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Age and Size of Spiny Dogfish (*Squalus acanthias*) from the Northwest Atlantic Ocean

by

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Abstract

Age determinations of sharks are always attached to some serious problems of both methodological, and practical nature. A number of considerable troubles arises when working with the spiny dogfish, as well. The task becomes complicated not only with an existence of the additional rings in the spine ground edge but also with a necessity of introduction of a correction for the spine diameter in the place of the ground edge production. Just those very problems have been examined in the paper.

Introduction

Studies on the age-size composition of population are the basis of the modern mathematical methods used when calculating stock and value of fish possible catch. An accurate age determination is of the great importance for such studies as rather small errors may have a considerable influence upon the final results of calculation.

At present, the scientist carry out a lot of fundamental investigations on the determination of fish age, including shark age determination. However, shark age determinations have been attached up to date to substantial troubles both of methodological and practical nature. That is why every investigation of this character will be of great value.

The author of the paper gives an account of his approach to the problem and suggests the method of age determination of the spiny dogfish from the Northwest Atlantic Ocean.

Material and Methods

Most scientists use the spines before dorsal fins for the spiny dogfish age determinations (Kaganovskaya, 1933; Kondiurin, 1973; Probatov, 1957; Holden and Meadows, 1962; Templeman, 1944; Ketchen, 1975, et al.). Either marks on the outer spine surface (Kaganovskaya, 1933; Probatov, 1957) or annual growth zones on the spine sawing down (Kondiurin, 1957), or both are studied for the control.

There are technically complicated methods, as well, which are presented in later papers (Jonsen and Glen, 1977; Ketchen, 1975).

An examination of these methods has shown that determination of the spiny dogfish age by the second dorsal spine sawings down was the most profitable one. This method has not only been well worked out theoretically in the paper by Holden and Meadows (Holden and Meadows, 1962), but it was successfully used by some posterior authors, and by other explorers (Kondiurin, 1973). This method is a rather good one for the area of the Northwest Atlantic as the spines of the spiny dogfish inhabiting the area are much obliterated, and the annual zones of growth in the spine surface are often seen badly. As to the technical aspect, the method is quite simple.

However, the use of this method requires thorough investigations on laying down of annual zones of growth which are closely connected with the characters of the spiny dogfish biology in the area under investigation.

The spines collected in the period of 1972-1978 were used for age determinations. The spines were kept and transported in the usual scale books.

The ground edges were produced by a special electric machine,

i.e. by a thin steel cutter without teeth. The thickness of the ground edges was 0.2-0.3 mm. They were slightly grounded with the aid of fine abrasive paper. The ground edges were fixed in the glass by the Canada balsam and were observed under the binocular with the magnification of 2 x 8 or 4 x 8.

Better visibility of the annual rings was achieved with the daylight and with the polarizational light filters use (Holden and Meadows, 1962; Redkozubov, 1973).

Turpentine was used in addition to the Canada balsam, as a clarifying substance. In this case the ground edge was placed into a special small bath with a transparent bottom (Kondiurin, 1973). Annual zones of growth which consist of hyaline and opaque parts of rings were counted when observing the ground edges. The measurement of the spine diameter at the base of the enamel layer in the direction of the front to the rear pole (fig. 1), as well as of the distance between the lateral edges of the spine was carried out. Some spines were cut out into the parallel ground edges which were observed in turn. The spine diameter was measured in each 5 mm of length for the least obliterated spines. The oblique opaque zones in the spine surface were counted for the control. Longitudinal ground edges were produced of several spines.

Vertebrae were taken from five fish specimens of 42-48 cm in length and dyed with silver nitrate, distinct annual rings not being observed in the vertebrae surfaces.

As the author worked by himself, the ground edges were examined twice to minimize the error in the age determination, the period between the examinations being 1.5-2 months. The material was not taken into account, if the period between the age determinations was more than two years. If the difference in time between the determinations was two years, the mean value was taken, and the ground edge was thoroughly examined once more with the difference in time of 1 year, and the author chose the value of age

which was considered as the most accurate.

Totally 500 ground edges were examined.

