http://journal.nafo.int
J. Northw. Atl. Fish. Sci., Vol. 7: 89–98

Length-weight Relationships, Morphometric Characteristics and Thorniness of Thorny Skate (*Raja radiata*) from the Northwest Atlantic

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Abstract

Research on length-weight, morphometrics and thorniness of thorny skate in the Northwest Atlantic was carried out in 1947–72. Length-weight data for the northern and southern regions, where sexual maturity begins at smaller and larger sizes respectively, were compared by sex and maturity. Slopes of the log-log length-weight regressions were lower for matures than for immatures, and, consequently, mature fish had lower average weights than immatures of the larger size-groups. Morphometric characteristics by sex and maturity, as percentages of total length of fish, indicated that tail length was shorter than disc length in mature skate, and that length from snout to posterior tip of pelvic fin was greater, and head width across mid-pupils and distance between the fifth pair of gill slits were less in mature males than in mature females, immature males and immature females. Dorsal thorniness decreased with increase in skate length and advance toward sexual maturity, with males showing a much greater and earlier loss of thorniness than females. Thorniness decreased at smaller sizes in northern waters, where sexual maturity occurs at small sizes, than in southern waters, where sexual maturity occurs at larger sizes.

Introduction

Published measurements of the body proportions of thorny skate (*Raja radiata*) are very scarce: two specimens from waters off Massachusetts by Bigelow and Schroeder (1953) and two specimens from South African waters by Hulley (1970) were noted with extensive measurements. Studies of morphometrics and weights of this species in the present paper provide comparative information on these parameters for immature and mature male and female thorny skate from different parts of the Northwest Atlantic. Insufficient data from each of the various parts of this large area (West Greenland to Georges Bank) led to combination and comparison of data for two regions where sexual maturity begins at smaller and at larger sizes and the skate grow to correspondingly smaller and larger maximum sizes. The Scotian Shelf (Div. 4VWX), for which the available length-at-maturity data are not precise but the maximum sizes are large, is included in the second area for morphometrics only.)

When the investigation began in 1947, the interest in making observations on relative thorniness of the dorsal surface of thorny skate originated from Garman's (1913) description of the new species of North American thorny skate (*Raja scabrata*) as being larger and less thorny than the European species (*R. radiata*). Subsequently, after Bigelow and Schroeder (1953) did not find species differences between thorny skates from the Northwest and Northeast Atlantic and restored *Raja radiata* as the scientific name of the North American species, the author's investigation continued with emphasis on discovering what differences exist between thorniness of this skate in different stages of maturity by sex from areas where first maturity occurs at smaller and larger sizes.

Differences in dorsal spine and tooth-row numbers among Northwest Atlantic populations of thorny skate were reported by Templeman (1984), and differences in size of thorny skate egg-capsules from various parts of the area in relation to the sizes of females which produced the capsules were reported by Templeman (1982).

Materials and Methods

Length-weight data

The length and weight data for this paper were obtained during 1947–72 from measurements of thorny skate which were caught off southern Labrador (NAFO Div. 2J), off northeastern Newfoundland (Div. 3K), on the Grand Bank and St. Pierre Bank (Div. 3LNOPs), and in the Gulf of St. Lawrence (Div. 4RS). Most of the specimens were collected incidentally from the catches of research vessels of the St. John's Biological Station (now called Northwest Atlantic Fisheries Centre) during surveys to study commercially-important species. The fish were either stored in ice or frozen in ice until the vessel returned to the laboratory, where the length and weight measurements were taken after the fish were thawed in ice. Typically, the skate were collected on the last day or two of fishing during a cruise. Inshore fishermen from St. John's supplied some specimens (16 in all) which were measured and weighed in fresh condition in the laboratory. Total length from tip of snout to end of tail was recorded to the nearest centimeter, and whole weight was taken to the nearest 50 g.

The skate were not specifically selected for any of the parameters being studied, except that they were occasionally collected by sex within 5 to 10 cm length categories. Since the requested samples of skate by length category were never complete, the distribution of skate within and between length categories was apparently not biased. Weights of skate less than 40 cm long were not used in the analysis. The distribution of thorny skate samples was the same as that reported by Templeman (1982, 1984), as illustrated in Fig. 1.

