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Cod migrations in the Gulf of St. Lawrence and south areas off Newfoundland

by

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1. Introduction.

To analyse the cod populations distributions and their migratory schemes in west - Gulf of St Lawrence - and/or south areas off Newfoundland (Fig. 1 and 2), numerous tagging experiments were conducted by Canadian scientists (Thompson 1943, Templeman and Fleming 1962, Templeman 1962, 1974, 1979, Lear 1984, Lear 1988a and 1988b).

During four years 1975, 1976, 1980 and 1982, tagging experiments were also conducted by the IFREMER laboratory of Saint Pierre and Miquelon to complete the previous studies.

In 1975 and 1976, tagging was carried out principally in the Gulf of St Lawrence (Div. 4 R) and neighbouring areas (Subdiv. 3 Pn) and on the northern part of St Pierre Bank (Subdiv. 3 Ps). First results and conclusions were presented by Minet (1975 and 1977). In the last two years, 1980 and 1982, tagging experiments were exclusively conducted on St Pierre Bank (Subdiv. 3 Ps). Results have never been published.

An analysis of all recoveries from these four tagging experiments is presented here and cod migration schemes in the Gulf of St Lawrence and areas south off Newfoundland are deduced integrating results from previous studies. The consequences for cod stocks assessments are discussed.

2. Material and methods.

The tagging experiment process (trawling operation, type of gear, fish selection, type of tag, tagging location on the fish body...) was described by Minet (1977). Each tagging operation has been conducted in a similar way for 1975, 1976, 1980 and 1982.

This is the standard process generally conducted for this kind of experiment in the area (Templeman 1962, 1974, 1979, Lear 1984 and 1988a).

Tagging periods were selected from the knowledge on cod biology and from fisheries informations. In the Gulf of St Lawrence, and neighbouring areas (Subdiv. 3 Pn and northern part of St Pierre Bank) tagging experiments in 1975 and 1976 were carried out in winter, when cod is distributed along the Newfoundland coast. On St Pierre Bank, in 1980 and 1982, tagging experiments were conducted in fall when cod is distributed in the shallow waters of the bank.

For the analysis all recoveries have been taken into account, from the year of the tagging until the last year of reported recaptures. Recoveries have been grouped by quarter in tables.

Probability of catching tagged cod depends on the abundance of tagged fishes but also on the fishing effort deployed in the area. Relation with the fishing activity of the St Pierre and Miquelon trawler fleet have been considered.

3. Results and discussion.

Over the four years, 6000 cods have been tagged (Table 1). Percentage of recoveries by division and year varies between 2 and 13 % (Table 2). This level, low when the number of tagged cods is too small (< 200), is similar to the level commonly observed in these kind of studies.

The major proportion of tagged cods was between 45 and 75 cm in length (Table 11, Fig. 3).

The number of recoveries by quarter, year and areas are presented in tables 3 to 10 for each NAFO division and subdivision of tagging.

Migrations of each cod from the position of tagging to the position of recovery over the years have been plotted for each tagging experiment (Fig. 4).

Recoveries from tagging experiments in the Gulf of St Lawrence (Div. 4 R) are, during the first quarter, most important in the south neighbouring area just outside the Gulf (Subdiv. 3 Pn). Some recoveries are also recorded but with a lower level on Burgeo Bank (Subdiv. 3 Ps). The percentage of recaptures outside the Gulf of St Lawrence is decreasing along the year, and in the third quarter all recoveries are inside the tagging division (Fig. 5 and 6, Table 3 and 4).

On the contrary, the percentage of recoveries from tagging experiments just outside the Gulf of St Lawrence (Subdiv. 3 Pn) in winter is lower inside the Gulf than outside - the tagging area and the northern part of Subdiv. 3 Ps. Recoveries in Subdiv. 3 Ps are observed on Burgeo Bank, and for a large part along the south coast of Newfoundland. The percentage of recaptures inside the Gulf is increasing along the year, being optimal in spring or/and summer (Fig. 7 and 8, Table 5 and 6).

The results of these two tagging experiments clearly indicate that in winter, cod migrates from the north and the centre of the Gulf of St Lawrence (Div. 4 R) to the south along the west coast of Newfoundland down to the exit of the Gulf. This migration can extend to the south coast of Newfoundland and/or Burgeo Bank (Subdiv. 3 Ps). In spring and summer, the migration is reversed and cod moves into the Gulf from Burgeo Bank (Subdiv. 3 Ps) and Subdiv. 3 Pn.

This migratory process has been described by Templeman (1962, 1974, 1978, 1979), Minet (1975, 1977), Bertrand (1989). All the authors pointed out the migration from the Gulf to south neighbouring areas and concluded on the presence in Subdiv. 3 Ps - but only on Burgeo Bank - of cod coming in winter from the Gulf. They also stated on the return of a portion of these cods to their original area of distribution. Analysis of length at 50 % maturity, meristic characters and parasitic infection - essentially by nematodes - also confirmed this scheme (Templeman *et al.* 1957, Mabeau *et al.* 1986, Bishop *et al.* 1988).

Lear (1988a, 1988b) confirmed the observations of Templeman (1962) pointing out the migration from Subdiv. 3 Pn and Burgeo Bank to shallow waters along the south coast of Newfoundland - as it is shown here. An analysis of the fishing activity of the French trawlers fleet in the Gulf during the winter on the period 1978-1989 (Fréchet, 1990) described also the cod migration, but only inside the Gulf. Gascon *et al.* (1990) attempted to quantify this migration, and particularly the proportion of cod escaping the Gulf. They observed similars results as Templeman (1974, 1978, 1979),

estimating the proportion between 2.3-2.7 % for the period 1954-1955 and 10-12 % for the period 1962-1966, and only about 10 % of return.

The migration rate which depends on the abundance of the cod stock in the Gulf (Div. 4 R - 4 S) and on a combination of various factors (hydrological - presence or not of ice in winter - food, predators...) is varying from year to year. For example, in the years 1984 and 1986, large concentrations have been noted on the western slope of Burgeo Bank (Subdiv. 3 Ps). It was assumed that a large proportion of these cods were coming from the Gulf (Bishop *et al.* 1991, Moguedet 1991a and 1991b). Return rates depend of the abundance of migrating cods, and also on the combination of various above mentioned factors more the fishing activity on Burgeo Bank. It is then difficult to conclude and quantify the annual level of mixing in cod stocks in this area, especially if the migration concerns only a part of the population - matures individuals for example (not proven at the moment) - it would then depend on the abundance of some cohorts and the fishing activity interaction on these cohorts.

Recoveries rates from tagging experiments conducted in Subdiv. 3 Ps on winters 1975 and 1976 were low (Fig. 9, Table 7 and 8). This was essentially due to the small numbers of cods tagged, so an analysis of the migration scheme in winter was difficult.

Recoveries from tagging experiments conducted in the Subdiv. 3 Ps, on St Pierre Bank in fall were - for a very large percentage (70 to 100 %) - reported from this same subdivision (Fig. 10 and 11, Table 9 and 10), as observed by Lear (1988a and 1988b). Some of them were realized in coastal waters, others in deeper waters. The migratory rate to the Grand Bank (Div. 3 NO) was superior to the migratory rate to the Gulf of St Lawrence (Div. 4 R 4 S) and neighbouring areas (Subdiv. 3 Pn). A quarterly analysis of the migration from St Pierre Bank doesn't show any cyclic process. For example, recoveries from the 1980 experiment were reported on the Grand Bank mostly in spring and summer while they were observed in fall and winter in the gulf. This was not confirmed by the recoveries obtained from the 1982 tagging experiment.

