

**DIFFERENCES IN HEART SIZE BETWEEN OCEAN-CAUGHT AND  
LABORATORY-GROWN LARVAE OF THE NORTHERN ANCHOVY,  
*ENGRAULIS MORDAX* Girard**

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**Abstract:** Large differences in heart size occur between ocean-caught and laboratory-grown larvae of the northern anchovy, *Engraulis mordax* Girard. At 4 mm in standard length (3 days), laboratory-grown larvae had hearts only slightly larger than ocean-caught larvae, but at 9 mm (16 days), hearts of laboratory-grown larvae were 40% longer. Thereafter, the percentage decreased to 24% at 19 mm, the longest laboratory-grown larvae available. The percentage probably decreases further in larvae longer than 19 mm as indicated by trends in the allometric growth equations. At the first-feeding stage in the laboratory, larvae that had been feeding for 2 days had larger hearts and deeper bodies than non-feeding larvae.

INTRODUCTION

While examining ocean-caught and laboratory-grown anchovy (*Engraulis mordax* Girard) larvae, side-by-side, it became apparent that there was a substantial difference in heart size between larvae of these two types. As heart size might be associated with other morphological and apparent behavioral differences (Arthur, 1976), an examination of heart size of ocean-caught and laboratory-grown larvae over the length ranges available was conducted.

METHODS AND MATERIALS

All larvae examined had been preserved in 4% formalin. Laboratory-grown larvae were from three groups reared at the Southwest Fisheries Center, La Jolla. Group 1, preservation time 1 month to 2 yr, were reared at 17 and 19 °C on a diet of laboratory-reared dinoflagellates, rotifers, and copepods (Hunter, 1976). Group 2, preservation time 8 yr, were reared on wild plankton at 17 °C in 1968 (Kramer & Zweifel, 1970). Group 3, preservation time 9 yr, were reared on wild plankton at an unknown temperature. Ocean-caught larvae came from January, April and July California Cooperative Oceanic Fisheries Investigations (CalCOFI) cruises from 1963 and 1965. There should be no effect of shrinkage on body length between the

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groups, as Blaxter (1971) found no consistent shrinkage in herring larvae after the first day of preservation.

Measurements were made with an ocular micrometer of specimens immersed in glycerine. All body length measurements of larvae were standard length. The ventricle was used as an index of heart size because it has definite anterior and posterior edges, whereas the conus tapers gradually and has no readily visible anterior boundary. Ventricle length can be measured without excising the heart but the pectoral fin must often be manipulated in order to view all edges.

## RESULTS

### HEART SIZE

Heart size at first feeding appears to be the same for ocean-caught and laboratory-grown larvae (Fig. 1). When larvae grew to 4.6 mm in the laboratory, most appeared

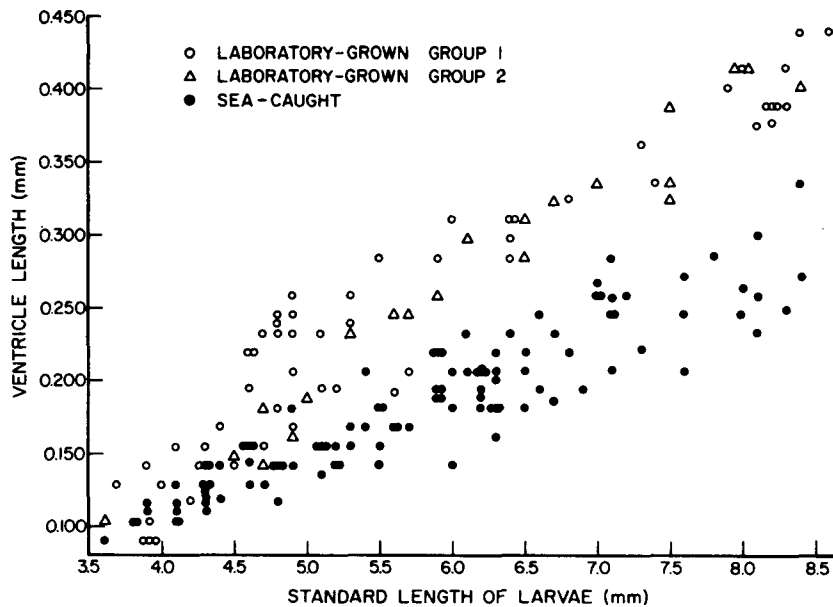


Fig. 1. Comparison of heart length near first feeding stages of ocean-caught and laboratory-grown northern anchovy larvae: see p. 99 for a description of the groups used.

