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Introduced Cyprinid (Carp) Fishes in Western Australia and Their Management Implications

K. R. Breheny

Edith Cowan University

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INTRODUCED CYPRINID (CARP) FISHES IN WESTERN AUSTRALIA
AND THEIR MANAGEMENT IMPLICATIONS

BY

Keith R. Breheny

A Thesis Submitted in Partial Fulfilment of the Requirements for the Award of
Bachelor of Science (Environmental Management) Honours
at the Faculty of Science, Technology and Engineering,
Edith Cowan University

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Date of Submission: 8th November, 1996.
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Abstract

Australia has no native cyprinid species and five introduced species have established self-sustaining populations. This study examines the cyprinid species present in Western Australia and estimates their distribution. The potential for introduced cyprinids to cause environmental impacts is explained and ameliorative action recommended.

The presence and distribution of cyprinid species is assessed by examination of museum records, published literature, reported collections, anecdotal evidence and sampling of wetland habitats. Two species, *Carassius auratus* (Goldfish) and *Cyprinus carpio* (Koi carp) are believed to have established populations and a map of estimated distribution is compiled.

The capacity for introduced carp to undergo sudden population explosions, long after initial introduction, has been clearly displayed in New Zealand and in the eastern states of Australia. Carp’s unique biological and morphological characteristics are examined and the capacity for these characteristics to lead to wider dispersal and environmental impacts in Western Australian wetlands is assessed. The assessment is supplemented by a literature review and a compiled bibliography of published Australian research literature.

Principles of effective management of cyprinid populations are discussed and recommendations for amelioration of potential impacts is provided. This is a preliminary study and suggests further avenues of essential research.
Declaration

I certify that this thesis does not incorporate without acknowledgement any material previously submitted for a degree or diploma in any institution of higher education; and that to the best of my knowledge and belief it does not contain any material previously published or written by any other person except where due reference is made in the text.

Signature

Date 8 November 1996
Acknowledgments

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This work is dedicated to the memory of my father, Keith Snr., and my daughter, Elysia Fleur, who were with me when I needed them most.
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CHAPTER 1

INTRODUCTION

Background.

Cyprinid fishes constitute the greatest number of all freshwater teleost fish species and despite their great diversity in Asia, Europe, Africa and North America, there are no native cyprinids in Australia, New Zealand or New Guinea. Cyprinids were introduced to Australia 150 years ago probably as a result of dissatisfaction with native sport-fish or a desire to retain homeland familiarities (Brumley, 1991).

Five species of introduced cyprinids have successfully colonised the coastal and inland waterways, wetlands, and lakes of Australia (Fletcher, 1986). The introduction of *Carassius auratus* (Goldfish carp), *Cyprinus carpio* (Common or European carp and Koi), *Tinca tinca* (Tench) and *Rutilus rutilus* (Roach) began in the mid-1800's in New South Wales, Victoria, South Australia (Brumley, 1991) and Western Australia (Coy, 1979). *Puntius conchonius* (Rosy barb) was first reported in Queensland in 1970 (Arthington, Milton and McKay, 1983).

Two species of Cyprinidae have been recently reported in Western Australia, *Carassius auratus* (Sarti and Allen, 1978, Coy, 1979 and Fairhurst, 1993), and the Koi strain of *Cyprinus carpio* (Department of Fisheries and Wildlife, 1972 and 1976 and Lawrence, 1993). Coy (1979) indicated that a further species, *Carassius carassius* (Crucian carp) was introduced to the south-west of Western Australia in 1840. Allen (1982) also refers to the presence of *C. carassius* but there is no other literature which supports the presence of populations of this species in Western Australia. *Tinca tinca* was also introduced (Miller, 1980).
Cyprinid introductions were recorded in Australia in the 1840’s but it was not until the 1960’s that the hybridisation of two or more varieties of the European carp, *Cyprinus carpio*, produced the Boolarra variety (Arthington, 1991). They spread dramatically throughout the Murray-Darling River system of eastern Australia (Morison and Hume, 1989). The initial spread of the Boolarra variety has been followed by continued rapid expansion into all States and Territories except the Northern Territory and Western Australia. In 1977, the carp were introduced into Tasmania (Anderson, 1977). The impact of these invasion’s has been so serious as to warrant several costly (and unsuccessful) attempts in eastern Australia to eliminate the carp from the rivers and wetlands (Morison and Hume, 1989).

The Koi variety of *Cyprinus carpio* has gained popularity as an aquarium species (Balon, 1995) and, in New Zealand in 1983, this variety rapidly spread and established self maintaining populations in the Waikato River (Brumley, 1991). Earlier attempts to eradicate the fish from dams and ponds where they first appeared, were unsuccessful. Brumley (1991) cites a personal comment by S. Hanchet indicating that a research program assessing means of eradication and control was being recommended in 1988, five years after the Waikato River population had become established.

Koi is now found in numerous ponds and ornamental lakes in Perth, Mandurah, Bunbury and other urban locations (pers. obs.). The implications of a similar spread of this variety of *Cyprinus carpio* into the wetlands and waterways of Western Australia deserves urgent consideration, given that the sudden expansion in eastern Australia and New Zealand was unprecedented, unexpected and occurred a century after the carp were initially introduced.
According to Arthington and Mitchell (1986), cyprinids possess the biological attributes of successful invaders and Australia provides a wide range of receiving environments. Cyprinids are capable of withstanding a wide range of environmental conditions, and therefore can invade and persist in a wide range of habitats (Courtenay, 1990-a).

Richardson, Whoriskey and Roy (1995) and Roberts, Chick, Oswald and Thompson (1995), reported Cyprinus carpio responsible for turbidity increasing by an order of 10 in controlled experimental ponds. Fletcher, Morison, and Hume, (1995) reported C. carpio was not responsible for fluctuations in turbidity in sample sites and that natural fluctuations in water levels was responsible for increases in turbidity in many areas subjected to carp introductions.

Breukelaar, Lammens, Klein-Breteler and Tatrai, (1994), reported that suspended sediments increased linearly with biomass of cyprinids and that benthivorous feeding reduced as alternative food (zooplankton) became available. Crivelli (1995) offered the possibility that a shift from benthivorous feeding to opportunistic predation of zooplankton reduced predation of phytoplankton and created an increase in phytoplankton blooms.

Cyprinids feed by sucking up sediments and foraging for food in the suspension (Crivelli, 1995, Breukelaar, Lammens, Klein-Breteler & Tatrai, 1994, Reynolds, 1979 and Richardson & Whoriskey, 1991). This form of foraging alters the structure and dynamics of the benthic community. Wilcox and Hornbach, (1991), reported reductions in community diversity, evenness and richness in experimental samples, and attributed the reductions to carp-induced predator-mediated community modification and, to a lesser extent, direct predation.

The impact of carp on emergent and submergent aquatic vegetation has been well
documented. The uprooting of 100% of (uncaged) emergent plants and 45-90% reduction in stem counts of submerged plants was attributed to the diet and foraging habit of *Carassius auratus* in experimental ponds (Richardson, Whoriskey & Roy, 1995). Roberts, Chick, Oswald and Thompson, (1995), recorded carp directly effecting 2 of the 5 plant species tested and that up-rooting, and not herbivory, was the most likely reason for plant loss.

Breukelaar, Lammens, Klein-Breteler and Tatrai, (1994), reported that the measured increases in chlorophyll *a*, Total P and Kjeldahl-N all showed a positive correlation with carp biomass. Carp reduced levels of percentage saturation of dissolved oxygen and lowered pH levels according to Wahab, Ahmed, Aminul Islam, Haq, and Rahmatullah, (1995). They caused increases in water temperature (Roberts, Chick, Oswald and Thompson, 1995).

There is no published research specifically dealing with cyprinid fishes in Western Australia and this study forms a preliminary foundation for future studies.

**Aims**

The aim of this study is to assess the risk posed by cyprinids to the wetlands and river environments of Western Australia. Specifically:

- To determine which species are present,
- To clarify the taxonomy of the species present,
- To determine the distribution of cyprinids in Western Australia,
- To assess whether populations are self-sustaining,
• To review the biology of cyprinids and assess the impact of this fish in
  Western Australian wetlands,
• To evaluate the potential risks posed by introduced cyprinids in Western
  Australia.

An underlying goal of this study is to generate awareness of the potential
environmental hazards facing Western Australia as a result of cyprinid
introduction.
CHAPTER 2

TAXONOMY

General Taxonomy.

Cyprinids are a taxonomically complex group and, according to Howes (1991), their taxonomy and classification is unsatisfactory. Their taxonomy is further complicated as several different common names refer to the same species. This is the case with *Cyprinus carpio*, which may be called Common carp, King carp, European carp, Koi, Singapore carp, Mirror carp, Leather carp, Prospect strain, Boolarra strain, Yanco strain, River carp and wild carp.

According to Arthington (1991) and Brumley (1991), five cyprinid species have established populations in Australia, and their taxonomy is shown in Figure 2.1. The Super Order Ostariophysi is sometimes referred to as a Division (Howes, 1991) and consists of the series Anatophysi and the mainly freshwater series Otophysi. Otophysi consists of four co-orders and the co-order Cypriniformes contains 2,422 species in the single Sub-order Cyprinoidei (sometimes omitted due to absence of other Sub-orders).

Within Cyprinoidei are six Families including Cyprinidae which constitutes 80% of the Cypriniforme species and comprises the two sub-families Cyprininae and Leuciscinae. These two sub-families constitute the taxa of cyprinid species with reported self-sustaining populations found in Australia.

The genera *Cyprinus*, *Carassius* and *Puntius* are in the sub-family Cyprininae (Barbin lineage) and *Rutilus* is in the sub-family Leuciscinae (Abramin lineage). The genus *Tinca* was allotted its own sub-family Tincinae (Howes, 1991 citing Kryzonovski,
Figure 2.1. Taxonomy of Cyprinid Species Introduced into Australia

NOTE: * Only those with reported established populations in Australia are listed.
** The status of this Genus is incertae sedis (uncertain or disputed).

1947) but, according to Howes (1991), is also attributed to Cyprininae or Leuciscinae in various literature. It does not readily hybridise with either of the genera *Cyprinus* or *Carassius* and has been deemed by Howes to be *incertae sedis*. *Cyprinus* x *Carassius* hybrids are common and are considered fertile. The major distinguishing variation is the development of posterior barbels in hybrids whereas *Cyprinus* has both posterior and anterior barbels and *Carassius* has no barbels.

**Specific taxonomy and basic biology of species introduced into Western Australia**

Investigation of anecdotal information obtained in this study has found instances of incorrect identification of carp. Most incorrect identifications are related to *Carassius auratus* (goldfish) reported as *Perca fluviatilis* (Redfin perch) or to orange coloured fish which may be *Cyprinus carpio* being reported as goldfish. Black or darker coloured fish were sometimes called 'Crucian carp' (*Carassius carassius*) or are mistakenly dismissed as not being goldfish because they were not orange or gold coloured. A billabong beside the Blackwood River at Nannup contains numerous *Carassius auratus* (pers. obs.) but for 11 years, the fish were presumed to be *Perca fluviatilis* (H. Pocock, Nannup Tourist Information Bureau, pers. comm.).

Most problems of identification are related to visual similarities between species. Further complications arise with hybridisation or where a single species develops phenotypes suited to specific habitat types and possibly as a result of selective predation of brighter coloured, easily seen fish. Loss of bright colours regularly occurs in feral populations of *Carassius auratus* (Plate 3), which develop darker green/grey to black colours (Lake, 1967). Loss of bright colour also occurs with *Cyprinus carpio* (Koi variety) which adopt bronze or olive/gold colours in feral populations (Brown, 1996).
The presence or absence, number and configuration of barbels, the number of scales on the lateral line and the configuration and shape of the fins are the basic characteristics used for identification. Differentiating between Goldfish and Crucian carp requires anal fin ray and/or gill-raker counts.

Biological information presented here is compiled from Eastern Australian and overseas literature. The information may be relevant to Western Australian populations, although this has not been tested and must be treated accordingly. The presence or absence of *Carassius carassius* (Crucian carp) in Western Australia has not been confirmed and its inclusion is based on early reports of introduction (Coy, 1979) and Museum of Western Australia records of collection. *Tinca tinca* were introduced into Lake Monger but do not appear to have survived (Dr. M. Lund, Edith Cowan University, pers. comm.) and *Rutilus rutilus* are not confirmed as present and their general biology is included here as a guide. A summary of basic diagnostic features for identification of the cyprinids present in Australia is provided in Table 2.1.

### Table 2.1. Summary of diagnostic features of the cyprinids in Australia

<table>
<thead>
<tr>
<th>Species</th>
<th>Colour</th>
<th>Lat-line scales</th>
<th>Anal fin rays</th>
<th>Barbels</th>
<th>1st gill-arch raker-count</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Carassius auratus</em></td>
<td>Aquarium: Bright colours and Orange, some mottled. Feral: Orange or olive-bronze, darker shades to Black</td>
<td>26 - 29</td>
<td>5 - 6</td>
<td>0</td>
<td>35 - 40</td>
</tr>
<tr>
<td><em>C. carassius</em></td>
<td>Olive-green to reddish-brown dorsal, lighter ventrally. Possibly darker lateral spot near the tail</td>
<td>35 - 38</td>
<td>6 - 8</td>
<td>0</td>
<td>26 - 31</td>
</tr>
<tr>
<td><em>Cyprinus carpio</em></td>
<td>Aquarium: Bright colours with some mottled and spots. Feral: Bronze or olive-gold, lighter beneath</td>
<td>34 - 37</td>
<td>5 - 6</td>
<td>2 pr. (4)</td>
<td>-</td>
</tr>
<tr>
<td><em>Rutilus rutilus</em></td>
<td>Silvery scales with reddish ventral fins and dusky dorsal and caudal fins</td>
<td>&gt;40</td>
<td>10 - 11</td>
<td>0</td>
<td>-</td>
</tr>
<tr>
<td><em>Tinca tinca</em></td>
<td>Olive-brown to dark grey dorsally and lighter ventrally. (rarely yellow-orange)</td>
<td>&gt;60</td>
<td>6 - 7</td>
<td>1 pr. (2)</td>
<td>-</td>
</tr>
</tbody>
</table>

*Cyprinus carpio* (Common carp, Koi and other variations)

Males mature at 2 to 3 years (300 mm), and females at 3 to 4 years (350 mm). Spawning occurs through Spring and Summer (Brown, 1996) when temperatures are $>18^\circ$C (Wood, 1994). The adhesive cream or yellow coloured eggs are 2 mm in diameter according to Lake (1967) or 0.5 mm according to Brown (1996). The eggs are externally fertilised by males who spray milt over the eggs as the female releases them in clumps on any available surface. Spawning usually takes place in shallow water, accompanied by thrashing at the surface. The number of eggs produced varies with the size of the fish and can range from 80 000 to more than 1 000 000 (Lake, 1967 and Brown, 1996). Temperature influences hatching time and ranges from 2 days at $25^\circ$C to 6 days at $18^\circ$C. Growth varies according to food availability and environmental conditions. The nominal weights and lengths for a range of age classes, according to Brown (1996), are shown in Table 2.2.

