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Age and Size of Spiny Dogfish, *Squalus acanthias*, in the Northwest Atlantic

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Abstract

A study of transverse and longitudinal sections of dorsal spines from spiny dogfish, *Squalus acanthias*, in the Northwest Atlantic indicated that there were serious methodological and practical problems associated with age determination. The task is complicated not only because of additional interannual rings in the spine cross-sections, especially in older individuals, but also because of the need to introduce a correction to the age based on analysis of the diameters of the spine cross-sections. These problems are discussed, and estimated length-at-age values are presented for male and female spiny dogfish.

Introduction

Data on length and age composition of fish in a population are the basis of mathematical methods for calculating stock size and potential yields. Reasonably accurate determination of age is very important, because small errors will adversely affect the final results of the calculations. Much fundamental research has been applied to age determination in many species of fish, using a variety of structures such as otoliths, scales, spines, etc. However, considerable difficulty, both methodological and practical in nature, has been associated with efforts to determine the ages of sharks.

Spines in front of the dorsal fins have been commonly used for age determination in the spiny dogfish, *Squalus acathias* (Kaganovskaya, 1933; Templeman, 1944; Probatov, 1957; Holden and Meadows, 1962; Kondiurin, 1973; Ketchen, 1975). Usually, ages were determined from marks on spine surfaces or annual growth zones on spine cross-sections or both. Also, technically complicated methods have been used in recent studies (Ketchen, 1975; Jones and Geen, 1977).

An examination of the various methods and structures that have been used for spiny dogfish has shown that cross-sectioning of the second dorsal spine is the most appropriate for age determination. This method was described theoretically by Holden and Meadows (1962) and successfully applied by other workers (e.g. Kondiurin, 1973). However, use of the method requires thorough investigation of the formation of annual zones of growth which are closely related to the biology of spiny dogfish in the area under study. In this paper, an approach to the problem is outlined and a method of age determination for spiny dogfish of the Northwest Atlantic suggested.

Materials and Methods

Second dorsal spines were collected from spiny dogfish caught in 1972-78 during cooperative USA-USSR bottom-trawl surveys of the continental shelf from the southern part of the Scotian Shelf to Cape Hatteras (NAFO Subareas 4, 5 and 6). Fish measurements were recorded as total length to the nearest millimeter.

In the laboratory, spine cross-sections (0.2-0.3 mm thick) were cut with a special electric sectioning machine, ground slightly with fine abrasive paper, and examined under a binocular microscope with magnification of 16× or 32×. Turpentine was sometimes used as a clearing agent, in which case the ground cross-section was placed in a transparent glass dish for examination (Kondiurin, 1973). Annuli were more easily recognized in daylight and with polarized light filters (Holden and Meadows, 1962; Redkozubov, 1973). The number of annuli was determined from the alternating transparent and opaque zones in the cross-section.

The spine diameter at the base of the enamel layer was measured in an anterior-posterior direction, and the total length of the spine was recorded (Fig. 1). Parallel sections of 37 spines were thoroughly examined to determine the most appropriate diameter and distance from the tip for age determination. Oblique dark zones on the surface of the spines were counted for control. Measurements of the spine diameter were made at 5 mm intervals for 26 spines with obviously indistinct zones. Several spines were cut longitudinally for examination. Vertebrae from five spiny dogfish (42-48 cm long) were dyed with silver nitrate, but no distinctive annual zones or rings were evident.