Results

1. Internal spine structure and correction for the age taking into account the diameter of spine.

The investigations by Holden and Meadows have shown that spine growth took place in the internal part facing the pulp of the spine, "loss" of annual rings being possible (fig. 2) when determining the age (Holden and Meadows, 1962; Kondiurin, 1973).

Longitudinal spine ground edges examined have shown that the annual zones of growth got thin while gradually moving away from the spine peak. Then they approached the zone of the external dentine and faded. The decrease in number of the annual growth zones while moving away from the spine peak was observed when examining the spine sawn into the parallel cross ground edges, as well (Table1, Table 2).

The same investigations have shown that some annual rings were also absent in the ground edges produced too close to the spine peak. That is why the ground edge is to be produced as close as possible to the spine peak, but with the pulp diameter not less than 0.7-1.0 mm. Otherwise the accuracy of age determination is considerably reduced.

The practice has shown that the diameter of ground edges prepared for an examination could attain 3.5-4.0 mm, and they were produced at the distance up to 25 mm from the spine peak. If these values are introduced into the graphs (figs. 3, 4), one can deduced that the specimen's length more than 50 cm and the age more than 5 years correspond to these values (Tables 4, 5). Therefore, exactly the same number of annual growth zones will be absent in the ground edge. Thus, the ground edge diameter is to be taken into account when determining the age, and the respective correction is to be introduced basing on the table 5.

It must be also taken into account the fact that the accuracy of age determination decreases with an increase in the ground edge diameter.

2. Annual growth zones laying down

(a). Spiny dogfish embryos

As is generally known (Ketchen, 1972; Kondiurin, 1973), embryo development inside the spiny dogfish female lasts about two years, that is why the annual growth zone can appear in the embryos' spines.

As the result of the study of embryos spine ground edges taken from the females in October 1974 one may state that they have an obscure zone in the outer dentine edge, the embryo's length approximately being 25 cm. This zone is characterized by somewhat indistinct edges and by a gradual transition into a lighter growth zone. An inverse calculation has shown that the zone was formed with the embryo's length of about 10.5 mm, the spine diameter being less than 1 mm. The annual mark in the embryo's spine surface was not seen. As this obscure zone appeared before the embryo's birth, they have called it an "embryonal annual ring".

(b). Fry up to 50 cm in length

Spines of this size-group of fish have been taken in August 1975. The smallest individuals of 25-31 cm in length have by this time the only annual growth zone which consist of an "embryonal annual ring" and a light zone. In addition, they had some kind of dentine destruction as a light strip which had appeared inmthe individuals of 25-27 cm in length, being apparently connected with their birth and so being called as a "birth mark".

In fry of 31-36 cm already two annual growth zones have been observed. However, the second zone is also similar by its form to the "embryonal zone", and the "birth mark" position evidences the fact that it has appeared either prior to the

embryo's birth, or just in birth moment. The increment in the light zone of growth following these "embryonal annual rings" is a considerable one.

In fry of 36-40 cm in length two annual zones of growth were also present. However, a "birth mark" was seen between them. Therefore, the second annual ring did not belong to the embryo, but it pertained to a free-living individual, although it was very alike by shape with the "embryonal" one. In this case the increment in the dentine light zone was somewhat less than in the preceding one.

Three annual growth zones were observed in larger individuals, including two "embryonal zones". Three annual growth zones with an "embryonal" one and four annual zones with two "embryonal rings" were noted in fish of 45-50 cm in length.

Since the light zone of annual growth corresponded to the summer growth period with shadowed screen, and the obscure one corresponded to the winter-spring period, the obscure zone of winter growth was considered to be the annual ring, the obscure growth zone transition into the light one being the border of annual increment.

(c). Mature individuals

A study on age samples in the order of an increase of sizes of individuals under consideration has shown that the structure of annual growth zones varied in spiny dogfish of the length more than 50 cm. The first 3-5 annual rings are obscure with indistinct edges. They slightly differ from "embryonal rings". The following rings are narrower and have a distinct border. In addition to the annual rings, some supplementary rings appear. These are narrower and unclosed. Sometimes the additional rings are very similar to the annual ones, the determination of age being rather complicated in such a case. The additional rings were observed more frequently in the individuals taken in the area of Browns Bank.