### Table 2.2. Nominal weights and lengths for age classes of *Cyprinus carpio*

<table>
<thead>
<tr>
<th>Age (years)</th>
<th>Length (mm)</th>
<th>Weight (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>200</td>
<td>100</td>
</tr>
<tr>
<td>2</td>
<td>300</td>
<td>500</td>
</tr>
<tr>
<td>3</td>
<td>400</td>
<td>800</td>
</tr>
<tr>
<td>6</td>
<td>650</td>
<td>3 800</td>
</tr>
</tbody>
</table>

Banarescu & Coad (1991) reported a carp aged $>50$ years, although scale growth rings from the fish indicated an age of $>250$ years. Banarescu & Coad question the accuracy of scale growth-ring counts for ageing and Pierce, (1984-a and 1984-b), confirms the need for alternative methods for determining age. According to Wood (1994), common carp may reach $>35$ kg and $1.5$ m TL, and Lake (1967) reported specimens of over 45 kg.
Carp prefer permanent lakes, wetlands and billabong habitats with warm, still waters and silty bottoms. They are rarely found in clear, fast-flowing cool water (Brown, 1996).

All carp tolerate wide ranges of environmental conditions. Temperature tolerance spans 4°C to 35°C (Korwin-Kossakowski, 1992) with optimum temperatures within the range 15-30°C. Carp tolerate ion concentrations up to one-third the concentrations of seawater (Horvath, Tamas and Seagrave, 1992) and Wieser (1991) confirms the upper limit of salinity tolerance as 12000 to 15000 mg L⁻¹. Korwin-Kossakowski (1992) subjected newly-hatched fry to high pH levels (>pH 9) and to dissolved oxygen levels as low as 0.5 mgL⁻¹ and reported >50% survival.

There are no reports of long-distance spawning migrations other than pre-spawning (Spring) movement to shallow marshes or swamps (Reynolds, 1987). Juveniles of *Cyprinus carpio* (up to 200 mm) become highly mobile at 20°C (Brown, 1996).

Pelicans, cormorants, water rats, carnivorous fish and humans are known predators. According to Brown (1996), there is evidence of an inverse relationship between numbers of carp and numbers of predators (especially piscivorous fish). The cause of this inverse relationship has not been reported and research into the range of possible factors (e.g., biomass domination, habitat disturbance, preferential feeding) may be valuable in assessing species interaction.
Species: *Cyprinus carpio*, Linnaeus
Common name(s): Koi, Singapore carp, Japanese carp.

![Identifying features of Cyprinus carpio.](image)

**Figure 2.2. Identifying features of Cyprinus carpio.**

**Colour:** Ranges from brightly-mottled multiple colours to black or white or bright single colours, to shades of olive/gold/bronze or light drab gold (see Plates 1 and 2). Lower parts are often light yellow or white in feral populations.

**Variations:** The varieties Koi, Prospect, Boolarra and Yanco have similar morphology and require genetic identification to differentiate although Koi and Yanco are more likely to be brightly coloured. Figure 2.3. shows other forms of *Cyprinus carpio* which may be less common in Western Australia.
Species: *Cyprinus carpio*, Linnaeus.

Other Common Variations

Common carp
(or King carp)

Wild carp
(European carp)

Mirror carp

Leather carp

Figure 2.3. Representations of other common forms of *Cyprinus carpio*

(Adapted from Wood, 1994)

Colours: Usually drab single colour of olive/bronze with lighter lower parts.

Variations: The Mirror carp have several forms. The fully scaled form is covered in large, irregular shaped shiny scales; the scattered form has individual randomly located scales; the linear form has a continuous line of scales along the lateral line; and the plated form has a few very large plated scales along the lateral line. Leather carp have no (or very few) scales.
Plate 1. *Cyprinus carpio* (Koi)

Plate 2. *Cyprinus carpio* (Koi)

Plate 3. *Carassius auratus* (Goldfish)

Plate 4. *Carassius auratus* (Goldfish) Juvenile
**Carassius auratus** (Goldfish carp)

Goldfish carp prefer still or stagnant water or slow-flowing streams. They spawn in spring and summer, and according to Lake (1967) spawning usually occurs at temperatures above 15°C and often after sunrise. Coy (1979) claims much higher water temperatures (25°C) are required for spawning. This variation requires further research to more accurately define spawning times. Eggs are 1 mm diameter, adhesive and are attached to any available submerged substrate or vegetation surface. The hatched fry feed on plankton and small fish feed on microcrustaceans while the diet of older fish includes algae, detritus and aquatic invertebrates (Scott, Glover & Southcott, 1980) and plant matter (Hume, Fletcher & Morrison, 1983).

Hume, Fletcher & Morrison (1983) report the size-range of *Carassius auratus* caught in a major survey of Victorian rivers and lakes to be 60 to 300 mm. They reached maturity at 53 mm (male) and 65 mm (female). Growth rates increased to 0.4 mm d⁻¹ in warmer temperatures after flooding. Lake (1967) indicates that maturity may be reached at 1 year and the species are long-lived given suitable habitat. Banarescu & Coad (1991) cite a specimen in England surviving for over 40 years.

Species: *Carassius auratus*, Linnaeus.
Common name: Goldfish

**Adult *Carassius auratus***
- Deep body
- Single dorsal ray
- Serrated spine
- 26 to 29 scales along lateral line

**Juvenile *Carassius auratus*** (Body not deep but other features similar)

Figure 2.4. Identifying features of *Carassius auratus* (adult and juvenile).

**Colours**: Variation in adults range from typical orange/gold to mottled and multiple colours. Also single colours including white and yellow, and darker colours through to black (see Plate 3). Juveniles are usually drab olive-brown with orange fin-tips (see Plate 4).

**Variations**: Distinguishing features include the anal fin having a serrated spine at the anterior of the fin with 5-6 branched rays posterior of the spine. The first gill arch has 35-40 gill rakers (Wheeler, 1978).
*Carassius carassius* (Crucian carp).

This species is very similar to *Carassius auratus*. Lake (1967) states that eggs are 0.8 mm in diameter and that the main distinguishing features are a more laterally compressed, deeper body with larger scales and a blotch on the caudal peduncle, anterior to the tail fin. According to Wheeler (1978), the first gill arch has 26-31 gill rakers and the anal fin has 6-8 branched rays. Wheeler also states that Crucian carp grow larger and faster than goldfish. Coy (1979) indicates that 'true Crucians' are dark coloured, presumably referring to a comparison between Crucian and goldfish carp.

Banarescu & Coad (1991) state that the species are extremely tolerant of wide ranging environmental conditions and can survive several weeks in mud. Penttinen and Holopainen (1992) indicated the capacity for Crucian carp to survive for six-month periods without food in anoxic conditions. Sibbing (1991) and Lammens and Hoogenboezem (1991) confirm the similarity of salinity, dissolved oxygen and temperature tolerance limits of Crucian, goldfish and common carp.

Fletcher (1986) and Brumley (1991) discuss the likelihood that earlier reports in Australian literature of Crucian carp were probably misidentified specimens of *Carassius auratus*. Fletcher (1986) further states that no Crucian carp were collected in un-published surveys (by Tilzey, Hume, Morrison and Fletcher) between 1967 and 1985 in south-eastern Australia. This uncertainty has implications for identification of species present in Western Australia given the statement by Coy (1979) that the first cyprinid introductions to the south-west of Western Australia were Crucian carp and given collected specimens in the Museum of Western Australia.
Species: *Carassius carassius*, Linnaeus.

Common name: Crucian carp

![Identifying features of Carassius carassius.](Adapted from Wood (1994) p.134)

**Figure 2.5. Identifying features of Carassius carassius.**

**Colour:** Olive-green or reddish-brown on the back graduating to lighter yellowish shades ventrally (Wheeler, 1978).

**Variations:** Visual features are very similar to *Carassius auratus*. The main distinguishing features of *C. carassius*, according to Wheeler (1978) are a slightly convex dorsal fin (concave in *C. auratus*), the anal fin has 6-8 branched rays (5-6 in *C. auratus*) plus the serrated spine and the first gill arch has 26-31 gill rakers (35-40 in *C. auratus*).

The convexity of the dorsal fin is verified in Lake (1967) but not supported in representations of the species in Wood (1994). The body is more compressed and deeper than goldfish, with larger scales and a blotch on the caudal peduncle, anterior to the tail fin (Lake, 1967). Identification of *Carassius carassius* may be very difficult without close examination and a count of the number of gill rakers.
**Rutilus rutilus** (Roach).

Roach are a deep-bodied fish reaching 2 kg and are known to hybridise with bream (Wood, 1994). They thrive in still water, canals and slow-moving streams and rivers and prefer habitats with submerged vegetation. They lay sticky yellow eggs on aquatic plants and are slow-growing in temperate climates, reaching 500g in 9-10 years (Wood, 1994). Allen (1989), when referring to Australian introductions, indicates common TL of 15-20 cm and maximum size of 45 cm TL (2 kg).

Roach are omnivorous and feed mainly on plants, insects and fish fry (Wood, 1994).

**Species: Rutilus rutilus** (Linnaeus)

Common name: Roach

![Identifying features of Rutilus rutilus](Adapted from Wood, 1994, p. 137)

**Figure 2.6. Identifying features of Rutilus rutilus.**

**Colour:** Silvery with red eyes, red pectoral, pelvic and anal fins and dusky dorsal and tail fins (Wood, 1994).

**Variations:** Readily discerned from the other cyprinids found in Australia by the shorter length of the truncate angular dorsal fin and smaller scales.
**Tinca tinca** (Tench)

Tench are slow-growing fish but may reach 70 cm TL and weigh 9 kg but are commonly 30 cm TL (Allen, 1989) and 2 kg (Wood, 1994). According to Scott, Glover & Southcott (1980) tench prefer still, muddy backwaters but sometimes inhabit upper reaches of streams and rivers (Wood, 1994). They spawn in late spring to early summer and the adhesive eggs which, according to Banarescu and Coad (1991), are poisonous, are laid on aquatic plants to hatch after 6-10 days. Their diet includes aquatic plants, molluscs, crustaceans and insects.

**Species: Tinca tinca** (Linnaeus)

Common name: Tench

![Diagram of Tinca tinca](image)

(Adapted from Wood (1994) p. 130)

**Figure 2.7. Identifying features of *Tinca tinca*.**

**Colour:** *Tinca tinca* are variable but usually olive-brown or dark grey above, lighter below and markings absent (Scott, Glover & Southcott, 1980). A rare yellow/orange variety with pink tinged fins and scattered black markings (Wood, 1994).
CHAPTER 3

THE HISTORY AND INTRODUCTIONS OF CYPRINID FISHES

The History of Cyprinid Fishes

Cyprinids are the most specious of all freshwater teleost fish (Sibbing, 1982, and Howes, 1991) and occur world-wide except in the Polar regions and on most oceanic islands (Brown, 1996). Native cyprinid species occur in all continents except Australasia (including New Zealand and New Guinea), South America and in Madagascar (Brumley 1991). The native species in South-East Asia extend to Java and Borneo but no further east.

Fossil records of ancestral Cypriniformes are from the Eocene age (58-37myBP) in Europe, the Oligocene age (37-24myBP) in North America and the Miocene age (24-5myBP) in Africa (Cavender 1991).

According to Billard (1991), cyprinids probably arose in China migrating south and west replacing early characoids and siluroids and crossing to Borneo. They reached Africa, after the South American and African continents had separated (130myBP) thus preventing further dispersal.

Common carp originated in the Black, Caspian and Aral sea drainages and spread east into Siberia and China and west to the Danube River (Balon, 1995). Earliest historical records of carp are from the sacred fish ponds of Mesopotamia around 3000 BC. The cultivation of common carp is described by Fan Li in China in 473 BC (Billard,1991). Culture of common carp was practiced until banned by the Tang Dynasty (618-907AD), and, to maintain food resources, alternative carp species were developed with specific habitat and food requirements. According to Billard (1991),
this specialisation led to the development of the polyculture form of aquaculture. The Ming Dynasty (1522-1566) fostered the greater diversity of polyculture and current world aquaculture still utilises principles developed by the early Chinese aquaculturists.

Breeding of common carp continued outside China and they ultimately spread through Greece and Italy during the Roman Empire and through Europe in monastries during the Middle Ages (Balon, 1995). Introduction into Japan in the 13th Century (the Kumakura period), led to the development of carp as a major food source. In Japan, the monetary value of the recently developed aquarium variety ‘nishikigoi’ carp (called ‘swimming flowers’ or Koi) now exceeds that of carp food culture (Balon, 1995).

Carp were introduced into England in the late 15th Century and into America in the early 19th Century (Billard, 1991). According to Welcomme (1988), cyprinids constitute 10% of the 1354 introductions of exotic fish species recorded since the late 1800’s (237 species in 140 countries). Common carp have been introduced into 59 countries since 1870. The number of introductions peaked in 1910 and again in the 1960’s when grass carp (Ctenopharyngodon idella) were introduced for the control of aquatic macrophytes (Clugston & Shireman, 1987), and other cyprinids were introduced for the control of aquatic microalgae.

Cyprinid fish culture dominates world aquaculture. All major farmed cyprinids are introduced Asian species and constitute 33% of all fish species cultured in more than 60 countries. They produce 70% of the weight of cultured fish world-wide - 5 million tonnes in 1990 (NSW Fisheries 1996) and 6.6 million tonnes in 1992 (Billard 1991) - and provide over 90% of Chinese cultured fish production.

