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Growth of plaice larvae in captivity

by

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Ryland (1966) described a plaice-rearing experiment in which the length, wet weight and development stages of plaice larvae, fed to excess on Artemia nauplii were, after preservation, related to age between hatching and metamorphosis, in arbitrary conditions of temperature and other physicochemical variables. He divided the cumulative growth curve for wet weight into two phases (a) an initial 45-day period during which growth proceeded to a maximum at a gradually increasing rate, and (b) rectilinear growth at this maximum for the subsequent 20 days or so to metamorphosis. Growth in length followed a similar, though not identical pattern. This work has now been repeated at Port Erin, using fresh material, making no assumptions (unlike Ryland) concerning the wet weight of newly-hatched larvae based on length measurements.

TECHNIQUE

A batch of approximately 2 000 pond-spawned plaice eggs liberated on 30 March 1969 was transferred into a black polythene tank (120 cm x 60 cm x 30 cm) filled to a depth of 25 cm with sea water containing a standard dose of the antibiotics benzyl-penicillin and streptomycin sulphate. The tank remained static until hatching; thereafter it was aerated gently and irrigated with an equal volume of fresh sea water twice per week. Artemia nauplii were first added as food five days after hatching, and maintained in excess until the experiment ended. The tank was illuminated for 12 hours per day by a fluorescent source giving an intensity of 400 mc at the water surface; the temperature was controlled at 5-6°C during the 21 days of incubation, rising after hatching at a rate of 0.1°C per day for the following 73 days to the completion of metamorphosis.

Two samples of 50 eggs (early and late) were weighed wet, and then dry at constant weight after treatment in a vacuum oven at 50°C. One day after hatching and at subsequent nine or ten-day intervals, representative samples of 50 larvae, lightly narcotized with M.S.222, were staged, measured and weighed wet and vacuum-dry.

THE CUMULATIVE GROWTH CURVE

Results are summarized in Table 1; Figure 1 shows that a slight, but perceptible weight loss occurred during egg incubation, followed by a marked loss at hatching representing the weight of egg shell and perivitelline fluid. The larval wet weight continued to decline for the next 11-day (yolk-sac) period reaching a minimum approximately one third of the original egg weight. During the following 35 days of pelagic life the growth curve progressed geometrically to a maximum rate of increase ($\frac{dw}{dt}$) of 1.217 mg/day (wet), the attainment of this maximum coinciding with the onset of population metamorphosis. For the remaining 27 days of the experiment to the completion of metamorphosis growth proceeded in an uninterrupted rectilinear fashion at maximum rate. These changes in the direction and velocity of growth in weight are emphasized when weight values are plotted on a logarithmic scale (Figure 2).

The growth curve for larval length has two features in common with that for weight, i.e. a phase of slowly accelerating growth to a maximum for approximately 45 days after hatching in the conditions of this experiment followed by a rectilinear increase in length at constant velocity ($\frac{dl}{dt}$ = 0.169 mm per day) throughout the period of metamorphosis. Of particular interest is the evidence for positive growth in length during the 11-day yolk sac stage in conditions of diminishing weight.

WET WEIGHT/DRY WEIGHT RELATIONSHIP

Estimates of larval dry weight, if based on wet weight measurements must take into account a progressive change in the ratio of dry weight to total wet weight during the course of development (Figure 3). The relative water content (a buoyancy factor in the egg) diminishes in a curvilinear fashion from approximately 90 per cent total weight one day after hatching to 81 per cent at the completion of metamorphosis. This transformation can be related to major morphological changes such as the gradual disappearance of the voluminous, plasma-filled subdermal spaces, so prominent a feature in the newly-hatched larva (Shelbourne 1956), and to ecological drift from a pelagic to demersal habit.

