Rationale, results and management implications of recent carp research in Australia

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ABSTRACT

Carp are the most prominent pest freshwater fish species in Australia, being relatively large, visible in high numbers and caught by anglers. They have spread rapidly since the 1960s, occur throughout most of southeastern Australia and now dominate many fish populations there, in addition to populations in Western Australia. There is now considerable public pressure for carp control. In response to this there have been several new research initiatives which provide information for management actions. This work includes some information on impacts; mainly confined to wetlands rather than rivers, and involving turbidities and waterplants. More definitive biological information has been obtained on movements, spawning areas and conditions, ageing, and population structure. Carp densities have been correlated with the degree of river regulation and research has been conducted on control options which include: daughterless carp technology, commercial harvest, manipulation of water levels and exclusion. A brief review of these new findings is presented in this paper together with management implications, the future of carp in Australia, and lessons which may be learnt for management of carp in New Zealand.

1. BACKGROUND

Although there are 36 species of introduced fish now recorded or established in Australian inland fresh waters (Arthrington et al. 1999), carp are the largest, most visible and cause the most public concern. Despite not being recognisable by external features, there are four strains of carp in Australia: Koi (mainly in Australian Capital Territory, Tasmanian and Western Australia), Prospect (Sydney), Yanco (Murrumbidgee Irrigation Area) and Boolara. Although carp were first introduced into Australia mid last century, carp populations remained relatively contained until the introduction of the 'Boolara' strain to Gippsland in Victoria in the 1960s. Once this strain was introduced it spread rapidly. Carp are now widely distributed throughout southeastern Australia with smaller populations in Western Australia and Tasmania (Fig. 1). Carp now dominate fish

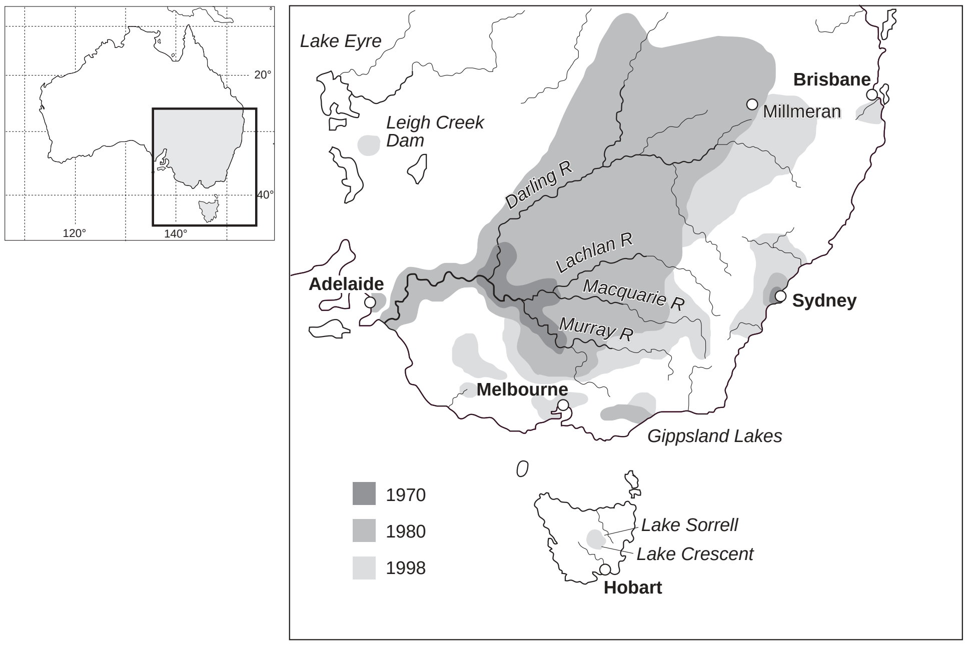

Figure 1. Map of the distribution and spread of carp in Australia from 1970 to 1998 (adapted from Koehn et al. 2000).

communities throughout much of their range particularly in the Murray-Darling Basin.

Carp are not widely harvested in Australia, although commercial harvest is increasing. Because carp are not popular for eating or angling, most anglers have a negative image of them (Koehn et al. 2000) and as a large proportion of the general public would like to see carp eradicated or reduced to low numbers there is considerable public pressure for carp control. These attitudes are partially countered by a much smaller sector of the community who are interested in retaining carp for commercial and/or ‘coarse’ recreational angling. Most attitudes towards carp in Australia are negative. Many conservationists, fish scientists and recreational and commercial fishers, however, believe that carp are used as a scapegoat, being blamed for environmental problems which have other causes.