Most culture is for food with some production for biological manipulation of water
quality, baitfish and fish research. Major production is in Asia and Europe with some in the Middle East and Africa, and minor production in Indonesia, Thailand and North America. The remaining commercial production is limited to the aquaria industry which produces substantial numbers of display and hobby quality carp (especially goldfish and Koi) along with many other cyprinid fish species.

**History of Cyprinids in Australia**

Anecdotal reports of the first introductions to Australia (see Table 3.1.) are from the 1850’s in New South Wales and the 1870’s in Victoria (Brown, 1996). The first documented record of *Cyprinus carpio* was in 1872 by the Acclimatisation Societies of Victoria (1862) and New South Wales (1865) referring to the presence of European carp and confirming the 1850 and 1870 introductions (Olsen, 1995). Stead (1906, p.38) reported *Carassius auratus* as “common in most cities and towns”, in nearly all rivers (coastal and inland) and in the smallest creeks, “almost as ubiquitous as the Sparrow on the land”. Stead (1906) also referred to the presence of roach and tench which were introduced along with *Betta pugnax* (the fighting fish).

Stead (1939-40) published details of his introduction of *Cyprinus carpio* into the Prospect Reservoir, part of Sydney’s domestic water supply. He purchased specimens from a vendor in Sydney that were mixed with an imported goldfish consignment and, after noting their rapid growth-rate in an aquarium, placed them into the reservoir. This introduction has culminated in a self-sustaining population of the Prospect strain of European carp.
Table 3.1. Introductions of Cyprinid Species into Australia

<table>
<thead>
<tr>
<th>Species</th>
<th>Date</th>
<th>Reason for Introduction</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Tinca tinca</em> (tench)</td>
<td>1876</td>
<td>Familiar sport</td>
<td>Merrick and Schmida (1984)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Cadwallader (1983)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Cadwallader and Backhouse (1983)</td>
</tr>
<tr>
<td><em>Rutilus rutilus</em> (roach)</td>
<td>1860-80</td>
<td>Course angling</td>
<td>Cadwallader and Backhouse (1983)</td>
</tr>
<tr>
<td><em>Carassius auratus</em> (goldfish carp)</td>
<td>1866-70</td>
<td>Ornamental</td>
<td>Merrick and Schmida (1984)</td>
</tr>
<tr>
<td></td>
<td>1876, 1840</td>
<td></td>
<td>Coy (1979)</td>
</tr>
<tr>
<td><em>Carassius carassius</em> (Crucian carp)</td>
<td>1840</td>
<td>Familiar sport</td>
<td>Coy (1979)</td>
</tr>
<tr>
<td><em>Cyprinus carpio</em> (carp)</td>
<td></td>
<td></td>
<td>Stead (1929-31), Shearer and Mulley (1978)</td>
</tr>
<tr>
<td>Prospect strain</td>
<td>1850-60</td>
<td>Ornamental</td>
<td>Shearer and Mulley (1978)</td>
</tr>
<tr>
<td>Yanco strain</td>
<td>1940-50</td>
<td>Ornamental</td>
<td>Brumley (1991),</td>
</tr>
<tr>
<td>Boolarra strain</td>
<td>1960-64</td>
<td>Aquaculture</td>
<td></td>
</tr>
</tbody>
</table>


During the 1940's and 1950's farmers reported carp (Singapore Koi variety) in irrigation canals in the Murrumbidgee Irrigation Area near Yanco, New South Wales, probably the result of an intentional introduction (Brown, 1996). This population of *Cyprinus carpio* is called the 'Yanco' strain and has maintained a limited distribution and its distinctive orange colour. The strain is located in an extensive open catchment of the Murrumbidgee and Murray Rivers. It has survived successful hybridisations (Hume, Fletcher and Morison, 1983b) and subsequent invasion by *Carassius auratus* and the vigorous Boolarra strain of *Cyprinus carpio*.

In the 1950's, *Cyprinus carpio* were present in many ornamental ponds in Victoria and
New South Wales. The Director of the Victorian Department of Fisheries and Wildlife was concerned at the possibility of escapes to natural waterways and in 1958, legislation was passed in Victoria prohibiting the stocking of public waters with carp. The legislation did not prohibit the stocking of private waters.

The most notorious introductions and subsequent invasions of Eastern Australian waterways occurred in the 1960’s, emanating from a variety of *Cyprinus carpio* of European origin and subsequently called the ‘Boolarra’ strain.

**The ‘Boolarra Karpfen’**

In 1960, according to Olsen (1995), a resident of Boolarra in East Gippsland applied to the Victorian Fisheries and Wildlife Department for approval to import specially bred carp from Germany for commercial aquaculture production in farm dams. The Department refused the application.

In July 1960, fingerlings from Boolarra Fish Farms were advertised as ‘for sale’. A Departmental officer inspected the property and reported an unusual variety of *Cyprinus carpio* previously unseen, called a ‘Mirror carp’. The proprietor claimed they were from the Prospect Reservoir in New South Wales. As the 1958 legislation restricting the stocking of public waters with *Cyprinus carpio* did not cover private water, the Department could take no action. In 1961, another advertisement in the Weekly Times indicated the availability of “Boolarra Karpfen” for sale.

In December 1961, a proclamation was issued in Victoria prohibiting the sale of European carp. Opposition from aquarium retailers led to a Public Inquiry which, in turn, led to the enactment of the ‘Noxious Fish’ Act in May, 1962. This gave the Department the authority to destroy existing stocked populations in private waters. Between May and November, 1962, more than 1300 dams were treated to destroy
carp, and subsequent testing of 200 of the dams indicated the removal had been successful.

Meanwhile, according to Olsen (1995), fingerlings had been illegally and secretly released into Serpentine Creek, a tributary of the Yallourn Storage Dam in Gippsland. Removal attempts proved unsuccessful and the carp spread into the Latrobe River and continue to thrive.

In 1962 the Boolarra Fish Farm requested and was refused permission to use Lake Hawthorn, adjacent to the Murray River near Mildura, as a site for experiments with European carp. In 1964 and 1965 carp were reported in Lake Hawthorn and in 1967 carp up to 5 kg were reported by Wildlife Officers. These were most likely a result of initial releases in 1961-62 (Olsen 1995). In 1968, in accordance with the State Water Commission river regulation requirements, the lake was drained into the Murray River releasing the carp into the Murray-Darling System.

In December, 1969, a South Australian commercial fisherman reported an unusual looking fish being regularly caught. A 6.8 kg (60 cm TL) specimen caught at Renmark was identified as a ‘Mirror’ type of *Cyprinus carpio*, the same type being reported in other parts of the Murray River and other tributary rivers and creeks.

In Tasmania, around the time of the 1961 ‘Boolarra Karpfen’ advertisement, carp fingerlings were released into dams in the Blyth River Valley. Legislation was passed in 1974 enabling the destruction of these populations in 1975.

Olsen (1995) claims that the Boolarra variety of fast-growing ‘Mirror’ type carp was illegally imported and introduced into natural waterways. The progeny has now colonised most of the waterways of South-Eastern Australia.
With the benefit of hindsight, the chain of events leading to this introduction of *Cyprinus carpio* expose a disturbing level of ignorance, arrogance, a lack of social and environmental ethic and the inadequacy and incompetence of crisis-management legislation. The inability of individuals and institutions to instigate rapid effective control and the failure of public institutions to display adequate preventative intent are hopefully lessons learnt.

### The Extent of Cyprinid Distribution In Australia

The species of Cyprinidae which have established self-maintaining populations (Arthington, 1991) following introduction by Europeans in Australia are:

- **Cyprinus carpio** Linnaeus. European, Common, Mirror, Leather or Singapore carp, Koi.
- **Carassius auratus** Linnaeus. Goldfish
- **Puntius conchonius** (Hamilton-Buchanan). Rosy barb
- **Rutilus rutilus** (Linnaeus). Roach
- **Tinca tinca** (Linnaeus). Tench

In addition, *Carassius carassius* (Crucian carp) has been reported by Coy (1979) and Allen (1982) as having established populations and has been identified in Museum of Western Australia records. Reports of the presence of *C. carassius* have been attributed to a possible mis-identification of *Carassius auratus* (Fletcher, 1986 and Brumley, 1991). This has not been confirmed and further research is required to determine if *C. carassius* is present in Australia.
Figure 3.1. Distribution of introduced cyprinid fishes in Australia, (according to Brumley, 1991).
The widespread distribution of 'Goldfish' (*Carassius auratus*) and 'European carp' (*Cyprinus carpio*), are shown in Figure 3.1., but *Tinca tinca* (tench), *Rutilus rutilus* (roach) and *Puntius conchonius* (rosy barb) are confined to localised populations.

According to Brown (1996), *Cyprinus carpio* is now present in coastal river systems from Queensland (Logan and Albert Rivers) through to New South Wales (Hawkesbury, Nepean, Shoalhaven and Richmond Rivers), across Victoria (Latrobe River and Wimmera Streams), and into South Australia (Onkaparinga and Torrens Rivers). *C. carpio* are also present in many major water-storage reservoirs (Hume, Burrinjuck, Keepit and Yallourn Storage Dams) and throughout the Murray-Darling River Basin. In 1995, *C. carpio* were reported in Lake Sorrel and Crescent Lake in Tasmania and are the subject of a dramatic program of eradication (Anderson, 1995). They have been recently reported in the Leigh Creek Dam in the Lake Eyre drainage system (Brown, 1996).

Harris (1994) reported that carp dominate the fauna in many areas of the Murray-Darling Basin, and in an initial sampling of the Murrumbidgee River and Murray River in 1993 for a native fish recruitment research project, carp constituted 93% of 4400 fish collected.

**The History of Cyprinids in Western Australia**

Earliest reports of carp in Western Australia, according to Coy (1979), were of introductions in the South-West in the 1840's of *Carassius carassius* (Crucian carp) and *Carassius auratus* (Goldfish). These introductions were instigated by the founder of the Perth Zoological Gardens, Colonel E. A. Le Souef.

The 1972 summer edition of the Department of Fisheries and Wildlife newsletter,
entitled 'State Wildlife Advisory News Service' (SWANS), indicated that the 'European carp' had been placed into ornamental lakes, connected to the Swan River by overflow drains, in the Narrows Interchange in Perth. The newsletter claimed that the carp were introduced to biologically control weeds and water quality. An awareness of the feeding ecology of carp, by those responsible for the introduction, would have shown this reasoning to be misguided. The Department of Fisheries and Wildlife requested the Main Roads Department to drain the lakes. The date the lakes were drained was not stated. No live fish were found and contamination of the Swan River was considered unlikely, but carp tolerate salinity levels up to 15°/oo (Wieser, 1991) and, if the draining was carried out in late winter, when salinity levels in the river are lowest, the likelihood of contamination should probably not have been so readily dismissed.

In 1975, it was reported that a citizen had informed the Department that they had received an incorrect consignment of Koi carp from Singapore, which had eluded all restriction checks into Australia (February, 1976 edition of SWANS). The consignment was destroyed and, citing dramatic experiences from Eastern Australia, the article went to considerable lengths to explain the hazards of carp introductions. This avoidance of import checks indicates the capacity for accidental (or even illegal) introductions at the time.

Sarti and Allen (1978) reported Carassius auratus in Loch McNess, Lake Jandabup and Lake Chandala in a study limited to the Northern Swan Coastal Plain. Allen (1982) states that Carassius auratus is found mainly in lakes and ponds in the vicinity of Perth and that C. carassius (Crucian carp) have been reported around Perth, but are probably rare.

Brumley's (1991) distribution (Figure 3.1.) indicate that European carp are absent from Western Australia and shows the occurrences of Goldfish extending from
Moore River, north of Perth to the Warren River near Walpole in the south-west of the state. Twyford’s (1991) distribution maps (Fig 3.2.) vary considerably from Brumley’s (1991) maps and depict the Western Australian distribution of ‘Goldfish’ confined to regions around Perth and the distribution of ‘Carp’ extending over the south-west of the State.

![Figure 3.2. Australian distribution of Cyprinus carpio (Carp) and Carassius auratus (Goldfish) according to Twyford (1991).](image)

Twyford includes Carassius auratus and aquarium fish in his ‘Goldfish’ distribution whilst his ‘Carp’ distribution includes Crucian carp (Carassius carassius) and all other carp species including Cyprinus carpio. Twyford’s indication that Cyprinus carpio are widespread in the south-west of Western Australia is not supported by any other literature and his maps may have been of more value for consideration of Western Australian distributions if they had differentiated between distributions of Carassius species and Cyprinus species. The variation displayed by Brumley (1991) and Twyford (1991) indicates that knowledge of the distribution of cyprinids in Western Australia has been poor.
Table 3.2. Record of Museum Collections of Cyprinids in Western Australia.

(Source: Museum of Western Australia (database listing), June 1996.

<table>
<thead>
<tr>
<th>Genus</th>
<th>Species</th>
<th>Latitude</th>
<th>Longitude</th>
<th>LOCATION</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carassius</td>
<td>--</td>
<td>22 57</td>
<td>115 42</td>
<td>White Rocks (Parabadoo)</td>
<td>07. 11. 60</td>
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<tr>
<td>Carassius</td>
<td>auratus</td>
<td>31 39</td>
<td>116 40</td>
<td>Swan River, Northam</td>
<td>15. 08. 30</td>
</tr>
<tr>
<td>Carassius</td>
<td>auratus</td>
<td>32 37</td>
<td>115 52</td>
<td>Murray River, Pinjarra (Pool)</td>
<td>21. 08. 34</td>
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<tr>
<td>Carassius</td>
<td>auratus</td>
<td>32 07</td>
<td>115 43</td>
<td>Drain in Rockingham</td>
<td>--</td>
</tr>
<tr>
<td>Carassius</td>
<td>auratus</td>
<td>32 03</td>
<td>115 44</td>
<td>Harbour drain, Fremantle</td>
<td>-- . -- . 39</td>
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<td>31 57</td>
<td>115 54</td>
<td>East Perth, Perth</td>
<td>-- . -- . 41</td>
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<td>31 37</td>
<td>116 28</td>
<td>Avon River, Northam</td>
<td>-- . 11. 43</td>
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<tr>
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<td>auratus</td>
<td>&quot;</td>
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<tr>
<td>Carassius</td>
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<td>31 57</td>
<td>115 53</td>
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<td>auratus</td>
<td>31 46</td>
<td>116 04</td>
<td>Osborne Park, Perth (nursery)</td>
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</tr>
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<td>Carassius</td>
<td>auratus</td>
<td>33 33</td>
<td>115 33</td>
<td>Muddy lake, Capel</td>
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</tr>
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<td>Carassius</td>
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<td>31 56</td>
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<td>Garret Rd, Swan River, Belmont</td>
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<td>33 44</td>
<td>116 33</td>
<td>Blackwood River, Boyup Brook</td>
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<tr>
<td>Cyprinus</td>
<td>carpio</td>
<td>31 58</td>
<td>115 47</td>
<td>Butlers Swamp, Perth</td>
<td>28. 02. 47</td>
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<tr>
<td>Cyprinus</td>
<td>carpio</td>
<td>31 45</td>
<td>116 04</td>
<td>Swan River, Upper Swan</td>
<td>03. 03. 57</td>
</tr>
</tbody>
</table>

(The locations have been transposed to a distribution map, Figure 5.1.a.)

