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Different growth and processing traits in males and females of European catfish, *Silurus glanis*

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Abstract – Two experiments were developed in France to assess whether growth and processing traits differ for males and females in the European catfish, *Silurus glanis*. In the first experiment, fish were raised from 5 to 200 g in a pond for 7 months. A significant sex effect is demonstrated in males for live weight at the end of the experiment (males 147.5 ± 5.4 g vs females 132.9 ± 4.9 g) and head index (males 20.6 ± 0.1 % vs females 21.2 ± 0.1 %, $P < 0.05$). In the second experiment, fish were raised from 885 ± 196 g to 2 266 ± 418 g in a recirculated system at 20.7 ± 1.4 °C for 120 days. A differential growth between the sexes is also registered. Males are heavier and longer (+ 357 g or + 17.0 % and + 6.2 % in length at day 120) and present a higher gutted weight and yield (+ 367 g or + 18.7 %; 95.0 ± 0.9 % vs 93.8 ± 1.8 %) and fillet weight (+ 233 g or + 20.9 %) than females after slaughter. © Ifremer/Elsevier, Paris

Growth / sexual dimorphism / body weight / processing traits / European catfish / *Silurus glanis*

Résumé – Croissance et rendement en filets différents chez les mâles et femelles du silure *Silurus glanis*. Deux expérimentations ont été développées en France pour estimer l'importance des dimorphismes de croissance et d'aptitude à la découpe chez le poisson-chat européen *Silurus glanis*. Dans la première expérience, les poissons ont été élevés en étang pendant 7 mois, entre 5 et 200 g. À la fin de l'expérience, les mâles sont significativement plus lourds que les femelles (mâles 147,5 ± 5,4 g vs femelles 132,9 ± 4,9 g) et présentent un rapport poids de tête/poids du corps plus faible (mâles 20,6 ± 0,1 % vs femelles 21,2 ± 0,1 %, $p < 0,05$). Dans la seconde expérience, les poissons ont été élevés en circuit fermé, eau recyclée, à la température de 20,7 ± 1,4 °C pendant 120 jours de 885 ± 196 g à 2266 ± 418 g. Les mâles sont encore significativement plus gros et plus grands (+ 357 g soit +17,0 % en poids et + 6,2 % en longueur). Ils présentent aussi à l'abattage un poids de viscères, un rendement à l'éviscération et un poids de filet significativement plus élevés (+ 367 g soit + 18,7 % ; 95,0 ± 0,9 % ; 93,8 ± 1,8 % ; + 233 g soit + 20,9 %). © Ifremer/Elsevier, Paris

Croissance / dimorphisme sexuel / poids / rendement de la chair / Silure / *Silurus glanis*

1. INTRODUCTION

The estimated volume of production of European catfish, *Silurus glanis* in Europe (without the former USSR) by aquaculture was more than 358 t in 1993 and it had increased six times from 1985 till 1993 [19]. The development of farming is based upon commercialization at individual weights ranging from 1.5 to 10 kg [13]. An important effect of sex on growth has been reported in other Silurids such as the channel catfish *Ictalurus punctatus* or the atipa *Hoplosternum littorale* [9]. In the channel catfish, the males are 18 to

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43 % heavier than the females at a commercial weight in mixed populations [2, 4, 7]. This result oriented research towards all-male populations through the development of YY genotype [8]. Still, this requires cytogenetic manipulation and it is more time-consuming and expensive than the development of all-female populations, when the female is homogametic. Gynogenesis and triploidization have already been achieved in European catfish by cold shock treatment ([10, 11], Linhart et al., unpubl.), heat shock treatment ([12], Linhart et al., unpubl.) and hydrostatic pressure shock (Linhart et al., unpubl.). It is therefore interesting to evaluate the sex-related difference in growth in this species in order to evaluate the possibility of monosex populations to improve productivity and quality in new farming activity. The objectives of the present work were to investigate the differences in performance of growth and processing traits in 2-years old males and females of European catfish.

