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Review

The culture of the European catfish, *Silurus glanis*, in the Czech Republic and in France

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Abstract

The European catfish *Silurus glanis* has been cultivated in extensive ponds in central and Eastern Europe in association with carps for more than 100 years. The total production of *S. glanis* in aquaculture from ten European countries (Austria, Bulgaria, Croatia, Germany, France, Hungary, Greece, Macedonia, Poland, Czech Republic and Romania) was 602 t in 1993 and presently is about 2 000 t. Production is increasingly from intensive pond culture or in heated/geothermal waters. The flesh is white, boneless, easy to prepare, and low in fat (6 to 8%). The taste is mild but is subject to off-flavour. The fish are filleted (yields about 40% without skin) and the flesh is cut into steaks or smoked). During the last 10 years, research in Czech Republic, France and other European countries have developed technologies for artificial reproduction, evaluated population genetics and addressed problems of conservation. Growth is higher in males and research is in progress to produce triploids fish. While propagation techniques have progressed, production remains low and the cost of production is still high. Thus availability is low and the product remains poorly known.

Résumé

L'élevage du silure, *Silurus glanis*, en Tchéquie et en France. Le silure, *Silurus glanis*, est élevé en bassins en Europe centrale et orientale, en association avec des carpes depuis plus de 100 ans. La production totale de *S. glanis* provenant de l'aquaculture de 10 pays européens (Autriche, Bulgarie, Croatie, Allemagne, France, Hongrie, Grèce, Macédoine, Pologne, Tchéquie et Roumanie) était de 602 t en 1993 et actuellement, elle est de 2 000 t environ. La production est en augmentation pour les silures provenant d'élevage intensif en bassins ou en eaux chauffées par géothermie. La chair est blanche, sans arête, facile à préparer et contient peu de gras (6 à 8 %). Le goût est fade mais peut présenter des goûts de vase indésirables. Les poissons sont filetés (rendements de 40 % environ, sans peau) et la chair peut être présentée coupée en darnes ou fumée). Durant ces 10 dernières années, la recherche en Tchéquie, en France et autres pays européens a développé des techniques de reproduction artificielle, évalué la génétique des populations et soulevé des questions de sauvegarde de l'espèce. La croissance est plus élevée chez les mâles et la recherche progresse vers l'obtention de poissons triploïdes. Tandis que la propagation des techniques se développe, la production reste faible et les coûts de production sont encore élevés. Ainsi, la disponibilité est restreinte et le produit demeure peu connu.

Keywords: Aquaculture; Reproduction; Genetic; European catfish; *Silurus glanis*

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1. Introduction

Silurids are Eurasian freshwater catfishes with two species present in Europe (east of the Rhone). The large European catfish (wels or sheatfish), *Silurus glanis* Linneaus 1758, (six barbels) is widely distributed and was introduced into France in the 1950s and more recently in Spain. The smaller Aristotle's catfish, *Silurus (Parasilurus) aristotelis* Agassiz 1857, (only four barbels) is endemic to the western part of Greece (Teugels, 1996). All other silurids are native to Central and South Asia. This paper reviews the state of aquaculture compared to the wild fisheries in Czech Republic and France, technological developments in culture and the status of the market.

1.1. The aquaculture and fisheries production and the product

The European catfish has been cultivated extensively in the ponds of central and Eastern Europe for more than 100 years (Linhart and Proteau, 1993). Its culture has expanded more recently to Bulgaria, France, Hungary, Croatia and the Czech Republic in more intensive aquaculture systems. The total production of European catfish in culture from ten countries (Austria, Bulgaria, Croatia, Czech Republic, France, Hungary, Greece, Macedonia, Poland and Rumania) was 602 t in 1993 (Proteau et al., 1996) and currently is about 2 000 t. Production increased from 0 to 1 364 t between 1993 and 1999 in Bulgaria, from 150 to 340 t in France, from 90 to 123 t and from 34 to 44 t in the Czech Republic (FAO, 1999b). The total production of European catfish by aquaculture and the captive fisheries in all Europe and Azerbaijan, Georgia, Kazakhstan, Tajikistan, Turkmenistan and Uzbekistan decreased from 17 459 t in 1990 to 11 286 t in 1999 primarily due to lower catches in former USSR (Russia, Kazakhstan, and Ukraine) in Volga River delta and in other rivers (FAO, 1999a,b). The market size has been 1.5-3 kg but there is an increasing demand for bigger fish (3–4 kg) in central Europe. There is also an interest in very large fish (more than 20 kg) for trophy sport fishing.

