Asian Fisheries Science **12**(1999):91-103
Asian Fisheries Society, Manila, Philippines

https://doi.org/10.33997/j.afs.1999.12.1.010

A Comparative Analysis of Growth Performance in Aquaculture of Tilapia Hybrids and Their Parent Species

J. MOREAU[1] and D. PAULY[2]

[1]*Tropical Fisheries Research unit*
E.N.S.A.T. I.N.P. Toulouse
P.O.Box 107 Auzeville Tolosane
31 326 CASTANET TOLOSAN FRANCE

[2]*Fisheries Center*
University of British Columbia
VANCOUVER BC Canada.

Abstract

Growth parameters of hybrid tilapias (Cichlids) involving *Oreochromis niloticus*, *O. mossambicus*, *O.Hornorum*, and *O. aureus* as parent species were compiled from existing literature and their growth performances were compared with that of the parent species.

Evidence of positive heterosis for growth in the F1 hybrids of these four species emerged. This trend was even clearer when parent species and hybrids were grown under the same culture system.

Introduction

There are several reasons why Tilapia hybrids have been produced in the past, some of which are the following:

1) To obtain an all male progenies which eliminates reproduction in culture ponds (Chen and Prowse 1964, Pullin 1988). This leads to better growing individual because male Tilapines grow better than females (Pullin and Mac Connell 1982, Trewavas 1983).

2) To combine the genetic properties of parent species. An example is the fast growth of *O. niloticus* and the cold tolerance of *O. aureus* in Israel (see Lee 1979 and contributions in Pullin 1988 and Pullin et al 1988).

These advantages may be more important to the aquaculture industry than to growth performance alone and one should not expect that the hybrids reported in the literature necessarily grow better than their parent species. A few experiments only reported in the literature explicitly compare the growth of parent species with those of the hybrids such as: Avault and Shell (1968), Hickling (1959), Pruginin (1968), Chotiyarnwong (1971), Dunseth (1977), Alvarenga and Green (1986), McAndrew and Majumdar (1989).

Therefore, a compilation of growth parameters of Tilapia hybrids in aquaculture will be presented in this paper in the manner of Moreau et al (1986) and Pauly et al (1988). An attempt will be made to compare indices of growth performance of hybrids and their parent species and to interpret the resulting patterns.

Materials and Methods

All data used here are taken from published contributions (Tables 1 and 2). Growth was modelled using the von Bertalanffy Growth Function which has for length the form:

$$Lt = L_{\infty} (1 - \exp(-K(t-to))) \quad (1)$$

where Lt is the length at age t

$L\infty$ is the asymptotic length i.e. the mean length the fish would reach if they were to grow indefinitely according to the model

K is a growth parameter with dimension 1/time and which expresses the rate at which Loo is approached and

to is the abcsisse of the intersection of the curve with the time axis (the theoretical «age» for which Lt = 0) according to the model.

Table 1. Growth parameters and growth performance indices of 75 «stocks» of tilapia hybrids in aquaculture.

Hybrid Location (% male)	W_{∞} (live weight, g)	L_{∞} (cm)	K ($year^{-1}$)	Ø'	Reference
O. aureus x O. niloticus Taiwan (54)	304.1	19.8	7.127	3.45	Sing and Ting 1977
O. mossambicus x O., hornorum Auburn USA (100)	164.0	16.7	6.247	3.24	Suffren et al. (1978)
	83.3	13.3	10.153	3.26	Suffren et al. (1978)
	107.0	14.3	4.726	2.98	Suffren et al. (1978)
	63.0	11.9	7.910	3.05	Suffren et al. (1978)
O. mossambicus x O. hornorum Tennessee USA (100)	258.1	19.5	18.930	3.86	Marshall and De Angelis (1981)
	2417.6	39.2	1.670	3.42	Marshall and De Angelis (1981)
	308.3	20.6	5.044	3.33	Marshall and De Angelis (1981)
	819.9	28.6	1.077	2.95	Marshall and De Angelis (1981)
O. mossambicus x O. hornorum Malaysia (100)	944.0	30.0	2.592	3.37	Chen and Prowse (1964)
	567.7	25.3	2.074	3.12	Chen and Prowse (1964)
	212.2	18.2	5.151	3.23	Chen and Prowse (1964)
	311.9	20.7	3.402	3.16	Chen and Prowse (1964)
	199.9	17.9	4.314	3.14	Chen and Prowse (1964)