Details of all carp species collected and identified up to June 1996 by the Museum of Western Australia are shown in Table 3.2. There are no records of *Tinca tinca* or
*Rutilus rutilus* and some specimens of *Carassius auratus* are not yet processed (Collected Nov. 1995 from Kalgoorlie).

Research on the distribution of cyprinid (carp) fishes in Western Australia is limited to *Carassius auratus*, reported by Sarti and Allen (1978) (collected in the northern Swan Coastal Plain), Fairhurst (1993) (reporting it present in North Lake and Munday Swamp, Perth) and Young, Potter, Hyndes and Lestang (1996) (reporting it at Moore River). There are no other published reports on aspects of cyprinid research. There are no published reports of collections of *Cyprinus carpio* or any other carp species. The absence of published studies of carp has limited the availability of historical data and created the need for the development of a starting point for future research.
CHAPTER 4

SAMPLING FOR CYPRINIDS

Introduction

The most widely used methods for cyprinid collection in eastern Australia are boat-mounted electro-fishing units and gill nets. Seine nets and traps are also used but are not considered as efficient as electro-fishing (P. Brown, NSW Fisheries, pers. comm.). A suitable electro-fishing unit was not available for this study, however a range of gill nets, seine nets and fish traps were used to assess their suitability for sampling a range of wetlands on the Swan Coastal Plain.

To find out which species are present over an area, and to determine if self-sustaining populations are established, it is preferable to sample the total area, or carefully design a representative sampling program. It is also essential to use efficient equipment. In this study, a limited number of wetlands could be sampled and the equipment chosen was untested for cyprinid collection in Western Australian wetlands. The variety and spatial distribution of habitats and the mobility and evasive capacity of cyprinids posed several challenges. The method of collection was designed to overcome as many of these challenges as possible, and was based on methods recommended by professional fishers, familiar with carp collection in eastern Australia.

The sites sampled were representative of a range of wetland types suitable for assessing the likelihood of cyprinid presence, distribution and viability over the wider area. The risks associated with developing wide spatial inferences from restricted spatial data can be minimised if a sound knowledge of the variables is combined with an awareness of the limitations. The variables, in this case are the
biology of cyprinids and the ecology of the wetlands.

Awareness of the wide environmental tolerance range of cyprinids and their capacity to selectively utilise varied and fluctuating resources (see Chapter 6) reduces some of the hazards associated with projections based on limited data. The biology of cyprinids, particularly related to their capacity to populate a wide range of habitats, is well reported in literature and particular attributes are discussed elsewhere in this study (Chapters 1, 2 and 6).

There is considerable information available on the ecology of the wetlands of the Swan Coastal Plain. Physical and chemical characteristics for 33 wetlands, from Gingin Brook in the north to Lake Cooloongup near Rockingham, were reported using 13 water chemical variables and multi-variate analysis of invertebrate communities assessed along with environmental variables (Growns, Davis, Cheal, Schmidt, Rosich and Bradley, 1992). The classification of the 33 wetlands using the environmental variables provides a strong basis for site selection. Similar environmental characteristics were recorded by Balla and Davis (1993), for six urban wetlands; by Environmental Protection Authority (1987) for 5 urban wetlands; by Davis, Rolls and Wrigley (1991) for 16 wetlands and by Davis, Rosich, Bradley, Growns, Schmidt and Cheal (1993) for 41 wetlands.

Previous studies of the ecological, physical and chemical characteristics of wetlands in the Swan Coastal Plain provided a wide selection of data for assessing sample sites which represent the different types of wetland habitats. An assessment of the biology of carp and their habitat requirements, indicated that permanency of water, and salinity levels below $15000 \text{ mgL}^{-1}$ may be the only limiting factors.

Species will be identified using literature (see Table 2.1.) and population viability determined by collection and examination of females, males, adults, juveniles, and
assessing the capacity for reproduction. Sex will be determined by visual (external) examination and by dissection analysis of gonads. Ageing will be attempted using scale ridge counts and maturity estimated by comparison of TFL (total fork length) measurement to length/age indices in literature (Brown, 1996 and Hume, Fletcher and Morison, 1983a).

The aims of the sampling program in the representative wetlands were:

- to assess the suitability of a range of nets and traps for cyprinid collection,
- to determine the species present,
- to determine if populations were self-sustaining,
- to estimate the likely distribution of cyprinids within the wetlands, and
- to utilise collection data to determine the likely wider distribution.

**Methods**

**Pilot Study Methods.**

A pilot study was carried out in April, 1996, in Lake Joondalup, Lake Goolalal and Lake Gwelup, to assess the suitability of using seine nets and fish traps for collection of carp specimens. A description of the nets and traps is provided in Table 4.1.

The seine net S1 was deployed in Lake Joondalup and Lake Gwelup, as shown in Figure 4.1., and retrieved. Non-target contents were recorded and released and cyprinids transferred to water tubs for transportation to prepared aquarium tanks for examination.
TABLE 4.1. Description and details of fish traps and nets used for sampling.

<table>
<thead>
<tr>
<th>Style</th>
<th>Type</th>
<th>Dimensions (m)</th>
<th>Mesh Gap (mm)</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>T1</td>
<td>Small Trap (8)</td>
<td>0.25 x 0.25 x 0.4</td>
<td>2</td>
<td>Funnel mouth 60mm - baited</td>
</tr>
<tr>
<td>T2</td>
<td>Med. Trap (2)</td>
<td>0.25 x 0.40 x 0.6</td>
<td>10</td>
<td>Funnel mouth 75mm - baited</td>
</tr>
<tr>
<td>T3</td>
<td>Med. Trap (2)</td>
<td>0.25 x 0.45 x 0.6</td>
<td>12</td>
<td>Mod. Marron, mouth 45mm - baited</td>
</tr>
<tr>
<td>T4</td>
<td>Lg. Trap (1)</td>
<td>0.45 x 0.5 x 1</td>
<td>15</td>
<td>Mouth 160mm - baited</td>
</tr>
<tr>
<td>T5</td>
<td>Fyke Trap (1)</td>
<td>0.45 x 0.5 x 5</td>
<td>15</td>
<td>Mouths 160mm &amp; 140mm - baited</td>
</tr>
<tr>
<td>S1</td>
<td>Large Seine (1)</td>
<td>2.4 drop x 60</td>
<td>30</td>
<td>One piece heavy filament</td>
</tr>
<tr>
<td>S2</td>
<td>Small Seine (1)</td>
<td>2.1 drop x 30</td>
<td>5</td>
<td>10m wings with 10m centre pocket</td>
</tr>
<tr>
<td>S3</td>
<td>Med. Seine (1)</td>
<td>1.5 drop x 50</td>
<td>12</td>
<td>One piece heavy filament</td>
</tr>
<tr>
<td>G1</td>
<td>Gill Net</td>
<td>1.8 drop x 90</td>
<td>20</td>
<td>Three 30m panels joined together. (All fine filament mesh)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(3x30m panels)</td>
<td>Panel 1</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Panel 2</td>
<td>30</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Panel 3</td>
<td>55</td>
</tr>
</tbody>
</table>

Note: See Figure 4.2. for diagram of T4 and T5 - both custom-made.

Fish traps T1, T2, and T3 were baited with a mixture of chicken pellets, minced meat and aniseed oil, a mixture used for carp attraction (P, Brown, NSW Fisheries, pers. comm.) and placed in Lake Goolalal in the following habitats:

- in open water 0.5m deep,
- in open water 1.5m deep,
- within and abutting aquatic vegetation,
- abutting submerged logs,
- other locations chosen to provide a range of habitat types.

In addition to the fish traps, the composite gill-net, G1, was deployed in Lake Goolalal, from a point 10m from the shoreline and traversing open water. The depth
of the net was sufficient to reach from the surface to the bed of the lake for the full net length. It was monitored over 96 hours and contents checked and recorded every 3 hours during daylight (5 times/day).

The method of deployment, ability to retrieve, contents and general suitability of the seine net and traps was assessed to determine the viability of these methods for the study. To avoid unnecessary habitat disturbance, fish traps were to be preferentially used and seine nets deployed only where habitat disturbance was not considered likely.

Pilot Study Results

Three *Carassius auratus* juveniles were collected in the first seine net retrieval from Lake Joondalup. The net also collected several *Chelodina oblonga* (long-necked tortoise), and numerous *Pseudogobius olorum* (Swan River Goby) and *Gambusia affinis* (Mosquito fish). No cyprinids were collected from Lake Goolellal and Lake Gwelup.

The preliminary sampling highlighted problems associated with the use of seine nets in wetlands with deep benthic ooze, low water levels and submerged obstructions. The seine net collected non-target species and caused extensive physical disturbance to the substrate and to aquatic macrophytes. As a result of the assessment, a larger fish trap (T4) was constructed (see Figure 4.2.) with a larger funnel opening (160mm), for collection of larger fish, and with provision for access to air for trapped, non-target species (tortoises, water rats, etc.). A finer-meshed seine
net, S2, was obtained for targeting smaller (juvenile) cyprinids. Sampling effort was increased to efficiently utilise the limited sampling period.

**Sampling Phase 1: Methods.**

Ten natural and artificial wetlands with permanent water, or seasonal wetlands linked to a permanent water body, in urban areas of Perth were selected (see Table 4.2.). The selection of each site included consideration of factors such as public access, proximity to watercourses or drain systems, historical information on introductions and collections, and surrounding land-use. These factors, combined with the data from the Swan Coastal Plain studies, were considered relevant for the assessment of likely points of introduction and dispersal. The selection criteria are indicated in Table 4.2.

**Table 4.2. Wetland sites chosen for sampling.**

<table>
<thead>
<tr>
<th>Wetland</th>
<th>Characteristics * (sampling criteria)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Gingin Brook</td>
<td>Natural watercourse and high levels of colour</td>
</tr>
<tr>
<td>2. Loch McNess</td>
<td>Low invertebrate abundance, ultra-oligotrophic</td>
</tr>
<tr>
<td>3. Lake Joondalup</td>
<td>Pilot study site (and mesotrophic)</td>
</tr>
<tr>
<td>4. Lake Gooellal</td>
<td>Oligo-mesotrophic and surrounding land-use</td>
</tr>
<tr>
<td>5. Lake Gwelup</td>
<td>Oligotrophic, totally urban surrounded</td>
</tr>
<tr>
<td>6. Jackadder Lake</td>
<td>Ornamental, degraded and publicly accessible</td>
</tr>
<tr>
<td>7. Herdsman Lake</td>
<td>Drains, surrounding vegetation with public access</td>
</tr>
<tr>
<td>8. Lake Monger</td>
<td>High invertebrate abundance and eutrophic</td>
</tr>
<tr>
<td>9. Munday Swamp</td>
<td>Eu/hyper-trophic and a closed canopy wetland</td>
</tr>
<tr>
<td>10. Bibra Lake</td>
<td>Hypertrophic and no fish recorded</td>
</tr>
</tbody>
</table>

* Wetland characteristics based on Davis et al., (1993)
A 20-day sampling program was commenced on the 3rd June, 1996. Conductivity, pH, temperature, turbidity (FTU), Secchi Disc depth and physical features of each sample site were recorded.

Six of the ten selected sites were initially sampled (Lake Joondalup, Lake Gwelup, Jackadder Lake, Herdsman Lake, Bibra Lake and Gingin Brook) using seine nets S1 and S2. Nets were retrieved and fish contents noted and representative collections retained in 70% ethanol for laboratory examination and identification.

Fish traps T1, T2, T3 and T4 were baited and deployed in Lake Joondalup, Lake Gooellellal, Herdsman Lake and Balingup Brook, at a range of habitat types -

- in open water 0.5m deep,
- in open water 1.5m deep,
- within and abutting aquatic vegetation,
- abutting submerged logs,
- other opportunistic locations

The traps in Lake Joondalup, Lake Gooellellal and Herdsman Lake were monitored over 24 hours, and in Balingup Brook for 8 hours, and collections recorded and retained as described for netting samples.

**Sampling Phase 1: Results.**

**Gill Nets.**

At Lake Gooellellal, (Temperature 10.2 - 11.0°C, pH 7.2, salinity 390mgL⁻¹), total of 8 long-necked tortoise, *Chelodina oblonga*, were collected and, although they were usually very torpid when extricated from the net, they regained mobility within
minutes and were released, apparently unharmed. Three adult grebe and 3 juvenile black ducks while diving became entangled and drowned in the net during the sampling. No cyprinids were collected and use of the gill net was terminated.