WEIGHT/LENGTH RELATIONSHIP

The commonly-used equation for relating wet weight to length for fish is:

$$W = \frac{KL^n}{D}$$

where the exponent has a value of 3, and k, known variously as the "condition factor" (Borley 1912) or "ponderal index" (D'Arcy Thompson 1959) fluctuates about unity according to age and season. D is a divisor dependent on the units used for measuring weight and length. The above equation implies the regression of X and Y values to pass through the origin, but it will be seen from Figure 4 that this is not the case with larval plaice, where the values produce a form of association generally expressed by:

$$Y = a + bX$$

where $Y = L^3$, a is the Y-intercept; b is the regression coefficient (= pomderal index) and X = W (wet or dry). Regression A (continuous line) in Figure 4 represents the best fit to 397 paired values; length being measured in mm and weight in mg. By computation:

1. wet weight
   $L^3 = 484.08 + 93.4116\ W_3$ (Y on X)
   $W = -4.8222 + .01048\ L^3$ (X on Y)

2. dry weight (not included in Figure 4)
   $L^3 = 534.71 + 473.2201\ W_3$ (Y on X)
   $W = -1.0349 + .00205\ L^3$ (X on Y)

These estimating equations are offered as better alternatives to $W = kL^n$ for calculating the weight of plaice from length, or vice-versa, during the larval stage of development between yolk resorption and metamorphosis. The anomalous length/weight relationship during the 11-day yolk-sac phase has been omitted in the interests of accuracy. The appropriate correlation coefficients, standard errors and confidence intervals for regressions are given in Table 2.

Though the ponderal index is usually regarded as having a mean value specific to each species, it really reflects the bodily proportions of an animal. A change in form, for instance during metamorphosis, might be expected to produce a corresponding change in k (= b). In Figure 4 the discontinuous lines represent the regression of L^3 on wet weight during (B) the pelagic phase from day 11 to 45, and (C) from day 46 to complete

metamorphosis. The corresponding values for b (see Table 2) are 141.042 and 87.769; found to be significantly different to one another, at the 0.1 per cent level, by comparing the ratio of the difference between the two slopes to its standard error, against a t-variable with $n_1 + n_2 - 4$ degrees of freedom $t = \frac{b_1 - b_2}{S_B}$. It will be noticed, however, that the correlation coefficients of regressions B and C, though highly significant, have values somewhat lower than for regression A (all data). This might be explained by the relatively marked effect on larval weight variance of a standard balance error, at weights near the lower resolution limit of the instrument. Using a more sensitive micro-balance, it should be possible to establish, beyond doubt, the existence of a varying ponderal index during the larval development of the plaice, and with the aid of two or more principal estimating equations, improve further on the accuracy of weight prediction from length measurements, and vice-versa.

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Table 1 Mean lengths and weights of developing plaice larvae

Development stage*	Days from hatching	Mean length (mm)	S.D. ±	Mean wet weight (mg)	S.D. ±	Mean dry weight (mg)	S.D. ±
Eggs: early	-19	-	-	3.47	0.12	0.30	0.06
Eggs: late	- 4	-	-	3.41	0.21	0.27	0.06
Larvae:							
Stage 1	+ 1	7.24	0.26	1.71	0.22	0.19	0.03
1	+10	7.59	0.26	1.07	0.18	0.13	0.04
1-2	+19	8.18	0.41	1.47	0.37	0.22	0.06
2-3	+28	8.57	0.49	2.22	0.63	0.37	0.11
3	+37	9.40	0.67	3.66	1.11	0.62	0.20
3-4	+46	10.68	1.17	6.85	2.85	1.25	0.56
4	+54	12.54	1.55	15.4	7.74	2.83	1.54
4-5	+64	14.36	1.73	26.69	12.56	5.09	2.35
5+	+73	15.22	2.56	37.57	20.49	7.37	4.13

*According to Ryland (1966)

Table 2 Regression analyses for the length (mm)/weight (mg) relationship in plaice larvae (see Figure 4)

Regression	Development Stage*	Number of paired values	Days after hatching	Estimating equations ($Y_c = a + bX$)	Correlation coefficient (r)	Standard error of regression ($\pm S_r$)	95% confidence limits of regression ±
A	2–5+	397	11–73	(wet) $L^3 = 484.08 + 93.4116\ W_3$ (Y on X) (wet) $W = -4.82 + 0.01048\ L^3$ (X on Y)	0.989	214.44 2.27	420.30 4.45
				(dry) $L^3 = 534.70 + 473.2201\ W_3$ (Y on X) (dry) $W = -1.03 + 0.00205\ L^3$ (X on Y)	0.986	248.00 0.52	486.08 1.02
B	2–3	220	11–45	(wet) $L^3 = 315.91 + 141.0420\ W_3$ (Y on X) (wet) $W = -1.86 + 0.00650\ L^3$ (X on Y)	0.958	57.79 0.39	113.27 0.76
				(dry) $L^3 = 362.57 + 738.5031\ W_3$ (Y on X) (dry) $W = -0.40 + 0.00121\ L^3$ (X on Y)	0.947	64.48 0.08	126.38 0.16
C	4–5+	177	46–73	(wet) $L^3 = 689.12 + 87.7693\ W_3$ (Y on X) (wet) $W = -6.82 + 0.01102\ L^3$ (X on Y)	0.984	275.43 3.09	539.84 6.06
				(dry) $L^3 = 777.24 + 439.2216\ W_3$ (Y on X) (dry) $W = -1.50 + 0.00218\ L^3$ (X on Y)	0.948	316.79 0.71	620.91 1.39