Additional rings appear much rarely in spiny dogfish which is older than 12-18 years.

Some difference has been observed between the annual rings in males and females. Thus, in females of spiny dogfish they are more distinct, dark, and in males they are indistinct and narrow. Additional rings have been noted somewhat rarely in males.

Three zones can be distinguished in larger spiny dogfish specimens when studying the ground edges; these zones having the shape of a circle. The first zone passing along an outer border of the ground edge has indistinct, dark rings with indistinct edges. The number of rings may be equaled to 2-6. Further a zone with narrower annual rings and great number of additional rings is situated. A zone with distinct annual rings and without additional ones is seen in the center of the ground edge.

In many larger females an alternation of a distinct annual ring with a poorly seen one which can be distinguished only under thorough examination of the ground edge is observed in the central zone.

Discussion

The papers by a number of scientists evidences of the existence of a close relation between the spiny dogfish length, spine length and diameter, number of dark strips in the spine surface and number of annual rings in the ground edge (Kaganovskaya, 1933; Kondiurin, 1973; Probatov, 1957; Holden and Meadows, 1962).

Detailed studies by Holden and Meadows (Holden and Meadows, 1962) give us a basis for judging of spine structure and main features of annual ring formation in the spine of spiny dogfish (figs. 1, 2). The formation of a darker zone of winter growth and of a lighter zone of summer growth is certainly related to different individual growth rate, to the activity reorientation of fish organism under the influence of abiotic and biotic factors. Such factors which may be a cause for the fish growth delay and

for the appearance of a dark ring usually are:

(a) water temperature decrease in winter period;

(b) falling off in winter habitat;

(c) migrations;

(d) spawning

(Linskaya, Oven, 1970; Nikolsky, 1971; Sokolova, Anivova, 1976; Ketchen, 1972; Springer, 1965; Templeman, 1965).

The influence of these environmental factors must aggravate, if we take into account the fact that all of them influence simultaneously on the spiny dogfish just in winter and in the adjacent months from November to March-April (Soldat, 1976; Bigelow and Schroeder, 1953; Jensen, 1968; Ketchen, 1972; Springer, 1967; Templeman, 1965). Combined influence of these factors reflects in the main features of annual growth zones which are seen in sawings down of the spine.

Thus, the existence of a dark zone of growth in embryos and immature individuals points out to the fact that the spawning is not an obligatory factor for the formation of the annual ring at this time. The absence of the additional rings evidences the fact that autumn and winter migrations by immature individuals do not greatly influence upon their vital activity.

The influence of migration as a factor for growth delay and for a dark growth zone formation is well observed in the individuals of more than 50 cm in length. The additional rings have been rather often noted in those individuals. These rings were observed especially clear in the spiny dogfish caught in the area of Nova Scotia that is in the individuals which undertake long-distant migrations.

Finally, the formation of a distinct annual ring in mature spiny dogfish points out to the spawning which plays an important part in the annual ring appearance. The spawning period exactly coincides with the spiny dogfish wintering, and a combined influence of these factors is the reason for the distinct annual ring

formation. However, in spiny dogfish females poor visibility of the annual ring layed down in the year of lack of spawning is observed.

Conclusion

1. The age of the spiny dogfish from the Northwest Atlantic can be determined by the annual rings which are seen in the spine sawing down.

2. The annual rings are formed as a result of changes in the spine dentine structure in winter-spring period.

3. The main reason for the change of the spine dentine structure is the variation in the spiny dogfish growth rate under the influence of such factors as water temperature, habitat, migrations and spawning.

4. A correction for the spine diameter in the place of the ground edge production must be introduced when determining the spiny dogfish age.