Table 4.3. Non-target species collected in fish traps T1, T2, T3 and T4

<table>
<thead>
<tr>
<th>Location</th>
<th>Species</th>
</tr>
</thead>
<tbody>
<tr>
<td>Balingup Brook</td>
<td><em>Edelia vittata</em> (Western pygmy perch)</td>
</tr>
<tr>
<td></td>
<td><em>Bostockia porosa</em> (Nightfish)</td>
</tr>
<tr>
<td></td>
<td><em>Perca fluviatilis</em> (Redfin perch)</td>
</tr>
<tr>
<td>Lake Joondalup</td>
<td><em>Pseudogobius olorum</em> (Swan River Goby)</td>
</tr>
<tr>
<td></td>
<td><em>Gambusia affinis</em> (Mosquito fish)</td>
</tr>
<tr>
<td></td>
<td><em>Chelodina oblonga</em> (long-necked tortoise)</td>
</tr>
<tr>
<td>Lake Gooellal</td>
<td><em>Pseudogobius olorum</em> (Swan River Goby)</td>
</tr>
<tr>
<td></td>
<td><em>Gambusia affinis</em> (Mosquito fish)</td>
</tr>
<tr>
<td></td>
<td>(shrimp sp.)</td>
</tr>
<tr>
<td>Herdsman Lake</td>
<td><em>Pseudogobius olorum</em> (Swan River Goby)</td>
</tr>
<tr>
<td></td>
<td><em>Gambusia affinis</em> (Mosquito fish)</td>
</tr>
<tr>
<td></td>
<td>(Yabby and shrimp sp.)</td>
</tr>
</tbody>
</table>

Fish Traps.

Traps T1, T2, T3 and T4 were deployed at 4 locations (see Table 4.3.) for a total of 968 trap hours (number of traps x set hours x number of locations) in habitats ranging from open water to reed-beds and flowing streams. Numerous non-target fish species (Table 4.3.) were collected and released. No cyprinids were collected over the sampling period.
Seine nets.

Seine net S1 collected 3 juvenile specimens of *Carassius auratus* from Lake Joondalup in the pilot study in May, but no cyprinids were collected from S1 or S2 in the seven deployments at six sites during the main sampling program. The use of these nets was terminated and the prototype S3 used for subsequent sampling.

Fyke trap (T5)

The fyke trap (T5) was deployed for 192 hours in Lake Joondalup (temperature 10.2 - 11.0°C, pH 7.8, salinity 740mgL⁻¹). A total of 35 long-necked tortoise, *Chelodina oblonga*, were collected over the sampling period and released unharmed. No cyprinids were collected.

Revision of Sampling Program.

At this stage of the sampling program, no cyprinids had been collected (other than in the pilot study). The possibility of future collections was uncertain and alternative sampling locations were chosen, and a revised program undertaken. A flow chart of the sampling program is shown in Figure 4.3. Selection of the revised sites was based upon strong anecdotal evidence that cyprinids were present. This selectivity of sites was necessary as it was essential to determine if the equipment and methods used for collection were the cause of the failure of the sampling so far.

The sites selected were:

- a wetland on Carramah Park Estate (Perth),
- Balingup Brook (Balingup),
- a farming property dam (Bridgetown)
In addition to the revision of the sampling sites, a new seine net, S3, and prototype trap, T5 (see Figure 4), were designed, manufactured and tested. The seine net was trialed in Lake Joondalup at previous sampling sites. It was found to be superior to S1 and S2 for retrieval, and was no less efficient in collecting non-target species during testing. Fish trap T5 was deployed over 8 days in Lake Joondalup and no cyprinids were collected, but was very effective for the capture, and safe release, of non-target species.

**Large Fish Trap -T4**

This trap is designed to capture large fish. It has a raised top to provide access to air for trapped non-target species. Sampling depth is limited to 0.5m.

**Large Fyke Trap -T5**

This trap is designed to capture large fish and retain smaller fish. Access to air is provided by the raised top of the entry chamber and the floatable tail section. Sampling depth is limited to 0.6m.

**Figure 4.2. Diagrams of fish traps T4 and T5**

Sampling Phase 2: Methods.

The seine net was deployed once at each of the three sites and the collected specimens measured, weighed, cooled till torpid, then killed by freezing and
retained for laboratory examination. Fish traps T1, T2, T3 and T4 (one of each) were deployed for 8 hours in Balingup Brook. Collections were preserved in ethanol for later identification and analysis.

<table>
<thead>
<tr>
<th>Phase</th>
<th>Location</th>
<th>Equipment</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>PILOT STUDY</td>
<td>L. Joondalup</td>
<td>S1, T4</td>
<td>yes</td>
</tr>
<tr>
<td></td>
<td>L. Goolallal</td>
<td>G1, T1, T2, T3</td>
<td></td>
</tr>
<tr>
<td></td>
<td>L. Gwelup</td>
<td>S1</td>
<td></td>
</tr>
</tbody>
</table>

| PHASE 1     | L. Joondalup*     | x                       |         |
|             | L. Gwelup*        | x                       |         |
|             | Jackadder L.      | x                       |         |
|             | Herdsman L.*      | x                       |         |
|             | Bibra L.          | x                       |         |
|             | Balingup Bk.*     | x                       |         |

| PHASE 2     | New net S3 and newtrap T5 | yes (S3) |       |
|             | Carramah Park      | x         |       |
|             | Balingup Bk.       | x         |       |
|             | Farm dam           | yes (S3)  |       |

* See Table 4.3.

(x = no cyprinids collected, yes = cyprinids collected and equipment used for collection is indicated)

Figure 4.3. Flow Chart of Revised Sampling Program

In the laboratory, the frozen specimens were thawed and the contents of the gut cavity removed and examined. Gill raker and scale ring counts were undertaken using a dissecting microscope. A compound microscope was used to examine the development and condition of gonads. Results were tabulated and cavity contents of each specimen were separately identified, labelled and placed in 5% formalin solution for future reference. Fish were labelled, frozen and stored.
**Sampling Phase 2: Results.**

Fifteen fish, all identified by gill raker counts as *Carassius auratus* (TFL 192 - 364 mm, mean 315 mm), were collected from the farm dam site (temperature 9.8°C, pH 7.2, salinity 607 mgL⁻¹). Area covered by the netting was 2 500m² and weight range was 202g to 1281g (mean 793g) with a biomass of 47.6 kg/ha, comprising 9 females, 4 males and 2 juveniles. All females were heavily gravid. The colour range of the specimens is shown in Plate 3 (Chapter). The age of 2 specimens (333 mm TFL and 357 TFL) was estimated (using scale ring counts) to be 8 to 12 years, but the poor definition of the rings suggest that this method of ageing was not satisfactory.

Thirty three specimens (TFL 226 - 380mm, mean 301mm), all identified as *Cyprinus carpio* were collected from the ornamental Carramah Park Lake (temperature 10.8°C, pH 8.2, salinity 320mgL⁻¹). Area of netting was 340m² and weight range was 198g to 869g (mean 507g) with an estimated biomass of 490 kg/ha. Twelve specimens were retained for laboratory analysis, the rest were released. The 12 comprised of 5 females, 4 males and 3 juveniles. One female was heavily gravid. Ageing was attempted but was abandoned due to lack of definition of scale rings.

No cyprinid specimens were collected from Balingup Brook. (temperature 9.4°C, pH 7.4, salinity 320mgL⁻¹).

**Discussion**

The most important outcome of the sampling program, and the assessment of nets and traps, was that no cyprinids were collected from the six of the original study sites sampled. Without a boat-mounted electro-fishing unit, the remaining methods
were always likely to be less efficient but are all proven means of collection.

The influence of environmental conditions was always considered a major factor in success of the collection methods. In the literature which refers to the activity of cyprinids, the minimum temperature likely to reduce activity or induce torpidity was 4°C to 8°C. Temperatures in all the wetlands sampled were above these minimum. Seine nets were used in the study to overcome any problems associated with reduced mobility. There is substantial evidence from the literature and anecdotes which point to the efficiency of collections undertaken in warmer seasons (Spring, summer and autumn). This study has shown that exhaustive sampling undertaken in winter (water temperatures between 9°C and 11°C) using a range of seine nets and fish traps does not provide suitable data on cyprinid species.

The population sizes may be small and therefore difficult to detect without more efficient collection methods, such as electro-fishing. There is also the possibility that the fish move away from shorelines to deeper water during winter, out of range of shoreline seine nets.

The result also raises questions as to the relevance to Australian conditions, of environmental tolerance limits widely reported in overseas literature. The literature may be applicable at its origin but may not be applicable here. There is no literature from Australian research of temperature levels to induce torpor. These observations emphasise the lack of essential knowledge of the ecology of cyprinid populations in Australia and highlight the need for related research.

The sampling of *Carassius auratus* from the dam site near Bridgetown resulted from an inquiry by the property owner. Fish were not known to be present until, in 1982, flooding from the nearby Blackwood River in 1982 had inundated the dam. The owners assert that no fish have been introduced to the dam before or since the
flooding and the current population is as a result of the 1982 inundation. The implication of this assertion is that the fish originated in the Blackwood River and were spread by the flooding. Numerous anecdotal references were obtained in this study confirming that receding waters from the 1982 floods had trapped *Carassius auratus* in open fields and drying lowlands.

The reproductive capacity of the dam population is confirmed by the examination of juveniles, gonads and the heavily gravid females sampled. The biomass (47.6 kg/ha) is well below the level of 450kg/ha which, according to Fletcher, Morison and Hume, (1985), can influence water quality. The presence of *Carassius auratus* in this type of habitat and the considerable anecdotal evidence (see Table 5.1.) of other occurrences are strong grounds for assuming that this species is well established in this area.

The collection of *Cyprinus carpio* from Carramah Park did not confirm that the species had established a self-sustaining population (lack of juveniles and only one gravid female). The lake was not typical of natural wetlands and the fish were reported to be artificially fed. Anecdotal evidence (F. Griffin, City of Wanneroo, pers.comm.) indicates that fingerlings are sometimes added to the population. No small juveniles were collected and, given the low instances of gonad development in 33 adult specimens sampled, there is some doubt as to the viability of this population. Whether this is an indication of the situation for other populations is speculative and would require further research.
CHAPTER 5

DISTRIBUTION OF CYPRINID FISHES IN WESTERN AUSTRALIA

Introduction

Knowledge of the distribution of cyprinid fishes in Western Australia is extremely poor and the literature which deals with distribution provides only general comment. The distribution maps by Brumley (1991) (see Figure 3.1.) and Twyford (1991) (see Figure 3.2.) show conflicting distribution information but generally refer to the presence of Carassius auratus in areas around Perth and the south-west of the State. These maps also show conflicting distributions of Cyprinus carpio. Coy (1979) restricts the distribution of Carassius auratus to the Perth region and also reported Carassius carassius present in the Blackwood River system, the Vasse, Preston and Canning Rivers, in farm dams and in ponds and lakes in the Perth area. Fletcher (1986) and Brumley (1991) consider past identifications of C. carassius as doubtful and the lack of certainty over its distribution adds to the confusion.

Methods

To define the distribution of all cyprinid fishes with self-supporting populations in Western Australia would require vast resources for the sampling and investigation of a wide range of wetlands and river systems throughout the State, that are beyond this study. Accordingly, this study focussed on establishing the presence/absence of cyprinids in representative locations which would give an overview of the likely distributions within the State.
The wetlands and rivers around Perth, and the Blackwood River and its tributaries in the south-west of the State, were sampled for cyprinids using a range of methods described in Chapter 4. Sampling provided data on the species present and was supplemented by Museum records, literature and anecdotal evidence from a range of sources. Distribution maps (see Figures 3.1. and 3.2.) from recent literature were of limited value but were used as a guide. Anecdotal information on historical and recent occurrence of cyprinid fish was sought from the public by means of the electronic and print media, personal interviews and notifications in periodicals and newsletters.

A presentation to the Western Australian Naturalists' Club (Inc.) in May, 1996, included a brief outline of the proposed research and information brochures were circulated to members in the monthly newsletter, The Naturalist News. An interview was given on ABC South-West Regional Radio and an article and photographs were provided to the Blackwood-Greenbushes Mail newspaper (published in Bridgetown). Information was provided to 6NR radio station for inclusion in a weekly program directed to amateur fishers. Posters notifying the public of the request for information were provided to, and distributed by the:

- Conservation Council
- Marine and Coastal Community Network
- Blackwood Regional Centre (Boyup Brook)
- Blackwood Catchment Co-ordination Group
- Friends of Yellagonga
- Friends of Gwelup
- Nannup Trout Fishing Club
- Trout and Freshwater Angling Association
- Recreation Fishing Council
- Western Angler
The presentations, interviews, articles and posters provided postal, telephone, fax and e-mail contact details, and all incoming contact was monitored and answered. Locations, dates, names and other information relating to the presence and distribution of cyprinids was recorded and each respondent interviewed where possible. These interviews were undertaken to determine the relative 'value' of the information provided, and to avoid errors in interpretation of the information.

In most cases, the use of anecdotal evidence for map compilation was limited to areas where literature, research collections (published and un-published), and Museum records (Table 3.2.) verified the anecdotal information. In cases where the anecdotal evidence was not supported by records, opportunistic sampling using seine nets and fish traps at reported locations was carried out, where possible, to verify the reports. In cases where further assessment could not be undertaken, or where sampling failed to confirm the report, the information was not utilised in distribution mapping.

The location of Museum collections and referenced collections from A. Chapman (CALM, Kalgoorlie) were plotted using latitude and longitude. In cases where river or stream names were provided, the locations were plotted as a general location (on the waterway). In cases where the locations were not specific (eg. river names or general localities), the scale of distribution maps was chosen so as to eliminate inaccuracies.

The information collected was used to compile likely distribution maps for all cyprinid species recorded.
Results

The details of anecdotal sightings and collections are summarised in Table 5.1. The species listed are determined from specimens, photographs and descriptions provided by the source.

(a) Museum Records.

Four species of cyprinids were recorded:

i. *Carassius auratus*.

Distribution of 17 records, collected between 1930 and 1992, ranged from Gingin Brook (1948) to the Blackwood River, Boyup Brook (1992), with 7 specimens from lakes, drains and the Swan River in Perth (1939 - 64), 4 from the Swan River near Northam (all pre-1944). The remaining records were from the Murray River (1934), Rockingham (?), Capel (1976) and Waroona (1991). In addition to the recorded collections, specimens from White Flag Lake and Lake Owen, near Kalgoorlie (1995) are yet to be processed by the Museum (A. Chapman, CALM, pers. comm.).

ii. *Carassius carassius*.

Three collections are recorded - Lake Craigie, Wanneroo (1916), Harvey River, Harvey (1937) and Margaret River (?). The Lake Craigie record is the oldest cyprinid collection reported. There is no existing lake of that name but the locality of Craigie is close to what is now called Lake Goolollal or Lake Joondalup.

iii. *Cyprinus carpio*.

