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On condition factor measurements in Pacific herring larvae

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ABSTRACT: Condition factors (CF = mg · mm^{-3} · 100) of Pacific herring larvae from Departure Bay, Canada, were determined from two larval year classes and compared for yolk sac and post-yolk sac feeding larvae. Decline in condition factors for yolk sac larvae was similar in both years. Subsequent increase of condition factors after passing the transitional phase between loss of yolk and first feeding was identical for both years. The occurrence of emaciated larvae in 1976 was attributed to poor food supply during the "critical period" (the time of first food uptake).

INTRODUCTION

The length/weight relationships of fishes were used as early as 1948 for assessment of the fishes' condition and condition factors (CF) were determined as weight in grams multiplied with 100 and divided by standard length in millimeters to the third power (CF = g · l^{-3} · 100) in order to determine the state of nutrition of a fish. The higher the condition factors of a given species, the more truncate the fish. Within one species high condition factors indicate well fed individuals. Beckmann (1948) made use of the condition factor in the description of the condition of seven Michigan fishes. The condition factor or coefficient of condition has also been mentioned by Rounsefell & Everhardt (1953) in their treatise on fishery science as expressing the ". . . relative well-being of the fishes". Thus condition factors are generally used to indicate suitability of an environment or to compare the same species of fish from one area with those from another with different environmental conditions.

Recently, condition factors have been used to determine the condition of fish larvae as well (Hempel & Blaxter, 1963; Vilela & Zijlstra, 1971; Ehrlich et al., 1976) and an attempt has been made to relate the condition of, for instance, larval plaice to feeding conditions and subsequent success in recruitment (Shelbourne, 1957). The hypothesis, that some relation exists between larval condition and recruitment, was refuted by Vilela & Zijlstra (1971) while investigating the condition of North Sea herring larvae and its relation to year-class success.

In order to provide more insight into the understanding of the development of condition factors in yolk sac and post-yolk sac larvae, this study presents the development of larval condition in Pacific herring caught at the same sampling site during the years 1974 and 1976.

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MATERIAL AND METHODS

We collected data on dry weight and total length of Pacific herring larvae, *Clupea harengus pallasi*, at the Nanaimo Pacific Biological Station, Canada, during April and beginning of May in the years 1974 and 1976. Larvae were attracted at night with a 300 W light bulb suspended directly over the water surface. Larval fish were then caught with a pail and after transfer to the laboratory (5 min) anaesthetized and measured. The measured specimens were dried at 60 °C on silicon coated glass slides from which they could be easily removed for later dry weight determination. Condition factors of larvae were calculated according to the formula CF = (weight in mg) $\times$ (total length in mm)$^{-3}$ $\times$ 100. In the literature multiplication with 1000 is also commonly used; this affects the factor, however, only in the decimal place.

Yolk volumes were calculated by measuring the large (a) and small (b) diameter of the yolk and applying the data to the formula V (volume) = $4/3\ \pi\ b^2a$.

RESULTS AND DISCUSSION

The development of the 1974 and 1976 condition factors is depicted in Figure 1 for yolk sac and post-yolk sac larvae. During the yolk sac phase larvae continuously lose weight. They start gaining weight shortly after the onset of feeding. Thus both phases have been considered separately and linear regressions have been calculated for each phase. As can be seen from the regression equation (Fig. 1), in both groups of yolk sac larvae the slopes of the regression lines indicating the development of the condition factors are almost identical (– 0.00571 in 1974; – 0.00574 in 1976).

Although we can assume that the larvae investigated during this study were derived from the same parental stock (spawning of herring takes place every year in a nearby cove), we found considerable differences in condition factors within the same length groups (Fig. 1). These pronounced variations are caused by the size of the yolk sac as shown in Figure 2. The yolk adds to the weight without increasing the length of the larvae (see Blaxter & Hempel, 1963). In the groups sized 8.75 to 10.25 mm there exists an almost linear relationship between condition factors and yolk sac volume. The larger the yolk sac the greater the condition factors at given lengths (Fig. 2). With increasing length and decreasing yolk sac volume condition factors tend to become smaller and more uniform (Fig. 1). Variations are low at the beginning of feeding shortly after yolk absorption (Fig. 1, Table 1). This means that most of the larvae, after having resorbed their yolk, start with almost the same condition factor at the time of first feeding, having a total length of approx, 11.0 mm. Those larvae which initiated feeding early still preserve some of their yolk remnants, as can be taken from Figure 1a for the 9.5 to 10.5 mm larvae and from Figure 1b for the 10.5 to 11.5 mm (Fig. 1b) larvae and thus display higher mean condition factors than larvae of the same length without yolk vestiges when comparing open and closed circles in Figure 1. This phenomenon has already been described by Blaxter (1971) for Clyde herring larvae.

