Some Aspects of Reproduction in the Pointed-snout Dogfish *Squalus japonicus* Taken off Nagasaki and Choshi*¹

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Specimens of the pointed-snout dogfish *Squalus japonicus* taken off Nagasaki and Choshi, were investigated to study its reproduction. Specimens from Choshi were larger in the size at maturity as well as in the maximum size than those from Nagasaki. The size at first maturity for females was 560–579 mm in Nagasaki and 740–759 mm in Choshi. Maximum lengths were greater by 14 cm for males and 19 cm for females in Choshi than in Nagasaki. Testis weights and clasper lengths showed a rapid increase with onset of maturity. The gestation period was estimated to be roughly one year since both full-term embryos and fertilized eggs occurred in the same period. Litter size ranged from 2 to 8 for each region but average litter size was 3.9 in Nagasaki and 5.3 in Choshi. Litter size increased with size of the parent. A difference was also noted in the average number of ovarian eggs per adult female between the two regions (4.4 in Nagasaki and 6.6 in Choshi). Ova usually outnumbered embryos and showed a similar growth pattern to embryos. The ratio of males to females in embryos was approximately 1:1 as a whole in both regions.

The reproductive mode of sharks of the genus *Squalus* is aplacental type of viviparity according to the categories given by Wourms.¹⁾ Embryos are provided with nutrition from yolk reserves. In the spiny dogfish *S. acanthias* embryos grow up in the uteri of the parent for about two years, showing approximately similar gestation period to the elephant. Litter size is very small ranging from 7 to 22 (average 12.4) around Japan,²⁾ from 2 to 16 (average 6.6) in British Columbia Waters,³⁾ and from 1 to 11 (mostly 2 to 4) in the eastern North Atlantic.⁴⁾ The reproductive rate, which is a basic parameter for the estimation of population growth, has been calculated for the spiny dogfish in the North Sea⁵⁾ and in British Columbia Waters.⁶⁾ Thus, extensive studies have demonstrated that the spiny dogfish possesses a peculiar reproductive strategy of low fecundity and large gestation period. However, reproduction of other *Squalus* species except for *S. brevirostris*^{7,8)} has scarcely been reported probably because they are not direct subjects of commercial fisheries.

There are five species of *Squalus* around Japan according to a recent revision of the *S. blainville* group.⁹⁾ Among them, the pointed-snout dog-

fish *S. japonicus* occurs widely from central Japan to Kyushu and Taiwan and is one of the most abundant species.⁹⁾ This paper reports some aspects of reproduction in *S. japonicus* taken off Nagasaki and Choshi located in southern and central Japan respectively.

Materials and Methods

Specimens were collected in fish markets in Nagasaki and Choshi. They were caught with bottom longline and trawl net in the depths of 150–300 m off Choshi and chiefly with bottom longline in the depths of 120–300 m off Nagasaki. Date, locality, and the number of specimens examined are indicated in Table 1. Small specimens were not available because they have little commercial value. The specimens were examined in fresh state.

Maturity stages of females were classified into three categories, immature, maturing, and mature. "Immature" was defined as sharks having ova less than 5 mm in diameter in the ovary and thread-like uteri, "maturing" as those having both ova larger than 10 mm in diameter and relatively ex-

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Table 1. Date, locality, and number of specimens examined in this study

Locality	Nagasaki (125°-130°E) (28°-34°N)		Choshi (141°-141°20'E) (35°30'-36°N)	
	Nov.'74-Nov.'76		Oct.'74-Oct.'76	
Number of specimens	Male	Female	Male	Female
January	1	40		
February	4	62	1	3
March	16	18	2	13
April	1	46	3	11
May	82	22	5	15
June	14	34	39	63
July		27		
August		33		
September		52	1	
October	16	104	2	3
November	31	14	7	20
December	6	47	2	15
Total	171	499	62	143

panded uteri, and "mature" as those having either ova larger than 10 mm in diameter in the ovary or uteri containing embryos or fertilized eggs. The size of ovarian eggs was the average diameter of all eggs in both ovaries. Maturity of males

was estimated on the basis of the presence of sperm in the spermduct and the rigidity of claspers. Clasper length was measured from cloaca to the tip of the clasper. Full-term embryos were judged by the absence of both external and internal yolk sacs. Ova immediately before ovulation was considered as those larger than 30 mm in diameter before or just after parturition of embryos. Litter size includes the number of fertilized eggs as well as the number of embryos.