*Stages of Ryland (1966)

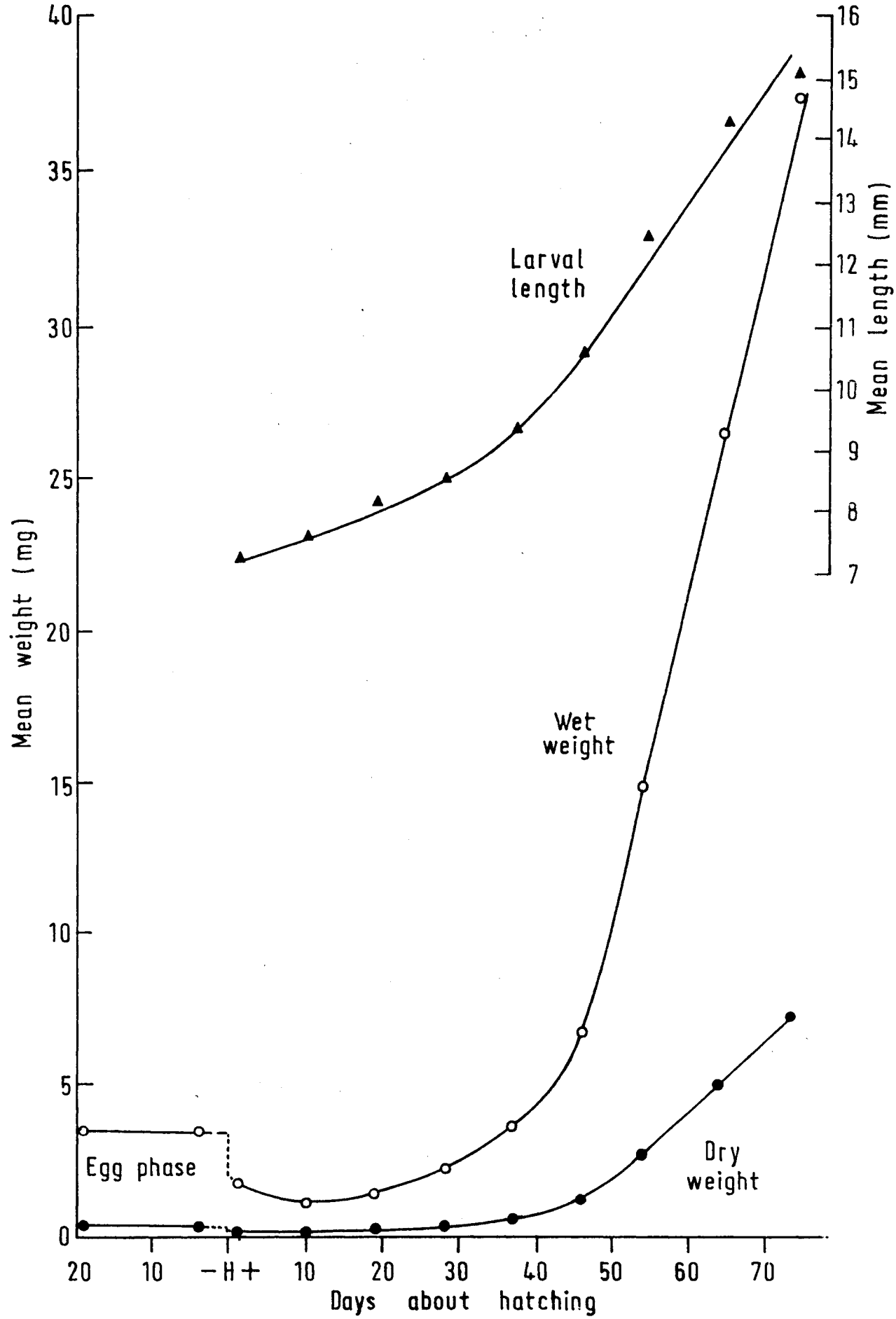

Figure 1. Cumulative growth curves for an egg and larval population of captive plaice