European catfish flesh is highly palatable, it is white and boneless, and has 6–8% fat. The taste is mild, but it is susceptible to off-flavour (Fauconneau and Laroche, 1996). Generally the fish are filleted (yield around 40% without skin), cut into steak or smoked. The filleting may be mechanised but sometimes the yield is variable due to variations in the morphology of the body. The freeze-thaw process has a detrimental effect on the quality of fillets, particularly after chilled storage (Benjakul and Bauer, 2001). Genetic selection of body conformation traits may improve processing yields. In Central European countries, many freshwater fish species are appreciated and the European catfish must compete with other delicious species such as pike and pike perch. In shops and special fish restaurants, the European catfish is of similar price as pike, *Esox lucius* and pike perch, *Stizostedion lucioperca*, but it is more expensive than common carp, trout, and tench or frozen sea fish. The export price of one kilogram of live European catfish from Central Europe to EU decreased by 25% during the last 5–6 years and its price on the biggest market (Germany) decreased by 25-40% In France, the product is not yet well recognised and still needs promoting.

2. Cases studies in the Czech Republic and in France

2.1. Larval rearing, extensive pond culture and intensive production in closed

In the Czech Republic, after hatch, catfish larvae are maintained at 200–300 per l in nets used for pike culture, or special cages with nets or tanks with low water levels of 15–30 cm at 22–25 °C. For the first 2-3 days after hatching (PH) the larvae are yellow and remain motionless on the bottom. On day 2-3 PH, they gradually turn grey and seek dark corners; 5-6 days PH, they swim well and begin to feed. During the first feeding period (at 25-28 °C) the stocking rate should be decreased to 30-50 larvae per liter. The artificial universal starter feed (EWOS for trout) is appropriate to 16 days, (mean total length -22 mm; weight - 0.1 g) (Prokes et al., 1999). During the first 10 days of feeding, dimetridazol is added to the artificial feed (56 mg per kg of fish) to prevent infection with *Ichthyophthirius multifilis*. Fish are grown to the size of 10–15 cm and sold as 3-month-old catfish for stocking to fish ponds or rivers, lakes, etc. Fish of this size are often used in the traditional semi-intensive large pond culture as a predator to control coarse fish (small cyprinids). In the Czech Republic, the European catfish is usually stocked with the common carp which produce 15 000 to 16 000 t per year. When stocked into ponds for 2-year culture, the density is about 100–150 fish per ha together with 2-year-old common carp. Then catfish production usually ranges from 10-20 $kg.ha^{-1}$ with mean weight of 1.5-3 kg. Very large ponds of more than 100 ha are stocked with 10–20 kg catfish per ha, each catfish of 1–2 kg body weight (b.w.) together with common carp bigger than 1 kg for 2 years resulting in catfish production of 10-30 $kg.ha^{-1}$.

The production of European catfish in the Czech Republic, in closed thermoregulated systems, and total annual harvest from aquaculture increased from 2 to 10 t and 27 to 96 t between 1993 to 1999, respectively (FAO, 1999a,b). The Švarc Fish Farm is the largest producer of marketable catfish, at 8 $t.year^{-1}$ of catfish in a recirculation system (Fig. 1). There are two recirculation systems on this farm, one for culturing fingerling (size up to 10–15 cm) at 25–28 °C and the second one for producing of market-size fish, 1.5–2 years old, up to 4 kg at 20–22 °C. Survival during the first phase is 10–50% and 90% during the second. Conversion coefficients of feeding range between 1.2 to 1.3 per kg of weight gain in marketable size category using Aquafood