Results

Maturity

A large difference existed in the size at first maturity between Nagasaki and Choshi specimens (Table 2). Females reached their first maturity at 560-579 mm in Nagasaki and 740-759 mm in Choshi. Approximately a difference of 18 cm existed between the two regions. Fifty percent maturity was reached at lengths of 660-679 mm in Nagasaki and 820-839 mm in Choshi. All female specimens from Nagasaki except one had attained maturity at a length of 66 cm while all females from Choshi had reached maturity at

Table 2. Number of specimens taken from Nagasaki and Choshi

Total length of specimens (mm)	Number of specimens									
	Nagasaki (Male)		Choshi (Male)		Nagasaki (Female)			Choshi (Female)		
	Immature	Mature	Immature	Mature	Immature	Maturing	Mature	Immature	Maturing	Mature
300-399	3		2							
400-439	3									
440-499	5				5					
500-519	4				4					
520-539	14	2			4					
540-559	19	11			11					
560-579	9	33	1		5	2	1			
580-599	5	24				14	8			
600-619	5	18	1	1		16	27			
620-639	1	6	1	1		3	50			
640-659		2	1	2		4	59			
660-679			1	8			81	6		
680-699				13			74	12		
700-719				12	1		74	9		
720-739				6			29	2		
740-759				2			9		2	4
760-779				1			1		4	9
780-799									2	7
800-819										16
820-839										12
840-859										6
860-879										9
880-899										3
900-919										4
Total	68	96	7	46	30	39	413	29	8	70

Fig. 1. Relationship between total length and testis weight in *S. japonicus* collected from Nagasaki.

80 cm. Maturing condition was found between 560–749 mm in Nagasaki and 740–799 mm in Choshi. The maximum size of female specimens in the samples was also larger in Choshi (950 mm) than in Nagasaki (758 mm).

The same difference was found in male specimens. Males reached maturity at a length of about 50 cm in Nagasaki but did not attain maturity until 70 cm in Choshi. Similarly, the maximum size of males in the samples was greater in Choshi (700 mm) than in Nagasaki (640 mm). Males became mature at a smaller size than females (Table 2).

The relationship between total length and testis weight (Fig. 1) shows that testis weight increased abruptly at a length of 50–55 cm in Nagasaki. In Choshi, testis weight showed a rapid increase at a length of 60–65 cm, although the small specimens were very few. The relationship between total length and clasper length also demonstrates that the claspers grew rapidly when the sharks reached about 50 cm in Nagasaki (Fig. 2). In Choshi, this size was about 60 cm. Thus, both testis weight and clasper length showed rapid increases with onset of maturity and can be used as indices of maturity for male specimens of this species.

Growth of Embryos and Eggs

Each fertilized egg is enveloped in a membrane which develops as an embryonic membrane after

Fig. 2. Relationship between total length and clasper length in *S. japonicus* collected from Nagasaki.

hatching from an egg. Frequency occurrence of fertilized eggs is indicated in Fig. 3, together with monthly frequency distributions of embryos in Nagasaki. Fertilized eggs and embryos less than 40 mm in total length which seemed to be in a stage after hatching out from fertilized eggs were observed from January to May in Nagasaki. The embryos reached 41–60 mm in June, 61–100 mm in August and September, 101–180 mm in October and 161–220 mm in November and December, although considerable variation existed in size distributions of embryos. Embryos ranging from 191 to 235 mm, which occurred from January to May, were regarded to be full-term embryos because both external and internal yolk sacs were almost fully absorbed. At this time, we frequently observed remains of embryonic membranes in the uteri of adult females without embryos. These facts suggest that the reproductive season lasts from January to May. Since fertilized eggs and embryos soon after hatching out of eggs were found during that time, gestation period of this species was estimated to be roughly one year. However, monthly gonad indices of male specimens showed no marked seasonal change in both regions, so that gonad index was not a useful character as means of the estimation for the mating season. It is probable that females give birth to young each year because fertilized eggs were found in the uteri of females which apparently had just delivered embryos. The same trend of growth of embryos was recognizable in the specimens from Choshi,

