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GROWTH OF ANCHOVY LARVAE (*ENGRAULIS MORDAX* GIRARD) IN THE LABORATORY AS INFLUENCED BY TEMPERATURE

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INTRODUCTION

The northern anchovy (*Engraulis mordax* Girard) spawns between 13° and 17° C off California and occasionally at warmer temperatures. Growth rates of larvae are unknown for this species yet these data are needed for estimating the size of the spawning population. This report describes a method for rearing larval anchovies in the laboratory and the effect of two temperatures, 17° and 22° C on their growth rates.

REARING AT 17° C

Anchovy eggs for two experiments at 17° C (17-I and 17-II) were collected in the ocean off San Diego, California. In each experiment 2,000 eggs of approximately the same stage of development were put into the tank and hatched almost synchronously. The larvae were sampled as soon as possible after all eggs were hatched and sampling continued through 23 days in 17-I and 35 days in 17-II (Table 1, Figures 1 and 2).

A rectangular glass tank, 183 cm long by 71 cm wide by 38 cm high, was used for rearing the anchovy larvae. It contained 380 liters of sea water and was sprayed inside with a non-toxic, glossy black epoxy paint against which the larvae could be seen and which allowed them to detect their food (Blaxter, 1962; Shelbourne, 1964). The tank was built into a deep water table which served as a water bath in which temperature was maintained at ±0.5°C with a mixing valve (Lasker and Vlymen, 1969).

TABLE 1

Size ranges and mean lengths ($\bar{x}$) of anchovy larvae reared from hatching in two 17° C experiments (17-I and 17-II) and one 22° C experiment (S.D. = standard deviation)

Age (days)	17-I				17-II				22°			
	Number of larvae sampled	Size range of sample (mm)	$\bar{x}$	S.D.	Number of larvae sampled	Size range of sample (mm)	$\bar{x}$	S.D.	Number of larvae sampled	Size range of sample (mm)	$\bar{x}$	S.D.
0	10	2.9– 3.4	3.2	0.17	10	2.5– 3.5	3.2	0.30	—	—	—	—
1	10	3.5– 4.0	3.7	0.16	10	3.2– 3.9	3.6	0.22	7	2.5– 3.3	2.9	0.28
2	10	3.3– 4.0	3.7	0.24	6	3.0– 4.2	3.7	0.43	12	3.1– 3.7	3.4	0.17
3	10	3.6– 4.1	3.9	0.13	9	3.5– 4.0	3.8	0.21	12	3.4– 4.9	3.7	0.46
4	11	3.4– 4.2	3.8	0.22	—	—	—	—	11	3.7– 4.6	4.0	0.26
5	10	3.5– 4.5	4.0	0.25	7	3.7– 4.8	4.1	0.33	15	2.9– 5.4	3.9	0.74
6	10	3.6– 4.8	4.1	0.32	—	—	—	—	9	4.2– 6.3	5.2	0.70
7	10	3.8– 5.1	4.3	0.46	10	3.9– 5.0	4.6	0.42	12	3.8– 6.9	5.6	0.80
8	10	3.9– 5.8	4.7	0.67	—	—	—	—	8	6.0– 7.8	7.0	0.57
9	9	4.5– 6.7	5.8	0.73	—	—	—	—	—	—	—	—
10	10	4.4– 6.7	5.7	0.77	10	4.5– 8.4	6.4	1.15	5	7.1– 9.0	8.1	0.74
11	10	4.9– 7.7	6.6	0.83	—	—	—	—	—	—	—	—
12	10	5.7– 8.4	7.2	0.79	13	4.3– 9.2	6.7	1.47	5	8.5–11.9	10.0	1.53
13	11	6.1– 9.4	7.6	1.06	—	—	—	—	—	—	—	—
14	10	7.5– 9.6	8.8	0.64	15	6.3–11.1	9.1	1.47	5	8.0–11.4	9.8	1.34
15	10	5.8– 9.1	8.2	1.03	—	—	—	—	5	11.3–14.3	12.8	1.18
16	10	7.7–10.5	9.2	0.76	6	6.4–10.3	8.0	1.30	—	—	—	—
17	10	6.1–11.7	9.5	1.80	—	—	—	—	8	10.0–15.4	13.3	2.01
18	10	7.6–12.3	10.5	1.23	9	6.8–13.4	10.4	2.09	—	—	—	—
19	—	—	—	—	—	—	—	—	—	—	—	—
20	9	7.9–13.7	11.8	1.74	7	5.5–13.3	9.6	2.74	—	—	—	—
21	—	—	—	—	—	—	—	—	—	—	—	—
22	10	10.2–16.0	12.6	1.78	10	7.9–17.3	12.4	2.49	—	—	—	—
23	—	—	—	—	—	—	—	—	—	—	—	—
24	—	—	—	—	15	10.0–17.0	13.3	2.07	—	—	—	—
25	—	—	—	—	—	—	—	—	—	—	—	—
26	—	—	—	—	6	9.4–18.4	14.4	2.96	—	—	—	—
27	—	—	—	—	—	—	—	—	—	—	—	—
28	—	—	—	—	10	10.0–18.9	15.3	2.70	—	—	—	—
29	—	—	—	—	—	—	—	—	—	—	—	—
30	—	—	—	—	—	—	—	—	—	—	—	—
31	—	—	—	—	9	11.0–19.8	15.6	2.81	—	—	—	—
32	—	—	—	—	—	—	—	—	—	—	—	—
33	—	—	—	—	—	—	—	—	—	—	—	—
34	—	—	—	—	12	9.8–20.7	17.4	3.15	—	—	—	—

