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Research Article

A possible genetic basis for species replacement: preliminary results of interspecific hybridisation between native crucian carp *Carassius carassius* (L.) and introduced goldfish *Carassius auratus* (L.)

Joseph Smartt

School of Biological Sciences, The University of Southampton, Bassett Crescent East, Southampton SO16 7PX UK

E-mail: jsmartt@soton.ac.uk

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Abstract

Reciprocal crosses between non-native goldfish *Carassius auratus* and native crucian carp *Carassius carassius* were produced. The F1 hybrids were viable and vigorous, but attempts to produce F2 progenies were not successful, nor were attempts to produce back crosses. The implications of hybridization, with regard to perceived decline in crucian carp numbers, are considered for water bodies in which these species are now sympatric.

Key words: ornamental fish, non-native species, F1 viability, fertility, ecological consequences

Introduction

The status of the crucian carp *Carassius carassius* (L.) as a British native has been confirmed using zoogeographical and archaeological evidence (Wheeler 1972, 2000, Copp et al. 2005). The goldfish *C. auratus* (L.), which is native to the Far East, is a closely-related species that was introduced into this country in the 17th century (Lever 1977) and has become widely distributed in ornamental water bodies, feral populations also occur. Cross-breeds of crucian carp and goldfish are known in aquarist circles (Smartt 1999), and where both species are sympatric in the wild, putative hybrids have been found. This has generated concern that native crucian carp populations could be in jeopardy as a consequence (Wheeler 2000). The aim of the present paper is to report on a series of preliminary studies on the experimental cross-breeding of native crucian carp and introduced goldfish, and to discuss the relevance of these results to wild crucian carp populations.

Material and methods

In the summer of 1991, six crucian carp were purchased from a local garden centre in Southampton (Allington Lane Nurseries). Authenticity of the material was checked morphologically, the profile of the dorsal fins was convex (it is concave in the other carps), body depth was greater than in the common brown goldfish and the pelvic fins had the characteristic orange colour of the crucian. Further confirmation of identity was provided by the resulting young-of-the-year, which developed the transient dark marking on the caudal peduncle characteristic of young crucian carp but not developed in goldfish. Of these, five were found to be males and one was female. Their fertility was confirmed when they spawned in 1992, producing many viable young-of-the-year. The goldfish brood stock used were obtained from members of the Goldfish Society of Great Britain. A pair of London Shubunkins (Smartt 2001) was donated by Mr. Bill Leach and

a female and two male Red Metallic Veiltails were obtained from the strain developed by Mr. Tony Roberts. These varieties were chosen as parents for the crosses with crucian carp to see how the effectively wild-type genetic background of the crucian carp would affect the dominance relationships of several characteristic mutant genes of the goldfish. The fertility of these parents had been established by successful prior spawnings. The stock was maintained in 150 L fibre-glass tanks with undergravel filtration and provided with Java moss (*Vesicularia dubyana* (C.Mull) Broth). Spawnings took place in a 200 L glass aquarium also provided with undergravel filtration and Java moss, which was also used as a spawning substratum. After spawning, the parent fish were removed.

After hatching, the onset of feeding in the free swimming larvae began initially on "Liquifry" egg yolk preparation, followed by brine shrimp nauplii, then *Daphnia* and "Aquarian" fry and growth foods. The methodology used was essentially that outlined in Smartt and Bundell (1996) as per the general practice of many goldfish breeders, resulting in a high level of fertilization of eggs at spawning (95%+) and of hatching (90%+). The young-of-the-year achieved lengths of ±5cm total length at six months after hatching.

Results and Observations

All initial crosses were successful (Annex). The cross with the London Shubunkin was carried out reciprocally. The first cross made was between a London Shubunkin female × crucian carp males (five were used) and a very prolific spawning resulted in over 1,000 fertilised ova. The reciprocal cross was made with the crucian carp female and a male progeny of the female London Shubunkin used previously. Although not as prolific, the quality of fertilised ova was as good as the reciprocal. The Veiltail cross was carried out with a Veiltail female and crucian carp males, spawning was successful and several hundred fertilized eggs were produced. All three F1 progenies were viable and vigorous and showed good longevity (±10 years). The authenticity of F1 hybrids is much more easily confirmed when exotic goldfish are parents in crosses than when brown (wild type) goldfish are used. However, this would require detailed meristic and/or genetic studies. For example, Hänfling et al. (2005) have identified characteristic microsatellites in the parent species and demonstrated transmission to putative hybrids.