Recoveries of cods tagged in Subdiv. 3 Ps reported 1000 days and more after tagging only concerned mature individuals (> 60 cm length at tagging). This was not so clearly observed for cods tagged in the Gulf (Fig. 12).

These two tagging experiments conducted on St Pierre Bank in fall of 1980 and 1982, clearly pointed out that a cod population is mainly distributed in this area - as observed by Templeman (1962, 1974, 1979), Templeman and Fleming (1963). The major migratory process takes place from offshore areas to inshore coastal waters areas and reverse. This was described by Templeman (1962). As it was noted on Burgeo Bank in winter, largest cod concentrations have been also identified in western and south slopes of St Pierre Bank in winter. From recoveries reported from a tagging experiment conducted in 1986, Lear (1988b) concluded that this large concentrations were staying offshore only migrating in shallow waters on the south and central parts of the Grand Bank. This was in contradiction with Templeman (1962) and Templeman and Fleming (1962) and with the migratory process observed here. However, it was noted that a part (7-10 %) of cod population of St Pierre bank could migrate to the Grand Bank. This was also noted by Bishop *et al.* (1991) and Moguedet (1991b).

On the other hand, no migration was observed from St Pierre Bank to Burgeo Bank. All recoveries were observed in the northern part of the St Pierre Bank.

4. Conclusions.

Migratory schemes of cod populations in Gulf of St Lawrence and south areas off Newfoundland are mainly a result of environmental conditions and are characterised by their high temporal variability.

Cod population in the Gulf of St Lawrence migrates in winter from the centre and north areas southward down to outside areas - Rose Blanche, Subdiv. 3 Pn and Burgeo Bank, Subdiv. 3 Ps - and reverse in spring and summer. Cod distributed at the limit of the Gulf (Subdiv. 3 Pn) also migrates to coastal areas of Newfoundland. This migratory process is mainly a reply to hydrological conditions in winter - ice for example.

On St Pierre Bank, most of the migrations take place from offshore to inshore waters and reverse. They are related to hydrological conditions - water temperatures - and food availability.

These migratory patterns were observed by Templeman (1962, 1974, 1979) and Templeman and Fleming (1963). They stated on a large complex cod stock distributed in the Gulf of St Lawrence (Div. 4 R, 4 S) and the nearest outside areas (Subdiv. 3 Pn, north of Subdiv. 3 Ps - Burgeo Bank - and coastal areas south off Newfoundland).

The cod population on St Pierre Bank remained for a large portion in this area. It is well separated of the above mentioned complex stock by the Hermitage channel - between Burgeo Bank and St Pierre Bank - which acts like a barrier. Some exchanges with Grand Bank cod population have been pointed out. The level of this migratory process variable from a year to another, seems generally low.

This study pointed out the various exchanges between cod populations in the area. The high variability of migratory rates, - depending mainly on environmental conditions - prevent any yearly estimation of the percentage of mixing in cod populations. It is therefore impossible to take into account the influence of migrations in conducting assessments of cod stocks in these areas.

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Year\Tagging area	Div. 4R	Subdiv. 3Ps	Subdiv. 3Pn
1975	465	199	206
1976	1496	35	1462
1980		958	
1982		1492	
	1961	2684	1668

Table 1 - Number of cod tagged by year and division.

Year\Tagging area	Div. 4R	Subdiv. 3Ps	Subdiv. 3Pn
1975	6.5	2.5	6.8
1976	13.6	2.8	10.5
1980		4.5	
1982		4.3	

Table 2 - Percentage of recoveries by year and division.

Tagging	4R	Quarter I		Quarter II		Quarter III		Quarter IV		TOTAL		% 4R	% 3Pn
February 1975, N= 465	Year of recapture	Number	Subdiv.	Number	Subdiv.	Number	Subdiv.	Number	Subdiv.	Number	Subdiv.		
	1975	1	4R	3	4R	2	4R			6	4R	54.5	27.3
		1	3Pn	2	3Pn	1	4T			3	3Pn		
				1	3Ps					1	3Ps		
										1	4T		
	1976	3	3Pn	4	4R	1	4R			5	4R	50.0	30.0
		1	3Ps							3	3Pn		
		1	4Vn							1	3Ps		
										1	4Vn		
	1977	1	4R	1	4R					2	4R	100.0	
	1978	1	3Pn	1	4R					1	4R	33.3	33.3
		1	3Ps							1	3Pn		
										1	3Ps		
	1979	1	4R	1	4R					2	4R	50.0	25.0
				1	3Pn					1	3Pn		
				1	3K					1	3K		
	TOTAL	5	3Pn	10	4R	3	4R			16	4R	53.3	26.7
		3	4R	3	3Pn	1	4T			8	3Pn		
		2	3Ps	1	3Ps					3	3Ps		
		1	4Vn	1	3K					1	3K		
										1	4T		
										1	4Vn		
	% 4R	27.3		66.7		75.0				53.3			
	% 3Pn	45.5		20.0		0.0				26.7			
	% 3Ps	18.0		6.0		0.0				10.0			

Table 3 - Number of recoveries by year, quarter and NAFO div., from cod tagging experiment in the Gulf of St Lawrence (div. 4 R) in 1975 (Feb).

Tagging	4R	Quarter I		Quarter II		Quarter III		Quarter IV		TOTAL		% 4R	% 3Pn
January 1976 N= 1496	Year of recapture	Number	Subdiv.	Number	Subdiv.	Number	Subdiv.	Number	Subdiv.	Number	Subdiv.		
	1976	8 3 1	4R 3Pn 3Ps	42 4 3	4R 4S 4T	28 5 1 1	4R 4T 3K 4S	3 1	4R 4Vn	81 8 5 3 1 1 1	4R 4T 4S 3Pn 3Ps 3K 4Vn	81.0	3.0
	1977	4 1	4R 4Vn	21 1 1 1 1 1	4R 4S 4T 4Vn 3K 3M	7 4 1 1	4R 4S 4T 3K			32 5 2 2 2 1	4R 4S 4T 4Vn 3K 3M	72.7	0.0
	1978	6 1 1	4R 4S 4Vs	11 1 1 1	4R 4T 3O 3Ps	14 3 2	4R 3K 3O	1	3L	31 3 3 1 1 1 1	4R 3K 3O 4S 4T 3L 3O 3Ps	73.8	0.0
	1979	2 1	4R 4S	1	4R	1 1 1	4R 3K 3L	1	4R	5 1 1 1	4R 4S 3K 3L	62.5	0.0
	1980	1	4R					1	4R	2	4R	100.0	0.0
	1981	4	4R	1	4R	1 1 1	4R 3K 3Ps			6 1 1	4R 3K 3Ps	75.0	0.0
	TOTAL	25 3 2 1 1 1	4R 3Pn 4S 4Vn 4Vs 3Ps	76 5 5 1 1 1	4R 4S 4T 4Vn 3K 3O 3Ps	51 7 6 5 2 1 1	4R 3K 4T 4S 3O 3L 3Ps	5 1 1	4R 4Vn 3L	157 12 11 8 3 3 3 2 1	4R 4S 4T 3K 3Pn 4Vn 3Ps 3O 3L 4Vs	77.3	1.5
	% 4R	75.8		84.4		69.9		71.4		53.3			
	% 3Pn	9.1		0.0		0.0		0.0		26.7			
	% 3Ps	3.0		1.0		1.0		0.0		1.4			

Table 4 - Number of recoveries by year, quarter and NAFO div., from cod tagging experiment in the Gulf of St Lawrence (div. 4 R) in 1976 (Jan).

