Northwest Atlantic Fisheries Organization

Serial No. N4739 **NAFO SCR Doc. 02/118**

SCIENTIFIC COUNCIL MEETING – SEPTEMBER 2002

Some Aspects of the Thorny Skate, *Amblryraja radiata*, Reproductive Biology in NAFO Division 3N

(Elasmobranch Fisheries – Oral)

by

J. L. del Río Iglesias

Instituto Español de Oceanografía, Apdo. 1552, Vigo, Spain
e-mail: joseluis.delrio@vi.ieo.es

ABSTRACT

Thorny skate samples from August to December 2000 were examined to determine both sexes maturity stages, length at maturity and females potential fecundity. The size and number of the ovarian oocytes increase as the maturation progress. In fully mature ovaries the average number of developed eggs is between 40 and 45 and its final mean size is 12.5 mm. The minimum number of developing eggs per female found in the ovaries was 2 and the maximum 88. Very few females at either the capsule extrusion or other of the active uterine stages have been found. On the contrary most part of the adult males were at the fully mature stages, suggesting that the samples could be taken on a mating aggregation season.

Using data from 1997, 1999 and 2000, both maturity ogives have been fitted. The females length at maturity obtained ranged between 60 and 54 cm and that of the males between 43 and 51 cm.

INTRODUCTION

The thorny skate, *Amblyraja radiata*, is found commonly in Northwest Atlantic along the coast of West Greenland from Disko Bay, and on the North American side, from Hudson Bay to South Carolina (Bigelow and Schroeder, 1953). Is it also the most abundant skate in Newfoundland waters, distributed primarily on the southwest part of the Grand Bank and on St. Pierre Bank, in depths from near shore to 1 700 m. in commercial fisheries (Kulka and Mowbray, 1998).

Skates have biological characteristics that determine a low reproductive potential: slow growth rates, late sexual maturation, low fecundity and long reproductive cycles. These characteristics result in very low intrinsic rates of increase (Smith *et al*., 1998) and very low resilience to fishing mortality (Hoenig and Gruber, 1990). Thus, they are highly susceptible to over-exploitation and recoveries of population numbers from severe depletions, caused either by natural phenomena or human action, should take many years for the majority of species. The skate fishery in the Grand Bank and the Scotian Shelf is regulated within the Canadian waters since 1994 (Simon and Frank, 1996; Kulka and Mowbray, 1998) though this fishery outside 200 miles is unregulated and is becoming increasingly important.

Almost nothing is known about the reproductive biology of the thorny skate in the Northwest Atlantic. Templeman (1982, 1987) reported on the occurrence of egg capsules of the *Amblyraja radiata* in the Northwest Atlantic. Apart of this, the only available data on thorny skate are obtained under experimental conditions in the southern Barents Sea (Berestovskii, 1994). Numerous dissections of sexually mature female thorny skates shown

that their ovaries usually hold 10-12 or more pairs of eggs at different stages of development and the synchronous formation of pairs of capsules in the oviducts (Hobson, 1930; Chinarina and Troshicheva, 1980; Templeman, 1982; Berestovskii, 1989). Two mature eggs are liberated from the ovaries and are fertilised in the upper part of the oviduct, these eggs are enclosed with yolk and albumen in a capsule formed by the shell gland (Clark, 1922).

In this study a number of variables were measured in thorny skate females to identify changes in sexual maturity with size. The presence of egg capsules in the oviduct, the numbers and egg sizes in the ovary and the variations in the width of the shell gland are presented.

MATERIAL AND METHODS

Data for this study have been obtained from the scientific observers on board the Spanish trawlers in the skate commercial fishery in the southern part of Grand Bank (Div. 3N) Regulatory Area (Fig. 1). The gear used in this fishery is a bottom trawl with a codend mesh size about 220 mm, and the fishing activity occurs in shallow waters, between 42 and 215 m.

Fish were sexed, measured and weighed on board. Total length (LT), from tip of snout to terminal point of the caudal fin were measured to the nearest centimetre.

A total of 739 females caught from August to December 2000 were examined and classified into maturity stages according to the macroscopic maturity scale shown in ANNEX 1. In females the entire cycle of maturation was divided into six stages, three ovarian and three uterine ones. The size of the ovarian eggs and the condition of the oviducts were considered to determine maturity stages. The total number of eggs in the ovary left and right were counted and their diameter were measured with a calliper to the nearest tenth of a millimetre, except the small oocytes (<2 mm in diameter) occurring during the early stages of maturity. The presence of egg capsules in the oviduct and the width of the shell gland were also recorded to assess maturity. Length and largest width of 55 egg capsules were measured. The sampling description and characteristics examined are presented in Table 1. In males four maturity stages were established, based on the progressive increase of the claspers length through the maturation process.

The length at 50% maturity (L_{50}) for both sexes has been calculated using data from 1997, 1999 and 2000. Both males and females were classified as “immatures” when they were in stage 1 (Annex 1) and as “matures” (meaning adults) in either of the further stages.

The method of Ashton (1972) for turning proportions of mature individuals into so-called logits and then fitting a straight line have been used. The proportion of mature males and females at length was adjusted to a logistic function as described as follows:

$$\hat{P} = \frac{e^{a+bL}}{1+e^{a+bL}}$$

and the logarithmic transformation:

$$\ln \frac{\hat{P}}{1-\hat{P}} = a + bL \qquad (1)$$

where $\hat{P}$ is the predicted mature proportion, a and b are the coefficients estimated of the logistic equation and L the length. The length at maturity can be estimated as the minus ratio of the coefficients ($-a / b$) by substituting $\hat{P}$ = 0.5 in equation (1). The curves fitting have been made using the Statistica package (StatSoft, Inc., 1995).