2. MATERIALS AND METHODS

2.1. Experiment 1: Growth in European catfish from 5 g to a final weight of 200 g

The first experiment used an experimental batch of fish produced by Anjou Fish Farm, France, which was a reciprocal cross between French (A; Morannes) and Czech (B;Vodòany) populations using the technology reported by Proteau and Linhart [17] based upon artificial reproduction [14]. During the first year, progeny of populations A and B were cultivated separately in ponds; during the second year, they were kept in communal pond stocks after marking by clipping off a ventral fin. Altogether, 542 fish of 5.2 g mean weight were stocked in earthen ponds in March, and fed a commercial trout pelleted feed. We divided the populations as follows: i) in pond 2, 50 % of the fish from each population without any form of selection; ii) the other 50 % of fish from both population lines was divided into small and big fish to decrease the possibility of cannibalism and cultivated in pond 1 and 3, respectively. During the experiment, the fish were fed pelleted trout feed at the level of 2–6 % of body weight. In October, 349 fish were collected (64 % survival), out of which a random sample of 253 was taken. Live weight, total length and length of head were measured for every specimen, and a coefficient of condition K (live weight × length^{-3}), as well as a head index HI (length of head/total length), were calculated. Sex was determined by visual examination of gonads and histology [15].

2.2. Experiment 2: Growth in European catfish from 1 kg to a final weight of 2.3 kg

This experiment used a second commercial batch of fish produced by the hatchery of the 'Pisciculture de La Rotière' (France), using the technology reported by Proteau and Linhart [17] based upon artificial reproduction [14], first feeding on natural food, such as zooplankton and forage fish, in small ponds and weaning on dry food at 2 weeks. In June 1994, 2 815 one-year old fish (mean weight = 27 g) were randomly collected and grown in a recirculated system (Pisciculture de Consacq, France) for 1 year at a mean temperature of 19.3 ± 2.8 °C, until the beginning of the experiment.

The experiment began on 24 April 1995. Altogether, 200 fish were randomly selected and individually tagged with Pit Tag® injected in the dorsal muscle above the pectoral fin. They were kept in the same facility for 4 months, with the temperature at 20.7 ± 1.4 °C. Individual weight and length were measured 4 times: at tagging, at 56 days (half batch only), at 106 and at 120 days.

Length (L, mm), body weight (BW, g), gutted weight (GuW, g), fillet weight (FW, g) and gonad weight (GoW, g) were recorded at slaughtering on day 120 (fillet weight is the sum of the weight of the two fillets with skin). The sex of each individual was recorded. The following morphometric, processing and reproductive indexes were calculated:

- Coefficient of condition (K) = BW × L^{-3}
- Gutted yield = GuW/BW
- Fillet yield = FW/BW
- Gonado somatic index (GSI) = GoW/BW

Two tagged fish died during the experiment and were sexed, and 12 fish could not be identified at slaughtering and were removed from the results.

2.3. Statistical analysis

In experiment 1 (*table I*), λ^2-test was used for sex ratio and ANOVA (Statgraphics 5.0 with multiple range test) for effects of sex on weight, HI and K between the sex. In experiment 2 (*tables II* and *III*), significance of mean differences was evaluated with the Student's *t*-test after control of normality and variance homogeneity. Means are expressed as means ± stan- dard deviation. The Mann and Whitney test was used for comparing gonad weights, as their distribution is not normal. Linear regression is used to evaluate the relationships between traits.

3. RESULTS

3.1. Experiment 1: Growth from 5 g to a final weight of 200 g

The males of both populations (A and B) grew faster than females (*table I*). In testing pond 2, without any form of fish selection, the males of the A and B populations were bigger by about 15.16 % and 8.19 % than females, respectively, but these differences are not significant ($P < 0.05$). The sex ratio (males:females) was 1:1.28 in population A and 1.1:1 in population B.

In the second testing system (separation of small and big fish into pond 1 and 3, respectively) (*table I*), the

Table I. Relationship between the growth of males and females from an initial weight of 5 g to a final weight of 300 g (Pond 2 – no selection; Ponds 1 and 3 – separate culture of small and big fish; differences between males and females are not significant; A – Morranes population; B – Vodňany population; statistics in Materials and Methods).

Pond	Population	Weight of males (g ± SD)	Weight of females (g ± SD)	Significant difference	*n*	
					males	females
1	A	81.39 ± 23.89	83.33 ± 22.45	NS	23	20
	B	77.82 ± 16.98	83.33 ± 19.86	NS	21	21
2	A	163.00 ± 28.78	138.29 ± 31.66	NS	30	38
	B	141.80 ± 21.01	130.19 ± 28.78	NS	30	29
3	A	197.83 ± 23.02	182.33 ± 28.49	NS	18	27
	B	170.23 ± 25.32	158.22 ± 26.48	NS	26	18

NS Denotes no significant differences between males and females ($P > 0.05$).

males were not significantly ($P < 0.05$) bigger (2.32 %) or smaller (6.61 %) than females of populations A and B, respectively, in pond 1. In pond 3, the males of populations A and B were not significantly ($P < 0.05$) bigger than females (about 7.84 % and 7.06 %, respectively). The sex ratio from the separate testing of both ponds was 1:1.3 in population A and 1:1.13 in population B. The total sex ratio was 1:1.1, which does not differ from the expected one of 1:1 ($P > 0.4$).