Tagging	3Pn	Quarter I		Quarter II		Quarter III		Quarter IV		TOTAL		% 3Pn	% 4R
February 1975, N= 206	Year of recapture	Number	Subdiv.	Number	Subdiv.	Number	Subdiv.	Number	Subdiv.	Number	Subdiv.		
	1975	1	3Ps	1	3Pn	1	4R			1 1 1	3Pn 3Ps 4R	33.3	33.3
	1976			1	3Ps	1	3Ps			2	3Ps	0.0	0.0
	1977	2 2 1	3Ps 4R 3Pn	1 1	3K 4R					2 3 1 1	3Ps 4R 3K 3Pn	14.3	42.9
	1978			1	3Pn					1	3Pn	100.0	0.0
	1980	1	4R							1	4R	0.0	100.0
	TOTAL	3 2 1	3Ps 4R 3Pn	2 1 1 1	3Pn 3Ps 3K 4R	1 1	3Ps 4R			5 5 3 1	4R 3Ps 3Pn 3K	21.4	35.7
	% 3Pn	16.7		40.0		0.0				21.4			
	% 4R	33.3		20.0		50.0				35.7			
	% 3Ps	50.0		20.0		50.0				35.7			

Table 5 - Number of recoveries by year, quarter and NAFO div., from cod tagging experiment outside the Gulf of St Lawrence (subdiv. 3 Pn) in 1975 (Feb).

Tagging March 1976 N= 1462	3Pn Year of recapture	Quarter I		Quarter II		Quarter III		Quarter IV		TOTAL		% 3Pn	% 4R
		Number	Subdiv.	Number	Subdiv.	Number	Subdiv.	Number	Subdiv.	Number	Subdiv.		
	1976	11 2 1	3Pn 4R 3Ps	35 3 3 2 2 1	4R 3Pn 3Ps 4T 4S 3K	9 4 2	4R 4S 3Ps	3 1	4R 4Vn	49 14 6 6 2 1 1	4R 3Pn 3Ps 4S 4T 3K 4Vn	17.7	62.0
	1977	10 4 1	4R 3Pn 3Ps	9 2 1	4R 3Pn 3L	10 1	4R 4S			29 6 1 1 1	4R 3Pn 3L 3Ps 4S	15.8	76.3
	1978	2 2 2 1	4R 3Pn 3Ps 4S	8 2 1 1	4R 3Pn 3L 4S	2 1	4S 4R			11 4 4 2 1	4R 3Pn 4S 3Ps 3L	18.2	50.0
	1979	3	4R			3 1 1	4R 3K 3L			6 1 1 1	4R 3K 3L	0.0	75.0
	1981	1	4Vn			4	4R			4 1	4R 4Vn	0.0	80.0
	TOTAL	17 17 4 1 1	3Pn 4R 3Ps 4S 4Vn	52 7 3 3 2 2 1	4R 3Pn 3Ps 4S 4T 3L 3K	27 7 2 1 1	4R 4S 3Ps 3K 3L	3 1	4R 4Vn	99 24 11 9 3 2 2 2	4R 3Pn 4S 3Ps 3L 4T 3K 4Vn	15.8	65.1
	% 3Pn	42.5		10.0		0.0				15.8			
	% 4R	42.5		74.3		71.1				65.1			
	% 3Ps	10.0		4.0		5.0				5.9			

Table 6 - Number of recoveries by year, quarter and NAFO div., from cod tagging experiment outside the Gulf of St Lawrence (subdiv. 3Pn) in 1976 (March).

Tagging February 1975, N= 199	3Ps Year of recapture	Quarter I		Quarter II		Quarter III		Quarter IV		TOTAL		% 3Ps
		Number	Subdiv.	Number	Subdiv.	Number	Subdiv.	Number	Subdiv.	Number	Subdiv.	
	1975	1	4W	1 1	3Ps 4R					1 1 1	3Ps 4R 4W	33.3
	1978			1	4R					1	4R	0.0
	1982			1	4S					1	4S	0.0
	TOTAL	1	4W	2 1 1	4R 3Ps 4S					2 1 1 1	4R 3Ps 4S 4W	20.0
	% 3Ps	0.0		25.0						20.0		

Table 7 - Number of recoveries by year, quarter and NAFO div., from cod tagging experiment on the Burgeo bank (subdiv. 3 Ps) in 1975 (Feb).

Tagging March 1976 N= 35	3Ps Year of recapture	Quarter I		Quarter II		Quarter III		Quarter IV		TOTAL		% 3Ps
		Number	Subdiv.	Number	Subdiv.	Number	Subdiv.	Number	Subdiv.	Number	Subdiv.	
	1977					1	4S			1	4S	0.0
	% 3Ps					0.0				0.0		

Table 8 - Number of recoveries by year, quarter and NAFO div., from cod tagging experiment on the Burgeo bank (subdiv. 3 Ps) in 1976 (March).

Tagging	3Ps	Quarter I		Quarter II		Quarter III		Quarter IV		TOTAL		% 3Ps
October 1980 N = 958	Year of recapture	Number	Subdiv.	Number	Subdiv.	Number	Subdiv.	Number	Subdiv.	Number	Subdiv.	
	1980							11	3Ps	11	3Ps	100
	1981	5	3Ps	1	3Ps	1	3L	9	3Ps	15	3Ps 3L	93.8
	1982			3	3Ps	3	3Ps	3	3Ps	9	3Ps 3L	90.0
	1983			1	3L					1	3L	
	1983			3	3Ps	2	3Ps			5	3Ps	100.0
	1985							1	4R	1	4R	100.0
	1986	1	3Pn	1	3O					1	3Pn 3O	50.0
	TOTAL	5	3Ps 3Pn	7	3Ps 3L 3O	5	3Ps 3L	23	3Ps 4R	40	3Ps 3L 3O 3Pn 4R	88.9
	% 3Ps	83.3		77.8		83.3		95.8		88.9		

Table 9 - Number of recoveries by year, quarter and NAFO div., from cod tagging experiment on the St Pierre bank (subdiv. 3 Ps) in 1980 (Oct).

Tagging	3Ps	Quarter I		Quarter II		Quarter III		Quarter IV		TOTAL		% 3Ps
October 1982 N = 1492	Year of recapture	Number	Subdiv.	Number	Subdiv.	Number	Subdiv.	Number	Subdiv.	Number	Subdiv.	
	1982							5	3Ps	5	3Ps	100.0
	1983	1	3Ps	7	3Ps	3	3Ps	18	3Ps	29	3Ps	80.6
	1983	1	4V			3	3L	2	3L	5	3L 4V	
	1983							1	3O	1	3O	
	1984	2	3Ps	2	3Ps	2	3Ps	4	3Ps	10	3Ps	90.9
	1984					1	4T			1	4T	
	1985	4	3Ps	2	3Ps	1	4R	2	3Ps	8	3Ps	80.0
	1985	1	4Vs							1	4R 4Vs	
	1986	1	3Ps	1	3Ps					2	3Ps	66.7
	1986	1	3O							1	3O	
	TOTAL	8	3Ps 3O	12	3Ps	5	3Ps 3L	29	3Ps 3L 3O	54	3Ps 3L 3O 4R 4T 4V 4Vs	83.1
	% 3Ps	72.7		100.0		50.0		90.6		83.1		

Table 10 - Number of recoveries by year, quarter and NAFO div., from cod tagging experiment on the St Pierre bank (subdiv. 3 Ps) in 1982 (Oct).

