Aquaculture Research, 2004, **35**, 552–558

Comparison of growth performance and biometric relationships in two reciprocal sturgeon hybrids reared in net cages (Sicily, Mediterranean)

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Abstract

This study was designed to investigate growth performance in two sturgeon hybrids reared in two quadrangular floating cages moored in an artificial pond, representing the first experience of sturgeon culture performed at Southern Mediterranean latitudes. The research was carried out from December 2000 to July 2001 and tested the growth performance, feeding parameters and biometric relationships.

The sturgeons were randomly collected from the cages on a monthly basis, and total length, standard length (SL) and wet weight (WW) were recorded. The specific daily growth rate (SGR_W) as somatic WW, food conversion ratio and condition factor (CF) were calculated. Biometric relationships, as linear regression, were also calculated on SL and WW data.

Both hybrids grew slowly from December to April, but faster during the warm months. The growth performance of the two hybrids seems to be influenced by variability of the environmental conditions and, for both fish groups, there was a strong correlation between water temperature and SGR_W at temperatures below 25 °C. The CF (constantly below 1) was similar for both hybrids. The regression analysis for WW and SL calculated for the entire period showed a positive allometry for both hybrids, indicating that the fishes grew in weight at a greater rate than required to maintain constant body proportion.

Keywords: sturgeon, aquaculture, growth performance, biometric relationship

Introduction

In the last two decades, the need to diversify aquaculture production has led Italian fish farmers to change production considering new fish species, particularly the acipenserids (Bronzi, Rosenthal, Arlati & Williot 1999). The overall adaptability of acipenserids makes them particularly easy to cultivate at various latitudes. Indeed, various cultivation experiences have shown high growth rates under rearing conditions (Prokes, Barus & Penaz 1996), low mortalities and a good overall health even at high stocking densities (Williot, Ronault, Brun, Miossec & Rooryck 1988; Steffens, Jahnichen & Fredrich 1990; Prokes *et al.* 1996; Williot, Sabeau, Gessner, Arlati, Bronzi, Gulyas & Berni 2001), a particular resistance to handling and a good palatability (Prokes *et al.* 1996).

In Italy, the first trial of sturgeon rearing (*Acipenser naccarii*) was carried out in 1977, and artificial spawning was first obtained in 1988 (Rosenthal & Gessner 1992; Bronzi *et al.* 1999). Currently, Italy boasts ten hatcheries and fish farms, and the total sturgeon species production in 1999 was 800 t (Williot *et al.* 2001).

In the last decade, many sturgeon hybrids have been cultured, since it is well known that hybrids generally have shown better growth performance than their parental species (Steffens *et al.* 1990; Bronzi *et al.* 1999; Williot *et al.* 2001). The hybrid between *A. naccarii* (Bonaparte) and *A. baerii* (Brandt) was first obtained in 1993 in an Italian sturgeon fish farm (Arlati, Hernando, Poliakova-Belysceva & Soriguer 1999). To date, the hybrid *A. naccarii* × *A. baerii* (AL) and the reciprocal *A. baerii* × *A. naccarii* (LA) have been cultivated in Italy for ongrowing (Williot *et al.* 2001), while the parental species *A. naccarii*, due to specific programmes in Italy, is by now reared only for restocking activities in natural environments (Bronzi *et al.* 1999). Moreover, *A. naccarii* presents till problem with effective weaning methods that ensure good larval survival (Bronzi *et al.* 1999).

To our knowledge, no information is available on AL and LA hybrids growth under farming conditions at Southern Mediterranean latitudes. This is the first study designed to investigate the growth performance of AL and LA hybrids reared in floating cages moored in an artificial pond at low latitudes, in Sicily (Italy).

The main aims of our study were to test and to compare growth performances, feeding parameters and biometric relationships in these two sturgeon hybrids reared under identical environmental conditions.

Materials and methods

Growth trials were carried out between December 2000 and July 2001 in an artificial pond (25 000 m^2; Sicily, Southern Italy) with a maximum depth of 6 m. Two quadrangular net cages ($4 \times 4 \times h$ 1.2 m, 19.2 m^3 submerged volume, 5-mm mesh size for the walls and 1 mm for the net bottom) were moored in the artificial pond. A submerged aerator was used to maintain a constant oxygen concentration of over 5 mg L^{-1}. Each cage was divided into two identical sections ($4 \times 2 \times h$ 1.2 m each), by means of a vertical net (5 mm mesh size).