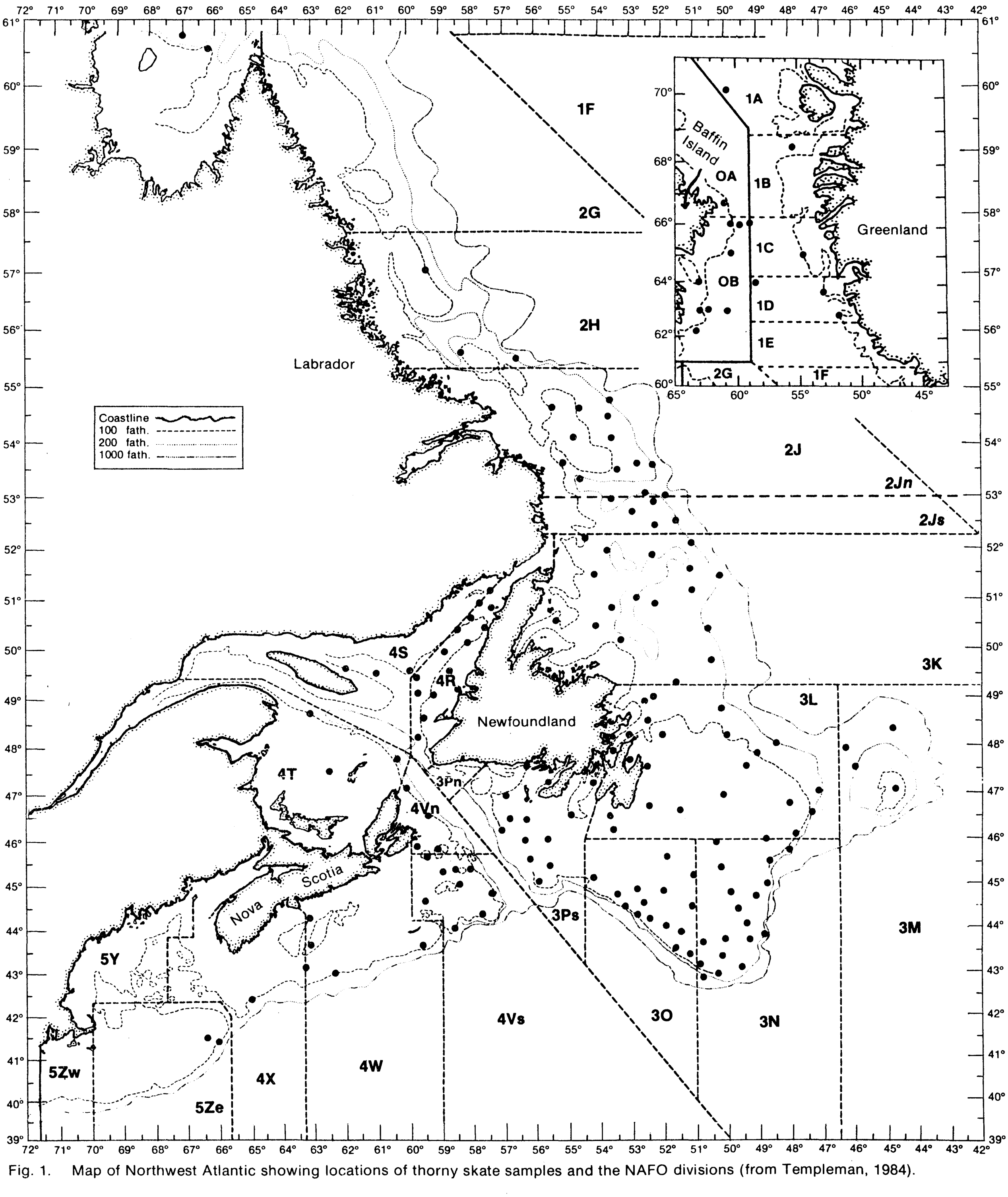

Fig. 1. Map of Northwest Atlantic showing locations of thorny skate samples and the NAFO divisions (from Templeman, 1984).

For analysis, the length and weight data were logarithmically-transformed (base 10), linear regressions were fitted to pairs of observations by sex, maturity condition and area, and covariance analysis was used to test for differences in regression coefficients (slopes) and intercepts. Some variances of the data sets were not homogenous, but Zar (1984) noted that analysis of covariance, as well as analysis of variance, may be used with considerable heterogeneity of variances, if the samples being compared are approximately equal in size.

Morphometrics

The morphometric data were collected during 1965-70 from skate which, after preservation in ice, were examined by the author in the laboratory and occasionally aboard the research vessel at sea. Twenty body measurements, as described by Bigelow and Schroeder (1953), were recorded generally to the nearest millimeter but some small measurements (i.e. cornea diameter) were taken with dial calipers to the nearest 0.1 mm. Most body measurements were taken, as in Bigelow and Schroeder (1953, p. 3-4), as shortest distance between parallel perpendicular planes. The others (Items 8, 9, 10, 13, 14, 20 of Table 3) were taken between points. The sum of the measurements from snout to mid-cloaca and from mid-cloaca to tail tip, taken with the ventral surface of the specimen upward, usually differed from the total length which was measured with the dorsal surface upward. When this occurred, the two partial measurements were adjusted proportionately so that their sum equalled the total length of the skate. Also, the distance from posterior border of cloaca to tail tip was adjusted accordingly. The width of the mouth was taken as the distance between the inner edges of skin folds covering the corners of the mouth.

Hubbs and Ishiyama (1968) recommended the use of disc width as the independent variable in computing the relative proportions of body measurements of skate because of the negative allometry of tail length as part of the total length. According to Templeman (1973), repeated measurements of skate in the fresh condition indicated that disc width was highly variable. The greatest width of the disc in fresh specimens (not in rigor) depends on the researcher's judgment of what the shape of the skate should be, and this differs when the fish are measured on different occasions and by different observers. In preserved material, the disc width depends on the shape in which the specimen was preserved. Hulley (1970) favored total length as the standard reference measurement for body proportions, having found greater variation in the proportions when disc width was used as the reference measurement. Stehmann (1970) also preferred total length over disc width as the reference measurement for rajid fishes.

Although the extreme negative allometry of the tail length, especially the part posterior to the second dorsal fin, reduces the effectiveness of the total-length standard in embryonic and small juvenile skates, total length is used by most researchers as the independent variable in describing morphometrics of skate species, and it is considered as a suitable standard for all except the very small individuals. Thus, the various morphometric data in this paper are compared as percentages of total length.