continued

Table 1. continued

Hybrid Location (% male)	W_∞ (live weight, g)	L_∞ (cm)	K (year^{-1})	Ø'	Reference
O. mossambicus x	220.7	18.3	5.170	3.24	Sin and Chiu (1983)
O. niloticus	433.7	22.9	1.864	2.99	Sin and Chiu (1983)
Hong Kong (15)	462.0	23.2	2.847	3.19	Sin and Chiu (1983)
	1153.0	31.5	2.019	3.30	Sin and Chiu (1983)
O. mossambicus x *O.aureus* Taiwan (90)	358.6	20.9	6.957	3.48	Sing and Ting (1977)
O. mossambicus x *O. niloticus*	1868.8	36.9	1.585	3.34	Costa-Pierce et al (1989)
Indonesia (50)	3403.6	45.6	1.199	3.40	Costa-Pierce et al (1989)
	2510.8	41.1	1.434	3.39	Costa-Pierce et al (1989)
O. mossambicus x *O. niloticus* Thailand (70)	76.6	12.7	5.811	2.98	Chotiyarnwong (1971)
O. mossambicus x *O. niloticus* Taiwan (15)	156.0	16.3	4.803	3.11	Kuo (pers. comm.)
O. niloticus x O; aureus	2123.0	37.6	1.701	3.38	Rothbard et al (1988)
Gan Shmuel, Israel (100)	1560.0	33.9	1.693	3.29	Rothbard et al (1988)
	342.0	20.4	3.210	3.13	Rothbard et al (1988)
	1235.0	31.4	1.610	3.20	Rothbard et al (1988)
	383.0	21.2	3.117	3.15	Rothbard et al (1988)
	272.0	18.9	3.962	3.15	Rothbard et al (1988)
	224.0	17.8	4.547	3.16	Rothbard et al (1988)
	1232.1	31.9	1.018	3.02	Aquaservice (1984)
	323.0	20.1	3.853	3.19	Rothbard et al (1988)
	323.0	20.1	4.993	3.30	Rothbard et al (1988)
	627.9	25.5	1.075	2.84	Aquaservice (1984)
O. niloticus x O.aureus	502.0	23.2	4.014	3.34	Hulata et al (1988)
Dor and Nir David	1026.0	29.5	2.161	3.27	Hulata et al (1988)
Israel (100)	3945.0	46.2	1.243	3.42	Hulata et al (1988)
	9780.0	62.5	0.596	3.36	Hulata et al (1988)
	2210.0	38.4	1.062	3.19	Hulata et al (1988)
O. niloticus x O.aureus	1324.2	32.6	1.095	3.07	Pruginin et al (1988)
Arava, Israel (100)	280.0	19.5	2.345	2.95	Pruginin et al (1988)
O. niloticus x O.aureus	243.9	18.6	9.298	3.50	Barash and Schroeder (1984)
Bet Dagan, Israel (100)	206.9	17.4	9.182	3.45	Barash and Schroeder (1984)
	1416.8	33.1	1.844	3.31	Barash and Schroeder (1984)
	436.1	22.4	4.547	3.36	Barash and Schroeder (1984)
O. niloticus x O.aureus	1579.9	34.9	1.014	3.08	Kuo and Tian (1984)
Taiwan (100)	457.3	23.1	2.177	3.06	Kuo and Tian (1984)
	874.2	28.4	0.933	2.88	Sing and Ting (1977)

continued

Table 1. continued

Hybrid Location (% male)	W_∞ (live weight, g)	L_∞ (cm)	K (year^{-1})	Ø'	Reference
O. niloticus x O.hornorum at Dor, Israel	602.0	24.6	2.850	3.24	Hulata et al (1988)
O.niloticus x O.hornorum Brazil (100)	-	27.3	1.724	3.11	Verani et al (1983)
	-	29.4	1.835	3.20	Verani et al (1983)
	-	31.1	1.447	3.15	Verani et al (1983)
	1401.1	33.4	1.081	3.08	Lovshin et al (1977)
	709.8	28.5	2.020	3.15	Lovshin et al (1977)
O. niloticus x O.hornorum Auburn, USA (100)	430.0	22.6	6.735	3.54	Collis and Smitherman (1978)
	257.8	19.1	7.181	3.42	Collis and Smitherman (1978)
O. niloticus x O. hornorum Puerto Rico (100)	265.6	19.3	8.016	3.47	Fram and Pagan-Font (1978)
	341.5	21.10	6.617	3.46	Fram and Pagan-Font (1978)
O. niloticus x O. honororum Peru (100)	308.2	20.4	3.899	3.21	Alvarenga and Green (1986)
O. niloticus x O. mossambicus Thailand (60)	54.2	11.5	8.087	3.03	Chotiyarnwong (1971)
O. niloticus x O. mossambicus Taiwan (55)	184.8	17.2	5.620	3.22	Kuo, pers. comm;
Red tilipia [O. niloticus x O. mossambicus] Thailand (100)	133.4	15.3	5.544	3.11	Jarimopas (1986)
	143.9	15.7	3.308	2.91	Jarimopas (1986)
Red tilipia [O. niloticus x O. mossambicus] Thailand (60)	34.8	9.9	8.966	2.92	Jarimopas and Kumnane (1986)
	36.1	10.0	8.353	2.91	Jarimopas and Kumnane (1986)
	33.3	9.8	6.872	2.80	Jarimopas and Kumnane (1986)
	1250.1	32.3	1.793	3.27	Jarimopas and Kumnane (1986)
	2605.2	41.3	1.158	3.29	Jarimopas and Kumnane (1986)
	644.0	25.9	1.780	3.07	Jarimopas and Kumnane (1986)
Red tilipia [O. niloticus x O. mossambicus Taiwan (90)	282.7	19.6	3.310	3.11	Liao and Chang (1983)
	613.2	25.5	2.192	3.15	Liao and Chang (1983)
	1259.9	32.4	1.293	3.13	Liao and Chang (1983)
	225.4	18.3	6.686	3.35	Liao and Chang (1983)
	235.0	18.5	4.798	3.22	Liao and Chang (1983)

Table 2. Growth parameters of various species of tilapia in aquaculture not previously documented in Pauly et al (1988).

