

## A Comparison of Overall Growth Performance of Tilapia in Open Waters and Aquaculture\*

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### Abstract

There are several indices for fish growth potential and growth performance comparisons available in the literature. One such index, found to allow meaningful comparisons for tilapia in the open waters of Africa and Asia, is:  $\phi' = \log_{10}K + 2\log_{10}L_{\infty}$ , where K and  $L_{\infty}$  are parameters of the von Bertalanffy growth equation. Overall, we found that tilapia in culture have higher values of  $\phi'$  than in nature. The difference is highest in *Oreochromis aureus*, whose growth potential now appears to be fully realized. On the other hand, aquaculture systems based on *O. niloticus* appear to have hitherto failed to fully exploit the growth potential of this species. A discussion of the implications of our findings with regard to selecting suitable species and strains for aquaculture completes the paper.

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## Introduction

Tilapia growth, both in nature and in aquaculture, can be described by the von Bertalanffy growth function (VBGF), i.e.:

$$L_t = L_\infty (1 - \exp(-K(t-t_0))) \quad \dots 1)$$

or

$$W_t = W_\infty (1 - \exp(-K(t-t_0)))^3 \quad \dots 2)$$

where  $L_t$  (or  $W_t$ ) is the size at age  $t$ ,  $L_\infty$  (or  $W_\infty$ ) is the average size the fish of a given stock would reach if they were allowed to grow indefinitely,  $K$  is a growth constant (with dimension  $1/t$ , i.e. not  $l/t$  or  $w/t$ , as implied by growth rates) and  $t_0$  is the theoretical (usually negative) age of the fish at length zero (this parameter is of no relevance here and is not further discussed).

The present contribution is a followup to Moreau et al. (1986) in which 100 sets of growth parameters from natural populations of tilapia in Africa and Asia were used to identify the most useful of four different growth indices.

These most useful indices were:

$$\phi' = \log_{10} K + 2 \log_{10} L_\infty \quad \dots 3)$$

and

$$P = \log_{10} K + \log_{10} W_\infty \quad \dots 4)$$

The algebraic relationships between  $P$  and  $\phi'$  are given by Moreau et al. (1986, Table 3) as:

$$P = \phi' + (1/3) \log_{10} W_\infty + (2/3) \log_{10} a \quad \dots 5)$$

and

$$\phi' = P - (1/3) \log_{10} W_\infty + (2/3) \log_{10} a \quad \dots 6)$$

with "a" defined by an isometric length-weight relationship of the form

$$W = a \cdot L^3 \quad \dots 7)$$

In this contribution, these indices are used to compare the growth performance of tilapias belonging to various species, and of fish raised under culture conditions, with conspecifics that grew under natural conditions.

## Materials and Methods

Table 1 summarizes the 150 sets of growth parameters, growth performance indices and related information assembled for the purposes of the present study.

The growth parameters were all estimated from size-at-age data in the literature cited in Table 1. All estimates refer to aquaculture growth experiments lasting at least three months and conducted with fishes stocked at weights usually not less than 10 g. Most estimates were obtained using the ETAL I computer program (Gaschütz et al. 1980), which allowed consideration of seasonal growth oscillations when these were manifest in the data.

In some cases, an alternative to the VBGF was used for describing growth, i.e., a logistic curve of the form:

$$W_t = W_\infty / (1 + \exp(-G(t-t_i))) \quad \dots 8)$$

where  $W_t$  is the weight as age  $t$ ,

$G$  a growth constant

and  $t_i$  the age of the fish at which  $W_i = W_\infty/2$  (Moreau 1987).

This equation was fitted to data using the Microsimplex routine of Schnute (1983). Equation (8) implies that growth rate ( $dw/dt$ ) is maximum when  $W = W_\infty/2$ , i.e., at  $t_i$ . Maximum growth rate can thus be computed from:

$$(dw/dt)_{\max} = W_\infty G/4 \quad \dots 9)$$

In the VBGF, on the other hand, maximum growth rate is defined by:

$$(dw/dt)_{\max} = (4/9) \cdot K \cdot W_\infty \quad \dots 10)$$

Table 1. Growth parameters and growth performance indices of 150 "stocks" of tilapia grown in controlled environments (ranked, within spp. according to  $\phi'$ ).