RESULTS AND DISCUSSION

In Fig. 2 a general scheme of the female skates reproductive organs is presented. From a total of 739 females examined, ranging in length between 36 cm and 86 cm, only 353 had developing eggs in the ovaries (Table 1). In the samples analysed, individuals below 49 cm of length do not showed ovarian eggs, whereas all individuals larger than 75 cm had ovarian eggs (Fig. 3). The total numbers, minimum and maximum numbers, mean numbers and mean length of the ovarian eggs measured in each ovary are shown in Table 2. A total of 10844 ovarian eggs were measured from August to December 2000. Both ovaries were found to be functional. In immatures females the ovaries are elongated and dorsoventrally compressed. A number of small oocytes (<2 mm in diameter) can be observed in the ovaries at this stage. As the females reach maturity, several eggs in both ovaries start to develop faster than the others. The number of developing eggs in the two ovaries is not always equal, been usually larger in the right one. The mean number of developing eggs in the right ovary over the period analysed was 16 *versus* 14 in the left one, that gives an average number per female of 31 eggs. The minimum number observed was 1 single egg per ovary, occurring at maturity stages 2 and 3, in females of length ranging between 58 cm and 68 cm (Table 2). The maximum number found was of 88 eggs, 46 in ovary left and 42 in ovary right, in a female of 73 cm, at maturity stage 3. The mean length of the ovarian eggs was 11 mm in both ovaries.

In Table 3 the proportions of fish (both sexes) at the successive maturity stages are presented. From the total skates sampled between August and December 2000, 53% of the females and 30% of the males were at maturity stage 1 (immature = juvenile), in agreement with previously reported results (Del Río and Junquera, 2000). The maturing stage (2) in both sexes includes both prespawners juveniles, that are maturing for the first time, and adult postspawners. At this stage the mean number of developing eggs per female is 9, with a mean diameter of 7.5 mm. A 26% of the sampled females, and 35% of the males were at this stage. The proportions of males and females at the 'mature' stage (3) were 35 % and 17% respectively. During the sampling period, the proportion of females at either of the uterine stages was very small (1-2 %). The mean number of eggs per ovary at the 'active' stage (4) is 45, with a mean diameter of 12.5 mm. The mean number of eggs per ovary at the 'advanced' stage (5) is 43, with the same mean diameter than in the prior stage. Only 8 % of the females were at the 'extruding' stage (6) in September, that is 2 % of the females sampled over the whole period. At this stage, completed egg capsules are found in either one or both oviducts, while in the ovary the mean number of developing oocytes are 40 with a mean diameter of 12 mm.

The monthly proportions of mature females thorny skate containing egg capsules found during the sampling period are presented in Table 4. Capsules in various stages of development were observed in only 29 females caught in August, September and November. Most part of them appeared in September and, except 5 females found in November, they are absent thereafter. The majority (64%) of these females with egg capsules have been caught in only two hauls conducted at depths between 188 and 208 m in September. A remarkable feature of those hauls is that the proportion of females in the catches was unusually large compared with that of the males. Egg capsules of thorny skate are light brown, possessing the prominent projection or "horns" at the four corners. Only one single fertilized egg was observed within every capsule. In most of the mature females examined (26) there was one capsule in every oviduct, while the rest (3) only had one capsule in one of the oviducts. Measurement of all capsules found in the samples have been taken. Mean length, mean width and range of egg capsules in thorny skate are shown in Table 5. Those are similar in both oviducts, with average values of 74 mm in length and 62 mm width and increase with the female length and weight, according to the relationships illustrated in Fig. 4.

During the females maturation process, an enlargement of the shell gland have been observed. There is a significant exponential relationship between the shell gland width and the female total length, and also between the shell gland width and the total number and diameter of the oocytes in the ovary, as illustrated in Fig. 5. The relationship between the female size and weight and the potential fecundity (number of developed oocytes in the ovaries) is presented in Fig. 6.

The maturity curves for females and males in 1997, 1999 and 2000 are presented in Fig. 7, and the corresponding fitting parameters in Table 6. Female length at 50% maturity decreased from 60 cm in 1997 to 55 cm in 1999, and remain at a similar value (54 cm) in 2000. In males L_{50} ranges from 43 cm in 1997 to 51 cm in 1999, and then decreased to 49 cm in 2000.

In summary, the results obtained confirm the low potential fecundity of this specie. Both the number and size of the oocytes developing in the ovaries increase as the maturity process advance. At the fully mature stages, the number of eggs in the ovary remains established, between 40 and 45, and their size unchanged at about 12 cm. The period of sampling apparently was not the season of capsules extruding, thus is not possible to ascertain wheatear this final numbers of fully developed oocytes at the ovary, that constitute the potential fecundity, are all fertilized and spawned or what fraction of them could be resorbed.

Most part of adult females in the sampling period was at fully mature ovarian stages, but active uterine stages were almost absent. In contrast, most part of males were at the most advanced maturity stages. This is probably indicating that the autumn skate concentrations in the shallow waters of the shell could be mating aggregations. After fertilization, the process of capsules development and extrusion would follow, though based on the available data the duration of this cannot be determined. If the fleet activity can be considered as an index of the stock aggregation, it could be thought that after fertilization skates get dispersed, probably going to deeper waters. This would explain the low catch rates observed in this fleet since the end of November every year which determine the end of the fishing activity.

ACKNOWLEDGEMENTS

This study was made with the financial support of the European Commission (DG XIV, Study 98-048) and the Spanish Fisheries Administration.

REFERENCES

Asthon, W. D. 1972. *The logit transformation with special reference to its uses in bioassay.* Hafner Publishing Co., Inc., New York, 88 p.

Berestovskii, E.G. 1989. The diet of the skate, *Raja radiata* and *Raja fyllae* in the Barents and Norwegian Seas. *Voprosy ikhtiologii*, 29(6), 994-1002.