Year	Div. 4R		Subdiv. 3Pn		Subdiv. 3Ps			
	1975	1976	1975	1976	1975	1976	1980	1982
Length(cm)								
27	1						1	
30							2	5
33		2						2
36	3	10	3				1	3
39	4	27	5		1		1	8
42	11	58	4		1		10	30
45	23	80	10	20	1		14	122
48	19	100	17	106	3	3	30	258
51	52	150	16	224	6	7	69	343
54	65	202	22	261	29	2	113	253
57	70	210	36	232	28	11	176	123
60	71	205	33	202	31	1	172	74
63	53	170	16	161	25	3	138	59
66	25	126	16	114	26	1	94	68
69	17	50	8	60	15	2	36	53
72	12	40	3	40	10	1	23	37
75	11	22	7	19	8	3	28	20
78	7	18	3	8	5		21	16
81	7	8	3	6			10	7
84	1	8	1	2	5		9	5
87	1	3	2	1			5	2
90	2	4		5	2		4	3
93	2	1	1		2		1	1
96	2			1	1			
99		1						
102	2					1		
105								
108	2							
111	1	1						
114								
117								
120								
123								
126	1							
Total	465	1496	206	1462	199	35	958	1492

Table 11 - Length distribution of cods tagged in the Gulf of St Lawrence (div. 4 R) and south areas of Newfoundland (subdiv. 3 Pn and 3 Ps) in 1975, 1976, 1980, 1982.

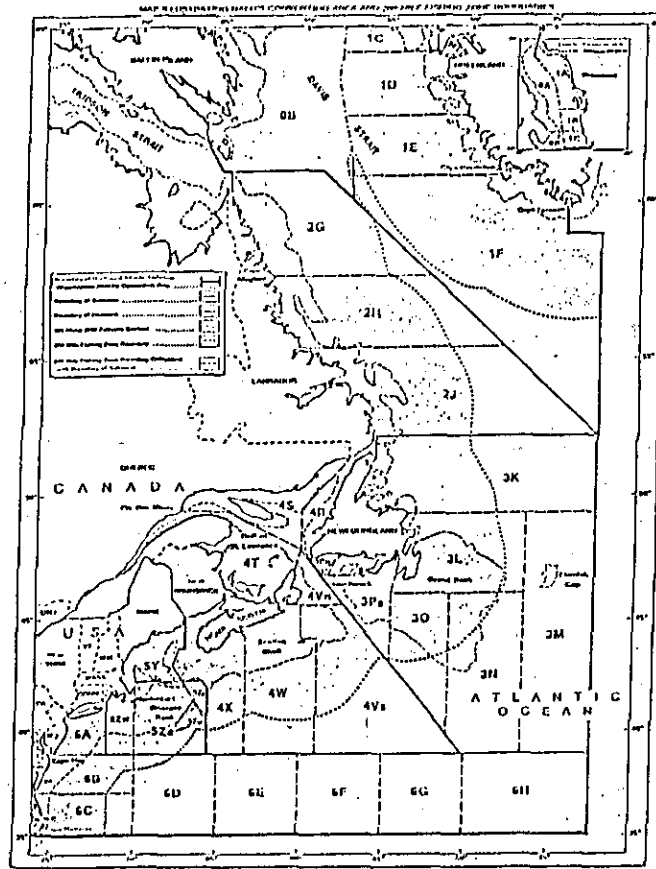


Figure 1. Location of NAFO divisions and subdivisions.

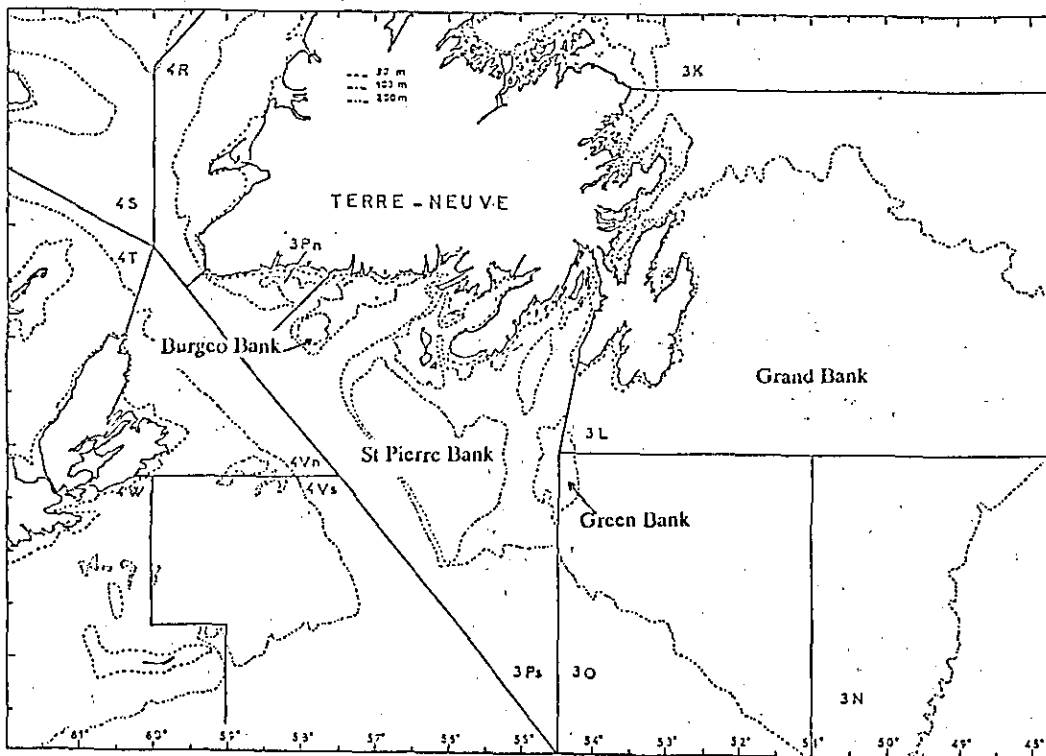


Figure 2. Location of the Banks in the tagging areas.