Species	[A	B	C] <sup>a</sup>	W <sub>∞</sub>	L <sub>∞</sub>	K	P	$\phi'$	Area	Reference
<i>O. andersonii</i>	F&M	P	S	387.3	21.9	0.727	2.45	2.54	Zambia	Mortimer (1959)
	F&M	P	S	498.8	23.8	0.635	2.50	2.56	Zambia	Mortimer (1959)
	F&M	P	S	142.6	15.7	1.956	2.44	2.68	Zambia	Mortimer (1959)
	F&M	P	S	234.2	18.5	1.403	2.52	2.68	Zambia	Mortimer (1959)
	F&M	P	S	176.4	16.7	1.911	2.53	2.73	Zambia	Mortimer (1959)
	F&M	P	S	249.1	18.9	1.562	2.59	2.75	Zambia	Mortimer (1959)
	F&M	P	S	218.1	17.9	2.260	2.69	2.86	Uganda	Maar et al. (1966)
	F&M	P	S	230.5	18.4	2.474	2.76	2.92	Zambia	Mortimer (1959)
	F&M	P	V	196.1	17.4	8.204	3.20	3.40	Zambia	Lema et al. (1975)
<i>O. aureus</i>	F&M	P	V	89.4	13.0	4.038	2.56	2.83	El Salvador	Ramirios (1975)
	F&M	T	L	84.0	12.7	4.667	2.59	2.88	USA	Stickney et al. (1977)
	F&M	T	L	101.0	13.8	4.672	2.69	2.95	USA	Stickney et al. (1977)
	F&M	P	V	131.2	16.3	3.504	2.66	2.97	Costa Rica	Porras (1986)
	F&M	P	V	207.1	15.2	4.124	2.93	2.98	Costa Rica	Porras (1986)
	F&M	P	V	168.1	16.0	4.804	2.91	3.09	El Salvador	Ramirios (1975)
	F&M	P	V	147.1	15.3	5.239	2.80	3.10	El Salvador	Bowman (1975)
	F&M	P	L	384.2	21.3	2.761	3.03	3.10	USA	Henderson and Stickney (1981)
	F&M	P	V	269.4	18.7	4.016	3.03	3.15	El Salvador	Bowman (1975)
	F&M	P	V	108.4	13.8	7.478	2.91	3.16	El Salvador	Ramirios (1975)
	F	C	V	163.8	15.9	5.970	2.99	3.18	Belgium	Melard and Philippart (1981a)
	F&M	P	L	72.0	12.1	11.164	2.91	3.21	USA	Henderson and Stickney (1981)
	F&M	P	V	54.6	14.2	8.285	2.65	3.22	Costa Rica	Porras (1986)
	F&M	P	V	217.6	17.4	5.508	3.08	3.22	El Salvador	Bowman (1975)
	F&M	P	L	79.0	12.4	11.270	2.95	3.24	USA	Henderson and Stickney (1981)
	F&M	P	L	95.0	13.2	11.859	3.05	3.32	USA	Henderson and Stickney (1981)
	F&M	P	V	95.2	13.2	12.146	3.06	3.33	El Salvador	Bowman (1975)
	M	C	V	354.8	20.5	5.350	3.28	3.35	Belgium	Melard and Philippart (1981a)
	(M)	P	V	652.2	25.1	3.590	3.37	3.36	USA	Anderson and Smitherman (1978)
	M	P	V	496.4	23.0	5.027	3.40	3.42	USA	Anderson and Smitherman (1978)
<i>O. esculentus</i>	F&M	P	V	75.4	12.9	7.957	2.78	3.12	Tanzania	Payne (1971)
<i>O. macrochir</i>	F&M	P	S	2,250.9	39.3	0.235	2.72	2.56	Zambia	Mortimer (1959)
	F&M	P	S	104.2	14.0	2.603	2.43	2.70	Zambia	Mortimer (1959)
	F&M	P	S	3,669.9	46.3	0.274	3.00	2.77	Zambia	Mortimer (1959)
	F&M	P	V	104.8	14.0	3.113	2.51	2.79	Uganda	Maar et al. (1966)
	F&M	P	S	141.4	15.1	2.906	2.61	2.82	Zambia	Mortimer (1959)
	F&M	P	L	404.0	22.0	3.060	3.09	3.17	Cameroon	Bard (1960)
<i>O. mossambicus</i>	F&M	P	V	103.7	14.6	19.901	3.31	2.63	Philippines	Camacho et al. (1984)
	F&M	T	V	68.2	12.7	4.271	2.46	2.83	Zambia	Mabaye (1971)
	F&M	T	V	42.3	10.7	7.194	2.47	2.92	Thailand	Chotiyarnwong (1971)
	F&M	T	V	39.5	10.6	8.359	2.52	2.97	Thailand	Chotiyarnwong (1971)
	F&M	T	L	121.0	15.4	4.402	2.73	3.02	Zambia	Mabaye (1971)
	F&M	P	V	74.1	13.1	6.305	2.67	3.03	USA	Henderson and Stickney (1981)
	F&M	P	V	101.5	14.5	5.547	2.75	3.07	USA	Henderson and Stickney (1981)
	F&M	T	L	203.0	18.3	3.830	2.89	3.11	Zambia	Mabaye (1971)
	F&M	P	V	70.0	12.8	7.803	2.73	3.11	El Salvador	Bowman (1975)
	F&M	P	V	79.4	12.6	8.564	2.83	3.13	Philippines	O. Galman (pers. comm.)
	F&M	P	L	101.0	14.5	6.531	2.82	3.14	USA	Henderson and Stickney (1981)

