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Otolith analysis of age and growth of larval redfish (Sebastes spp.) on Flemish Cap, 1981

by

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ABSTRACT

Sagittae of larval redfish (Sebastes spp.) were used to estimate age and growth of 8-17 mm S.L. larvae on Flemish Cap in 1981. The average growth rate of 0.08 mm/day is less than 60% of the growth rates recorded for 1979 and 1980. Back-calculation procedures are investigated and shown to be useful in determination of instantaneous growth rates for examination of the individual growth history of larval redfish. Mean instantaneous growth rates of 0.96% per day were recorded.

INTRODUCTION

The occurrence of daily growth increments in fish otoliths was first reported by Pannella (1971). Since that time, many researchers have applied this technqiue to the larvae of many fish species, demonstrating its facility for direct age determination: e.g. Engraulis mordax, Leuresthes tenius, Morone saxitilis (Brothers et al. 1976); Menidia menidia (Barkman 1978, Barkman et al. 1981). The utilization of larval otolith ageing techniques for direct growth measurement of sea-caught fish larvae has been very successful for some pelagic species (e.g. Engraulis mordax, Methot and Kramer 1979; Methot 1980) but has, thus far, been successfully used in only one demersal groundfish species, Sebastes spp. (Penney and Anderson MS 1981). The objective of this study was to estimate the growth rate of larval Sebastes spp. from Flemish Cap in 1981 in comparison to 1979 and 1980 (Penney and Anderson MS 1981) and investigate other growth-related aspects of larval redfish otolith microstructure to determine their suitability for back-calculation procedures useful in studies of individual growth histories.

MATERIALS AND METHODS

Ichthyoplankton samples for otolith studies were collected from Flemish Cap (NAFO Area 3M) during survey cruises April 27 - May 10, 1981 and May 22-27, 1981. Individual sampling locations are indicated in Fig. 1. Preservation and measurement of larvae and procedures for otolith extraction and processing have been previously described (Penney and Anderson MS 1981). Measurement of otolith radii were carried out using an ocular micrometer with a compound microscope.

RESULTS

The sagittae of 85 sea-caught Sebastes spp. larvae were examined. Of these, 81 (95%) were found to be readable. The length at age information with mean growth rate per day is summarized for each length group in Table 1. Mean increment counts ranged from 10.38 in the 8.0-8.9 mm S.L. length group to a high of 89.00 in the 16.0-16.9 mm S.L. length group while the mean growth rate ranged from a low of 0.038 mm/d for the 8.0-8.9 mm S.L. length group to a high of 0.102 mm/d for the 12.0-12.9 mm S.L. length group.

Growth rates for larval redfish on Flemish Cap in 1981 were linear over the length range examined (8.0-16.9 mm S.L.) (See Fig. 2). Linear regression by the least squares method yielded:

$$Y = 0.08X + 8.27 \quad (n = 81, R^2 = 0.79) \qquad (1)$$

where Y is the standard length in millimeters and X is the increment count (age) in days. The slope, 0.080 mm/d, estimates the larval growth rate from the onset of increment formation.

Back-calculation procedures (Bagenal 1978; Ricker 1975) were carried out on measurements of otolith radii. Of the 81 sagittae available, 52 (64%) were found suitable for such measurements. For the fish size range examined (8.0-14.9 mm S.L.), increase in the maximum otolith radius was found to be linear (see Fig. 3). Linear regression by the least squares method yielded:

$$Y = 0.757X + 7.556 \quad (n = 52,\ R^2 = 0.84) \tag{2}$$

where Y is the fish total length in millimeters and X is the otolith radius measured as the maximum distance from the focus.

The effect of fish age on otolith radius was evaluated. This relationship also proved to be linear (see Fig. 4). Linear regression by the least square method yielded:

$$Y = 0.748X - 12.427 \quad (n = 359;\ R^2 = 0.91) \tag{3}$$

where Y is the age from onset of increment formation in days and X is the maximum otolith radius measured from the focus.

