of aquatic conditions, including high temperatures and low oxygen levels, and they breed prolifically (Koehn *et al.,* 2000).

Carp affect the natural values of the Murrumbidgee River and surrounding waterways in a variety of ways. These include infecting a range of native fish species in the ACT region with the parasitic copepod *Lernaea sp*. including Mountain galaxias, Golden perch, Macquarie perch, Murray cod, along with other non-native species (Lintermans, 2002), competing with native fish for food, damaging macrophyte beds (aquatic plants, growing in or near water that are either emergent, submergent or floating) and the re-suspension of sediment and nutrients (Koehn *et al.,* 2000). Additionally, carp can occupy habitat that would otherwise be available for native fish species in the temporary habitats created by significant flow events.

The re-suspension of bottom sediments by carp through their mode of feeding may encourage further growth of algae and bacteria on hard substrates. These are of poor nutritional value for macroinvertebrates that form the food chain for native species, thus impacting riverine condition, productivity and amenity values.

The presence of carp is likely to exacerbate existing river health issues as opposed to being the cause for much of the issues affecting the site. The success of their invasion is arguably due to the decline in health and productivity of the Murray-Darling Basin native fish communities resulting from alterations to land use and river management. However, because of the popular belief that carp are the cause of many of the issues affecting rivers, they provide an opportunity to engage with the broader community on these and other issues such as agricultural practices, stormwater management and human assisted dispersal of carp and other alien fish species.

For this reason it is important to not lose sight of these broader management needs and to take on carp control within such a broader river restoration context (as the UMDR initiative does); not as a stand alone activity. Rehabilitating habitat has been suggested as a potential form of pest species control by making the environment more suitable for self-sustaining native fish populations while reducing the suitability of conditions for the pest (Harris 1997).

For the UMDR, Section 1.3 presented the overall vision, aspirational goals and short-medium term objectives, as documented in the Implementation Plan. At a more detailed level the range of management interventions put forward in the Implementation Plan for the UMDR that carp control measures will work in concert with are as follows:

- Improving the availability and management of environmental and general flows;
- Remedial actions to address low-flow barriers to fish migrations;
- Undertaking an inventory of farm dams to determine the presence of carp and other alien species;
- Undertaking remedial actions to address major sediment and pollution inputs;
- Rehabilitating high priority riparian sites;
- Reviewing existing fishways and seeking modifications to these as appropriate, including carp trapping options;

- Designing fish passage remediation solutions for priority barriers, including carp trapping provisions;
- Surveying and mapping the distribution and condition of in-stream habitats, identifying those of greatest importance to native fish and recognised icon species;
- Investigating the cost-benefit and feasibility of installing in-stream structures (jams and groynes) to restore deep pools;
- Compiling an inventory of critical habitats for threatened species, and undertaking remedial works;
- Identifying priority areas and opportunities to re-establish riparian corridors;
- Supporting works to see the condition of degraded riparian areas rehabilitated;
- Supporting, encouraging or assisting targeted, ongoing willow, blackberry and poplar control efforts;
- Implementing this Carp Reduction Plan;
- Prioritising and then developing strategies to address other fish pest species;
- Implementing the Communication, Education, Participation and Awareness Plan;
- Implementing the Monitoring and Evaluation Plan.

Objectives of the Carp Reduction Plan

The overall aim is to enhance the recovery of native fish communities, and aquatic vegetation, by targeted reduction of the damage due to carp within the Upper Murrumbidgee Demonstration Reach, and from surrounding waterways.

More specifically the objectives of the carp management plan are to:

1. Promote community awareness and understanding and through this increased involvement in carp management and other rehabilitation activities across the site and region;

2. Investigate the effectiveness of the appropriate control techniques in reducing carp abundance and impacts;

3. Record targeted and sustained reduction of carp abundance within the reach and relevant source populations*;

4. Limit carp recruitment within the Demonstration Reach and the linked catchment, without negatively impacting on native fish recruitment;

5. Better understand the movement of carp within the reach and relevant source populations in order to guide intervention; and,

6. Improve the understanding of carp population dynamics within the region to better understand their impacts on upland reaches of the Murray-Darling Basin.