Thorniness

The author's observations on thorniness of the dorsal surface of thorny skate were made during 1948-72, but those before August 1949 were not used in order to allow time for standardization of judgments. Observations were made on nearly 2,000 thorny skate in the 13-105 cm length range, and each was assigned to one of three categories: relatively thorny and rough, intermediate thorniness, and relatively smooth.

Results

Length-weight relationships

Data for thorny skate from various parts of the Labrador-Newfoundland region were used to estimate parameters of the length-weight relationships by sex and maturity from "least squares" log-log regressions (Table 1). For analysis, the grouping of data by area follows that of Templeman (1982), whereby the waters off southern Labrador, northeastern Newfoundland and western Newfoundland (Div. 2J, 3K and 4RS respectively) represent part of the northern region where sexual maturity in thorny skate begins at smaller sizes (Area A), and the waters off eastern and southern Newfoundland (Div. 3LNOPs) represent the southern region where sexual maturity begins at considerably larger sizes (Area B). Correlation coefficients (r) of the log-log regressions were quite high (0.87-0.97). Regression coefficients (slopes) were close to 3.0 (i.e. 2.9-3.1) for immature skate of both sexes and both areas, but the corresponding values for mature skate were considerably lower (i.e. 2.5-2.7).

Covariance analysis was used to test for differences between slopes of the regression lines by sex, maturity condition and area and between intercepts for cases where the slopes did not differ significantly (Table 2). The variances were homogeneous for more than half of the comparisons, and the departures from homogeneity for the others were generally not great. In Area A, only the slopes of the regression lines for immature and mature male skate differed significantly (Table 2), with the slope for immatures being greater than that for matures (Table 1). In Area B, however, highly signif-

TABLE 1. Parameters of log-log regressions of whole weight and total length for male (M) and female (F) thorny skate by maturity condition and area, and calculated weights for selected lengths from the weight-length relationships. (Imm = immature, Mat = mature.)

Area (Fig. 1.)	Sex	Maturity condition	No. of fish	Length range (cm)	Log-log regression parameters: Slope	Intercept	Correlation coefficient (r)	Calculated weights (kg) for selected lengths (cm): 40	60	80	100
2J+3K+4RS (Area A)	M	Imm	66	40-77	3.0483	-5.1050	0.97	0.60	2.07	4.97	—
		Mat	129	48-76	2.6934	-4.4728	0.93	0.70	2.07	4.50	—
	F	Imm	43	40-65	2.8617	-4.7763	0.96	0.64	2.05	4.68	—
		Mat	65	46-75	2.6450	-4.3897	0.97	0.70	2.06	4.41	—
3LNOPs (Area B)	M	Imm	142	40-94	3.0384	-5.1017	0.97	0.58	2.00	4.79	9.44
		Mat	194	62-104	2.5628	-4.1926	0.92	—	2.32	4.84	8.57
	F	Imm	282	40-91	3.0802	-5.1680	0.97	0.58	2.04	4.94	9.82
		Mat	404	60-94	2.4986	-4.0916	0.87	—	2.25	4.61	8.05
A & B	M+F	Imm	533	40-94	3.0099	-5.0420	0.98	0.60	2.04	4.85	9.50
		Mat	792	46-104	2.7871	-4.6318	0.98	0.68	2.11	4.70	8.76

TABLE 2. Results of covariance analyses relevant to comparisons of log-log regressions whose parameters are given in Table 1. (Intercepts were not compared when slopes were significantly different.)

Area (Table 1)	Groups compared	F-values[a]: Equality of variances	Log-log regressions: Slope	Intercept
Area A	M (Imm, Mat)	1.25	6.88*	—
	F (Imm, Mat)	1.71*	1.72	2.89
	Imm (M, F)	1.20	1.29	3.09
	Mat (M, F)	1.14	0.13	0.27
Area B	M (Imm, Mat)	1.67**	21.10**	—
	F (Imm, Mat)	1.23*	46.17**	—
	Imm (M, F)	1.11	0.32	2.57
	Mat (M, F)	1.22*	0.33	21.43**
A and B	M Imm (A, B)	1.50	0.04	2.52
	M Mat (A, B)	1.13	1.06	15.00**
	F Imm (A, B)	1.13	2.04	5.00
	F Mat (A, B)	1.57*	1.10	13.67**
A and B	M+F (Imm, Mat)	1.42**	44.64**	—

[a] Asterisk indicates significant difference between parameters, where * implies P<0.05 and ** implies P<0.01.

icant differences between immature and mature skate were indicated for both males and females (Table 2), with the slope of the regression line for immatures being larger than that for matures in each case (Table 1). While the slopes of the lines for mature males and females from each area did not differ, there was a highly significant difference between the intercepts of these lines in Area B but not in Area A (Table 2). In the comparison of regression parameters between Areas A and B, neither slopes nor intercepts of the lines for immature males and immature females were significantly different (Table 2). However, for mature males and mature females, while the slopes of the lines were not statistically different, areal differences in elevation of the lines were highly significant.

