THE AGE, GROWTH, AND MATURATION OF THE SPINY DOGFISH, *Squalus acanthias L.* OF THE NORTHWEST ATLANTIC

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by

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ABSTRACT

The spiny dogfish is the largest under-utilized finfish resource of the northeastern fisheries of the U.S., yet little critical data is available on its biological parameters. This study describes the age-length relationships, growth and maximum size for both males and females; estimates were also made of size at reproductive maturation. Dorsal fin spines were used to determine the age of fish. The samples for data development were collected in 1976, 1979, 1980, and 1981 at sites in the Gulf of Maine and the New York Bight and comprised 218 male and 434 female fish.

Von Bertalanffy growth curves were fitted to the age-length data for each sex separately. Male fish were found to mature earlier and to reach a smaller final size than females. Comparisons were made with growth in other populations of spiny dogfish. These Northwestern Atlantic fish were somewhat slower growing than the European population in the Northeastern Atlantic. Both Atlantic populations were found to have higher growth coefficients (K) and lower $L_{(max)}$ and L_∞ values than reported for dogfish populations of the Pacific coast, indicating that the Atlantic fish grow faster but do not achieve sizes as large as the Pacific populations.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ACKNOWLEDGMENTS

We are indebted to Dr. Hal Boyer for arranging for collections of material to be made aboard the National Marine Fisheries Service (NMFS) Shelf Survey vessels and Dr. Gordon Waring was very helpful in providing dogfish on board the vessels; Mr. Don Flescher and Mr. S. Shawn McCafferty made collections of spines on other NMFS fishing surveys. Captain A. Sherman kindly allowed one of us (RC) to collect samples aboard the M.V. Tioga fishing on Stellwagen Bank. Ms. Peggy Morgan collected samples of spines at the Isles of Shoals, N.H. Dr. Anthony Guarino and his students made a detailed collection of data from dogfish at Mourt Desert Island Biological Laboratory (MDIBL), Salsbury Cove, ME. Avril, Rod and Claire Woodhead assisted with all of the collections at MDIBL in 1976, 1979 and 1980. The contributions of all of these participants in supplying the materials for this investigation is very gratefully acknowledged.

This work was supported by the reward of a grant from New York Sea Grant Institute to one of us (PMJW) with a Traineeship (RC). The Marine Sciences Research Center, SUNY at Stony Brook also provided a graduate assistantship (TPS). The initial work at MDIBL in 1976 was partly supported from a NSF grant to MDIBL which paid for lab accommodations and dogfish samples.

INTRODUCTION

Status of the Fishery

The spiny dogfish, or grayfish, Squalus acanthias, occurs in very large numbers off the Mid-Atlantic States and New England. It has traditionally been regarded as a costly nuisance by commercial and recreational fishermen alike, damaging gear, spoiling the catch and hindering fishing operations. Dogfish are reputed to be voracious feeders and their large populations may have significant effects in reducing the size of stocks of traditional food fish. Although landed commercially in small numbers, the dogfish has been considered one of the most important under-utilized fishery resources in the northeast. The size of the dogfish resource is not precisely known, but all recent estimates indicate that it is large, indeed it has been suggested that at times the dogfish represent the major part of the groundfish biomass in the Mid-Atlantic Bight (Jensen, 1978). Similarly, it has been established that dogfish contribute as much as 50% of the biomass to trawl catches in the Bight during the winter months (Colvocoresses and Musick, 1978).

Although large numbers of northeastern dogfish are now caught by U.S. bottom trawlers, they are largely considered to be unmarketable and discarded at sea (Mayo et al., 1981). During the 1970's a trawl fishery developed for dogfish of the northeastern stocks off both the U.S. and Canadian coasts. Total catches approached 20,000 metric tons annually (Figure 1), but the greater part of the resource was taken by foreign vessels (mainly Russian) and only with the offshore extension of U.S. and Canadian fishing limits was this foreign fishery reduced. Catches for ICNAF statistical areas 6, 5 and 4 (equivalent to Mid-Atlantic, New England and maritime Canada, respectively) are given below for the years 1973 to 1978, Table 1.

FIGURE 1: Total landings of dogfish from Maine to Cape Hatteras (in metric tons), 1964-1979.

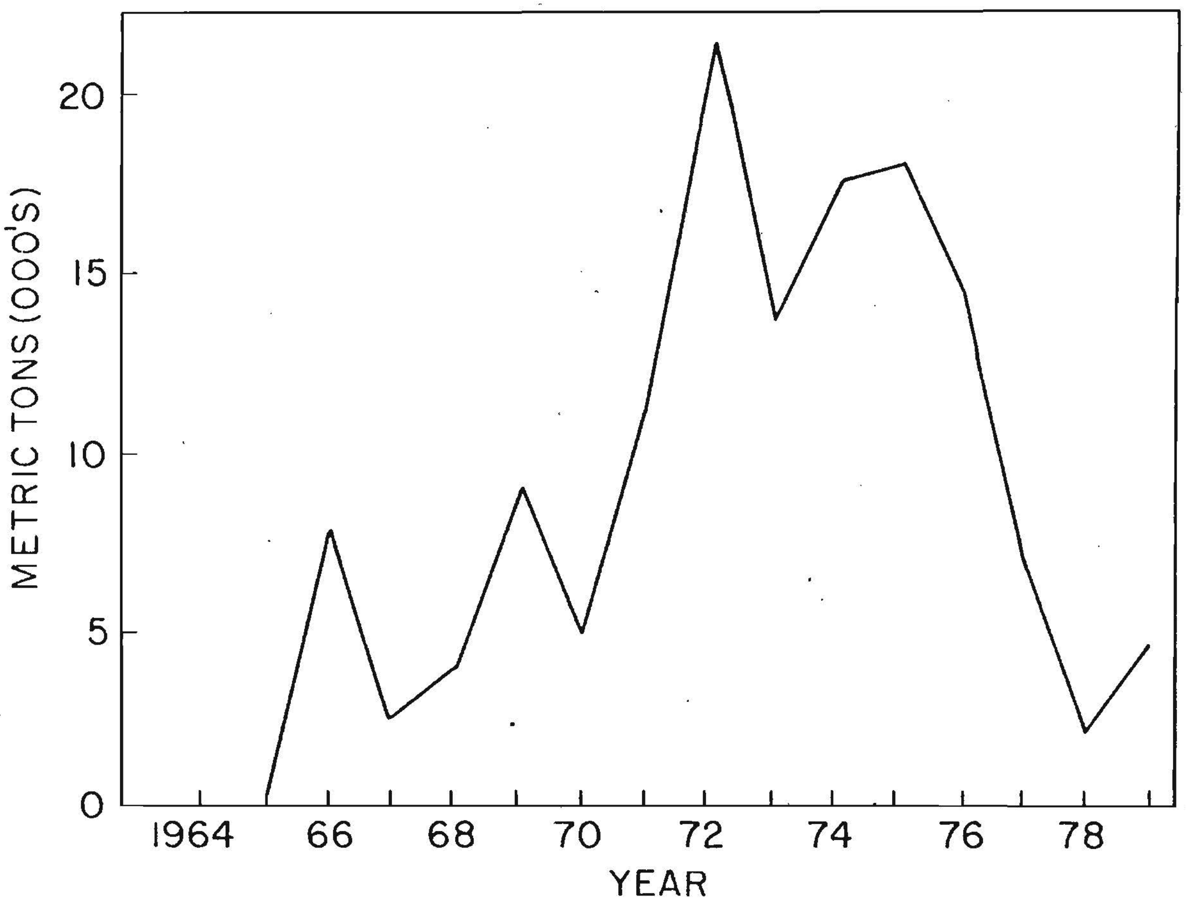

METRIC TONS (000'S)
20
15
10
5
0
1964
66
68
70
72
74
76
78
YEAR

Table 1. Northeastern dogfish catch, from ICNAF statistics. (Total catches in metric tons).

Year	Subarea 6 (Mid-Atlantic)*	Subarea 5 (New England)	Subarea 4 (E. Canada)*	Total
1973	3,400	10,400	3,500	17,300
1974	5,400	12,200	6,800	24,400
1975	2,000	16,300	4,200	22,500
1976	1,600	12,900	2,900	17,400
1977	1,900	5,800	400	8,100
1978	200	1,200	-	1,400

* Equivalent region.

Since 1975/76 a significant human food market has developed in the United States for dogfish. Both back fillet and belly flap were exported as frozen products to European markets from New England, as well as from the State of Washihgton. The flesh of the spiny dogfish, properly processed, is very palatable and of good nutritional value, and has long been a popular item of the European diet. The European dogfish stocks have decreased due to overfishing in recent years and it is estimated that they will not recover quickly. This market potential for U.S. catches should therefore continue, although the market failed to hold in 1980 due to high transportation costs. There is also strong interest in the use of dogfish flesh in frozen processed fish products. The regional Fisheries Councils have interests in fisheries development for the spiny dogfish and are also formulating regulatory programs for the fishery. The Mid-Atlantic Fisheries Development Foundation, Inc. is active in supporting projects related to its harvesting, processing and marketing. If successful development occurs, it will enlarge the extent of the new fishery, and this will be important in broadening the resource base of fishermen, -- this expansion can readily be done using fishing techniques and facilities which are already fully established for conventional fisheries.