Species	Sex	M_∞ (g)	L_∞ (cm)	K (y^{-1})	Ø'	Reference
Oreochromis aureus	*M	733.0	26.8	0.949	2.83	Hopkins et al (1988)
	*M	1775.0	36.0	0.949	3.09	Hopkins et al (1988)
	*M	488.3	23.2	2.239	3.08	Sing and Ting (1977)
	*M	447.4	22.5	3.628	3.27	Hargreaves et al (1988)
	*M	413.0	22.0	3.991	3.28	Hargreaves et al (1988)
	*M	592.5	24.8	2.860	3.24	Hargreaves et al (1988)
	*M	605.2	24.9	2.405	3.17	Hargreaves et al (1988)
	*M	211.9	17.7	2.460	2.89	Kuo and Tian (1984)
	M+F	288.6	19.7	1.826	2.85	Kuo and Tian (1985)
	M+F	658.8	25.9	1.081	2.86	Kuo and Tian (1986)
	M+F	315.3	20.2	1.723	2.84	Kuo and Tian (1987)
	M+F	6862.3	56.5	0.325	3.02	Kuo and Tian (1988)
	M+F	173.0	16.6	2.114	2.76	Kuo and Tian (1989)
Oreochromis hornorum	*M	216.7	23.1	4.101	3.34	Hickling (1959)
	*M	2305.8	40.4	0.565	2.96	Kuo and Tian (1984)
	M+F	240.0	19.0	1.936	2.85	Kuo and Tian (1985)
	M+F	539.7	24.9	1.089	2.84	Kuo and Tian (1986)
	M+F	423.2	22.9	1.764	2.97	Kuo and Tian (1987)
	M+F	1278.2	33.2	0.821	2.96	Kuo and Tian (1988)
	M+F	139.7	15.9	2.344	2.77	Kuo and Tian (1989)
Oreochromis niloticus	M+F	425.5	22.4	1.946	2.99	Kuo and Tian (1985)
	M+F	2782.8	41.8	0.637	3.05	Kuo and Tian (1988)
	M+F	274.9	19.3	2.268	2.93	Kuo and Tian (1989)
	M+F	396.7	21.9	2.718	3.11	Kuo (pers. comm.)
	*M	233.0	18.3	4.160	3.15	Boidy (1984)
	*M	212.4	17.7	3.573	3.05	Boidy (1984)
	*M	174.2	16.6	3.813	3.02	Boidy (1984)
	*M	232.9	18.3	3.508	3.07	Mair et al (1990)
	*M	402.8	21.8	3.809	3.26	Edwards et al (1990)
	*M	304.2	19.8	4.138	3.21	Edwards et al (1990)
	*M	241.1	18.3	3.418	3.06	Edwards et al (1990)
	*M	977.2	29.5	2.883	3.40	Lin (1990)
	*M	552.4	24.3	4.566	3.43	Lin (1990)
	*M	365.3	21.4	3.826	3.24	Alvarenga and Green (1986)
	*M	767.6	27.2	1.399	3.02	Kuo and Tian (1984)
Oreochromis mossambicus	*M	123.9	15.5	2.655	2.81	Pruginin and Arad (1977)
	*M	93.3	14.1	3.474	2.84	Pruginin and Arad (1977)
	*M	231.5	18.9	4.660	3.22	Guerrero and Guerrero (1990)
	*M	170.1	17.1	5.718	3.22	Guerrero and Guerrero (1990)
	*M	92.2	13.9	14.473	3.45	I.F.P.P. (1976)
	*M	94.6	14.1	15.166	3.48	I.F.P.P. (1976)
	*M	74.5	13.0	15.518	3.42	I.F.P.P. (1976)
	*M	61.6	12.2	25.580	3.58	I.F.P.P. (1976)
	*M	109.1	16.8	21.09	3.66	I.F.P.P. (1976)
	*M	64.1	12.3	16.621	3.40	I.F.P.P. (1975)
	*M	203.8	18.2	18.160	3.19	I.F.P.P. (1975)
	*M	144.1	16.2	7.787	3.31	I.F.P.P. (1975)
	*M	119.1	15.2	15.269	3.55	I.F.P.P. (1975)
	*M	82.9	13.5	17.141	3.49	I.F.P.P. (1975)
	*M	114.3	15.0	13.563	3.48	I.F.P.P. (1975)
	*M	100.4	14.3	20.029	3.61	I.F.P.P. (1975)

asterisk (*) indicates that parameters were used for Table 3.

The VBGF can also be expressed for growth in weight as:

$$Wt = W_\infty (1- \exp (-K(t-to)))^b \quad (2)$$

where W_∞ is the weight corresponding to L_∞

K and to are as in (1)
and b is the exponent (generally near or equal to 3) of the length-weight relationship of the form

$$W = a L^b \quad (3)$$

The growth parameters (K, L_∞ and/or W_∞) were all estimated from size-at-age data in the literature cited. All estimates refer to aquaculture growth experiments lasting at least three months and conducted with fish stocked at weight usually not less than 10 g. Most estimates were obtained using the ETAL computer program (Gaschütz et al 1980) which allows consideration of seasonal growth oscillation when these were manifested in the data.

In cases where the growth curve in weight did not exhibit the typical S shape of a VBGF for weight growth (resulting in irrealistic values of W_∞ when fitted to the data) an alternative to the VBGF was used to describe growth i.e. logistic curve of the form

$$Wt = W_\infty / (1 + \exp(-G(t-ti))) \quad (4)$$

where G is a constant of dimension 1/time
ti is the age of fish for which Wti = $W_\infty/2$ (Moreau 1987).

