# BEAUFORTIA

INSTITUTE OF TAXONOMIC ZOOLOGY (ZOOLOGICAL MUSEUM)
UNIVERSITY OF AMSTERDAM

Vol. 32 no. 7 December 22, 1982

# SOME ASPECTS OF THE DISTRIBUTION, METAMORPHOSIS AND GROWTH IN *SERRIVOMER PARABEANI* BERTIN, 1940 (PISCES, APODES, SERRIVOMERIDAE) RELATED TO GROWTH FEATURES IN THEIR OTOLITHS

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ABSTRACT

Metamorphosis and growth of *Serrivomer parabeani* Bertin, 1940, are analysed, in relation to growth features in their otoliths. The animals were caught during the spring expedition in the Mid North Atlantic in 1980. It proved that the actual metamorphosis from leptocephalus to eel-like animal is of short duration. Growth in length and the development of the pigmentation is relatively slow. The animals from this series of samples do not show vertical migration. They are mainly restricted to water layers with temperatures between 8° and 12° C and depths between 450 and 1000 m, except at station 24, at the western side of the Great Meteor Bank, where some animals were caught at depths between 110 and 300 m, during the night.

## INTRODUCTION

In the course of the sampling programme of the Amsterdam Mid North Atlantic Expedition *, held from April 11th to May 2nd 1980, between latitude 55° N and 25° N along longitude 30° W, a number of larval, postlarval and adolescent individuals of *Serrivomer parabeani* Bertin, 1940, were collected. The present paper is mainly restricted to metamorphosing and adolescent specimens of this species as reasonable numbers of them became available. This offered the possibility to analyse some aspects of the development of this species, in relation to the age of the animals.

* AMNAPE, Project 101A, rep. no. 9 supported by a grant of the Netherlands Ministry of Education and Sciences, NRZ (rep. no. 8 appeared in Beaufortia, vol. 32, no. 6, 1982).

## METHODS

The samples were caught with a combined I.O.S. RMT 1+8 opening and closing net, as described by Baker, Clarke and Harris (1973). Measurements of the depth of the net, flow and temperature were recorded by a net monitor system. For details about the stations, positions, hydrographic conditions etc. see Van der Spoel (1981). All specimens mentioned in this paper and also the leptocephali of this species were invariably caught in the RMT 8 net.

After landing the nets on deck, the cod ends were taken off as soon as possible. The contents were carefully transferred into coolboxes filled with filtered seawater of ambient temperature. As soon as time permitted, sorting of the sample started after which the leptocephali immediately were transferred and preserved in alcohol 70%. This prevents damage or dissolution of the otoliths. Fixation for some time in formalin 4% resulted in dissolution of the otoliths of some metamorphosing and adolescent animals, whereas their bony parts were etched. In these cases the fixation had lasted too long before the animals were transferred to alcohol.

Afterwards, the definitive identification took place, and a series of measurements was taken. The otoliths were prepared for microscopical examination. In table I the data concerning the metamorphosing and adolescent animals caught during this expedition are given. All specimens are incorporated in the collections of the Zoological Museum, Amsterdam.

## RESULTS

Table I shows that most samples contained a single specimen of *Serrivomer parabeani*, except in station 25 and 27, where 26 and 23 animals were caught, respectively. In the samples from the stations between 49° and about 40° N latitude, this species was absent. Whether this is caused by seasonal variations in abundance and distribution is uncertain.

From data about the depth at which *Serrivomer* was caught (see Fig. 1 and table I) it is not clear if they perform diurnal vertical migrations. Most animals of this species were caught at depths between 500 and 1000 m during daytime, at the same stations shallower hauls were made during the night. At station 21 one individual of *S. parabeani* was caught even during the night between 500 and 1000 m, whereas at station 24 some individuals were caught between 110 and 300 m during the night and around dawn. However, this station was close to the western side of the Great Meteor Bank, which may influence the conditions in such a way that the animals are forced in some way or another to go into higher levels. Only at stations 25 (28°42'N 29°59'W) and 27 (24°48'N 28°47'W) over 20 specimens of *S. parabeani* were caught during daytime at a depth between 450 and 1000 m. Thus, from the present samples it seems likely that post-larval and adolescent specimens of this species show only little or no diurnal vertical movements. They are mainly restricted to waters with a temperature between 8° and 12° C. However, in the north at about 49° N, one animal was caught in a layer with a temperature between 5° and 9° C. In the south, between about 30° and 25° N, only a few