Population Parameters

At present, there is little critical data available concerning the population biology and migrations of the eastern U.S. spiny dogfish and much has been surmised by reference to data for the west coast and for the European stocks (Jensen, 1965). There are no quantitative data in the literature for the reproductive maturation of the Mid-Atlantic/New England dogfish; the only determination of age and growth for this stock is Russian (Soldat, 1980) which uses an unreliable technique about which the author himself expresses some reservations, stating that "considerable troubles arise when working (aging) with the spiny dogfish". Reliable age/length keys and related information are not at present available for the northeast coast stocks. This lack is a serious impediment to calculations of growth and mortality rates necessary for purposes of preparing a stock assessment of fishery management of the eastern spiny dogfish.

Because of the lack of reliable data on the fundamental population parameters of age-structure, growth, maximum size and age, ages at sexual maturation and fecundity, one of us (PMJW) obtained funding support from New York Sea Grant Institute in 1979/80 to establish such data. We have now developed satisfactory techniques for age determination, using dorsal fin spines. These methods have been used to establish life tables, growth rates and other biological parameters for each sex separately. Similarly, quantitative data were obtained for sexual maturation and for relating fecundity to maternal size. The preliminary results are very satisfactory to allow direct comparisons of these basic population parameters to be made between the underfished east coast stocks and the heavily overfished European spiny dogfish stocks.

MATERIALS AND METHODS

Representative sampling of dogfish was conducted in 1976, 1979, 1980, and 1981. All fish in 1976 and many in 1979 and 1980 (448 fish) were taken from waters around Mount Desert Island, Maine, during the months of July and August by A. D. and P. M. J. Woodhead, working at the

Mount Desert Island Biological Laboratory; in 1976 these samples were supplemented by a collection made by Dr. Anthony Guarino. The majority of these fish were sexually mature and many were females. The other samples of dogfish in 1979 and 1980 were collected by Raoul Castaneda on Georges Bank, Brown's Bank and other sites included in NMFS bottom trawl surveys (Figure 2). Fish were also collected in 1981 on NMFS groundfish surveys off Long Island, New York, by Shawn McCafferty. All these latter sites yielded approximately equal numbers of immature and mature fish, with no apparent sex predominance. Total lengths, defined as the distance from the snout tip to the tip of the upper lobe of the caudal fin when depressed to align with the longitudinal axis of the fish, were recorded for all fish. When possible, the total body weight, total embryo number, and number of ripening ovarian eggs were also determined.

AGE DETERMINATION

Age determination in elasmobranchs is difficult, for they lack calcareous otoliths or bony ridge scales, both of which are commonly utilized in teleost aging techniques. The use of vertebral centra for elasmobranch aging has been a fairly useful method (Daiber, 1960; Aasen, 1963; Stevens, 1975) but this technique proved to be problematic with Squalus acanthias, as staining failed to differentiate growth rings on centra. The use of the dogfish dorsal fin spines for age determination has been successfully undertaken by numerous researchers and this technique was utilized in the present study (Kaganovskaia, 1933; Templeman, 1944; Bonham, 1949; Holden and Meadows, 1962; Ketchen, 1975; Soldat, 1980). The dorsal fin spine consists of a polished enamel outer layer overlying a thin layer of pigment, three layers of dentine, and a central pulp cavity; this is shown diagrammatically in Figure 3. A cartilage rod at the spine base connected to the dorsal fin cartilage keeps the spine in place. The spine grows from its base in a series of steps which can be likened to a series of dentine cones laid on top of each other. The cones are laid down annually and pigment bands form between the enamel and dentine at the base of each cone, forming an annual mark (Holden and Meadows, 1962), as seen in Figure 3 and 4. The number of growth bands occurring along the length of the spine is

FIGURE 2: Collection areas for *Squalus acanthias* (outlined by dashed line) during the years 1976, 1979, 1980, and 1981.

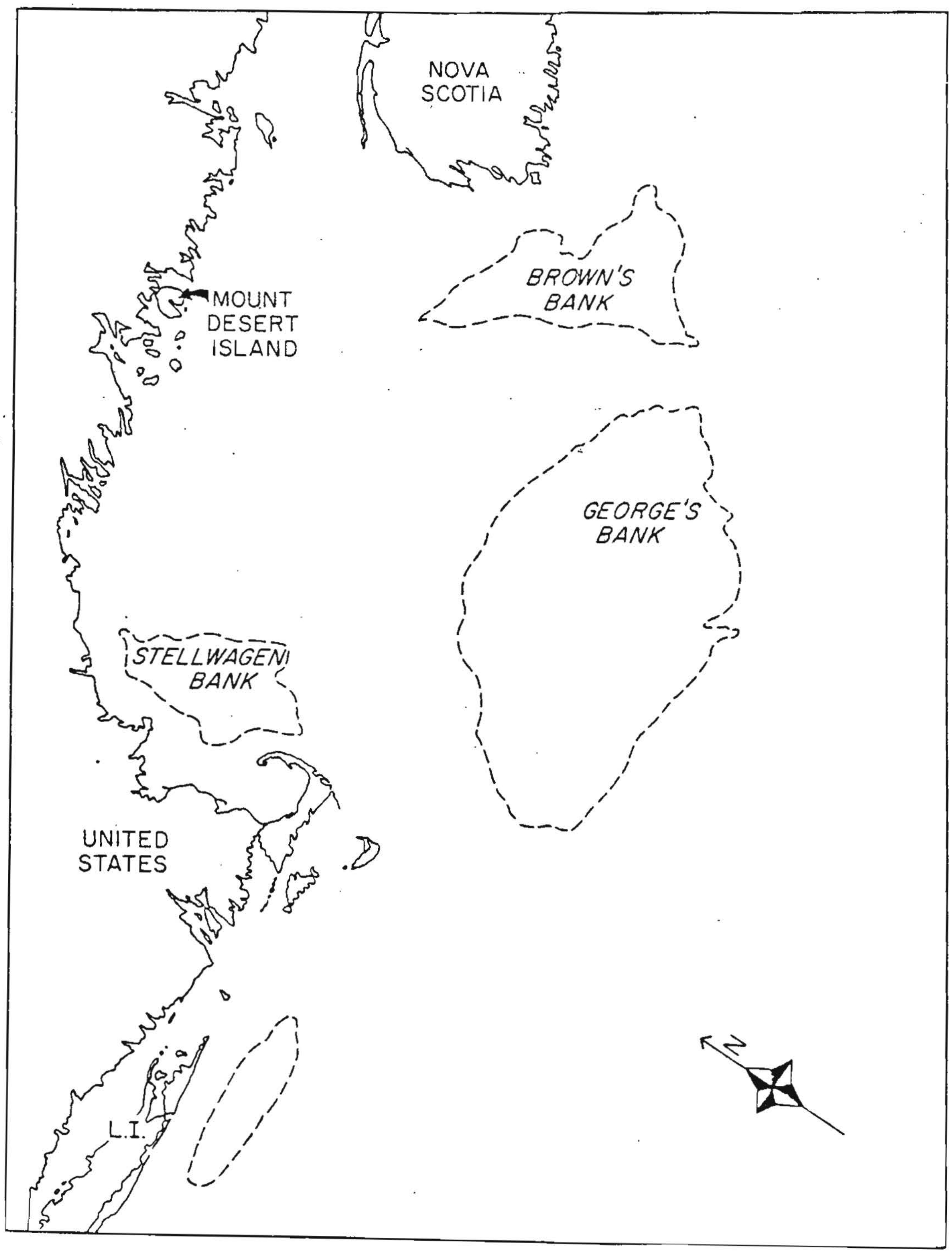
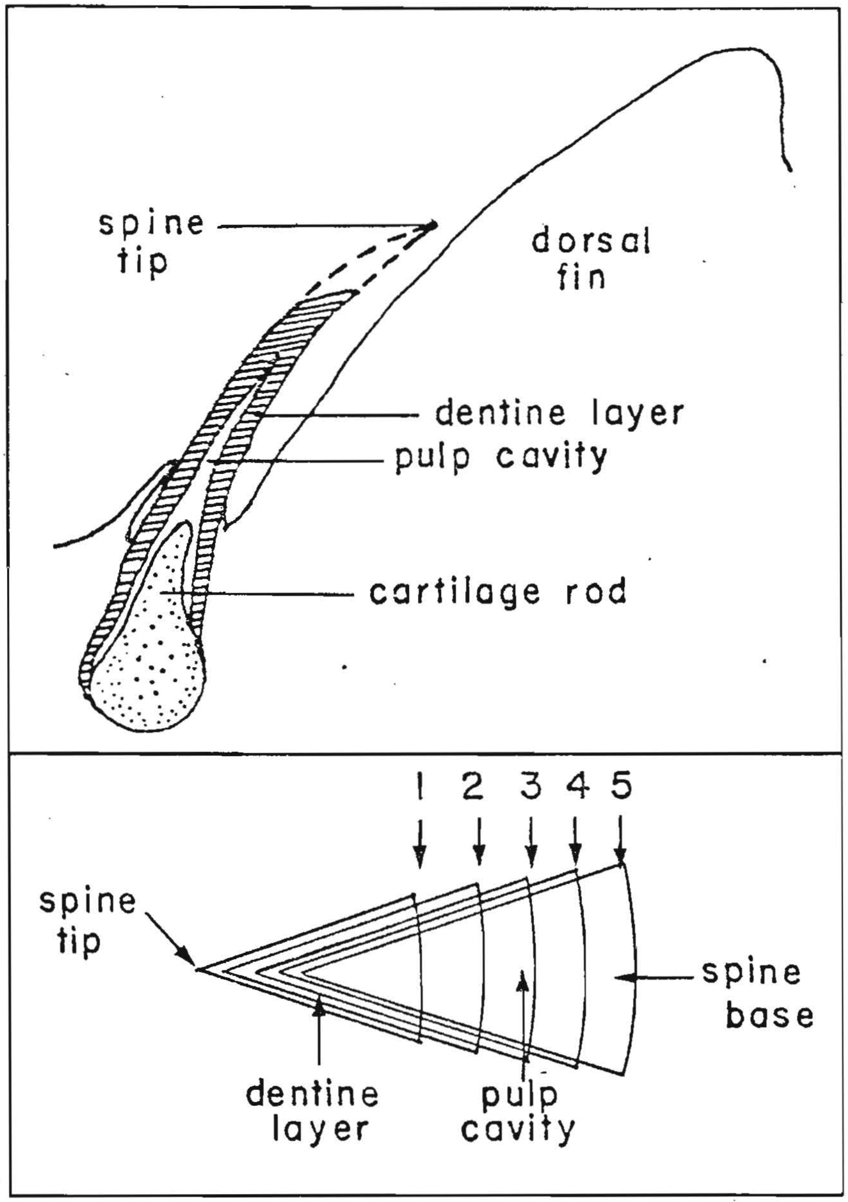
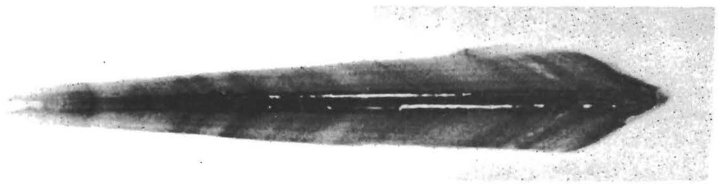