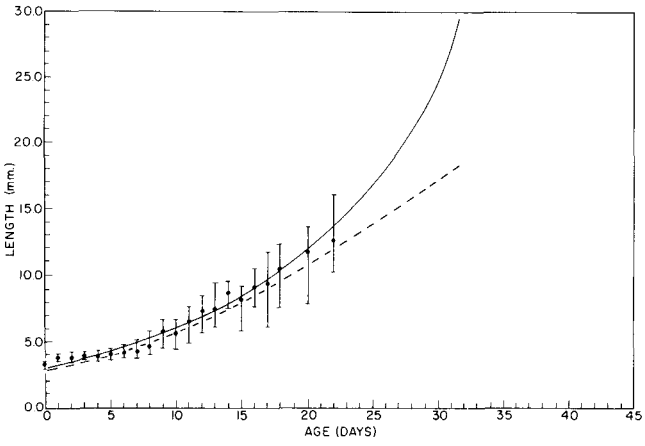

FIGURE 1. Growth of anchovy larvae reared from hatching for 23 days (17-I) at 17° C. Solid line is based on the equation

$$l_t = l_o e^{ct}$$

broken line was obtained by fitting the Gompertz model to the data (see text). The mean length and range are shown for each sample (see Table 1).

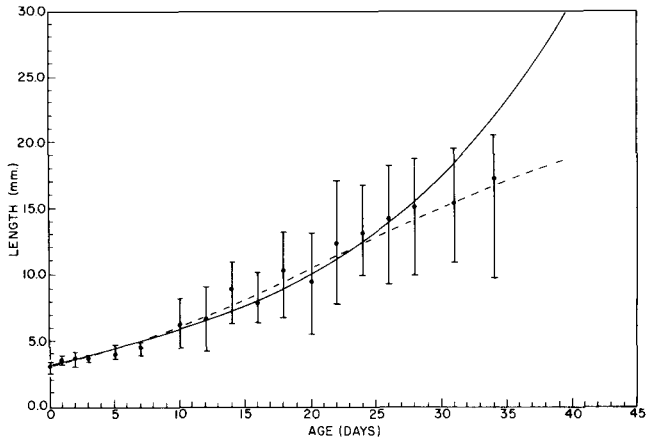

FIGURE 2. Growth of anchovy larvae reared from hatching for 35 days (17-II) at 17° C. Solid line is based on the equation

$$l_t = l_o e^{ct}$$

broken line was obtained by fitting the Gompertz model to the data (see text). The mean length and range are shown for each sample (see Table 1).

