Reduction of cannibalism in pike (*Esox lucius*) fry by isolation of full-sib families

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Summary. After 50 days of pond culture fewer pike fingerlings (20 to 33 p. 100) were recovered from the mixing of two full-sib families than from isolated families. Growth and survival were influenced by the family effect. Environmental parameters, such as depth and extent of the banks, may also affect growth and survival. Our results indicated that isolating full-sib families and using small, shallow ponds increased the recovery and growth rate of fingerlings.

Introduction.

Since the early work of Colas (1937) on the production of 3 to 7-week pike fingerlings in small ponds, numerous authors have reported on this extensive culture technique (Huet, 1948 ; Huet and Timmermans, 1958 ; Hiner, 1961 ; Chauderon, 1969 ; Arrignon, 1972 ; Huet, 1976). The lack of precise data on fingerling weight or size often makes comparison of the various results difficult. However, numerical yields usually range from about 50 to 250 fingerlings per 100 m^2 (fingerling total length : 50 to 100 mm ; mean individual weight : 0.5 to 5 g).

Three interrelated factors which are difficult to control limit the efficiency of this type of culture :

1) climatic conditions, especially temperature change ;

2) nature and quantity of available food : zooplankton, invertebrates, fry of other species ;

3) cannibalism.

In extensive or semi-intensive conditions, work has mainly been focused on the availability of food : pond fertilization (Colas, 1938), supply of plankton (Arrignon, 1972 ; Huet, 1976) and of perch fry (Chauderon, 1969 ; Arrignon, 1972),

Cannibalism is common in pike, especially in the fry which even prefer this way of feeding (Chodorowski, 1973). It may be one of the main factors in regulating pike populations (Hunt and Carbine, 1951 ; Kipling and Frost, 1970). After yolk sac resorption, fry at the swimming stage are 12 to 15 mm long (Wurtz, 1944 ; Franklin and Smith, 1963), and cannibalism may occur as early as at 21 mm (Hunt and Carbine

1951). A plentiful supply of adequate food, suited to the sequential nutritional require-
ments of the pike juvenile, as well as a moderate temperature and low density can
reduce the intensity of cannibalism (Buss, 1961 ; Chauderon, 1969 ; Chodorowski,
1973). However, even under the most optimal conditions, cannibalism remains latent
and inevitably depends on the size heterogeneity among individuals. Cannibalism
can even occur when there is a size difference of about only 20 to 30 p. 100 in total
length (Hunt and Carbine, 1951 ; Buss, 1961).

In extensive culture, cannibalism is reduced by using fry of identical age and
by draining the pond early (4 to 6 weeks after yolk resorption : Colas, 1938 ; Hiner,
1961). It is nevertheless possible to keep high densities of young pike or spawners
(200 to 500 kg/ha) during several months and in excellent conditions (< 10 p. 100 loss),
provided that the size is standardized (Huet, 1972 ; Bry, unpublished data).

We therefore tried to increase size homogeneity by isolating the offspring of the
various females and compared the yields given by these isolated full-sib families with
the performances of mixed lots made up by mixing two full-sib families. We also
attempted to answer the following questions : (i) does a family effect still influence
growth 6 to 7 weeks after yolk sac resorption, (ii) can morphological features of the
small ponds have an effect on yields ?

Material and methods.

Experimental design.

The experiments were carried out from March to May 1978 at the « L. Paraclet »
pike culture facility (Conseil Supérieur de la Pêche). Pike females were injected intra-
peritoneally and immediately after capture with a preparation of partially purified
salmon gonadotropin (de Montalembert et al., 1978a ; Bry et al., 1978). Three females,
referred to as A, B and C, were used. Ova were inseminated 5 days after the ovula-
tion-inducing treatment using the « 532 » diluent, a dilution ratio (volume of sperm/vo-
lume of diluent) of 1 : 1 000, and a ratio of approximately 2 between the volume of
the ova and that of the diluent (Billard et al., 1976 ; Billard, 1977 ; de Montalembert
et al., 1978b). Ova from females A and B were inseminated with the sperm of the same
male, thus establishing two full-sib families. Ova from female C were inseminated
with the pooled sperm of 5 males. Eggs were incubated in Zuger incubation jars up
to 80 degree-days, then transferred into a fine meshed trough. At about 100 degree-
days post-hatching, i.e. approximately at 2/3 of yolk sac resorption, the fry were siphon-
ed from their trough of origin, counted and stocked in 6 grassy ponds measuring 240m²
(18 × 13.5) and in 5 measuring 80 m² (14.5 × 5.5), with respective depths of 0.2 to
1 m and 0.2 to 0.6 m. Fry total length was close to 13 mm and individual weight ave-
raged 12 mg. Regardless of the size of the pond, the same stocking density was used:
6 fry/m² (1 500 in the 240 m² ponds and 500 in the 80 m² ponds). These ponds had been
fertilized with organic manure and filled approximately 10 days before stocking. The
fry were alloted as follows :
— fry A : lots $A_1/240$, $A_2/240$, $A/80$;
— fry B : lots $B/240$, $B_1/80$, $B_2/80$;

