Using the Growth Performance Index ϕ' to Choose Species Aquaculture: An Example from Kuwait

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Introduction: The Advantages of ϕ' as a Growth Performance Index

Pauly (1987a) drew attention to the importance of studying growth performance of fish where inadequate infrastructure in the fishery sector and the lack of species-specific investigations exclude the highly informed type of choice which is possible in developed countries. Pauly et al. (1988) applied the growth index ϕ' (where $\phi' = \log_{10}K + 2\log_{10}L_\infty$, and L_∞ and K are parameters of the von Bertalanffy growth equation)* to 150 pond-cultured "stocks" of tilapia. They showed that the growth performance of most species they studied could be higher in culture tanks than in wild populations, although for one species *(Oreochromis niloticus)* this was not so clear. This species showed the highest growth performance index in wild populations but cultured populations failed to realize fully its growth potential. Moreau et al. (1986) found that ϕ' values have a normally distributed frequency distribution with a smaller standard deviation than other growth performance indices, some of which have skewed distributions. They also noted that ϕ' has the dimensions of length and time, whereas other indices include weight. This gives ϕ' the biological advantage of being based on length. Fish often lose weight but rarely lose length, so that ϕ' may be less liable to biases. The above-mentioned studies combine to show that ϕ' is the most flexible and precise estimator of growth performance so far presented.

Successful use of estimates of ϕ' from wild populations as an index of growth performance in aquaculture requires that such estimates should not be biased, e.g., through sampling methods or because of seasonal or annual variations in the size and age composition of the stocks being studied.

Marine Finfish Culture in Kuwait: How Species Were Chosen and How ϕ' Could Have Helped

In Kuwait, *Epinephelus suilis* and *Acanthopagrus cuvieri* have been cultured from spawning to market size. This resulted from an ambitious and successful program established in 1967. These species were chosen after experimenting with a variety of other candidates. Most of the results have been published in research reports with restricted circulation and in non-peer reviewed annual research reports (available from the Kuwait Institute for Scientific Research) which give few details. Full descriptions of this work await analysis of all the relevant data but sufficient data on fisheries management and biology are already available in publications on the main cultured and closely related species to permit discussion of the criteria used in choosing species for culture purposes, and in particular to determine whether use of ϕ' could have helped, had this index been available. This will shed light on the best way to make such choices in the future.

Mathews and Samuel (1987) and Samuel and Mathews (1987) provide data on the growth parameters of five species of *Epinephelus* and four species of *Acanthopagrus* from Kuwait (all data not specifically sourced here are available from these authors). Table 1 shows that estimates of all available growth parameters for *E. suilis* (usually referred to as *E. tauvina* in the Kuwaiti literature) and *A. latus* over five years of stock monitoring exhibit distinctly wider ranges than ϕ', which varied by about 4% compared with ranges of 10-43% for the other parameters. Values of ϕ' based on a single year's data for length at age will give reliable estimates of growth performance provided age determination is reliable (Samuel and Mathews 1985; Williams 1985; Samuel et al. 1987) and sample size is adequate. Table 1 gives examples for two species used in the Kuwait study.

Table 2 provides similar data for 10 species which may be compared in respect of their growth performance indices. For the groupers, the highest value of ϕ' is that

*Editor's note: Throughout this contribution, ϕ' assumes TL_∞ in cm and K in year^{-1}.

Table 1. Growth parameters and growth indices (ϕ') for two species of Kuwait fish, sampled in successive years.

Species	L_∞[a]	K[b]	t_{max}[c]	L_{max}	ϕ'	n
Epinephelus suilis						
1981	94.00	0.1378	19	104	3.086	378
1982	90.04	0.1614	21	111	3.117	466
1983	89.08	0.1924	22	110	3.184[e]	426
1984	99.17	0.1705	21	120	3.225	614
Mean	93.07	0.1655	-	-	3.156	-
1982[d]	101.66	0.1207	-	-	3.096	-
1983[d]	91.76	0.1709	-	-	3.158	-
1984[d]	100.92	0.1306	-	-	3.124	-
Mean[d]	98.09	0.1407	-	-	3.132	-
C.V. (%)	12	38	10	13	4	-
Acanthopagrus latus						
1981	48.73	0.200	10	42	2.677	92
1982	52.29	0.169	14	50	2.665	240
1983	41.51	0.214	9	39	2.567	170
1984	40.48	0.258	13	45	2.626	314
1985	38.30	0.298	10	40	2.641	215
Mean	44.26	0.227	-	-	2.635	-
C.V. (%)	33	43	36	22	4	-

[a] TL, in cm
[b] per year
[c] in years
[d] Using age/length keys. All other data are based on growth curves fitted to data on length at age.
[e] Two extraordinarily large fish, 127 and 130 cm TL, were measured but otoliths could not be taken.

of *E. latifasciatus*, followed by *E. jayakari*, followed closely by *E. suilis* in third place. Interestingly, L_∞ and L_{max} are both higher for *E. suilis* than for *E. latifasciatus*. *E. suilis* shows a lower value of K than any other grouper excepting the dwarf grouper *Cephalopholis miniatus*. For groupers, ϕ' therefore gives a different, as well as a more stable, estimate of growth performance than other growth parameters.