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Table 1. Number of the annual growth zones in the ground edges of different diameter

Ground edge diameter, mm	♀ L = 89.6				♀ L = 83.0				
	3.15	3.35	3.60	4.20	2.65	3.05	3.30	3.70	4.10
Number of annual growth zones	17	16	15	12	12	11	10	9	8

Ground edge diameter, mm	L = 54.5 ♂				L = 74.1 ♂			
	1.85	2.25	2.45	2.65	1.80	2.05	2.75	2.85
Number of annual growth zones	3	2	2	1	11	10	9	8

Table 2. Decrease in number of annual growth zones in the spine parts of different diameter

Spine diameter, mm	1.6-2.0	2.0-2.5	2.5-3.0	3.0-3.5	3.5-4.0
Difference in number of annual growth zones	1	1-2	2	2-3	3

Table 3. The value of correction for age depending on spine diameter

Ground edge diameter, mm	1.70 1.80	1.85 2.30	2.35 2.65	2.70 2.90	2.95 3.10	3.15 3.40	3.45 3.70	3.75 3.90	3.95 4.05	4.10 4.20
Value of correction (years)	+1	+2	+3	+4	+5	+6	+7	+8	+9	+10

Ground edge diameter, mm	4.25 4.35	4.40 4.50	1.65 1.70	1.75 2.20	2.25 2.50	2.55 2.80	2.85 3.05	3.10 3.25	3.30 3.45	3.50 3.60
Value of correction (years)	+11	+12	+1	+2	+3	+4	+5	+6	+7	+8

Table 4, Age and growth of spiny dogfish (Sq. acanthias)

Age	1	2	3	4	5	6	7	8	9	10	11	12	13
Mean length determined without a correction for the ground edge diameter	32.5	40.0	46.0	48.0	54.0	56.5	63.5	69.5	71.5	75.0	76.5	80.0	83.0
Mean length determined with a correction for the ground edge diameter	30.7	36.7	46.6	48.3	53.8	58.4	64.5	68.0	69.4	71.2	72.6	73.8	75.8

Age	14	15	16	17	18	19	20	21	22	23	24	25	26
Mean length determined without a correction for the ground edge diameter	86.0	87.5	88.5	91.0	93.0	93.5	95.0	97.0	98.5	100.5	102.0	-	-
Mean length determined with a correction for the ground edge diameter	76.1	80.4	82.5	85.4	87.3	88.3	91.8	91.1	93.2	95.0	95.4	99.0	101.0

Table 5. Age and growth of males and females of spiny dogfish

Age	1	2	3	4	5	6	7	8	9	10	11	12	13
Mean length of males	32.0	35.6	48.2*	47.1	56.8	58.9	64.7	69.5*	69.2	71.6	72.9	73.7	75.6
Mean length of females	29.9	37.7	46.1	50.4*	52.4	58.2	64.4	67.8	69.8*	69.5*	73.7	75.0*	78.0*

Age	14	15	16	17	18	19	20	21	22	23	24	25	26
Mean length of males	75.7	79.2	80.9*	81.3*	-	88.0*	-	-	-	-	-	-	-
Mean length of females	79.0*	83.3*	83.7*	85.8	87.3	88.4	91.8	91.1	93.2	95.0*	95.4	99.0*	101.0*