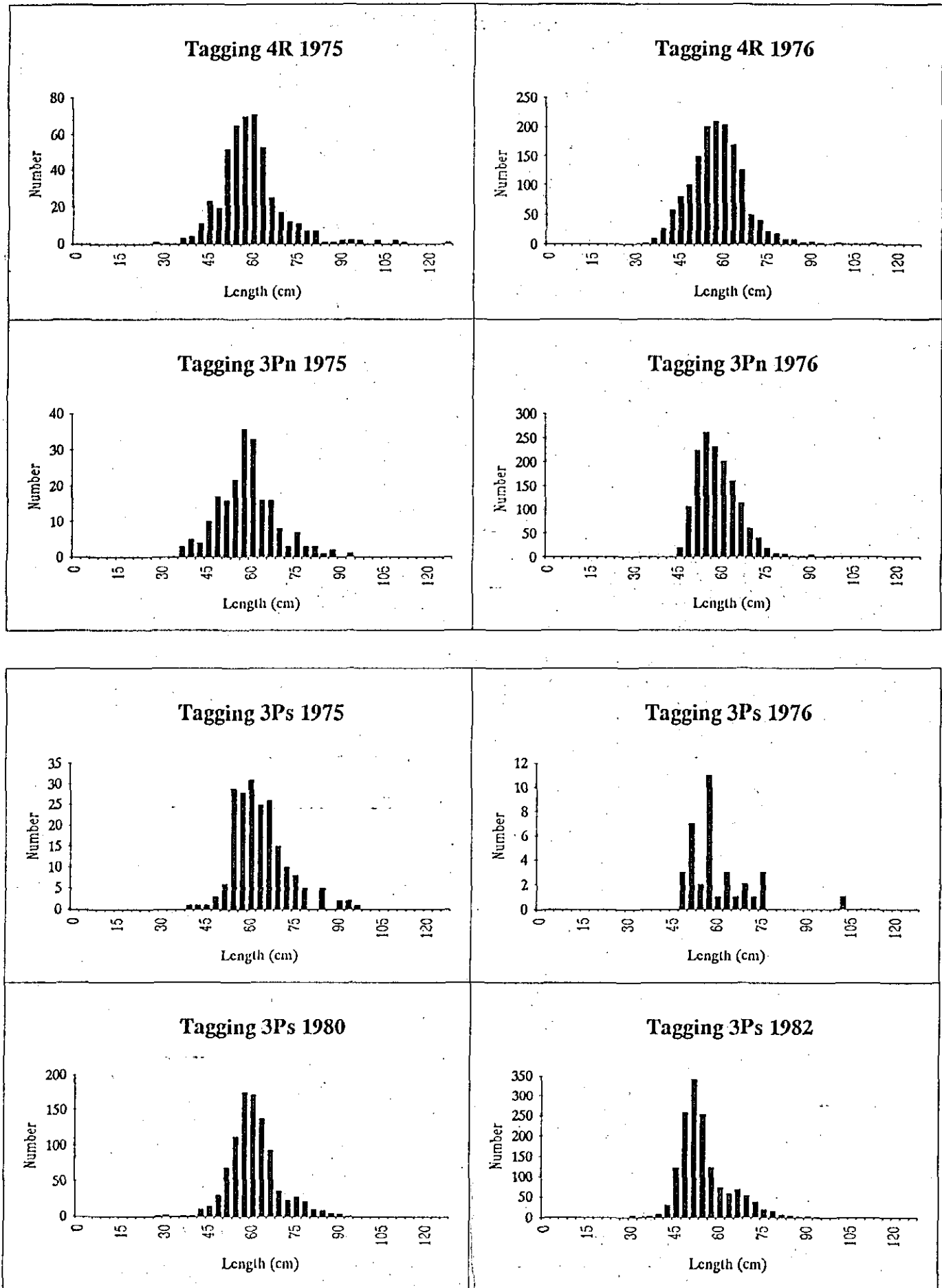
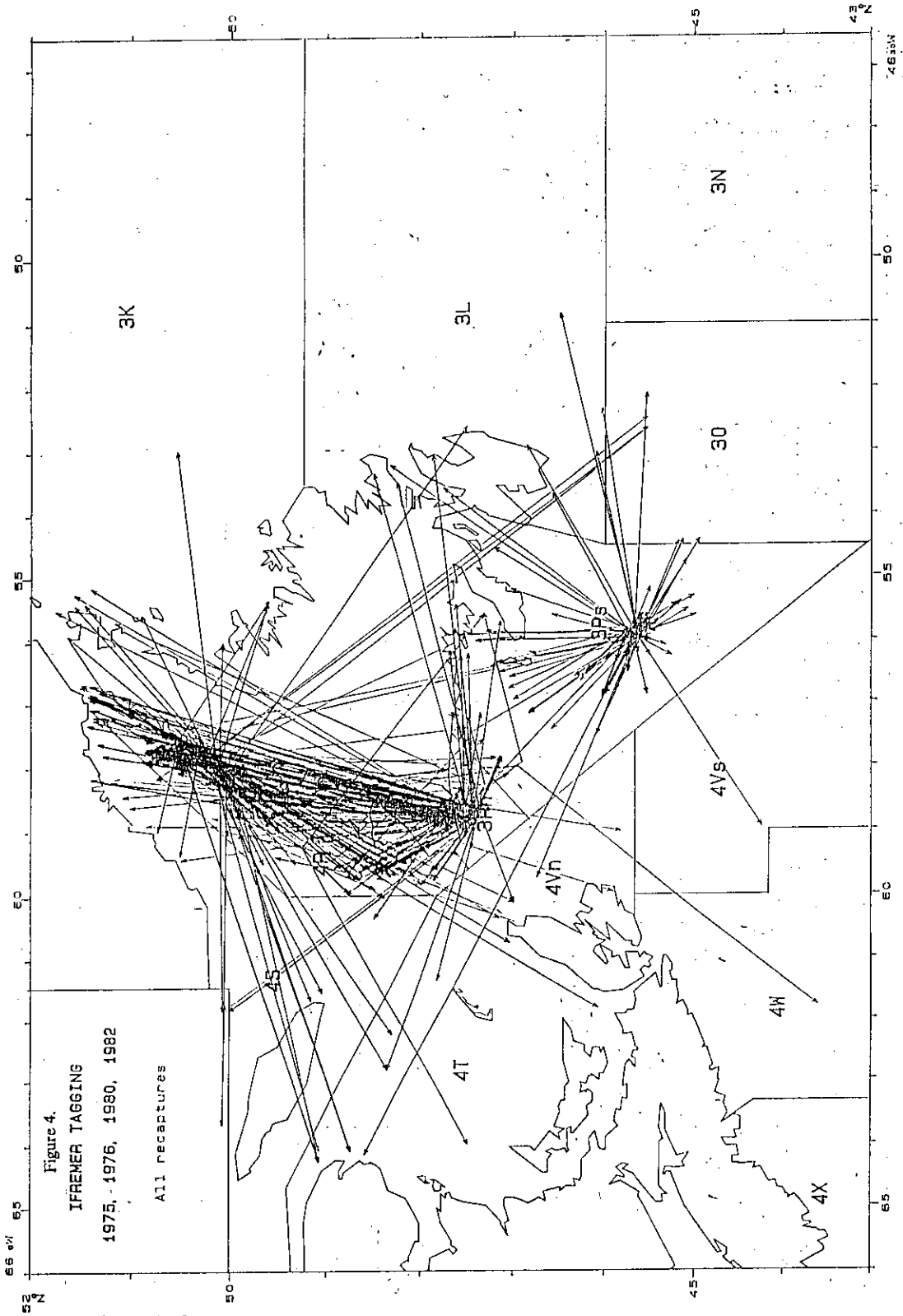
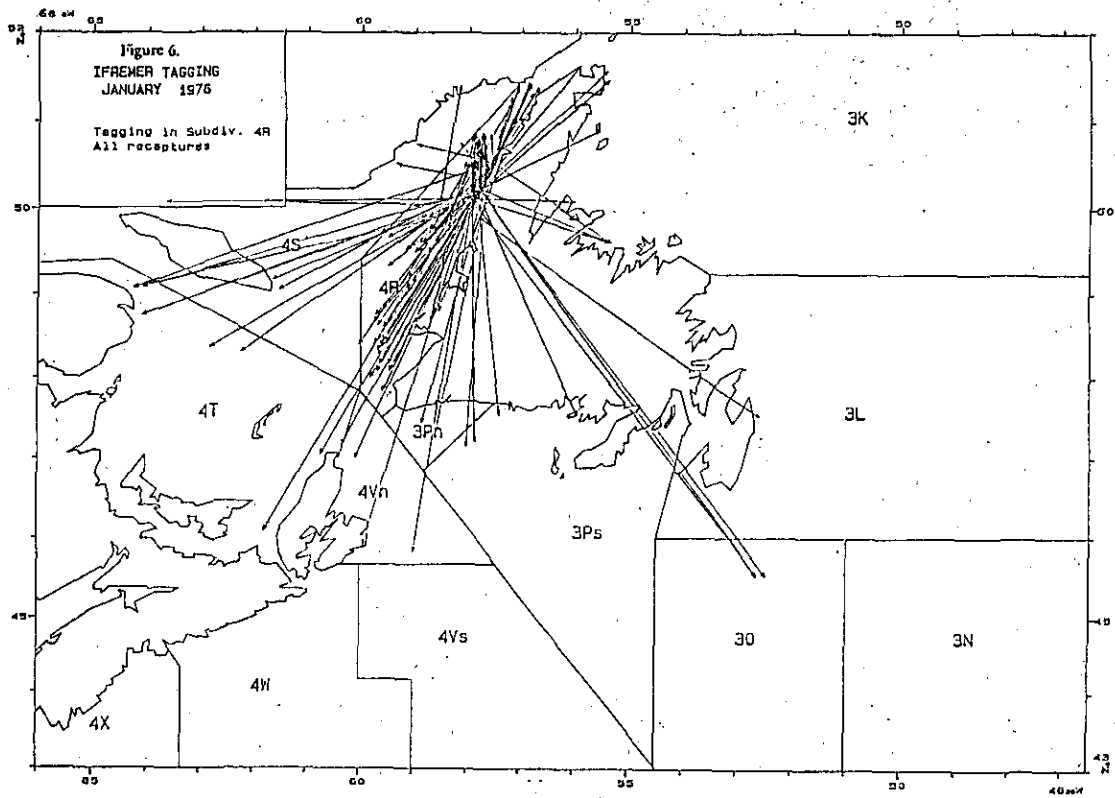
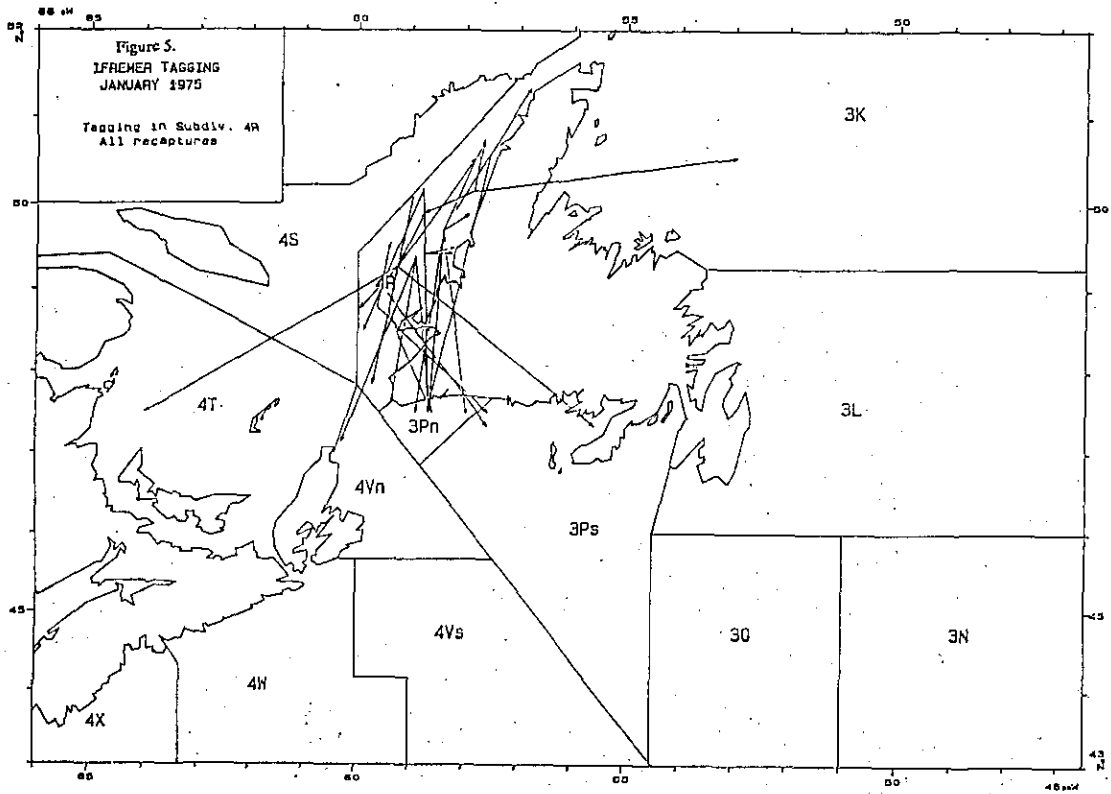