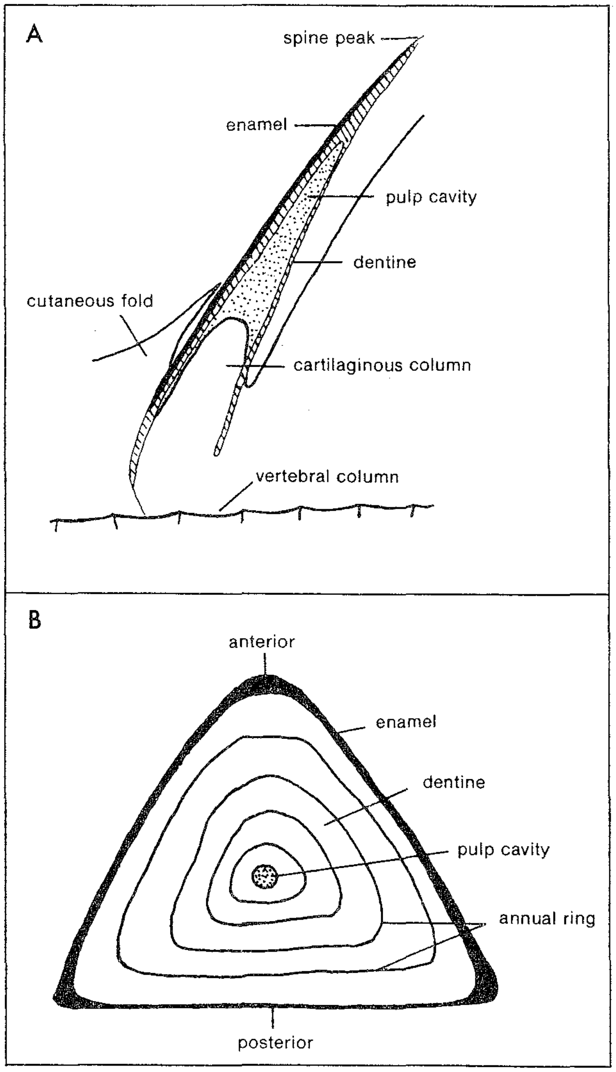

Fig. 1. Longitudinal section (**A**) and cross-section (**B**) of the spine in spiny dogfish (from Holden and Meadows, 1962).

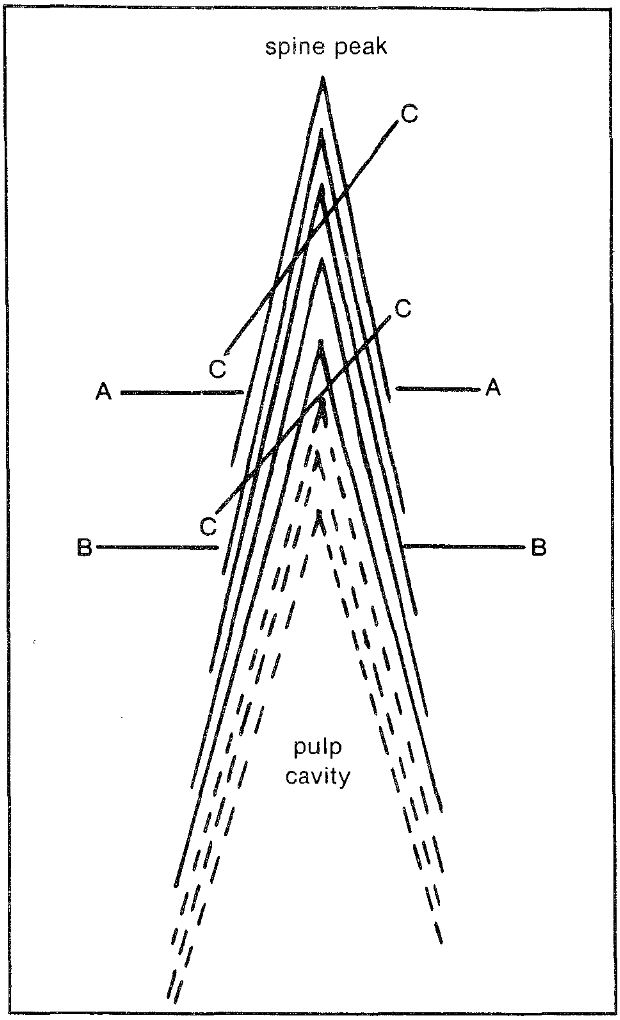

Fig. 2. Schematic illustration of dentine layers in the spine of spiny dogfish (from Holden and Meadows, 1962). (AA = cross-section in immature fish of 4-5 years of age does not require a correction for age; BB = cross-section in older fish requires a correction for age; CC = lines of possible annual ring obliteration.)