We also notice in Figure 1 that post-yolk sac larvae, sized between 9.0 and 11.0 mm still lose weight, growing only in length, a phenomenon also observed by Blaxter (1971) and by Vilela & Zijlstra (1971) in herring larvae from the Clyde area and the central North Sea. This phase probably reflects the process of learning how to prey and the improvement of snapping success (Rosenthal & Hempel, 1970; Blaxter & Staines, 1971)

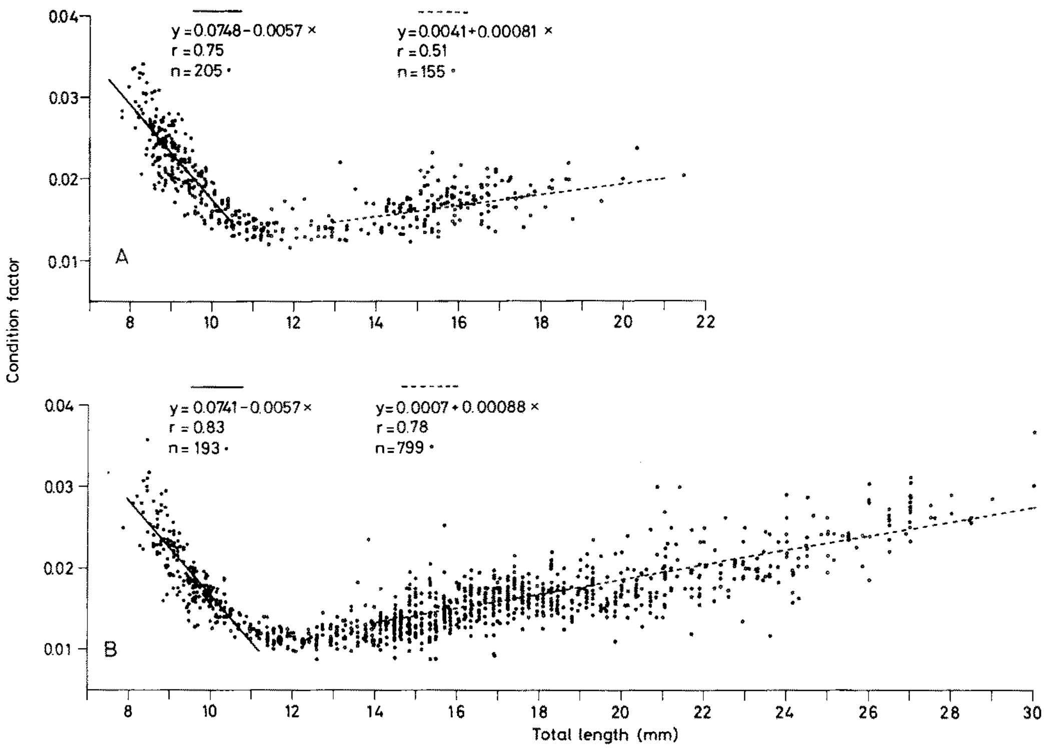

Fig. 1. Change of condition factor (mg · mm^{-3} · 100) with growth in herring larvae from Departure Bay, Canada. Full circles: yolk sac larvae; open circles: post-yolk sac larvae; mean surface water temperature during the yolk sac phase was 9.3–9.4 °C. a: 1974; b: 1976. Broken lines indicate feeding larvae, starting at 13.00 mm for 1974 and 14.00 mm for 1976

during the time between loss of yolk and first food uptake when more energy is consumed by the swimming larvae than is taken up via food.