to have substantially larger hearts than ocean-caught larvae, and by 5.0 mm there was little overlap between laboratory-grown and ocean-caught larvae. Hearts of 5.2 mm laboratory-grown larvae nearly fill the pericardial cavity, whereas hearts of ocean-caught larvae of the same length take up a noticeably smaller amount of space

(Fig. 2). Pericardial cavities seem to be about the same size for the two types of larvae. The curves for body length to ventricle length relationships in Fig. 3 were

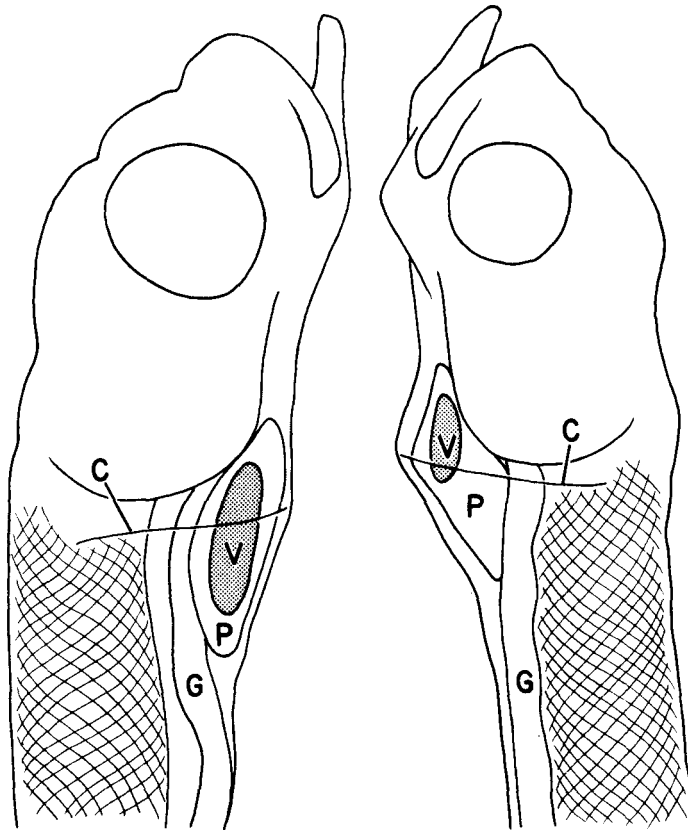


Fig. 2. Pericardial area of a typical 5.2 mm SL laboratory-grown northern anchovy larva (left) and a typical 5.2 mm SL ocean-caught anchovy larva (right): C, cleithrum; G, gut; P, pericardial cavity; V, ventricle.

derived by using Marquardt's algorithm (Conway *et al.*, 1970) for fitting Zweifel's allometric growth model (Zweifel, unpubl.).

$$\ln HL = a - b(c - \ln SL)^d.$$

HL and SL are heart length and standard length, respectively. Zweifel noted that the parameter  $b$  has no simple biological meaning,  $a$  corresponds to the logarithm of the maximum heart length,  $c$  represents the logarithm of the maximum standard length, and  $d$  is the ratio of the rates of change with time of the separate instantaneous growth rates (Laird, 1965). When  $d = 1$ , this equation becomes  $\ln HL = a + b \ln SL$ , the equation of simple allometry. Zweifel conducted an analysis