Continued

Table 1. Continued

Species	[A	B	C] <sup>a</sup>	W <sub>∞</sub>	L <sub>∞</sub>	K	P	φ <sup>b</sup>	Area	Reference
	F&M	P	V	101.1	14.5	9.506	2.98	3.30	El Salvador	Bowman (1975)
	F&M	P	V	96.9	14.3	10.130	2.99	3.32	El Salvador	Bowman (1975)
	F&M	P	V	92.6	14.1	10.735	3.00	3.33	El Salvador	Bowman (1975)
	F&M	P	V	101.3	14.5	13.215	3.13	3.45	Philippines	Camacho et al. (1984)
	F&M	P	V	101.5	14.5	13.809	3.15	3.46	Philippines	Camacho et al. (1984)
	F&M	P	V	84.1	13.6	16.978	3.15	3.50	Philippines	Camacho et al. (1984)
<i>O. niloticus</i>	F&M	P	V	442.9	22.3	0.880	2.59	2.64	Burkina Faso	Traore (1985)
	F&M	P	V	123.7	14.6	2.385	2.47	2.70	Burkina Faso	Traore (1985)
	F&M	T	L	66.0	11.8	4.150	2.44	2.76	Thailand	Edwards et al. (1980)
	F	T	L	151.0	15.6	3.003	2.66	2.86	Centr.Afr.Rep.	Micha (1973)
	F&M	T	L	47.0	10.7	7.263	2.53	2.92	Thailand	Wee and Nag (1986)
	F&M	T	L	60.0	11.4	6.423	2.59	2.92	Thailand	Chotiyarnwong (1971)
	F&M	T	L	102.0	13.7	4.750	2.68	2.95	Thailand	Edwards et al. (1985)
	M	T	V	206.0	17.3	2.997	2.79	2.95	Centr.Afr.Rep.	Micha (1973)
	F&M	P	V	86.5	12.9	5.476	2.67	2.96	Thailand	Edwards et al. (1984)
	F&M	T	V	695.5	25.9	1.447	3.00	2.99	Centr.Afr.Rep.	Micha (1973)
	F	T	V	616.8	24.9	1.572	2.79	2.99	Centr.Afr.Rep.	Micha (1973)
	F&M	P	V	417.2	21.5	2.265	2.99	2.99	Belgium	Melard and Philippart (1981a)
	F&M	T	L	75.0	12.3	6.534	2.69	3.00	Thailand	Chotiyarnwong (1971)
	F&M	P	V	270.0	18.9	2.950	2.90	3.02	Sierra Leone	Iscandiri (1985)
	F&M	C	V	611.2	23.9	1.881	3.06	3.03	Côte d'Ivoire	Coche (1977)
	F&M	P	L	77.0	12.4	7.155	2.74	3.04	Philippines	Guerrero (1976)
	F&M	C	V	92.3	13.2	6.544	2.78	3.06	Philippines	Aquino and Nielsen (1983)
	F	P	V	2,848.4	40.8	0.716	3.31	3.08	Belgium	Melard and Philippart (1981a)
	F&M	P	V	129.3	14.9	5.685	2.87	3.09	Philippines	Cruz and Shehadeh (1980)