A significant sex effect was noted on live weight (males 147.5 ± 5.4 g; females 132.9 ± 4.9 g; $P < 0.005$) and head index (males 20.6 ± 0.1 %; females 21.2 ± 0.1 %; $P < 0.05$), but no effect was seen for condition coefficient K (males 0.59 ± 0.01; females 0.62 ± 0.01, $P < 0.05$).

3.2. Experiment 2: Growth from 1 kg to a final weight of 2.3 kg

Taking into account the 2 dead fish, the sex ratio of the experimental group was 98 females to 90 males (52.1 % females, $n = 188$), which did not differ from 1:1 ($P > 0.3$). The food conversion rate (FCR) was 1.08, and the density of fish increased from 15.5 to 80 $kg \cdot m^{-3}$. At slaughtering, a significant effect of sex was observed for growth rate (1.32 % per day for males vs 1.28 % per day for females, $P < 0.02$). Still, no difference was found before slaughtering. Mean weight increased from 885 ± 196 g to 2 266 ± 418 g during the experiment (*table II*), and length increased from 513 ± 40 mm to 707 ± 46 mm.

Males were significantly ($P < 0.01$) heavier and longer than females at each of the 4 days tested. The superiority of male mean weight were +102 g (+12.2 %) at day 0, +162 g (+13.2 %) at day 56, +189 g (+9.3 %) at day 106 and +357 g (+17.0 %) at day 120 (*table III*). The difference in length was stable until day 106 (+3.9 %), but increased to 6.2 % from day 106 to day 120.

A strong linear correlation was found between initial and final weight ($r = 0.79$), as well as for length ($r = 0.82$). Correlation coefficients between weight and length at each step ranged from 0.90 to 0.97. No difference was found for condition coefficient (males 0.63 ± 0.04 vs females 0.64 ± 0.03 at slaughtering).

Male gutted weight was significantly ($P < 0.01$) higher (+ 367 g or + 18.7 %) than that of females (2 330 ± 369 g vs 1 963 ± 346 g). Male gutted yield was also significantly ($P < 0.01$) higher than that of females (95.0 ± 0.9 % vs 93.8 ± 1.8 %), with a higher standard deviation for females (*table III*). There was no correlation between gutted yield and weight ($r = 0.13$).

Male fillet weight was significantly ($P < 0.01$) higher (+ 233 g or + 20.9 %) than that of females (1 346 ± 245 g vs 1 113 ± 213 g), but there was no significant ($P < 0.05$) difference between male and female gutted yield (54.6 ± 4.4 % vs 53.2 ± 6.5 %) (*table III*). A strong correlation between weight and fillet weight was found ($r = 0.97$), but no correlation was found either between fillet yield and weight ($r = 0.20$) or between fillet yield and gutted yield ($r = 0.16$).

Gonado somatic index (GSI) was significantly ($P < 0.01$) higher in females than in males (1.3 ± 0.9 % vs 0.3 ± 0.1 %), the variability being also higher in females than in males (*table III*).

Table II. Mean weight ± SD (g) of mix populations in *Silurus glanis*, males and females at the 4 different days of measurements (statistics in Materials and Methods).

Day	Mixed weight population (g ± SD)	Male weight (g ± SD)	Female weight (g ± SD)	*n*	
				males	females
0	885.0 ± 196.8	942.4 ± 196.4	839.9 ± 177.3*	91	95
56	1 386.5 ± 290.7	1 475.2 ± 296.0	1 312.1 ± 254.6*	91	95
106	2 144.0 ± 340.8	2 236.9 ± 337.1	2 047.5 ± 318.6*	68	59
120	2 267.0 ± 417.6	2 451.3 ± 385.6	2 094.2 ± 371.4*	91	95

* Denotes significant differences between males and females ($P < 0.01$).

Table III. Mean values (m ± SD) of carcass traits (fillet weight, gutted weight, gutted yield and fillet yield) and GSI of males and females in *Silurus glanis* at slaughtering (2 266 g) (statistics in Materials and Methods).