* as measured using standard techniques via an appropriate monitoring and evaluation program.

4.2 What we know about carp in the region of the UMDR

Carp are highly mobile and often move considerable distances along rivers and into tributaries and adjacent wetlands.

Lintermans (2002) outlined the distribution of carp throughout the region and their initial arrival to the rivers of the ACT:

> "Carp were first detected in the ACT in 1976 when several individuals were captured in Lake Burley Griffin. It is thought these fish may have been introduced as a contaminant of fish stockings of other species (trout, Murray cod or Golden perch). Carp are now present in all of Canberra's urban lakes. Carp are present in the majority of the ACT's rivers and creeks with the exception of the Tidbinbilla, Naas, Orroral rivers, the Cotter River (upstream of Cotter dam) and the Queanbeyan River (upstream of Googong Reservoir). Two large carp were captured in Googong Reservoir in 1990 and there were unconfirmed angler reports of carp from this waterbody in May 1999, but carp are not yet established in this waterbody. They are present in the Murrumbidgee River up to and above Cooma, the Bredbo, Numeralla, Yass, Kybean and Goodradigbee rivers in the Upper Murrumbidgee catchment. Carp comprise around 70% of the fish biomass in the Murrumbidgee River in the ACT and between 70 and 90% of the fish biomass in Canberra's urban lakes."

Today, little has changed regarding the distribution of carp, in the Canberra region. Carp occur in the three largest urban lakes (Lake Burley Griffin, Tuggeranong and Ginninderra). The status of carp in these urban lakes has been regularly monitored since the mid 1970s, with carp regularly contributing more than 80% by number of the catch, although numbers appear to have declined slightly in the 1990s (M. Lintermans, pers. comm. 2010).

In the Murrumbidgee River catchment, above Burrinjuck Dam, there have been no specific studies of carp movement or their source populations. Genetic studies undertaken by Haynes *et al*., (2009) shed little light on the dynamics of the specific riverine populations describing the upper Murrumbidgee River carp population as a single management unit. However, it is likely that a proportion of carp move among the different reaches and habitats seasonally based on studies undertaken elsewhere (Stuart and Jones 2006, Jones and Stuart 2009). This is important in terms of future management of carp populations in the region as it is unlikely that broad sections of the region's rivers act as breeding sites. It is more likely that key habitats within them such as the urban lakes act as recruitment 'hotspots' or habitats that periodically reconnect with the region allow re-population and infestation of the region's rivers. Knowing where carp are moving to and from provides opportunities to intercept them before breeding can occur or preventing them from accessing high value breeding habitat and potentially reducing native fish recruitment success.

In 1994 the ACT Government established a long-term fish monitoring program in the Murrumbidgee River, with monitoring conducted every two years at six sites in the ACT (Lintermans unpublished data). A range of sampling techniques for adult and juvenile fish are employed but larval sampling does not occur. Lintermans (2002) outlined fish surveys undertaken in 1998 and 1999 specifically aimed at threatened fish but which also recorded information on alien species across 20 sites in the Upper Murrumbidgee catchment. A range of sampling methods were used in the survey providing an excellent overview of fish distributions and their present status. A range of carp size and age classes were represented at almost all sites, indicating that local recruitment is widespread in the catchment. However, the contribution of 'boom' years in maintaining carp populations throughout the catchment and the potential locations of carp recruitment hotspots is unknown.

At a broader level, Gilligan (2005) outlined a survey of the entire Murrumbidgee catchment, including the tributaries of the region, across 50 individual sites using similar techniques to those of Lintermans (2002). Unfortunately, little to none of that information is directly applicable to the Demonstration Reach and development of this Carp Reduction Plan except in terms of the general description of fish communities. Demographic information may assist but has yet to be published as outlined above.

Considered together, the data collected in 1998 and 1999 by Lintermans, the long-term dataset for the Murrumbidgge River in the ACT, and also the data collected by Gilligan (2005), is likely to provide a solid basis for understanding changes in the fish community resulting from actions taken within the region. This information, however, does not provide a clear basis to understand the ecology of carp within the region and how management can be effectively targeted to maximise the effectiveness of management. It does not provide insights into vital details about the population, broad habitat use, inter-breeding among meta-populations and broader movement patterns, especially between habitats such as preferred breeding locations. Improving understanding of these life history aspects will better enable actions to be taken to target carp during susceptible elements of their lifecycle and increase the chances of success.