A. cuvieri shows a markedly higher value of ϕ' than any other bream studied; while *A. berda* has a slightly higher value than *A. latus*, which was cultured experimentally for several years.

Growth curves based on extrapolation from data on older fish, combined with data on a few small young fish of known age, were used to estimate which species were more likely to be useful for culture (Figs. 1a and 1b) and it was concluded that *E. latifasciatus* and *A. cuvieri* were the best choices, if growth rates during the first year or so were to be the sole criterion. This evidence was, however, difficult to obtain and was not as clear and objective as the evidence presented here using ϕ'.

Determining the suitability of fish for culture using growth parameters.

a. Using material from wild populations to age fish

(i) obtain a size-structured sample of at least 100 specimens (sexes may be mixed) and remove otoliths;
(ii) age these specimens as accurately as possible using annual marks if they occur, or otolith microstructure ("daily marks") if necessary. (This should be contracted out if no 'homegrown' capability is available);
(iii) determine values of L_∞ and K by fitting the von Bertalanffy growth formula to the data on length at age:

$$L_\infty = L_t\,(1-e^{-K(t-t_0)})$$

(iv) determine ϕ' from the equation:

$$\phi' = \log_{10}K + 2\log_{10}L_\infty$$

(v) populations showing higher values of ϕ' are more likely to be suitable for aquaculture;

b. Using length frequencies for fish from wild populations:

(i) obtain length frequency data representative of the whole population (i.e., not biased by migration, seasonality, sampling gear or other factors) for several successive months, ideally for 6 to 12 months in a single year.

(ii) estimate L_∞ and K by fitting the equation

$$L_t = L_\infty\,(1-e^{-[K(t-to)+(\frac{K}{2\pi}\sin 2\pi\,(t-ts))]})$$

to the length-frequency data (Pauly 1987b).

(iii) determine ϕ' using the procedure given in a (iv) above.

c. Using data from cultured populations:

Length frequencies may be used together with the sampling date to estimate L_∞ and K using the procedure described in b. It is necessary to hold fish for some time to obtain valid results: the technique will not work with very young or larval fish because they will not yet have shown the size-related decrease in growth which the von Bertalanffy growth curve models.

Other Considerations

The choice of fish for culture purposes can never be made on the basis of growth performance indices alone. In Kuwait, *E. suilis* was chosen partly because it is Kuwait's preferred fish species and is high-priced and partly because it is abundant in Kuwaiti waters and broodstock were therefore readily available in the early days of the aquaculture program. *E. latifasciatus* is landed frequently but is rarely caught in Kuwait and because of this was never seriously considered for culture. It is impossible to determine what might have occurred had the data made available through the later fisheries management research been available at the time *E. suilis* was chosen. There were, however, good reasons for choosing this species which would have been as valid with the new information as without it.

Both *A. cuvieri* and *A. latus* are popular and high-priced in Kuwait and are readily available in Kuwaiti waters. Nevertheless, both species were cultured for many years before *A. cuvieri* was finally chosen for large-scale culture and it is at least possible that fisheries data could have been used to assist in the choice had an objective index such as ϕ' been available at the time.

Other species have also been considered as possible candidates for culture in Ku-

Table 2. Growth parameters and growth performance indices for some species of grouper and bream in Kuwait.