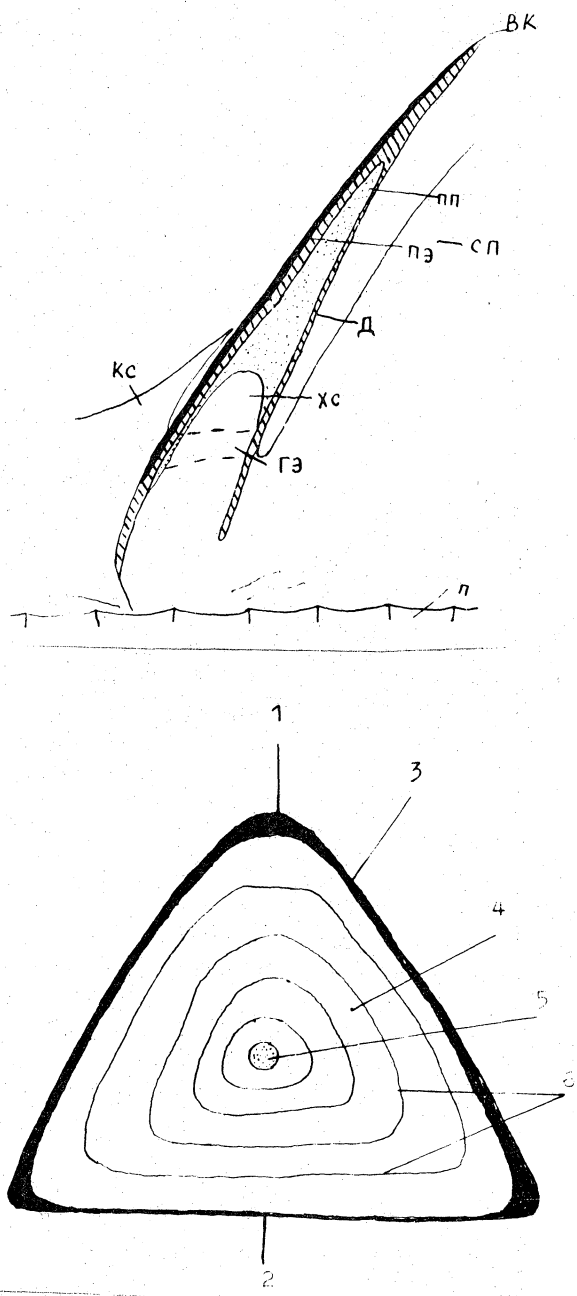

Fig. 1. Longitudinal (top) and cross (bottom) section of spine (by Holden and Meadows, 1962).

1 - front pole; 2 - posterior pole of spine;

3 - ПЭ - pigmented enamel; 4 - Д - dentine;

5 - ПП - pulp cavity; 6 - annual ring;

7 - ВК - spine peak; 8 - СП - dorsal fin;

9 - ХС - cartilaginous column; 10 - КС - cutaneous fold;

11 -ГЭ - enamel border; 12 - П - vertebral column.

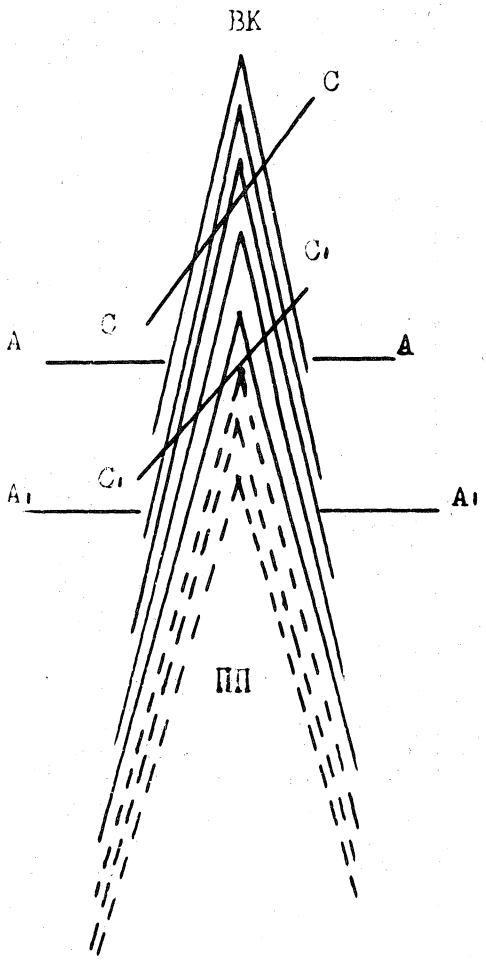

Fig. 2. Scheme of dentine layers in the spiny dogfish spine (by Holden and Meadows, 1962).

AA - sawing down place in immature individuals of the age of 4-5 years. A correction for age is not introduced.

A_1A_1 - sawing down place in older individuals. A correction for age is necessary.

CC, C_1C_1 - line of a possible spine obliterating in fry and in older individuals.