This equation was fitted to data using the Microsimplex routine of Schnute (1983). Equation (4) implies that growth rate dW/dt is maximum when Wti = $W_\infty/2$ i.e. at ti. Maximum growth rate can thus be computed from

$$(dw/dt)_{max} = W_\infty * G/4 \quad (5)$$

In the VBGF, on the other hand (see Pauly 1979 in Moreau et al 1986), maximum growth rate is defined by

$$(dw/dt) = (4/9) * K * W_\infty \quad (6)$$

Hence, if W_∞ and G have been estimated using equation (4), dw/dt max can be estimated using equation (5) equated to equation (6) and the latter solved for K;

All weights are in g live weight, all lengths are standard lengths in cm and all values of K are in year-1.

Comparisons of growth performance were done following Moreau et al (1986) and Pauly et al (1988) on the basis of the index

$$0' = \log K + 2 * \log L_{\infty} \quad (7)$$

as defined by Pauly and Munro (1984). The values of Ø' thus obtained were then plotted in two graphs comparing the growth of hybrids and their parent species. These comparisons all refer to all male hybrids except in the case of *O. mossambicus* * *O. niloticus* where both sexes are involved.

The arithmetic mean and its standard error have been computed for the index 0' for those Tilapia hybrids in which three or more data sets are available. Similar information is provided for the four most important parental species: *O. aureus, O.niloticus, O. mossambicus* and *O. hornorum.*

Results

A compilation of the growth parameters and Ø' values are shown in Tables 1 and 2 while mean Ø' values and associated statistics of well documented hybrids and parent species are presented in Table 3. A summary of comparisons between hybrids and parent species for all cases in Tables 1 and 2, i.e. mainly cases in which hybrids and parent species have been grown in various systems is presented in Figure 1. In three groups of hybrids out of four, the growth performance of hybrids was, on an average, intermediate to that of the parent species. Only one case, (*O. mossambicus* * *O. niloticus*),

Table 3. Growth performance index and relative statistics for some tilapia hybrids and their parental species (n=number of studies : i;e; Sets of K and L_{∞} values.

Hybrid[a] or species; Location (% males)	n	Ø' min	Ø' mean	Ø' max	s.e	c.v
O. mossambicus x O. hornorum[b] *(100)*	13	2.95	3.24	3.86	0.06	7.0
O.mossambicus x O.niloticus[b] *(33)*	9	2.98	3.22	3.39	0.05	4.7
O.niloticus x O.aureus[b] *(100)*	25	2.84	3.2	3.5	0.03	5.3
O.niloticus x O.hornorum[b] *(100)*	11	3.08	3.28	3.54	0.05	4.8
Red tilapia *O.niloticus x O.mossambicus* Thailand (80)	8	2.8	3.04	3.29	0.06	5.5
O. niloticus						
(50) [c]	43	2.64	3.17	3.59	0.03	6.5
(100) [c,d]	27	2.95	3.3	3.72	0.04	6.4
O. mossambicus						
(50) [c]	17	2.63	3.14	3.5	0.06	7.3
(100) [c,d]	16	2.81	3.36	3.61	0.06	7.2
O.aureus						
(50) [c]	16	2.83	3.11	3.33	0.04	4.7
(100) [c,d]	11	2.83	3.18	3.42	0.05	5.7
O. hornorum						
(50) [c]	5	2.77	2.88	2.97	0.03	2.6
(100) [c,d]	2	2.96	3.15	3.34	0.13	6.0

[a]maternal x paternal species
[b]from Table 1
[c]from Pauly et al (1988)
[d]from Table 2

Table 4. Growth performance index of tilapia hybrids and parent species cultivated under the same culture system.

Location: hybrids[a] or parent sp. (% males)	n	Ø' min	Ø' mean	Ø' max
Taiwan *O. niloticus*[b] *(50)*	4	2.93	3.02	3.11
O. aureus[b] *(50)*	5	2.76	2.87	3.02
O. hornorum[b] *(50)*	55	2.77	2.88	2.97
O. hornorum x O. aureus[c] *(67)*	1	-	3.01	-
O. aureus x O. niloticus[c] *(54)*	1	-	3.45	-
O. niloticus (100)[b]	1	-	3.02	-
O. aureus (100)[b]	1	-	2.89	-
O. niloticus x O. aureus (100)[c]	2	3.06	3.07	3.08
Thailand				
O. niloticus[d] *(50)*	2	2.92	2.96	3.00
O. mossambicus [d] *(50)*	2	2.92	2.95	2.97
O. niloticus x O. mossambicus [c] *(65)*	2	2.98	3.01	3.03

[a]maternal x paternal species
[b]from Table 2
[c]from Table 1
[d]Pauly et al. (1988), based on Chotiyarnwong (1971)

suggested that the tilapia hybrids may have a better growth performance than the parent species. However, productions systems in which people grow hybrids may have been more sophisticated than the production systems in which the parent species were raised. In order to account for this treatment effect we have extracted from Tables 1 and 2 the growth parameters for hybrids and parent species raised in the same culture system; this led to Table 4 and Figure 2. All groups of hybrids for which appropriate data are available have growth performance indices higher than their parent species.

Although the scantiness of the data at hand does not warrant strong statements, this result suggests evidence of positive heterosis for growth in F1 hybrids.

Discussion and Conclusion

Direct comparisons of growth performance between hybrids and parental species in ponds showed better growth of the hybrids even if it was not regarded as a «significant difference». For instance, Smitherman et al (1984, quoted by McAndrew and Majundar 1989) stated that hybrids *O.niloticus* * *O. hornorum* did not grow better than the all male *O. niloticus* whereas *O. niloticus* * *O. aureus* exhibited better growth. Lovshin et al (1977) showed that all males *O. niloticus* * *O. Hornorum* grew 18% higher than male *O. niloticus*. A similar result was obtained by Dunseth (1977) in a different culture system.