The cages were filled on 12 December 2000, the first cage with 1000 0^+ AL specimens (initial wet weight (WW) = 49.5 ± 19.4 g) and the second cage with 1000 0^+ LA specimens (initial WW = 45.5 ± 10.5 g), transplanted from a commercial fish farm (Salmopan s.r.l.) in Northern Italy. The original broodstock used to generate the test fish was from a commercial fish farm ('Azienda Agricola VIP', Orzinuovi, Brescia, Italy). In each cages, fish were equally distributed (500) within the two sections. During the growth trials, fish were fed automatically with pelleted food (Hendrix s.p.a., Verona, Italy, Europa HD; 48.0% crude protein, 20.0% crude lipids, 8.5% ash and 1.7% crude cellulose; pellet size was 2 mm). The feeding rate was maintained at 2.5% of the reared biomass.

The sturgeons were randomly collected on a monthly basis using a landing net, manually moved into each sections of the two cages during a sampling time of 10 min. Total length (TL, cm), standard length (SL, cm) and WW (g) were immediately recorded for each sampled specimen.

Water temperature (°C) and oxygen concentration (mg L^{-1}) were recorded at 1 m depth using a multiparameter probe (Surveyor 3; Hydrolab, Loveland, CO, USA).

Growth performance was tested by calculating the daily specific growth rate as somatic WW (SGR_W, %) as follows (Jobling 1983):

$$SGR_W = [(\ln WW_t - \ln WW_0)/\Delta t] \times 100$$

where WW_t and WW_0 represented the final and initial mean WW, respectively, and Δt the time interval (day). The food conversion ratio (FCR), considered to be an expression of the WW of feed used per unit live weight gain, was calculated for each sampling time and at the end of the trial, according to the following equation (Stead, Houlihan, McClay & Johnston 1996):

$$FCR = TF_{WW}/(WW_t - WW_0)$$

where TF_{WW} was the total WW of food and WW_t and WW_0 were the initial and final fish biomass respectively. The condition factor (CF) was monthly calculated using the following relationship (Ricker 1975):

$$CF = 100\,(WW)/(TL)^3$$

where WW was the mean wet weight and TL the mean total length.

The simple allometric regression was used monthly to study the biometric relationships by means of a logarithmic (ln) transformation of SL and WW data, according to the following equation (Gould 1966):

$$WW = a SL^b$$

Initially, we verified the possibility of intra-hybrid variability in the growth performance. Statistical data analyses performed did not detect any difference between the two sections of each cage. Specific data are not reported. Such an absence of differences between sections allowed us to pool data across sections of each cage and to test for potential differences between the two sturgeon hybrids.

The Student's *t*-test was used to ascertain monthly differences in WW and SL between the two hybrids, while the Mann–Whitney *U*-test was used to ascertain differences in SGR_W and FCR between the AL and LA hybrids (Sokal & Rohlf 1981).

Linear regression analysis was performed to investigate the correlation between water temperature and the regression coefficients of the length–weight relationships. Moreover, the correlation between environmental variables (water temperature or oxygen concentration) and SGR_W was examined.

The constants *a* (intercept) and *b* (slope) of the length–weight regression analysis were compared monthly between the two hybrids using ANCOVA with a covariate (Underwood 1997; Zar 1999).

Statistical analysis on growth data was performed with Statistica 6.0 (Statsoft, Tulsa, OK, USA) software.

Results

Environmental conditions

The water temperature at 1 m depth ranged from 9.8 °C (January) to 26.4 °C (July), due mainly to climatic changes (Fig. 1a), while the oxygen concentration was between 6.8 mg L^{-1} (May) and 9.0 mg L^{-1} (January).