Initial research on carp was conducted in Victoria in the early 1980s (Hume et al. 1983), then effectively ceased, recommencing with a range of projects in the late 1990s. This paper will briefly outline the results of some of this recent research which will be relevant to the management of carp in both Australia and New Zealand.

2. DISTRIBUTION AND ABUNDANCE

There have been no systematic surveys to determine the distribution and abundance of carp in Australia. Most information has come from data collected from other studies. The most comprehensive of these is the NSW Rivers Survey which surveyed fish species at 80 sites across a wide range of river types and regions in that state (Harris & Gehrke 1997). The initial spread of carp was greatly assisted by floods in the early 1970s, when carp invaded most of the Murray-Darling Basin and southeastern Australia (Fig. 1). They now make up

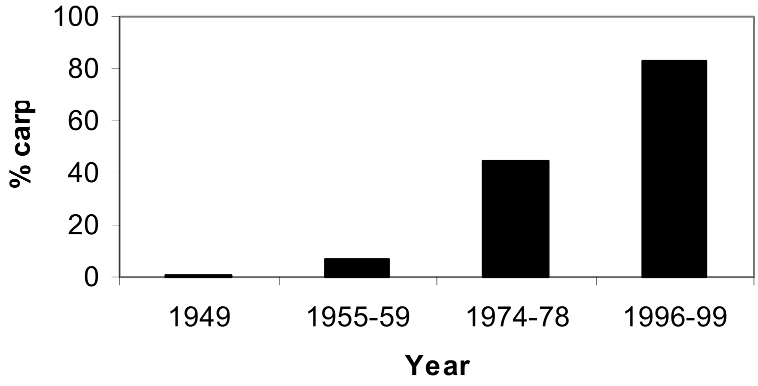

Figure 2. Percentage of carp in catches of large fish species in the Murrumbidgee River for 1949 (from Cadwallader 1977), 1955–59, 1974–78 (from Brown 1984) and 1996–99 (from Harris & Gehrke 1997; NSW Fisheries unpubl. data) (adapted from Koehn 2001).

over 90% of the fish biomass in many areas and have been being recorded in densities of up to one per square metre of water. They have been recorded in a range of habitat types including upland river reaches to 500 m elevation (Harris & Gehrke 1997).

The rapid expansion of carp numbers in the Murrumbidgee River can be seen in Fig. 2, where the Yanco strain had been introduced in 1930s and 1940s and where the Boolara strain invaded in the early 1970s. The percentage of large fish catches comprising carp increased from 1% to the current 83% between 1949 and 1996–99. The non-carp fish in these catches were native species including Murray cod, golden perch, silver perch and freshwater catfish. Concurrent with the increase in carp as a percentage of the fish catch was a decrease in the number of the native species.

A key component of many of these studies and the survey results they have provided has been the use of electrofishing as a sampling technique. Of particular importance in larger rivers and lakes has been the use of boat electrofishing as an efficient and semi-quantitative sampling method.

The invasion by carp in Australia has been associated with habitat disturbance caused by development and environmental exploitation of Australian waters during post-European settlement (Cadwallader 1978), which has favoured invasion by carp and made many habitats less suitable for native fish (Koehn & O'Connor 1990).

3. IMPACTS

There has been limited research in Australia on the environmental impacts of carp and many of the impacts are not clear because they can also be caused by other factors. Although carp are often regarded as having a harmful effect on aquatic habitats and native aquatic species, there is little scientific information on their overall impact and the costs that may be incurred. A summary of evidence for suggested impacts of carp in aquatic habitats in Australian studies has been given in Table 1. Most evidence has been collected from wetlands and billabongs rather than rivers, and very little from controlled experiments.

The biology and ecology of carp are major reasons for their success in Australia. Carp have broad environmental tolerances and thrive in habitats which are disturbed by human activities, such as where river flows are altered, nutrients are enriched and streamside vegetation is cleared. They are highly fecund and breed at lower water temperatures, hence earlier in the spring–summer season, than most native species. Most of the damage caused by carp is through their feeding mechanism which involves sucking up mud from the substrate and sieving it to extract food items. There is clear evidence that through this feeding action carp increase water turbidity and destroy many aquatic plants, especially those with soft stems and shallow roots, and some evidence of increases in

TABLE 1. SUMMARY OF SUPPORTING EVIDENCE FOR SUGGESTED IMPACTS OF CARP IN AQUATIC HABITATS IN AUSTRALIAN STUDIES.
Point scale: * anecdotal evidence only, † survey and/or dietary studies, ‡ field experimental studies (adapted from Koehn et al. 2000).