Because of the lack of significant difference between sexes in slopes and in intercepts for immature thorny skate of each area and within sexes between areas, data for all immatures were combined. Similarly, because the slopes of the regression lines for mature males and mature females were not significantly different within areas and within sexes between areas (although the intercepts were usually different), all weight data for mature fish were combined (Table 1). There was a highly significant difference in slope between immature and mature skate of the combined data, and significant or highly significant differences in slope also was evident in three of four instances where areas and sexes were separate (Table 2). Although there is some loss of confidence in the significance of results due to heterogeneity of some of the variances of the pairs being compared, the sample sizes are large and the pairs of slopes and intercepts for the male and female immatures and matures of Table 1 have comparably similar patterns. The calculated weight-at-length values from the log-log regressions show that mature fish of each area and sex and combined sexes have lower weights than immatures of the higher length classes. The fish lengths beyond which the weights of immature fish exceeded those of matures were 60 cm (2.07 kg) for males and 61 cm (2.15 kg) for females in the northern area (Div. 2J, 3K, 4RS) and were 81 cm (5.0 kg) for males and 71 cm (3.42 kg) for females in the southern area (Div. 3LNOPs).

Morphometric characteristics

Nineteen morphometric measurements of thorny skate from the Northwest Atlantic are presented by maturity condition and sex as percentages of total length (Table 3). Data for immature specimens were assigned to two size categories, with Group I length ranges being 157-168 mm for males and 162-217 mm for females, and Group II length ranges being 257-653

TABLE 3. Morphometric characteristics of male (M) and female (F) thorny skate from the Northwest Atlantic. (Areas of capture and numbers of specimens in the four groups are given as footnotes.)

			Body measurement as percent of total length of skate (Items 2-20)											
Item			Immature (Group I)			Immature (Group II)			Mature (Group III)			Mature (Group IV)		
No.	Body measurement	Sex	No.	Mean	Range	No.	Mean	Range	No.	Mean	Range	No.	Mean	Range
1.	Total length (mm)	M	2	163	157-168	14	391	257-653	13	528	473-627	14	807	639-977
		F	2	190	162-217	21	411	238-630	7	521	450-598	8	764	674-853
2.	Length from snout to pos-	M	2	51.1	49.7-52.4	14	54.6	52.1-57.4	13	56.0	54.1-58.7	14	53.2	48.7-56.0
	terior end of pectorals	F	1	55.3	—	21	54.8	52.5-57.2	7	54.9	53.7-57.1	8	52.3	51.0-53.8
3.	Length from snout to pos-	M	2	58.8	58.0-59.5	14	65.7	62.4-70.0	13	71.5	68.2-74.0	14	68.6	65.6-70.6
	terior end of pelvics	F	2	63.0	60.5-65.4	21	66.2	62.0-70.3	7	67.3	66.2-68.4	8	66.7	65.8-68.1
4.	Greatest width of disc	M	2	68.9	68.8-69.0	14	75.1	68.6-79.5	13	74.9	71.4-77.6	14	75.3	70.4-80.4
		F	2	74.8	71.6-77.9	21	74.4	68.1-79.1	7	73.1	69.3-78.6	8	76.2	73.0-78.1
5.	Tip of snout to center	M	2	47.1	46.5-47.6	14	50.9	48.4-53.0	13	52.8	50.8-55.6	14	51.5	48.9-53.5
	of cloaca (disc length)	F	2	48.5	46.3-50.7	21	52.1	48.8-56.1	7	53.1	51.2-54.6	8	53.2	52.2-55.2
6.	Center of cloaca to tip	M	2	53.0	52.4-53.5	14	49.1	47.0-51.6	13	47.2	44.4-49.2	14	48.5	46.5-51.1
	of tail (tail length)	F	2	51.5	49.3-53.7	21	47.9	43.9-51.2	7	46.9	45.4-48.8	8	46.8	44.8-47.8
7.	Posterior border of cloaca	M	2	52.4	51.8-52.9	14	48.4	46.2-51.0	13	46.6	43.8-48.6	14	47.8	45.9-50.4
	to tip of tail	F	2	50.0	47.5-52.5	21	47.4	43.2-50.5	7	46.2	44.9-48.0	8	45.9	43.9-47.2
8.	Snout to midpoint of line	M	2	12.3	11.9-12.7	14	13.1	11.3-13.9	13	13.1	12.6-13.7	14	12.5	11.0-13.3
	through orbits anteriorly	F	2	12.9	12.8-12.9	21	13.5	10.6-14.9	7	13.0	12.8-13.3	8	12.9	12.0-13.6
9.	Snout to midpoint of line	M	2	14.5	14.3-14.6	14	15.6	13.6-16.9	13	15.7	14.9-16.5	14	14.7	12.8-15.6
	through middle of pupils	F	1	13.9	—	21	15.9	14.2-17.4	7	15.5	15.1-15.8	8	14.9	14.2-15.6
10.	Snout along midline to	M	2	14.2	14.0-14.3	14	14.9	13.8-16.1	12	14.5	13.8-15.2	14	13.7	12.2-14.7
	anterior margin of mouth	F	2	15.1	14.5-15.7	21	15.0	13.3-16.7	6	14.5	14.0-14.9	8	14.0	13.6-14.9
11.	Head width across middle	M	2	41.0	40.5-41.4	14	41.1	36.8-46.7	13	35.3	33.8-36.6	14	34.7	32.3-37.4
	of pupils	F	2	42.6	—	21	42.1	38.0-47.9	7	39.4	38.1-41.3	8	42.1	40.3-44.1
12.	Interorbital width (least	M	2	5.0	4.9-5.1	14	5.1	4.7-5.8	13	5.2	4.9-5.6	14	5.3	5.0-5.7
	cartilaginous)	F	2	5.1	5.0-5.1	21	5.1	4.3-6.1	7	5.1	4.7-5.4	8	5.3	4.8-5.6
13.	Greatest horizontal dia-	M	—	—	—	6	5.0	4.7-5.4	7	5.4	4.6-5.9	9	4.6	3.9-5.5
	meter of orbit	F	—	—	—	12	4.8	4.2-5.5	2	4.9	4.8-4.9	2	4.5	4.3-4.7
14.	Greatest horizontal dia-	M	—	—	—	2	3.1	2.9-3.3	4	2.9	2.8-3.0	9	2.4	2.1-2.9
	meter of cornea	F	—	—	—	9	2.8	2.5-3.2	1	3.2	—	2	2.6	2.4-2.8
15.	Shortest distance between	M	1	8.5	—	14	8.4	7.7-8.9	13	8.3	7.8-8.7	14	7.6	7.1-8.0
	spiracles	F	2	9.0	8.7-9.2	21	8.5	7.5-9.8	7	8.2	7.6-8.9	8	7.9	7.7-8.4
16.	Shortest distance between	M	2	8.6	8.3-8.9	14	9.3	8.9-9.7	13	9.4	8.0-10.3	14	9.3	8.6-10.1
	nostrils	F	2	8.9	8.8-9.0	21	9.1	8.0-9.8	7	8.8	7.9-9.5	8	9.2	8.7-9.7
17.	Width of mouth	M	2	8.8	8.6-9.0	12	10.2	9.3-11.2	11	11.1	9.6-12.5	14	10.8	9.8-11.8
		F	2	9.6	9.1-10.1	18	9.9	9.2-10.8	3	10.8	10.5-11.1	8	10.1	9.5-10.6
18.	Shortest distance between	M	2	17.3	16.6-17.9	14	19.3	17.6-20.8	13	18.5	17.2-19.6	14	18.7	17.5-20.2
	first pair of gill slits	F	2	19.2	18.1-20.3	20	18.9	16.9-20.3	6	18.4	17.3-20.2	8	19.4	18.6-20.6
19.	Shortest distance between	M	2	11.7	11.1-12.2	14	12.8	11.2-14.3	13	11.6	10.7-12.6	14	11.4	10.6-12.1
	fifth pair of gill slits	F	2	13.1	12.3-13.8	21	12.7	11.6-13.9	7	12.6	11.7-13.3	8	13.0	12.6-13.4
20.	Posterior base of second	M	2	5.8	4.5-7.0	14	2.6	1.2-3.7	13	1.7	0.7-2.1	14	2.5	1.6-3.1
	dorsal to tip of tail	F	2	4.7	4.3-5.1	21	2.3	1.1-4.1	7	2.0	1.1-3.0	8	2.2	1.1-3.2

