Common carp - *Cyprinus carpio*

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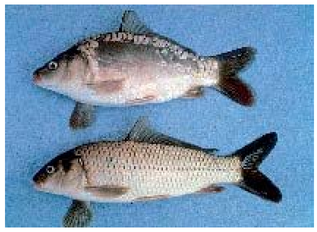

Biology, ecology and genetics

Distribution

The common carp [*Cyprinus carpio* Linnaeus (1758)] has been one of the oldest domesticated species of fish for food. Culture of carp in China dates back to at least the 5th century BC, although domestication began much later. The European races of carp derived from wild carp of the Danube; the earliest attempts date back to the Roman Empire and spread of Christianity in Europe, from where its domesticated forms were later introduced to other continents (1 and references therein, Fig.1). The common carp is divided into two subspecies, *C. c. carpio* from Europe and *C. c. haematopterus* from Asia, as reviewed by population genetic data (2 and references therein); populations of the Asian subspecies may be further subdivided into Central Asian and East/Southeast Asian ones (3). Productive populations were domesticated from both ancestral forms, as well as from their mutual hybrids and backcrosses followed by mass selection (2).

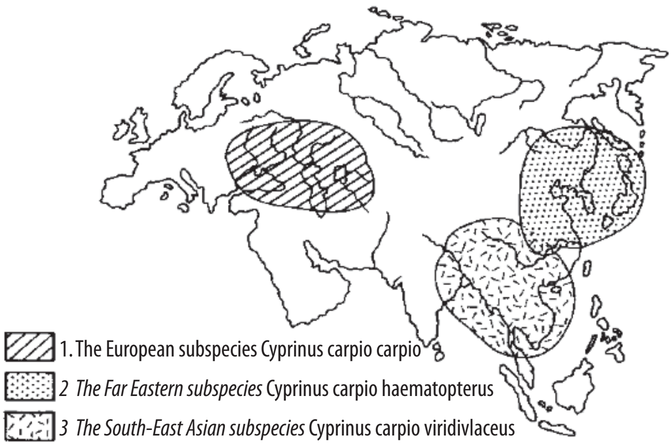

Fig. 1. *Ranges of wild common carp populations in Eurasia (4)*

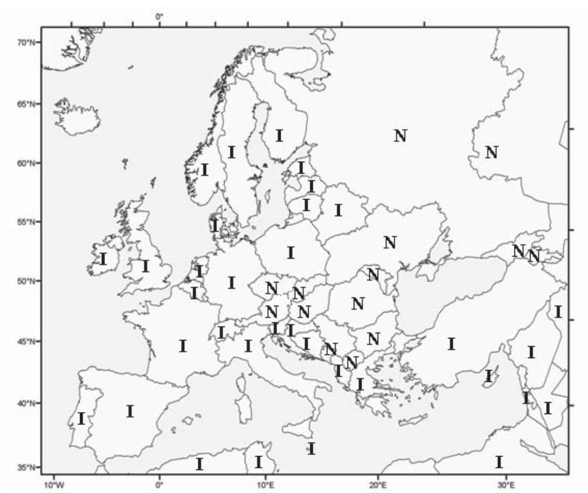

Fig. 2. *Status of common carp in Europe (N=native; I=introduced).*

Common carp is native to only a limited number of European countries, namely those of the Danube River drainage system. However, present occurrence of wild Danubian carp populations is questionable, probably limited to only a few areas in the drainage system, and are threatened by anthropogenic effects as well as farm escapees and restocking farmed populations into open waters (Fig.2). A few wild populations have recently been reported from Turkey, and although these are not native, they constitute an important resource. Wild stocks are also to be found in Central Asian countries, e.g. Uzbekistan, which cluster with the European populations.

Biology

Common carp dwells in middle and lower reaches of rivers and shallow confined waters. Best growth is obtained at water temperature of 23-30°C. The fish can survive cold winter periods. Salinity up to about 5‰ is tolerated, optimal pH is 6.5-9.0; common carp can survive low oxygen concentration (0.3-0.5 $mg.l^{-1}$) as well as supersaturation.

Carp are omnivorous, with a high tendency towards the consumption of benthic organisms, such as water insects, larvae of insects, worms, molluscs, and zooplankton. Digging in the bottom in search for food items results in turbid water. Zooplankton consumption is dominant in fish ponds where the stocking density is high. Additionally, the carp consumes the stalks, leaves and seeds of aquatic and terrestrial plants, decayed aquatic plants, etc. Typical carp ponds in Europe are shallow, eutrophic with a muddy bottom and dense aquatic vegetation at the dikes. Pond farming of common carp is based on natural food with supplemental feeding of cereals. Daily growth can be 2 to 4% of body weight (bw). Carps can reach 0.6 to 1.0 kg bw within one season in subtropical/tropical polyculture. Growth in temperate climate is slower, the fish reach 1.5 kg bw after 3 rearing seasons.