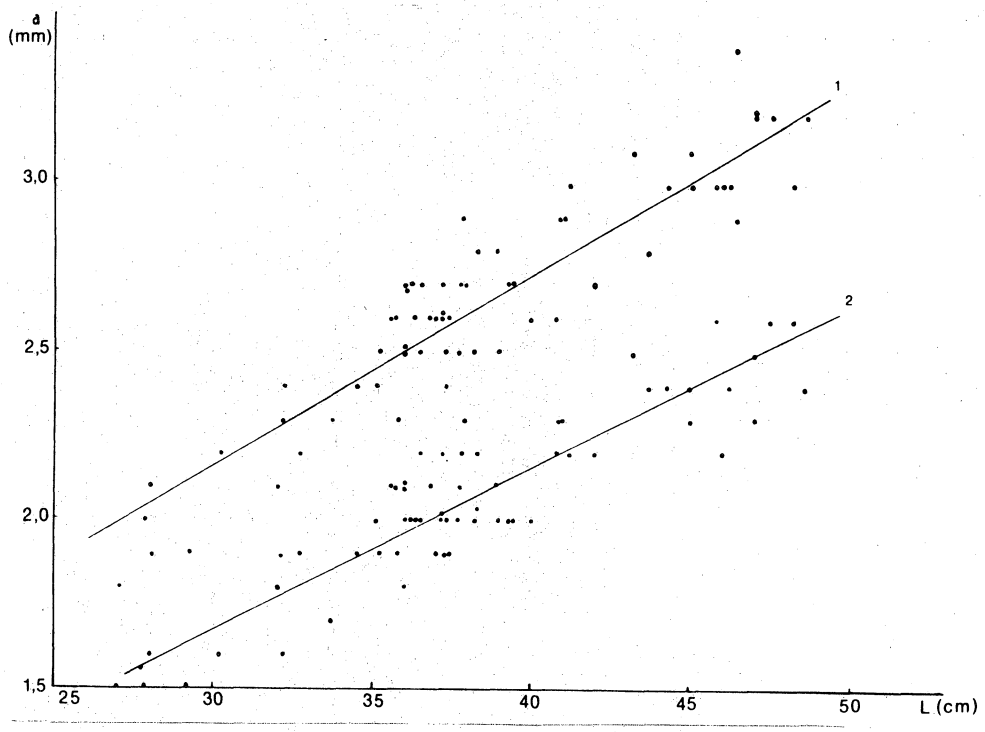

Fig. 3. Spine diameter change at its base depending on fish length. 1 - the second dorsal fin spine; 2 - the first dorsal fin spine.

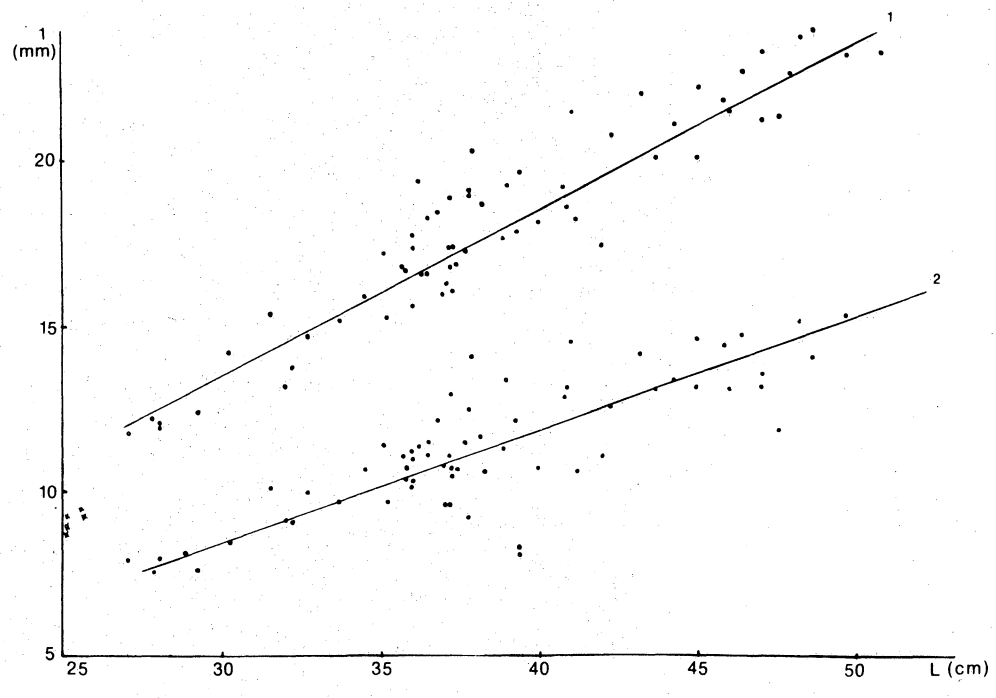

Fig. 4. Spine length change depending on fish length. 1 - the second dorsal fin spine; 2 - the first dorsal fin spine.