Table I. Geographical and bathymetrical data for *Serrivomer parabeani*.

| Station | Haul | Position | Date 1980 | D(ay) N(ight) | Depth in m | Temp. at depth | Number of specimens | ZMA | Length in mm |
|---|---|---|---|---|---|---|---|---|---|
| 13 | 9 | 49°00.8'N 29°18.5'W | 17-IV | D | 480-1005 | 6.7° C | 1 | 118.777 | 293 |
| 18 | 10 | 39°53.9'N 35°58.9'W | 22-IV | D | 440- 910 | 10.4° C | 1 | 118.778 | 191 |
| 19 | 22 | 37°48.5'N 35°17.4'W | 24-IV | D | 500-1000 | 10.2° C | 2* | 118.779 | 123 |
| 21 | 6 | 33°40.5'N 30°40.6'W | 27-IV | N | 510-1000 | 10.6° C | 1 | 118.780 | 112 |
| 23 | 2 | 30°39.9'N 29°59.5'W | 28-IV | D | 505- 960 | 11.0° C | 1 | 118.781 | 113 |
| 24 | 1 | 29°48.1'N 29°57.5'W | 29-IV | N | 110- 205 | 18.1° C | 2* | | |
| 24 | 3 | 29°44.0'N 29°57.7'W | 29-IV | N/D | 200- 300 | 16.2° C | 1 | 118.782 | 110 |
| 25 | 1 | 28°42.0'N 29°59.1'W | 29-IV | D | 490-1000 | 10.5° C | 26 | 118.783 | 62.5–126.5 |
| 27 | 10 | 24°48.6'N 28°47.2'W | 2-V | D | 475-1000 | 10.3° C | 23 | 118.784 | 69.5–215 |

* More or less badly damaged animals.

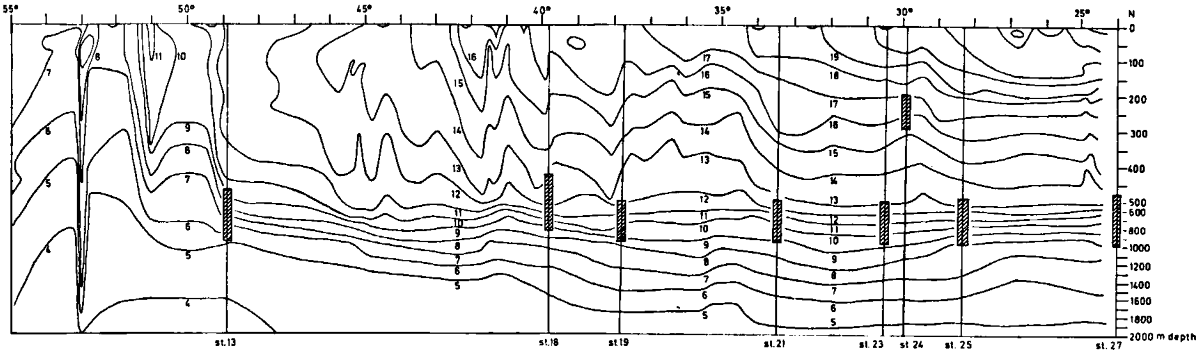

Fig. 1. Positions of the stations, depth and temperature at which *Serrivomer parabeani* is caught.

animals were caught in layers in which the temperature of the water varied between 14° and 20° C.

It seems likely that the southern section of the present series of stations is relatively close to the spawning area of this species, since most small animals and all metamorphosing specimens were caught here. The longest animal in the present series (TL = 293 mm, see table I) was caught far north at station 13, at about 49°00'N 29°18'W. This fits well with the data about size and distribution of *Leptocephalus lanceolatus* Strömman, 1896, presented by Beauchot (1959: 55, fig. 42; and : 59, fig. 47), who assigned this leptocephalus to *Serrivomer parabeani*.

*Changes in body shape*

The present series of animals offers the possibility to analyse metamorphosis and growth and to relate these to the growth features present in their otoliths.