In Europe, females mature after 11 000 - 12 000 degree-days in the temperate and subtropical climatic zones; males mature 25-35% earlier. Maturity period of Asian breeds is slightly shorter (5). The spawning of European carp populations starts when water temperature reaches 17-18°C. Females release 100 to 230 g of eggs per 1 kg bw. Eggs are laid on submersed aquatic plants and after contact with water, they become adhesive and swell 3-4 times in volume. Embryonic development takes 60-70 degree-days. Hatched fry stick to substrate and live from yolk supplies. Three days after hatching the posterior part of the swim bladder develops, the larvae start to swim and consume external food of 150-180 µm size (5). Methods of fry production in Asia in hapas, netted channels etc. using natural or artificial substrate (spawning nests), as well as European production of fry in ”Dubravius” or ”Dubisch” ponds are based on this natural process.

Population genetics

The genetic structure of wild populations is very poorly understood. Most phylogeographic and population genetic studies were done on farmed stocks, and looked at differences between the two sub-species, genetic variability within and among populations and the genetic distance among them.

Breeding and culture practices

Production

According to the FAO statistics of 2004 (5), production of farmed common carp was ca. 13% (3,387,918 tonnes) of the total global freshwater aquaculture production. Common carp production increased by an average global rate of 9.5% per year between 1985 and 2004 and in the past decade (1993-2004), this has increased to 10.4% per year. Asia is the main producing region of the species (China claimed about 70% of the 2005 world production) with the majority of production consumed domestically.

European common carp production in 2004 was 146,840 tonnes, a substantial reduction from the peak production of over 402 000 tonnes in 1990, and reflecting socioeconomic changes in Central and Eastern Europe (Fig.3-4). The European market mostly requires live or freshly dressed fish; processing appears to increase the price to less competitive levels.

Apart from production for human consumption, common carp is produced for leisure as well: i) a significant quantity of the species produced in aquaculture is stocked into fishing grounds for angling purposes, and ii) ornamental fancy varieties, known as Japanese "nishikigoi", are produced for the pet fish market with some prize-winners sold for 10^4 to 10^6 US$, and probably represent the most expensive market of individual freshwater fish (1).

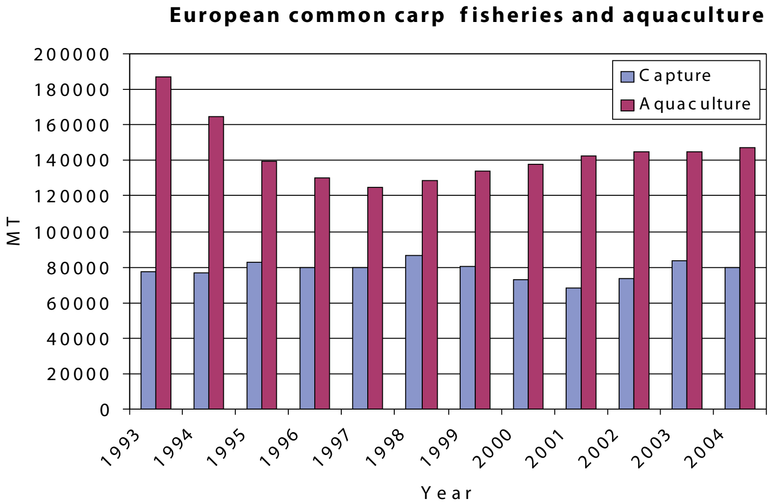

Fig. 3. *Common carp capture fisheries and aquaculture production in Europe (6).*