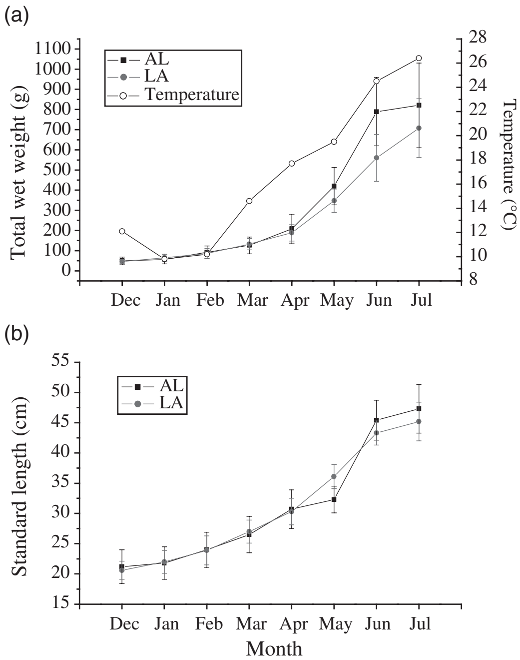

Figure 1 Monthly trends of wet weight (a) and standard length (b) of *A. naccarii* × *A. baerii* (AL) and *A. baerii* × *A. naccarii* (LA) hybrids. Temperature trend of water at 1 m depth is reported in (a). Bars indicate standard deviation.

Growth performance

Monthly trends of WW and SL of the two sturgeon hybrids during the trial period are reported in Fig. 1a and b. Both hybrids had a very similar WW at the beginning of the trial (49.5 ± 19.4 and 45.5 ± 10.5 g for AL and LA respectively), and both fish groups grew slowly until the temperature exceeded 17 °C. From April, the AL group grew more rapidly than LA, and WW showed a significant difference between the two hybrids in May (*t*-test; $P<0.05$), June (*t*-test; $P<0.05$) and July (*t*-test; $P<0.05$). WW at the end of the experiment was 820.8 ± 210.1 and 707.8 ± 145.4 g for AL and LA respectively (Fig. 1a). A significant difference between the two hybrids was observed for SL in June (*t*-test; $P<0.05$) and July (*t*-test; $P<0.05$). At the end of the experiment, SL was 47.3 ± 4.0 and 45.2 ± 3.2 cm for AL and LA respectively (Fig. 1b).

The mortality of the two hybrids was very low, considering that the entire experiment period mortality did not exceed 4.0% of the total number of fishes (3.9% and 3.4% for AL and LA respectively).

In Table 1, SGR_W and FCR data are reported. SGR_W ranged from 0.13% (July) to 2.63% (June) for AL hybrid, while it was fairly constant for LA, ranging from 0.78% (July) to 1.99% (June). FCR values for the AL group ranged from 0.76 to 18.61 (June and July respectively), and for the LA group from 0.97 to 2.85 (June and July respectively). Testing SGR_W and FCR values of the two hybrids, we did not detect significant differences (*U*-test, $P>0.05$). The cumulative SGR_W and FCR values (entire trial period) were, respectively, 1.39% and 1.69 for AL hybrid and 1.24% and 1.55 for LA. SGR_W values for both hybrids increased in time with increasing water temperature and then dropped suddenly in July, when the water temperature exceeded 25 °C (Table 1; Fig. 1a).

Linear regression analysis showed a good correlation between water temperature and SGR_W values [$SGR_W = -0.12\ (\pm 0.73) + 0.11\ (\pm 0.04)T$; $r = 0.78$; $P = 0.06$ for AL hybrid; $SGR_W = 0.49\ (\pm 0.14) + 0.06\ (\pm 0.01)T$; $r = 0.96$; $P = 0.002$ for LA], considering the whole experimental period except for July. By contrast, no correlation was observed between water temperature and SGR_W when the entire experimental period, from December to July, was considered. No correlation was observed between oxygen concentration and SGR_W.

As shown in Table 1, CF was very similar for the two sturgeon groups. CF values increased linearly with fish size and were always lower than 1, ranging from 0.32 to 0.54 and from 0.33 to 0.48 for AL and LA respectively.

Table 1 Monthly values of SGR_W, FCR and CF for AL and LA hybrids

	SGR_W (%)*		FCR†		CF (%)‡	
	AL	LA	AL	LA	AL	LA
Dec	–	–	–	–	0.32	0.33
Jan	0.46	1.25	6.17	1.91	0.34	0.39
Feb	1.79	1.07	1.05	1.52	0.42	0.41
Mar	0.95	1.26	2.34	1.64	0.45	0.43
Apr	2.08	1.47	0.99	1.40	0.47	0.43
May	2.01	1.75	0.91	1.08	0.50	0.46
Jun	2.63	1.99	0.76	0.97	0.54	0.45
Jul	0.13	0.78	18.61	2.85	0.51	0.48
Total period	1.39	1.24	1.69	1.55	–	–

*$SGR_W = [(\ln WW_t - \ln WW_0)/\Delta t] \times 100$, where WW_t and WW_0 represent the final and initial mean wet weight, respectively, and Δt is the time interval in days.

