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CARASSIUS AURATUS GIBELIO – THE MOST SUCCESSFUL INVASIVE FISH IN WATERS OF THE CZECH REPUBLIC

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Carassius auratus gibelio is considered an alien fish species in the hydrographic system of the Czech Republic. Around 1976, this form immigrated from the River Danube into the confluence of the Morava and Dyje rivers and gradually spread over the hydrographic network over the course of the next 15 to 20 years. Helped by man, this species overcame the boundaries between particular drainage areas, expanding its range and colonising suitable habitats. *C. a. gibelio* has become fully naturalised and has produced numerous stable populations. This is the only non-indigenous fish species in the Czech Republic showing distinct characteristics of an invasive taxon. Initial populations of *C. a. gibelio* colonising the new area consisted solely of triploid females. The occurrence of males after 1990 started a process of transformation of the originally monosexual female (triploid) population into a mixed population containing both females and males. At present, males are predominantly diploid, with occasional triploid individuals. Females are predominantly triploid and less frequently diploid. Tetraploid individuals are quite rare. At the Morava-Dyje confluence, the population reproduces both gynogenetically and sexually. *C. a. gibelio* exerts important competitive, as well as destructive, effects upon the indigenous ichthyofauna. Native species of *Carassius carassius* and *Tinca tinca,* previously abundant, have vanished from those localities dominated by *C. a. gibelio. C. a. gibelio* is fished for on hook and line in natural habitats in the Czech Republic, with an annual recorded catch of 25–50 tonnes. Annual production in fishponds varies between 15 and 70 tonnes, yet its marketable utilisation is problematic.

Key words: invasive alien fish, *Carassius auratus gibelio*, sex ratio, ploidy status, impact.

As a rule, the occurrence of non-native fish species is generally considered to be negative as regards protecting the biodiversity of native ichthyofauna. The greatest risk factor is seen, above all, in taxa with wide ecological tolerance and exhibiting the properties of so-called invasive species [Allendorf, 1991; Moyle, Light, 1996; Cowx, 1997; and others]. The various forms of *Carassius auratus* can be considered as the most successful alien fish in Europe, being found in waters of almost all European countries [Szczerbowski, 2002] apart from Scandinavia. While it can be considered the most widespread fish over Europe and Asia, however, its taxonomic status remains equivocal. [Vasil'eva, Vasil'ev, 2000]. *C. auratus auratus* and *C. auratus gibelio,* the two forms most widely distributed over Europe, are considered as two subspecies by some authors [Bănărescu, 1964; Pelz, 1987; Szczerbowski, 2002], whereas others have treated them as two separate species [Kottelat, Freyhof, 2007]. In the present study, we put forward the opinion that *Carassius auratus* represents a complex comprising a number of forms of different taxonomic status. The results presented in this paper pertain exclusively to the form *C. auratus gibelio.* Occasionally, we also obtained individuals of *C. auratus auratus,* a decorative form that occurs under natural conditions in the Czech Republic as a result of having been released from aquarium cultures and/or reared for decorative purposes. In addition, individuals of the Japanese form *C. auratus langsdorfii* were ascertained at one locality, the population comprising females only [Vetešník et al., 2007; Kalous et al., 2007].

In the Czech Republic, investigations on *C. a. gibelio* have been carried out ever since its immigration in 1975 [Lusk et al., 1977; Lusk, 1986; Lusk et al, 1998; etc.]. In recent years,

intense investigations have been implemented under natural conditions, concerned with the biological characteristics of this fish and changes in ploidy and sex status of its populations [Lusková et al., 2002, 2004; Halačka et al., 2003; Vetešník et al., 2004]. The present paper gives both an overview and presents recent unpublished research results obtained on *C. a. gibelio* around the confluence of the Morava and Dyje rivers (Danube river system). Starting in 1976, *C. a. gibelio* produced numerous and stable populations in this region. At present, the local ichthyofauna is dominated by *C. a. gibelio.* The main aim of the present paper is to present a review of the changes in the sexual and ploidy status of *C. a. ibelio* in the hydrological region indicated.

