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DAILY GROWTH INCREMENTS IN OTOLITHS OF LARVAL WALLEYE *(STIZOSTEDION VITREUM)*

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ABSTRACT

Growth increments were formed daily in the otoliths of laboratory-reared walleye (*Stizostedion vitreum*) larvae for at least 19 days after swimup. The periodicity of increment formation did not differ between two groups of walleye growing at different rates. A metamorphic check in the otolith corresponding to the date of swimup (first feeding) was counted as the first daily increment. Distinct increments formed in the otolith prior to swimup but the number of increments did not correspond to the number of days from hatching. Subdaily increments were also visible in all otoliths examined, but were weakly defined. A linear relationship existed between otolith radius and fish length. Increments observed in the otoliths of field-collected walleye larvae were more distinct than those in laboratory-reared specimens, suggesting that age estimates of field-collected specimens may be more accurate.

INTRODUCTION

Daily growth increments in the otoliths of larval and juvenile fish are useful for estimating spawning dates and growth (Struhsaker and Uchiyama 1976; Methot

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and Kramer 1979; Radtke and Dean 1982; Radtke and Scherer 1982). This information can increase substantially our understanding of the effects of environmental factors on larval fish populations and subsequent development of year-class strength.

Daily increments consist of adjacent bands of calcium carbonate and organic matrix which make up the smallest visible growth units of the otolith (Pannella 1971). These increments appear as light and dark bands, respectively, under transmitted light. The formation of daily increments appears to be regulated by an internal circadian rhythm (Campana and Neilson 1982), but also may be influenced by photoperiod (Taubert and Coble 1977), feeding frequency (Neilson and Green 1982), and temperature (Taubert and Coble 1977).

Interspecific variation in the initiation of increment formation (Brothers et al. 1976) and evidence that not all species may deposit increments with daily periodicity (Geffen 1982) make it necessary to validate the frequency of increment formation for individual species. This study attempts to (1) document the occurrence of daily growth increments in the otoliths of laboratory-reared larval walleye, (2) determine the age at which increment formation begins, and (3) describe the relationship between otolith growth and fish growth.

METHODS

The otoliths of two groups of walleye were examined. Group A, obtained as fertilized eggs from Ohio, were incubated at 9-11 C until hatching, then temperature was gradually increased to 15 C over a 2-week interval. Eleven days elapsed between hatching and the start of feeding (swimup) for this group.

Group B walleye, obtained as prolarvae from Minnesota, were acclimated to 16 C, and then the temperature was gradually increased to 25 C over a 2-week interval. Approximately 7 days elapsed from hatching to swimup for Group B.

Both groups of walleye were stocked in circular fiberglass tanks (1.8-m diameter, 1500-L) at 25,000 per tank and fed live brine shrimp, *Artemia* sp., nauplii for 12 days. Thereafter, commercial salmon starter was also offered. Both groups of walleye were held at a constant photoperiod of 12-h light and 12-h dark.

Group A walleye were sampled at 16, 14, and 30 days after hatching. Group B walleye were first sampled 9 days after hatching and then at unequal intervals over the next 14 days. All fish were preserved in 70% alcohol.

Sagittae, the only otoliths used in this study, were dissected from preserved specimens and mounted in thermoplastic cement on glass slides. No further preparation was needed to observe increments. A drop of immersion oil, applied to each otolith, increased resolution and all otoliths were observed at 100-200x.

To prevent bias in increment counts, the otoliths from the two groups were intermixed and randomly assigned identification numbers. Individual otoliths were aged on two separate dates and their average was used as the estimated age of the fish.

To determine the relationship between sagittae radius and fish length, each otolith was measured to the nearest 0.01 mm along a plane extending from its center into the posterior field, following the plane of maximum growth. Measurements along this plane could be made for 45 of the 46 otoliths aged.

RESULTS

Otoliths removed from the first sample of Group A walleyes (n = 5) had 9-11 increments, whereas otoliths from the first sample of Group B walleyes (n = 5) had 6 increments. In both instances, the number of increments exceeded the number of days from swimup (first feeding) but were fewer than the number of days from hatching. Otoliths of both groups contained a dark band or check (approximately 0.03 mm from the center of the otolith) which corresponds to the date of swimup. This apparent metamorphic check, present in all otoliths examined, was designated as the first increment in subsequent counts; thus, increment counts estimated the number of days from swimup.

For both groups of walleye there was a close correspondence between the number of days from swimup and increment counts (Table 1). Correlation coefficients (r) relating number of increments to age were greater than 0.95 for both groups, while slopes and intercepts did not differ significantly between the two regressions (analysis of covariance; $P>0.01$). Thus, data from both groups were pooled to produce the predictive regression:

$$(1)\ Y = 1.05(X) - 0.64;\ r = 0.97$$

where Y is age in days from swimup and X is the number of otolith increments.

Differences in regression line slopes relating length to age indicated that Group B walleyes grew faster than Group A walleyes (analysis of covariance; $P>0.01$; Table 2), probably because rearing temperatures were higher. Differences in growth, however, did not affect the relationship between increment counts and age; therefore, increment counts were independent of growth rate over the range of growth rates observed. Fish length and otolith radius data from both groups of walleye were pooled and the resulting plot revealed a linear relationship (Figure 1). The assumption of linearity was supported by the significance of the relationship ($F = 449.7$; 1,43 df; $r = 0.96$) which was not improved by a double log transformation ($r = 0.94$). Thus, otolith radius was directly proportional to fish length over the size range examined.