— fry C : lot C/240 ;

— mixed lots, AB/240, AC/240, $(AB)_1/80$, $(AB)_2/80$, composed of equal pro-
portions of two families (A and B, or A and C).

Fifty days after stocking, i.e. 60 days after hatching and about 45 days after yolk
sac resorption, 10 of the 11 ponds were drained and the pike fingerlings counted and
individually weighed to the nearest 0.1 g. Each pond was drained and refilled
2 to 4 times, the first drainage providing about 90 p. 100 of the total production. As
there was considerable growth during the 1 to 9 days elapsed between the first drai-
nage and the following ones, only the fish taken during the first drainage were used
to calculate the average weight and the coefficient of variation of weight as well
as the distribution of individual weights.

On the other hand, numerical yields (recovery yield and yield per unit area of
surface) were computed from the total number of fingerlings N recovered in each lot.
Pike biomass was estimated using N and the mean weight of pike obtained when the
pond was first drained.

Taking into account the results of successive drainages, the absolute error on N
(total number of fingerlings recovered in each lot) was evaluated as 0 to 30 pike for
the 240 m² ponds (0 to 10 p. 100 of the number recovered) and 0 to 5 pike for the 80 m²
ponds (0 to 4 p. 100 of the number recovered).

The lot B/240 was drained 8 days after the other ponds ; the mean individual
weight and the biomass showed a high increase during this extra growth period.
Accordingly, those data were not taken into account in comparisons with the other
lots and are indicated in brackets in table 1 : The numerical production (N) of this
lot was used, nevertheless, since it could be considered, after subsequent observation,
as slightly lower than its true value 8 days before, and because it dealt with a full-sib
lot and not with a mixed one.

There were no forage fish in the ponds during the whole experimental period.

Statistical analysis.

The effects of pike origin and of pond type were tested with a 2-factor analysis
of variance (factorial pattern with fixed effects) of the lots involved in both pond types
($A_1/240$, $A_2/240$, B/240, AB/240, A/80, $B_1/80$, $B_2/80$, $(AB)_1/80$, $(AB)_2/80$) after angular
transformation of the percentages (table 2). Theoretical survival rates in the mixed
lots were computed by averaging the survival rates observed in the corresponding
isolated families. Survival rates were compared using either the normal deviation
(table 3) or the χ^2 test (table 4). Mean individual weights were compared using
Student's t-test. The relative variability of individual weight within a given lot was esti
mated as the coefficient of variation (ratio of the standard deviation to the mean in
p. 100).

Results and discussion.

The results are shown in table 1. The numerical production of fingerlings per
100 m² ranged from 125 (lot B/240) to 337 (lot A/80). The mean weight varied from

TABLE 1

Numerical production, biomass, mean weight and variability of weight in lots of pike fingerlings after 50 days of pond culture

Pike origin	Lots	240 m² ponds No(1) = 1 500						80 m² ponds No(1) = 500					
		N (2)	N/100 m² (3)	S (4) p. 100	W (5)	CV (6) p. 100	BM/100 m² (7)	N (2)	N/100 m² (3)	S (4) p. 100	W (5)	CV (6) p. 100	BM/100 m² (7)
A	A₁ A₂	405 544	169 227	27 36	3.1 3.2	27 39	530 720	270 —	337 —	54 —	4.1 —	32 —	1 390 —
B	B₁ B₂	301 —	125 —	20 —	[6.7] (8) —	35 —	[840] (8) —	158 142	197 177	32 28	2.9 3.6	32 30	580 650
AB	(AB)₁ (AB)₂	309 —	129 —	21 —	2.6 —	60 —	340 —	120 161	150 201	24 32	3.9 3.9	26 39	580 790
C	C	340	142	23	1.4	39	200	—	—	—	—	—	—
AC	AC	318	132	21	2.5	58	330	—	—	—	—	—	—

(1) No = number of fry stocked.
(2) N = Number of fingerlings recovered.
(3) N/100 m² = number of fingerlings recovered per 100 m².