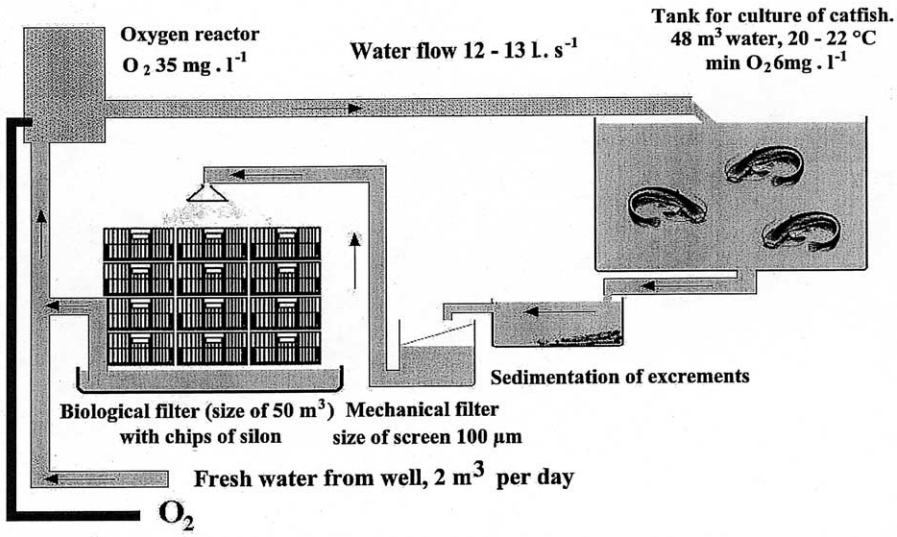

Fig. 1. Intensive culture in closed system at Svarc Fish Farm in the Czech Republic.

feeding for trout. Production costs are: feed, 50%; electricity, 15%; oxygen, 20%; labour, 10%; and water heating, 5%. The farm production cost European catfish is 2.4 Euro.kg^{-1}; market price is 3.6 to 4.2 Euro.kg^{-1} in the Czech Republic.

2.2. The European catfish as a new cultivated species in France

The European catfish was first introduced into the Huninge fish farm in France from the Danube basin in the middle of the XIX century, but this introduction was not successful. Again in 1956, a fish farmer introduced some specimens from the Danube into ponds in La Bresse; eventually some fish escaped and in the 1980s a population became well established in La Saône and Le Rhône. These fish were popular for angling and were disseminated into the other basins. As there was some demand for *S. glanis* in Germany, French fish farmers began to culture them in ponds in the mid-1960s but the production remained limited until the 1980s. The Ministry of Agriculture decided to develop its culture in ponds for increasing productivity of French freshwater fish farming. This was an original situation, a decision of a government body, a species still wild, with very limited information on biology, population genetics, pathology, etc. The private sector was encouraged and subsidised to develop a commodity chain and new ponds were constructed according to the technology used for the catfish culture in the USA. Processing plants were created and market analysis and promoting campaigns were launched. Research organisations were contracted, experimental units were created and various national or regional public and private structures including representatives of fish farmers were involved in extension programmes and teaching. Initially, there were first some difficulties with the species, the production cost was high and the species was not known on the market and some fish farms went bankrupt.

Presently, the production of *S. glanis* in France is about 340 t (in 1999; FAO, 1999b) by small-scale enterprises, mostly with other species. Hatcheries, which utilise modern technologies for artificial reproduction, offer swim-up or 6-week fry nearly all year round. Several production systems are in use; intensive, in geothermal water, in cages (density 15 kg.m^{-3}) or in 500 m^3 ponds (up to 20 kg.m^{-3}). In some cases the water is recycled into nearby large bodies of water in which effluents are released. More extensive systems, (sometimes in polyculture) at 0.5–2 ha (1.5 m deep) ponds (up to 1 t.ha^{-1}) are also used. The market size (1.5–3 kg) is reached after 2 years in warm water 25–28 °C and 3 years at ambient temperature 8–25 °C. All stages are given artificial feed, usually composed of 40–50% protein and 10–12% lipids; the conversion coefficient is 1.1–1.3. The linolenic fatty acid added to feed at level 1% increased significantly growth of fish and decreased feeding coefficient (Bogut et al., 1998). The probiotic preparation composed of 2×10^8 per g of *Enterococcus faecium* bacteria increased growth performance of fish (Bogut et al., 2000). Common diseases are fungal (*Saprolegnia melangaster.*) parasitic (*Ichthyophthirius multifiliis*), bacterial (*Cytophaga, Flexibacter, Flavobacterium columnare*) and viral, sheatfish iridovirus disease or iridovirus-like agent (Siwicki et al., 1999) with virus identical to epizotic haematopoietic necrosis virus (EHNV; Boon and Huisman, 1996). The usual treatment for fungal or parasitic diseases is bath of formaldehyde (0.125 ml.l^{-1}) and malachite green (0.25 mg.l^{-1}) (Citek et al., 1997) or eventually formaldehyde alone, because malachite green is prohibited in European Union. Bacterial diseases are treated with antibiotic in feed at 12 mg.kg^{-1} bw per day or by Flumequine bath at 50–100 mg.l^{-1} (Citek et al., 1997). Maintaining fish in good condition with optimal feeding and high content of vitamin C aids in prevention of disease (Boon and Huisman, 1996). Morand et al. (1999) used a challenge test with *Aeromonas hydrophila* and showed that dimerized lysozyme (KLP-602)