Analysis of meristic data of *S. parabeani* reveals that there is only a slight variation in the size of the eyes, since there is no increase in the diameter with increasing length. The animals have round eyes with a mean diameter of 0.6 mm (*var.* = 0.01; S.D. = 0.1; $N$ = 37). The other measurements shows an increase related to the growth of the animals.

Initially, in metamorphosing animals up to a length of about 80 mm, the postorbital width, the height in front of the eye, and the postcranial depth are about equal. (Fig. 2) During further growth the postorbital width shows a slight increase. The equation for the regression line is: $Y = 0.004X + 1.16$ ($N = 39$; $r = 0.44$; $P<0.01$). However, the postcranial depth and the height in front of the eye increase significantly, though the former more than the latter (Fig. 2). The equations for the regression lines are respectively: $Y = 0.017X + 0.371$ ($N = 48$; $r = 0.94$; $P<0.001$) and $Y = 0.012X + 0.212$ ($N = 48$; $r = 0.97$; $P<0.001$). The greater increase of the postcranial depth or height of the head is mainly caused by the marked development of the dental and angular bone during this period. This produces the marked lateral aspect of the head of *Serrivomer*, in which the sharp caudal angle of the lower jaw becomes clearly pronounced in caudo-ventral direction.

In Fig. 3 the length of the head and the snout length are plotted. The equations for the regression lines are respectively: $Y = 0.091X + 3.15$ ($N = 44$; $r = 0.95$; $P<0.001$) and $Y = 0.053X + 2.32$ ($N = 43$; $r = 0.88$; $P<0.001$). Here both lines differ significantly from the horizontal,

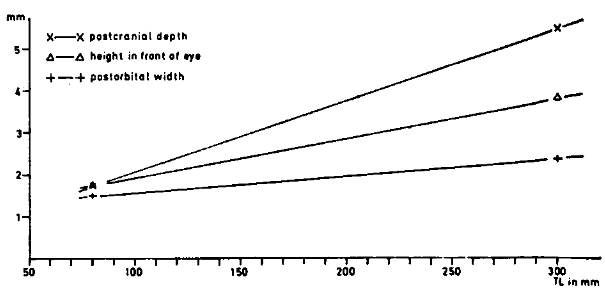


Fig. 2. Change in width and height of the head during growth.

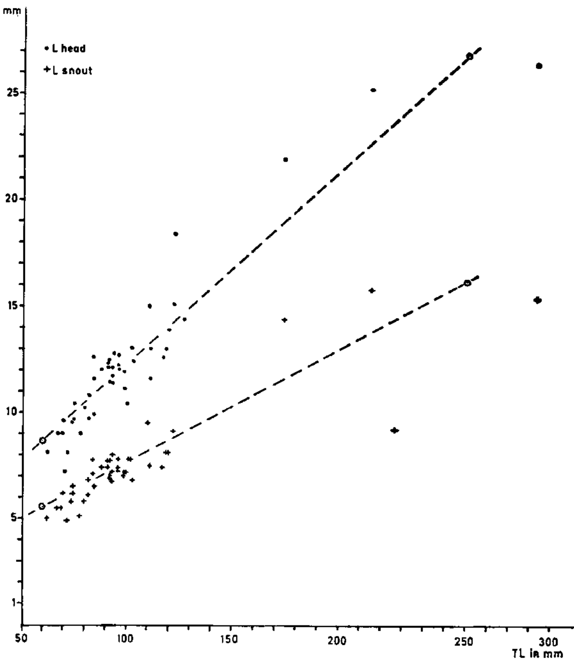


Fig. 3. Growth in length of the head and snout.

showing a steep increase. From these graphs it can be concluded that the increase of the proportions of the head is mainly caused by the increase in length of the neurocranium and, to a slightly lesser extent, to the increase of the snout length. As is described above only a small increase in width and height of the head occurs at the same time.