NOVA
SCOTIA
BROWN'S
BANK
MOUNT
DESERT
ISLAND
GEORGE'S
BANK
STELLWAGEN
BANK
UNITED
STATES
L.I.
N

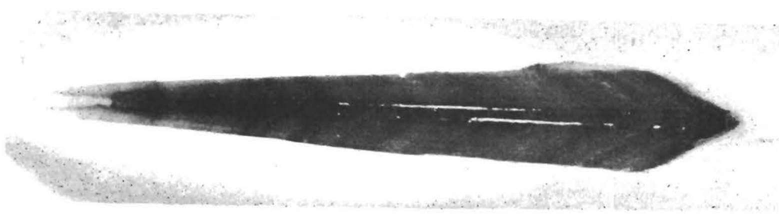
FIGURE 3: Depiction of dorsal fin spine located anterior to dorsal fin (top). Schematic of spine growth (bottom) showing five annual opaque rings or bands at "cone bases".

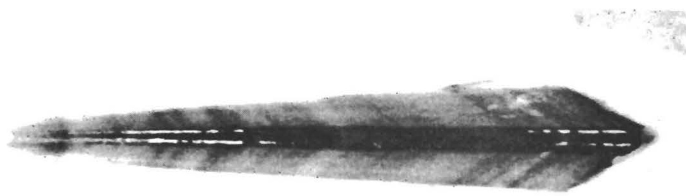


spine tip
dorsal fin
dentine layer
pulp cavity
cartilage rod
1 2 3 4 5
spine tip
spine base
dentine layer
pulp cavity

FIGURE 4: Three dorsal fin spines showing pigment bands used to determine fish age.







usually counted by viewing the external surface of the whole spine under a low power binocular microscope, but dentine rings have been described in both longitudinal sections and cross sections of the spine (Holden and Meadows, 1962; Soldat, 1980). Soldat (1980) used ground cross sections of spines to age dogfish from the Northwest Atlantic but, together with Holden and Meadows (1962), he commented on the difficulties in accurately counting cross-sectional rings. In particular there was the possibility of the "loss" of rings depending on where the spine was cut and the need to apply a correction for such neglected growth bands in attempting to estimate age from spine cross sections. Because of the difficulties encountered by other workers using this method, we did not attempt to determine fish ages from sections of spines but counted the bands observed on the external surface of the spines.

The anterior and posterior dorsal fin spines were removed from the fish and stored in vials with a 10% formaldehyde solution, for later use in age determination. The method utilized in this study was to count the opaque pigment bands separated by lighter, hyaline zones and is similar to the method employed by Holden and Meadows and others. The posterior spine was used for aging, being the larger of the two and having the rings spaced further apart. However, a comparison of age determined from both anterior and posterior spines was carried out when both were available. The spine was observed with a binocular microscope under low magnification (8x) using side lighting. If higher magnification was used, the bands appeared diffused and became difficult to count. The spine was moistened with water and placed on its concave, posterior surface in a clear, glass petri dish. The dish was angled by hand to allow light to pass through one side of the spine, thereby clearly illuminating the bands on the opposite side. Two counts were made of the opaque bands on one side of the spine; the same was done on the opposite, anterior face.

The ring structure on dorsal spines showed some variations between fishes. Holden and Meadows (1962) have also noted this and described a number of commonly occurring conditions. When changes in ring pattern were found, such as split or double rings they were carefully regarded and the interpretation of Holden and Meadows was followed in estimating the age from the spines. To eliminate possible unconscious bias, care was also exercised to keep from the reader all information about the fish whose spine was being analyzed. It was observed that the ring patterns on spines from male fish were less distinct overall than female fish spines. It was also noted that, as Ketchen (1975) had observed, the bands marking the first 5 to 7 years of growth were broader and fainter than later rings. The trend of reduction in annual band width with increasing age is shown for a group of ten fish in Figure 5. There was considerable variation in growth band width from year to year on any single spine but the gradual reduction in band width with age is fairly clear for the group as a whole.

The age range for any particular spine count was one to three or more years. Any spine with an age range of three or more years was read again at a later date, in an attempt to obtain a more precise reading. Spines from fish over 100 cm in length were reread also, to reduce any error due to worn or damaged spines. If the reading differed by one year, an averaging of ages was employed, by alternately choosing the higher and lower age in a particular size class of fish. If the count differed by two years, the mean age was accepted. A spine reading was discarded if the difference between readings was greater than two years. Any spine considered too worn to yield an accurate age was also rejected. This subjective decision usually occurred if the spine was worn to or beyond the start of the pulp cavity.

Of the 832 spines counted, 24% yielded a single age, 44% had an age range of one year, 20% ranged over two years, 3% had a three year range, and 10% were considered unreadable. This method eventually yielded age determinations for 434 female and 225 male fish.

RESULTS

Growth

The relationship of total fish length to estimated age for both males and females was plotted (Figures 6 and 7) and curves were fitted to this data using the familiar von Bertalanffy (1938) growth equation:

FIGURE 5: Relation between pigment band intervals and fish age for 10 fish, indicating decreased spine growth with age. Pigment band intervals measured in arbitrary units. Note that spines used are from fish of varying ages.