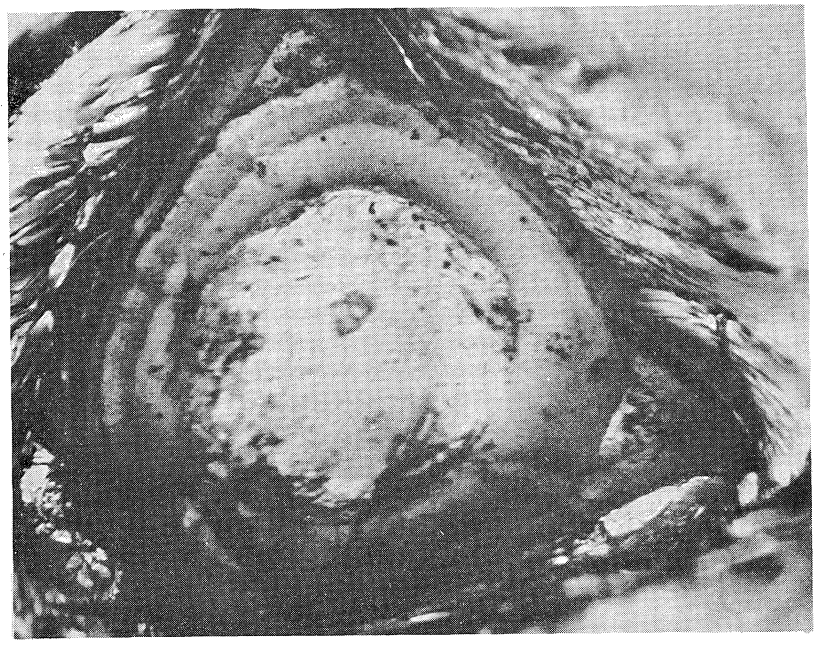

Fig. 5. Ground edge photograph of spine cross-section (25 cm embryo, 1 annual ring).

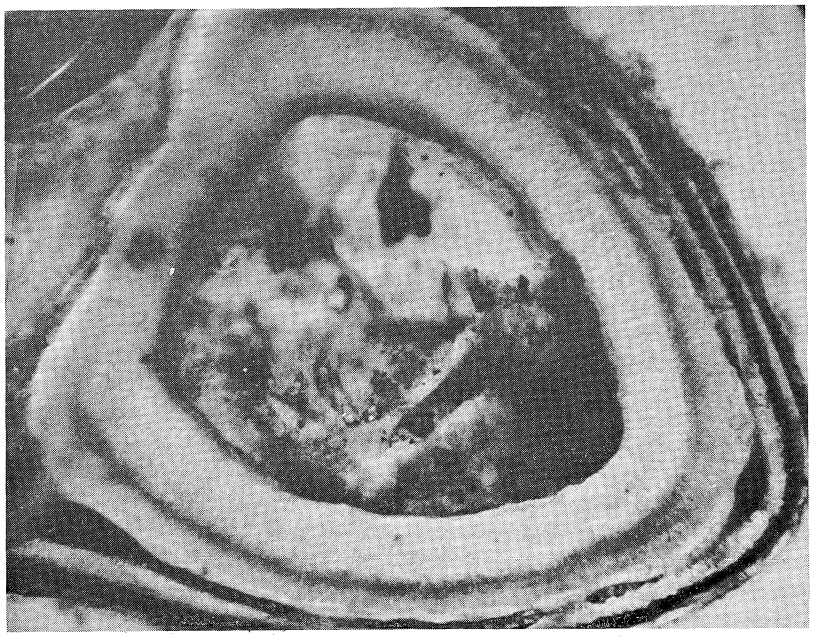

Fig. 6. Ground edge photograph of spine cross-section (32 cm immature dogfish, 1 "embryonoc annual ring").