increased the protection against motile *Aeromonas septicaemia* (MAS). Dimerized lysozyme stimulate nonspecific cellular and humoral mechanisms and protection against MAS.

3. Implementation of new technologies on European catfish culture

3.1. Artificial propagation

The artificial propagation of European catfish has been recently improved by techniques developed in the Czech Republic, and in France; currently, fry are primarily produced in hatcheries. The usual procedure is summarised in Fig. 2. Four- to eight-year-old broodfish are taken from growing ponds in April and the sexes are kept separately in two ponds and given forage fish, e.g., *Cyprinids* at the quantity of 4 kg per kg b.w. of catfish. Individual broodfish suitable for stripping are selected in May–July and kept isolated in 4 m^3 tanks divided into 3-4 compartments. Males and females are injected with 4–5 $mg.kg^{-1}$ body weight of carp pituitary or with 40 µg. kg^{-1} of GnRHa (Kobarelin-mamalian D-Ala^6, manufactured in the Czech Republic) (Kouřil et al., 1995). The effectiveness of GnRHa is not improved by the addition of domperidone (Kouřil et al., 1995). Brzuska and Adamek (1999) and Brzuska (2001) successfully stimulate ovulation with LHRHa and pimozide and also with Ovopel (LHRHa, D-Ala^6 manufactured in Poland). In males, spermiation can be sustained for 1 month by repeated weekly carp pituitary injections at a temperature of 22 °C (Linhart et al., 1997). Storage of ova in vitro should not exceed a few hours and it is advised to carry out insemination and activation steps as quickly as possible after ovulation (Linhart and Billard, 1995). Delay of fertilization increases the percentage of malformed larvae and chromosomal abnormalities (Varkonyi et al., 1998a,b). Contamination ova by urine during stripping should be avoided, but detrimental effects can be reduced if sperm is collected in an immobilisation solution (200 mM NaCl, 30 mM Tris-HCl, pH 7) at the ratio < 0.9:1, to (Linhart et al., 1987; Linhart and Billard, 1994; Saad and Billard, 1995). Ova and sperm are mixed in a solution made of 17 mM NaCl, 5 mM Tris-HCl, pH 8; optimum temperature is 21–23 °C. The optimum volume is 2 ml sperm + immobilising solution (usually of light-whitish colour) with a minimum concentration of $0.08.10^9.ml^{-1}$ spermatozoa per 100 g of ova (160 ova per 1 g) and 50 ml of activating solution. The mixture is stirred for 10 s, then after 2-min, an additional 25 ml of activating solution is added. The stickiness of the eggs is removed by treatment with alcalase enzyme (Merck EC 3.4.21.14), (20 cm^3, diluted in 980 ml of hatchery water) 5 or 6 min after fertilisation enzyme is added to eggs, volumetrically 1:1 and stirred for 2 min. then decanted and rinsed with water Fertilized eggs are loaded in Weiss jars of 10 l at 100 000 of eggs (Linhart et al., 1997). Hatching is