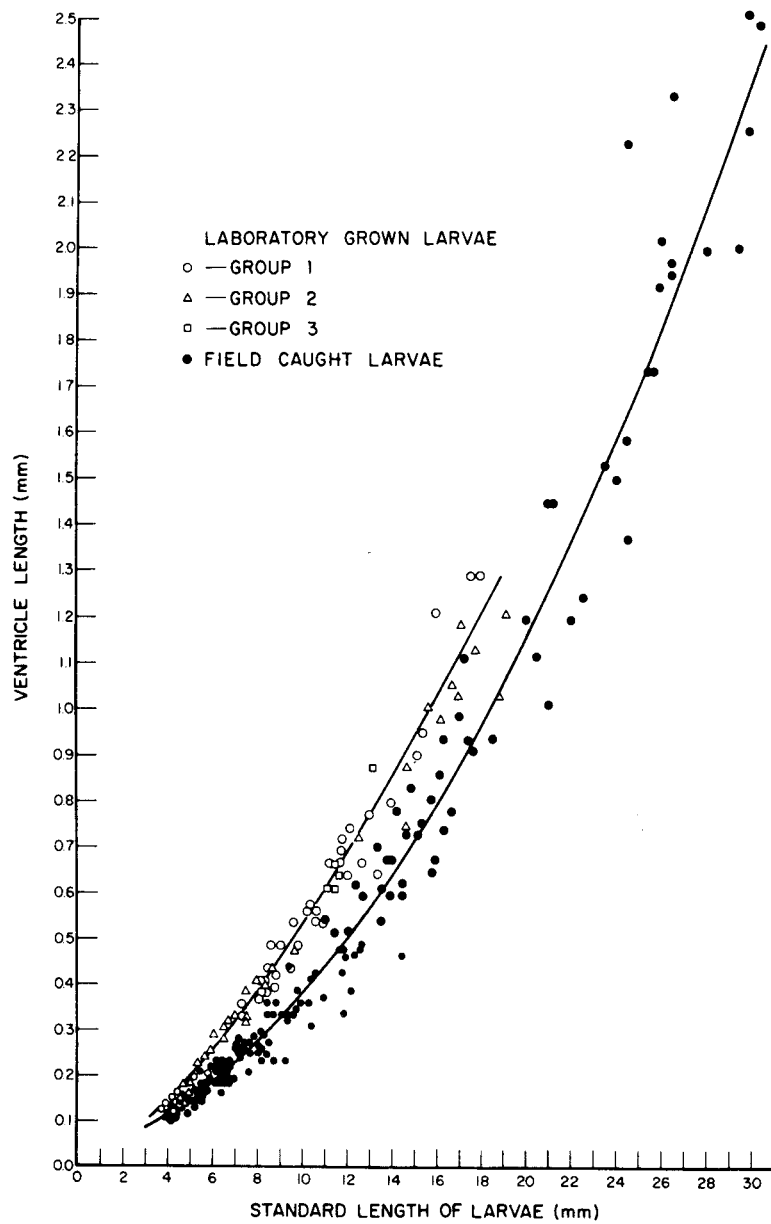


Fig. 3. Heart length to body length relationships of laboratory-grown and ocean-caught northern anchovy larvae: the line for laboratory-grown larvae was calculated from  $\ln HL = 1.2994 - 0.2742(5.0563 - \ln SL)^{1.9122}$ ; the line for ocean-caught larvae was calculated from  $\ln HL = 2.4309 - 2.5230(3.8764 - \ln SL)^{0.6549}$ ; see p. 99 for a description of the groups used.

of covariance of these data and found no difference in the slopes of the curves in Fig. 3 but a highly significant difference in their elevations.

The greatest percentage difference between body length and ventricle length occurred at 9 mm where hearts of laboratory-grown larvae averaged 40% longer. Thereafter, the percentage decreased to 24% at 19 mm, the longest laboratory-grown larvae available. Extrapolating from equations in Fig. 3 heart length differences became negligible at about 32 mm although Zweifel warns that extrapolating outside the range of observations must be done with caution.

#### EFFECTS OF FEEDING AND STARVATION ON HEART SIZE

The usual numbers of copepod nauplii in the ocean have seldom been found (Arthur, 1977) to equal those required for the laboratory rearing of anchovy larvae (Kramer & Zweifel, 1970; O'Connell & Raymond, 1970) although *Gymnodinium splendens* occurs in the ocean at times in high enough concentrations to support life over a short larval period (Lasker, 1975). It therefore seems reasonable to suppose that the small size of hearts of ocean-caught larvae might be associated with poor feeding conditions. To test this supposition, a group of first feeding anchovy larvae were placed in a container with *G. splendens* (100/ml) while another group from

TABLE I

Comparison of ventricle lengths and body depths of starved and fed (after two days of feeding) anchovy larvae from the same egg source.

	Fed	Starved	Fed	
			starved	<i>t</i> (independent)
Number of larvae	29	33		
Mean ventricle length (mm) ±SD	0.1250 ± 0.0269	0.0919 ± 0.0124	1.360	6.3457, <i>P</i> = <0.001
Mean body depth (mm) ±SD	0.4350 ± 0.0311	0.4036 ± 0.0208	1.078	4.6617, <i>P</i> = <0.001

TABLE II

Comparison of ventricle lengths and body depths of feeding and non-feeding anchovy larvae living in the same aquarium after two days exposure to food.