This species is reported from two urban locations, Butlers Swamp (1947) and the Swan River, Upper Swan (1957).
iv. *Cyprinus vulgaris*.

The collection is reported from Boyup Brook (1946) (this species name is not found in literature).

v. *Carassius sp.*

An unknown species was collected from White Rocks near Parabadoo (1960).

The location of these collections is shown in Figure 5.1.(a).

(b) **Collections from Literature.**

All collections in published literature were *Carassius auratus* as follows:

- Sarti & Allen, (1978) Loch McNess
  - Lake Jandabup
  - Lake Chandala
- Fairhurst, (1993) North Lake
  - Munday Swamp

The locations of collections from published literature are shown in Figure 5.1.(b).

(c) **Anecdotal Reports.**

There are 64 reports including *Cyprinus carpio* (12 reports, all of the Koi variety), *Carassius auratus* (29 reports), *Carassius carassius* (4 reports) and 22 reports of 'carp'
Table 5.1. Summary of Anecdotal Information:
Locations, Sighting dates, General Information and Sources

Species:  \(G\) = Goldfish  \(C\) = Crucian Carp  
\(K\) = Koi  \(\text{Blank}\) = unknown

<table>
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<th>Species</th>
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<tr>
<td>Perth</td>
<td>Canning River (above Kent St. weir)</td>
<td>1995</td>
<td>K,C, C</td>
<td>C. Fairclough</td>
</tr>
<tr>
<td></td>
<td>pre-96</td>
<td></td>
<td>C (19lb)</td>
<td>S. Seclier</td>
</tr>
<tr>
<td></td>
<td>pre-96</td>
<td></td>
<td>C (26lb)</td>
<td>L. Burgess</td>
</tr>
<tr>
<td></td>
<td>pre-96</td>
<td></td>
<td>G (0.5-2kg)</td>
<td>L. Burgess</td>
</tr>
<tr>
<td>Lake Monger</td>
<td>1950's</td>
<td></td>
<td>G</td>
<td>J. McConigley</td>
</tr>
<tr>
<td></td>
<td>pre-95</td>
<td></td>
<td></td>
<td>S. Seclier</td>
</tr>
<tr>
<td>Lockridge</td>
<td>1960's</td>
<td></td>
<td>C</td>
<td>C. Fairclough</td>
</tr>
<tr>
<td>Lake Gwelup</td>
<td>1970's</td>
<td></td>
<td></td>
<td>D. Wainwright</td>
</tr>
<tr>
<td>Wetlands in Gwelup (Gribble Rd.)</td>
<td>1996</td>
<td>G</td>
<td>J. Cunningham</td>
<td></td>
</tr>
<tr>
<td>Herdsman Lake</td>
<td>1960-'s</td>
<td></td>
<td>G</td>
<td>D. Wainwright</td>
</tr>
<tr>
<td>Drains near Herdsman Lake</td>
<td>1960-</td>
<td>G,C</td>
<td>K. McLean</td>
<td></td>
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<tr>
<td>Faulkner Rd. Belmont</td>
<td>pre-95</td>
<td>G</td>
<td>K. McLean</td>
<td></td>
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<tr>
<td>Sumps in Belmont</td>
<td>pre-95</td>
<td></td>
<td>K. McLean</td>
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<td>Munday Swamp</td>
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<td></td>
<td></td>
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<td>Tomato Lake</td>
<td>pre-85</td>
<td></td>
<td></td>
<td>Anon</td>
</tr>
<tr>
<td>Queens Gardens</td>
<td>1995</td>
<td></td>
<td></td>
<td>M. Lane</td>
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<td>Hyde Park</td>
<td>1996</td>
<td></td>
<td>G</td>
<td>P. Havord</td>
</tr>
<tr>
<td>Shenton Park Lakes</td>
<td>1970-</td>
<td></td>
<td>D. Wainwright</td>
<td></td>
</tr>
<tr>
<td>Perry Lakes</td>
<td>1970-</td>
<td></td>
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</tr>
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<td>1980-</td>
<td></td>
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<td>Wanneroo City</td>
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<td>Lake Gooeilal</td>
<td>1980-</td>
<td></td>
<td>G</td>
<td>P. Whittle</td>
</tr>
<tr>
<td>Loch McNess</td>
<td>1985-</td>
<td></td>
<td></td>
<td>Edyta Jadzinska</td>
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<td>1995</td>
<td></td>
<td>J. McConigley</td>
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<td>Creeks in Cannington</td>
<td>1985-</td>
<td></td>
<td>C. Fairclough</td>
<td></td>
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<tr>
<td>Warf Street Lake (drains to River)</td>
<td>1985-</td>
<td></td>
<td>C. Fairclough</td>
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<tr>
<td>Ponds, ornamental lakes and dams</td>
<td>1996</td>
<td>K</td>
<td>K. Breheny</td>
<td></td>
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<tr>
<td>Carramah Park, lake</td>
<td>1996</td>
<td>K</td>
<td>K. Breheny</td>
<td></td>
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<tr>
<td>Marangaroo, The Vines, Carramar Park (and numerous other) Golf Club Dams</td>
<td>1980-</td>
<td>K</td>
<td>F. Griffin</td>
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<tr>
<td>Central Park Lake, Joondalup</td>
<td>1996</td>
<td>K</td>
<td>F. Griffin</td>
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<tr>
<td>Mandurah</td>
<td>Dudley Park Estate Lakes</td>
<td>1996</td>
<td>K</td>
<td>R. Ellul</td>
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<td></td>
<td>Murray River</td>
<td>1996</td>
<td>K,G</td>
<td>B. Slight</td>
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<td>Kalgoorlie-Coolgardie</td>
<td>Lake Owen</td>
<td>1995</td>
<td>G</td>
<td>A Chapman</td>
</tr>
<tr>
<td></td>
<td>White Flag Lake</td>
<td>1995</td>
<td>G</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Rowles Lagoon</td>
<td>1970's</td>
<td>G</td>
<td></td>
</tr>
<tr>
<td></td>
<td>3km North of town (ponds)</td>
<td>1995</td>
<td>G</td>
<td>R. Bessen</td>
</tr>
<tr>
<td></td>
<td>Open-cut mine pits</td>
<td>1994</td>
<td>G</td>
<td>W. Bessen</td>
</tr>
<tr>
<td>Salmon Gums</td>
<td>Roadside dam</td>
<td>1939-40</td>
<td>C</td>
<td>Anon</td>
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Table 5.1. Summary of Anecdotal Information
(continued from previous page)

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<tr>
<td>Bridgetown</td>
<td>Blackwood River</td>
<td>1995</td>
<td>K,G</td>
<td>Ms. Philp</td>
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<td></td>
<td></td>
<td>1995</td>
<td></td>
<td>S. Low</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1985-</td>
<td></td>
<td>N. Giblett</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1970-</td>
<td></td>
<td>S. Lowe</td>
</tr>
<tr>
<td></td>
<td>Wrights Bridge</td>
<td>1994</td>
<td>K</td>
<td>S. Low</td>
</tr>
<tr>
<td></td>
<td>Revelly Bridge</td>
<td>1995</td>
<td>K (v large)</td>
<td>T Persey</td>
</tr>
<tr>
<td></td>
<td>Pine plantation dams</td>
<td>1990's</td>
<td></td>
<td>A. Brown</td>
</tr>
<tr>
<td>Nannup</td>
<td>Barabup Pool (Balingup Brook)</td>
<td>1995</td>
<td>G</td>
<td>S. Low</td>
</tr>
<tr>
<td></td>
<td>St. Johns Brook (turbid pool)</td>
<td>1995</td>
<td>G</td>
<td>J. McConigley</td>
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<tr>
<td></td>
<td>Blackwood River (billabong)</td>
<td>1996</td>
<td>G</td>
<td>P. Davies</td>
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<td></td>
<td>Kooyarup (farm dam)</td>
<td>1996</td>
<td>G</td>
<td>D. Jenkins</td>
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<td>Balingup</td>
<td>Balingup Brook (Townsite)</td>
<td>1996</td>
<td>G</td>
<td>C. Fairclough</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>S. Low</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>P. Pocock</td>
</tr>
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<td></td>
<td>Balingup Brook (fish kill)</td>
<td>1995</td>
<td>G</td>
<td>P. Ofham</td>
</tr>
<tr>
<td>Boyup Brook</td>
<td>Boyup Brook</td>
<td>1995</td>
<td>G</td>
<td>D. Wainwright</td>
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<tr>
<td>Boyanup</td>
<td>Preston River</td>
<td>1995</td>
<td>G (30cmTL)</td>
<td>J. McConigley</td>
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<td></td>
<td></td>
<td>pre-96</td>
<td></td>
<td>J. Heatherington</td>
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<td></td>
<td></td>
<td>pre-96</td>
<td></td>
<td>Aaron Brown</td>
</tr>
<tr>
<td>Stoneyville</td>
<td>Jane Brook</td>
<td>1995</td>
<td>G (20cmTL)</td>
<td>J. McConigley</td>
</tr>
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<td>Capel</td>
<td>Ludlow River</td>
<td>1996</td>
<td>G</td>
<td>S. de Lestang</td>
</tr>
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<td></td>
<td>RGC Wetlands</td>
<td>1995</td>
<td>G</td>
<td>S. de Lestang</td>
</tr>
<tr>
<td>Harvey</td>
<td>Welseley River</td>
<td>1995</td>
<td>K (0.9mTL)</td>
<td>D. Pierce</td>
</tr>
<tr>
<td>Collie</td>
<td>Wellington Dam</td>
<td>1986</td>
<td>C</td>
<td>L. Penn</td>
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<tr>
<td>Manjimup</td>
<td>Farm Dam</td>
<td>1987-88</td>
<td>G</td>
<td>J. Kitis</td>
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</table>
Figure 5.1. Locations of Museum records (a), published literature (b), anecdotal evidence (c) and composite map (d) of cyprinid fishes in Western Australia.
(unknown species). The majority of reports were urban areas of Perth (31) from the Swan, Helena and Canning Rivers, and numerous wetlands, ornamental lakes and drains. There were 13 reports from the Blackwood River, its tributaries and nearby dams, and the remaining reports were from the following locations:

- Lake Owen, White Flag Lake and Rowles Lagoon, Kalgoorlie.
- Mine pits and ponds, Coolgardie.
- Preston River, Boyanup.
- Jane Brook, Stoneyville.
- Ludlow River and RGC wetlands, Capel.
- Welseley River, Harvey.
- Wellington Dam.
- Murray River and Dudley Park Estate, Mandurah.
- Farm Dam, Manjimup.
- Dam, Salmon Gums.

The locations of anecdotal reports are shown in Figure 5.1.(c).

The composite map, Figure 5.1. (d), is an estimate of the likely State-wide distribution of cyprinids, derived from assessment of records, collections and reports. The estimated distribution of cyprinids in the south-west of the State is shown in the enlarged map, Figure 5.2.

**Discussion**

Figure 5.2. is based upon an assessment of all available information and includes some level of assumption. The assumptions are based on the proximity of wetlands to likely sources of introduction and translocation (eg. urban areas) and the ability
Estimated Distribution of Cyprinid Fishes in the South-west of Western Australia

Figure 5.2. Estimated distribution of cyprinid fishes in the south-west of Western Australia

- Carassius auratus (Goldfish carp)
- Cyprinus carpio (Koi carp)
for cyprinids to tolerate a wide range of environmental variables. They are also based on various literature (Arthington, 1991, Arthington and Mitchell, 1986, Auld and Tisdell, 1986, Cadwallader, 1979, Courtenay, 1990-a and others) which confirms the ability for introduced cyprinids to establish and spread.

Limitations to the spread and persistence of populations have also been considered in estimating distributions. Physical barriers such as weirs, dams, and dry watercourses limit the extent of distribution to some degree and, in the case of fluctuating water levels, can concentrate populations to permanent water-bodies. Environmental factors such as a lack of food resources, high salinity, swiftly-flowing cool, clean water and seasonal fluctuations in water levels at times of spawning (causing fatality by egg desiccation) are other limiting factors. Cyprinids are able to tolerate wide ranges of variability and are capable of opportunistic resource utilisation and are therefore only constrained by extreme variations. Western Australian rivers and wetlands are subject to high seasonal variability of physical and chemical characteristics and so possess factors likely to limit carp distribution.

Seasonally variable characteristics of eastern-states wetlands and waterways have not limited the spread of carp there and it is likely that other factors may be responsible for confinement of populations.

The recorded occurrence of feral populations of *Cyprinus carpio* in Western Australia by Lawrence (1993) did not specify locations. The presence of the Koi variety of this species in the Blackwood River (Wrights Bridge and Revelly Bridge), the Welesely River and the Canning River is based on multiple anecdotal reports. The estimated distribution of Koi (Figure 5.2.) is based upon strong anecdotal evidence, sampling in urban ornamental lakes in Perth and personal observations in numerous ponds, dams and ornamental lakes around Perth, Mandurah and Bunbury. The extent of distribution of Koi or other varieties of *Cyprinus carpio* in other areas of the south-
west is not known and cannot be assumed or discounted without further sampling.

The reports of *Carassius carassius* (Crucian carp) have not been confirmed by sampling and the current debate over identification (Fletcher, 1986 and Brumley, 1991) leaves the presence of this species in some doubt. Without confirming evidence, the distribution of this species is unsubstantiated and is not included.

The estimated distribution of *Carassius auratus* (Goldfish) extends from Moore River, north of Perth and south to the Pallinup River, west of Albany. The distribution may extend into the upper reaches of most of the coastal rivers and tributaries. There is a likelihood of populations existing in other locations, such as has been reported in lakes north of Kalgoorlie, but the long-term viability of these populations is uncertain.

The estimated distribution of *Cyprinus carpio* (Koi) is confined to lakes and ponds in urban locations from Perth to Bunbury. The strong likelihood of feral populations surviving in the Blackwood River near Nannup and Bridgetown has been established. The existence of self-sustaining populations in the Swan-Avon, Canning, Harvey, Murray and Welseley Rivers is not confirmed but should not be discounted.
CHAPTER 6

ENVIRONMENTAL IMPACTS

Introduction.