The cross-sections of 580 spines from specimens captured in February-March 1978 in Subareas 5 and 6 were examined twice, with a period of 1.5-2.0 months between successive age determinations. If the difference in age was more than 2 years, the results were considered unreliable and were not used in the growth study (13% of the specimens). If the difference was 2 years (12%), the mean value was taken. If the difference was 1 year (28%), the cross-section was examined again and a decision made on the most likely age. Absolute agreement between the successive age determinations was achieved for 47% of the specimens. Thus, a total of 504 age determinations were used for the analysis of mean length at age.

Results

Spine diameter and age

According to Holden and Meadows (1962), the spine grows on the internal side facing the pulp, and consequently annual rings may be omitted when determining the age from cross-sections (Fig. 2). Longitudinal sections of the spine showed that the annual zones of growth become thinner with increasing distance from the tip of the spine and ultimately disappear at varying distances from the tip. This was clearly evident in successive parallel cross-sections of the spine, four examples of which are given in Table 1. The decrease in the number of annuli for each 0.5 mm increase in spine diameter becomes greater with increasing spine diameter (Table 2). The analysis also showed that some annual rings were absent in cross-sections cut too close to the tip of the spine. However, the cross-sections should be cut as close to the tip of the spine as possible, provided that the pulp diameter is no less than 0.7-1.0 mm; otherwise, the accuracy of age determination will be substantially reduced.

TABLE 1. Number of annuli observed in different cross-sections of spines from four spiny dogfish.

Male			Female		
Fish length (cm)	Section diameter (mm)	Number of annuli	Fish length (cm)	Section diameter (mm)	Number of annuli
54.5	1.85	3	89.6	3.15	17
	2.25	2		3.35	16
	2.45	2		3.60	15
	2.65	1		4.20	12
74.1	1.80	11	83.0	2.65	12
	2.05	10		3.05	11
	2.75	9		3.60	10
	2.85	8		3.70	9
				4.10	8

TABLE 2. Relative variation in number of annuli observed in cross-sections of spines from spiny dogfish.

Cross-section diameter (mm)	1.6-2.0	2.0-2.5	2.5-3.0	3.0-3.5	3.5-4.0
Difference in annuli number	1	1-2	2	2-3	3

For various sizes of juvenile spiny dogfish from birth to about 50 cm in length, there appears to be a direct linear relationship between spine diameter at its base and total length of fish (Fig. 3A). A similar relationship exists between spine length and fish length (Fig. 3B). It is evident that the spine in a 50-cm fish is about 25 mm long and about 3.5 mm in diameter at its base. Consequently, for age determination of older individuals, the diameter of spine cross-sections should not exceed 3.5 mm, and the spines should be cut within 25 mm of the spine tip. However, since some annuli will be missing from such cross-sections, as is evident from Fig. 2, the spine diameter must be taken into account in estimating the age. From observations for a wide range of spine diameters, the mean age corrections applicable for male and female spiny dogfish are given in Table 3. Certainly, the accuracy of age determination by this method decreases with increased diameter of spine cross-section due to the application of corrections based on mean ages and also because no good relationship exists between spine diameter and fish length in large mature spiny dogfish.

Growth data for male and female spiny dogfish in the Northwest Atlantic, based on the analysis of second dorsal spines (as described above) from specimens collected in February-March 1968, are given in Table 4. Mean length-at-age values for males and females are similar up to age 8, after which females appear to grow faster than males.