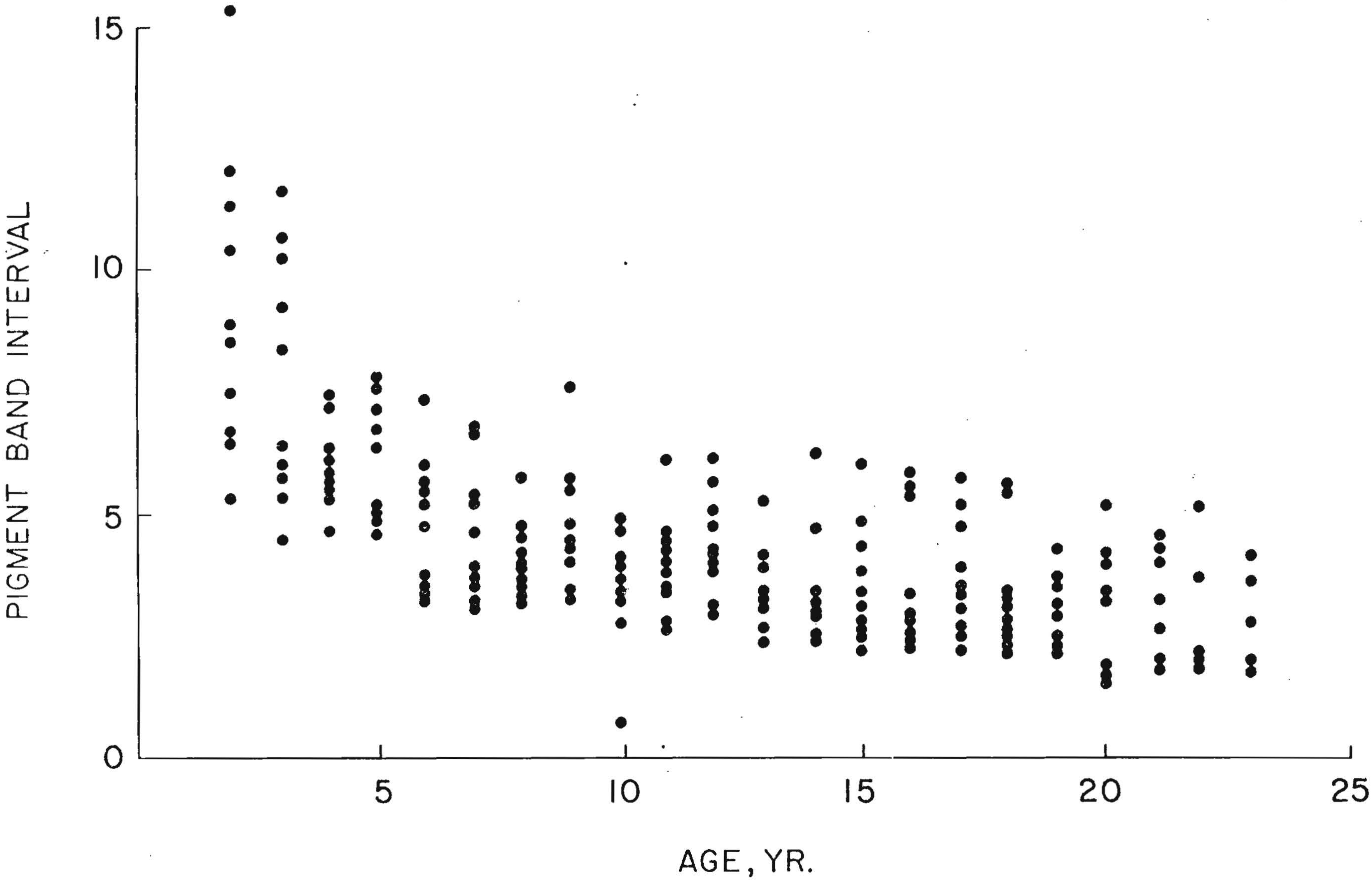

PIGMENT BAND INTERVAL
15
10
5
0
5
10
15
20
25
AGE, YR.

FIGURE 6: The von Bertalanffy growth curve fitted to the observed lengths at age for female S. acanthias (433 fish). Note that more than one fish may be represented by individual points.

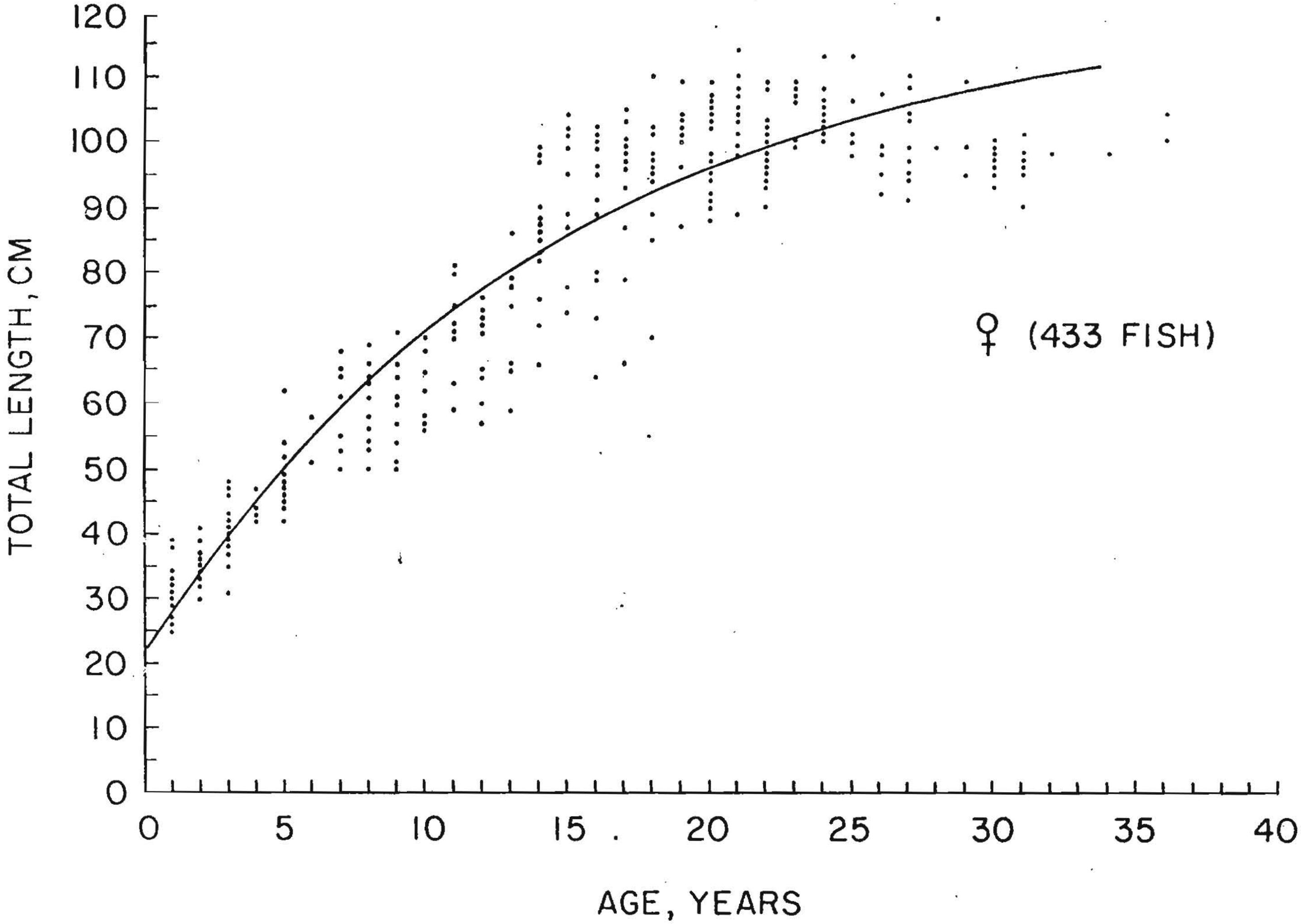
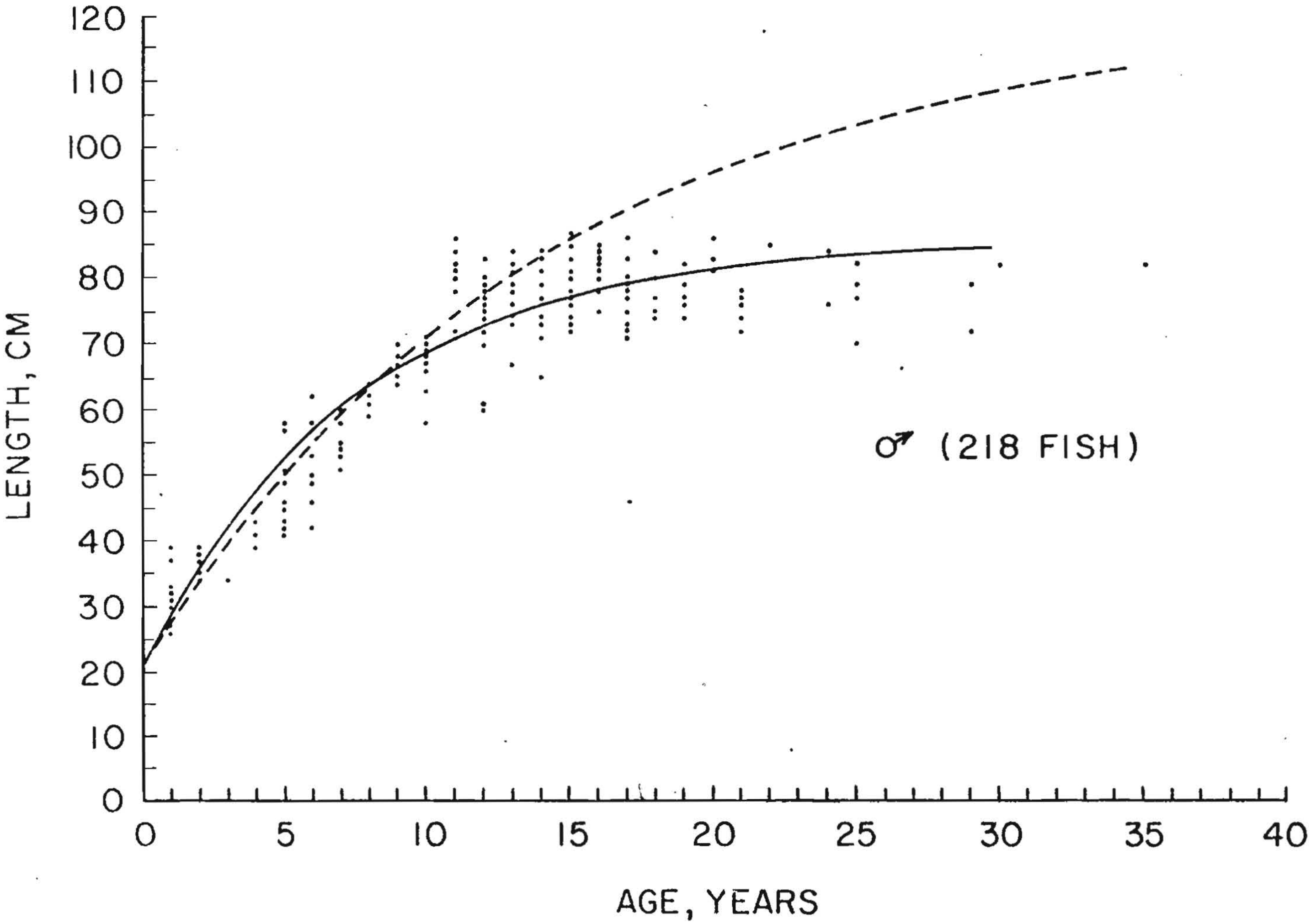