Analysis of the available population data within relevant organisations can provide insights into when breeding is successful in the region and whether this is linked to particular events. Or, alternatively, if it occurs each year and if so when. For example:

- If breeding only occurs periodically, and is linked to a particular catchment or habitat, then reconnecting this may guide action to better understand this and possible interventions that address this catchment.

- If breeding happens periodically and it is linked to particular flow events, this can guide management responses to be linked to such events and appropriate planning put in place. It also assist with investigating if new habitats, that would facilitate breeding are available, if access to them can be controlled, or if actions should seek to intercept them between habitats.

- If breeding happens every year then the priority habitats can be identified and actions could be implemented to intercept them between habitats or once again exclude them from those habitats (usually wetlands).

4.3 Preliminary life history and conceptual models for carp habitat use

To manage carp in the upper Murrumbidgee catchment it is useful to describe a conceptual life-history model which summarises scientific knowledge and draws on findings from other locations. The conceptual model is a diagrammatic representation of how carp populations might interact and is a simple way to help focus future research questions or management interventions.

While there is restricted local data on which to base the model it is still useful to gather ideas about how the carp population might function and to ensure all of the relevant habitats are integrated. The conceptual model should generate discussion and be updated as new information is collected and thereby help focus research and management. Preliminary life-history models are presented in Figures 8 and 9 and described below; ongoing discussion and changes to these models are a key to managing carp in the UMDR and the surrounding regional waterways and waterbodies.

Within the UMDR region, there are three major aquatic habitat types available to carp:

1. Rivers, streams, creeks and wetlands;

2. Lake Burley Griffin and other large lake impoundments; and,

3. Small urban ponds and farm dams.

Based on work undertaken elsewhere, a proportion of carp probably move among these habitats. In the Murrumbidgee River and major tributaries (for example, the lower Cotter and Molongo Rivers) carp are likely to be mobile within the main channel. From movement studies undertaken elsewhere in the Murray-Darling Basin (Stuart and Jones 2006, Jones and Stuart 2009) most carp would likely move locally (<5 km), though a considerable proportion might regularly move larger distances (i.e. >20 km) and a small proportion might move at a more regional scale (such as between Burrinjuck Dam and the ACT region).

Some data are available from weekly spring and summer fish trapping in the Casuarina Sands fishway between 1980 and 1991. Carp numbers were generally low (maximum of 91 fish in 133 trap-days) but there was a steady increase over the total sample period (Lintermans 2002), indicating that carp are undertaking movements along the river or between habitats during late spring/summer.

Carp are likely to exploit abundant emergent and riparian vegetation at the river margins, particularly in regulated reaches like the Molonglo River where it joins Lake Burley Griffin. Carp lay their adhesive eggs in the shallow relatively warm waters of the river margins or seasonally accessible urban wetlands and creeks, usually on vegetation. Some areas of the Murrumbidgee River have little or no emergent vegetation, while other sections had significant growth or emergent species such as *Typha* and *Phragmites* (Figure 7). Wetlands and small urban stormwater control ponds, both managed and un-managed, within the catchment had greater levels of emergent vegetation and therefore are likely to be priority locations for successful carp breeding.

Figure 7: Example riverine habitat near Point Hut Crossing showing the river channel and possible spawning habitat composed of *Typha* and *Phragmites* likely to be utilised by carp in the Murrumbidgee River.

In the major lakes, carp are likely to be highly mobile but would not necessarily re-enter the river with any predictable regularity. The margins of the large lakes and small in-flowing creeks would constitute spawning habitat, with carp probably retreating to thermal refuge aggregations in winter given the climate of the region and the cooler winter temperatures relative to other areas of the Murray-Darling Basin.