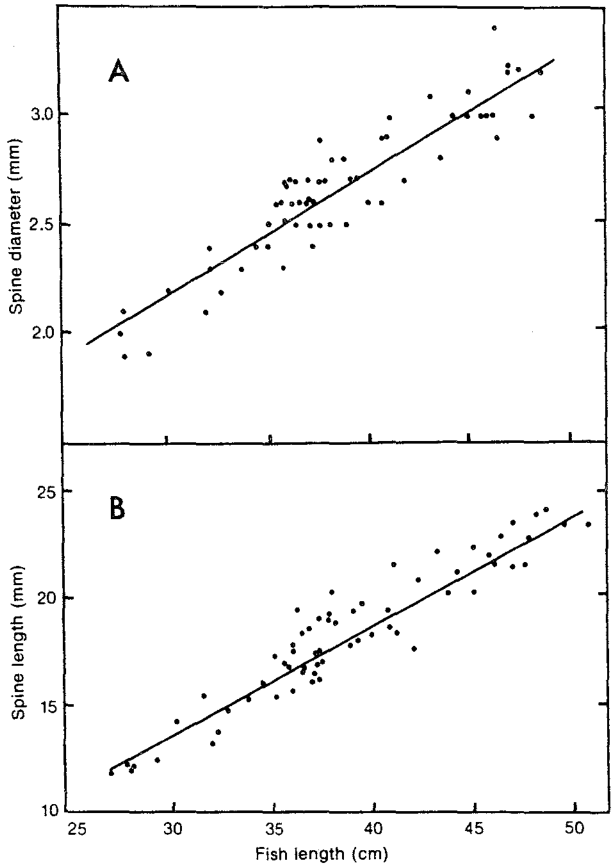

Fig. 3. Relationship between (**A**) fish length and spine diameter at its base, and (**B**) fish length and spine length, for spiny dogfish 25-50 cm in length from the Northwest Atlantic.

Formation of annual growth zones

The lighting arrangement for examination of the spine cross-sections was such that a translucent zone corresponded to summer-autumn growth and an opaque zone to winter-spring growth. The latter zone was taken as an annual ring, the outer edge of which was considered the border of the annual growth increment. Examples of spine cross-sections from dogfish of different sizes are shown in Fig. 4.

Embryos. As is generally known (Ketchen, 1972; Kondiurin, 1973), the embryonic growth of spiny dogfish lasts for about 2 years, and it is possible that factors affecting the growth of the parent female may also result in the formation of an annual growth zone in the spine of the embryos. Examination of cross-sections of drosal spines from embryos 25 cm in length, taken from females in October 1974, indicated a darkened zone in the outer part of the dentine layer, somewhat indistinct and gradually merging with a lighter growth zone. The spine diameter was less than 1 mm, and back-calculation indicated that the zone was formed

TABLE 3. Average correction to age relative to spine diameter for male and female spiny dogfish.

Male		Female	
Spine diameter (mm)	Correction to age (yr)	Spine diameter (mm)	Correction to age (yr)
1.65-1.70	+1	1.70-1.80	+1
1.75-2.20	+2	1.85-2.30	+2
2.25-2.50	+3	2.35-2.65	+3
2.55-2.80	+4	2.70-2.90	+4
2.85-3.05	+5	2.95-3.10	+5
3.10-3.25	+6	3.15-3.40	+6
3.30-3.45	+7	3.45-3.70	+7
3.50-3.60	+8	3.75-3.90	+8
		3.95-4.05	+9
		4.10-4.20	+10
		4.25-4.35	+11
		4.40-4.50	+12

when the embryo was about 10.5 cm long. There was no discernible annual mark on the surface of the spine. Since the darkened zone was formed before birth, it is termed an "embryonic annual ring".

Juveniles less than 50 cm in length. The spines of these dogfish were obtained in August 1975, at which time the smallest individuals (25-30 cm long) had a growth zone consisting of an embryonic ring and a translucent zone. Also, a light stripe was observed near the outer edge of the dentine layer, evidently related to birth and termed a "birth mark".

Two annuli could be recognized in the cross-sections of spines from juveniles 31-35 cm long, the first being the embryonic ring. The second annulus was similar to the embryonic ring in shape, and the position of the birth mark indicated that this annulus appeared either before or at the time of birth. Usually, the translucent zone adjacent to the embryonic ring was quite wide.