TOTAL LENGTH, CM
0
10
20
30
40
50
60
70
80
90
100
110
120
AGE, YEARS
0
5
10
15
20
25
30
35
40
♀ (433 FISH)

FIGURE 7: The von Bertalanffy growth curve fitted to the observed lengths at age for male S. acanthias (218 fish). Note that more than one fish may be represented by individual points. Dashed line depicts the female growth curve for comparison.



LENGTH, CM
AGE, YEARS
♂ (218 FISH)

$$L_t = L_\infty(1-\exp[-K(t-t_0)])$$

where L_t = length at time t

L_∞ = theoretical average maximum length

K = Brody growth coefficient indicating the rate at which length approaches L

t_0 = calculated time at which length (L) is equal to zero

The growth curves were fitted by least squares as described by Tomlinson and Abramson (1961). The curves were computed on a Univac 1100 computer utilizing Abramson's BGC-3 Fortran program. The von Bertalanffy growth parameters of the male and female growth curves are shown in Table 2. The mean lengths at age are listed in Table 3 and the distribution of fish lengths at age are given in Tables 4 and 5. The most noticeable differences between the males and females are the L_∞ and K values. Males have a larger value for K but a smaller L_∞ than females indicating that males reach their theoretical average maximum length (L_∞) more quickly than females. Caution must be exercised when interpreting K, for it should not be regarded simply as the growth rate of a particular fish or population (Ricker, 1975). Other factors besides growth rate of the fish influence K, such as the value of L_∞. An example of this can be seen when comparing the male and female growth parameters. The larger Brody growth coefficient for males might at first infer a faster rate of growth. Yet, comparison of the two growth curves together (Figure 7) shows their growth rates prior to maturation are very similar. However, the Brody growth coefficient (K) can be used for comparison as an indication of growth differences among populations of the same species, as long as such considerations are kept in mind.

The calculated time at which fish length equals zero (t_0) for both males and females in this study is close to -2 years, which corresponds to the two year uterine gestation period of dogfish. Estimates of the length at birth calculated from the curves obtained (20.0 cm and 20.8 cm for males and females respectively) are somewhat low compared to the estimated size range at birth of 23-28 cm for this population of dogfish.

Table 2. Calculated von Bertalanffy growth parameters for Northwestern Atlantic stock.

Sex	L_∞	K	t_0	n
F	120.96	.0689	-2.75	433
M	85.48	.1359	-1.96	218

Table 3. Mean lengths at age for male and female dogfish.

Age, year	1	2	3	4	5	6	7	8
M	32.2	36.9	34.0	41.5	47.6	52.9	56.4	61.0
n	11	11	1	3	12	10	8	8
F	32.0	35.0	39.9	43.8	47.6	53.3	58.6	58.0
n	25	23	17	9	20	3	8	18

	9	10	11	12	13	14	15	16
M	66.7	66.6	80.6	74.4	77.6	76.2	78.8	81.1
n	7	9	9	15	14	13	21	14
F	60.1	63.0	70.4	66.6	71.8	85.1	92.4	89.4
n	16	13	10	11	8	15	13	16

	17	18	19	20	21	22	23	24
M	78.8	78.5	77.3	83.3	75.5	85.0	–	80.0
n	17	8	6	3	6	1	–	2
F	95.4	95.5	100.3	96.6	104.6	99.2	104.7	104.4
n	23	19	28	23	19	24	11	13

	25	26	27	28	29	30	31	32
M	77.0	–	–	–	75.5	82.0	–	–
n	4	–	–	–	2	1	–	–
F	102.5	98.2	100.1	109.0	101.0	96.8	96.2	–
n	11	5	9	2	3	8	6	–

	34	35	36
M	–	82.0	
n	–	1	
F	98.0	–	102.0
n	1	–	2

Table 4. Distribution of fish lengths at age for females.

	Age, Years - Females																	
Lengths cm	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
25-29	4																	
30-34	17	12	1															
35-39	3	11	9															
40-44		1	4	7	4													
45-49			3	2	12													
50-54					3	2	3	6	3									
55-59						1	1	5	3	5	1	2	1					
60-64					1		2	3	6	2	2	3				1		
65-69							2	4	3	4		1	3	1			1	
70-74									1	2	4	4		1	1	1		1
75-79											1	1	3	1	1	1	1	
80-84											3			3		2		
85-89													1	5	4	1	1	3
90-94														1		2	4	2
95-99														3	3	5	9	6
100-104															4	3	7	6
105-109																		
110-114																		1
115-119																		

Table 4. Continued.

Lengths cm	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
							Age, Years - Females											
25-29																		
30-34																		
35-39																		
40-44																		
45-49																		
50-54																		
55-59																		
60-64																		
65-69																		
70-74																		
75-79											1							
80-84																		
85-89	1	2	1															
90-94	2	9		4				1	2			1	1					
95-99	2	4	2	7	1		1	3	3	1	2	6	4	1			1	
100-104	21	4	7	11	3	8	7		2			1	1					1
105-109	1	4	5	2	7	4	2	1	1		1							
110-114			4			1	1		1									
115-119										1								

Table 5. Distribution of fish lengths at age for males.

Lengths cm	Age, Years - Males																
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
25-29	2																	
30-34	6	1	1															
35-39	3	10		1														
40-44				3	4	1												
45-49					4	2												
50-54					2	3	3											
55-59					2	3	2	3		1								
60-64						1	3	5	1	1		2						
65-69									5	5			1	1				
70-74									1	2	1	4	2	6	4		3	1
75-79											2	6	7	2	7	3	7	4
80-84											4	3	3	4	8	9	6	3
85-89											1				2	2	1	
90-94																		
95-99																		
100-104																		
105-109																		
110-114																		
115-119																		

Table 5. Continued.

Lengths cm	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
							Age, Years - Males											
25–29																		
30–34																		
35–39																		
40–44																		
45–49																		
50–54																		
55–59																		
60–64																		
65–69																		
70–74	1		2				1				1							
75–79	4	1	3			1	2											
80–84	1	2					1					1					1	
85–89		1		1		1												
90–94																		
95–99																		
100–104																		
105–109																		
110–114																		
115–119																		

This indicates a poorer fit of the von Bertalanffy equation in these young size classes. The values for L_{∞} correspond closely with the greatest observed maximum lengths (L_{max}) of fish sampled, which were 91 cm for males and 119 cm for females.