Other research both nationally and internationally suggests that adult carp movements can be relatively predictable with a general model of:

1. Winter aggregations in the main river and warm lake thermal refuges with a high degree of site fidelity;

2. Spring movements to river and lake margins and wetlands and accessible urban ponds for spawning;

3. Low to moderate levels of dispersal movements for adults and sub-adults along the river through fishways during early spring and late summer respectively.

Figure 8: A preliminary conceptual model of carp movements in the ACT region.

4.3.1 Lake Burley Griffin and other major impoundments

Apart from Lake Burley Griffin, created by Scrivener Dam (see Plate 14), there are several large lakes (> 20 ha) in urban Canberra created by weirs as follows:

- Tuggeranong Creek (Lake Tuggeranong – 57.1 ha)
- Ginninderra Creek complex (Lake Ginninderra – 105 ha, Gungahlin Pond – 23.8 ha and Yerrabi Pond – 26.4 ha (see Figure 10).

See *Plan of Management for Canberra's Urban Lakes and Ponds* (August 2001) for further details about each.

It is likely that additional lakes will be built as urban development continues in Canberra (for example, in the new Molonglo development downstream of Lake Burley Griffin).

Figure 9: A preliminary conceptual model of carp life-history in a major impoundment

Figure 9 describes conceptually how carp are believed to utilise large lake and impoundment habitats in the ACT. In spring, adults move to marginal areas or reedy in-flowing creeks (for example Sullivans Creek and Jerrabomberra Creek - see plates 15 and 16) to spawn on emergent and submerged vegetation. A water level of as little as 100 mm can significantly increase the available spawning habitat.

Plate 14: Scrivener Dam. Photograph: Bill Phillips

In summer and autumn, larvae, young-of-the-year and adults move about the lakes and creeks for feeding, distributing themselves throughout the waterbody further than in spring and winter.

In winter, adults and sub-adults aggregate into small schools, often in deeper areas of the lakes, where the water temperatures are marginally warmer (thermal refuge areas).

Displacement over the dam spillway during higher flows is also likely to occur, increasing carp abundance in downstream habitats and providing an emigration pathway for recruits from these regulated waterbodies.

Lake Burley Griffin is a constructed lake, composed of a series of Basins (the East Basin, the Central Basin, the West Basin, West Lake, Tarcoola Reach and Yarramundi Reach). The lake was constructed beginning in 1960 and completed in 1963 by excavating part of the Molonglo floodplain and construction of Scrivener dam (see Plate 14), resulting in a lake with an average depth of four metres (Andrews, 1990).

Lake Burley Griffin when constructed used different materials for the bank of the lake with six artificial islands also being created in the western end of the complex. On the southern side of the Central Basin, low reinforced concrete retaining walls were used, while on the eastern side, grouted rock walls are found near Commonwealth Park, as well as much of the East Basin. The western half of the complex has sand and gravel beaches to cater for lakeside recreational pursuits, while rocky outcrops, steeply sloping stable shores with water vegetation such as bull rushes were also used in some locations, such as near Yarralumla Bay (on the western edge) (Andrews, 1990).

Figure 10 shows likely habitat use by carp in Lake Burley Griffin. The western and central basins appear to provide minimal likely carp spawning habitat given the limited emergent vegetation with the lake edge being formed in most areas by concrete. The likeliest carp

habitat in this region is the islands and far western banks although this is quite patchy compared to other areas further east.

Because of the depth of the lake, it probably provides substantial over-wintering habitat for carp regionally, with emigration primarily occurring in spring and immigration primarily occurring in autumn from the adjoining Molonglo reach and other connected habitats (downstream migration occurring during flow events and releases from Scrivener dam).

The East Basin connects to the Molonglo River and Jerrabomberra Wetland and these have significant amounts of emergent and riparian vegetation that provide suitable habitat for successful spawning. Because of the availability of habitat due to regulation of the waterbody through Scrivener Dam, it is likely that this habitat is a regional carp recruitment 'hotspot' and could be the focus of future carp management activities beyond harvesting winter aggregations.