(4) $S = \dfrac{N}{No} \times 100$ = survival rate (p. 100).

(5) W = mean weight (grams).
(6) CV = coefficient of weight variation (p. 100).
(7) BM/100 m² = pike biomass per 100 m² (grams).
(8) These data were not used for comparison. See material and methods.

1.4 g (lot C/240) to 4.1 g (lot A/80), and the biomass per 100 m² from 200 g (lot C/240) to 1 390 g (lot A/80), i.e. from 20 to 139 kg/ha.

These values are, on the whole, somewhat higher than those given by Chauderon (1969) and Huet (1976) who regarded productions over 50 kg/ha as exceptional. This suggests that the experimental conditions of our pond culture (pond features, water quality, temperature profile, food availability) were especially favorable.

Analysis of the causes of variation in survival rate. — The analysis of variance of lots A, B and AB involved in both types of ponds (table 2) demonstrated effects of pike origin and pond type and the lack of interaction.

TABLE 2

Analysis of variance : Effect of pike origin and pond type on survival rate after 50 days of pond culture (Lots of the A, B, and AB series)

Source of variation	Degree of freedom	Mean Square (MS)	F = MS/Residual MS	Level of significance
Pike origin	2	80.1	7.6	S 7 p. 100
Pond type	1	99.6	9.4	S 6 p. 100
Interaction	2	11.4	1.1	(NS)
Residual variation ...	3	10.6	—	—

A residual variance of 9.7 p. 100 relative value was computed between replicate ponds. The high value of this residual variance showed that the differences observed between replicate ponds did not correspond to ordinary sampling fluctuations, but to functional differences between small ponds of similar appearance. Similar observations were made by Buck *et al.* (1970) who obtained coefficients of variation in survival rate for young carp ranging from 3.3 to 8.5 p. 100.

TABLE 3

Comparison of survival rates of pike fingerlings : — computed from the data of isolated families (theoretical rates S_T) ; — observed in the mixed lots (experimental rates S_E)

Lots		Number of fingerlings recovered (N)	Survival rate (p. 100)	Normal deviation and level of significance of the difference $S_T - S_E$	Difference in survival rates (p. 100) $\dfrac{S_T - S_E}{S_T} \times 100$
AB/240	theoretical	$N_T = 388$	$S_T = 26$	4.25	20
	experimental	$N_E = 309$	$S_E = 21$	S 1 p. 1 000	
AB/80	theoretical	$N_T = 210$	$S_T = 42$	7.16	33
	experimental	$N_E = 140$	$S_E = 28$	S 1 p. 1 000	
AC/240	theoretical	$N_T = 407$	$S_T = 27$	4.71	22
	experimental	$N_E = 318$	$S_E = 21$	S 1 p. 1 000	

In our experiment, slight inter-pond variation of such conditions as temperature, flow rate, bottom shape, or other not yet identified parameters, might have created differences in the quality and distribution of pike prey as well as of vegetation, and thus modified survival.

Effect on survival of mixing two full-sib families. — The comparison of the theoretical survival rates computed from the performances of isolated families, and the rates observed in mixed lots (table 3) showed a negative mixing effect ($P < 0.001$) in all cases, which was equal to about 20 to 30 p. 100 of the standing crop.