	F&M	T	L	89.0	13.3	7.093	2.80	3.10	Thailand	Wee and Nag (1986)
	M	P	V	144.2	15.3	5.342	2.89	3.10	Puerto Rico	Fram and Pagan-Font (1978)
	F&M	T	L	95.0	13.3	7.628	2.86	3.13	Thailand	Edwards et al. (1985)
	M	P	V	516.1	23.1	2.540	3.12	3.13	Belgium	Melard and Philippart (1981b)
	F&M	T	V	68.7	12.0	9.871	2.83	3.15	Thailand	Edwards et al. (1980)
	F&M	T	V	269.7	18.6	4.221	3.06	3.16	Belgium	Melard and Philippart (1981a)
	F&M	C	V	450.2	22.4	2.915	3.12	3.16	Philippines	Aquino and Nielsen (1983)
	F&M	P	V	114.6	14.2	7.291	2.92	3.17	USA	Anderson and Smitherman (1978)
	F	T	V	455.4	22.5	2.984	3.13	3.18	Belgium	Melard and Philippart (1981a)
	F&M	T	V	55.1	11.1	13.000	2.85	3.20	Thailand	Edwards et al. (1980)
	F&M	P	V	317.4	23.8	3.854	3.08	3.19	Philippines	Prein (1985)
	F&M	P	V	198.3	20.6	5.409	3.03	3.20	Philippines	Prein (1985)
	M	T	L	137.0	15.1	7.305	3.00	3.22	Centr.Afr.Rep.	Micha (1973)
	F&M	P	L	99.0	13.5	9.220	2.96	3.23	Philippines	Cruz and Shehadeh (1980)
	F	P	V	286.6	19.0	4.789	3.14	3.24	Belgium	Melard and Philippart (1981a)
	F&M	C	V	315.0	19.3	4.737	3.17	3.24	Côte d'Ivoire	Coche (1977)
	F&M	T	L	131.0	15.8	7.109	2.97	3.25	Thailand	Edwards et al. (1985)
	F&M	T	V	155.2	15.7	7.157	3.06	3.25	Thailand	Edwards et al. (1980)
	F&M	P	L	104.0	13.7	9.712	3.00	3.26	Thailand	Edwards et al. (1984)
	F&M	C	V	146.1	15.4	7.843	3.06	3.27	Philippines	Aquino and Nielsen (1983)
	M	T	V	1,073.3	29.9	2.076	3.35	3.27	Belgium	Melard and Philippart (1981b)
	F&M	T	L	245.0	18.3	5.881	3.16	3.29	Thailand	Edwards et al. (1980)
	F&M	P	L	82.0	12.7	12.348	3.00	3.30	Philippines	Cruz and Shehadeh (1980)
	M	P	V	513.0	23.4	3.690	3.28	3.31	Côte d'Ivoire	J. Lazard (pers. comm.)
	F&M	T	V	44.3	10.3	19.644	2.94	3.32	Thailand	Edwards et al. (1980)
	M	P	V	462.9	22.2	4.271	3.30	3.33	Belgium	Melard and Philippart (1981a)