Using Equation 2, mean back-calculated total length at age data for age 0, extrusion and at 5 day intervals post-extrusion was generated (see Table 2). Using equation 1 and an equation to convert standard length to total length (Penney, unpubl.)

$$Y = 1.29X - 1.87 \quad (n = 133,\ R^2 = 0.99) \tag{4}$$

where Y is the total length in millimeters and X is the standard length in millimeters, the expected total length at age data for age 0, extrusion and at 5 day intervals post-extrusion was generated (see Table 2). The mean back-calculated total length at age data from Equation 2 and the expected total length at age from equation 1 and 4 were compared and were found to be not significantly different ($t = 0.40$, $P > .05$), supporting the accuracy of the back-calculation procedure.

Mean instantaneous growth rates were then calculated for each age group

$$\bar{X}_g = \frac{\Sigma \dfrac{\log_e L_t - \log_e L_{t-1}}{\Delta t}}{n} \tag{5}$$

where $\bar{X}_g$ is the mean instantaneous growth rate for the age group, L_t is the back-calculated total length for each fish at the age t, L_{t-1} is the back-calculated total length for each fish at the previous age t-1, Δt is the number of days elapsed since the previously calculated total length and n is the number of individual fish. All X_g values were expressed as %/d (see Table 2 and Fig. 5).

The mean instantaneous growth rates ranged from a high of 1.1% per day during the interval from onset of increment formation to extrusion to a low of 0.77% per day in the interval day 36-40 post-extrusion for an overall mean of 0.96% per day from the onset of increment formation to day 40 post-extrusion. The instantaneous growth rate declined steadily from extrusion to a low of 0.89% per day by day 15 post-extrusion, then rebounded to 1.06% per day by day 30 and declining thereafter.

DISCUSSION

For the April-May period on Flemish Cap results of larval ageing of Sebastes spp. indicated a growth rate of 0.08 mm/d in 1981. This is very low compared to estimates of 0.143 mm/d and 0.135 mm/d for redfish in 1979 and 1980 respectively (Penney and Anderson MS 1981) and is extremely low when compared to other species (i.e. 0.195 mm/d for Georges Bank herring, Lough et al. MS 1980) and 0.34-0.55 mm/d for Northern anchovy, Methot and Kramer 1979). The 1981 growth rate of 0.08 mm/d is significantly lower than either the 1979 growth rate ($F = 34.77$, $P < .0001$) or the 1980 growth rate ($F = 42.82$, $P < .0001$). The cause or causes of this low growth rate is as yet unexplained. Work on this aspect is continuing.

Back-calculation procedures were found to be possible on larval redfish otoliths. Total length rather than standard length was found to give the best correlations with otolith radii measurements. This is not surprising given the long and variable period when larvae are in flexion of the notochord (Penney MS 1982). Only 64% of available sagittae were found suitable for microstructure measurements. This is caused by the necessity to measure inter-ring radii in a straight line along the maximum otolith radius and by the increasing obscurity of inner rings in larger sagittae due to thickening in the central region.

Both total length and age from onset of increment formation were significantly and linearly related to otolith radius over the fish size range examined (8.0-15.0 mm). During this time the shape of larval redfish sagittae is elliptical. However, with increasing size, the sagittae become more elongate and otolith growth becomes distinctly asymmetrical. Although no sagittae of this type were available in the existing data, it is expected that such sagittae from fish >15 mm S.L. will show a different fish length to otolith radius relationship necessitating modification of the back-calculation equation.

Back-calculation mean length-at-age data were not significantly different from the expected mean length at age calculated from the population length versus age equation (Equation 1) indicating the potential accuracy of construction of individual growth histories based on this procedure for larval redfish. Construction of such growth histories may prove very profitable in assessment of the effect of specific oceanographic or environmental events on larval growth. Further work on this aspect is proceeding.

Instantaneous growth rates calculated from the back-calculated length at age data indicate the pre-extrusion period is the time of fastest growth (1.1% per day), at least in the period prior to day 40 post-extrusion. The early post-extrusion period up to day 15 was a period of declining growth rates followed by a period of recovery until day 30 post-extrusion. As yet, it is not known if this is the usual growth history pattern for larval redfish or whether it is peculiar to the overall poor growth of the 1981 year-class.