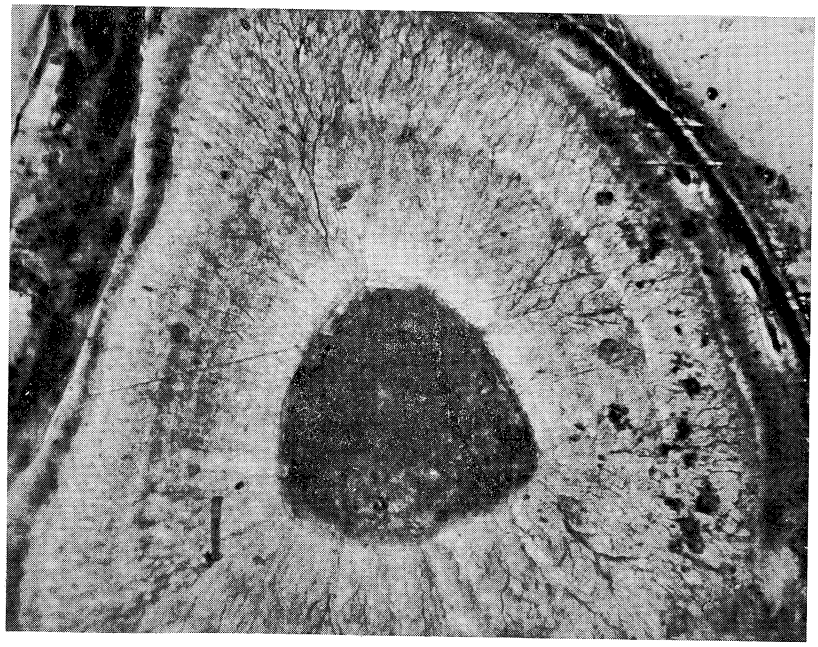

Fig. 7. Ground edge photograph of spine cross-section (50 cm dogfish, 3 annual rings, 3 years old).

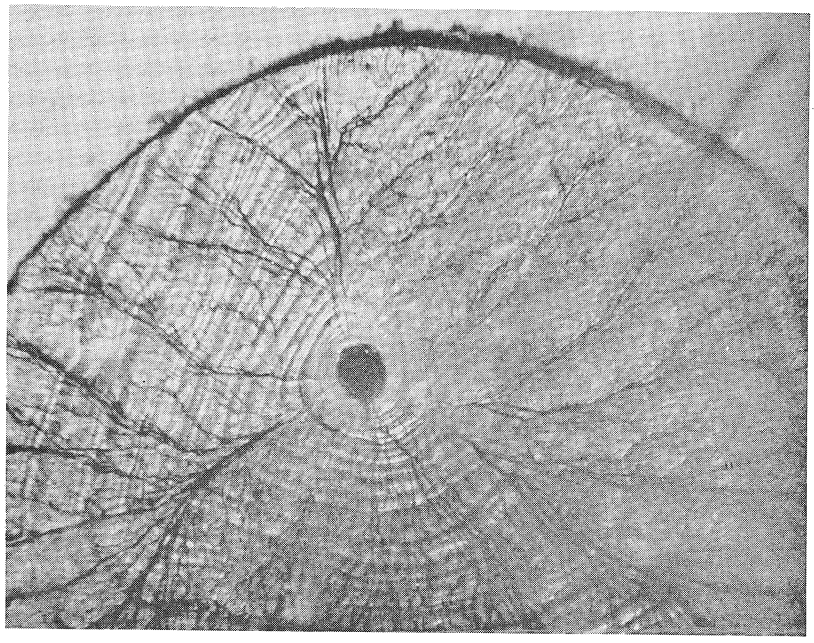

Fig. 8. Ground edge photograph of spine cross-section (90 cm dogfish, 16 annual rings, 21 years old).