Maturation

A cumulative frequency distribution of fish lengths was plotted to determine the length at 50% maturation for both males and females (Figures 8 and 9). Maturity of male dogfish was judged by clasper size, which enlarge noticeably at sexual maturation. Female maturity was defined by the presence of uterine embryos, or uterine eggs encapsulated in "candles". Only the fish caught offshore, in the Georges Bank, Stellwagen Bank, Brown's Bank, and NMFS sites, were used for the 50% maturation determination. These fish better represented a sample of the entire population length range, since most immature fish were caught offshore. Using the offshore samples, 148 males and 213 females were utilized; it is acknowledged that these form only small samples and are only intended for comparison purposes.

For these samples the lengths at 50% maturation were 75.7 cm and 92.8 cm for males and females respectively. A calculation of the age at which 50% of the fish became sexually mature was made utilizing the von Bertalanffy growth curves determined for this stock. The calculated ages of 50% maturity were 14 years for males and between 18 and 19 years for females.

An analysis of the age data with respect to sexual maturity yielded an important relation regarding dogfish growth and maturation. Immature females were consistently smaller than mature females of comparable age. These size differences are shown in Table 6 for females sampled at offshore sites. The finding that immature females are consistently smaller at age, or slower growing, indicates the significant influence of growth rate on the onset of sexual maturity.

FIGURE 8: Relation between length of female dogfish and percentage maturity (213 fish).

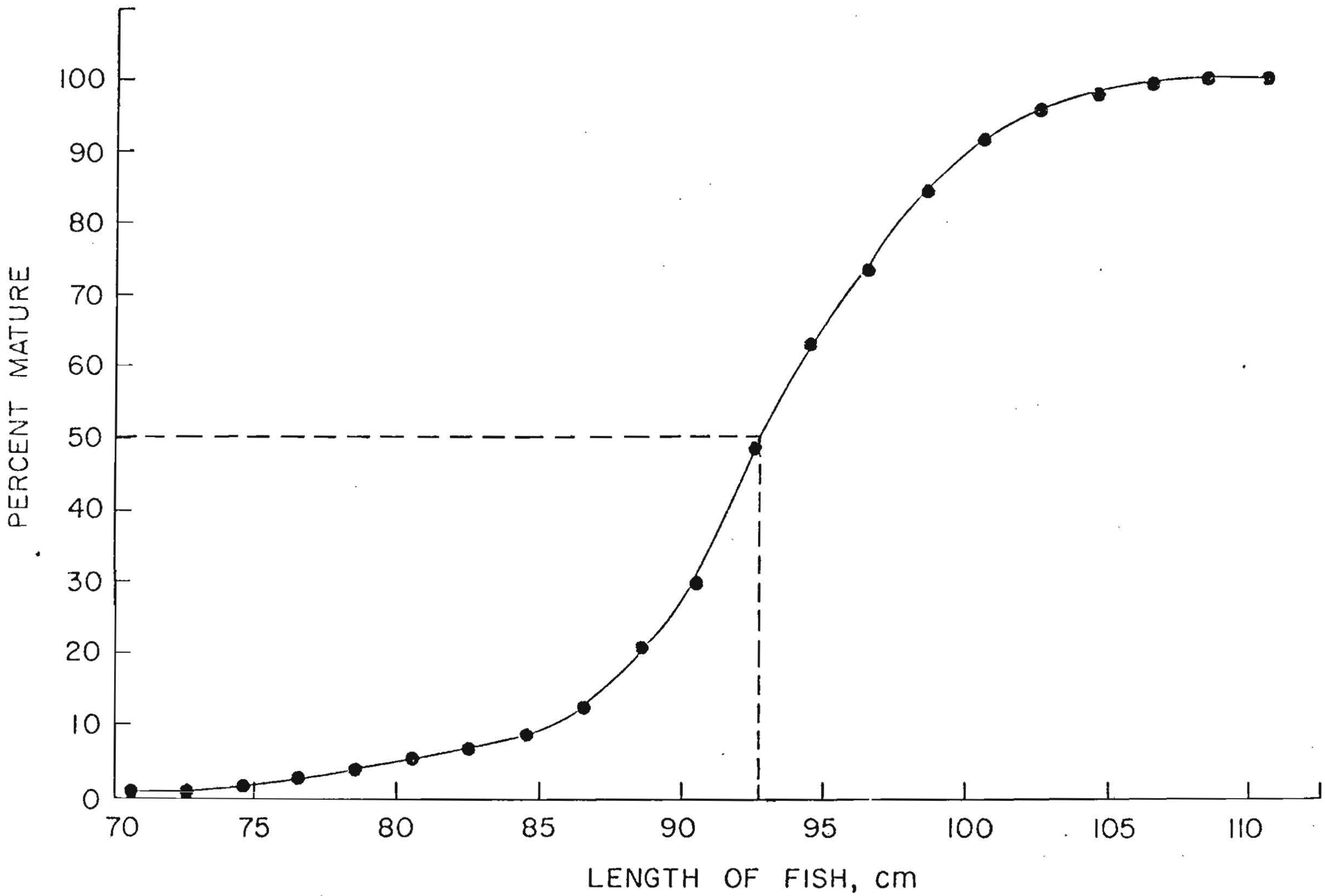
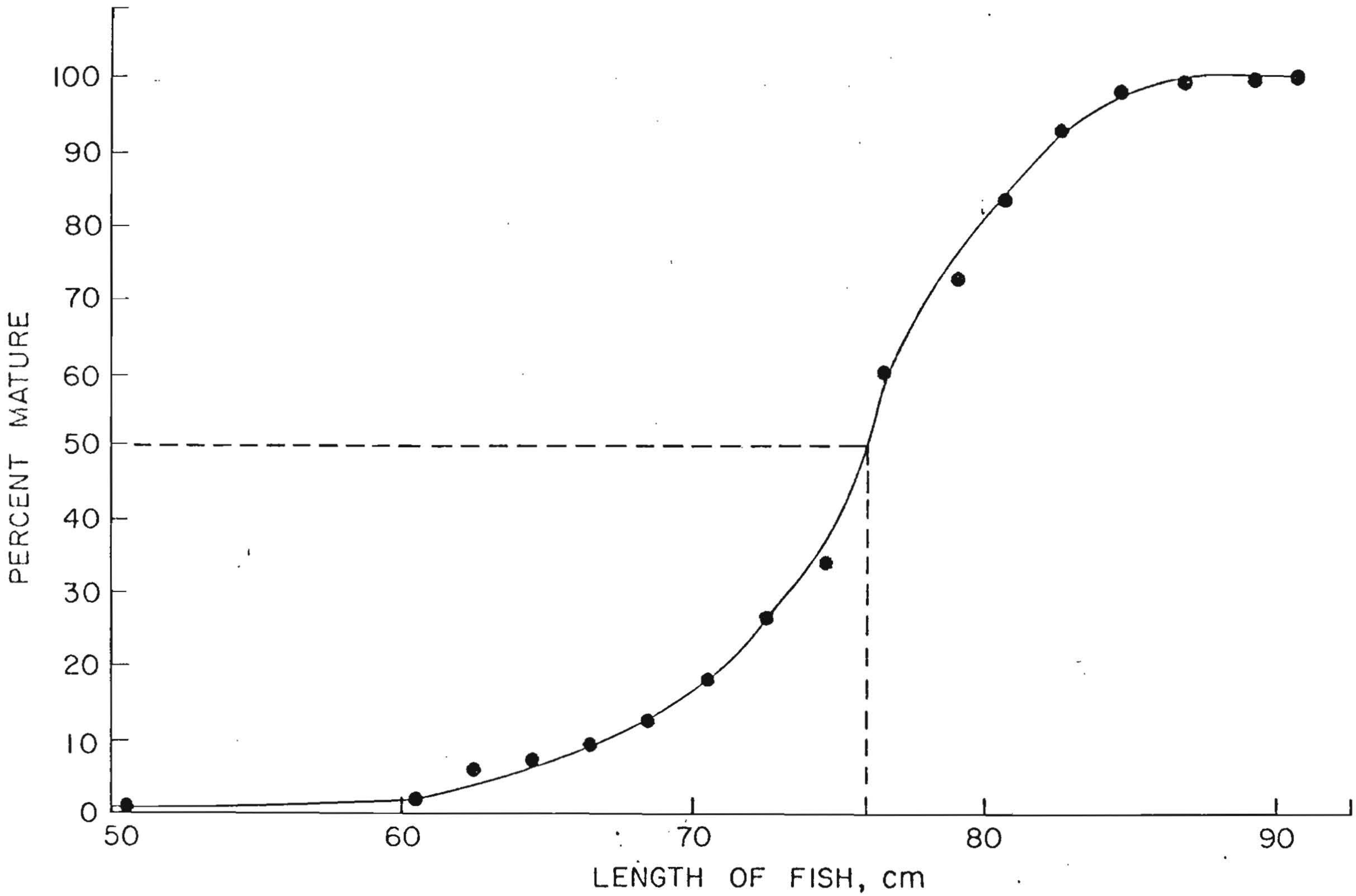

PERCENT MATURE
100
90
80
70
60
50
40
30
20
10
0
70
75
80
85
90
95
100
105
110
LENGTH OF FISH, cm

FIGURE 9: Relation between length of male dogfish and percentage maturity (148 fish).