DISCUSSION

The age at which daily increments begin forming differs among species (Brothers et al. 1976), possibly reflecting egg size and length of the incubation period (Radtke and Dean 1982; Radtke 1984). Consequently, the onset of increment formation needs to be determined for each species. Walleye began increment formation from 3 to 7 days after hatching but 4 to 6 days before swimup. Therefore, the metamorphic check that delineated swimup was used as the starting point for increment counts. This metamorphic check, which reflects the transition from endogenous to exogenous feeding (Marshall and Parker 1982; Radtke 1984), supports the hypothesis that otoliths provide an accurate record of the physiological changes that occur during a fish's life.

Prolarval increments (those formed prior to swimup) have been reported for a variety of species (Taubert and Coble 1977; Miller and Storck 1982). They generally are more weakly defined than postlarval increments and may become obscure as the otolith core becomes more opaque with increasing age (Miller and Storck 1982; Davis et al., in press). The 4 to 6 prolarval increments in walleye otoliths, however, were quite distinct and were clearly visible in all otoliths examined. Since the number of prolarval increments did not correspond to the number of days from hatching to swimup, it is important that they be excluded from increment counts and ages be determined as the number of days from swimup. Subdaily increments were observed in nearly all otoliths from walleye older than 5 days from swimup. They were usually easily distinguished from daily increments because they were weakly defined and not present in the lateral field of the otolith. The occurrence of these subdaily patterns have been noted for a number of species though factors affecting their occurrence are poorly understood. Factors implicated in their production include temperature (Brothers 1978) and feeding frequency (Campana 1983).

Increments similar to the daily increments found in our laboratory-reared specimens have been observed in otoliths from young-of-year walleye from Lake Shelbyville, Illinois. Increments in otoliths from wild-caught specimens exhibited greater contrast than those in otoliths from laboratory-reared specimens and subdaily and prolarval increments were relatively indistinct. Thus, assuming that the increments observed were also deposited daily, otolith ages of wild-caught specimens may be more accurate than those of laboratory-reared specimens.

Because otolith growth was directly proportional to body growth, daily increments can be used to back-calculate lengths and growth rates. Thus, daily increments provide a more precise method for evaluating growth of walleye larvae than has been previously available. The effects of various environmental factors on the otolith radius to fish length relationship, however, are poorly understood and warrant further investigation.

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Table 1. Chronological age and number of growth increments in otoliths of larval walleye.

Number of larvae	Age (post-swimup)	Mean number of increments	SE
	Group A		
5	5	5.8	0.8
5	13	12.6	1.1
8	19	18.4	0.9
	Group B		
5	2	2.8	1.1
3	4	4.3	1.2
5	6	7.2	1.8
3	11	11.0	3.0
3	12	12.0	1.0
4	14	13.8	2.1

Table 2. Regression statistics of total length against age in days from swimup for walleye larvae.

	Number of fish	Intercept	Slope	SD of slope	r
Group A	18	8.28	0.30	0.04	0.90
Group B	28	8.84	0.61	0.03	0.96

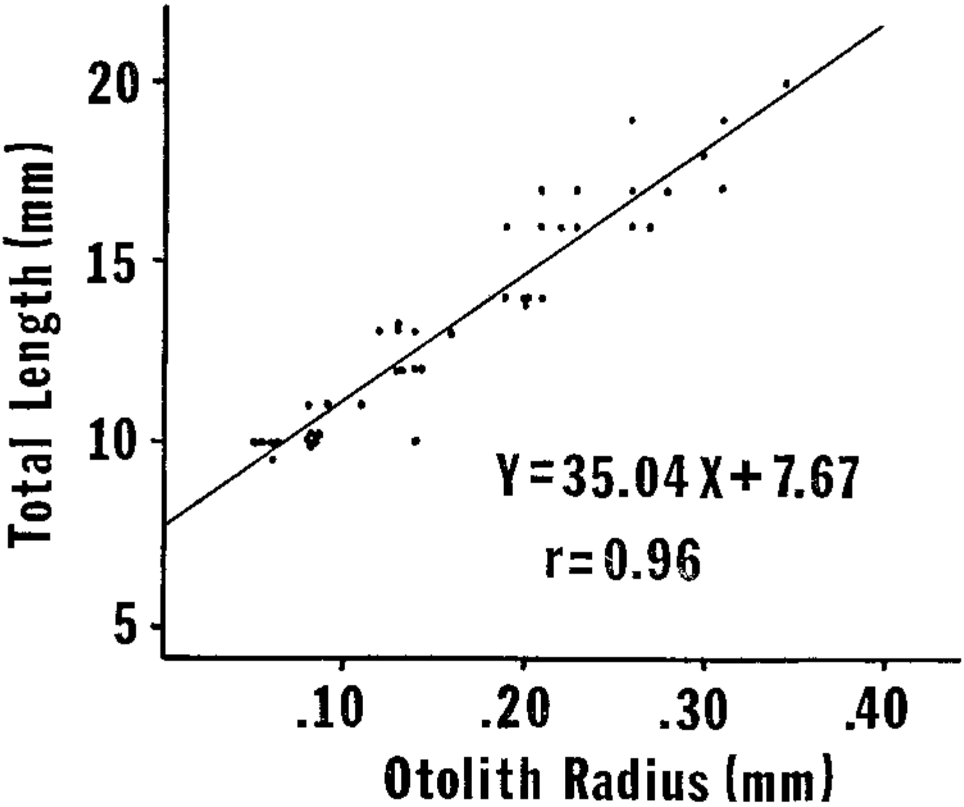

Fig. 1. Relationship of total length (Y) to otolith radius (X) for walleye larvae (n = 45).