The present paper provides similar information in a culture system basis but does not allow more general statements. This might come from the limits of the suitability of the index of growth performance 0' for the present purposes. It might have been intended to be used in conditions which are beyond its potential sensitivity for growth performance analysis. We have elaborated

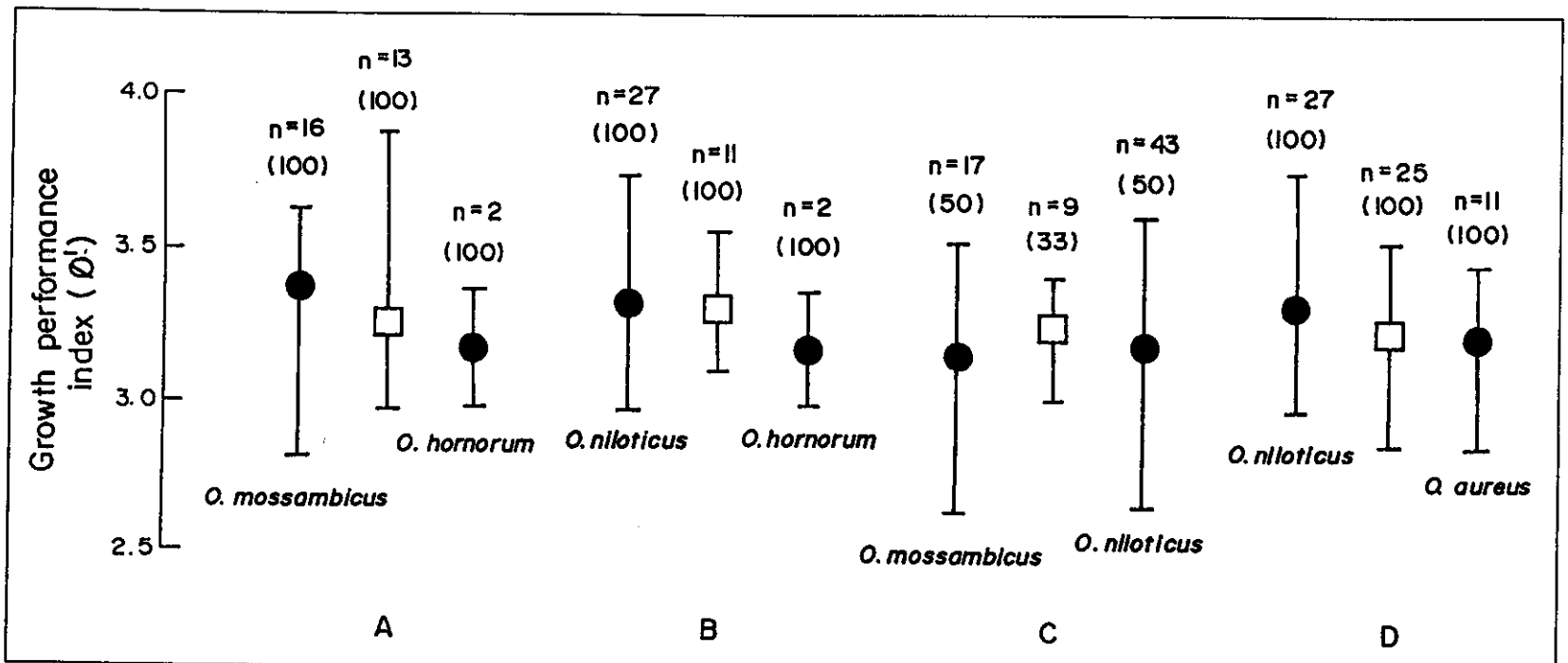

Figure 1: Mean growth performance index and range of Tilapia hybrids (open squares) and their parent species (left: maternal species, right: paternal species). Hybrid data from table 1; data on parent species from Pauly et al (1988) and table 2; n refers to the number of cases (i.e. sets of L_∞ and K values) and value in brackets to mean percentage of males. Note that 0' values stem from various culture systems.