Group I — Div. 3N (1M, 2F), Div. 3Ps (1M).
Group II — Div. 1CD (3M, 5F), Div. 2J (5M, 9F), Div. 3N (2M), Div. 3Ps (2M, 3F), Div. 4W (1M, 2F), Div. 4X (1F), Div. 5Ze (1M, 1F).
Group III — Div. 1CD (6M, 5F), Div. 2J (7M, 2F).
Group IV — Div. 3N (2M, 4F), Div. 3Ps (2M, 2F), Div. 4V (7M, 2F), Div. 4W (2M), Div. 5Ze (1M).

mm for males and 238–630 mm for females. The claspers did not reach the posterior tip of the pelvic fin in the males of these groups apart from two specimens in Group II with claspers extending 1.3–2.1% (of total length) beyond the pelvic fin. Data for the mature thorny skate are presented for two areas: Group III, with length ranges of 473–627 mm for males and 450–598 mm for females, includes skate from the northern Area A where sexual maturity and maximum length occur at relatively small size; and Group IV, with length ranges of 639–977 mm for males and 674–853 mm for females, includes skate from the southern Area B where they attain comparatively large sizes.

Some features of the morphomeric proportions in Table 3 are noteworthy. The average length from snout to posterior tip of pelvic fin (Item 3) was relatively greater in females than in males of the Group I immatures, but it was greater in males than in females of the two groups of mature skate. There was a wide range in the relative width of the disc (Item 4). The mean median disc length from snout to center of cloaca (Item 5) was greater than the tail length from center of cloaca to tail tip (Item 6) in mature males and females and the large immatures, but tail length was proportionately larger than disc length in the smaller immatures (Group I). On the average, mean disc length was consistently shorter in males than in females, and conversely for tail length. Head width across middle of pupils (Item 11) was clearly less in mature males than in mature females, with no overlap of the ranges in either of the two groups, whereas the difference was small with nearly complete overlapping of ranges for immature males and females of Group II (Table 3). The mouth (Item 17) was relatively wider in males than in females of all groups except the smaller immatures, but the differences in percentages were small and the ranges overlapped. The shortest distance between the fifth pair of gill slits (Item 19) was relatively less in males than in females of the two mature groups. In view of the similarity of these percentages for the larger immature males and females (Group II), the difference for the small immature males and females (Group I) was probably due to the small sample size of the latter group. The relative distances from posterior base of second dorsal fin to tail tip (Item 20) in the small immature males and females of Group I were at least twice as great as in larger immatures and in both groups of mature skate. Largely because of this extension of the tail near its tip in the smallest skate, the tail percentages were relatively greater and the disc length percentages were usually relatively less in the smaller (Group I) than in the larger fish.