Trait	Mixed population (± SD)	Males (± SD)	Females (± SD)	Significant difference	n	
					males	females
Fillet weight (g)	1 221.5 ± 252	1 346.0 ± 245.2	1 112.8 ± 212.5	**	72	74
Gutted weight (g)	2 145.0 ± 401.0	2 330.0 ± 669.0	1 936.0 ± 346.0	**	72	74
Fillet yield (%)	53.67 ± 2.71	54.15 ± 2.36	53.22 ± 2.93	NS	72	74
Gutted yield (%)	94.38 ± 1.56	95.05 ± 0.87	93.76 ± 1.79	**	72	74
GSI (%)	0.81 ± 0.06	0.34 ± 0.09	1.28 ± 0.91	**	88	94

** Denotes significant differences between males and females ($P < 0.01$),
NS Denotes no significant differences between males and females ($P > 0.05$).

4. DISCUSSION

The weight gain per day in the two experiments was lower than the weight reported by others [16, 18] in intensive breeding of European catfish. This can be explained as an effect of low growth temperature compared to the biological optimum of European catfish which is between 26 and 28 °C [18].

A significant sex effect was demonstrated for weight in both experiments and for length in the second experiment. Males grew from 2 to 15 % faster than females. In the first experiment, the GSI of males and females was 0.03 % ± 0.022 and 0.22 % ± 0.065, respectively [15]. The difference between males and females was evident in testing pond 2 (without any selection of fish), where the males of populations A and B were 15.16 and 8.19 % bigger than the females, respectively, but these differences were not significant. The same range of early difference of growth has been reported at 125 g (13 months) in the channel catfish [4].

In the second experiment, difference of growth between sex had occurred before 890 g (+12 %) were reached at 24 months of age, i.e. prior to beginning the experiment. Four months later (at 28 months) at slaughtering, this difference increased from 12 to 17 % for the weight and from 3.9 to 5.9 % for the length difference. The same range of differences between the sexes in Silurids was previously reported in channel catfish where males grew faster than females [1, 2, 4, 7] and in *Hoplosternun littorale* [9] in French Guyana. These results showed that the sex effect was found to be of major importance in European catfish as in other Silurids. Our study showed that the females slowed their weight growth during mainly the last period. This slower weight growth could be due to the initiation of sexual maturation observed in some females with higher GSI. This observation is in accordance with the timing of sexual maturation, which is between 12–16 months for males and 18–24 months for females kept at high temperature, as reported by Proteau and Linhart [17].

A search for the largest catfish in a population can inadvertently select mostly male fish which characteristically grow faster (*table III*) than females. Brooks et al. [3] reported that in the channel catfish populations studied, selecting only the largest 10 % of the fish by grading would have resulted in mostly male broodstock. They found that the largest 30 % of their channel catfish population had to be selected (by grading) at 6 or 18 months to ensure that the largest 10 % of the females were included.

Significant sex effects for males were also registered for gutted weight (+18.7 %), fillet weight (+20.1 %), and gutted yield (+1.2 %), but not for fillet yield (+1.4 %). The mean fillet and gutted yields were at the same range as reported yields [5] for European catfish and channel catfish [4]. It can not be excluded that the lack of significance of the sex effect on yield of fillet was induced by the operation of filleting. The bigger fillet and gutted weights in males were due to the combination of faster growth of males (+17 %), higher yield of gutted weight (+1.2 %) and lower GSI (–0.94 %) in males. The lack of correlation between yields of fillet and gutted weight show that the best fish for gutted performance are not necessarily the best ones for fillet performance. Low phenotypic variability of fillet and gutted yields, 1.56 and 2.71, respectively, is in the same range as yields reported for Salmonids [6, 20].

Development of all-male populations by genetic manipulation may be technically difficult and expensive, no matter the sex one starts from. Farming by separating the sexes to increase the difference between the two could be a solution as exemplified with channel catfish [7] when compared with mixed sex populations, but it necessitates sex determination as early as possible, and an evaluation of the real benefit for the farmers if the total biomass produced remains the same. Firstly, the 17 % higher live weight of European catfish males at slaughtering represents only a higher live weight of 8.1 % when compared to the mean weight of the entire population, which is not a strong increase when compared to other potential improvements such as in nutrition, hygiene, farming technology and selection. Secondly, a modification of flesh quality with sexual maturation in European catfish is still to be studied, and the consumer preference is also still to be identified.