	HABITAT TYPE	
	WETLAND/BILLABONG	RIVER
Turbidity	‡	†
Macrophytes	‡	†
Macroinvertebrates	‡	*
Phytoplankton concentrations	‡	*
Interactions with native fish	†	†
Stream bank erosion	*	*
Nutrient concentrations	‡	*

water nutrient concentrations. Such damage can threaten endangered species, alter ecological functions and destroy tourism and recreational values of otherwise scenic wetlands.

There is no evidence for carp predation on native fish species and suggestions of interference with the nesting behaviour and eggs of species such as freshwater catfish have not been examined. Carp also carry a number of disease organisms, but any effect on native species is unknown.

Impacts on native fish populations are less certain, but with such biomass and a dominance of fish communities, carp's ecological impact is likely to be substantial. If nothing else, with such large numbers and biomass, they have the potential to occupy large amounts of habitat space. The rapid rise to dominance of carp in fish communities came following the decline of native fish populations. This was because of a range of other factors including: changes to flows, habitat destruction, sedimentation, barriers to fish passage, release of cold water from dams and harvesting (Cadwallader 1978; Koehn & O'Connor 1990). Increases in carp populations were probably facilitated by these already reduced native fish populations, as opposed to a commonly held perception that carp caused these declines. Many of our larger native fish species such as Murray cod and golden perch are voracious predators which could exert high levels of predatory pressure on juvenile carp. However, the current population levels of these species are very low in most areas of their range.

4. MOVEMENT

Carp have been shown to move at any time of year, with some radio-tagged individuals having moved over 200 km in a few months (Koehn & Nicol 1998). Mallen-Cooper et al. (1997) found that the most movement occurred when water temperatures were greater than 24°C. Koehn & Nicol (1998) found carp to be more mobile than the other three native species they studied. Stuart et al. (2001), also using radio-tags, found that no individuals remained stationary, with fish making movements of 600 km downstream and 180 km upstream.

Both of these studies found fish moving between schools of fish and indicate the potential speed with which this species can invade new areas. Harris (1997) showed how the range expansion of carp can be greatly assisted by flooding. Radiotelemetry has been used specifically to study and follow schools of carp in lakes in Tasmania. This has proved successful in using radio-tagged 'Judas' fish to locate schools for capture (J. Diggle, Inland Fisheries Commission Tasmania pers. comm.).

5. SPAWNING

In a study of carp in Barmah-Millewa forest on the Murray River, some carp moved hundreds of kilometers to this floodplain area from winter residences. This floodplain area, which is often artificially flooded by irrigation releases, provides shallow, submerged vegetation which is ideal carp spawning habitat. This was one of the reaches of the Murray where spawning and recruitment of carp was more consistent. High numbers of juvenile carp were collected in the river downstream, compared with few in the river upstream, indicating the importance of this area as a spawning habitat (Stuart et al. 2001). Adamek (1998) documented the use of grass areas as spawning substrates in the Murrumbidgee Irrigation Area.

6. HABITATS

Gerhke et al. (1995) found increased carp numbers to correlate with amount of environmental disturbance, notably degree of river regulation. Other environmental damage poses negative effects on native fish species (including predators), hence benefiting carp. As carp have taken advantage of poor habitat condition and reduced native fish populations, the improvement of aquatic environments to favour native species is seen as a long-term option. Provision of more natural water flows, for example, can have direct benefits for native fish, as well as making conditions less favourable for carp. A wide range of catchment management factors also influence the condition of our aquatic habitats.

7. POPULATION STRUCTURE

A project being undertaken by Fisheries Victoria is currently investigating the population biology of carp in an irrigation channel, a river, a wetland and two lakes in Victoria (Brown et al. 1999). It has found regular recruitment to the Barmah and Murray Rivers' wetland stocks, but more sporadic recruitment in other rivers. Carp are relatively slow growing and a long-lived species, with Murray River stock still containing 23-year-old fish possibly from the original invading year classes. Evidence of first reproductive ages are 2+ for males and 3+ for females. Aging has been successfully undertaken by the removal and examination of otoliths (Vilizzi & Walker 1998, 1999).