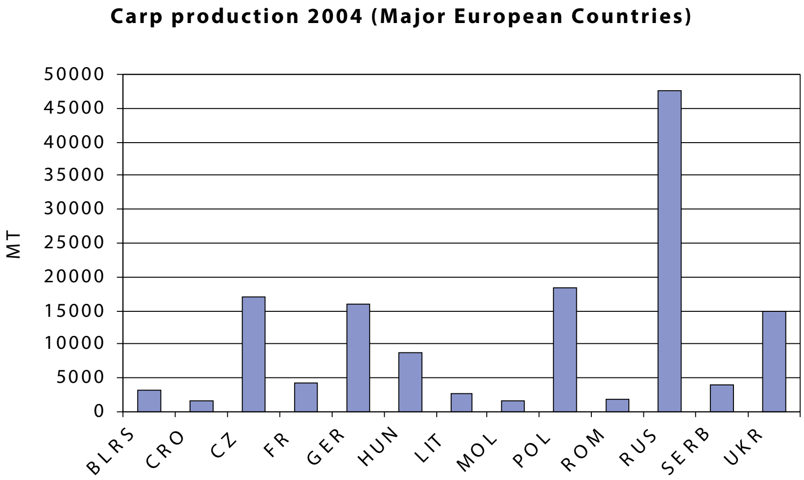

Fig. 4. *Common carp production in major European countries (6).*

Hatchery practices
The majority of production of swimming-up larvae is based on artificial propagation in hatcheries. Broodfish are kept sex-separated in tanks with oxygen-saturated water at 20-22°C. To induce and synchronize ovulation and spermiation by hormonal stimulants, fish receive injection of pituitary gland, pituitary extract or a mixture of GnRH/dopamine antagonist (7). Gametes are collected by the dry method for immediate fertilization but can be stored for several hours also (8, 9). After gamete activation, the adhesiveness of eggs is eliminated either by the "Woynarovich method" using salt/urea and tannic acid bath, by treatment in milk, or enzymatic treatment (10). Incubation is carried out in hatchery jars. Hatched fry are kept in large trays or conical tanks until stocking at the stage of swimming-up larvae into properly prepared nursery ponds. Approximately 300 000 to 800 000 newly hatched fry can be expected from a single female (5).

Grow-out
The farming cycle in Europe usually consists of the following steps (1, 5). Fry are nursed up to 0.5g bw in shallow drainable ponds in monoculture upon zooplankton with supplementary feeding or in tanks on zooplankton and starter feeds. Fingerling/yearling of up to 30–100g bw are produced in semi-intensive ponds upon manure/fertilizer-generated natural food and supplementary feeding. It can be performed in one step (stocking the swimming-up fry and harvesting fingerlings/yearlings), two-step (stocking nursed fry and harvesting fingerlings/yearlings), or multicycle systems (stocking the swimming-up fry and the fish are thinned out several times). Two-summer-old fish are produced in semi-intensive ponds in monoculture or in polyculture with herbivorous cyprinids, on natural food with supplementary feeding. In temperate climate, one-summer-old fish (20-100g bw) are reared up to 250-500g bw in the second year. Common carp can be reared to market size in extensive or semi-intensive ponds, in monoculture or in polyculture with other cyprinids, tilapias, mullets, etc. on natural food with supplementary feeding; or in intensive systems, in monoculture, on complete feeds (in cages, irrigation reservoirs, running water ponds and tanks, or in recirculation systems). Integrated systems with animal husbandry and/or plant production are also used (e.g. carp-cum-duck in Central and Eastern Europe).

Apart from freshwater predatory fish which may enter the productive systems through water inlets/outlets, the most serious predators are aquatic insects for common carp larvae, snakes and frogs for fry, birds (kingfishers, gulls, terns, herons, cormorants) for fingerlings and yearlings. Mink and especially otter prey on market-size fish and brood fish.

Escapement of common carp can occur from the hatchery (overflow of jars and trays) and from the pond farming systems to open waters (dropped by predators or poachers, draining off the ponds, during floods etc.). Moreover, it is a common practice in some European countries that angling clubs buy stockfish or old broodstock as "trophy fish" from production fish farms and release them into their fishing grounds.

Selective breeding
Qualitative genetic traits studied in common carp included the inheritance of scale pattern ("scaly" SSnn, Ssnn; "mirror" ssnn; "line" SSNn, SsNn and "leather" ssNn) and the lethal/deleterious effects of the N allele (12) , types of pigmentation (wild-type, black, grey, blue, gold, orange, red; 13) used as genetic markers or for selective breeding of coloured breeds, and pleiotropic effects of genes responsible either for

scale patterns or for colouration on various biological and productive characteristics. Compared to fully scaled and/or wild-type coloured carp, those with other scale and/or colour patterns mostly exhibit reduced growth, survival and disease resistance.

Quantitative traits studied involved growth rate, disease- and cold resistance (2, 14) with mostly low to intermediate heritability (h^2) estimates and burdened with environmental biases (2). Selective breeding for disease- and cold resistance resulted in developing several breeds [e.g. Krasnodar carp (15), Ropsha carp (4)], while simple mass selective breeding for growth did not show improvement in the line selected for faster growth (14). Population genetic studies with allozymes and/or microsatellites revealed lower variability of domesticated breeds compared to wild populations (3, 16, 17) and low genetic distance between breeds (3). It indicated that many breeds have been established using small effective number of broodstock, which has resulted in some inbreeding and, which might hamper possibilities of genetic gain from selective breeding (3). With construction of synthetic strains to start a within-strain selective breeding programme with sufficient number of families and standardized family size by separate rearing of families until fry mortality stops, or with parentage assignment by means of microsatellites, more efficient breeding programmes may be designed (3, 18, 19).