Continued

Table 1. Continued

Species	[A	B	C] <sup>a</sup>	W <sub>∞</sub>	L <sub>∞</sub>	K	P	φ'	Area	Reference
	F&M	P	L	157.0	15.8	8.889	3.14	3.34	Thailand	Edwards et al. (1984)
	F&M	P	V	195.2	16.9	7.651	3.17	3.34	Thailand	Edwards et al. (1984)
	(M)	P	V	477.5	22.8	4.179	3.30	3.34	USA	Anderson and Smitherman (1978)
	F&M	C	V	85.3	12.9	13.933	3.07	3.36	Philippines	Aquino and Nielsen (1983)
	F&M	P	L	143.0	15.3	10.377	3.17	3.38	Philippines	Cruz and Shehadeh (1980)
	M	P	V	277.6	19.1	6.604	3.26	3.38	Côte d'Ivoire	J. Lazard (pers. comm.)
	F&M	P	V	444.0	21.9	4.329	3.28	3.38	Cameroon	Bard (1960)
	F&M	P	L	174.0	16.3	9.352	3.21	3.40	Philippines	Cruz and Shehadeh (1980)
	F&M	P	L	152.0	15.6	10.742	3.21	3.42	Philippines	Cruz and Shehadeh (1980)
	M	P	V	357.9	20.8	6.580	3.37	3.45	USA	Anderson and Smitherman (1978)
	M	T	V	509.2	23.3	5.419	3.44	3.47	Belgium	Melard and Philippart (1981a)
	F&M	P	V	183.3	16.6	10.942	3.30	3.48	Thailand	Edwards et al. (1984)
	F&M	P	L	210.0	17.4	10.631	3.35	3.51	Philippines	Cruz and Shehadeh (1980)
	M	T	V	205.6	17.3	12.654	3.41	3.58	Belgium	Melard and Philippart (1981a)
	M	T	V	270.3	18.9	10.665	3.46	3.58	Belgium	Melard and Philippart (1981a)
	F&M	P	L	539.0	23.6	6.879	3.56	3.59	Philippines	Cruz and Shehadeh (1980)
	M	P	V	474.2	22.8	8.028	3.58	3.62	USA	Shell (1968)
	M	T	V	233.4	13.2	13.207	3.49	3.63	Belgium	Melard and Philippart (1981a)
	M	P	V	456.7	22.5	10.458	3.68	3.72	USA	Shell (1968)
<i>O. shiranus</i>	F&M	T	V	53.3	11.0	9.870	2.72	3.08	Malaŵi	Msiska and Cantrell (1985)
<i>O. spirulus niger</i>	F	A	S	217.8	18.5	0.956	2.32	2.51	Uganda	Cridland (1965)
	M	A	S	166.0	16.9	1.240	2.31	2.55	Uganda	Cridland (1965)
	F&M	P	S	381.5	22.3	1.640	2.80	2.91	Kenya	Van Someren and Whitehead (1960)
	F&M	P	S	394.7	22.6	1.950	2.89	3.00	Kenya	Van Someren and Whitehead (1960)
<i>O. variabilis</i>	F&M	P	L	635.0	25.3	1.148	2.87	2.87	Kenya	Rinne (1975)
<i>S. guineensis</i>	F	C	V	200.0	17.4	1.224	2.89	2.56	Côte d'Ivoire	Cissé (1985)
	F	P	L	181.0	16.8	1.386	2.40	2.59	Côte d'Ivoire	Legendre (1983)
	F&M	P	V	221.9	18.0	1.314	2.47	2.61	Côte d'Ivoire	Legendre (1983)
	F&M	P	V	359.5	21.1	0.958	2.51	2.63	Côte d'Ivoire	Legendre (1983)
	M	P	L	174.0	16.6	1.756	2.48	2.69	Côte d'Ivoire	Legendre (1983)
	F	C	V	161.2	16.2	1.933	2.49	2.70	Côte d'Ivoire	Cissé (1985)
	M	C	V	227.4	18.2	2.151	2.69	2.85	Côte d'Ivoire	Cissé (1985)
	F&M	P	L	54.0	11.0	8.390	2.65	3.01	Côte d'Ivoire	Legendre (1983)
	M	C	V	240.6	18.5	3.004	2.86	3.01	Côte d'Ivoire	Cissé (1985)
<i>S. melanotheron</i>	M	P	V	367.1	21.3	0.298	2.04	2.11	Côte d'Ivoire	Legendre (1983)
	F	P	V	143.1	15.5	1.727	2.39	2.60	Côte d'Ivoire	Legendre (1983)
	F	P	V	200.5	17.4	1.373	2.44	2.60	Côte d'Ivoire	Legendre (1983)
	F	P	L	146.0	15.7	1.649	2.38	2.61	Côte d'Ivoire	Cissé (1985)
	M	P	L	338.0	20.7	1.244	2.62	2.73	Côte d'Ivoire	Legendre (1983)
	M	P	V	115.2	14.6	2.546	2.47	2.74	Côte d'Ivoire	Cissé (1985)
	F	P	V	173.2	16.7	2.188	2.58	2.79	Côte d'Ivoire	Cissé (1985)
	M	P	L	131.0	15.2	2.929	2.58	2.83	Côte d'Ivoire	Cissé (1985)
	F	P	V	329.7	20.7	1.678	2.74	2.86	Côte d'Ivoire	Cissé (1985)
	F&M	P	L	73.0	12.2	7.250	2.72	3.04	Côte d'Ivoire	Legendre (1983)