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Table 1. Number of otolith growth increments and mean growth rate per day per unit standard length for larval *Sebastes* spp. from Flemish Cap, 1981.

Length group (mm S.L.)	Otoliths examined	Increments ($\bar{x}$)	S.D.	Range	Growth rate ($\bar{x}$ mm d^{-1})	S.D.
8.0- 8.9	8	10.38	2.62	76-102	0.038	0.038
9.0- 9.9	26	17.46	9.00	7-44	0.083	0.033
10.0-10.9	18	28.06	5.43	20-37	0.080	0.016
11.0-11.9	24	34.96	8.03	24-55	0.093	0.018
12.0-12.9	3	40.00	6.00	34-46	0.102	0.012
13.0-13.9	-	-	-	-	-	-
14.0-14.9	-	-	-	-	-	-
15.0-15.9	-	-	-	-	-	-
16.0-16.9	2	89.00	18.38	76-102	0.091	0.016

Table 2. Back calculated total length at age, calculated total length at age and instantaneous growth rate at age for larval redfish (*Sebastes* spp.) on Flemish Cap, 1981.

	Back-calculated mean length at age				Calculated total length at age from Eq. 1&2	Instantaneous growth rate at age		
Age	$\bar{x}$	S.D.	$S_{\bar{x}}$	7		(% d^{-1})	S.D.	$S\bar{x}$
0	8.56	0.16	0.022	56	8.84			
Extrusion	8.87	0.16	0.022	52	9.15	1.10	0.19	0.03
5[1]	9.32	0.17	0.024	51	9.67	1.00	0.17	0.02
10[1]	9.80	0.22	0.035	40	10.18	0.98	0.18	0.03
15[1]	10.26	0.28	0.046	37	10.70	0.89	0.18	0.03
20[1]	10.68	0.38	0.066	32	11.22	0.98	0.23	0.04
25[1]	11.35	0.49	0.093	27	11.74	0.99	0.23	0.04
30[1]	11.96	0.75	0.186	16	12.26	1.06	0.26	0.07
35[1]	12.77	1.05	0.428	6	12.77	0.90	0.16	0.07
40[1]	13.31	1.55	0.894	3	13.29	0.77	0.10	0.06

[1] Age in days post-extrusion.