Some of the disc-related morphometrics were relatively greater in the smaller mature skate (Group III) than in the larger mature ones (Group IV) (Table 3). Most of these cases were apparent for males or were more evident for males than for females: e.g. snout to posterior end of pectorals (Item 2), snout to posterior end of pelvics (Item 3), snout to midpoint of line through orbits anteriorly (Item 8), snout to midpoint of line through middle of pupils (Item 9), snout along midline to anterior margin of mouth (Item 10), greatest horizontal diameter of orbit (Item 13), and shortest distance between spiracles (Item 15).

Thorniness

Similar to the procedure that was followed for analysis of the length-weight data, observations on thorniness of thorny skate were grouped for two major regions of the Northwest Atlantic (Table 4): the northern Area A where sexual maturity occurs at relatively small sizes and the skate do not grow to large maximal size, and the southern Area B where sexual maturity begins at considerably larger sizes and the skate grow to greater maximal size (Templeman, 1982), While Area B covers the same region as described previously (i.e. 3LNOPs), Area A data include some observations from

TABLE 4. Percentages of immature (Imm) and mature (Mat) thorny skate in three categories of dorsal thorniness by length group from Areas A and B where sexual maturity begins at smaller and larger sizes respectively. (N = number of fish.)

Fish length (cm)	Percent thorniness (Area A)						Percent thorniness (Area B)						Number of skate			
	Thorny		Medium		Smooth		Thorny		Medium		Smooth		Area A		Area B	
	Imm	Mat	Imm	Mat	Imm	Mat	Imm	Mat	Imm	Mat	Imm	Mat	Imm	Mat	Imm	Mat
								Male								
13-21	92	—	8	—	—	—	—	—	—	—	—	—	12	—	5	—
22-30	100	—	—	—	—	—	70	—	30	—	—	—	31	—	10	—
31-39	77	—	20	—	2	—	83	—	8	—	8	—	44	—	12	—
40-45	29	8	68	75	2	17	42	—	58	—	—	—	41	12	12	—
46-51	13	—	61	53	26	47	27	—	55	—	18	—	46	34	11	—
52-57	5	1	47	30	47	69	32	—	40	—	28	—	38	96	25	—
58-63	—	—	38	17	63	83	15	—	68	33	18	67	8	78	34	3
64-69	—	—	50	9	50	91	—	—	60	30	40	70	4	22	40	10
70-75	—	—	—	—	100	100	—	—	19	14	81	86	1	2	16	29
76-81	—	—	—	—	100	100	9	—	27	3	64	97	1	1	11	64
82-87	—	—	—	—	—	—	—	—	—	7	100	93	—	—	3	41
88-105	—	—	—	—	—	—	—	—	—	—	100	100	—	—	2	38
N	96	2	89	71	41	172	44	0	80	13	57	172	226	245	181	185
								Female								
13-21	100	—	—	—	—	—	100	—	—	—	—	—	7	—	5	—
22-30	100	—	—	—	—	—	89	—	—	—	11	—	23	—	9	—
31-39	100	—	—	—	—	—	100	—	—	—	—	—	37	—	17	—
40-45	90	58	10	42	—	—	89	—	11	—	—	—	39	12	18	—
46-51	68	44	32	56	—	—	100	—	—	—	—	—	28	32	19	—
52-57	88	61	12	37	—	2	76	—	22	—	3	—	25	84	37	—
58-63	45	55	45	45	9	—	78	25	20	63	2	13	11	49	54	8
64-69	—	20	100	60	—	20	47	27	53	66	—	7	2	5	88	56
70-75	—	—	—	—	—	100	24	12	76	80	—	8	—	1	62	153
76-81	—	—	—	—	—	—	16	9	80	82	4	9	—	—	25	139
82-87	—	—	—	—	—	—	—	3	100	85	—	13	—	—	4	40
88-96	—	—	—	—	—	—	—	—	100	87	—	13	—	—	1	15
N	148	100	23	79	1	4	195	48	140	326	4	37	172	183	339	411

the north coast of Iceland, West Greenland (Div. 1ABCD), Baffin Island (Div. 0AB), Ungava Bay (west of Div. 2G), and Flemish Cap (Div. 3M), in addition to those from Labrador (Div. 2HJ), northeastern Newfoundland (Div. 3K), and Gulf of St. Lawrence (Div. 4RS).

It is apparent from Table 4 that both immature and mature thorny skate became less thorny (dorsally) with increasing length and that matures were smoother than immatures at the smaller fish lengths. In the smooth category, where fish were mainly quite large, males were typically much smoother than females, with only 1% of immature and 7% of mature females being described as smooth in contrast to 24 and 80% respectively for males. Examples of thorniness are shown in Fig. 2. In agreement with the progression toward a smoother dorsal surface with the approach of sexual maturity, the decrease in thorniness occurred at smaller skate sizes in Area A, where sexual maturity begins at small sizes, than in Area B, where sexual maturity begins at larger sizes. This is especially evident for males in which the extent of change from thorny to smooth was generally greater than for females.