Continued

Table 1. Continued

Species	[A	B	C] <sup>a</sup>	W <sub>∞</sub>	L <sub>∞</sub>	K	P	φ'	Area	Reference
<i>T. rendalli</i>	F&M	P	S	1,594.8	33.9	0.189	2.48	2.34	Zambia	Mortimer (1959)
	F&M	P	S	418.6	21.7	0.615	2.41	2.46	Zambia	Mortimer (1959)
	F&M	P	S	107.5	13.8	3.19	2.53	2.78	Zambia	Mortimer (1959)
	F&M	P	V	91.6	13.1	3.785	2.54	2.81	Uganda	Maar et al. (1966)
<i>T. zillii</i>	F&M	P	V	9,899.0	61.8	0.143	3.15	2.76	USA	Hauser (1975)
	F&M	P	V	141.1	15.0	3.434	2.69	2.89	Tanzania	Payne (1971)
	F&M	P	V	978.9	28.6	1.190	3.06	2.99	Uganda	Cridland (1962)

<sup>a</sup> A = sex (F or M); F & M refers to females + males; (M) refers to sex-reversed all-male broods.

B = culture type (P, C, T, A; P = ponds; C = cages; T = tanks; A = aquaria)

C = method of curve-fitting (V, S, L; V = ordinary VBGF fitting methods; S = seasonally oscillating VBGF fitted with ETAL-1)

L = Logistic growth curve fitted with microsimplex (Schnute 1983).

Hence, if  $W_{\infty}$  and  $G$  have been estimated using equation (8),  $(dw/dt)_{\max}$  can be estimated using equation (9), equated to equation (10) and the latter solved for  $K$ .

Growth parameters obtained via equations (8) to (10) are indicated as such in Table 1.

All weights are in g live weight, all lengths are standard lengths, in cm, and all values of  $K$  are in year<sup>-1</sup>. The arithmetic mean and its standard error have been computed for the indices  $P$  and  $\phi'$  in those tilapia species in which three or more data sets were available from both aquaculture systems and natural waters (Table 2).

The details of these computations, including the size-at-age data used and a listing of the ETAL I program are available on request from any of the authors.

## Results and Discussion

Both Table 2 and Fig. 1 show that tilapia generally display, under culture conditions, a higher growth performance, as defined by the  $\phi'$  index, than in nature.

Overall,  $P$ -values (referring to growth rate -  $dw/dt$  - at the inflexion point of the VBGF) of tilapia in aquaculture are equal to 2.951 while the mean  $P$  value of tilapia in nature is 2.681 (weighted means). Thus  $\Delta P = 0.270$ , corresponding (see equation 4)

to a multiplicative increase of  $10^P = 1.86$ . Put differently, one may say cultured tilapia grow about 86% better than in nature (note that this percentage can be as high as 300 when, e.g., male monosex culture of a certain species is considered, see Table 1 and Fig 2). Fig. 1 shows, however, that  $\Delta\phi'$  (roughly equivalent to  $\Delta P$ ) is very uneven among different tilapia species (at least with respect to the data sets compared here). Thus, in *T. rendalli*,  $\Delta\phi'$  is only 0.149, while  $\Delta\phi'$  reaches as much as 0.658 in *O. aureus*, the species in which the difference between aquaculture and natural growth performance appears to be highest. We attribute the high "realized domestication bonus" of *O. aureus* to the fact that this species is generally cultured under intensive or at least semi-intensive conditions (see Table 1); see for example the discussion on cage culture performance in the review by Coche (1982) in which *O. aureus* was ranked above *O. niloticus*.

This last point brings us to *O. niloticus* which, although it has the highest growth performance of any tilapia both in nature (Moreau et al. 1986) and in aquaculture (see Fig. 1), displays here a high degree of overlap between growth performance in nature and in aquaculture, with a  $\Delta\phi' = 0.558$ , less than *O. aureus* and even *O. mossambicus* (Table 2). We conclude from this that, as a whole, aquaculture systems based on *O. niloticus* have hitherto failed to fully exploit the

Table 2. Comparison of mean growth performance indices and related statistics of 7 species of tilapia grown in controlled environments (Table 1) with the corresponding statistics in conspecific wild stocks (data from Table 1 of Moreau et al. 1986).