Material and Methods

Samples of *C. a. gibelio* for the analysis of the sexual and ploidy status were collected from the lower section of the Dyje River (r. km 0.0 – 27) and the adjacent floodplain (about 3,500 hectares in area).The samples were obtained by electro-fishing or netting. Quantitative data were obtained by fishing up the whole fish stock in the habitat, using electro-fishing and netting, or by the mark-and-recapture method [Lusková et al., 2002]. The fish were sexed according to visual or microscopic examination of the sexual products in killed specimens. Ploidy was determined according to nucleus size in erythrocytes, either through optic analysis using an Olympus MicroImage 4.0 analyser, or by means of a continuous-flow cytometer (Partec CCA 1 cytometer – Partec GmBH, Germany) on the basis of relative DNA content in the erythrocyte nuclei (Vindelov, Christensen, 1994; Flajšhans, 1997; Halačka, Lusková, 2000]. Karyological analysis was also used to a limited extent in ploidy determination.

Results and Discussion

Distribution: *C. a. gibelio* immigrated into the river network of the Czech Republic from the River Danube via the River Morava. The first finds, around the confluence of the Morava and Dyje rivers, date from 1976 [Lusk et al., 1977]. Over subsequent years, *C. a. gibelio* gradually invaded streams within drainage areas through auto-migration, overcoming boundaries due to both the intentional and unintentional help of man, predominantly as an admixture to carp (*Cyprinus carpio*) stocking material. Within 15 years, *C. a. gibelio* had occupied all suitable habitats in the Czech Republic [Lusk et al., 1998; Lusková et al., 2004]. In 2005–2008, the occurrence of *C. a.gibelio* was confirmed in 387 mapping quadrats (11.1 by 12 km in size, the territory of the Czech Republic being covered by 675 mapping quadrats) (our own results).

Sex and Ploidy Status: The form of *C. a. gibelio* that immigrated into the Morava River drainage area from the Danube is of eastern Asian origin. From its original range in the Danube river system (Bulgaria, Romania, Hungary), the form connected with introductions in the then Soviet Union after 1950 and began gradually invading waters of the lower and middle stretch of the Danube basin [Holčík, Žitňan, 1978; Holčík, 1980]. During its period of invasive occupation, the *C. a. gibelio* population consisted exclusively of females. They reproduced gynogenetically, utilising the males of other cyprinid species (e.g. *C. carpio, Carassius carassius, Rutilus rutilus, Abramis brama, Abramis bjoerkna, Leuciscus idus,* etc.). After 1990, small numbers of males began occurring in populations in the area of the Dyje-Morava concluence, starting a transformation process from single-sex to a mixed population type. At the same time, the ploidy status of these populations also changed. These developments are documented by data collected at the Morava and Dyje confluence (Table 1), i.e. the area of first occurrence of this fish form in the Czech Republic [Lusk et al., 1977].

A total of 2,092 individuals between 2 and 8 years of age were analysed between 2001 and 2007, with ploidy being diagnosed in parallel with sex determination. Males made up 20.75 % of the population, with the greater proportion being diploid. Only 24 males were triploid and 4 tetraploid. Females (79.25 %) were primarily triploid (74.25 %) and diploid (24.79 %), with only 16 females being tetraploid. Of the total material examined, 60 % were triploid (most of the females). Diploids made up 39 %, with equal representation of males (49.69 %) and females. The share of tetraploids was very low,

Table 1. Sex ratio and ploidy status in samples of *Carassius auratus gibelio* from the lower reaches of the River Dyje; 2n – diploid, 3n – triploid, 4n – tetraploid

Year	Total (N)	Males (N) Total-2n-3n-4n	Males (%)	Females (N) Total-2n-3n-4n
1976 – 1990	5840	0	0	5840
1995	78	5	6.41	73
1976	185	7	3.78	181
1997	342	15	4.39	327
1998	485	34	7.01	451
1999	359	64	17,83	295
2000	183	16	8.74	167
2001	210	17-15-2-0	8.09	193-10-178-5
2002	185	22-19-3-0	11,89	163-14-147-2
2003	369	82-68-10-4	22.22	287-52-227-8
2004	476	137-136-1-0	28.78	339-133-206-0
2005	342	94-90-4-0	27.49	248-73-174-1
2006	184	37-33-4-0	20.11	147-56-91-0
2007	326	45-45-0-0	13.80	281-73-208-0

and higher in females (16 ind.) than males (4 ind.). The percentages of males to females and their ploidy status in consecutive years are given in Table 1. Using the present data, it is not possible to conclude unequivocally whether the transformation into a mixed population type has already reached a stable level or whether it will continue, with the number of diploid individuals increasing. The high percentage of triploid females strongly suggests that, in the area under study, the asexual form of reproduction (gynogenesis) may be of decisive importance in maintaining local populations of *C. a. gibelio*.