Berestovskii, E.G. 1994. Reproductive Biology of Skates of the Family Rajidae in the Seas of the Far North. *Journal of Ichthyology*, 34 (6): 26-37.

Bigelow, H., and Schroeder, W.C. 1953. Fishes of the western North Atlantic. Sawfishes, guitarfishes, skates and rays. *Mem. Sears Found. Mar. Res.*, 1(2): 514 p.

Callard, I.P., Fileti, L.A. and Kood, T.J. 1993. Ovarian steroid synthesis and the hormonal control of the elasmobranch reproductive tract. *Environmental Biology of Fishes*, 38: 175-185.

Clark, R.S. 1922. Rays and skates (Rajidae). Nº 1, Egg-capsules and young. *J. Mar. Biol. Assoc. U.K.*, 12 (4): 577-643.

Chinarina, A.D. and Troschicheva, N.V. 1980. Diet and feeding behavior of the skate *Raja radiata* under experimental condition. *Tr.Murman. biol. in-ta*, 19, 65-74.

Del Río, J. L. and S. Junquera. 2000. Seasonality and reproductive parameters of the thorny skate (*Raja radiata* Donovan 1808) in NAFO Division 3N. *NAFO SCR Doc.*, No. 18. Serial No. N4247, 8 p.

Hobson, A.D. 1930. A note on the formation of the egg-case of the skate. *J. Mar. Biol. Assoc. U. K.*, 16: 577-581.

Hoenig, J. M. and S. H. Gruber. 1990. Life-history patterns in the elasmobranchs: implications or fisheries management. Pages 1–16 *in* H. L. Pratt, Jr., S. H. Gruber, and T. Taniuchi, eds. Elasmobranchs as living resources: advances in the biology, ecology, systematics, and the status of fisheries. *NOAA Tech. Rep.* NMFS 90.

Kulka D.W. and Mowbray F.K. 1998. The Status of Thorny skate (*Raja radiata*), a non-traditional species in NAFO Divisions 3L, 3N, 3O and Subdivisions 3Ps. *DFO Res. Doc*. 98/131, 70 p.

Templeman, W. 1982. Development, Occurrence, and Characteristics of Eggs Capsules of the Thorny Skate, *Raja radiata*, in the Northwest Atlantic. *J. Northw. Atl. Fish. Sci.* 3(1):47-56.

Templeman, W. 1987. Differences in Sexual Maturity and Related Characteristics Between Populations of Thorny Skate (*Raja radiata*) in the Northwest Atlantic. *J. Northw. Atl. Fish. Sci.* 7:155-168.

Simon, J.E. and Frank, K.T. 1996. Assessment of the Division 4VsW skate fishery. *DFO Res. Doc.* 96/105, 51 p.

Smith, S.E., D.W. Au and C. Show. 1998. Intrinsic rebound potentials of 26 species of Pacific sharks. *Mar. Freshw. Res.* 41:663-678.

StatSoft, Inc. 1995. STATISTICA for Windows [Computer program manual]. Tulsa, OK.

Table 1. Number of female thorny skate sampled, left and right ovarian eggs, egg capsules and shell gland measured in NAFO Div. 3N in 2000.

Month	Div.	Range deep (m)	Number of skates examined		Length range (cm)	Ovarian eggs measured		Egg capsules measured		Shell gland measured	
			Total	With eggs		Left	Right	Left	Right	Left	Right
Aug.	3N	42 – 58	131	53	38 – 80	778	880	1	1	-	-
Sept.	3N	42 - 215	236	106	40 – 85	1450	1534	22	21	-	-
Oct.	3N	62 – 69	45	24	36 – 80	183	193	0	0	-	-
Nov.	3N	47 – 71	282	140	45 – 85	2181	2426	5	5	120	120
Dec.	3N	53 – 75	45	30	52 – 86	586	633	0	0	45	45
		42 - 215	**739**	**353**	**36 – 86**	**5178**	**5666**	**28**	**27**	**165**	**165**

Table 2. Mean number and mean length of ovarian eggs per ovary in thorny skate from August to December 2000 in NAFO Div. 3N.

Month	Stage maturity	Skates sampled	Length range (cm)	Ovarian eggs measured (mm)							
				Left				Right			
				Number total	Mean number	Mean length	Number min-max	Number total	Mean number	Mean length	Number min-max
Aug.	2	14	50–70	99	7	5.75	1-20	111	8	4.60	2-18
	3	37	56–80	648	18	10.76	1-46	731	20	10.39	1-45
	4	1	70	13	13	12.80	13	12	12	12.10	12
	5	1	67	18	18	12.00	18	26	26	15.63	26
		53		**778**	**14.6**	**10.28**		**880**	**16.6**	**9.90**	
Sept.	2	15	57–68	53	4	7.77	2-11	51	3	7.92	1-15
	3	60	59–84	849	14	11.54	1-33	896	15	11.66	1-27
	4	5	62–85	88	18	14.00	16-20	96	19	12.89	11-25
	5	10	65–83	141	14	13.17	9-22	172	17	13.15	7-27
	6	16	62–84	319	20	12.31	1 -29	319	20	11.94	11-27
		106		**1450**	**13.6**	**11.86**		**1534**	**14.5**	**11.87**	
Oct.	2	11	58–75	27	2	9.00	1-5	25	2	8.40	2-19
	3	12	62–78	137	11	12.33	4-26	148	12	12.87	5-25
	4	1	80	19	19	15.30	19	20	20	13.50	20
		24		**183**	**7.6**	**12.15**		**193**	**8**	**12.17**	
Nov.	2	34	58–74	159	5	7.86	1-11	172	5	8.26	1-13
	3	96	58–85	1770	18	10.55	1-38	1979	21	10.67	4-51
	4	5	71–84	111	22	11.24	13-33	147	29	10.38	17-48
	5	5	68–79	141	28	10.41	19-38	128	26	12.18	17-39
		140		**2181**	**15.6**	**10.38**		**2426**	**17.3**	**10.53**	
Dec.	3	29	61-86	552	19	11.53	4-37	594	20	11.58	5-34
	4	1	79	34	34	10.64	34	39	39	12.25	39
		30		**586**	**19.5**	**11.48**		**633**	**21.2**	**11.62**	
TOTAL		**353**		**5178**	**14.6**	**11.04**		**5666**	**16**	**11.11**	

Table 3. Monthly percentages of skate (*A. radiata*) at the successive maturity stages by sexes observed in the second half of 2000 in Div. 3N.