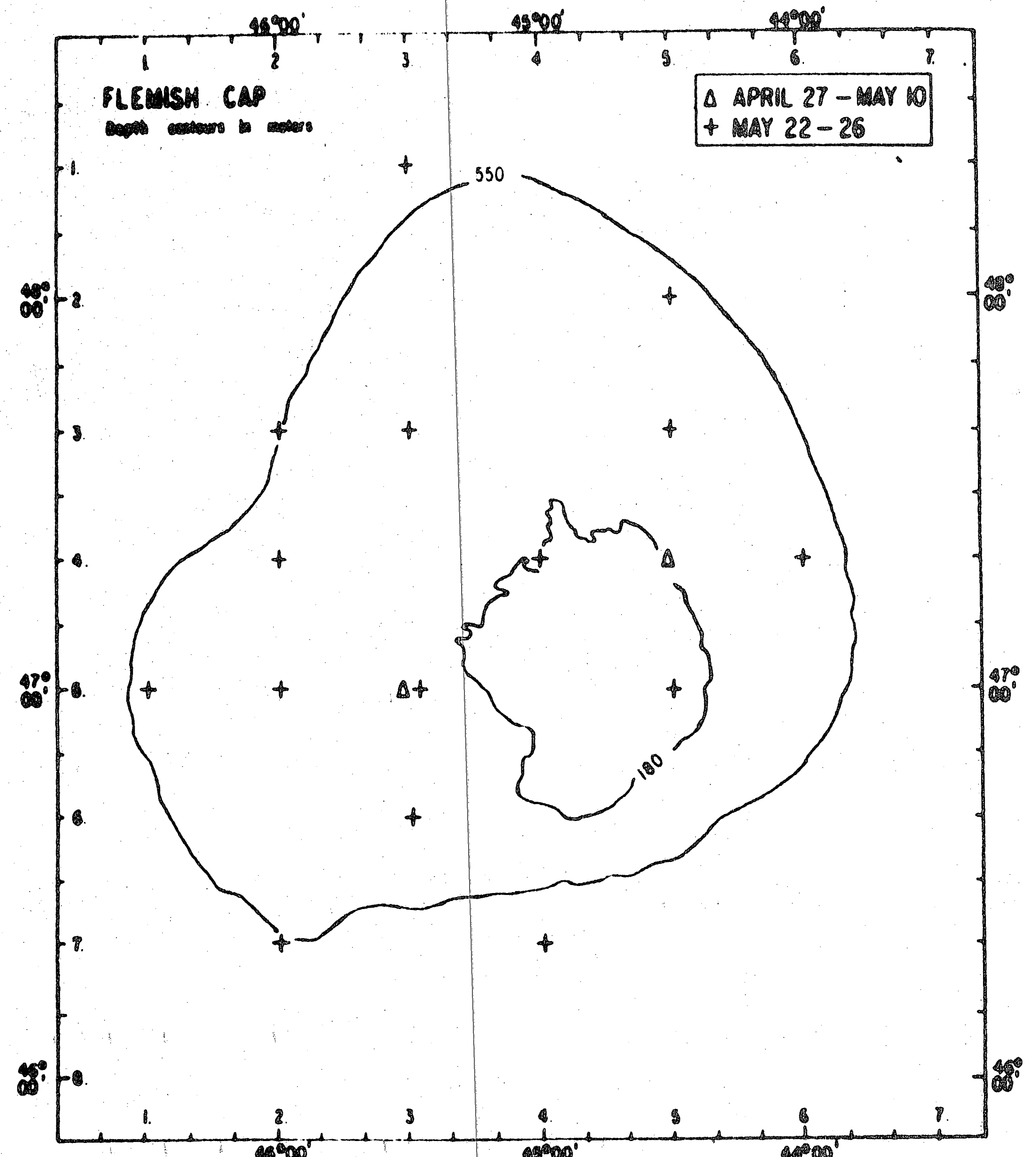

Figure 1. Redfish sample locations in 1981 used for otolith examinations. (Δ denotes GADUS 50, April 27-May 10, + denotes GADUS 51, May 22-26)