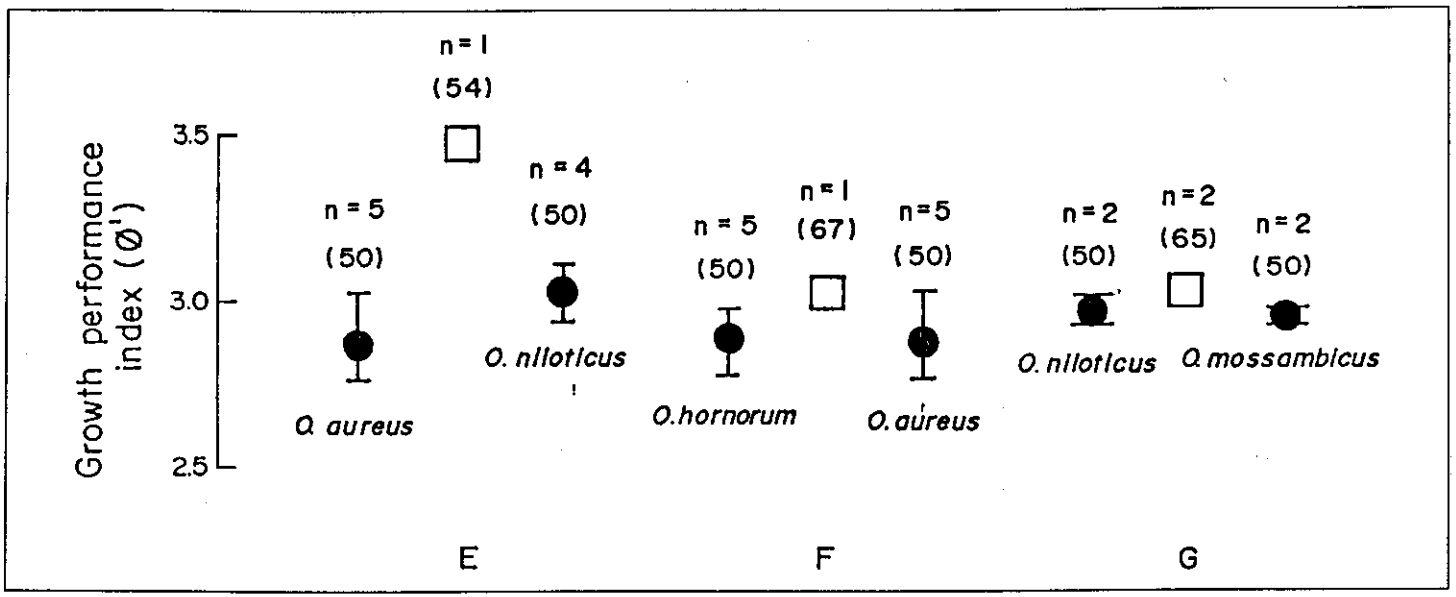

Figure 2: Mean growth performance index and range of Tilapia hybrids (open squares) and their parent species (left:maternal species; right: paternal species), kept in the same culture system (data from table 4).

E: Kuo and Tian (1985, 1986, 1987, 1988, 1989)
F: Kuo and Tian (1985, 1986, 1987, 1988, 1989)
G: Chotiyarnwong (1971)
H: Kuo and Tian (1984)

another approach to characterize Tilapia populations based on the concept of «growth space» (Pauly et al 1996) which will be used for future contributions.

Tilapia hybrids have sometimes been produced not only for growth performance but also to obtain or maintain certain phenotype features not appearing in mother species e.g. the "red coloration" of "red tilapia" not occurring in any of the parent species (Galman 1987). This paper does not cover red tilapias whose genetic status is unknown. In addition, there are now non-hybrid red tilapias. The growth performance and systematic status of these fishes should be compared to one of the other main cultivated Tilapine fish, including non-red hybrids which were considered here, using also the concept of growth space (Pauly et al 1996) already mentioned.

Acknowledgments

The authors wish to thank Mr. Victor Sambilay Jr. for his help in compiling the tables included in this contribution and the two anonymous referees for their helpful comments on the preliminary draft of this paper.

References

Alvarenga H. and B. Green. 1986. Production y crecimiento de *Tilapia nilotica* machos y el hybrido de *Tilapia nilotica* x *Tilapia hornorum* en estanques. Rev. Lat. Aqui. Lima. Peru. 29 (9) : 32-27

Aquaservice. 1984. Programme d'essai d'élevage de tilapias sur rejets d'eau chaude de centrales électriques. Aquaservice, S.A. Centre Commercial, Château Vert 34200 Sète, France. 32p. (mimeo)

Avault J.W. and E.W. Shell 1968: Preliminary studies with the hybrid of tilapia *Tilapia nilotica* * *Tilapia mossambica*. F.A.O. Fish. Rep. 44 (4): 237-242.

Barash H.; and G.L. Schroeder. 1984. Use of fermented cow manure as a feed substrate for fish polyculture in stagnant water ponds. Aquaculture 36 : 127-140.

Boidy K. 1984. Essais d'alimentation de *Tilapia nilotica* avec la farine de banane. National Polytechnique Institute, Toulouse, France, 86p (M.Sc Thesis)

Chen F. Y. and G.A. Prowse. 1964. The effect of living space on the growth rate of fishes. Ichtyologica 3 : 11-20

Cheong L., F.K. Chan, F.J. Wong and R. Chou. 1987. Observations on the culture of red *tilapia* (O. *niloticus* hybrids) in sea water. Sing. J. Pri. Ind. 15 (1) : 42-56

Chotiyarnwong A., 1971. Studies on *Tilapia nilotica*, T. *mossambica* and their hybrids. Dept. of Biology, Kasetsart University, Bangkok, Thailand, 27p. (M.Sc Thesis)

Collis W.J. and R. Smitherman. 1978. Production of tilapia hybrids with cattle manure or a commercial diet. p 43-54. In AFS Symposium Proceedings on Culture of Exotic Fishes. American Fisheries Society, Atlanta, Georgia.

Costa-Pierce B.A., H.Y. Hadikusumah and A. Dhahiyat. 1989. Tilapia (*Oreochromis* sp.) and carp (*Cyprinus carpio*) productions in cage systems in West Java, Indonesia, p 84-96. In E.A. Huisman, N. Zonneveld and A.H.M. Bouwmans (eds). Aquacultural research in Asia : management techniques and nutrition. Pudoc, Wageningen, The Netherlands.

Dunseth D.R. 1977: Polyculture of Channel Catfish, *Ictalurus punctatus*, Silver Carp, *Hypophthalmichthys molitrix*, and three male tilapias, *Sarotherodon spp*, PhD Dissertation, Auburn University, Auburn Alabama, 59 p

Edwards P., C. Parachaprakiti and M. Yomjinda. 1990. Direct and indirect reuse of septage for culture of Nile tilapia (*Oreochromis niloticus*), p 165-168. In R.R. Hirano and I. Hanyo (eds). The Second Asian Fisheries Society Forum. Asian Fisheries Society, Manila, Philippines, 991 p.