Two annual zones of growth with a birth mark between them were present in the cross-sections of spines from juveniles 36-40 cm long. Although the second zone resembled the embryonic zone in shape, it was evidently formed after birth. In this case, the width of the translucent zone adjacent to the embryonic ring was somewhat less than in the smaller individuals.

In the cross-sections of spines from larger juveniles (41-50 cm in length), three annual growth zones with two embryonic rings, three annual growth zones with one embryonic ring, and four annual growth zones with two embryonic rings were recognized.

Adults greater than 50 cm in length. Examination of the age samples of successively larger spiny dogfish indicated a change in the pattern of the annuli. Usually the first 3-5 opaque annuli had indistinct edges and differed only slightly from the embryonic rings. Subsequent annuli were narrower and more distinct, but they were often interspersed with additional narrow and often incomplete rings which made interpretation of the annuli difficult because of their similarity to the extra rings. Such extra rings were more common in the spine cross-sections from specimens taken on Browns Bank off Nova Scotia than from specimens taken farther southward off the United States coast. The extra rings were more prominent in fish of intermediate ages (up to age 12) and became less pronounced in older individuals as the growth zones became narrower and the annuli more closely grouped.

In larger and older spiny dogfish, three zones could generally be distinguished in the spine cross-sections: an inner zone containing several fairly distinct annuli without intermediate rings, a middle zone containing narrower annuli and many additional rings, and an outer zone around the edge of the spine with several (2-6) indistinct opaque rings. In many cross-sections from large females, distinct annuli alternated with less prominent rings, making interpretation of annuli quite difficult. The additional interannual rings were usually less common in males.

TABLE 4. Average length-at-age of male and female spiny dogfish from the Northwest Atlantic in February-March 1978.

	Male		Female	
Age (yr)	Number of fish	Mean length (cm)	Number of fish	Mean length (cm)
1	25	26.8	24	27.1
2	18	34.2	19	34.0
3	18	40.9	13	39.5
4	18	45.7	17	47.1
5	19	49.5	17	50.6
6	17	53.0	17	53.5
7	19	59.5	22	59.0
8	20	64.0	19	63.7
9	14	66.6	17	70.9
10	12	69.8	14	72.6
11	6	73.0	7	77.0
12	14	74.3	11	80.5
13	6	76.2	12	82.8
14	9	77.3	9	85.2
15	3	77.0	9	86.3
16	2	77.5	6	85.7
17	4	76.5	4	87.5
18	3	80.7	3	87.0
19	3	81.0	4	92.0
20	1	85.0	6	93.2
21			8	93.3
22			7	96.0
23			2	97.5
24			1	90.0
25			2	99.5
26			3	96.7