	MATURITY STAGES (%)									
	1		2		3		4		5	6
	M	F	M	F	M	F	M	F	F	F
Aug.	23	41	43	41	34	17	0	0	0	0
Sept.	25	55	40	18	35	17	0	1	1	8
Oct.	33	55	31	33	37	10	0	1	1	0
Nov.	40	59	26	23	33	17	0	1	0	0
Dec.	35	53	25	21	40	24	0	1	1	0
TOTAL	30	53	35	26	35	17	0	1	1	2

Table 4. Presence of egg capsules in mature female of thorny skate.

Month	Number of rays		Proportion
	examined	with capsules	with capsules
Aug.	53	4	7.54
Sept.	106	20	18.86
Oct.	24	0	0
Nov.	140	5	3.57
Dec.	30	0	0
	353	29	7.93

Table 5. *Amblyraja radiata* egg capsule dimensions.

Parameter	Left		Right	
	Mean (mm)	Range (mm)	Mean (mm)	Range (mm)
Capsule length	74,0	66-84	74,4	65-87
Capsule width	61,8	53-74	61,8	49-71

Table 6. Parameters of the thorny skate females (F) and males (M) maturity curve in Div. 3N (1997, 1999 and 2000). 'a' and 'b'= coefficients of the adjusted logistic curve; St. error = standard error of the estimates; L_{50} = length at 50% maturity; Var. exp. = variance explained by the model; r = correlation coefficient and N = numbers sampled.

	FEMALES					
	1997		1999		2000	
	a	b	a	b	a	b
Estimate	-19,75	0,32	-21,56	0,39	-21,26	0,39
St. error	1,97	0,03	2,69	0,05	1,03	0,01
L_{50}	**60 cm**		**55 cm**		**54 cm**	
Var. exp.	65%		75%		66%	
r	0,8		0,86		0,81	
N	461		222		2284	
	MALES					
	a	b	a	b	a	b
Estimate	-15,28	0,35	-11,39	0,22	-23,86	0,48
St. error	1,66	0,03	1,67	0,03	1,13	0,02
L_{50}	**43 cm**		**51 cm**		**49 cm**	
Var. exp.	59%		57%		63%	
r	0,77		0,75		0,79	
N	439		216		2628	