The analysis of the relation between the mid-body depth and the length reveals some features

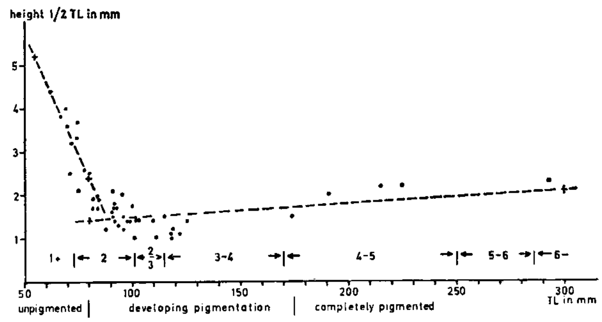


Fig. 4. Change of the form of the body during metamorphosis and growth (dotted lines) and development of the pigmentation related to the age of the animals, indicated by the numbers of growth zones in their otoliths, given in the lower part of the graph.

of the metamorphosis and growth in the present series of animals, ranging in length from 62.5 mm to 293 mm. This largest specimen is about half the maximal length mentioned by Beebe & Crane (1936). In Fig. 4 the relation of the mid-body depth with the total length is plotted. This graph shows a division into two groups of animals in the present sample. One group comprises animals shorter than about 85 mm, in the second group all specimens from 85 mm to 293 mm are included. At the left in the graph a sharp decline of the height of the body is visible, from about 4.5 mm to about 1.5 mm. Thereafter, a slow increase in height of the body takes place, from 1.5 mm to about 2.5 mm. The regression lines have the following relations: $Y = -0.11X + 11.36$ ($N = 11$; $r = 0.8$; $P<0.01$) for the left side of the graph, and $Y = 0.003X + 1.19$ ($N = 36$; $r = 0.4$; $P<0.01$) for the right side. The left part represents the last stages of the metamorphosis, from the leaf-like body form of the leptocephalus to the developing eel-like body form in the adolescent animals. The decrease in height of the body is significant and steep, suggesting that this transformation takes relatively short time. This was also supposed by Beebe & Crane (1936). There is only a small increase in body length during this period. The right part of the graph shows a small increase in height of the body with increasing length. The animal now becomes more and more eel-like. This process seems to be rather slow.

*Development of pigmentation*

The animals in the present series, up to about 80 mm body length, are almost all completely unpigmented. In some individuals between 75 mm and 80 mm first signs of the onset of pigmentation are present. In *Serrivomer* the pigmentation starts as very small light brown spots at the ventral side of the body. The spots are well separated from each other. This pigmentation is first visible just behind the head in the region of the branchial apparatus, and in the caudal region near the tip of the tail. Up to a body length of 100-120 mm the small spots are gradually spreading along the entire ventral side, and over the lateral sides to about half way the height of the body. In the mean time, the pigmentation grows gradually denser at the ventral and lateral sides. This process spreads from both the cranial and caudal end of the body to the middle. At the same time, it is gradually spreading over the dorsal surface. So, at a length of about 170 mm the pigmentation is at last completed. In the mean time, the colour of the animals darkens more and more as the pigment spots become larger and darker. However, the stomach is already dark brown to black early after metamorphosis, when the animals have attained a length of at least 100 mm. There are, however, individual variations in this process when considering the lengths of the specimens.

### *The otoliths*

Through a small incision in the skull, lateral of the brain, at least one sagitta and in some cases also the lagena was taken and mounted on a glass-slide in canada balsam for microscope examination and recording of the variations in density by a set of apparatus described already before (Van Utrecht, 1971; Van Utrecht & Schenkkan, 1972; Deelder, 1976a, 1976b). The amount of light passing through the otolith and projected on a light dependent resistance, determines the course of the line written by a stripchart recorder. The light and dark parts along the recorded track of the otolith are represented by successive peaks and hollows in the recording in which the amount of light, transmitted through the otolith, determines the height of the line.

Initially, the otoliths of the leptocephali are small, nearly circular bodies, flattened on one side. This remains so until they reach a length of about 100 mm. Then the growth in antero-posterior direction becomes predominant over the growth in dorso-ventral direction. From table II and fig. 5 and 6 it is obvious that they become more and more oval. This elongation is demonstrated by the upper of the two lines in fig. 5. This line shows a strong increase from 0.19 mm in the smallest specimen to 0.77 mm in the longest. The increase along the other axis, perpendicular to the longest axis, stays behind and is from 0.17 mm to 0.46 mm. This is also demonstrated by the difference of the angle of both regression lines with the horizontal.