The environmental impacts of cyprinids in Western Australia have not been examined in any known literature. Several studies have been undertaken in southeastern Australia since the dramatic spread of *Cyprinus carpio* (European carp). The research was in response to concerns arising from perceived changes to environmental quality such as turbidity, reduced aquatic plants and increased bank erosion in natural waterways invaded by carp (see Chapter 1, pp. 3-4). These studies have been fragmentary and widely distributed between research institutes (J. Roberts, pers. comm.). Recent forums such as The 1994 Forum on European Carp (Nannestad, 1994) and the 1995 National Carp Summit (Moor, 1995) have been organised to attempt to coordinate carp-related research, but these initiatives have yet to prove successful (J. Roberts, pers. comm.).

The lack of coordinated research and a perceived paucity of literature led to investigation of the availability and content of published Australian literature dealing with introduced cyprinids.

The biology of cyprinids, and especially their feeding ecology, influences their impacts on wetland ecology. Specific characteristics of cyprinid feeding mechanisms, morphology and resource selectivity, which are relevant to Western Australian wetlands, are examined.
Methods

Australian published literature was compiled from computer database information, published works and their reference lists, journal searches and direct inquiry to research institutes studying the impacts of carp in eastern Australian.

Informit (RMIT University Libraries) ‘Heritage and Environment’ CD-Rom provided access to the Australian databases CELIS (Library of Natural Resources), ENDANGER (Deakin University Library), EPIC (Planning and EPA Libraries), and STREAMLINE (Infoscan Pty. Ltd.). The Applied Science and Technology Index (H. W. Wilson Company) CD-Rom (October, 1983 to June, 1996) provided access to Cambridge Scientific Abstracts. Uncover, First Search and Current Contents databases were available through Edith Cowan University Library Internet link and provided access to National and International publications and journal article titles for examination. Reference lists and bibliographies from more than 200 publications were used as a further guide to relevant journal titles and scientific publications.

The topic words used for searches in all databases were carp, cyprinus, carassius, goldfish, tinca, tench, rutilus and roach. Australia and cyprinid were added to these topic words when searching international databases.

Local, national and international journal articles and publications related in any way to cyprinid fishes were examined to determine whether the topic or location of the study originated in Australia or was directly related to Australian studies. Unpublished papers and proceedings from Conferences, Summits and Symposiums (etc.) can be a useful source of reference material but are extremely time-consuming to retrieve and, due to time constraints, were not included.

Literature detailing the morphology of cyprinid feeding processes provided
information for assessment of those characteristics likely to influence the way that cyprinids utilise invaded wetland habitats.

Results and Discussion.

Eighty two articles on cyprinid research in Australia were located and assigned into three topic categories (derived from article content) to eliminate complexity - Environmental (26 articles), Introduction-Distribution (36 articles) and Biological (20 articles). Some articles cover multiple topics and may contain information on the other categories. The summarised details, and a full bibliography indicating author(s), date, title and source is included in Appendix 1.

The Australia cyprinid literature focus on the introduction, translocation, distribution and environmental issues related to perceived impacts. The low number and restricted focus of the biological studies may be a limiting factor when considering the potential for cyprinids to cause environmental impacts. The adaptability of cyprinids to local situations and the possibility of a shift in tolerance limits induced by acclimatisation suggest that the physiological factors which have been widely investigated in the Northern Hemisphere, may be less relevant to the different habitats and climatic conditions of Western Australia.

European, Asian and North American literature forms a basis for Australian studies but most research undertaken in Europe and Asia is directed towards issues related to aquaculture. Some of the recent overseas literature (eg. Sibbing, 1991) details the efficiency of cyprinid feeding mechanisms in utilisation of resources. There is no cyprinid aquaculture and only limited cyprinid aquarium culture in Australia, and literature on morphology and feeding mechanisms have not featured in local research.
The processes of resource utilisation can be used to assess the likely impacts of resource utilisation on local ecosystems and this provides an essential starting point for preliminary assessments of the influence of the processes on habitat, food availability, resource utilisation and conflicts with native fish feeding regimes.

**Food Processing by the Cyprinid Fishes.**

It seems likely that two species of cyprinids, *Carassius auratus* and *Cyprinus carpio*, are established in Western Australia and all discussions here refer to these species. Gosline (1973) states that the only variation in the feeding processes of *Carassius auratus*, *C. carassius* and *Cyprinus carpio* is related to the pharyngeal teeth formula. All other processes are considered to be functionally identical and this is supported by Sibbing (1987).

The close association between suction feeding, development of pharyngeal jaws, loss of teeth in the jaws and in development of a premaxilla protrusion (protrusible jaws) have contributed to the cyprinid's status as the largest Family of freshwater fishes. In order to better understand the feeding processes of carp, Sibbing (1987) poses a series of questions paraphrased as follows:

- What are the mechanics of cyprinid food processing?
- What are critical structures and their value in feeding?
- Do cyprinids adapt their mechanics depending upon the availability of particular food types?
- Are the functions the same for other teleost fishes?
- What are the consequences of characteristics for the utilisation of resources?
- What makes cyprinids successful utilisers of food?
Sibbing (1982 and 1987), Alexander (1966) and Gosline (1973) deal in considerable depth with the physical/functional morphology of cyprinids and, when viewed from an ecological perspective, provide insight into the way carp utilise food.

The success of carp in competing with other fish and their efficiency in exploiting new habitats and resources depends upon the efficiency of their feeding specialisations (Sibbing 1987). Cyprinids are characterised by highly protrusible mouthparts (Figure 6.1.), toothless jaws, toothless palate, tooth-bearing pharyngeal bones (modified gill rakers), the absence of a stomach and often with anterior (rostral) and/or posterior barbels (Figure 6.2.). Location, capture, selection, purification, transportation mastication, ingestion and digestion (Figure 6.3.) are typical functions undertaken by teleosts and involve complicated and interrelated processes (Sibbing, 1982).

When feeding at the benthos, cyprinids swim horizontal to the bottom (avoiding energy-wasting inclination) using sensory barbels to detect food (Alexander, 1966). They usually ingest food by extending the protrusible jaws (Figure 6.1.) and sucking up the benthic material. Carp can suck items from as deep as 12 cm below the substrate at a velocity of 50 cm/sec. (Sibbing, 1982). The process is called ‘pipette feeding’ (Gosline, 1973) or ‘mumbling’ (Brown, 1996). The sucking action and a similar gulping action is utilised in the water-column when not feeding at the benthos. The sucking function is not selective and, as food, mud and other inert and inorganic matter are ingested, part of this mixture passes directly to the digestive tract. Intestines often contain relatively large amounts of inert particles of sand, silt and inorganic matter. A multiple process of selection is undertaken in the oral and buccal cavity and at the pharyngeal slit (Lammens and Hoogenboezem, 1991).
Some ingested material is held by the branchial sieve (gill arches) and some is selectively sorted by the sensory taste buds of the palatal organ (sometimes called the pharyngeal pad or pharyngeal roof) above the pharyngeal slit (Figure 6.2.). Discarded particles (<250um) are ejected through the branchial sieve and larger particles and all material >4% body length are expelled from the mouth by spitting. The retained matter is ground or crushed to varying degrees between a keratinous pad in the upper posterior pharynx and the pharyngeal teeth pad in the lower posterior pharynx (Figure 6.3.). Masticated matter is swallowed into the oesophagus and passes through a sphincter and directly to the intestine. The alimentary tract lacks a stomach.
The features used for intake, selection, purification, transportation, mastication, ingestion and digestion (Figure 6.3.) and each feeding apparatus (Figure 6.2.) show specialisations for each function.

Simplified Representation of Anterior of Cyprinid Fishes. Showing location and layout of mouthparts.

Vertebrae
Oesophagus
Sphincter
Intestine
Pharyngeal teeth
Branchial slit
Keratinised grinding pad
Pharyngeal roof
Toothless palate
Toothless jaws
Anterior barbel
Posterior barbel
Pharyngeal floor


Figure 6.2. Simplified representation of anterior of cyprinid fishes showing oral, buccal and pharyngeal features.

Some of the specialisations can have disadvantages, for example the narrow pharyngeal slit is a specialised apparatus which assists in selection of small particles, but it limits the maximum prey-size handled by the pharyngeal cavity. Only items <4% body length in diameter can enter the chewing cavity, although items up to 10% SL can enter the mouth cavity (Sibbing, 1987).

The lack of a stomach may increase the demands on the masticatory function and may have influenced the development of the long digestive tract, which can be 8 to 13 times body length (Hofer, 1991).
Figure 6.3. Diagram of the ventral and dorsal oral food processing features in cyprinid fishes.

The size of the mesh gap of the branchial sieve (gill-arches) limits the retention of items <250um (Sibbing, 1987, citing Uribe-Zamora, 1975 and Lammens and Hoogenboezem, 1991) which excludes most forms of phyto-plankton and diatoms from carp diet. The lack of a stomach prevents lysisation of the cell walls of blue-green algae by the low pH gastric fluids, such as occur in Tilapia, and no cellulases are reported in carp gastric juices (Hofer, 1991). These factors combined with the limited efficiency of carp mastication infers that the larger (>250um) phytoplankton and diatoms are not efficiently digested. Zooplankton (>250um) is effectively retained and processed (Sibbing, 1991) although retention is dependant upon the branchial sieve mesh gap size which varies with fish size and as a consequence, food may change with age. The lack of teeth and limited mastication prevents efficient...
utilisation of filamentous algae or macrophytes but soft, floating macrophytes, such as *Lemna minor*, may be ingested (Roberts et al., 1995).

Carp are not considered fast-moving fish and a lack of grasping teeth limit their capacity to capture fast-moving prey such as fish (Sibbing, 1991). The pharyngeal teeth are not raked or piercing and are therefore of no benefit for transporting or lacerating. Struggling objects any larger than 4% TL cannot be processed. These factors greatly limit the capacity for carp to predate juvenile native fish and excludes predation of large fish.

The function of mastication includes crushing, grinding and, to a limited degree, cutting and shearing. Soft organisms (worms etc.) are punctured and squashed. Encased tubificids are partly compressed or remain intact and the chitinous skeletons of chironomid larvae are undamaged. *Daphnia* and planktonic crustaceans are crushed. Vegetation shows some levels of compression and minor disruption of fibrous material but remains mostly unaffected and cells generally remain intact. Seeds (macrophytes, cereals etc.) are readily treated by the cracking, crushing and grinding function of the pharyngeal teeth. Benthic invertebrates (larvae, tubificids and molluscs) are efficiently utilised.

Faeces examination indicates that mastication aids the entry of digestive fluids into fractures and carapace openings and allows flushing of cells from casings (Sibbing, 1987, citing Uribe-Zamora, 1975). Undamaged (sealed) matter and inert or inorganic matter is expelled intact.

The detritus retained (>250um) is processed more by lack of refinement rather than by preference since there are no specialisations which seem to target this material apart from the branchial mesh-gap and the taste sensory organs.
The most effectively processed foods (in order) are:

- Benthic invertebrates
- Zooplankton
- Thallose algae and macrophytes
- Detritus

Sibbing (1987) claims *Cyprinus* sp. and *Carassius* sp. may exhibit a specific ability above other cyprinids in efficiently processing food from ingested matter. Whether this specialisation broadens or narrows the adaptive feeding capacity is unknown and requires further research. It does indicate a capacity for efficiency above other species even within the same Family and must be considered as a factor in their ability to utilise available food resources.

Consideration of feeding specialisations and functions were either limited or omitted in early studies of environmental impacts of carp in Australia. The work by Sibbing (1982, 1987 and 1991) and Lammens and Hoogenboezem (1991), has been cited in more recent studies on the impacts of carp on aquatic vegetation. In one study of the impacts of the European carp on aquatic vegetation in ponds in eastern Australia, Roberts, Chick, Oswald, and Thompson, (1995), included morphological considerations and concluded that the carp were not preferentially consuming the plants but were dislodging them when foraging for other resources. The study by Roberts et al. (1995) shows that the feeding processes of carp directly and indirectly influence their environmental impact and also emphasises the value of close consideration of biological features when assessing impacts.

Intestinal tract contents analysis is regularly used to determine the role of cyprinids and other fish in competition for food. Opportunistic feeders (most fish) will display representations of available food at the time of analysis, rather than the ability or propensity for utilisation of a specific food resource. In order to effectively consider
what food resources are used, the variety and variability of available resources must both be clearly established.

In the study by Fairhurst (1993), the intestinal tract contents of *Carassius auratus* was reported as mainly planktonic crustaceans (64.1% chydorid cladocerans) in smaller (<25mm TL) fish, and mainly diatoms, filamentous algae, copepods and cladocera in larger fish (25-80mm TL). Fairhurst did not list the taxa present in the intestine of *C. auratus*. Studies which focus on the differentiation between the species utilised in the diet of carp will provide valuable data for assessment of competition for resources. In opportunistic feeders such as carp, intestinal tract contents may not necessarily be a result of preferential consumption of resources but may be a consequence of incidental ingestion and lack of selectivity. The need for selective differentiation of intestinal tract contents, along with an understanding of the feeding processes, is essential when assessing resource utilisation and the capacity for inter specific competition (such as dietary overlap).

**Resource Selectivity.**

The seasonal regime of carp diet in Europe as reported by Uribe-Zamora (1975) cited in Sibbing (1987), was as follows:

**Winter**

Benthos - tubificids and chironomid larvae.

(Feeding reduced at lower temperatures - absent at <6°C)

**Spring**

Larger crustaceans - (diatoms, daphnia and cyclops)

(Carp utilise water-column zooplankton resources as benthic resources decrease and zooplankton resources increase).

**Summer**

Soft littoral vegetation and epifauna - (molluscs, copepods, trichopterans...
and oligochaetes).

(Larger zooplankton decreases due to fish predation and macrophytes increase).

Autumn

Oligochaetes and dipterans.

Oxygen levels decrease and activity slows. Efficiency of feeding dictates the utilisation of the most abundant resources).

These observations are widely reported (Lammens and Hoogenboezem, 1991, Hofer, 1991, and Horvath, Tamas, and Seagrave, 1992) and confirm the diet to be mainly Chironomids, tubificids, larger zooplankton and larger zooperiphyton. There are no reports of piscivornism by carp in natural habitats and herbivornism is inefficient and limited to smaller soft species of macrophytes (Roberts, Chick, Oswald and Thompson, 1995).