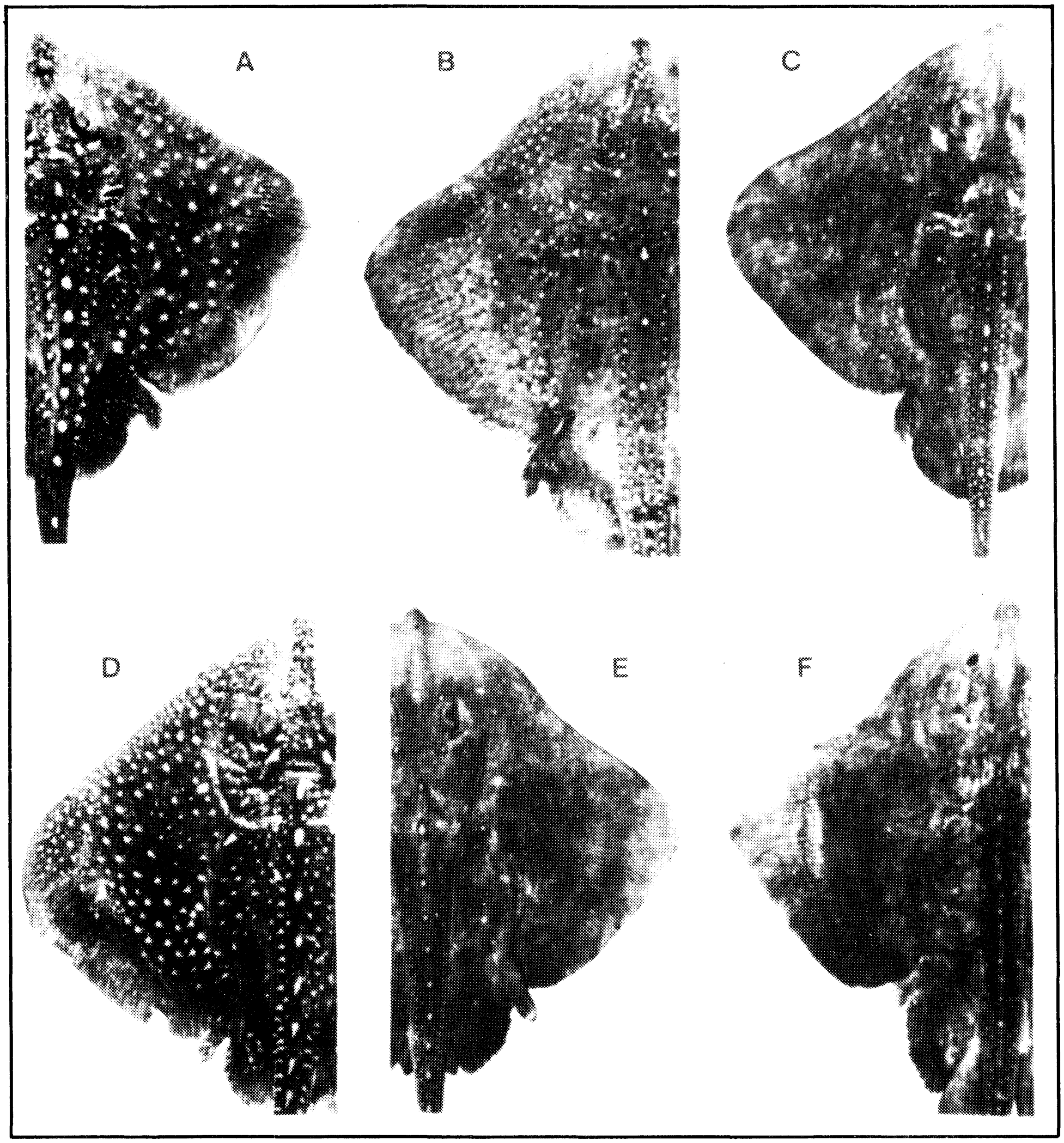

Fig. 2. Dorsal views of thorny skate of different total lengths and degrees of thorniness. **A**, immature female, 32 cm, from Div. 3L; **B**, mature female, 55 cm, from Div. 3K; **C**, mature female, 75 cm, from Div. 3O; **D**, immature male, 33 cm, from Div. 3L; **E**, immature male, 66 cm, from Div. 3O; **F**, mature male, 89 cm, from Div. 3Ps.

Discussion

Length-weight relationships

The lower slopes of the regression lines and the consequent lower weights of mature skate than of immatures at the larger sizes were presumably due to the diversion of protein and other food values in mature skate to the production of sexual products. The effect occurs earlier in northern waters where sexual maturity occurs at smaller sizes, producing lower weights for mature than for immature fish at lesser lengths in these waters than in the southern waters where earliest sexual maturity begins at larger sizes.

Seasonal variation in weight at length was not considered in this paper because, for most of the areas, the length-weight data were collected in a small part of the year. Spawning of female thorny skate, with the consequent utilization of energy for the process, occurs throughout that year (Templeman, 1982). There is no indication of differences in seasonal feeding activity of *Raja radiata* from the east coast of North America (McEachran *et al*., 1976). However, Antipova and Nikiforova (MS 1983) reported that the food consumption of thorny skate in the Barents sea was highest in autumn and winter and decreased in spring to a minimum in summer. Fitz and Daiber (1963) observed that the quantity of food in the stomachs of *Raja erinacea* from Delaware Bay was twice as great in spring and autumn than in winter. They suggested that the increased amounts of food may be related to increased requirements for spawning, because the egg production was greatest in spring and least in February-March. The principal spawning periods for *R. erinacea* off the USA coast from Connecticut to Rhode Island were November-January and June-July (Richards *et al*., 1963).