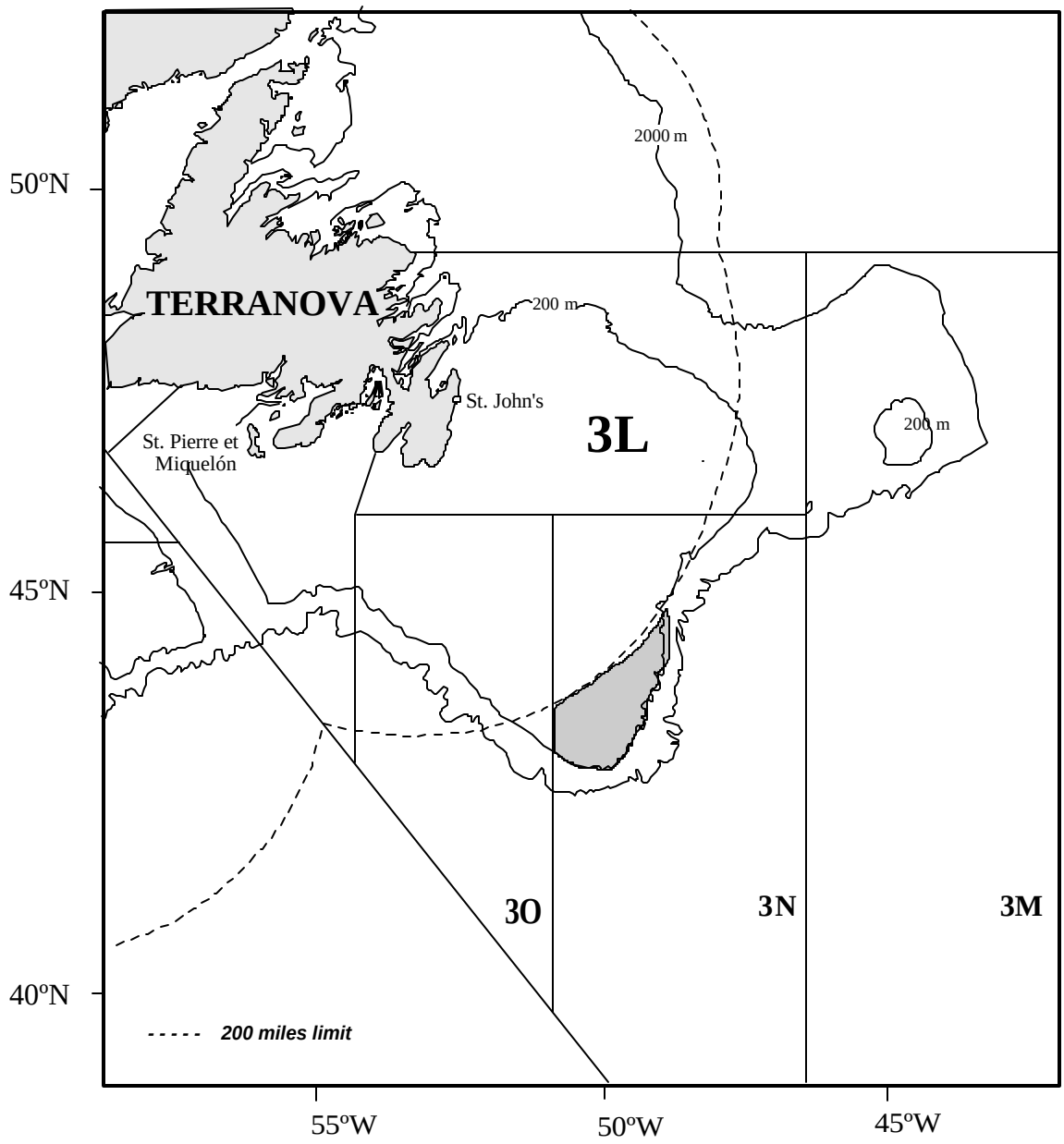


Fig. 1.- Fishing area in the southern part of Grand Bank region.

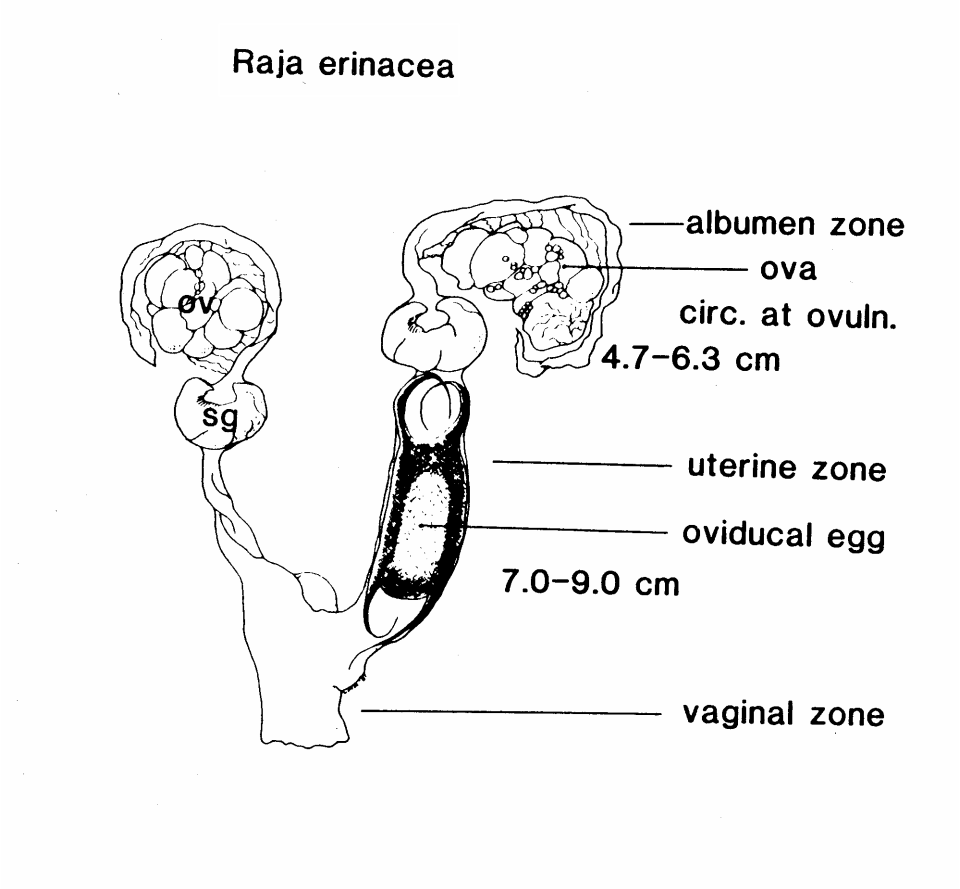


Fig. 2.- Skate female reproductive tracts: ov = ovary; sg = shell gland (From Callard et al., 1993).

