THE CSIRO-AUSTRALIAN ANIMAL HEALTH LABORATORY, GEELONG IS A HIGH-SECURITY DISEASE LABORATORY BUILT FOR RESEARCHING AND DIAGNOSING EXOTIC DISEASES OF AUSTRALIAN ANIMALS

KOI HERPES VIRUS: DREADED PATHOGEN OR WHITE KNIGHT?

DRS KENNETH A MCCOLL, AGUS SUNARTO, LYNETTE M WILLIAMS AND MARK ST J CRANE
(CSIRO-AAHL FISH DISEASES LABORATORY, GEELONG, AUSTRALIA)

Disease associated with koi herpes virus (KHV) was first described in common carp (*Cyprinus carpio carpio*) in Israel in 1998, although retrospective studies have since shown that the virus was responsible for mortality in common and koi carp (*Cyprinus carpio koi*) from about 1996.

Since then, the virus has spread throughout much of Europe and Asia, and to South Africa and the United States, and represents a serious threat to important carp industries. Consequently, in many areas of the world, significant resources are currently being directed toward developing control strategies for the disease.

By contrast, common carp in Australia is an introduced pest, and KHV represents one of a number of potential weapons that might be used in a multi-pronged attempt at controlling them.

THE AUSTRALIAN SCENE

There are approximately 300 species of freshwater fish in Australia, a small number by comparison with other similar-sized landmasses. Of these, at least 43 alien fish species are recognised in Australian inland waters, with 31 of these species now thought to be present as self-sustaining populations.

While there are no native salmonid, percid or cyprinid fish in Australia, the alien species include representatives of these families (for example, rainbow trout, brown trout, redfin perch and carp). In addition, highly undesirable species, such as *Tilapia* sp and *Gambusia* spp, are also present.

Cyprinidae is the largest family of freshwater fishes in the world, with over 2000 species in 210 genera. Native species occur in all the tropical and temperate regions except Australia, New Zealand, Madagascar and South America.

However, they have been introduced to each of these previously cyprinid-free locations. Apart from carp, a number of other cyprinids have also been introduced to Australia, including goldfish (*Carassius auratus*), rosy barb (*Puntius conchonius*), roach (*Rutilus rutilus*) and tench (*Tinca tinca*).

Carp were first introduced to Australia in the 1850s as an ornamental fish, but had little impact until the 1960s, when the Boolara strain gained access to the Murray River in southeastern Australia. This particular strain adapted very well to Australian conditions (aided by floods in 1974 and 1975), and the carp population expanded dramatically.

Although there have been no systematic surveys of the distribution of carp in Australia, they are found throughout the Murray-Darling system, and all of southeastern Australia (Figure 1).

They are said to comprise 80 to 90 percent of the fish biomass of the Murray-Darling basin, and have favoured rivers that are highly regulated for irrigation. Carp have also been found in Tasmania and Western Australia, the former state having staged a decade-long eradication programme in the Ramsar-listed wetland (Interlaken) at Lakes Crescent and Sorell.

While four strains of carp have been described in Australia – koi, Prospect, Yanco, and Boolara – it is the latter which has been responsible for the massive extension of the range of carp. As an example, numbers of the Yanco strain in the Murrumbidgee Irrigation Area (MIA) changed very little from the time of its introduction. However, following the invasion of the Boolara strain, carp numbers in the MIA increased dramatically.

ENVIRONMENTAL ISSUES

So, why all the fuss about carp in Australian river systems, and why is there now such an effort to control them? Davidson (2002) has

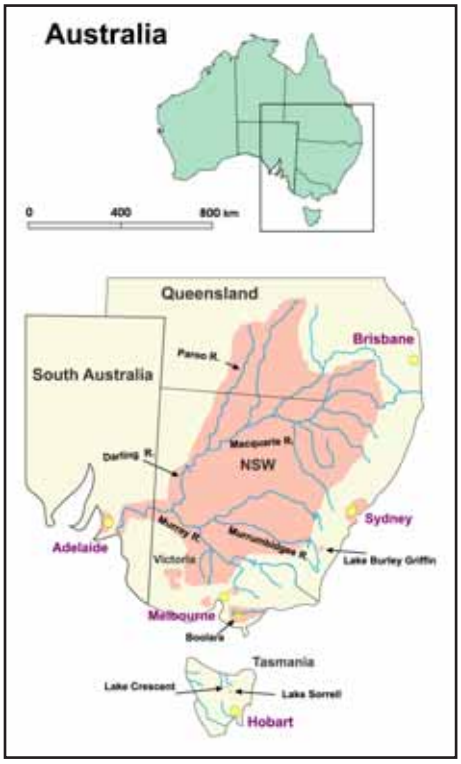

FIGURE 1: DISTRIBUTION OF CARP IN SOUTHEASTERN AUSTRALIA. THE GEOGRAPHICAL RANGE IS REPRESENTED BY THE SHADED AREA AND INCLUDES TWO LAKES IN TASMANIA

dubbed the carp the "rabbit of the river", an epithet that is perhaps an indicator of:

- **fecundity.** A female carp may produce a million eggs per year and can spawn a number of times in a year on a variety of substrates and environmental conditions.
- **adaptability.** While they prefer warm, still waters, they may be found in virtually all aquatic environments, including saline waters, except free-flowing rivers and mountain streams.
- **carrying capacity.** Carp have been known to dominate fish assemblages, in some cases up to 96 percent of the fish biomass in parts of the Murray-Darling Basin. In addition, carp are omnivorous and there are no native detritivorous fish to compete for food resources.

Because of the ubiquitous nature of carp in many areas of Australia, they are considered to be a national problem. Nevertheless, Davidson also says carp may be "the first scapegoat to have fins and scales", that is, perhaps carp are not responsible for all of the problems that have been attributed to them.

There has been very limited research on the environmental impact of carp in Australia, and very little of the information that is available has come from controlled experiments. In the years since their introduction, many environmental problems have been attributed to carp, but the only confirmed cause-and-effects have been:

- increased water turbidity. The feeding mechanism of carp, (sucking mud from the substrate, and then sieving it to detect food) no doubt increases turbidity
- a reduction in submerged vegetation, due to direct and indirect effects (uprooting of plants, and a reduction in light, respectively), and
- effects on the frequency of algal blooms, due to increased nutrients in the water.

Despite claims to the contrary, there is apparently little evidence for a role for carp in erosion of riverbanks, spread of disease, and declines in the number of native fish. In fact, declines in the numbers of various native fish have been documented prior to the expansion of carp, and it is likely that these declines are the result of human intervention (eg regulation of river flows, eutrophication of waters and increased salinity).

Carp are probably favoured by the declining state of many of our river systems, and therefore it is now considered that carp are not only one of the causes of the environmental degradation of our inland waterways, but also that their proliferation is an effect of the degradation.

Nevertheless, while hard evidence for the damaging effect of carp may presently be lacking, there is little doubt that the very high absolute, and relative, numbers of carp has a seriously deleterious effect on Australian freshwater ecosystems. For this reason, a variety of approaches have been examined in an attempt to control carp.

CONTROL STRATEGIES

Potential future strategies for controlling carp include methods that have been used in the past, together with other new and innovative approaches that are currently being evaluated through the Invasive Animals Cooperative Research Centre. Realistically, it is likely that controls will probably rely on a combination of approaches, and it should be known that there will be no "silver bullet" for controlling common carp.

Commercial harvesting and poisoning. This approach probably has little effect on established populations of carp, due to their fecundity. It appears that the increased resources that are available to those carp that escape a harvest, or a poisoning campaign, simply allow very rapid repopulation by the survivors. In other words, even a decimated population will bounce back very quickly.

"Daughterless carp". The underlying principle of this approach is to control carp by genetically interfering with sex ratios and biasing towards male-only offspring. If the approach proves successful, over many decades there would be a gradual reduction in the number of female carp in wild populations, with a concomitant reduction in the overall number of carp.

Immunocontraception. Any approaches to reducing carp fertility are at a very early stage of development, and would require much more work before being considered for implementation.

Environmental restoration. There is increasing interest in the idea of restoring the health of rivers, and in the process making them less attractive to carp and more appropriate for native fish. The reintroduction of carnivorous native fish, in particular, may contribute to a reduction in carp numbers by predation on young carp.

Physical controls. Carp in Australia have predictable season spawning movements, and display innate jumping behaviours that lend them to trapping and screening technologies. These are currently being investigated and trialed in the IA CRC.

Chemical controls. The large amount of ecological work done on carp in the wild shows that carp release and respond to chemical cues, including pheromones and environmentally borne cues. The IA CRC is investigating the isolation and evaluation of these potential cues.

Biological control with infectious agents. While spring viraemia of carp virus has been considered a potential candidate in the past, there are documented limitations with it. For that reason, attention in Australia has more recently focussed on a possible role for KHV.

POTENTIAL BIOLOGICAL CONTROL

Although there is some continuing debate over the taxonomy of KHV, it is currently recommended that it be classified as a herpes virus. Certainly, at a genetic level, it appears to be most closely related to two other herpes viruses of cyprinids – one causing carp pox, and the other goldfish haematopoietic necrosis – so it is now officially known as cyprinid herpes virus 3 (CyHV-3). Further research may yet provide some taxonomic surprises.