Although the 1974 and 1976 larvae start with different condition factors (see Table 1, 8.45 mm), Figure 1 shows the rate of decline in condition factors of yolk sac larvae to be identical in 1974 and 1976. When the larvae attain the length of 8.8 mm, condition factors in both year classes are already very much alike (1974: 0.0247; 1976: 0.0251) and after reaching a total length of 10.00 mm their common mean condition factor is 0.016. This is the moment of first feeding and after the transitional phase of first food uptake when condition factors drop to as low as 0.0137 in 1974 and 0.012 in 1976, the condition of the larvae improves at a total length of around 13.00 mm (1974) and 14.00 mm (1976).

There arises the question why condition factors of the 1976 larvae had to drop to 0.012 before they started to improve. A possible explanation is that, although the surface water temperature was the same in both years, there was a major phytoplankton bloom in April 1974 (Kennedy & LeBrasseur, 1977), thus food availability must have been better in 1974 during the time of first feeding, the "critical period" sensu Hjort (1914). Once food availability became better for the 1976 larvae too, the progress of growth of this year class was practically identical to that displayed by the 1974 animals. Figure 1 indicates

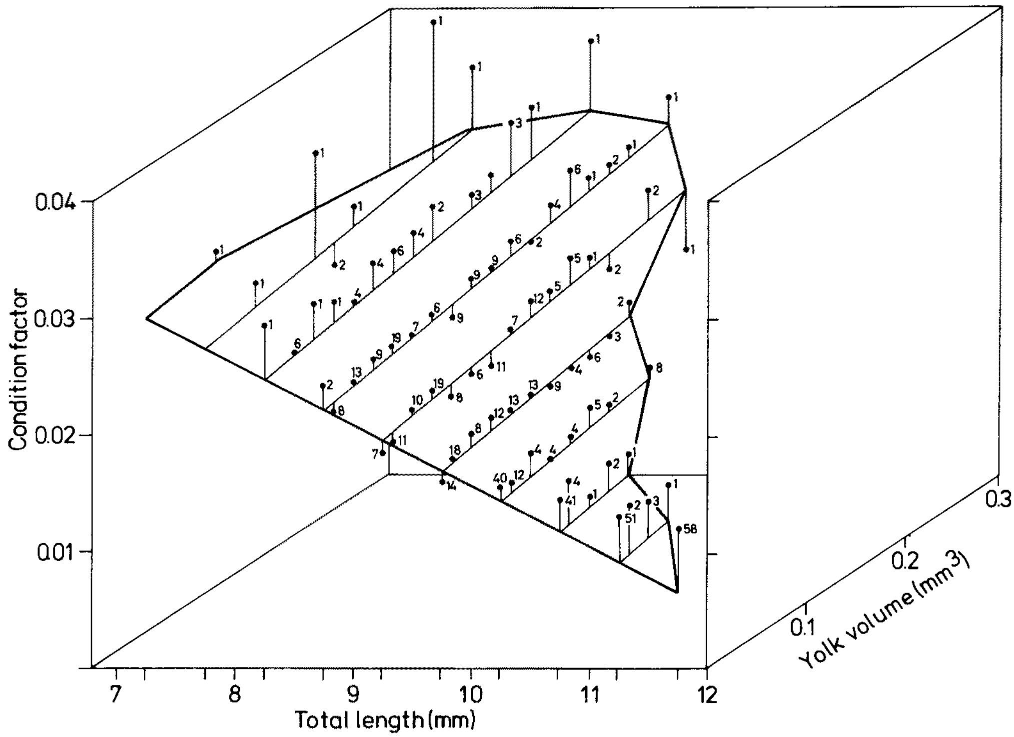

Fig. 2. Condition factors (mg · mm^{-3} · 100) of Pacific herring larvae in relation to yolk sac size (mm^3) and total length. Full circles are means of several measurements (figures) at a certain total length. Outlined plane indicates correspondance with or deviation from a linear length/yolk sac volume/ condition factor relationship according to the formula $z = 0.068 - 0.0052x + 0.014y$. z: condition factor; x: mm total length; y: mm^3 yolk volume. Vertical lines to full circles indicate deviations of measured data from the calculated plane

growth of the larvae after having reached their lowest condition factors, and after passing through the transitional phase (broken regression line, 1974 at 13.00 mm; 1976 at 14.00 mm).