†$FCR = TF_{WW}/(WW_t - WW_0)$, where TF_{WW} is the total wet weight of food and WW_t and WW_0 are the initial and final fish biomass respectively.

‡$CF = 100\ (WW)/(TL)^3$, where WW is the mean wet weight and TL the mean total length.

SGR_W, specific growth rate in weight; FCR, food conversion ratio; CF, condition factor; AL, *A. naccarii* × *A. baerii*; LA, *A. baerii* × *A. naccarii*.

Table 2 Regression constants and analysis of covariance for SL vs. total WW variables in two sturgeon hybrids

	AL hybrid					LA hybrid					*F*-values†	
	n	*a*	*b*	*r*	*P*	*n*	*a*	*b*	*r*	*P*	Slopes	Intercepts
Dec	60	−5.09	2.93	0.98	***	60	−4.98	2.90	0.92	***	0.060 (NS)	3.141 (NS)
Jan	55	−4.84	2.86	0.98	***	59	−5.96	3.26	0.96	***	7.626**	53.914***
Feb	48	−4.21	2.73	0.97	***	48	−4.29	2.75	0.93	***	0.001 (NS)	3.272 (NS)
Mar	46	−5.28	3.07	0.95	***	47	−4.85	2.95	0.96	***	0.001 (NS)	0.335 (NS)
Apr	27	−5.35	3.11	0.97	***	30	−4.92	2.97	0.94	***	0.276 (NS)	3.232 (NS)
May	30	0.46	1.54	0.60	**	29	−2.28	2.26	0.76	***	1.343 (NS)	9.818*
Jun	24	−3.97	2.79	0.91	***	40	−5.74	3.20	0.74	***	46.882***	0.632 (NS)
Jul	25	−4.39	2.87	0.91	***	40	−3.13	2.54	0.84	***	0.681 (NS)	0.245 (NS)
Total period	315	−6.64	3.48	0.99	***	353	−6.25	3.35	0.99	***	11.446***	0.432 (NS)

Dependent variable, ln WW (g); independent variable, ln SL (mm). Cochrans C has not been significant for each test. *n*, sample size; *a*, intercept; *b*, slope in the allometric equation; ln (weight) = ln $a + b$ ln (length); *r*, correlation coefficient; NS, non-significant difference. SL, standard length; WW, wet weight; AL, *A. naccarii* × *A. baerii*; LA, *A. baerii* × *A. naccarii*.

*Analysis significant at $P<0.05$.

**Analysis significant at $P<0.01$.

***Analysis significant at $P<0.001$.

†Between-species comparison using ANCOVA with covariate.

Biometric relationships

The results of regression analysis for SL and WW are reported in Table 2. For both hybrids, the regression coefficient values (*b*) showed a high monthly variation. For the AL group, the allometric coefficient ranged from 1.54 to 3.11 (May and April respectively), and for the LA group from 2.26 to 3.26 (May and January respectively). Considering the entire trial period, the slope of SL and WW regression was 3.48 and 3.35 for AL and LA respectively. The test of the heterogeneity of slopes (Table 2) revealed significant differences between the two hybrids in January ($P<0.01$) and June ($P<0.001$) and in the total regression ($P<0.001$). As for SGR_W and FCR, the slope also showed more constant values for the LA hybrid than for AL.

No correlation was observed between water temperature and the regression coefficients of the length–weight relationships (data not reported).

Discussion

The first experience of sturgeon culture carried out in the Southern Mediterranean region presented in this study produced results indicating good zootechnical performance of these fishes even at these latitudes. Nevertheless, at study site latitudes, environmental variability, particularly the temperature, seems to play a role in the growth.

Indeed, although in the study area, from May to July, the water temperature fell in the range (19.5–26.4 °C) indicated by several authors as optimal for sturgeon welfare and growth (Milsztejn 1972; Steffens 1986; Steffens *et al.* 1990; Kolman, Falkowski & Sidorowicz 1994; Filipiak, Sadowski & Trzebiatowski 1997; Filipiak, Sadowski, Trzebiatowski & Plust 1998), the growth of both hybrids was influenced by the low temperatures measured from December to April.