Fram M. and F.A. Pagan-Font. 1978. On the cultivation of male hybrids S. *niloticus* xS. *hornorum* in Puerto Rico, p55-64. *In* AFS Symposium Proceeding on Culture of Exotic Fishes. American Fisheries Society, Atlanta, Georgia.

Galman O.R. 1987. Le Tilapia rouge des Philippines (*Oreochromis*, Pisces, *Cichlidae*), caractères morphologiques, génétiques et biologiques. Conséquences pour l'aquaculture. Institut National Polytechnique, Toulouse, France. 142 p. (Ph. D. Thesis).

Gaschütz G., D. Pauly and N. David. 1980. A versatile BASIC program for fitting weight and seasonally oscillating length growth data. ICES. C.M. 1980/D : 6, Statistics. 14p

Guerrero III, R.D. and L.A. Guerrero. 1990. The Mozambique tilapia as an aquaculture genetic ressource in the Philippines. Paper presented at the Asian Regional Workshop on Tilapia Genetics, 29-31 August 1990, Central Luzon State University, Muñoz, Nueva Ecija, Philippines.

Hargreaves J.A., J.E. Rokocy and A. Nair. 1988. An evaluation of fixed and demand feeding regimes for cage culture of *Oreochromis aureus*, p 335-339. In R.S.V. Pullin, T. Bhukaswan, K. Tonguthai and J.L. Maclean (eds). The Second International Symposium on Tilapia in Auqaculture. ICLARM Conf. Proc. 15, 623p.

Hickling C.F. 1959. Some marking experiments with tilapia fish. Malayan Agric. J. 42 : 21-30.

Hopkins K.D., M.L. Hopkins and D. Pauly. 1988. A multivariate model of tilapia growth, applied to seawater tilapia culture in Kuwait; p 29-39. In R.V.S. Pullin, T. Bhukaswan, K. Tonguthai and J.L. Maclean (eds). The Second International Symposium on Tilapia in Auqaculture. ICLARM Conf. Proc. 15, 623 p.

Hulata G., G.W. Wohlfarth and A. Halevy. 1988. Comparative growth tests of *Oreochromis niloticus* x O. *aureus* hybrids from different farms in Israel, in polyculture, p 191-195. In R.S.V. Pullin T. Bhukaswan, K. Tonguthai and J.L. Maclean (eds). The Second International Symposium on Tilapia in Aquaculture. ICLARM Conf. Proc. 15, 623 p.

IFPP. 1975. Inland Fisheries Project Philippines. Technical Report 7 : 84p.

IFPP. 1976. Inland Fisheries Project Philippines. Technical Report 8 : 67p.

Jarimopas P. 1986. Realized response of Thai red tilapia to weight specific relation for growth. In IDRC genetics in Thailand. IDRC/NIFI Technical Reports Bangkok, Thailand, 56p.

Jarimopas P. and A. Kumnane. 1986. Production of red tilapia (O. *niloticus/mossambicus*) culture in cage with different stocking densities. IDRC/NIFI Technical Paper Nangkok, Thailand. 52p.

Kuo H. and T.T. Tian. 1984. Studies on the genetic improvement of red tilapia cross breeding and its growth. Bull. Taiwan Fish. Res. Inst. 35 (2) : 69-92.

Kuo H. and T.T.Tian. 1985. Studies on the genetic improvement of red tilapia cross breeding and its growth. Bull. Taiwan Fish. Res. Inst. 39 (1) : 1-14.

Kuo H. and T.T. Tian. 1986. Studies on the genetic improvement of red tilapia cross breeding and its growth. Bull. Taiwan Fish. Res. Inst. 42 : 243-257.

Kuo H. and T.T.Tian. 1987. Studies on the genetic improvement of red tilapia cross breeding and its growth. Bull. Taiwan Fish. Res. Inst. 42 : 259-272.

Kuo H. and T.T. Tian. 1988. Studies on the genetic improvement of red tilapia cross breeding and its growth. Bull. Taiwan Fish. Res. Inst. 44 : 151-165.

Kuo H. and T.T. Tian. 1989. Studies on the genetic improvement of red tilapia cross breeding and its growth. Bull. Taiwan Fish. Res. Inst. 46 : 171-184.

Lee J.C. 1979: Reproduction and hybridization of three cichlid fishes, *Tilapia aurea* (S.), *T. hornorum* (T.) and *T. nilotica* (L.) in aquaria and in plastic pools. phD Dissertation, Auburn University, Auburn, Alabama U.S.A. 84 p.

Liao C. and S.L. Chang. 1983. Studies on the feasability of red tilapia culture in saline water. p 524-533. Proceedings of the First International Symposium on Tilapia in Aquaculture, Nazareth, Israel.

Lin C.W. 1990. Integrate culture of walking catfish (*Clarias macrocephalus*) and tilapia (*Oreochromis niloticus*) p209-212. In Hirano R. and I. Hanyo (eds). The Second Asian Fisheries Society Forum. Asian Fisheries Society, Manila, 991p.