Species	Stock <sup>a</sup>	n	$a_{(SL)}$ <sup>b</sup>	S.E.M.	Mean P	S.E.M.	Mean $\phi'$	Min	Max	S.E.M.
<i>T. rendalli</i>	A	4	0.409	0.01	2.49	0.05	2.60	2.34	2.81	0.12
<i>T. rendalli</i>	N	16	0.410	0.08	2.55	< 0.01	2.45	2.24	2.80	0.03
<i>O. andersonii</i>	A	9	0.372	0.02	2.63	0.04	2.79	2.54	3.40	0.09
<i>O. andersonii</i>	N	4	0.365	0.33	2.68	0.13	2.56	2.46	2.63	0.07
<i>O. macrochir</i>	A	6	0.382	0.06	2.73	< 0.01	2.80	2.56	3.17	0.08
<i>O. macrochir</i>	N	8	0.401	0.05	2.41	0.07	2.41	2.31	2.50	0.02
<i>T. zillii</i>	A	3	0.419	< 0.01	2.97	0.07	2.88	2.76	2.99	0.07
<i>T. zillii</i>	N	8	0.385	0.14	2.30	0.16	2.39	2.09	2.68	0.08
<i>O. niloticus</i>	A	65	0.407	0.10	3.05	0.02	3.21	2.64	3.72	0.03
<i>O. niloticus</i>	N	16	0.395	0.15	2.80	0.07	2.65	2.36	3.11	0.06
<i>O. mossambicus</i>	A	17	0.337	0.04	2.86	0.05	3.14	2.63	3.50	0.06
<i>O. mossambicus</i>	N	20	0.421	0.12	2.57	0.02	2.48	2.05	2.80	0.04
<i>O. aureus</i>	A	20	0.401	0.16	2.95	< 0.01	3.15	2.83	3.42	0.04
<i>O. aureus</i>	N	4	0.363	0.23	2.36	0.05	2.50	2.31	2.61	0.07

<sup>a</sup>A = Aquaculture; N = Natural stocks.

<sup>b</sup> $a_{(SL)}$  refers to multiplicative term of length-weight relationship (equation 7) based on standard length (SL).

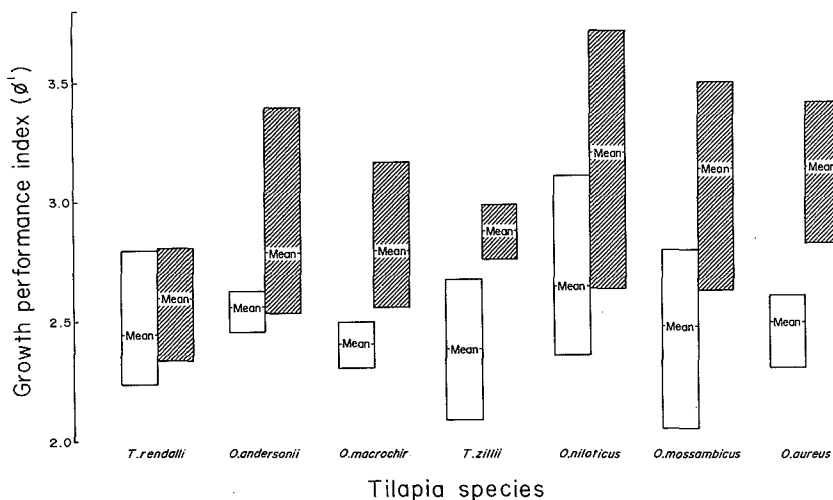


Fig. 1. Mean and range of the growth performance index  $\phi'$  in 7 tilapia species for which at least three sets of growth parameters were available for both wild stocks (clear) and controlled environments (shaded). The 7 species are ranked according to their mean response to being cultured (i.e., according to the difference between their values of  $\phi'_A$  and  $\phi'_N$ , see Table 2).