Daylight fluorescent lights were used to illuminate the rearing tank. The main light, centered over the tank was set on a diurnal schedule—12 hours on and 12 hours off. In order to avoid sudden reaction by the larvae to the tank lights' going on and off, the room lights were turned on 1 hour before the tank lights went on and turned off 1 hour after the tank lights went off. Light at the surface of the water in the tank averaged 44 ft-c with the tank and room lights on and 32 ft-c with only the room lights on. The room in which the experiments were conducted had walls which did not reach the ceiling (Lasker and Vlymen,

TABLE 2

Feeding of anchovy larvae reared in two 17° C experiments (17-I and 17-II)

Experiment	Feeding schedule	Larvae		Diet		
		Age (days)	Size range (mm)	Kind[2]	Approximate size range (width in μ)	Average food density[1] (no/ml)
17-I	Every day	2–15	3.3– 9.1	Plankton Copepod nauplii	70– 90	0.4
		16–17	7.7–11.7	Plankton Copepod nauplii Copepodites Brine shrimp nauplii[3]	70–120 200–500	2.0
		18–22	6.1–16.0	Brine shrimp nauplii	200–500	0.8
17-II	Every other day	2–16	3.0–10.3	Plankton Tintinnids Copepod nauplii	50– 90	2.3
		18–22	6.8–17.3	Plankton Tintinnids Copepod nauplii Copepodites	50–130	2.2
		24–31[4]	10.0–19.8	Plankton Tintinnids Copepod nauplii Copepodites Copepods	50–190	2.6
		33	—[5]	Brine shrimp nauplii	200–500	1.0

[1] Calculated as homogeneous dispersion but only upon addition to tank (see text).
[2] Predominant types.
[3] Supplement to plankton.
[4] On day 28 brine shrimp nauplii only—no plankton collection.
[5] No sample of larvae.

1969). Consequently when the tank and room lights were off 3 ft-c of light illuminated the surface of the tank from lights in the adjoining corridor.

The main diet for the anchovy larvae for most of each experiment was plankton collected with an 80-μ mesh net in Mission Bay, San Diego. Food size, controlled by mechanical straining through various size meshes, was determined and maintained for different sizes of larvae as nearly as possible in accordance with the data of Arthur (1965) and Berner (1959) (Table 2).

As noted in Table 2, densities of food organisms were calculated as though for homogeneous dispersions in the tank but only for the times when they were introduced. Once in the tank, plankters concentrated in the brightest areas, usually near the surface of the water and at the sides and bottom of the tank so it was never possible to determine the true density of plankton. In experiment 17-II, food organisms totalled more than a million at each feeding and remained available to the fish larvae for as long as 2 days after each addition of plankton. Food densities were classed as adequate or inadequate by the sighting of larvae feeding on plankton or by the incidence of food in the guts of sampled larvae. Using these criteria, feeding incidence was noted as "low" in 17-I and "high" in 17-II.

REARING AT 22° C

The larvae sampled at 22° C were from a mass-rearing experiment conducted by G. O. Schumann with techniques similar to those described by Longhurst (1968). No data is available on the numbers of eggs put into the tank, the feeding schedule, nor the numbers of organisms added to the tank with each feeding. The larvae were sampled only on the days shown in Table 1 and as depicted in Figure 3.