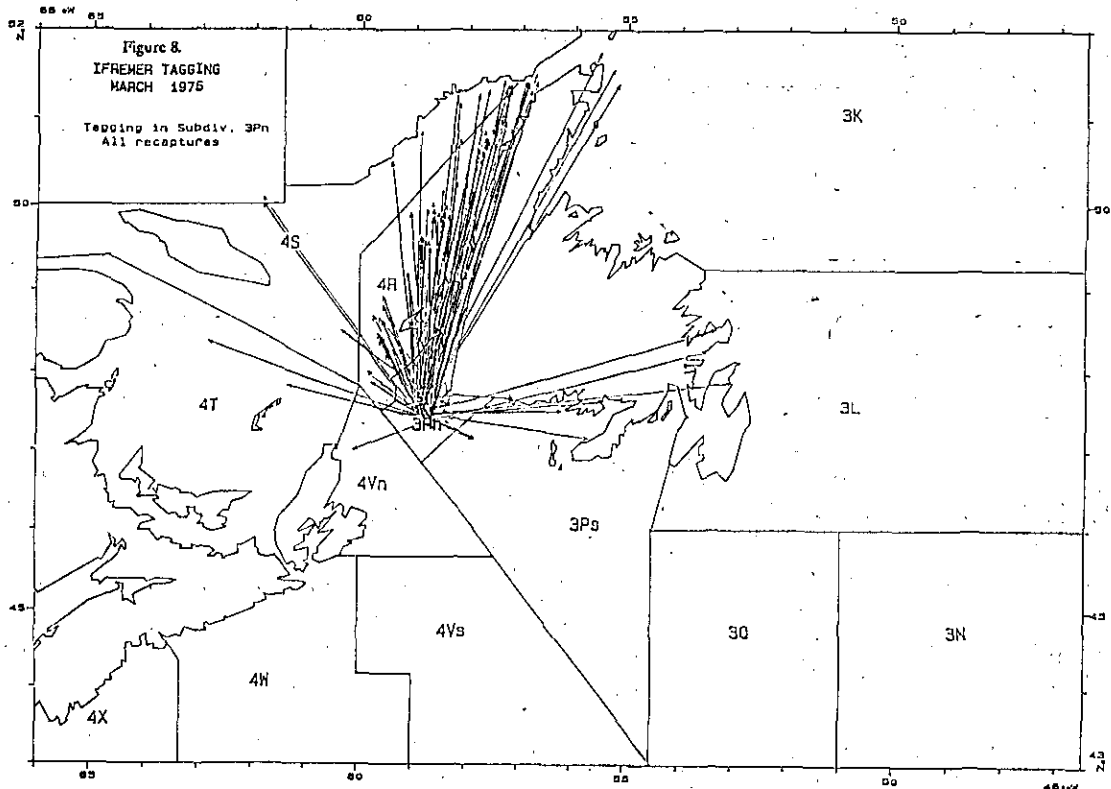
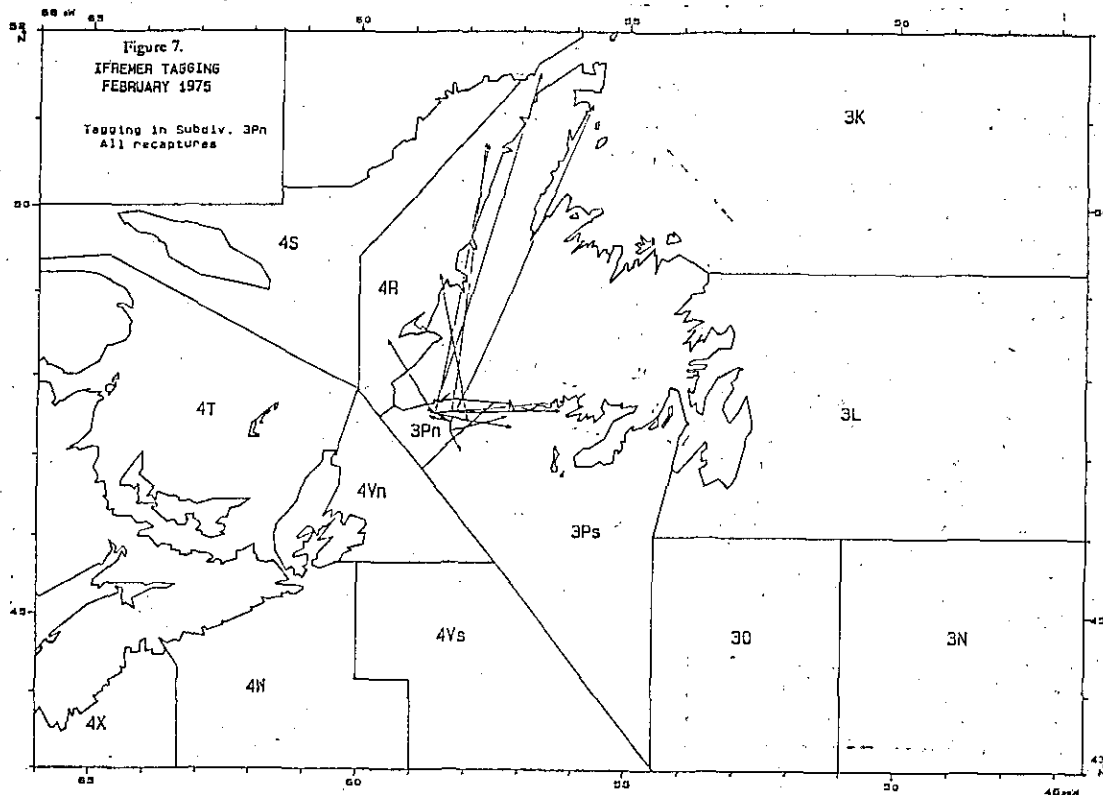
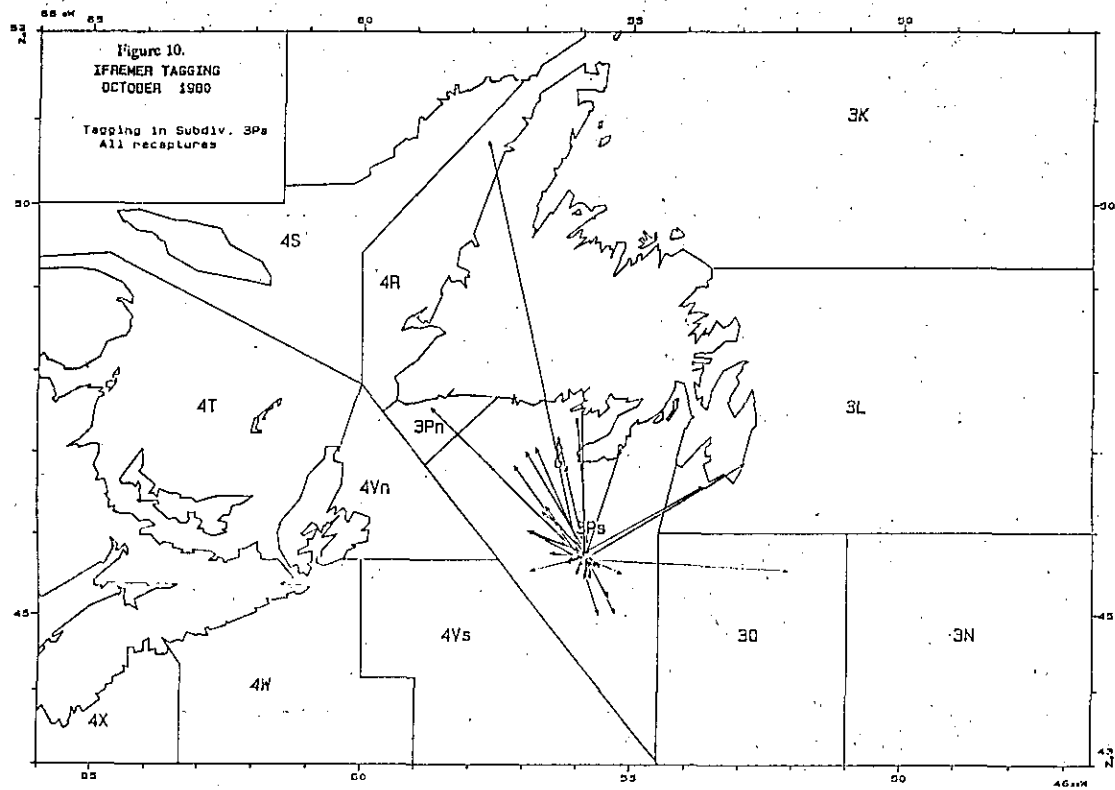
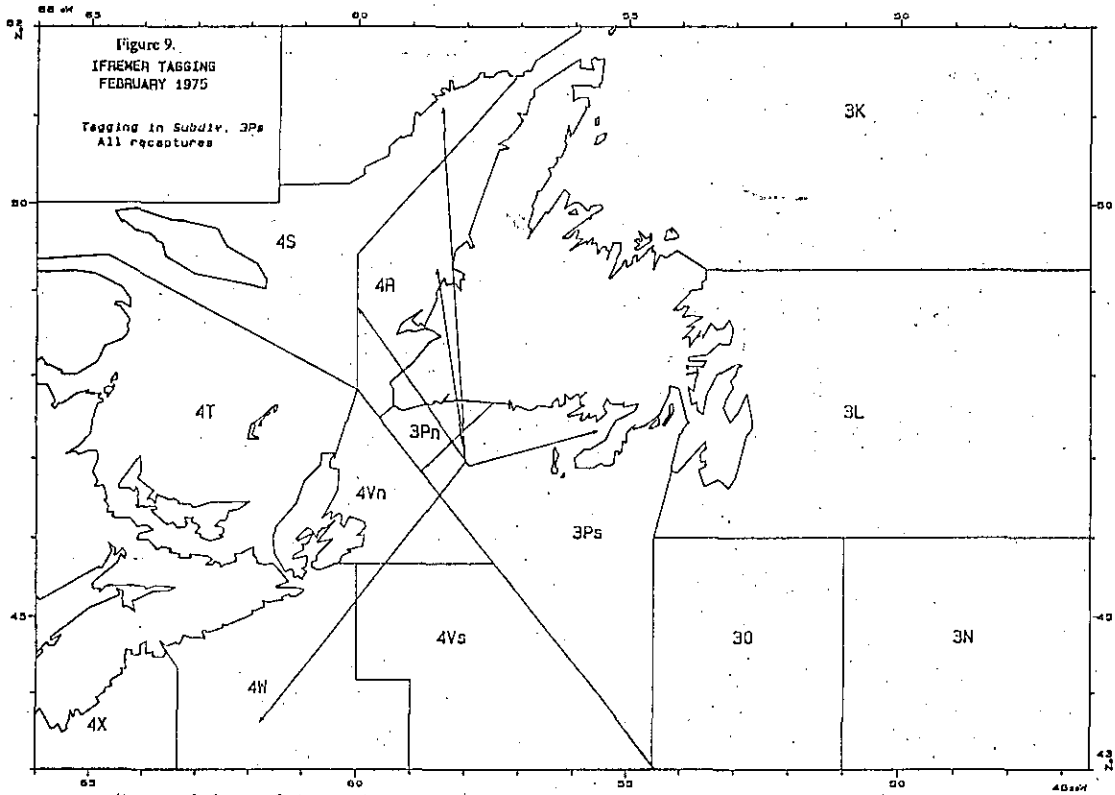