PERCENT MATURE
100
90
80
70
60
50
40
30
20
10
0
50
60
70
80
90
LENGTH OF FISH, cm

Table 6. Comparison of lengths at age for immature and mature female fish sampled at offshore sites.

Age	TOTAL LENGTHS					
	Immature			Mature		
	Mean	Std. Dev.	N	Mean	Std. Dev	N
13	67.3	8.42	4	86.0	-	1
14	74.0	2.83	2	85.9	2.42	8
15	74.0	-	1	87.2	6.10	5
16	68.5	6.36	2	89.0	7.77	6
17	66.0	-	1	92.3	7.41	7
18	70.0	-	1	89.7	5.03	3

DISCUSSION

Growth

Comparison of our data with previous studies is limited, because many earlier studies pooled male and female growth data, making comparisons inappropriate (Kaganovskaia, 1933; Aasen, 1961; Holden and Meadows, 1962). The present growth curves and their parameters for male and female fish separately are given in Table 7, together with comparable data for spiny dogfish from the Northeastern Atlantic (Scottish-Norwegian) stock and for west coast, Pacific stocks of this species. The Pacific dogfish are found to be between 5 and 10 cm larger than Atlantic stocks. The maximum observed lengths (L_{max}) for Pacific stocks range from 100-107 cm for males and 124-130 cm for females (Ketchen, 1972). L_{max} for Atlantic stocks range from 83-91 cm for males and 109-119 cm for females (present study). The increased size of Pacific dogfish can also be seen in comparison of the L_{∞} parameters in Table 7, which should reflect the L_{max} values obtained from samples. However, the comparison of observed maximum lengths (L_{max}) is more applicable than comparison of L_{∞} in this case, due to inappropriately large estimates of L_{∞} by Bonham (1949) which were not matched by equally large fish in catches.

Although Atlantic stocks apparently do not grow as large as Pacific dogfish, Atlantic populations seem to grow faster during immaturity, as shown by the K parameters and by simultaneous comparison of the various growth curves (Figures 10 and 11). The growth curve predicted by Ketchen (1975) is taken to be representative of Pacific stocks and is therefore the curve depicted for comparison in Figures 10 and 11. The higher K value for Atlantic stocks is indicated by the steeper slope of the growth curve, while the larger L_{∞} of Pacific dogfish is denoted by the greater height of the growth curve. It can also be seen that the growth curves of previous studies begin with slightly greater lengths at birth (age zero) indicating a somewhat better fit of the curve at younger ages. However, comparison of t_0 values in Table 7 shows that the present study has values quite close to -2 years, reflecting the 2 year gestation period of dogfish whereas previous studies obtained t_0

Table 7. Comparison of von Bertalanffy growth parameters for Atlantic and Pacific stocks of spiny dogfish.

Area/Source	Sex	L∞	K	t_o	n*
Northwest Atlantic	F	120.96	.0689	-2.75	433
Present Study	M	85.48	.1359	-1.96	218
Northeast Atlantic	F	101.4	.11	-3.6	445
Holden and Meadows (1962)	M	79.7	.21	-2.0	317
British Columbia	F	125.3	.048	-4.88	418[b]
Ketchen (1975[a]	M	99.3	.070	-4.70	
Strait of Georgia-B.C.	F	128.0	.037	-6.6	8
Jones and Geen (1977)[c]	M	98.4	.072	-4.1	7
Washington Coast	F	152.9	.036	-6.7	107
Bonham (1949)	M	101.8	0.71	-5.2	109

* Sample size

a Average of Hecate Strait and Strait of Georgia results

b Sexual breakdown not specified

c Age determination by x-ray spectometry

FIGURE 10: Comparison of von Bertalanffy growth curves for male *S. acanthias* from three different fish populations, from North Sea (Holden and Meadows, 1962), from British Columbia (Ketchen, 1975), and from the Northwestern Atlantic (present study).

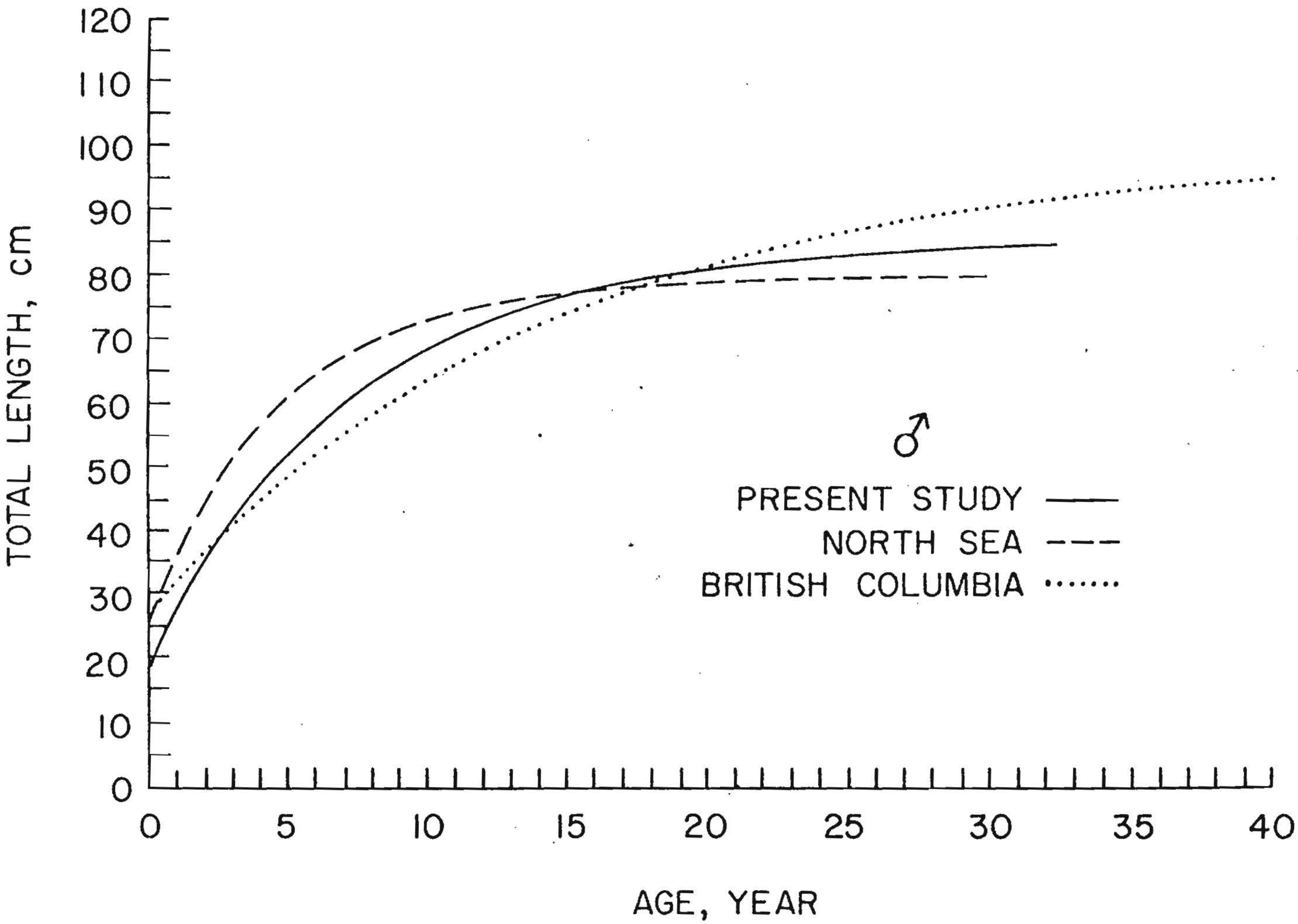
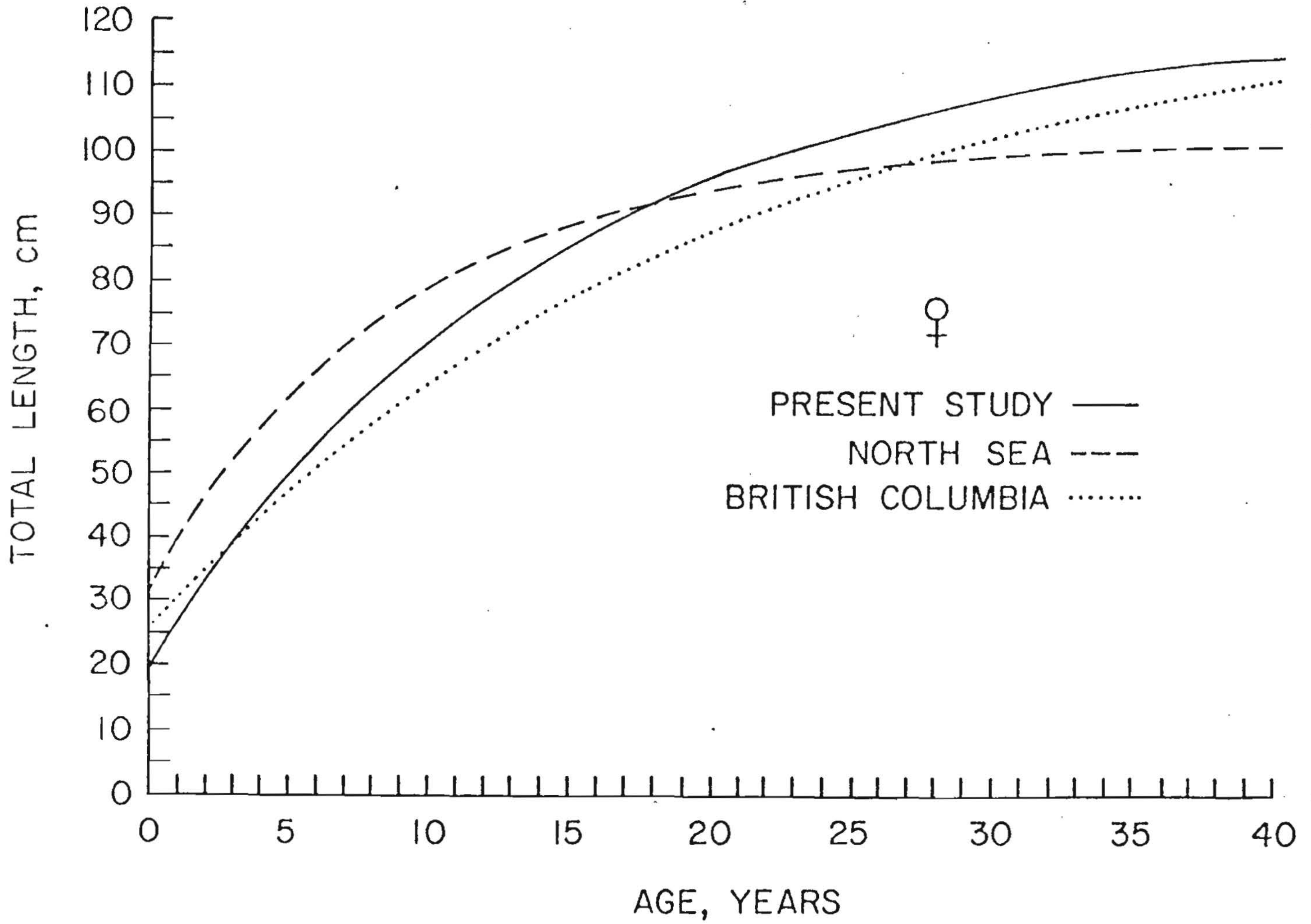