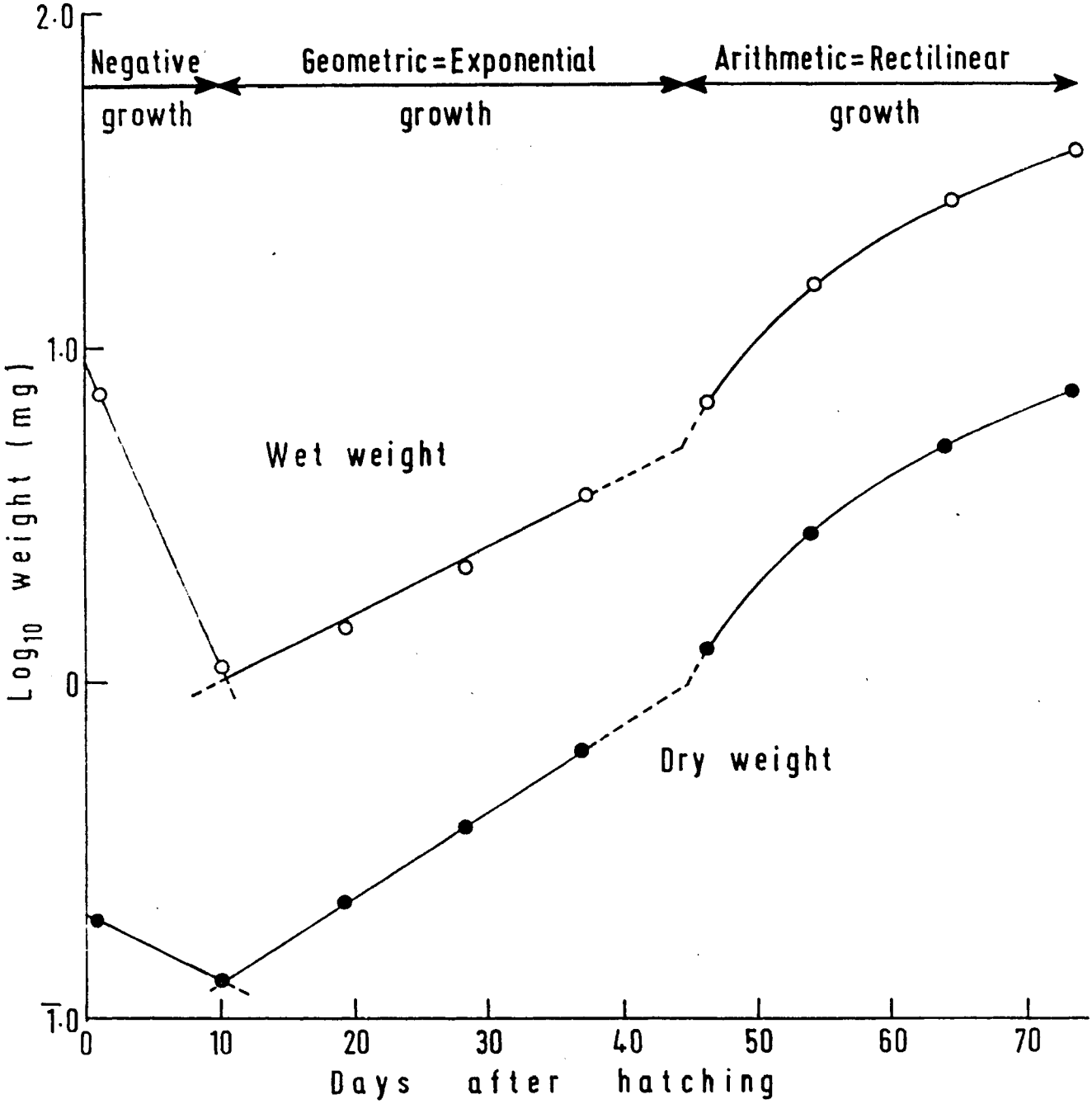

Figure 2 Weight-Growth phases of larval plaice

Figure 3. Changes in the water content of hatchery plaice during larval development.