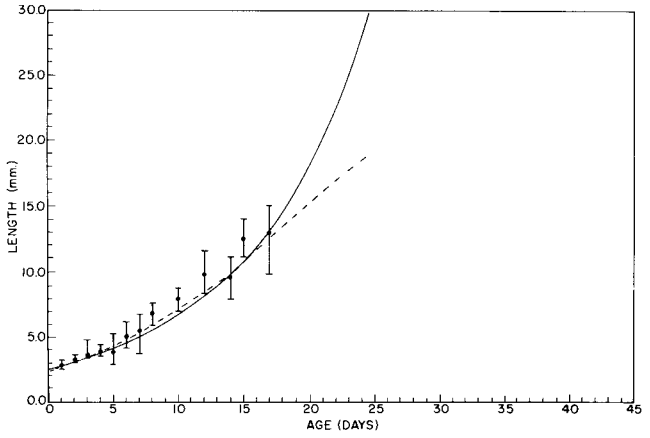

FIGURE 3. Growth of anchovy larvae reared from hatching for 18 days at 22° C. Solid line is based on the equation

$$l_t = l_o e^{ct}$$

broken line was obtained by fitting the Gompertz model to the data (see text). The mean length and range are shown for each sample (see Table 1).

GROWTH

Growth in these experiments can be expressed by the equation

$$l_t = l_o e^{ct}$$

where l_t = length at time t
l_o = length at hatching
c = instantaneous growth rate expressed as mm/mm of length

In 17-I $l_t = 2.739e^{.0718t}$
In 17-II $l_t = 3.24e^{.0555t}$
In the 22°C experiment $l_t = 2.543e^{.0972t}$

These curves are illustrated by the solid lines in Figures 1, 2, and 3 respectively.

Although these simple logarithmic curves fit the experimental data well, extrapolation is dangerous since growth rates are known to decrease with age. Laird (1969) showed that a Gompertz model characterized by the set of differential equations

$$dW(t)/dt = \gamma W(t)$$
$$d\gamma/dt = \alpha\gamma$$

or $W(t) = W_o exp\{A_o/\alpha[1-exp\ (-\alpha t)]\}$

where W_o = weight at time 0
A_o = growth rate at time 0
γ = instantaneous growth rate
α = instantaneous change in γ

describes the early growth processes of a large number of organisms in which growth is fundamentally exponential (implied by the normal binary fission of cells) and undergoes some intrinsic (as opposed to environmental) exponential retardation by some unknown physiological mechanism. This equation was fitted to our experimental data using the length-weight relationships of the data of Lasker et al. (1970) where $W = b \log l^k$ provided a better fit for premetamorphic larvae than does the classic allometric formula $W = bl^k$ for which weights must be estimated.

The iterative least squares estimates were obtained by minimizing the expression

$$\sum_1^n \left[l^k - l_o^k exp\{A_o/\alpha[1-exp(-\alpha t)]\} \right]^2$$

with respect to l_o, k, A_o, and α. It was found that k close to 6.0 provided the best fit. Therefore a common $k = 6.0$ was used for all sets and the estimated values for b were

.00070 in 17-I
.00084 in 17-II
and .00049 in the 22° C experiment.

The growth rate at 22° C was about 1.75 times that in 17-II but it is not possible to make a definite conclusion about the higher rate at 22° C. Absolute food densities and food availability were not known in the 22° C experiment since rearing was not continued through metamorphosis. The most tenable hypothesis for the more rapid rate at the higher temperature is that as a consequence of greater activity the larvae fed more frequently and increased feeding produced a higher rate of growth. Although there is no experimental evidence for this mechanism in larval fishes it has been demonstrated for the post juvenile stages of a serranid, *Epinephalus guttatus* (Menzel, 1960) and a cichlid, *Cichlasoma bimaculatum* (Warren and Davis, 1967). Other variables such as the use of continuous light and a larger container may also have been responsible for or contributed to the higher growth rate.

The higher rate of growth in experiment 17-I with lower food densities than in 17-II may have been the result of selective early mortality of smaller larvae which were unable to find sufficient food and thus, by such mortality, benefited the larger larvae by increasing their available food supply. Another view is that the larger larvae may have been better able to seek out the scarce food items and benefit from them while the smaller larvae could not and ultimately died.

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