Species	Parameter L_∞ (TL, cm)	K (year)	t_{max} (year)	L_{max} (cm)	ϕ'	n	No. of years sampled
Cephalopholis miniatus	34.11	0.110	26	37	2.108	36	1
Epinephelus areolatus	34.10	0.288	25	46	2.525	153	1
Epinephelus chlorostigma	64.83	0.195	41	75	2.914	98	1
Epinephelus suilis	93.07	0.165	22	120	3.132	1884	4
Epinephelus jayakari	72.65	0.273	28	75	3.159	49	1
Epinephelus latifasciatus	82.11	0.328	30	92	3.345	131	1
Acanthopagrus bifasciatus	34.89	0.189	19	36	2.362	21	1
Acanthopagrus latus	44.26	0.227	14	50	2.635	1031	5
Acanthopagrus berda	37.35	0.325	14	37	2.657	287	2
Acanthopagrus cuvieri	81.80	0.278	11	83	3.269	231	1

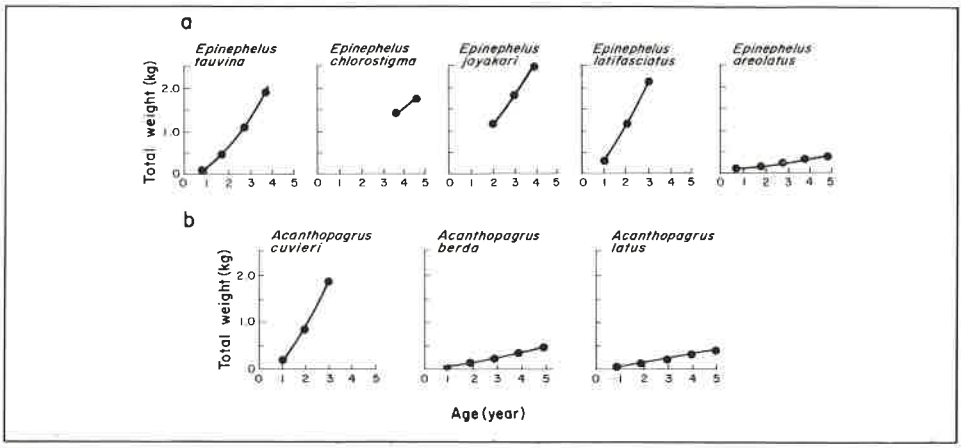

Fig. 1. Growth in weight of a. *Epinephelus* and b. *Acanthopagrus* species, in Kuwait within their first five years.

wait: grey mullets (Mugilidae), *Otolithes argenteus* and *Pomadasys argenteus*. *O. argenteus* is a fast growing croaker reaching 55 cm in 4-5 years with L_∞=69.6 and K=0.505 (Mathews and Samuel 1985) giving a value of ϕ'=3.38: higher than any Kuwaiti species for which ϕ' is available excepting *E. latifasciatus* (Table 2) and higher than the value for both *E. suilis* and *A. cuvieri*. Trials showed very fast growth in culture but this species was not chosen because it is highly cannibalistic. *P. argenteus* is a large, high-priced and very popular grunt. Growth parameters were obtained by fitting von Bertalanffy growth curves to a small number of data on length at age (Brothers and Mathews 1987), and gave the following estimates: L_∞=66.0, K=0.238, ϕ'=3.02, but this species is also cannibalistic. The crimson snapper *Lutjanus malabaricus* (often identified as *L. coccineus* in Kuwait) was shown by Mathews and Samuel (1985) to have L_∞=68.9 and K=0.358, giving ϕ'=3.26, a value comparable to or higher than the values for the species currently cultured. Although this species is popular in Kuwait it is generally consumed only by the expatriate or poorer sections of the community and therefore has a very low price; culture was never seriously considered. *Pampus argenteus* (the silver pomfret) is, after *E. suilis*, probably Kuwait's most popular species; no attempt was made to culture it because it is excessively sensitive to handling, and because its spawning grounds are unknown.

Discussion: The Relevance of the Kuwaiti Experience for Other Countries

This analysis of the Kuwaiti experience may be useful in that it provides guidelines for future choices in other countries. Kuwait's situation is typical of many warm-water countries that may need to choose new species for culture without the rich technological background on the biology of potential candidates typically available in temperate countries. Not all countries in this situation can afford to acquire this background knowledge.

The question of sample size needed to obtain an estimate of ϕ' sufficiently robust to justify a choice of species has not yet been addressed; results presented here suggest that at most a few hundred size-stratified specimens (conceivably as few as around 100 fish) may be sufficient if they can be aged reliably. In Kuwait, a sophisticated fish ageing laboratory has been established. It is not necessary to create such a capability for ϕ' to be used as a criterion in choosing species for culture: ageing may be contracted cheaply to laboratories if it is too expensive to establish a 'homegrown' capability.

The use of ϕ' as a criterion for choosing species for culture is not confined to finfish. It can readily be determined for any species showing von Bertalanffy growth. Most molluscs and crustaceans can be studied in this way and L_∞ and K may be determined by using e.g. the ELEFAN software (Pauly 1987b), provided that adequate unbiased length-frequency data are available for estimating the growth parameters.

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