Understanding the drivers of population structure is important both for targeting recruitment and the dispersal of many genetic or other biological control vectors throughout populations.

8. CONTROL OPTIONS

Potential control techniques for carp include: removal (commercial and recreational), environmental rehabilitation, environmental manipulation, bio-manipulation (e.g. predators), exclusion, poisoning and future biological controls such as immunocontraception, molecular manipulations, fertility control, transgenic manipulation, hormonal treatment, daughterless technology and sterility. These and other options are explored more fully in Roberts & Tilzey (1997) and Koehn et al. (2000). Many of these 'biocontrol' options have yet to be developed and tested, and are therefore not available at present.

Removal by commercial operators and anglers is currently being encouraged by several state fisheries agencies. Commercial harvest from Gippsland lakes has remained at between 370 and 640 t for the past decade without any noticeable decline in catch (MAFRI 2000). Thresher (1997) recommended that a population needed to be fished to less than about 10% of virgin biomass before removal could be seen as an effective control option. This would rarely be possible whilst remaining commercially viable and would not be achievable at all under most Australian situations. Given the remote and difficult range of habitats that carp now occupy, commercial harvesting is only likely to contribute to their control in certain localised areas and is unlikely to achieve wide-scale population reductions. This is particularly so in many of Australia's inaccessible, large, snaggy rivers.

Work on daughterless carp technology is currently being undertaken by CSIRO in Tasmania.

Water-level reductions have been successful in preventing spawning in Tasmanian lakes, and other trials conducted by the Cooperative Research Centre for Freshwater Ecology have shown that desiccation of eggs can occur within hours if water levels are reduced. Given that hatching times are limited to a couple of days, exact timing is required for this to be successful.

Exclusion of adult carp using mesh barriers has been carried out in several wetland areas to prevent recolonisation, and the use of a small weir has had the same effect on a small stream (Koehn et al. 2000). However, such barriers can also prevent the movement of native species.

Poisoning may still be applicable to small, new incursions, but is difficult and has other environmental problems on the wider scale. This option was considered but later disregarded for Tasmanian lakes although it has been used on smaller scales previously for carp and other species (Sanger & Koehn 1997; Koehn et al. 2000).

9. MANAGEMENT IMPLICATIONS

- The range of carp is still expanding and new habitat areas will continue to be affected.
- There are high densities and biomasses of carp which are causing damage in many areas.
- Carp are a long-lived species. Therefore, without harvesting or other forms of destruction, current individuals may persist for 40+ years even if recruitment is prevented.
- They have high mobility and can colonise or recolonise areas quickly.
- Carp take advantage of flooded spawning areas, and limiting access to these areas can reduce recruitment.
- Harvesting is not a feasible control option in many environments.
- Information on contributions to bank erosion is inconclusive.

10. THE FUTURE OF CARP IN AUSTRALIA

There remain many suitable habitats in Australia in which carp do not yet occur. Their spread to date has been rapid, and increased knowledge of their movement patterns indicates their ability to colonise is great. Only relatively recently they have been introduced into Tasmania and very recently have been recorded in the Glenelg and Hopkins catchments in Victoria. With likely vectors including anglers and flooding, there is great potential for further spread. There is much concern regarding their potential to enter the Cooper drainage basin, especially given the recent floods. Once introduced into a new river basin they will be difficult to contain. It is highly likely that carp will continue to expand their range in Australia.

11. LESSONS FOR NEW ZEALAND

- Consideration should be given to the differences between Koi and Boolara strains of carp. New Zealand carp are thought to be Koi (McDowall 1997), but this should be confirmed.
- Range and population expansions can happen quite quickly with their mobility and ability to recolonise.
- As New Zealand has few large catchments, cross-catchment transfers will be the main method of spread. Prevention of spread to the South Island needs to be considered.
- Environmental damage can be severe with high densities/biomasses.
- Angling is one of the most popular recreational activities in Australia and the dominance of carp in many fish communities has the potential to reduce angler participation, particularly where numbers of preferred native fish species are also low. The introduction of carp into prime trout fishing waters in Tasmania caused concern for the local tourist industry.
- Are there issues relating to indigenous culture and rights?

- Harvesting or removal may be easier in smaller, shallower, New Zealand river habitats. The use of electrofishing boats should be considered.
- New Zealand is a smaller country, therefore spread may be quicker.
- New Zealand water temperatures are lower, which carp may take advantage of. Spawning times and success may be altered.

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