Analysis of weight distribution. — The weight distributions in isolated lots were generally unimodal and asymmetrical (fig. 1 : lots $A_2/240$ and $C/240$; fig. 2 : lots $A/80$ and $B_1/80$). In mixed lots, the weight distributions were bimodal, when the mean weights
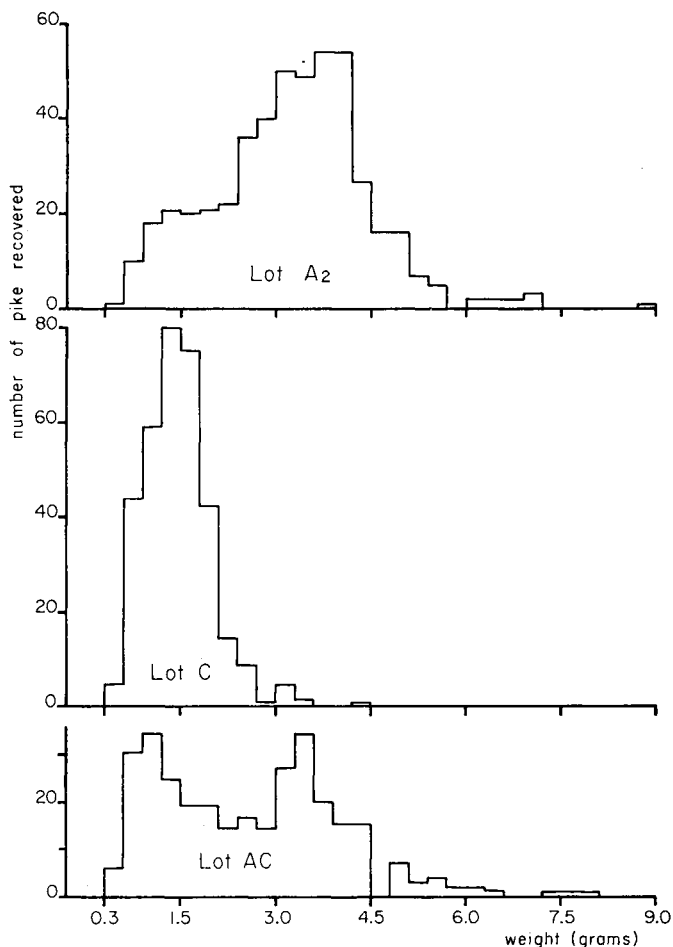

FIG. 1. — *Profile of weight distributions within two families*
(lots $A_2/240$ and $C/240$) and one mixed lot ($AC/240$).

of compound families were sufficiently different (fig. 1 : lot AC/240), or they were irregular (fig. 2 ; lot (AB)$_2$/80).
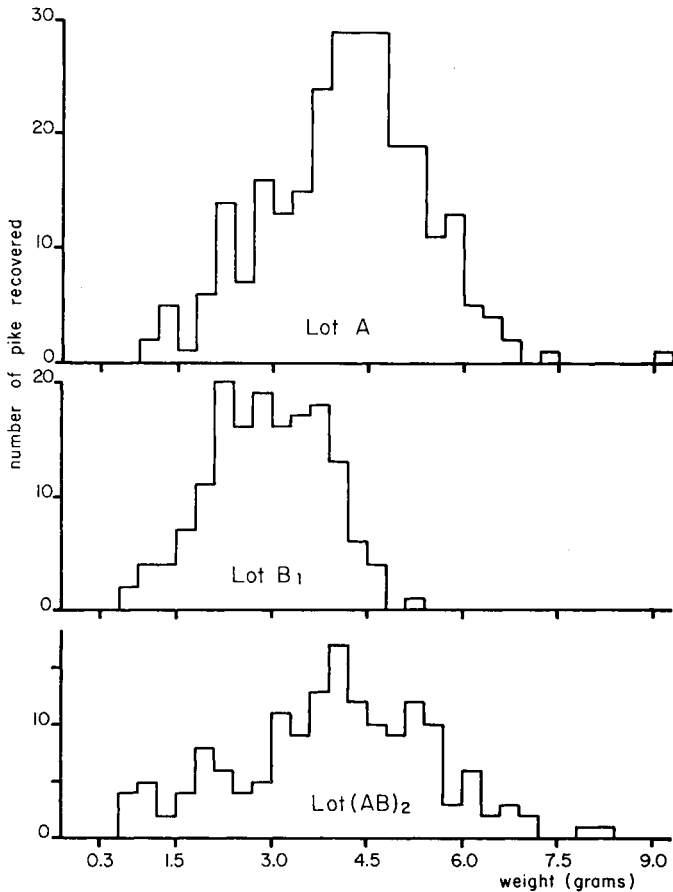

FIG. 2. — *Profile of weight distributions within two families*
(lots A/80 and B$_1$/80) and one mixed lot ((AB)$_2$/80).