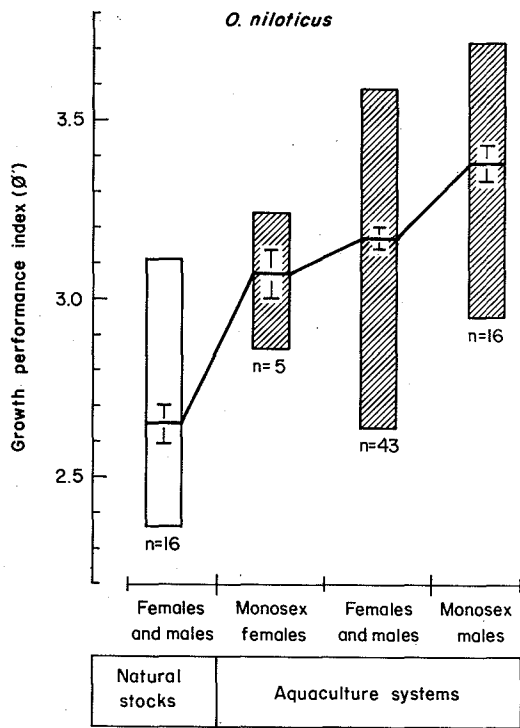


Fig. 2. Mean, standard error and range of the growth performance index  $\phi'$  in various *O. niloticus* stocks (based on data in Tables 1 and 2).

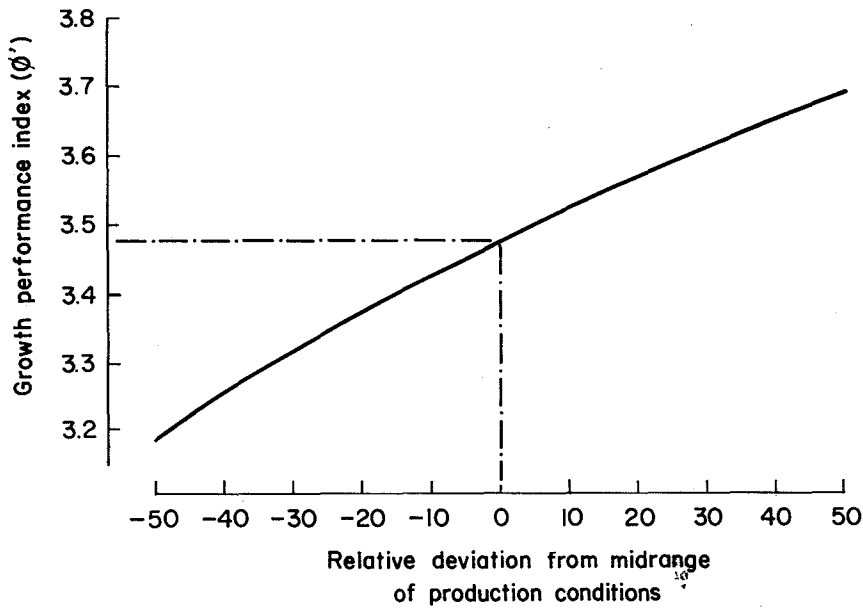


Fig. 3. Response of the growth performance index  $\phi'$  to relative changes in pond condition in an integrated animal/fish system, Central Luzon State University, Philippines. Relative changes of pond condition refer to the aggregated effects of changes of 5 variables shown to affect *O. niloticus* growth (computed from data in Prein 1985).



growth potential of this species. This is also suggested by Fig. 3, based on data in Hopkins and Cruz (1982) and a multiple regression model in Prein (1985) which shows the response of *O. niloticus* growth performance to improvement of pond conditions, as well as by Fig. 2 showing the dramatic growth increases obtained in (male) monosex systems.

Future increases in growth performance will also come from the selection of improved strains and the identification of suitable hybrids - an area in which the growth performance indices used here may be useful. This is fully discussed by Pullin and Capili (this vol.).

Intuitively, the index P appears more useful than  $\phi'$  given that it has the dimension  $(\log_{10})$  w/t while  $\phi'$  has the awkward dimension  $(\log_{10})$  L<sup>2</sup>/t. However weight is, in fish, far more variable than length, as illustrated by the fact that fish may often lose weight but hardly ever "lose length". Therefore, the possibility of biases will tend to be greater in a weight-based index. Possibly, the best approach would be to rely, for future comparative studies of the type reported here, on both indices, and to devote attention to the species and/or strains whose growth performance is high in terms of both indices.

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