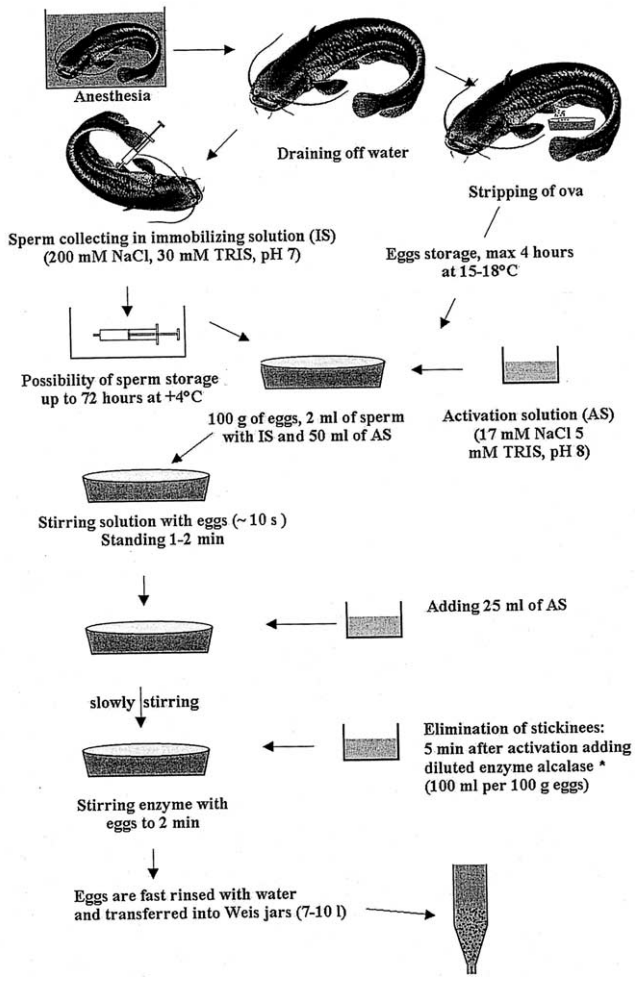

Fig. 2. Procedure of the artificial insemination in European catfish (* 20 ml of alcalase enzyme, Merck EC 3.4.21.14, was diluted with 980 ml of hatchery water).

expected 2.5–3 days (60 degree-day) after fertilisation at 22–23 °C, and the 1-day-old embryos weigh 2.6 mg each.

3.2. Genetic diversity of European catfish and its conservation

Little is known about genetic characteristics of native European catfish populations. Studies on allozyme, DNA and mitochondrial DNA variation in *Silurus glanis*, *Silurus aristotelis* (Triantaphyllidis et al., 1999a,b; Krieg et al., 2000) and *Silurus triostegus* (from the Euphrates River, Krieg et al., 2000) revealed low to moderate variability. Historical factors such as glaciations could account for this low variability, but in restriction fragment length polymorphism (RFLP) haplotype diversity index in *Silurus glanis*, Triantaphyllidis et al. (1999a) observed large variation from 0.00 to 0.79 between the Greek population and the Danube Delta population. The domesticated stocks show less ge netic diversity than natural ones, possibly due to passive selection in the hatchery conditions (Krieg et al., 2000). This suggests that conservation programmes for *Silurus*

glanis with two isolated populations should be undertaken. In the Czech Republic, there exists a conservation programme for the Bohemian European catfish population (Flajshans et al., 1999).

3.3. Sexually dimorphic growth

In the European catfish, males are larger than the females and processing traits are different as shown in experiments performed in France and Czech Republic. In pond experiment starting with 5 g fish, a significant live weight effect favouring males was demonstrated after 7 months (males 147.5 ± 5.4 g vs. females 132.9 ± 4.9 g, $P<0.05$) and for the size of the head (males 20.6 ± 0.1% vs. females 21.2 ± 0.1 %, $P<0.05$) (Haffray et al., 1998). In another experiment, fish were raised in a recirculating system at 20.7 ±1.4 °C for 120 days from 885 ± 196 g to 2 266 ± 418 g. At day 120, males were 17% heavier than females, longer by 6.2%, and presented 18.7% higher gutted yield and fillet weight (+20.9%) ($p<0.01$) (Haffray et al., 1998).

3.4. Production of triploids

Heat, cold and hydrostatic pressure shocks have been used to induce triploidy in *Silurus glanis* (Krasznai and Márián, 1986; Krasznai et al., 1984; Linhart and Flajšhans, 1995; Linhart et al., 2001). A 45-s heat shock of 41 °C, starting at 9 min after egg activation, induced 88% of triploids (39.1% triploids based on total egg numbers), but a high percentage (38.9% of hatched embryos) of embryos were malformed. A 20-min cold shock of 6 °C, starting at 9 min after gamete activation, gave a 100% triploid yield (33.4% of total eggs)(measured by flow cytometry with 42.7% abnormal embryos. Hydrostatic treatments (600 $kg.cm^{-2}$) applied earlier, 3 min after gamete activation and lasting for 4 min gave 97.8% of triploids and 33.7% of triploid yield (Linhart et al., 2001). Induction of triploidy under mass conditions in three experiments gave percentage of triploids comprised between 66 and 83% at hatching but after five months rearing it was only between 8.2 and 21.4% due to mortality occurring on triploids and cannibalism by diploid. The growth performance of yearlings was better for diploid (12.6 g) than for triploids (9.5 g) ($P<0.01$).