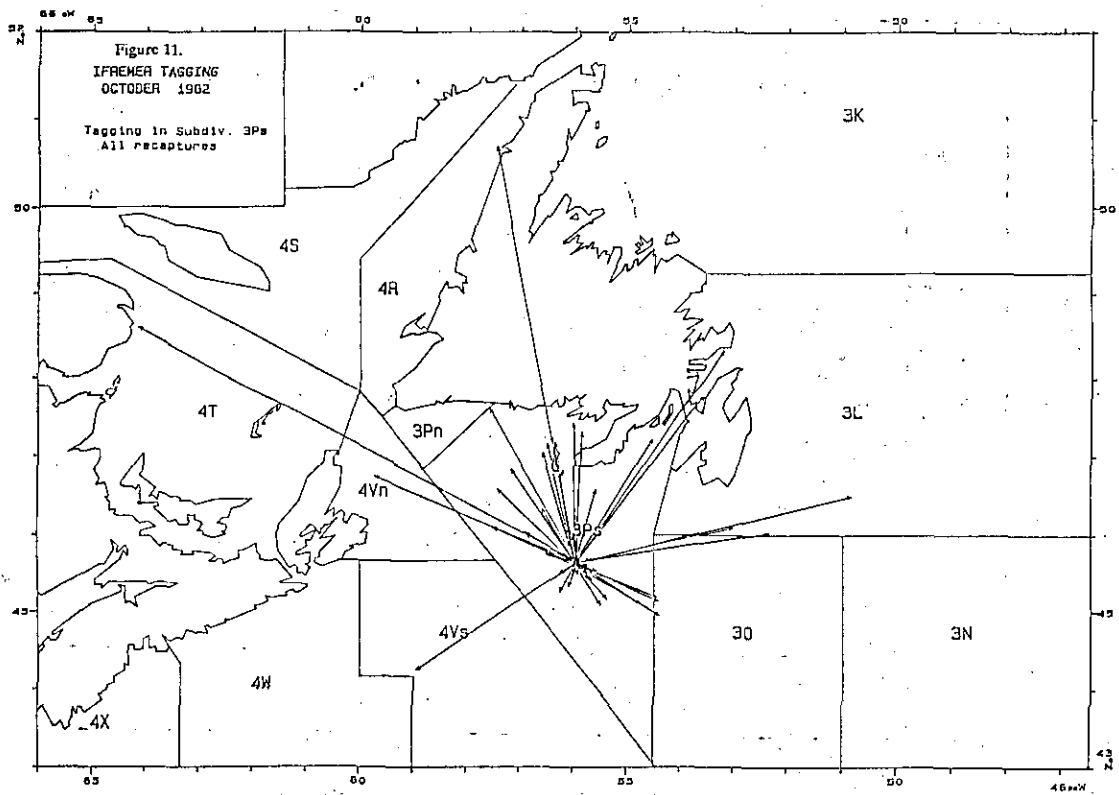
Figure 3. Length distribution of cods tagged in the Gulf of St. Lawrence and south areas off Newfoundland (Div. 3Pn and 3Ps) in 1975, 1976, 1980 and 1982.