	Feeding	Non-feeding	Feeding	
			non-feeding	<i>t</i> (independent)
Number of larvae	20	9		
Mean ventricle length (mm) ±SD	0.1358 ± 0.0225	0.0989 ± 0.0158	1.373	4.4109, <i>P</i> = <0.001
Mean body depth (mm) ±SD	0.4509 ± 0.0257	0.3999 ± 0.0298	1.128	5.1407, <i>P</i> = <0.001

the same laboratory-spawned egg source (Leong, 1971) were placed in a container with filtered sea water. After 2 days, both groups of larvae were preserved in 4% formalin. Ventricle length as well as body depth were significantly larger in the fed group (Table I). The fed group was introduced to food 1 day after yolk absorption, which is near the point of "irreversible starvation" (1.5 days after yolk absorption, Lasker *et al.*, 1970) when most northern anchovy larvae refuse to feed even when presented food. Apparently as a result of this delayed exposure to food nine of the 29 larvae had not eaten, as was indicated by their unexpanded guts. Differences in ventricle length and body depth between feeding and non-feeding individuals of these 29 larvae was significant (Table II).

#### DISCUSSION

There is evidence of several apparent morphological and behavioral differences between ocean-caught and laboratory-grown anchovy larvae (Arthur, 1976). Ocean-caught larvae, as opposed to laboratory-grown larvae: (1) do not increase the size of food particles ingested in proportion to increasing length for larvae larger than 4 mm; (2) show a steep decline in feeding incidence (percentage of larvae containing food) beginning at the 4.5 mm length to about 7.0 mm; and (3) undergo a decline in relative morphological condition (as measured by body depth) until they have attained a length of 17 to 18 mm. It was suggested that the lack of increase in food particle size and the decrease in feeding incidence indicated that most anchovy larvae in the ocean decreased their feeding activity after first feeding and fed on food items only in their immediate environment (which are mostly of the smaller sizes ingested at first feeding, Arthur, 1977). This suggestion is supported by the small hearts of ocean-caught anchovy larvae, because heart size probably indicates the activity level of swimming and feeding. Changes in cardiac output in fish are normally associated with large changes in stroke volume and small changes in heart rate, whereas increased cardiac output in mammals is usually associated with large changes in heart rate but with little change in stroke volume (Randall, 1968). The abundance of food in the laboratory may stimulate increased predatory activity, and therefore heart size, over that occurring in the ocean. Production of noradrenaline and adrenaline associated with cardiac output in teleosts (Randall, 1968) is markedly increased in trout larvae at the onset of first feeding (Meyer & Sauerbier, 1977). Heart-volume to body-volume ratios for active surface marine teleosts such as barracuda, 0.24%; mackerel, 0.20%; and salmon, 0.19–0.36% are higher than those of demersal fishes such as cod, 0.15% and haddock, 0.17% (Spector, 1956). Kishinouye (1923) noted that the tunas, which are characterized by swift and unceasing locomotion, have notably larger hearts than other scombroid fishes.

The large hearts of laboratory-grown larvae might partly be a result of laboratory conditions. Blaxter (1975) noted various morphological, behavioral and physiolo-

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gical differences between reared and wild fish. Activity and therefore heart size of larvae in the laboratory may be unnaturally high because of noises, or contact with walls or bottoms of aquaria, or contact with each other. This argument, however, does not explain the increase in heart size of older ocean-caught larvae in relation to that of laboratory-grown larvae. The large hearts of laboratory-grown larvae may also be partly a result of low oxygen availability, as oxygen content of rearing tanks is often less than that of the open ocean (Hunter, pers. comm.). Hunter (1972) reported that anchovy larvae spend more time swimming when in water with oxygen concentrations below saturation than in saturated water. Heart size, however, is more closely associated with feeding as indicated by the larger hearts of feeding than non-feeding larvae in the same container (Table II) and therefore at the same oxygen saturation.

Fish larvae with limited energy stores, such as first-feeding sardines and anchovies, cannot afford to waste much energy on unrewarded feeding activities. By the time a sardine larva has consumed all of its yolk and is ready to feed it is already in a metabolic deficit (Lasker, 1962). Emaciation as a result of unsuccessful feeding activities might be seen in the results of O'Connell (1976). He observed that most of the 2-day-old anchovy larvae reared with food (*Gymnodinium*) present were in poorer physical condition than larvae of the same age that had not been exposed to food. O'Connell suggested that the larvae with no food available were not stimulated to expend energy for feeding activities whereas most larvae exposed to food had been stimulated to capture food but had not been successful because of the brief learning period and/or low food density.

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