4. Conclusion

The acceptance of *Silurus glanis* as a commodity in Europe has taken 20 years, as in the case of other newly cultured species, with strong involvement of the public research and development sector. The rearing technologies are now developed, but the recognition of the catfish product on the market is still in transition, although better in the Czech Republic than in France. This achievement looks modest, but the silurus example illustrates the problems raised with the culture of a new species not well known by the consumers.

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References

Benjakul, S., Bauer, F., 2001. Biochemical and physicochemical changes in catfish (*Silurus glanis* L.) muscle as influenced by different freeze-thaw cycles. Food Chem. 72, 207–217.

Boon, J.H., Huisman, E.A., 1996. Viral, bacterial and fungal diseases of Siluroidei, cultured for human consumption. Aquat. Living Resour. 9, Hors série, 153–164.

Bogut, I., Bukvic, Z., Steiner, Z., Milakovic, Z., Stevic, I., 1998. Influence of linolenic fatty acid additive on Europan sheatfish (*Siluris glanis*) growth bred in cages. Czech J. Anim. Sci. 43, 133–137.

Bogut, I., Milakovic, Z., Brkic, S., Novoselic, D., Bukvic, Z., 2000. Effects of *Enterococcus faecium* on the growth rate and content of intestinal microflora in sheatfish (*Silurus glanis*). Vet. Medic. 45, 107–109.

Brzuska, E., 2001. Artificial spawning of European catfish, *Silurus glanis* L.: differences between propagation results after stimulation of ovulation with carp pituitary and Ovopel. Aquac. Res. 32, 11–19.

Brzuska, E., Adamek, J., 1999. Artificial spawning of European catfish, *Silurus glanis* L.: stimulation of ovulation using LHRH-a, Ovaprim and carp pituitary extract. Aquac. Res. 30, 59–64.

Citek, J., Svobodova, Z., Tesarcik, J., 1997. Nemoci sladkovodnich ryb. [Disease of freshwater and aquariolotique fish] Informatorium, Praha. pp. 217.

FAO, 1999a. FAO yearbook. Fishery statistics. Capture production. FAO, Rome, vol. 88/1, pp. 156–156.

FAO, 1999b. FAO yearbook. Fishery statistics. Aquaculture production. FAO, Rome, vol. 88/2, pp. 68–68.

Fauconneau, B., Laroche, M., 1996. Characteristics of the flesh and quality of products of catfishes. Aquat. Living Resour. 9, Hors série, 165–179.

Flajshans, M., Linhart, O., Slechtová, V., Slechta, V., 1999. Genetic resources of commercially important fish species in the Czech Republic. Present state and future strategy. Aquaculture 173, 471–483.

Haffray, P., Vauchez, C., Vandeputte, M., Linhart, O., 1998. Different growth and processing traits in males and females of European catfish, *Silurus glanis*. Aquat. Living Resour. 11, 341–345.

Kouřil, J., Hamáčková, J., Linhart, O., Barth, T., Glubokov, A.I., Haffray, P., 1995. Induced ovulation of the European catfish by carp pituitary, GnRH analogue and/or dopamine inhibitor isofloxythepin. Czech J. Anim. Sci. 41, 205–207.

Krasznai, Z., Márián, T., 1986. Shock induced triploidy and its effect on growth and gonad development of the European catfish, *Silurus glanis* L. J. Fish Biol. 29, 519–527.

Krasznai, Z., Márián, T., Kovács, G., 1984. Production of triploid European catfish (*Silurus glanis* L.) by cold shock. Aquac. Hung (Szarvas) 4, 25–32.

Krieg, F., Triantafyllidis, A., Guyomard, R., 2000. Mitochondrial DNA variation in European populations of *Silurus glanis*. J. Fish Biol. 56, 713–724.