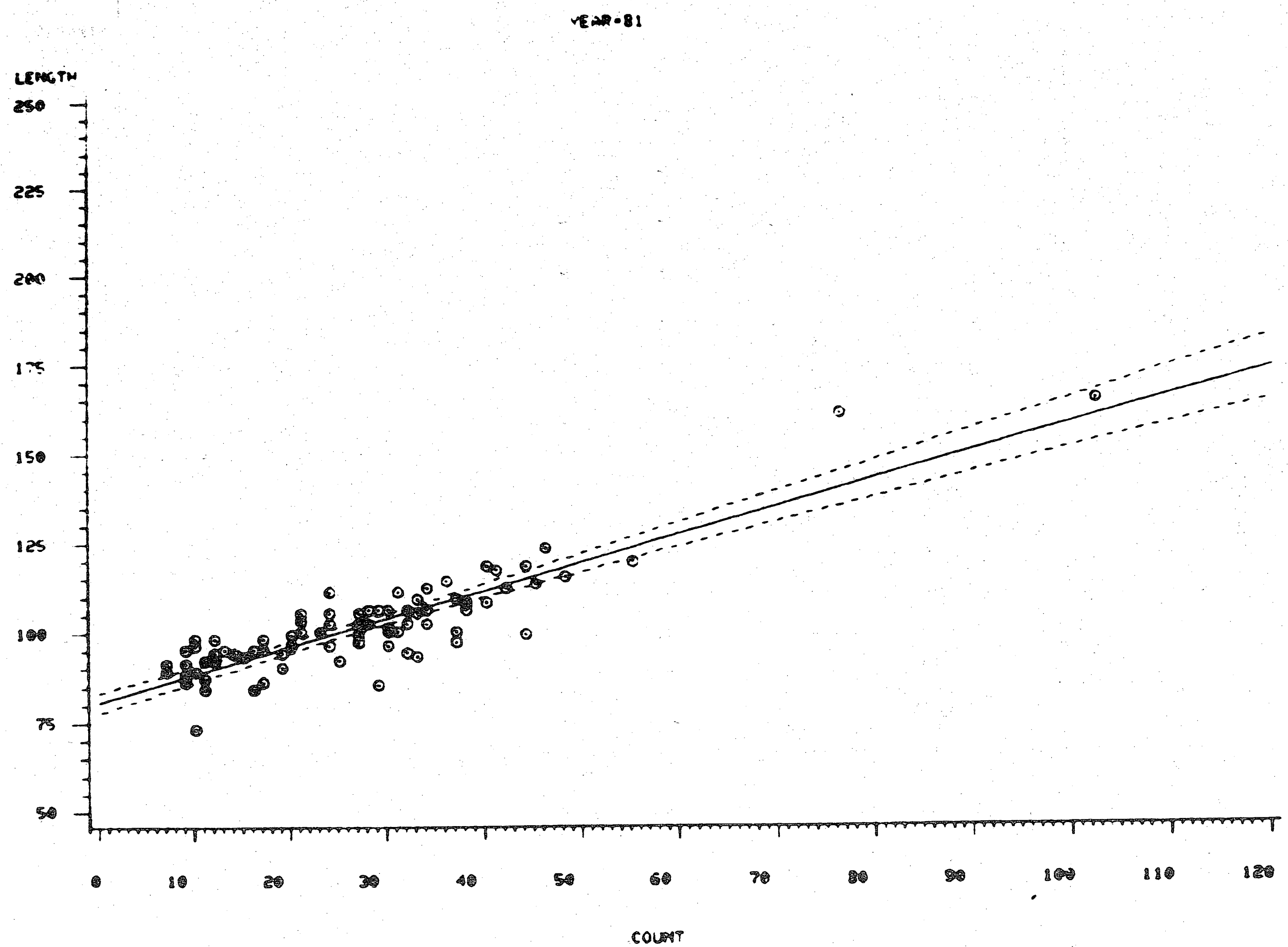

Figure 2. Age from onset of increment formation (count) versus standard length for larval redfish (Sebastes spp.) in 1981 (R^2 = 0.79). Dashed lines indicate 95% confidence intervals.