By contrast, the dissolved oxygen seemed not to influence the fish growth. Indeed, dissolved oxygen values were likely above the critical value suggested by Williot *et al.* (1988) for active metabolism (5.3–6.7 mg L^{-1}) in Siberian sturgeon (*A. baerii*) at water temperatures of between 10 °C and 25 °C. Milsztejn (1972) also observed that acipenserids rapidly gained biomass in water where the oxygen content was between 6 and 8 mg L^{-1}.

The environmental variability clearly mirrored on growth performance of the two hybrids, as shown by the variability of the SGR_W and FCR values. Moreover, for both fish groups there was a positive correlation between temperature and SGR_W when the temperature did not exceed 25 °C, suggesting that both hybrids show better growth performance with increasing temperature, until the temperature is below 25 °C.

From April to July, the AL group grew faster than the LA group. For both hybrids, SGR_W reached the lowest value and FCR the highest in July, when the temperature exceeded 25 °C. Such a phenomenon was more evident in the AL hybrid.

The growth rate and body size relationship of fish is generally described by an allometric function, where slope (*b*) is usually considered to be a weight exponent, assuming negative values, so that SGR_W decreases with fish size (Elliot 1975; Brett & Groves 1979; Jobling 1983, 1994). In our case, SGR_W increased from December 2000 to June 2001, suggesting that this factor was more strongly affected by water temperature than fish size.

For 0^+ and 1^+ acipenserids, reared in different conditions (e.g. in tank, cage or pond), various authors reported FCR values of between 1.13 and 2.98 (Giovannini, Colombo Bronzi & Arlati 1991; Filipiak *et al.* 1997; Filipiak *et al.* 1998; Abramenko 1999; Filipiak, Czerniejewski, Sadowski & Trzebiatowski 1999; Jahnichen, Kohlmann & Rennert 1999) and SGR_W values of between 0.40% and 3.03% (Ronyai & Péteri 1990; Giovannini *et al.* 1991; Filipiak *et al.* 1997, 1998, 1999; Prokes, Barus, Penaz, Jirasek & Mares 1997; Jahnichen *et al.* 1999). FCR and SGR_W for both hybrids assumed, throughout the study period, values that fell within these ranges highlighting a positive trend of growth performance.

The CF was similar in both hybrids remaining throughout the study period below 1. Such a trend fits with data reported by other authors for 0^+ sturgeons (Hung & Lutes 1987; Hung, Lutes, Shqueir & Conte 1993; Hung, Storebakken, Cui, Tian & Einen 1997), and the values found in this study fall well within the range of 0.40–0.90 recognized by Doroshov (1985) as typical for not mature juvenile sturgeon with fast growth in length.

In the current literature, there is a lack of data on biometric relationships for post-larval stages of acipenserids. In our experiment, monthly regression analysis generally showed a remarkable correlation between SL and WW. Accordingly, most slopes (*b* values) were around 3, suggested by Gould (1966) as an indicator value for isometric growth. The regression analysis between WW and SL calculated for the entire period showed a positive allometry (slopes > 3; Gould 1966) for both hybrids, indicating that cultivated fishes grew in weight at a greater rate than that required to maintain constant body proportions (Ricker 1979). The ANCOVA analysis (as slope heterogeneity test) showed that slopes significantly differed between the two hybrids in only 2 months (January and June), although a significant difference was also found by comparing slopes for the entire rearing period (December 2000–July 2001). In addition, although the AL hybrid grew in weight more than the LA, the regression coefficient (*b*) of the WW–SL relationship was statistically better (i.e. nearest 3) for the LA hybrid than the AL.

SGR_W and FCR values and length–weight regression coefficients assumed more homogenous values for the LA hybrid than for the AL. These data suggest that LA hybrid probably would have a better capacity to adapt to high environmental variability conditions (especially as regards temperature of waters) measured in the study site.

Acknowledgments

The authors are particularly indebted to the staff of the Gioia Farm (Sicily, Italy) for their collaboration during the culture trial. Thanks are also due to Dr A. Galioto for help with the installation of rearing structures and for his indispensable collaboration during sampling, and to Dr E. Favaloro (University of Palermo) for providing helpful suggestions on an earlier draft of the paper. This work is part of the doctoral thesis of A. M. V. and was supported by a grant from the *Ministero per l'Istruzione, l'Università e la Ricerca* (MIUR, Italy) (Progetto Giovani Ricercatori, Anno 2000, Dr Vaccaro) and *Ministero per le Politiche Agricole e Forestali* (MIPAF, Italy).

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