Regardless of the nature of the virus, however, observations recorded during natural outbreaks of KHV-associated disease, especially when combined with research results on the virus, ▶

KOI HERPES VIRUS: DREADED PATHOGEN OR WHITE KNIGHT?

LESIONS ASSOCIATED WITH FIELD CASES OF KHV INFECTION IN CARP.

have revealed a number of features that make KHV attractive as a potential biological control agent for carp in Australia.

1. It is known to cause high mortality in carp and koi carp. Not only are farmed carp susceptible to disease, but wild populations are also susceptible – an indication of this virus's virulence and an essential property if KHV is to be effective as a biological control agent for wild carp populations.

2. The susceptibility of a number of other species (including both cyprinids and non-cyprinids) has been tested in the laboratory, and not only are they insusceptible to KHV, but there is also no evidence that they are even capable of developing a subclinical infection during which they might transmit the virus to susceptible carp.

The susceptibility of a variety of species, both native and introduced, that are important in Australian aquatic ecosystems still needs to be tested, but at present, KHV appears to be highly specific for a particular species, ie carp and koi carp.

> An characteristic of KHV is that laboratory work has indicated that carp are susceptible to very low levels of virus

3. Both field and laboratory evidence suggests that KHV will affect carp of any age. For example, it has been estimated that in natural outbreaks of disease, mortality may vary from 70 to 100 percent, the implication being that many, if not all, age groups are affected, (although it is difficult to understand how such figures can be obtained with any accuracy in a natural environment).

Meanwhile, laboratory studies have suggested that although larvae may be insusceptible, very high mortality will occur in fish weighing between 2.5g and 6g. The mortality then apparently declines as fish become bigger and older.

Obtaining a more precise understanding of this age-related mortality would be very important for any future attempts to develop mathematical models of the potential effect of KHV on carp in Australia.

4. A very attractive characteristic of KHV when considering its potential as a biological control agent is that laboratory work has indicated that carp are susceptible to very low levels of virus. Given that in an aquatic environment large concentrations of virus might be diluted very rapidly, even in a slow-moving stream, this would seem to be an essential requirement for a possible biological control agent. There appears to be little, if any, available information on the potential for vertical transmission.

The outcome of KHV infection of carp is very dependent on environmental temperatures, with maximum losses tending to occur when water temperatures range from 17°C to 28°C.

Outside this range, mortality drops off considerably, eg, laboratory studies have suggested that the virus is relatively innocuous at 13°C or 30°C. Once again, these observations have important implications for the use of KHV as a control agent in Australia, where carp are said to survive in waters ranging in temperature from 2°C to 30°C.

While the innocuity of the virus at low temperatures is probably due to the concomitant low body temperatures of the host (and therefore slow virus replication in host cells), the lack of virulence at higher temperatures more likely reflects the level of stability of KHV at those temperatures.

There is only limited information available on the persistence of infectious virus in water at different temperatures, and this deficiency will need to be addressed in order to fully understand the potential of KHV as a biological control agent.

SUMMARY

It is the specificity of KHV for carp, the sensitivity of carp to infection with the virus, the subsequent high mortality in the host species (even in wild populations) and the capacity to affect carp of many ages that make KHV such an attractive option for the biological control of carp in Australia.

Because KHV is still not present in Australia (and is therefore a so-called exotic virus), the IA CRC has funded the Fish Diseases Laboratory at the high-security CSIRO-Australian Animal Health Laboratory to examine the potential of KHV as a biological control agent for carp in Australia.

These preliminary studies will be strictly confined to the laboratory, and even if the results are encouraging, it is likely to be many years, and after much public consultation, before the virus would be considered for use in a multi-pronged attempt to control carp in Australia.

FURTHER READING

Allen GR, Midgley SH and Allen M 2002. Field guide to the freshwater fishes of Australia. Western Australian Museum, Perth, WA. pp394

Crane M, Sano M and Komar C 2004. Infection with koi herpes virus – disease card. Developed to support the NACA/FAO/OIE regional quarterly aquatic animal disease (QAAD) reporting system in the Asia-Pacific. NACA, Bangkok, Thailand. pp11

Davidson S 2002. Carp crusades. Ecos 112. pp8-12

Koehn JD and MacKenzie RF 2004. Priority management actions for alien freshwater fish species in Australia. NZ J Mar Freshwater Res 38 (3). pp457-472

Roberts J and Tilzey R eds 1997. Controlling carp – exploring the options for Australia. CSIRO Land and Water, Griffith