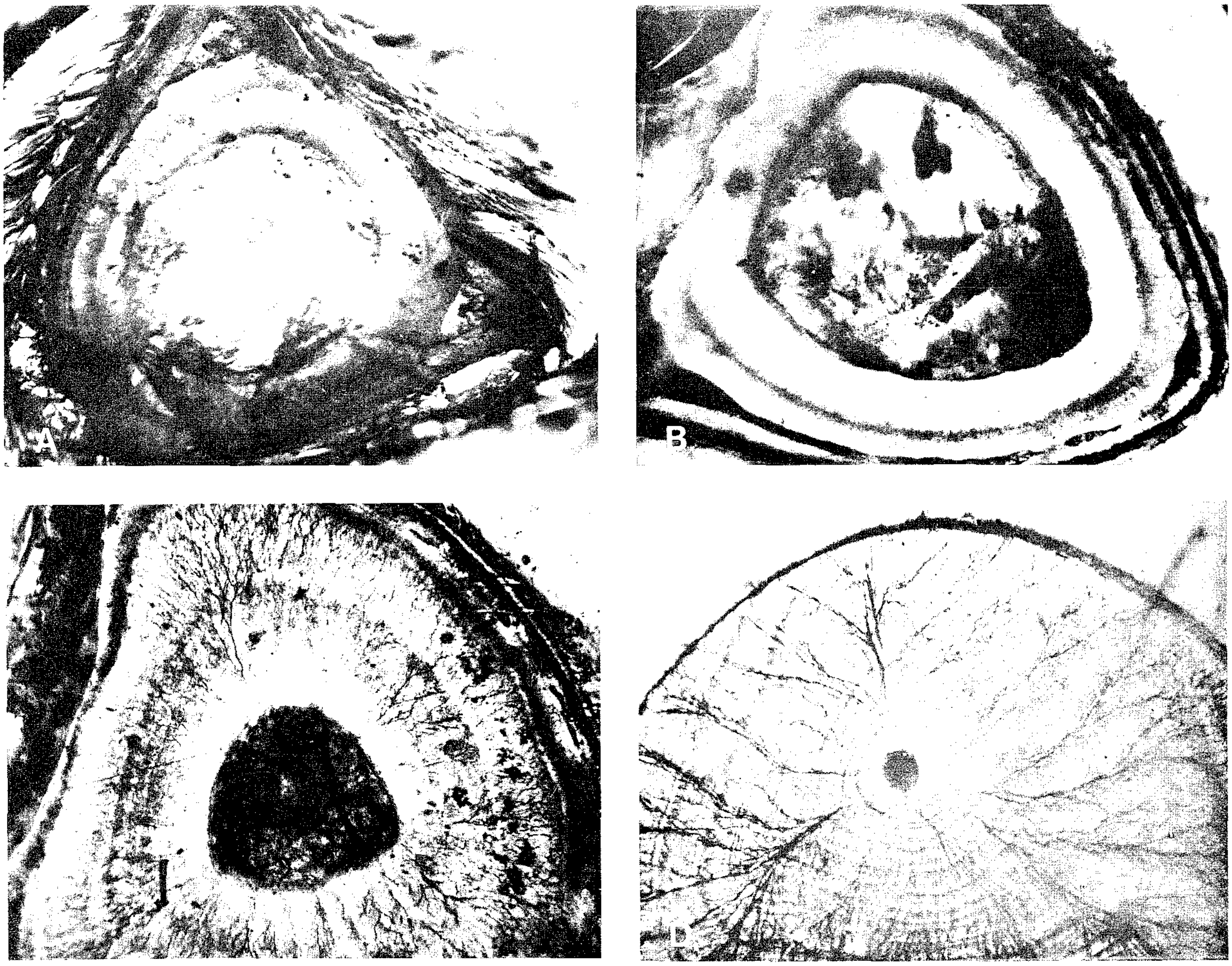

Fig. 4. Photographs of cross-sections of second dorsal spines from spiny dogfish. **A**, 25-cm embryo with one annual ring. **B**, 32-cm immature with one embryonic annual ring. **C**, 50-cm dogfish with three annual rings (age 3). **D**, 90-cm dogfish with 16 annual rings (age 21).

Discussion

Good correlations between length of spiny dogfish, spine length and diameter, number of dark stripes on the spine surface, and number of annuli in cross-sections of spines have been reported (Kaganovskaya, 1933; Probatov, 1957; Holden and Meadows, 1962; Kondiurin, 1973). It is evident that the alternating translucent and opaque zones apparent in the spine cross-sections are related to changes in growth rates and metabolic activity influenced by abiotic and biotic factors. Retardation of growth in fish have been attributed to a variety of factors such as decreased water temperature, decreased availability of food, migration and spawning (Templeman, 1965; Springer, 1967; Linskaya and Oven, 1970; Ketchen, 1972; Sokolova and Anivova, 1976). All of these factors affect spiny dogfish during the period from late autumn to spring (November-April) and exert considerable influence on growth (Bigelow and Schroeder, 1953; Templeman, 1965; Jensen, 1969; Ketchen, 1972). The aggregate effect of these factors is evident from the patterns of annuli in spine cross sections. The presence of slow growth zones in embryos and immature fish indicates that spawning is not a necessary factor for annuli formation, and the absence of extra interannual rings indicates that migration in autumn and winter exerts an insignificant influence on their vital activity.