Apart from the transitional phase between resorption of yolk sac and successful initiation of feeding, development of condition factors in feeding larvae is linear, with the suggestion of a non linear increase beyond a total lenght of 26 mm (Fig. 1b), a fact also noted by Vilela & Zijlstra (1971). Linear increase of CFs in feeding larvae has also been observed under experimental conditions by Laurence (1974) in early larvae of haddock *Melanogrammus aeglefinus.*

In Figure 1b, we notice among the larvae, sized 12 to 24 mm, several "dropouts" with extremely low condition factors, some being below 0.01. This is possibly an after-effect of the low food availability and the resulting poor condition of the 1976 larvae during the "critical period", because the condition factors of feeding fish larvae depend on the density of potential food organisms. Once prey concentration sinks below a certain level the condition of larvae starts to deteriorate (Laurence, 1974).

Observations on the low condition factors of sea caught larvae have also been

Table 1. *Clupea harengus palassi*. Variation of condition factors of herring larvae from Departure Bay, Canada, with larval development. Water temperature: 9.3–9.4 °C; * yolk sac larvae; SD: standard deviation; n: number of larvae measured; CF: condition factor (mg × mm^{-3} × 100)

1974				1976			
mm	CF	SD	n	mm	CF	SD	n
* 8.3 – 8.35	0.0284	± 0.0042	10	* 8.45	0.0301	± 0.0041	5
* 8.45	0.02635	± 0.0013	4	* 8.79	0.0251	± 0.0032	9
* 8.8	0.0247	± 0.0027	13	* 9.18	0.0202	± 0.0021	10
* 9.1	0.0222	± 0.0033	10	*10.00	0.0163	± 0.0012	11
* 9.2	0.0226	± 0.003	8	11.39	0.0124	± 0.0012	11
* 9.7 – 9.75	0.0187	± 0.0019	12	12.58	0.0120	± 0.00098	24
*10.00	0.0160	± 0.0021	5	13.79	0.0123	± 0.00070	10
10.5	0.0147	± 0.0017	10	13.97	0.0120	± 0.00098	10
11.0 –11.05	0.0147	± 0.0013	11	14.48	0.0125	± 0.0016	11
11.4	0.0141	± 0.0012	6	15.34	0.0145	± 0.0024	13
12.4 –12.6	0.0138	± 0.00083	6	16.21	0.0156	± 0.0018	12
12.95	0.0137	± 0.00075	6	17.24	0.0167	± 0.0018	25
14.6 –14.65	0.0152	± 0.0016	8	18.62	0.0157	± 0.0022	5
15.35–15.4	0.0174	± 0.0034	8	19.31	0.0179	± 0.0022	14
15.9	0.0172	± 0.002	7	21.03	0.0192	± 0.0034	11
16.2 –16.25	0.0178	± 0.00087	5	23.28	0.0198	± 0.00099	6
16.9	0.0179	± 0.003	6	24.14–24.48	0.0197	± 0.0023	12
17.2 –17.45	0.0182	± 0.0014	6	26.50	0.0248	± 0.0019	5

reported by Blaxter (1971) who collected Clyde Sea herring larvae displaying condition factors as low as 0.009, therewith being below Blaxter's laboratory determined CFs exhibited by larvae beyond the experimental starvation level. His own findings lead Blaxter (1971) to the following conclusion: "It must at present remain somewhat uncertain how valid comparisons are between experimental and sea-caught material".

In any case our findings and also the data provided by Shelbourne (1957) and Blaxter (1971) support the assumption that larval condition and also the rate of survival depend very much on how the larvae pass the "critical period". Although after having passed the obstacle "critical period" the condition factors in the 1974 and 1976 larvae develop at the same rate (Fig. 1). Table 1 shows, that the 1974 larvae at a given length always have better condition factors than the 1976 larvae. The occurrence of the "dropouts" in 1976 further demonstrates the lasting effects of the food shortage during the critical period in the 1976 larval population. Thus, effects on the later recruitment of this year class might have been expected (see also May, 1974). But when comparing the situation, theoretically to be expected, with the real one, we learn that the 1976 year class of the Gulf of Georgia herring population yielded an extremely good recruitment in 1979 and 1980, being twice as good as the recruitment resulting from 1974 (Hourston & Schweigert, 1980).

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