Together with the elongation of the otolith the development of a "rod"-like structure starts after the animals have attained a length of about 111 mm (figs. 5 and 6). Since the basis of this "rod" is not clearly defined, the measurement of its length has been taken from the centre of the otolith to its tip. The real length of the "rod" is somewhat shorter. However, these measurements give a good impression of its growth. Fig. 5 shows its growth being more or less the same as the increase of the smallest diameter of the otolith, though at a slightly lower level.

Table II. Growth of the otolith of *Serrivomer parabeani*. Animals selected from the samples and arranged according to their lengths.

| station | length in mm | ø otolith min./max. in mm | width of growth zone in mm I | II | III | IV | V | VI | VII | "rod" in mm |
|---|---|---|---|---|---|---|---|---|---|---|
| 25 | 70 | 0.18/0.20 | 0.09 | 0.05 | | | | | | |
| 25 | 71 | 0.17/0.19 | 0.07 | 0.06 | | | | | | |
| 25 | 74.5 | 0.18/0.22 | 0.09 | 0.07 | | | | | | |
| 25 | 100 | 0.21/0.25 | 0.08 | 0.09 | | | | | | |
| 25 | 103 | 0.21/0.26 | 0.08 | 0.08 | 0.03 | | | | | |
| 25 | 111 | 0.26/0.32 | 0.09 | 0.09 | 0.05 | | | | | |
| 27 | 118.5 | 0.24/0.33 | 0.09 | 0.09 | ? | | | | | 0.16 |
| 27 | 174 | 0.34/0.47 | 0.08 | 0.12 | 0.11 | 0.04 | | | | 0.22 |
| 18 | 191 | 0.39/0.55 | 0.09 | 0.11 | 0.08 | 0.07 | 0.06 | | | 0.25 |
| 27 | 215 | 0.39/0.64 | 0.08 | 0.08 | 0.09 | 0.08 | 0.02 | | | 0.30 |
| 25 | 255 | 0.43/0.64 | 0.08 | 0.09 | 0.08 | 0.07 | 0.05 | | | 0.32 |
| 13 | 293 | 0.64/0.77 | 0.07 | 0.08 | 0.06 | 0.06 | 0.08 | 0.07 | 0.03 | 0.33 |

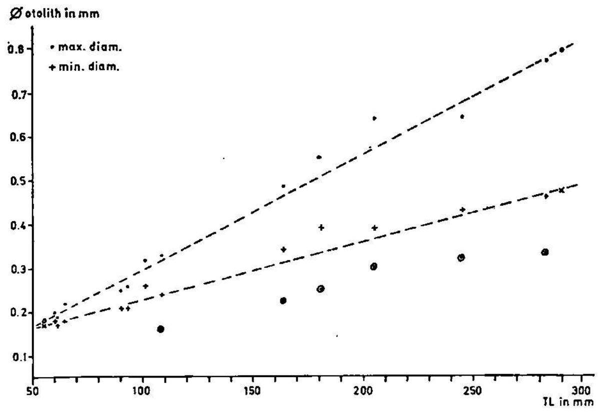


Fig. 5. Growth of the otolith measured along the longest and shortest axis. The encircled dots give the increase in length of the "rod-like" structure.

Microscopic examination of the otoliths shows increasing numbers of growth zones with increasing length of the specimens (table II). A growth zone is an area in the otolith, from the outer rim of a well pronounced dark line up to and including the next dark line. Without any further preparation, a number of lines are visible in a growth zone. These lines are finer and lighter than the lines marking the borders of a growth zone. In all cases these "secondary" lines could be counted, 10 to 13 of these being present in each growth zone. They were very regular interspaced.

In table II the results of the measurements of the growth zones are given. These measurements are taken along the long axis of the otolith. In its centre is a small dark spot, the kernel, surrounded by a small circle. This part is considered to be formed during the prelarval stage. The first measurement is taken from the kernel to the first conspicuous dark ring, which forms the border line of the first growth zone. The second and subsequent measurements are taken from that ring to the next one, and so on. The measurements are given in mm, arranged according to the total length of this series of selected animals, ranging in length from 71 mm to 293 mm. From this table it is obvious that the number of growth zones increases with increasing length. Moreover, the