Linhart, O., Proteau, J.-P., 1993. *Silurus glanis* L.: Market and prospects of development in Europe. In: Kestemont, P., Billard, R (Eds.), Aquacul

ture of freshwater species, Toremollinos, EAS, Spec. Publ., 20, pp. 16–18.

Linhart, O., Billard, R., 1994. Spermiation and sperm quality of European catfish (*Silurus glanis* L.) after GnRH implantation and injection of carp pituitary extracts. J. Appl. Ichthyol. 10, 182–188.

Linhart, O., Billard, R., 1995. Survival of ovulated oocytes and ova in the European catfish (*Silurus glanis*) after in vivo and in vitro storage or exposure to various solutions. Aquat. Living Resour. 8, 317–322.

Linhart, O., Flajšhans, M., 1995. Triploidisation of European catfish (*Silurus glanis* L.) by heat shock. Aquac. Res. 26, 367–370.

Linhart, O., Kouřil, J., Hamáčková, J., 1987. Increased rate of egg fertilization in artificial propagation of sheatfish (*Silurus glanis* L.) by means of suppressing the movements of spermatozoa with immobilization solution. Aquaculture 65, 353–358.

Linhart, O., Billard, R., Kouřil, J., Hamáčková, J., 1997. Artificial insemination and gamete management in European catfish (*Silurus glanis* L. Pol. Arch. Hydrobiol. 44, 9–23.

Linhart, O., Haffray, P., Ozouf-Costaz, C., Flajšhans, M., Vandeputte, M., 2001. Triploidization of European catfish (*Silurus glanis* L.) with heat-, cold-, hydrostatic pressure shocks and growth experiment. J. Appl. Ichthyol. 17, 247–255.

Morand, M., Siwicki, A., Pozet, F., Klein, P., Vinaize, J.C., Keck, N., 1999. Effects of dimerized lysozyme (KLP-602) on the cellular and humoral defence mechanismus in sheatfish (*Silurus glanis*): in vitro and in vivo study. Vet. Res. 30, 411–418.

Prokes, M., Barus, V., Penaz, M., Hamackova, J., Kouril, J., 1999. Larval development and growth of the European Wels (*Silurus glanis*) under experimental conditions fed natural and pelleted diets. Czech J. Anim. Sci. 44, 29–37.

Proteau, J.P., Hilge, V., Linhart, O., 1996. Etat actuel et perspectives de la production aquacole des poissons-chats (Siluroidei) en Europe. Aquat. Living Resour. 9, 229–235.

Saad, A., Billard, R., 1995. Production et gestion des spermatozoïdes chez le poisson-chat européen *Silurus glanis*. Aquat. Living Resour. 8, 323–328.

Siwicki, A.K., Pozet, F., Morand, M., Volatier, C., Terech-Majewska, E., 1999. Effects of iridovirus-like agent on the cell-mediated immunity in sheatfish (*Silurus glanis*)- an in vitro study. Virus Res. 63, 115–119.

Teugels, G.G., 1996. Taxonomy, phylogeny and biogeography of catfishes (Ostariophysi, Silurodei) an overview. Aquat. Living Resour. 9, 9–34.

Triantafyllidis, A., Abatzopoulos, T.J., Economidis, P.S., 1999a. Genetic differentiation and phylogenetic relationship among Greek *Silurus glanis* and *Silurus aristotelis* (Pisces, Siluridae) populations, assessed by PCR-RFLP analysis of mitochondrial DNA segments. Heredity 82, 503–509.

Triantafyllidis, A., Ozouf-Costaz, C., Rab, P., Suciu, R., Karakousis, Y., 1999b. Allozyme variation in European silurid catfishes, *Silurus glanis* and *Silurus aristotelis*. Biochem. Syst. Ecol. 27, 487–498.

Varkonyi, E., Bercsenyi, M., Ozouf-Costaz, C., Billard, R., 1998a. Chromosomal and morphological abnormalities caused by oocyte aging in *Silurus glanis*. J. Fish Biol. 52, 899–906.

Varkoniy, E., Horvath, L., Ozouf-Costaz, C., Billard, R., 1998b. The effects of oocyte ageing in *Silurus glanis* L. Cytogen. Cell Genet. 81, 130–131.