Common carp has been subjected to all kinds of chromosomal manipulations (20). Gynogenesis, both meiotic and mitotic, revealed increased homozygosity (with inbreeding coefficients F = 0.6 and 1.0, respectively) and female homogamety XX. Mitotic gynogenesis was used to produce clones. Androgenetic YY males were crossed with normal females to produce all-male progenies. Gynogenetic progeny subjected to hormonal sex reversal resulted in production of XX neomales, and crossing these with normal females produced all-female progenies. Rearing the female monosex stock enhanced production by 7-8% (females being 15% heavier than males), in tropical/subtropical conditions when fish reached sexual maturity before market size. However, in European temperate climate the female monosex stock grew better and had better slaughtering value only in the first three years, but not at market size. Triploids are characterized by reduction in gonad development but not with increased somatic growth.

Microsatellite DNA markers were developed and applied in studies of genetic variation and diversity (21-24), parentage assignment (18) and a genetic linkage map was constructed (26).

Growth hormone (GH) gene transfer was described and the technique was developed to enhance common carp production in China (27), firstly using human GH and later using grass carp GH fused to common carp β-actin promoter. The transgenics showed higher growth performance and food conversion efficiency than the controls, but no transgenic fish have been commercially approved for human consumption (28). Sterile triploid transgenics were produced to avoid environmental impacts.

Most of the world production is carried out using unselected strains (2). When they exist, breeding programmes are mostly based on crossbreeding (14, 29, 30) as it brings quick improvement of growth performance (heterosis effect) in F_1 generation. It is widely used in Hungary, Israel, Czech Republic and other countries. Crossbreeding of breeds developed from both subspecies (*C. c. carpio* and *C. c. haematopterus*) improved survival rate of fry, disease and cold resistance. But improper use of hybrids for further breeding brought contamination to the purebred stocks (31).

Live gene banks of common carp breeds are kept and new forms are continually tested e.g. in the Research Institute for Fisheries, Aquaculture and Irrigation, Szarvas, Hungary (32), Institute of Ichthyobiology and Pond Culture of the Polish Academy of Sciences, Golysz, Poland, and University of South Bohemia, Research Institute of Fish Culture and Hydrobiology, Vodnany, Czech Republic (1, 31).

Interaction studies

Feral populations, some of which could be hundreds of years old, dominate in the majority of the drainage system. Therefore, the status and genetic structure of wild populations are questionable and poorly understood. Phylogeographic and population genetic studies were mainly done on farmed stocks, and only occasionally involved «wild» stocks. Nothing can be said about local adaptation, given the status of wild populations.

The basic biology and distribution of the common carp, and especially of farmed stocks, is well understood.

Being a benthic feeder, carp typically make the water turbid. There is evidence from countries to which carp was introduced (e.g. Australia, USA, Mexico) that increased turbidity caused by carp has negatively affected local fish communities as well as vegetation which prefer clear water. Apart from competition for food and habitat, we are not aware of other direct negative ecological effects of carp. Since carp has been introduced to almost all European countries, and established in open waters, potential damage has already been done. Since carp is regarded as a premium angling species in many countries, measures should be taken to prevent further release into new open waters, and stocking for recreational purposes should be limited to closed water bodies.

Conclusions / Implications

- *Preservation of biodiversity***.** A comprehensive biodiversity survey, aiming at identifying wild populations (native as well as introduced) is urgently needed. It should be carried out in cooperation with local fisheries agencies and/or experts in each country, and should include documentation (including genetic analysis using modern genetic tools to delineate genetic relationships among wild stocks), as well as cryopreservation of semen samples. It is also recommended that areas where wild stocks still exist will be declared as sanctuaries to preserve those apparently rare wild resources. These wild populations should be subjected to detailed investigations of life history traits, including reproductive strategies, fecundity, survival and fitness under variable environmental conditions, e.g. pH, temperature regimes, etc., in attempt of identifying local adaptations.

- *Breeding programmes***.** A survey of farmers' needs is required to identify breeding goals and to make sure an improved stock will be well accepted (in view of the traditional preference of locally developed purebreds in some countries). A national or European family-based selective breeding programme should be started to meet those needs.

Dissemination of the improved breed should be done carefully, making sure it does not affect the rare wild resources that may still exist. Biocontainment methods should be applied.

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