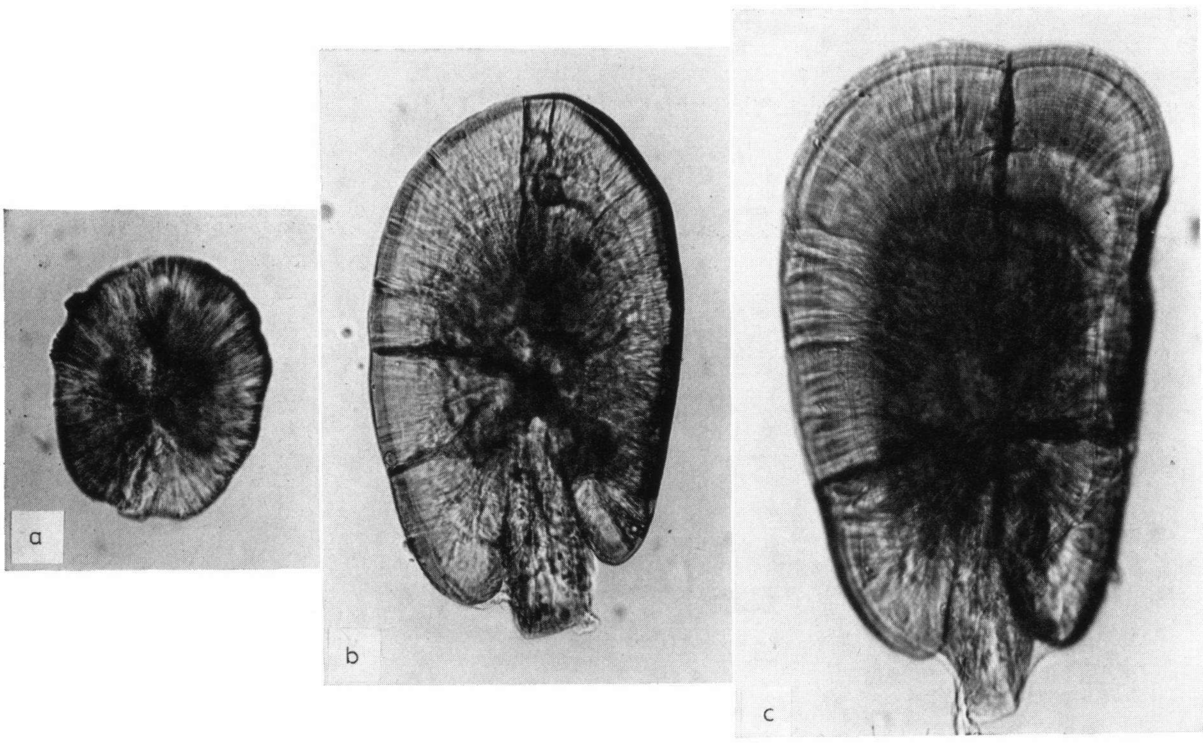


Fig. 6. Otoliths of *Serrivomer parabeani.* a) ZMA 118.782, TL = 111 mm; b) ZMA 118.784(1), TL = 215 mm c) ZMA 118.777, TL = 293 mm.

small variation in the measured distances is evident. The means of the distances varies between 0.07 and 0.09 mm. In most cases the last growth zone is incomplete as is expressed by the shorter distances and the greater variation.

The data concerning the numbers of growth zones are correlated with the data about metamorphosis and the growth thereafter, and with the data about the development of the pigmentation (see Fig. 4). From this figure it is evident that the metamorphosis from leptocephalus to the eel-like animal, expressed by the decrease in height, occurs very rapidly. This means that, from hatching to the completion of the metamorphosis, at least two complete growth zones are laid down in the otolith, and the animals have attained a length of about 90 mm. Thereafter the increase in height related to the growth in length is slow. At a length of about 170 mm four complete growth zones are formed. At a length of about 250 mm five complete growth zones are laid down, whereas in the otolith of the animal of 293 mm six complete growth zones were found with a part of the seventh zone already formed.

The development of the pigmentation can be related to these data. Up to a length of 70 mm the animals are completely unpigmented. When two growth zones are formed, pigmentation starts in the cranial and caudal region at the ventral side. This process is completed when at least four growth zones are deposited in the otoliths and the animals have attained a length of about 170 mm.

*Variations in density in the otoliths*

In Fig. 7 a selection is given of a series of recordings of the variations in density in the otoliths, arranged according to the increase in length of the animals. All are from stations 25 and 27 and are considered to be from the same area (for the exact positions see table I).