Lovshin L.L., A.B. Da Silva and J.A. Fernandez. 1977. El cultivo intensivo del hybrido macho de *Tilapia hornorum* (macho) *T. nilotica* (nembora) en el nordeste de Brazil. FAO Fish. Rep. 159 : 162-179

Mair G.C., M.M. Tayamen, J.A. Beardmore and D.O.F. Skibinski. 1990. Developing technologies for control of reproduction in cultured tilapia, *O. niloticus* (L). Paper presented at the Asian Regional Workshop on Tilapia Genetics. 29-31 August 1990. Central Luzon State University, Muñoz, Nueva Ecija, Philippines.

Marshall Adams S. and D.L. De Angelis. 1981. Factors affecting growth efficiency and body composition of tilapia in sewage oxidation ponds. US Department of Energy. Environmental Sciences Division Publ. 1520 (Mimeo).

McAndrew B.J. and K.C Majumdar 1989: Growth studies on juvenile tilapia using pure species hormone-treated and nine interspecific hybrids. Aquacult. Fish. Management. 20: 35-47.

Moreau J. 1987. Mathematical and biological expression of growth in fish : recent trends and further developments, pp 81-113. In R.C. Summerfelt and G.E. Hall (eds). Age and growth in fishes. Iowa State University Press, Ames, Iowa. U.S.A.

Moreau J., C. Bambino and D. Pauly. 1986. Comparison of four indices of overall fish growth performance : reference to 100 stocks of tilapias, p. 200-206. In J. Maclean and L. Dizon (eds). Proc. First Asian Fisheries Forum. ICLARM Conf. Proc. 14, 420p.

Pauly D., J. Moreau and F. Gayanilo Jr 1996: A new method of comparison of growth performance of fish, Application to wild and cultured tilapias. p 477-485 in R.S.V. Pullin, J. lazard, M. Legendre, J.B. Amon-Kothias and D. Pauly, The 3rd International Symposium on Tilapia in Aquaculture ICLARM Conf. Proc. 41 630 p.

Pauly D., J. Moreau and M. Prein. 1988. A comparison of overall growth performance of tilapia in open waters and aquaculture, p. 469-479. In R.S.V. Pullin, T. Bhukaswan, K. Tonguthai and J.L. Maclean (eds). The Second International Symposium on Tilapia in Aquaculture. ICLARM Conf. Proc. 15, 623 p.

Pauly D. and J.L. Munro. 1984. Once more on growth comparisons in fish and invertebrates. Fishbyte 2 (1) : 21.

Pruginin Y. 1968: The culture of carp and Tilapia hybrids in Uganda. F.A.O. Fish Rep. 44 A(4): 223-229.

Pruginin Y. and A. Arad. 1977. Fish farming in Malawi. A report prepared for the Promotion of the Integrated Fisheries Development Project. FAO Restricted Diffusion Paper 71/516/10 MLW, 22p.

Pruginin Y., Fishelson and A. Koren. 1988. Intensive tilapia farming in brackish water from an Israel desert Aquifer, p 75-81. In R.S.V. Pullin, T. Bukhaswan, T. Tonguthai and J.L. Maclean (eds). The Second International Symposium on Tilapia in Aquaculture. ICLARM Conf. Proc. 15, 623 p.

Pullin R.V.S. (ed) 1988. Tilapia genetic resources for aquaculture. ICLARM Conf. Proc. 16, 108 p.

Pullin R.S.V.P., T. Bhukaswan, K. Tonguthai and J.L. Maclean (eds). 1988. The Second International Symposium on Tilapia in Auqaculture. ICLARM Conf. Proc. 15, 623 p.

Rothbard S., Z. Yaron and B. Moav. 1988. Field experiments on growth enhancement of Tilapia (*Oreochromis niloticus* x *O. aureus* F_1) hybrids using pellets containing an androgen (17a-ethynyltestosterone), p 367-375. In R.S.V. Pullin, T. Bhukaswan, K. Tonguthai and J.L. Maclean (eds). The Second International Symposium on Tilapia in Aquaculture. ICLARM Conf. Proc. 15, 623 p.

Schnute J. 1983. A manuel for easy linear parameter estimation in fisheries research with interactive computer program. Can. Tech. Rep. Fish. Aquatic Sc. 1140.

Sin A.W.C. and M.T.I. Chiu. 1983. The intensive monoculture of the tilapia hybrid, *Sarotherodon nilotica* (male) x S. *mossambica* (female) in Hong Kong, p 506-516. In Proceedings of the First International Symposium on Tilapia in Aquaculture Nazareth, Israel.

Sing Hwa Hu and Ting Chi Yu. 1977. Hybridization and culture of *Sarotherodon aureus*. Bull. Taiwan Fish. Res. Inst. 29 (10) : 208-220.

Smitherman R.S. 1984.

Suffren J.S., S.M. Adams and B.G. Blaylock. 1978. Growth of monosex hybrids tilapia in the laboratory and sewage oxidation ponds, p 65-81. In AFS Symposium on culture of exotic fishes. American Fisheries Society, Atlanta, Georgia.

Trewavas E. 1983: Tilapiine fishes of the genera Sarotherodon, Oreochromis and Danakilia. Publ. Brit. Museum Nat. Hist. Londres 583 p.

Verani J.R., C.S.R.M. Pinto, P. de Paiva and Y.A. Tabata. 1983. Expérimental studies on intensive fish culture of the all male hybrids of *Sarotherodon niloticus* (female) x *Sarotherodon hornorum* (male) stocked at various levels, p 517-528. In L. Fishelson and Z. Yaron (eds). Proceedings of the First International Symposium on Tilapia in Aquaculture. Nazareth, Israel.

Manuscript recieved 15 December 1997; Accepted 06 June 1998.