Fig. 3. Monthly length frequency distributions of embryos in *S. japonicus* collected from Nagasaki. Oblique shaded histogram shows near-term embryos and crossed one indicates fertilized eggs.

although samples of gravid females were not sufficient. Full-term embryos in Choshi ranged from 206 to 240 mm in total length. No marked difference was observed in the size of full-term embryos between the two regions. Statistical examination reveals no relation between the sizes of gravid females and full-term embryos.

As in other species of *Squalus*, both left and right ovaries are functional in this species. Monthly size frequency distributions of ovarian eggs are presented in Fig. 4. From January to February, ova were small measuring 5–7 mm in diameter.

Fig. 4. Monthly diameter frequency distributions of ovarian ova in *S. japonicus* collected from Nagasaki. Shaded histogram indicates ova immediately before ovulation.

They increased in size with month and grew to 29–44 mm in diameter during the period from November to April. Since ova more than 28 mm in diameter seemed to be near-ovulation, we estimate that ovulation occurred between October and April with a peak in January and February. Therefore, it may be concluded from the above evidence that it takes about one year of development from the formation to its ovulation. There was no large difference in the size at ovulation between the two regions. The diameter of ova of near-ovulation in Choshi was 35–44 mm in diameter.

Thus, eggs in ovaries show an increase in diameter with growth of embryos in the uterus.

Litter Size

Litter size is shown by size group for each region in Table 3. As stated earlier, it is clear that the size range of gravid females in the two regions was quite different. Only 740–759 mm and 760–779 mm size groups overlap. Litter size ranged from 2 to 8 in both regions. However, the modal number differed by region, that is 4 in specimens from Nagasaki and 6 in those from Choshi. Most gravid females from Nagasaki carried 3 to 5 embryos whereas the bulk of gravid females from Choshi carried 4 to 6 embryos. The average litter size was 3.9 in Nagasaki and 5.3 in Choshi.

No marked difference was observed in the number of embryos in the left and right uteri. Most adult females carried an equal number of embryos in both uteri or possessed one more embryo in one side than in the other. Of 303 gravid females from Nagasaki only 4 specimens carried two more embryos in the right uterus than in the left.

Litter size varied with size of gravid females. For instance, females of the 600–619 mm size group carried 2 to 4 embryos with an average of 2.9 in Nagasaki whereas those of the 720–739 mm size group carried 3 to 5 embryos with an average of 4.4 (Table 3). Litter size of the former group

was about two-thirds as large as that of the latter. The same was true of litter size of the specimens from Choshi, although the difference was not as large as that in Nagasaki. Thus, litter size increased with the length of the parent. Analysis of covariance for the relation between total length of the parent and litter size showed no significant difference at the 5% level in the slopes and adjusted means between the two regions (Table 4-a). This indicates that the relationship between total length and litter size is not different by region if the size range of each population is extrapolated or interpolated. In fact, however, the fecundity differed greatly by region due to the large difference in the size range of mature females between the two regions. The same relation was observed between total length and number of ova per adult female between the two regions (Table 4-b).

The number of ovarian eggs per adult female is shown by size group for each region in Table 5. It ranged from 2 to 9 in Nagasaki and 4 to 12 in Choshi. The modal number was 4 in Nagasaki and 6 in Choshi. There was a great difference in the average number of ova between Nagasaki (4.4) and Choshi (6.4). Thus, the number of ova increased with the length of the parent similar to litter size. However, the average number of ova was always greater than that of embryos within each size group. Analysis of covariance showed a significant difference in the adjusted means be-