Attempts to produce F2 progenies were not successful (Annex). The London Shubunkin F1s went through the motions of spawning, and on two occasions eggs were produced. However, these eggs failed to develop further and disintegrated. Attempts were then made to produce backcross progenies, but the F1 individuals by then had lost their sexual drive. The Veiltail hybrids also engaged in courtship, but no eggs were produced. Of the several characteristic mutant genes of the goldfish, a number of these showed dominance or incomplete dominance. The London Shubunkin carries only a single such gene, the transparent scale mutant (Chen 1926) in the heterozygous state, and neither homozyote develops the characteristic and highly-prized multicoloured ‘calico’ pattern. A quarter of the progeny from Shubunkin spawnings were brown metallic goldfish. When crossed with crucian carp, a 50:50 proportion of calico and brown metallic fish was produced, as is the case when brown metallic goldfish are used. These progeny were thus F1 interspecific hybrids and in effect were similar to those produced from brown goldfish × crucian carp crosses. These developed the transient dark spot on the caudal peduncle, a feature of crucian young-of-the-year but otherwise not very different from brown goldfish. In this instance, the dominance relationship between the transparent scale mutant and the normal metallic allele was unchanged.

The most significant mutant carried by the Veiltail was the erythristic or depigmenting mutant of Kajishima (1976). This behaves as a dominant with variable penetrance. The F1 progeny in the interspecific cross retained the brown wild type coloration indefinitely. The significance of this is that erythristic common goldfish mating with crucian carp would produce uncoloured progeny, which would remain so. The twin tail mutant, which is also an incompletely penetrant dominant, behaves similarly. Clearly, in the interspecific hybrids both mutants act as recessives.

On the basis of the results obtained, it is possible to propose models of what can happen in mixed populations. Spawning of mixed flocks will produce progeny that comprise the two pure species and inter-specific hybrids. When both

species are equally frequent, then one would expect approximately 50% of hybrids and 25% of each of the parental species after the first round of crossing. The proportion of hybrids would increase further as 50% of each subsequent crossing round's progeny would again be sterile hybrids. This would generate a cumulative reduction of the size of the effective gene pool of both parental species.

When parental species frequencies are not equal, a lower proportion of the less frequent species' reproductive resources would go into the generation of reproductively competent (i.e. pure species) progeny. In these circumstances, the less frequent species would ultimately be eliminated. If this were the crucian carp, then the result would be local extinction. And where this phenomenon is widespread, the persistence of the native species would be compromised. There is a general belief that, over the past 50 years, crucian carp populations have been declining, and a significant factor in this may well have been the use of brown goldfish in restocking ponds. The existence of crucian carp over the long term in such mistakenly re-stocked ponds would be imperilled. Wheeler (2000) recorded ponds in which feral goldfish outnumbered crucian carp, the future of the latter could well be in jeopardy.

The production of small numbers of eggs by London Shubunkin hybrids suggests that sterility may not be total. Putative crucian x goldfish hybrids, collected from ponds, have also been reported to have well-developed ovaries (Hänfling et al. 2005). The existence of such individuals raises the possibility of introgression of goldfish genes into the natural populations of crucian carp. A prospect viewed with some concern. In addition, there is the possibility that F1 hybrids are heterotic and could out-compete their parents, and where parental species were not equally frequent, the elimination of the least abundant species could be accelerated. There is, however, one important ecological factor in the crucian carp's favour, its greater tolerance of anoxic water conditions occurring in the summer than that of the introduced goldfish and common carp. The results of the present, preliminary investigation suggest that further experimental hybridization with a wider range of parental genotypes of both crucian carp and goldfish is warranted, as they would provide useful reference material with which to assess putative hybrids collected in the field.

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Annex. Summary of inter-specific hybridization programme between native crucian carp *Carassius carassius* and varieties of non-native goldfish *C. auratus* (R.M. = Red Metallic).

Species	Variety/Sex	Cross & Date	Result	Fertility
C. auratus	Shubunkin/♀[1]	♂♂ crucian (1993)	viable F1	virtually sterile
		♀ crucian (1994)	viable F1	some eggs produced.
	R.M. Veiltail ♀[2]	♂♂ crucian (1996)	viable F1	Sterile, no eggs produced
C. carassius	wild ♂♂ and ♀[3]			

[1] Source: Mr. W. Leach (Goldfish Society of Great Britain);
[2] Source: M.A. Roberts (Goldfish Society of Great Britain);
[3] Source: Allington Lane Nurseries, Southampton, England.