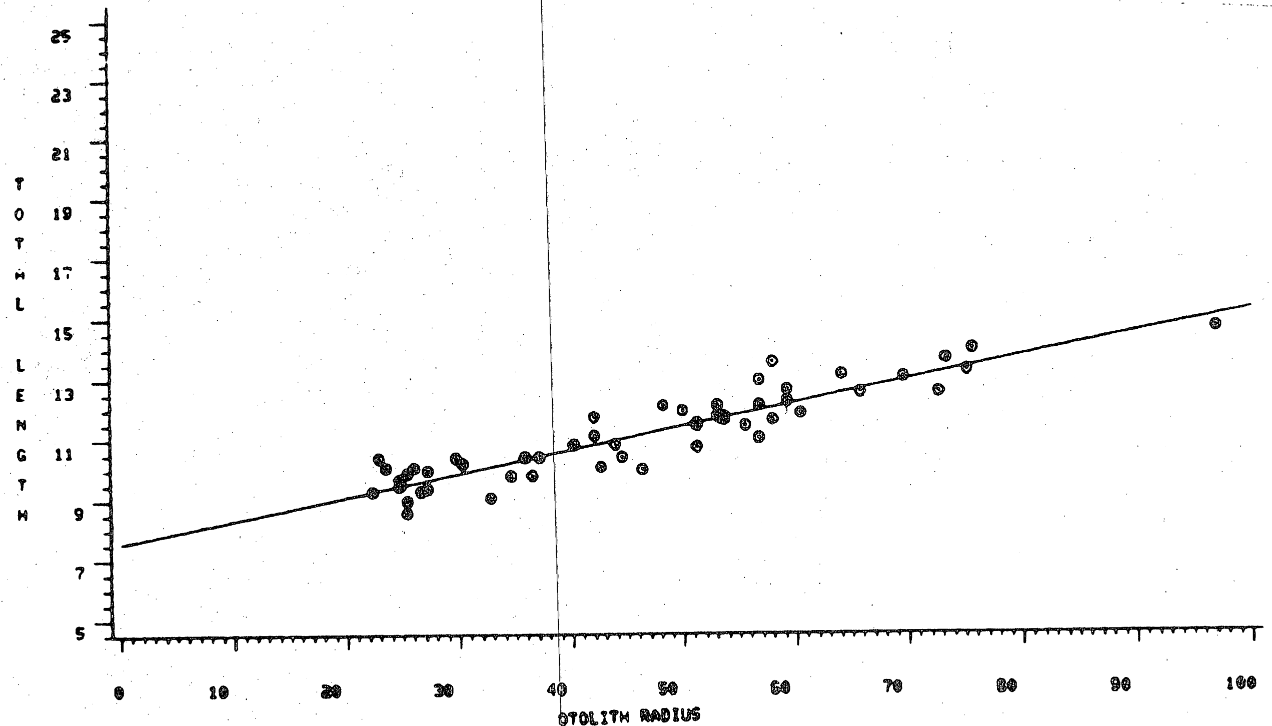

Figure 3. Maximum otolith radius (μm) versus total length for larval redfish (<u>Sebastes</u> spp. from Flemish Cap, 1981 (R^2 = 0.84).