Table 3. Litter size of specimens collected from Nagasaki and Choshi

Total length of mother (mm)	Number of embryos															
	Nagasaki							Choshi								
	2	3	4	5	6	7	8	Average	2	3	4	5	6	7	8	Average
580-599		3						3.00								
600-619	4	5	3					2.93								
620-639	11	8	15					3.12								
640-659	4	12	19	3				3.55								
660-679	4	16	30	7			1	3.78								
680-699	3	8	27	15	4			4.16								
700-719	3	12	29	22	4	1		4.21								
720-739		3	12	4	4			4.39								
740-759			3	3				4.50			1	1				4.50
760-779				1				5.00		2		1				3.67
780-799											2	2	3			5.14
800-819									1	1	2		4		1	5.00
820-839											2	2	3	4	1	6.00
840-859									1			3	3			5.00
860-879										1	1	1	2		1	5.33
880-899													1	2	1	7.00
900-919												1				5.00
Subtotal	29	67	138	55	12	1	1		2	4	8	11	16	6	4	
Total average								3.81								5.35

Table 4. Covariance analysis tables for pairs of samples by places and items. Fa and Fb are the variance ratios to test the significance of the regression coefficient and adjusted means respectively

(a). Reg. lines of embryo numbers comparison between Nagasaki region and Choshi region					
Source of variation	Deviations from regression				
	d.f.	s.s.	m.s.		
Total	357	361.582	1.013		
Within groups: pooled groups	356	359.500	1.010		
total deviations	355	359.414	1.012		
Differences between: slopes	1	0.087	0.087	$Fb = \frac{0.087}{1.012}$	$= 0.086^{n.s.}$
adjusted means	1	2.081	2.081	$Fa = \frac{2.081}{1.010}$	$= 2.061^{n.s.}$
(b). Reg. lines of ova numbers comparison between Nagasaki region and Choshi region					
Total	399	354.438	0.888		
Within groups: pooled groups	398	350.215	0.880		
total deviations	397	349.623	0.881		
Differences between: slopes	1	0.592	0.592	$Fb = \frac{0.592}{0.881}$	$= 0.672^{n.s.}$
adjusted means	1	4.223	4.223	$Fa = \frac{4.223}{0.880}$	$= 4.799^{n.s.}$
(c). Reg. lines of ova numbers and embryos numbers comparison in Nagasaki region					
Total	655	558.311	0.852		
Within groups: pooled groups	654	507.772	0.776		
total deviations	653	506.844	0.776		
Differences between: slopes	1	0.927	0.927	$Fb = \frac{0.927}{0.776}$	$= 1.195^{n.s.}$
adjusted means	1	50.539	50.539	$Fa = \frac{50.539}{0.776}$	$= 65.093^{**}$
(d). Reg. lines of ova numbers and embryos numbers comparison in Choshi region					
Total	101	232.443	2.301		
Within groups: pooled groups	100	202.720	2.027		
total deviations	99	202.193	2.042		
Differences between: slopes	1	0.527	0.527	$Fb = \frac{0.527}{2.042}$	$= 1.910^{n.s.}$
adjusted means	1	30.961	30.961	$Fa = \frac{30.961}{2.027}$	$= 10.760^{**}$

** Significant at the 1% level.

tween the number of ova and embryos (Table 4-c, 4-d). This means that ova outnumber embryos in the entire range of adult females.

Sex Ratio

Identification of sex of embryos was possible in individuals between the sizes of 70 to 80 mm in total length through the presence of claspers. Accordingly, the sex ratio treated here refers to that of embryos over 80 mm. The sex ratio of embryos differed by litter. For instance, two females possessed one female and 4 male embryos in the uteri. In another cases, two specimens carried 7 male and one female embryos. As a

whole the ratio of male to female embryos was 443:408 in Nagasaki and 43:59 in Choshi. Statistically, the null hypothesis that the ratio was 1:1 could not be rejected for both regions at the 5% significance level, according to χ^2 test. Thus, it is concluded that the sex ratio of embryos is about 1:1 as a whole in the two regions, although it differs largely by litter.

Discussion

It is clear that there were great differences in the size at maturity and the maximum size for both sexes between specimens from Nagasaki and Choshi