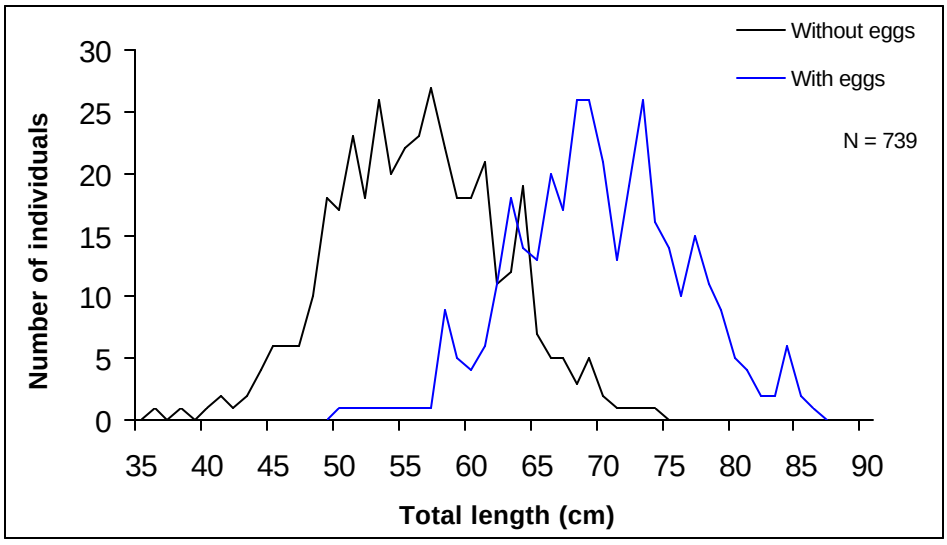
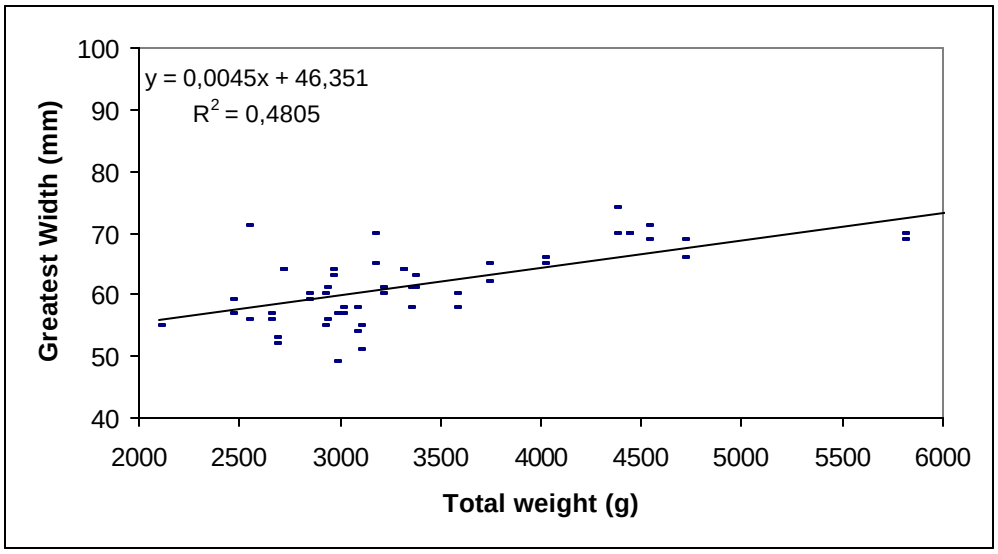


Fig. 3. Length distributions of the female thorny skate with and without ovarian eggs recorded in samples taken from the Spanish commercial catches (NAFO Div. 3N, Regulatory Area) in 2000.



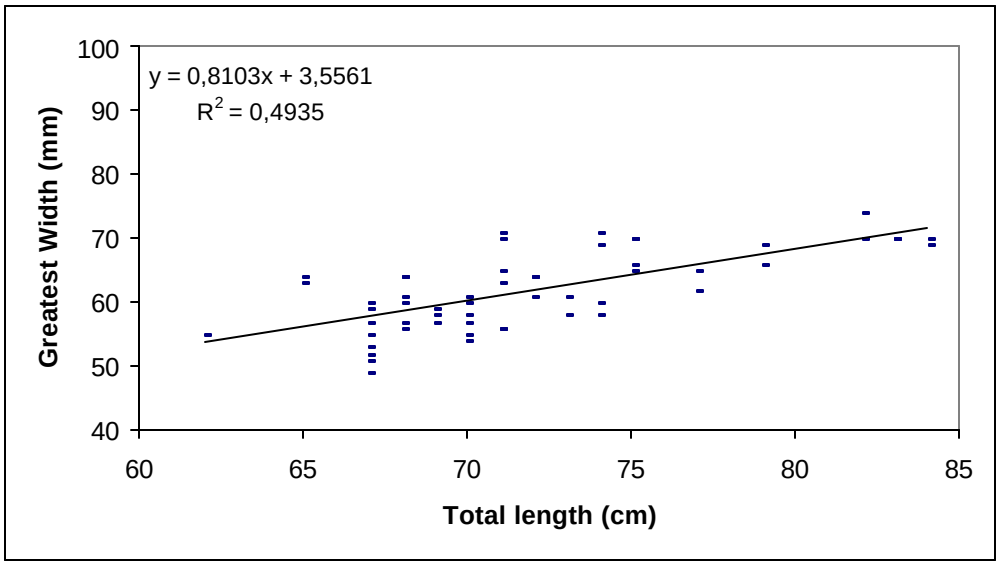
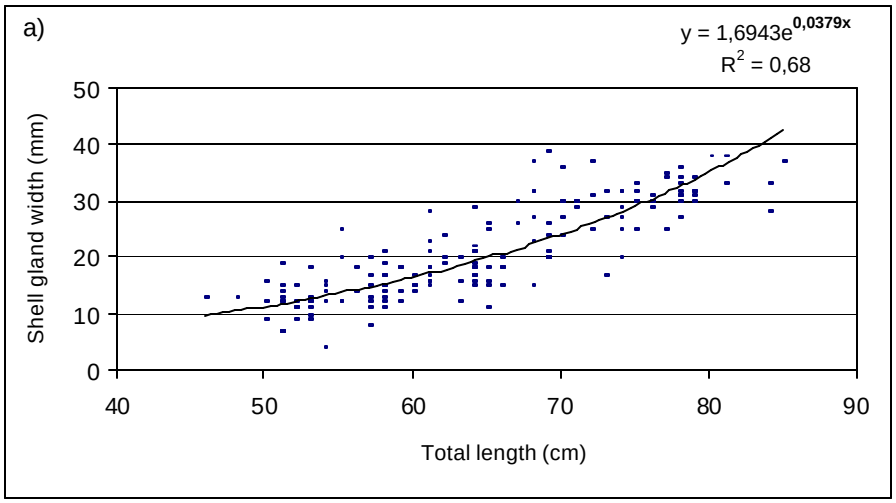
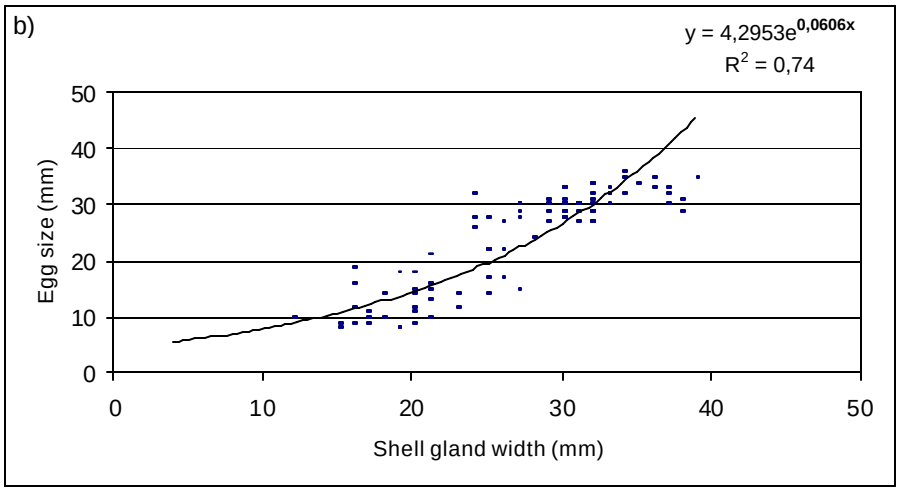