Similar to the trend for thorny skate in this paper, Richards *et al*. (1963) observed that the slopes of the length-weight regression lines (log-log) for *R. erinacea* were lower for mature than for immature fish and the decrease was more rapid for females than for males. They suggested that the increasing weight of claspers may account for the slower decrease in slope of the line for mature males. Whereas the regression coefficient (slope) in the length-weight relationships for thorny skate was usually close to 3.0 for immature fish and in the range of 2.5–2.7 for matures, Richards *et al*., (1963) found that the coefficients of the length-weight relationships for *R. erinacea* varied greatly among samples (1.5–3.2). However, Waring (1984) reported regression coefficients from 2.97 to 3.21 for this species (sex combined) off the northeastern United States. For the Atlantic stingray (*Dasyatis sabina*), the length-weight regression coefficients were 3.36 for males and 3.09 for females taken off Georgia and were in the range (different years) of 2.16–2.77 for males and 2.66–3.16 for females taken off North Carolina (Schwartz and Dahlberg, 1978). From combined data for immature and mature *Bathyraja richardsoni*, the length-weight regression coefficient was 2.71 (Templeman, 1973).

Morphometric characteristics

The discussion of morphometric comparisons below does not include the smallest immature thorny skate (Group I of Table 3), in which the posterior part of the tail was relatively more elongated than in the larger fish, unless that group is specifically mentioned.

The body proportions of the two thorny skate from Massachusetts waters (Bigelow and Schroeder, 1953) were generally within the ranges of the percentages for the specimens in Table 3 (excluding Group I). In both of the Massachusetts specimens, however, the median disc length (snout to mid-cloaca), although within the range of variation of the specimens in Table 3, was slightly less than the tail length (mid-cloaca to tip of tail), whereas the mean median disc length was greater than the tail length in the Northwest Atlantic specimens (Table 3). The two specimens *R. radiata* from South African waters (Hulley, 1970) had median disc lengths which were 57.5 and 59.7% of total lengths. Both of these proportions are above the range for the Northwest Atlantic specimens with greatest median disc length of 56.1% and means of 50.9–53.4% of total lengths. The greater disc length and shorter tail length of the South African specimens resulted in most of the disc measurements being greater than the mean (and sometimes even exceeding the range) for the Northwest Atlantic specimens. It should be noted that the specimens in Table 3 were measured in fresh condition, whereas those of Bigelow and Schroeder (1953) and Hulley (1970) were presumably measured after preservation.

The allometric increase during adolescence in the size of the claspers, which are part of the pelvic fin arrangement, evidently causes the pelvic fin of the male to increase allometrically also, whereas the pelvic fin of the female grows isometrically. A similar increase in length of the pelvic fin relative to disc width in large males but not in females was illustrated by Kato (1971, fig. 5) for *Bathyraja smirnovi*. The shorter head width across mid-pupils and the smaller distance between the fifth pair of gill slits (relative to total length) in mature males than in mature females correspond to the narrowing of the posterior part of the head near the anterior part of the pectoral fin in mature males, in contrast to mature females and immature males and females (Fig. 2). The narrowing neck of the male thorny skate, as it matures, may result in a more flexible neck to facilitate mating behavior, as described by Luer and Gilbert (1985) for *Raja eglanteria*: in mating, the male *R. eglanteria* grasps the trailing edge of the pectoral fin of the female, near its base, in his jaws, swings his tail underneath her pelvic fin and tail, and inserts one clasper into her cloacal aperture. Mating behaviour of the stingray (*Urolophus concentricus*) was described by McCourt and Kerstitch (1980).

The greater relative distance from the posterior insertion of the second dorsal fin to the tip of the tail (as well as the relative excess of tail length over disc length) in the smallest immatures than in the larger immatures and matures represents the residual effect, not yet completely lost, of the much greater relative length of that part of the tail in embryos and larvae (Jensen, 1914, 1948; Nordgaard, 1917; Clark, 1927; Ford, 1971) and also to some extent in recently-hatched skate (Clark, 1926; Jensen, 1948).

It is apparent that morphometric changes, which are related to sexual maturity of thorny skate, begin at smaller individual lengths in areas where maturity occurs at smaller sizes and at greater individual lengths in areas where maturity occurs at comparatively larger sizes. It is also evident that morphometric differences may occur between smaller mature skate from one area and larger mature skate from another area.

Thorniness

The available data on thorniness of thorny skate indicate the importance of considering length, sex, stage of sexual maturity, and lengths at the start of sexual maturity in making comparisons of thorniness of skates from different areas. The decreasing dorsal thorniness and the decline in relative sizes of dorsal thorns of *R. radiata* during progress toward sexual maturity, and the greater smoothness of mature males, are paralleled to some extent in *R. erinacea* (Bigelow and Schroeder, 1953, fig. 36 and 37). In both *R. erinacea* and *R. ocellata*, the row of mid-dorsal thorns in young fish is lost as the fish grow toward maturity (Bigelow and Schroeder, 1953). It is possible that the relatively larger thorns in the young skate offer a form of protection against predation that is less necessary for larger skate. The young are presumably closer to the ancestral type in the pattern of the major thorn systems of skates.

Acknowledgements

I am very grateful to E. M. LeGrow who worked with me in the collection of most of the data for this paper, and to S. H. Lee and J. V. Arklie who assisted in compilation and analysis. E. L. Rowe was responsible for the skate photographs.

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