Only the part of the recording from the centre of the otolith towards its rim, taken along the longest axis of the otolith, is reproduced here. The centre of the otolith is at the left side and indicated by a solid line. The dotted lines indicate the dark rings, marking the margins of the growth zones. From this figure it is evident that the length of the recorded track increases with the increasing length of the specimens (see also table II).

When comparing recordings, it is evident that a pattern of two groups of peaks and hollows is always present in each growth zone. The border line is mostly a deep sharp hollow between two such groups. The hollow marks the dark line, which in transmitted light has a far greater density than the preceding and following adjacent lines.

The resemblance of the pattern of peaks and hollows in the three first formed zones in each

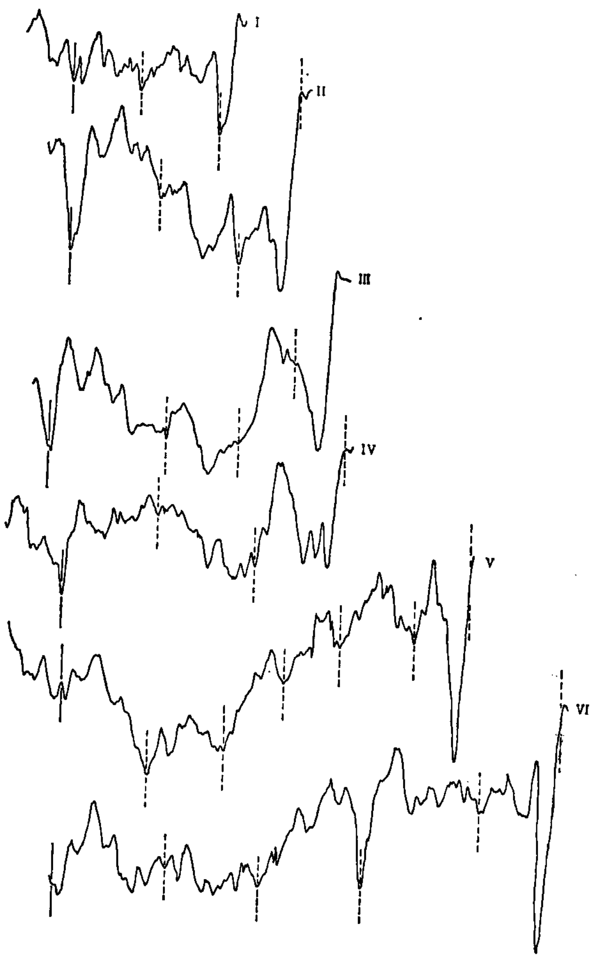


Fig. 7. Recordings of the variations of the density in otoliths of *Serrivomer parabeani*, with a length of respectively 71 mm (I), 103 mm (II), 111 mm (III), 118.5 mm (IV), 174 mm (V) and 215 mm (VI) (see also table II). The solid vertical line at the left in each recording indicates the centre of the otolith, the dotted lines indicate the borders of the growth zones.

individual recording as also in the series of recordings is evident. There is a regular and fairly constant interspaced repetition of the pattern. Thereafter, the pattern in the following growth zones differs from that in the preceding ones. This is visible in the recordings of animal ZMA 118.784(2) (TL = 174 mm), and ZMA 118.784(1) (TL = 215 mm). The records of the two animals, of station 13 and 18, show even greater differences. These are respectively 293 mm and 191 mm long.

The uniformity of the pattern in the records of the parts of the otoliths formed at young ages, the growth zones I, II and III, can be explained from the fact that all animals then lived under the same conditions, most probably in the Sargasso area. However, the longer animals from the same samples (station 25 and 27) with a greater number of growth zones in their otoliths, show differences in the pattern of the growth zones formed later on, though they lived under the same conditions. This change in the pattern in the older animals may indicate that the animals may enter another stage in their development after three growth zones are formed. As the numbers of larger and older animals in the present series of samples is to small, this point can not be elucidated here. However, it is striking that records of those parts of the otoliths deposited before and after metamorphosis do not show any visible difference, although great changes occur in the animals. This may indicate that the actual metamorphosis is of too short duration to be recorded in the otoliths (see also above p. 120).

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Received: June 28, 1982

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