Fig. 4.- Relationship between thorny skate egg capsule (greatest width) and female length.





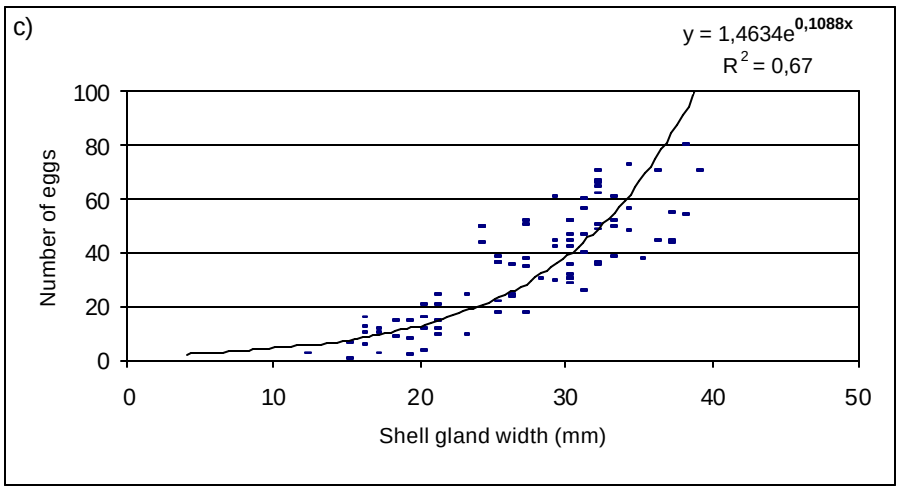
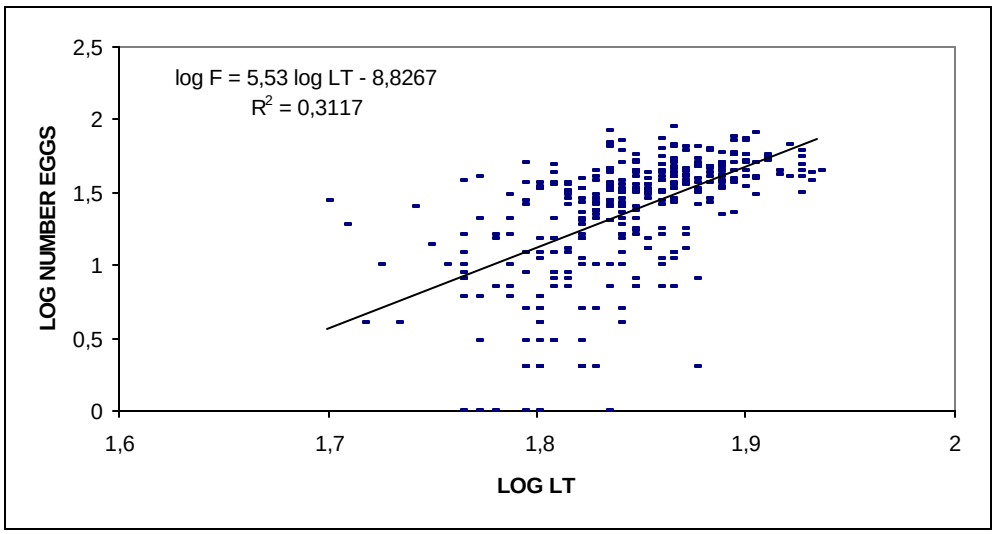


Fig. 5. Thorny skate relationship between: (a) shell gland width and total length, (b) egg size in the ovary and shell gland width, and (c) number of eggs in the ovary and shell gland width.