The seasonal variations in the food processed indicates a selective preference for readily available resources, commensurate with the carp’s processing capacity. Adaptability to available resources also indicates a capacity for carp to utilise a range of resources and may provide a predictive indication of likely target prey species in a given habitat with known resources.

As with all reported studies from outside Australia, the relationship between these findings and the Australian environment has not been established and inferences must be tempered accordingly. A well-founded understanding of the morphological and biological characteristics of carp provides the basis for objective assessment of the implications of it’s presence in the Western Australian.

In a 1989-90 study of 41 representative wetlands of the Swan Coastal Plain, Davis, et al., (1993), provide comprehensive details of water quality, trophic status, aquatic
invertebrates, physical and chemical characteristics and resource availability. The study also provides details of the dynamics of macroinvertebrate assemblages in a variety of different habitats and confirms the availability of a range of food resources utilised by cyprinids.

The macroinvertebrates which, according to Sibbing (1987), Lammens and Hoogenboezem (1991), Hofer (1991), and Horvath, Tamas, and Seagrave, (1992), form the major components of cyprinid diet (tubificids, chironomids, molluscs, copepods, trichopterans, oligochaetes, dipterans, daphnia and larger diatoms), were reported throughout the Swan Coastal Plain wetlands sampled by Davis, et al., (1993). The fluctuations in community structure (eg. chironomids larval densities from <2000 to >6900 m\(^{-2}\)) in macroinvertebrate and in phytoplankton community structure, described by Davis, are further indications that typical wetlands of Western Australia provide the required resources and environment for the successful establishment and long-term viability of cyprinid populations.

The essential requirements for successful invasion include wide environmental tolerances, flexible habitat requirements, opportunistic and adaptable feeding strategies, variability in resource utilisation and aggression (Arthington & Mitchell (1986). Cyprinids possess all these attributes and have come to dominate the fish fauna in eastern Australia. Western Australian wetlands do not pose a threat to cyprinid invasion.
CHAPTER 7

GENERAL DISCUSSION

The cyprinids species, *Carassius auratus* and *Cyprinus carpio*, have been introduced and have established populations in Western Australia. The study has described their likely distributions and their biological attributes for invasion, survival and persistence in aquatic habitats. New Zealand and Australia have no native cyprinids but, in both countries, *C. carpio* populations have dramatically increased and are credited with causing widespread environmental degradation. In eastern Australia they dominate the fish fauna in Australia’s largest river system, the Murray-Darling Basin (Harris, 1994).

Legislation, regulations, research and public opinion has failed to prevent the spread of invasion or to define and ameliorate the impacts. *C. carpio* (carp) have been blamed for increased turbidity, loss of aquatic macrophytes, stream-bank erosion, nutrient enrichment, algal blooms, reduced water quality, reductions of native fish populations and ecosystem alterations in many eastern Australian waterways. Research which began in the 1970’s has so far failed to define how much of the environmental degradation is directly attributable to carp.

Carp are believed to play some role in increasing turbidity (Richardson & Whoriskey, 1992, Breukelaar, et al., 1994, and Roberts, et al., 1995) but Fletcher, et al., (1985), claims that water-level fluctuation (natural and induced) plays a more prominent role. Reduction of aquatic macrophytes was attributed to direct predation (Richardson, Whoriskey & Roy, 1995), but a recent study by Roberts, et al., (1995), determined that disturbance of the substrate, rather than preferential consumption, was the cause of loss of aquatic plants.
The issues of stream-bank erosion, reduction in native fish populations, nutrient enrichment and increases in algal blooms are subject to current research and, as yet, are undefined. Although there may be some connection between these impacts and the presence of carp, the possibility of other causes cannot be dismissed.

The biology and morphology of cyprinids is widely researched in Europe and Asia, where aquaculture provides the impetus for research. Knowledge of the feeding ecology, resource utilisation and environmental tolerance limits, as derived from overseas research, may not be applicable to the Australian environment. Cyprinids have been present in Australia for over 100 years and are capable of developing feral populations and hybrids and can readily adapt to local environmental conditions (Arthington & Mitchell, 1986, and Courtenay, 1990-a). These attributes may be an indication that Australian populations have adopted specific characteristics attuned to local environmental variables. This possibility is raised in this study in relation to the possibility that carp become torpid at higher temperatures than reported in overseas literature. It is clear that there is insufficient data available to properly define and quantify the environmental impacts caused by cyprinids. The most important issue here is that a lack of scientific evidence is not a valid reason for dismissing the possibility.

There is a constant demand from the public, farmers and industry in Victoria, South Australia, New South Wales and Tasmania for authorities to define and, where necessary, ameliorate the environmental impacts of C. carpio introductions (Eagle, 1994, Hindmarsh, 1995, Killen, 1994, McFarland, 1994). In these States, the population explosion and rapid spread occurred 30 years ago. In Western Australia, the potential for a similar situation to occur must not be dismissed.
Carassius auratus and Cyprinus carpio are aquarium species and their initial introduction to Western Australia for aquarists has resulted in accidental or deliberate introduction and translocation into natural waterways and wetlands.

Carassius auratus is a permitted import but all varieties of Cyprinus carpio are banned from import into Australia according to the Wildlife Protection (Regulation of Exports and Imports) Act, 1982, Schedule 6. Within Australia, licensed aquaculture of C. carpio (mainly the Koi variety) for the aquarium industry is permitted. No health certification is required for the translocation of aquarium fish into Western Australia from interstate. The role of regulations which apply to overseas and interstate imports of cyprinids are confined to controlling the quality of stock and they do not prevent accidental or deliberate releases.

The introduction of cyprinids into Western Australia is indirectly due to the cultural and economic demands of aquarists. Stocking Koi variety of C. carpio in ornamental lakes, ponds and aquatic gardens in residential developments, public parks, resorts, commercial gardens, has become increasingly popular. An example of the capacity for such innocuous introductions to lead to contamination of natural waterways is Dudley Park in Mandurah. Ornamental lakes, stocked with Koi have recently been connected to the Peel-Harvey estuary by construction of an overflow drain. During winter the lakes discharge into the estuary and the likelihood of introduction of cyprinids into the estuary and the Murray and Harvey River cannot be discounted. Carp tolerate high salinity (15000 mgL⁻¹) and winter rains reduce salinity levels in the estuary.

There is considerable anecdotal evidence of recreational fishers undertaking a form of coarse fishing for cyprinids above Kent Street weir in the Canning River, Perth. Coarse fishing fosters the nurturing of the target species and releasing of captured fish, artificial feeding and stocking of potential habitats are typical coarse fishing
practices. There is evidence in eastern Australia of the acceptance, by recreational fishers, of the dominance of carp in many waterways, and they are now targeting the species for sport (Sheppard, 1996).

Trout fishers in the south-west of Western Australia report that trout are no longer collected from streams which have become dominated by *C. auratus*, but trout can still be caught in streams where carp have not yet been collected (S. Low, pers. comm.)

Fluctuations in species dominance in a waterway may be due to any number of causes but the anecdotal evidence of interactions between the two introduced species, trout and carp, points to the possibility of similar interactions between carp and native species populations. Lack of research means that any assessment of the impacts of carp on native fish is speculative.

Where research is lacking, such as in Western Australia, the capacity for cyprinid fishes to alter habitats may be interpreted from biological characteristics. The way cyprinids forage is conducive to increasing turbidity and their diet is conducive to selective predation of zooplankton in the water column and chironomids and tubificids in the benthos. These features, combined with wide tolerance limits, predispose cyprinids to habitat alteration and disruption of trophic stability. According to the principles of the trophic cascade theory, described by Carpenter, Kitchell and Hodgson, (1985), any alteration to trophic levels within an aquatic system will ultimately ‘cascade’ and impact upon the total ecosystem.

The cyprinids present in Western Australia inhabit a range of wetlands on the Swan Coastal Plain which have varying, and usually high, levels of productivity, and which usually support a diverse trophic ecology (Balla & Davis, 1993, Bekle, 1979, Davis et al., 1993, and Davis et al., 1991). The increasing levels of eutrophy of some of
these wetlands (Davis et al., 1993), may limit the presence of some native species but may provide suitable habitats for supporting much more tolerant cyprinid fishes, at no disadvantage to native populations.

Alternatively, in the waterways of the south-west of the State, productivity levels are generally low (Morrissy, 1995). The biomass of cyprinids in the waterways is not known, but strong anecdotal evidence collected in this study indicates that, although the cyprinids are wide-spread, they are not represented at biomass levels conducive to environmental degradation, such as defined by Fletcher, Morison and Hume, (1985). This might indicate that the low productivity either limits available resources and so acts as a natural control of cyprinid biomass, or is itself a direct result of the presence of cyprinids. In either case, a form of natural control is conceivable, but a great deal of research is required before the processes influencing the environmental implications of cyprinid introductions are known.

Whether there are any positive environmental impacts created by the introduction of cyprinids is not known, but the possibility should not be totally discounted. In the absence of supportive research, the issue is whether to adopt the precautionary principle in dealing with cyprinid introductions, or to accept the presence of cyprinids and let ‘nature take its course’.

What can be done?

Control measures have been undertaken in eastern Australia, where numerous costly attempts to remove, confine and control carp have failed. In Gippsland, Victoria, in the 1960’s and in Tasmania in the 1970’s, where there was early detection of the presence of carp in localised areas (farm dams), legislation was enacted and enabled authorities to effectively eradicate the populations from the dams (private property).
In both these cases, non-specific piscicides were used. Authorities were not aware of infestation of natural watercourses. In recent attempts to remove carp from lakes, piscicides and water draw-down have been attempted. In the Leigh Creek Dam (S.A.) in 1988, 6 million *Carassius auratus* and 0.5 million *Cyprinus carpio* were killed using rotenone (Moseley, 1988).

In cases where reduction or removal of carp from natural wetlands has been considered, the resultant impact on native fish and other aquatic organisms has precluded or limited the extent of action taken. As a result, and despite early successful removal from localised areas, carp have generally avoided all control measures and continued to persist and expand.

Biological control has been the topic of considerable debate as a possible alternative (Harris, 1994). *Rhabdovirus carpio* (Spring Viramea), is a virus which infected European aquaculture stocks of cyprinids. It is suspected to be specific to carp (Crane, 1995), but insufficient is known of the native specie’s resistance to virus. Much more research is required before this method of control can be considered. Harris (1994) questions the ethics of importing an infection, even with assurances of impunity.

Control in Western Australia may still be possible in localised populations using conventional methods of electro-fishing (and poisoning of private waterways) due to the relatively small populations and low biomass.

In the current absence of effective physical, chemical and biological controls, the only remaining means of control are prevention of introductions by education and allocation of resources for research into alternative means of eradication or amelioration.
Prevention of further introductions and translocation.

Education of authorities, researchers, fishers and the public to promote an awareness of the environmental implications associated with the importing, moving, placing, dumping and general fostering of cyprinid fishes is a basic essential of any control or amelioration effort. Given the lack of alternatives, fostering awareness may be the only method of reducing unintentional introductions.

Dictating by legislation is always a difficult and unpopular alternative and, based on the experiences of legislative action in eastern Australia, has proven unsuccessful. The presence of feral populations of *Cyprinus carpio* in Western Australia (Lawrence, 1993) renders current import and aquaculture regulations irrelevant as controls against introductions.

**Recommendations**

Lawrence (1993) listed three recommendations for action after introductions or translocation. They were:

- study the species and report it’s progress,
- attempt to contain the species within the waterbody, and
- encourage authorities to use the strongest possible preventative measures.

These options may seem sensible, but are they all that can be done?

This study serves as an introduction to cyprinid fishes in Western Australia and provides a picture of the capacity for the species to cause adverse environmental
impacts. The following recommendations are intended to provide decision-makers with a means to approach the problem of introduced cyprinids.

The established presence of *Carassius auratus* and *Cyprinus carpio* in wetlands throughout parts of the State, precludes recommendations for the prevention of introductions, so recommendations are aimed at amelioration of possible impacts.

The primary recommendation is for the Fisheries Department to acknowledge the environmental implications of introduced cyprinids in the wetlands of Western Australia by implementing a program of education, designed to foster community-wide awareness of the environmental impacts associated with introductions of cyprinid fishes. There is no commercial aquaculture of cyprinids in Western Australia, collection does not require a license and there are no regulations to prevent introductions. The Fisheries Department must formally acknowledge the presence of cyprinids and adopt licensing measures to control translocation and introduction by the aquarium industry and the public.

Considering that cyprinids have the capacity to affect viability of native fish and marron, and trout, a carp education program should be instigated and afforded similar status to, and be included in, similar programs for these aquatic animals. To be effective, the education program should be directed to all levels of society and requires the support of government, the aquarium industry and recreational fishing groups.

The secondary recommendation is for the State Government, the State’s aquarium and aquaculture industry, recreational fishing bodies, and research institutions to provide the necessary resources to investigate, develop and implement the means to ameliorate the environmental impacts associated with cyprinid introductions and translocation.
Positive action will be dependant upon the availability of knowledge, personnel, facilities, funding and community cooperation for authorities, institutes and individuals undertaking cyprinid research.

Authorities are committed to maintaining environmental biodiversity, and the aquarium/aquaculture industry and recreational fishers can be environmentally responsible and accountable. Authorities such as the Fisheries Department must accept responsibility for direction and guidance to industry and to the public in this issue.

Environmental research institutes are also committed to addressing issues affecting the States wetlands biodiversity, and they are responsible for ensuring that resources are made available and are effectively utilised. Some infrastructure is available through such bodies as the CSIRO, the Fisheries Department and University research units which will greatly assist in research into the implications of cyprinid introduction and the cooperation and direct involvement of these, and other authorities and experts is essential.

In my closing comments in Chapter 1, I stated that my underlying goal was to generate an awareness of the potential hazards facing Western Australia as a result of cyprinid introduction. Being aware of the hazards is being forewarned, but being aware and doing nothing is culpable. Hindmarsh (1995) refers to carp as ‘the underwater rabbit’ and it is sad to think that, if carp had long ears and fur, they might be afforded the urgent attention they deserve!


# APPENDIX 1

**Bibliography of literature based on Australian cyprinid research.**

(Sources: CELIS, ENDANGER, EPIC, STREAMLINE, Cambridge Scientific Abstracts, Uncover, First Search, Current Contents and literature.)

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