The influence of migration as a factor responsible for retarded growth and formation of slow growth zones is clearly seen in spine cross-sections from dogfish greater than 50 cm in length. Very often they had additional interannual rings which were especially easy to identify in the spiny dogfish caught off Nova Scotia, i.e. in individuals performing extensive migrations. The distinctness of the annuli in mature fish implies that spawning may be an important factor in their formation because of the coincidence of the spawning and wintering periods. However, the annual rings were usually less prominent in females in years when there was no evidence of spawning.

References

BIGELOW, H. B., and W. C. SCHROEDER. 1953. Fishes of the Gulf of Maine. *Fish. Bull., U.S.*, **53**: 47-51.

HOLDEN, M. J., and H. C. MEADOWS. 1962. The structure of the spine of the spur dogfish (*Squalus acanthias* L.) and its use for age determination. *J. Mar. Biol. Assoc.*, **U. K.**, **42**(2): 179-197.

JENSEN, A. C. 1969. Spiny dogfish tagging and migration in North America and Europe. *ICNAF Res. Bull.*, **6**: 72-78.

JONES, B. C., and G. H. GEEN. 1977. Age determination of an elasmobranch (*Squalus acanthias*) by x-ray spectrometry. *J. Fish. Res. Bd. Canada*, **34**: 44-48.

KAGANOVSKAYA, S. I. 1933. A method of determining the age and the composition of the catches of the dogfish (*Squalus acanthias* L.). *Bull. Far East Acad. Sci. USSR*, **1**(3): 139-141.

KETCHEN, K. S. 1972. Size at maturity, fecundity, and embryonic growth of the spiny dogfish (*Squalus acanthias*) in British Columbia waters. *J. Fish. Res. Bd. Canada*, **29**: 1717-1723.

1975. Age and growth of dogfish (*Squalus acanthias* L.) in British Columbia waters. *J. Fish. Res. Bd. Canada*, **32**: 43-59.

KONDIURIN, V. V. 1973a. Some data on the biology of spiny dogfish, *Squalus fernandinus*, from the Southeast Atlantic continental shelf. *Tr. Kaliningr. Tekh. Inst. Rybn. Prom.-sti. Khoz.*, **46**: 44-53.

1973b. On ageing methods of spiny dogfish, *Squalus fernandinus nolina*, from Southwest Africa. *Tr. Kaliningr. Tekh. Inst. Rybn. Prom.-sti. Khoz.*, **46**: 99-108.

LINSKAYA, N. Y., and L. S. OVEN. 1970. On the reasons of fish growth periodicity in the ocean tropical zone. *Biol. Morya (Kiev)*, **21**: 236-245.

PROBATOV, A. N. 1957. Material on the Black Sea spiny dogfish, (*Squalus acanthias* L.) study. *Utchionyie Zapiski, Rostov University*, **57**:(1): 5-26.

REDKOZUBOV, Yu. N. 1973. Use of polarized light when determining fish age. *Tr. Kaliningr. Tekh. Inst. Rybn. Prom.-sti. Khoz.*, **46**: 82-83.

SOKOLOV, L. I., and N. V. ANIVOVA. 1976. On the methods of age determination of Siberian sturgeon, *Acipenser baeri* Brand, from the Lena River. *Vopr. Ikhtiol.* **16**(5): 853-858.

SPRINGER, S. 1967. Social organization of shark populations. *In* Skarks, skates and rays, R. W. Gilbert (ed.), John Hopkins Press, Baltimore, Maryland, p. 149-174.

TEMPLEMAN, W. 1944. The life history of the spiny dogfish (*Squalus acanthias*) and the vitamin A values of dogfish liver oil. *Nfld. Dept. Nat. Resour. Res. Bull.*, No. 15, 102 p.

1965. Mass mortalities of marine fishes in the Newfoundland area presumably due to low temperature. *ICNAF Spec. Publ.*, **6**: 137-147.