There is no unequivocal explanation of the cause or causes of the transformation from a monosexual population with gynogenetic reproduction into a mixed bisexual type with sexual as well as gynogenetic reproduction. One possible cause is the inclusion (whether natural or artificial) of diploid males and females, or an unobserved occurrence of a small number of diploid individuals in the mass of triploid females. Another possible cause is a natural inversion of the ploidy and sexual status within gynogenesis, i.e. occurrence of males and diploid individuals. The change in ploidy status, or the occurrence of males, may also result from a change in environmental conditions [Goryunova, 1962]. In the latter case, of natural transformation of ploidy and sexual status into a mixed population type, a possible impulse may be seen in the stabilisation of *C. auratus* populations after the occupation of a new range. Such changes occur approximately 15-20 years after the invasion of the first wave of triploid females, as indicated by observations in central and southern Europe [Lusková et al., 2004]. Abramenko et al., [1997] described a continually increasing percentage of diploids in the *C. a. gibelio* in the lower Don basin. It remains to be seen in what way the development of the mixed populations will continue (ploidy 2n – males and females, ploidy 3n – females).

Importance: At present, *C. a. gibelio* is the dominant fish in the major rivers (Dyje, Morava, Labe) and their floodplains in the Czech Republic. It is the object of sport angling, with an annual catch ranging between 25 and 50 tonnes. In fishponds, it is an unwelcome competitor with cultures of the major reared species. The occurrence of numerous populations of *C. a. gibelio* in fishponds causes considerable economic loss as there is no market for the species in the Czech Republic. Even when it can be sold, it reaches a considerably lower price. There are no published data on the production of this fish in fishponds; however, on the basis of partial data, the annual catch is estimated to vary between 15 and 70 tonnes, the occurrence and production of *C. a. gibelio* in ponds being on the increase in recent years. In the "Lednické rybníky" fishpond system, 550 ha in area, lying in the region of the lower reaches of the Dyje river, the 2009 production of *C. a. gibelio* amounted to 120 tonnes as against 35 tonnes of *Cyprinus carpio*. From the fishponds this non-native, invasive fish can even invade natural ecosystems, which is quite undesirable in view of the ensuing negative impact on the local native fish populations.

According to our investigations implemented in 2004–2008 in the floodplain of the lower section of the Dyje River, the numbers and biomass of *C. a. gibelio* found in various habitat types (river branch, pool, small lake, pit, canal) attained 3,400–7,650 exx.ha^{-1} and 265–1,358 kg.ha^{-1} at the age of 2–9 years. In some habitat types, the numbers of individuals 0+ of age (35–50 mm in standard length) attained as much as 45–84 fish per 1 metre of shoreline (unpublished data). The presence of *C. a. gibelio* in natural ecosystems is an important negative factor as regards native fish species. Above all, it competes for space and food with most native cyprinids. One must also highlight the so-called sexual parasitism of this fish, which can utilise males of a number of cyprinid species through gynogenesis. The ability of *C. a. gibelio* to hybridise, especially with *C. carassius* and even *C. carpio*, exerts a destructive impact on populations of these species [Papoušek et al., 2008]. Numerous populations of *C. a. gibelio* have totally eliminated the previously dominant indigenous species *C. carassius* and *Tinca tinca* from alluvial habitats such as pools, dead oxbows, and woodland lakes [Lusk et al., 1998; Lusková et al., 2002].

Conclusion: The specific biological characteristics of *C. a. gibelio* (its diploid and polyploid forms, sexual and gynogenetic reproduction, transformation of the sexual and ploidy status of its population), its immense ecological tolerance (including its resistance to anoxia and its aggressiveness in enlarging and occupying new areas) have resulted in *C. a. gibelio* becoming the most successful non-native, invasive fish form in the waters of Central and Eastern Europe.

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