Development of a high quality market, a decrease in production cost and farming of large fish could stimulate interest for all-male populations of European catfish.

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REFERENCES

[1] Beaver T., Sneed K.E., Dupree H.K., The difference in growth of male and female catfish in hatchery pond, Progress. Fish-Cult. 28 (1966) 47–50.

[2] Bondari K., Reproduction and genetics of the channel catfish (*Ictalurus punctatus*), Aquat. Sci. 2–3 (1990) 357–374.

[3] Brooks M.J., Smitherman R.O., Chappell J.A., Dunham R.A., Sex-weight relations in blue, channel and white catfish: Implications for brood stock selection, Progress. Fish-Cult. 44 (1982) 105–106.

[4] Dunham R.A., Joyce J., Bondari K., Malvestuto S.P., Evaluation of body conformation, composition, and density as traits for indirect selection for dress-out percentage of channel catfish, Progress. Fish-Cult. 47 (1985) 169–175.

[5] Fauconneau B., Laroche M., Characteristics of the flesh and quality of products of catfishes, in: Legendre M., Proteau J.P. (Eds.), The biology and culture of catfishes, Aquat. Living Resour. 9 (special issue) (1996) 165–179.

[6] Gjerde B., Body traits in rainbow trout. I. Phenotypic means and standart deviation and sex effects, estimates of heritabilities and of phenotypic and genetic correlations, Aquaculture 80 (1989) 7–24.

[7] Goudie C.A., Simco B.A., Davis K.B., Carmichael G.J., Growth of channel catfish in mixed sex and monosex pond culture, Aquaculture 128 (1994) 97–104.

[8] Goudie C.A., Simco B.A., Davis K.B., Liu Q., Production of gynogenetic and polyploid catfish by pressure-induced chromosome set manipulation, Aquaculture 133 (1995) 185–198.

[9] Hostache G., Mol J.H., Reproductive biology of the neotropical armoured catfish *Hoplosternum littorale* (Siluriformes, Callichthyidae): a synthesis stressing the role of the floating bubble nest, Aquat. Living Resour. 11 (1998) 173–185.

[10] Krasznai Z., Marian T., Shock-induced triploidy and its effect on growth and gonad development of the European catfish, *Silurus glanis* L., J. Fish Biol. 29 (1986) 519–527.

[11] Krasznai Z., Marian T., Kovacs G., Production of triploid European catfish (*Silurus glanis*) by cold shock, Aquac. Hung. 41 (1994) 25–32.

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

[13] Linhart O., Proteau J.P., *Silurus glanis*: Market and prospects of development in Europe, in: Kestemont P., Billard R. (Eds.), Aquaculture of freshwater species (except salmonids), European Aquaculture Society, Toremollinos Spain, Spec. Publ. 20, 1993, pp. 16–18.

[14] Linhart O., Billard R., Kouřil J., Hamáčková J., Artificial insemination and gamete management in European catfish (*Silurus glanis* L.), Pol. Arch. Hydrobiol. 44 (1977) 9–23.

[15] Linhart O., Vandeputte M., Horák V., Interaction of sex and growth in two-years-old wels (*Silurus glanis* L.), Bull. VÚRH Vodňany 33 (1997) 189–196.

[16] Meske C., Fish Aquaculture, Technology and experiment, Pergamon Press, Oxford, 1985, 237 p.

[17] Proteau J.P., Linhart O., *Silurus glanis*: actual state of the techniques of reproduction, in: Kestemont P., Billard R. (Eds.), Aquaculture of freshwater species (except salmonids), Eur. Aquac. Soc., Toremollinos Spain, Spec. Publ. 20, 1993, pp. 12–15.

[18] Proteau J.P., Thollot T., Élevage intensif du silure glane en eau chaude: premiers résultats de croissance obtenus sur pilote expérimentale, Aqua-Revue 21 (1988) 23–26.

[19] Proteau J.P., Hilge V., Linhart O., État actuel et perspectives de la production aquacole des poissons-chats (Siluroidei) en Europe, in: Legendre M., Proteau J.P. (Eds.), The biology and culture of catfishes, Aquat. Living Resour. 9 (special issue) (1996) 229–235.

[20] Rye M., Refstie T., Phenotypic and genetic parameters of body size traits in Atlantic salmon *Salmo salar* L., Aquac. Res. 26 (1995) 875–885.