TOTAL LENGTH, cm
0
10
20
30
40
50
60
70
80
90
100
110
120
AGE, YEAR
0
5
10
15
20
25
30
35
40
♂
PRESENT STUDY
NORTH SEA
BRITISH COLUMBIA

FIGURE 11: Comparison of von Bertalanffy growth curves for female S. acanthias from three different fish populations, from North Sea (Holden and Meadows, 1962), from British Columbia (Ketchen, 1975), and from the Northwestern Atlantic (present study).



TOTAL LENGTH, cm
120
110
100
90
80
70
60
50
40
30
20
10
0
0
5
10
15
20
25
30
35
40
AGE, YEARS
♀
PRESENT STUDY
NORTH SEA
BRITISH COLUMBIA

values different from -2 years, suggesting that in this respect the present results give the better fit at younger ages.

Comparison of the growth curves and their parameters for Atlantic dogfish stocks show interesting differences between them. K values for the Northeastern Atlantic, or North Sea, dogfish population (Holden and Meadows, 1962) are higher for both sexes than values derived from Northwestern Atlantic stocks. The faster growth of Northeastern Atlantic stocks is possibly a reflection of increased fishing mortality on growth. An extensive commercial dogfish fishery expanded rapidly in the North Sea, off Scotland and Norway after the 1939-45 war, while Northwestern Atlantic stocks have had comparatively little commercial fishing pressure, at least until the mid 1970's. The North Sea stock studied by Holden and Meadows (1962) might therefore exhibit the increased growth rate, earlier maturation and reduced maximum lengths, indicative of a heavily fished stock when compared to relatively underutilized populations (Holden, 1973; Adams, 1980).

The increased growth rate can be seen in the higher Brody growth coefficient values and the larger mean lengths at age for North Sea samples. A reduction in the maximum predicted lengths attainable and maximum observed lengths is depicted by the comparatively lower L_∞ and L_{max} values for North Sea stocks (Table 7).

It can be seen from the overall results that male dogfish mature earlier and that they reach a smaller maximum size than female fish. The Northwest Atlantic stock of dogfish apparently grow faster than Pacific dogfish stocks, but they do not reach as large a maximum length. Compared to the North Sea stocks, the Northwest Atlantic population seems to have a slower growth rate and higher maximum length. These differences between Atlantic populations may be due to differences in fishing pressure.

Maturation

Both of the maturation estimates calculated for this population (75.7 cm for males; 92.8 cm for females) are high when compared to other estimates for Atlantic stocks. Holden and Meadows estimated the size of 50% maturation for North Sea males was 60 cm and 82 cm for females, while Nammack (1982) calculated values for Northwestern Atlantic stocks of 81.3 cm for females and 58-62 cm for males. The present study's estimates are actually more comparable to Pacific dogfish estimates of length at 50% maturation (Estimates from Ketchen (1972) were 72 cm for males and 93.5 cm for females). The estimated ages at 50% maturity for this stock, 14 years for males and 18-19 years for females, can be contrasted with 5 years for males and 11 years for females for the North Sea dogfish as determined by Holden and Meadows. The lengths and ages at 50% maturation for this stock are only estimates, since it is realized that the sample sizes used for these approximations are too small to expect accuracy.

Although the size at maturity values obtained for the small samples in this study are comparatively high, it is quite probable that this stock does exhibit a larger length at maturity than the North Sea stocks studied by Holden and Meadows, because this Northwestern Atlantic population grows more slowly and reaches larger maximum lengths. When comparing these two Atlantic stocks, it must be remembered that the North Sea dogfish have been exploited much more heavily than Northwest Atlantic dogfish stocks.

Finding that the immature females were smaller than mature females of the same age indicates that these immature fish are slower growing. The resulting conclusion, that faster growing fish mature at an earlier age, holds interesting implications concerning the fecundity of this dogfish population. One way which fish populations are able to control their fecundity is through density dependent changes in growth patterns. If population density is low or in the process of decreasing, fish growth will tend to increase, reducing the time to sexual maturation and thereby increase a fish's overall reproductive potential (Holden, 1973, 1974); reduction in the size at maturation may also occur. This may be related to the differences found when the two populations on either side of the Atlantic are compared. The North Sea population density is low due to fishing pressure and the fish grow more rapidly and increase fecundity by shortening the time to sexual maturation.

CONCLUSION

The von Bertalanffy growth parameters determined for the Northwestern Atlantic dogfish population exhibit relationships similar to other studies when compared between sexes and to Pacific stocks, while highlighting interesting differences between other Atlantic populations. The male dogfish mature earlier and reach a smaller maximum size than females. Growth of this Atlantic stock is apparently faster, but maximum attainable size is not as great as reported for Pacific stocks. The Northeastern Atlantic, North Sea, stock of dogfish was found to have higher growth coefficients (K), but lower $L_{(max)}$ and L_{∞} values, indicating that these fish grow faster, but do not achieve sizes as large as the Northwestern Atlantic populations. The differences in growth between the stocks on either side of the North Atlantic may be related in part to the greater fishing pressure exerted on the North Sea dogfish stocks.

Comparison of size at age among immature and mature female fish showed that faster growing fish mature at an earlier age. Increasing growth rate and the resultant earlier sexual maturation is considered to be a density dependent mechanism for control of fecundity, especially in more k-selected species. If the size of the Northwestern Atlantic dogfish population is reduced due to fishing or other environmental pressures, an increase in growth rate might be one response exhibited by these dogfish to increase overall fecundity. However, such an attempt at increased growth and an earlier maturation would have only limited effects in increasing the fecundity of this species, which exhibits such low reproductive potential and slow growth.

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DUE DATE