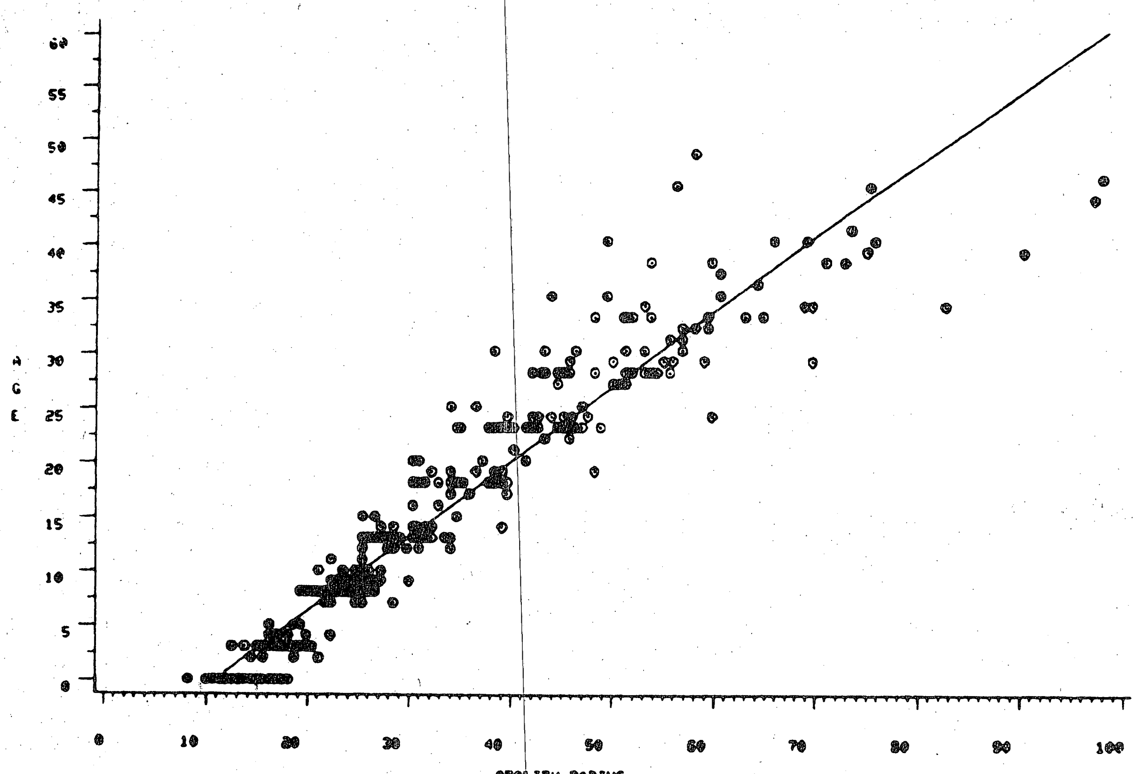

Figure 4. Back-calculated age from onset of increment formation versus maximum otolith radius (μm) for larval redfish (<u>Sebastes</u> spp.) from Flemish Cap, 1981. (R^2) = 0.91.

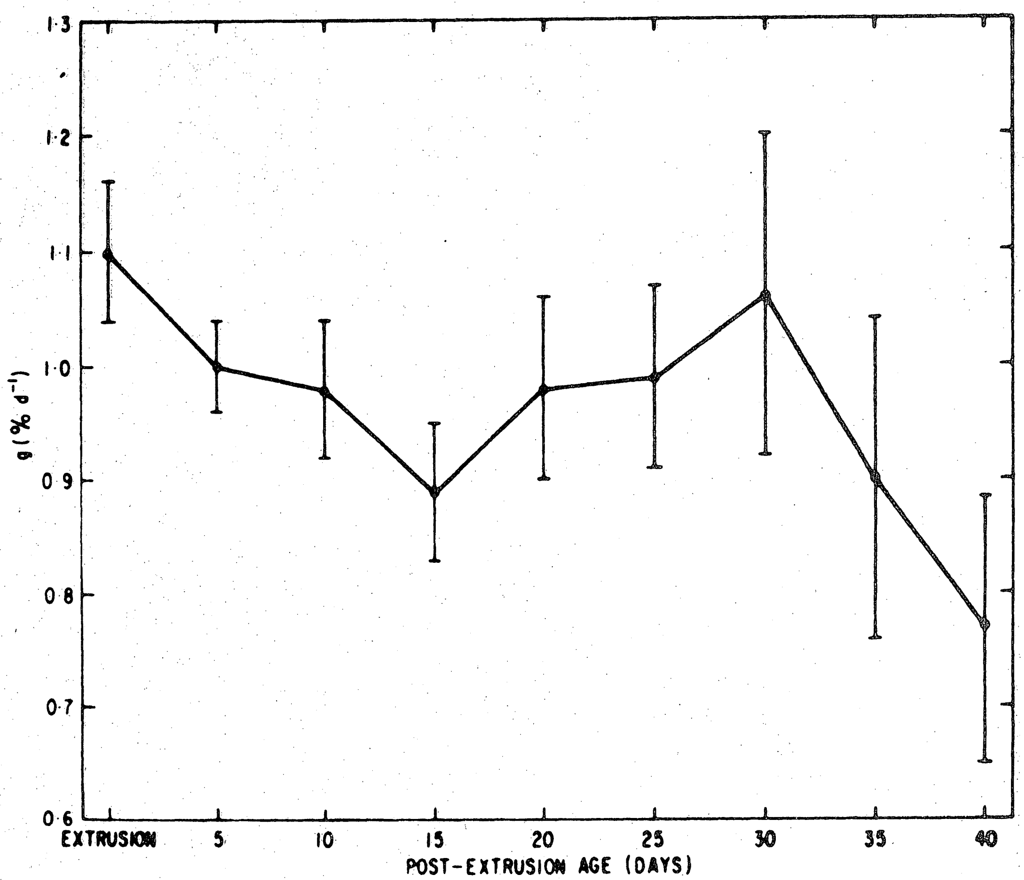

Figure 5. The instantaneous growth rate (g) in % d^{-1} versus post-extrusion age in days for larval redfish (Sebastes spp.) from Flemish Cap, 1981.