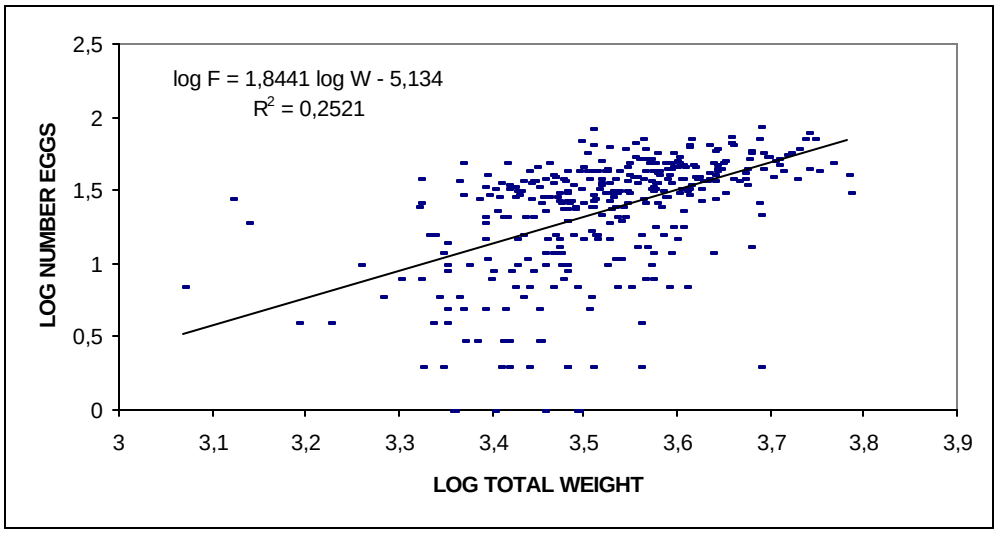


Fig. 6. Relationship between thorny skate length and weigth and potential fecundity (total number of fully developed oocytes in both ovaries).

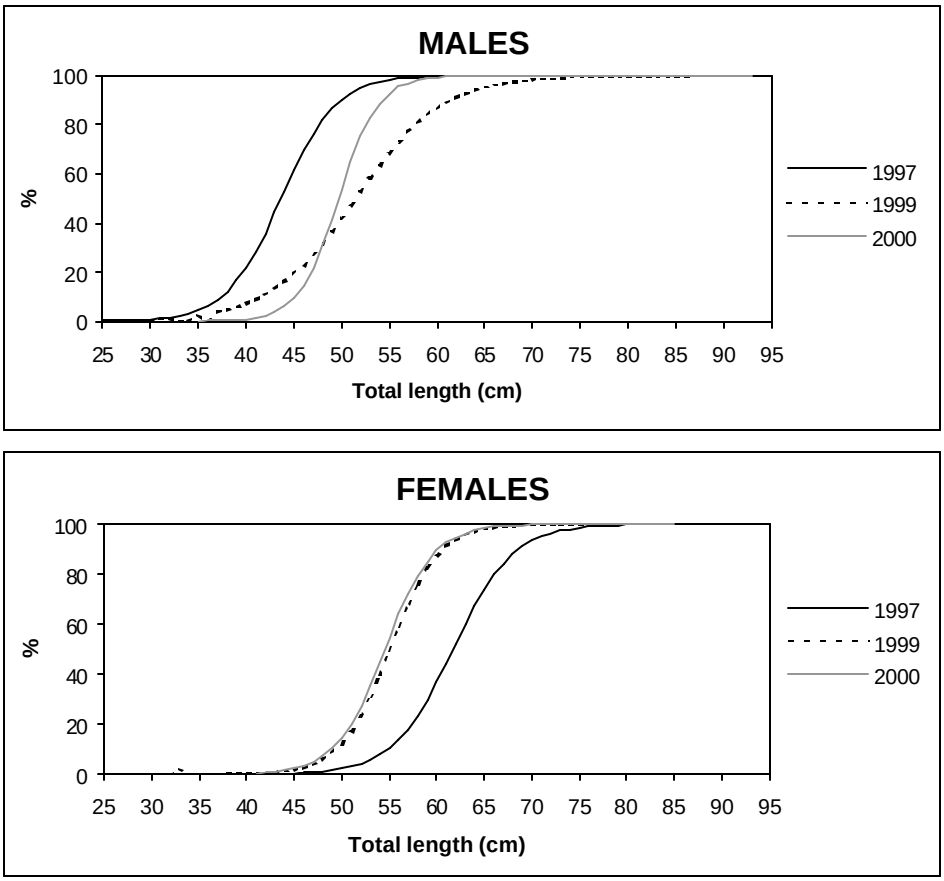


Fig. 7.- Maturity ogives of thorny skate in Div. 3N: 1997, 1999 and 2000.

ANNEX 1. Maturity Scale for Thorny Skate

MALES

1.- Immature. Claspers undeveloped as small, flexible sticks being shorter than extreme tips of posterior pelvic fin lobes.

2.- Maturing. Claspers becoming extended, longer than tips of posterior pelvic lobes, their tips (glans) becoming structured, but skeleton still soft and flexible.

3.- Mature. Claspers full length, external and internal glans structures fully formed, skeleton hardened so that claspers stiff and free glans components sharp.

4.- Active. Glans clasper often dilated, its structures reddish and swollen. Sperm flowing on pressure from cloaca and/or present in claspers groove or glans. Sperm ducts largely as stage 3 but may be less tightly filled, whereas seminal vesicle may be well filled.

FEMALES - ovarian stages

1.- Immature. Ovaries small, their internal structure gelatinous or granulated. No oocytes differentiated or all uniformly small, granular. Oviducts (uteri) narrow, thread-like.

2.- Maturing. Ovaries somewhat enlarged, walls more transparent. Oocytes becoming differentiated to various small sizes. Uteri largely as stage 1 but may become widened posteriorly.

3.- Mature. Ovaries large and tight. Oocytes enlarged, with some being very large. Uteri enlarged and widening over nearly their entire length.

FEMALES - uterine stages

4.- Active. A distinctly large yolk-egg present in one or both Fallopian tubes. No egg capsule yet visible in shell gland, or beginning formation of eggs capsule at most.

5.- Advanced. Large yolk-eggs in Fallopian tubes, or already passing through into egg capsules. Egg capsules about fully formed in one or both oviducts but still soft at upper end and located very close to Fallopian tubes.

6.- Extruding. Completed, hardened egg capsules in one or both oviducts, more or less separated from Fallopian tubes. Capsule surface covered with dense silky fibres. If oviducts empty but still much enlarged and wide, capsules have probably just been extruded.