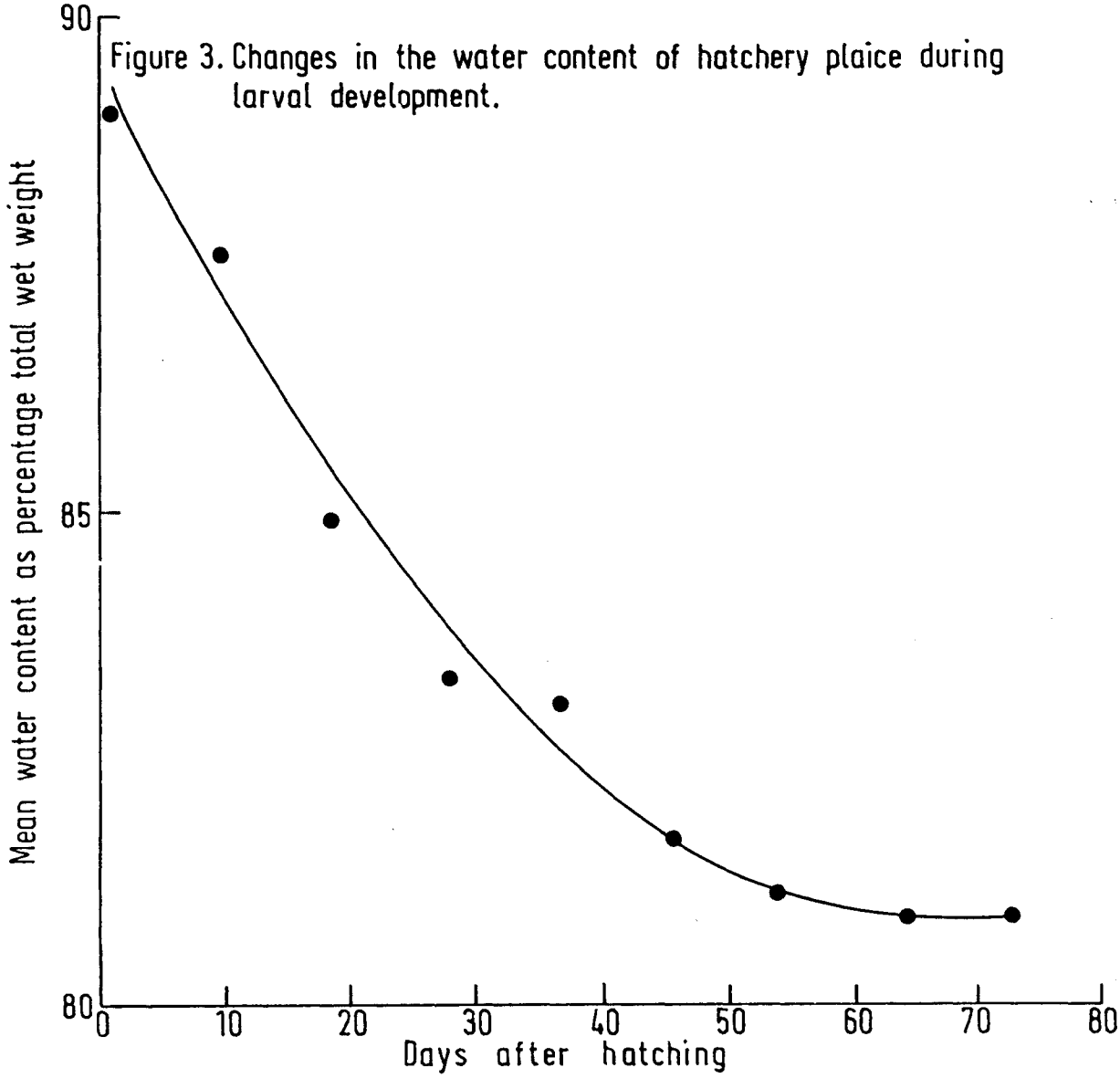

Figure 4. Length/weight relationship during larval development of plaice.