The relative variability of weight (coefficient of variation, table 1) was higher in mixed lots, especially in the 240 m² ponds where growth was slower : 60 and 58 p. 100, as opposed to 27, 39, 35, 39 p. 100 in isolated full-sib families. The lot (AB)$_1$/80, however had a coefficient of variation lower than that of both components, but survival was especially low in that lot.

Finally, when weight distributions in experimental mixed lots and in theoretical lots were compared, a general although non-significant tendency towards fewer individuals in the low weight class was noted.

These observations suggest that cannibalism intensity was highest where growth was most heterogeneous, i.e. in the mixed lots. Although the full-sib families proved to be the most homogeneous, they also showed a considerable range in weight (up to a

factor of 30 between extreme values). This observation is in close agreement with that of Carbine (1945) for pike and of Moav and Wohlfarth (1973) who described weights ranging from 1.5 to 82 g in a full-sib family of carp averaging 3.5 g.

Full-sib family effect. — A comparison of the performances of isolated families A, B and C indicated a family factor effect on survival and growth (table 4). The family effect could be considerable : family A growth was twice that of family C. Family A also showed a higher survival rate, so that family A yielded about 3 times as much as family C in terms of biomass : 530 and 720 g/100 m² as compared with 200 g/100 m² in 240 m² ponds, and twice as much as family B : 1 390 g/100 m² vs 580 and 650 in 80 m² ponds.

TABLE 4

Influence of fry origin (Families A, B, C) on survival rates and mean weights of pike fingerlings

Pond type	240 m² ponds			80 m² ponds	
Pike origin	A	B	C	A	B
Survival rate (p. 100)	31.6	20	23	54	30
χ^2 and level of significance	χ^2 (2 d.f.) = 83.8 S 1 p. 1 000			χ^2 (1 d.f.) = 81.5 S 1 p. 1 000	
Mean weight	3.2	—	1.4	4.1	3.2
t and level of significance	t = 38.1 S 1 p. 1 000			t = 9.2 S 1 p. 1 000	

Effect of pond morphology. — Pond morphology had an effect on both survival (table 2) and growth : the mean weight of family A fingerlings increased from 3.2 g (lots 240 m²) to 4.1 g in lot A/80 (normal deviation : 10.3 ; P < 0.001). The combination of a higher survival rate and a faster growth rate in the 80 m² ponds doubled the biomass, when compared to the 240 m² ponds. The small ponds demonstrated a remarkable productivity : 58 to 139 kg/ha in 50 days. The shallower 80 m² ponds probably were warmer and consequently may have contained more food (plankton and invertebrates).

The perimeter-surface ratio was twice as much in the 80 m² ponds as in the 240 m² ones, and the number of fry per meter of bank was therefore twice as low (12 and 24 fry/m). As a matter of fact, the banks might serve as an area of perferred shelter for the pike and their prey.

Conclusions.

Survival of pike fry cultured for 50 days in ponds was 20 to 33 p. 100 lower when two full-sib families were mixed than when the full-sib families were cultured separately. This difference was probably the result of a higher rate of cannibalism in the

mixed lots, due to a more heterogeneous growth. There was a considerable family effect, especially on growth. Small 80 m² ponds induced clearly higher survival and growth rates than those observed in the 240 m² lots. The biomass of pike recovered from the 80 m² ponds ranged from 58 to 139 kg/ha. This net production, achieved in 50 days, can be considered as high according to the literature (Huet, 1976).

Our data suggest isolating full-sib families and using small, shallow ponds for the extensive culture of pike fingerlings. The reduction of precocious cannibalism might also prove of interest in the case of intensive culture where the phenomenon may occur as soon as the delay between feeding sessions exceeds 6 hrs (Westers, 1978).

Résumé. Le mélange de 2 fratries d'alevins de Brochet s'est traduit, à l'issue d'un élevage de 50 jours en étangs, par un déficit numérique de 20 à 33 p. 100 par rapport au taux de survie moyen des composantes du mélange.

Il existe un « effet famille » important, à la fois sur la croissance et le taux de survie. Des paramètres de l'environnement tels que la profondeur des étangs et l'importance relative des berges sont également susceptibles d'influer sur les rendements numérique et pondéral de l'élevage. Les résultats obtenus indiquent que l'isolement des fratries d'alevins et l'utilisation de petits étangs peu profonds peuvent permettre d'améliorer la productivité de ce type d'élevage.

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