Plate 15: Sullivan's Creek (near where it joins Lake Burley Griffin). Photograph: Bill Phillips

Plate 16: Jerrabomberra Creek (near where it joins Lake Burley Griffin). Photograph: Bill Phillips

Figure 10: Likely habitat use by carp in Lake Burley Griffin – conceptual understanding of likely carp spawning habitat and high priority sites for carp management activities in the ACT. Note that Jerrabomberra wetland and related paleochannels are highlighted as likely carp recruitment 'hotspots' within what may be the major habitat supporting regional carp populations. The extent of spawning habitat is partially over-represented due to the scale of the figure and likely spawning habitats are inferred based on preferred habitat and historical observations

Lake Tuggeranong appears to have significant potential carp spawning habitat on the lake edge and given its regulated water level, is likely to provide permanent spawning habitat within it and around its islands (see Figure 11). This permanence, existing spawning habitat and connection to the Tuggeranong weir pool and Isabella pond, probably provides for a self-sustaining and abundant carp population. This suggests the likely need to manage these ponds in combination to mitigate them acting as a regional carp source but at present this is not known. It is likely that some of the Lake Tuggeranong is deep enough to provide appropriate over-wintering habitat for substantial numbers of carp.

Figure 11: Lake Tuggeranong showing presence of potential spawning habitat.

The Ginninderra Creek complex (Lake Ginninderra, Gungahlin pond and Yerrabi pond) operate as an interconnected system of lakes/wetlands (see Figure 12). Downstream movement from Yerrabi Pond to Gunghalin Pond to Lake Ginninderra and other stormwater systems (for example, Giralang wetlands) appears possible due to water movement between these systems. However, because of the weirs and other impediments including 'trashracks' and spillways, the likelihood of carp moving back upstream from Gunghalin to Yerrabi pond or Lake Ginninderra to Gunghalin pond are very low, unless it is human-assisted.

Lake Ginninderra would appear to offer significant habitat on the lake edge and given its regulated water level (see Figure 13) is likely to provide permanent spawning habitat also. This permanence, existing spawning habitat and connection to the Gunghalin and Yerrabi ponds (Figure 14), provides an interesting case-study for planning on-ground carp control. For example, given the connectivity between the various semi-connected ponds (Yerrabi, Gungahlin, Ginninderra and Giralang) following a control effort there remains a strong chance of re-infestation (from any remaining carp) and from the ponds upstream. Hence, the objective of the control effort should target the ponds from upstream to downstream, co-ordinating efforts among the ponds.

Figure 12: A conceptual model of a cascade downstream carp movement in the Ginninderra ponds system. The black bars represent barriers to upstream fish movement.

Figure 13: Lake Ginninderra likely habitat use by carp – note the significant submerged and emergent vegetation within the lake.

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Figure 14: Conceptual carp habitat in Gunghalin and Yerrabi Ponds

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5. 4.3.2 Urban siltation ponds

Canberra also includes a number of smaller urban ponds as follows:

- Tuggeranong: Point Hut Pond (16.7 ha), Gordon Pond (0.1 ha), Isabella Pond (5.7 ha), Lower Stranger Pond (4.1 ha), Upper Stranger Pond (4.4 ha) and Tuggeranong Weir (7.5 ha).

- Belconnen: Dunlop Pond 1 (0.7 ha), Dunlop Pond 2 (0.7ha) and West Belconnen Pond (9.9 ha)

See *Plan of Management for Canberra's Urban Lakes and Ponds* (August 2001) for further details about each.

Conceptually, the urban siltation ponds probably behave largely as enclosed carp systems with the likelihood that there is little or no immigration from adjacent waterbodies. They probably provide marginal winter habitat on the whole but due to their shallow nature have significant submerged vegetation and therefore are likely to provide suitable spawning habitat (see Figures 15-19 below. Such ponds are likely to provide an additional source of juvenile carp to downstream lakes or streams. Further siltation ponds will be constructed in the future and in the design of these carp control should be a consideration.

Figure 15: Conceptual carp habitat in Tuggeranong weir pool

Figure 16: Conceptual carp habitat in Isabella Pond

Figure 17: Conceptual carp habitat in Upper Stranger Pond

Figure 18: Conceptual carp habitat in Lower Stranger Pond

Figure 19: Conceptual carp habitat in Point Hut Pond