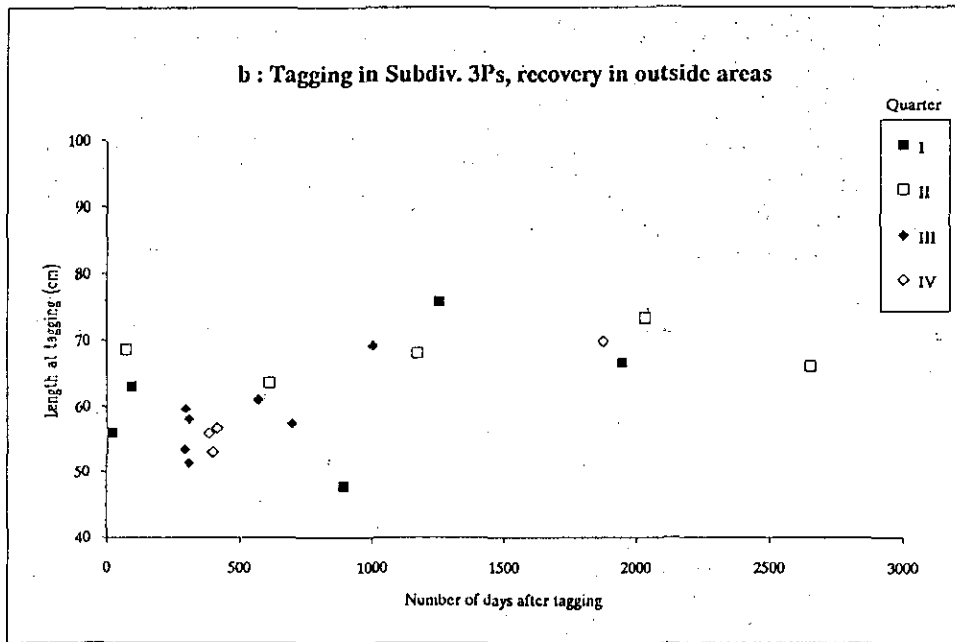
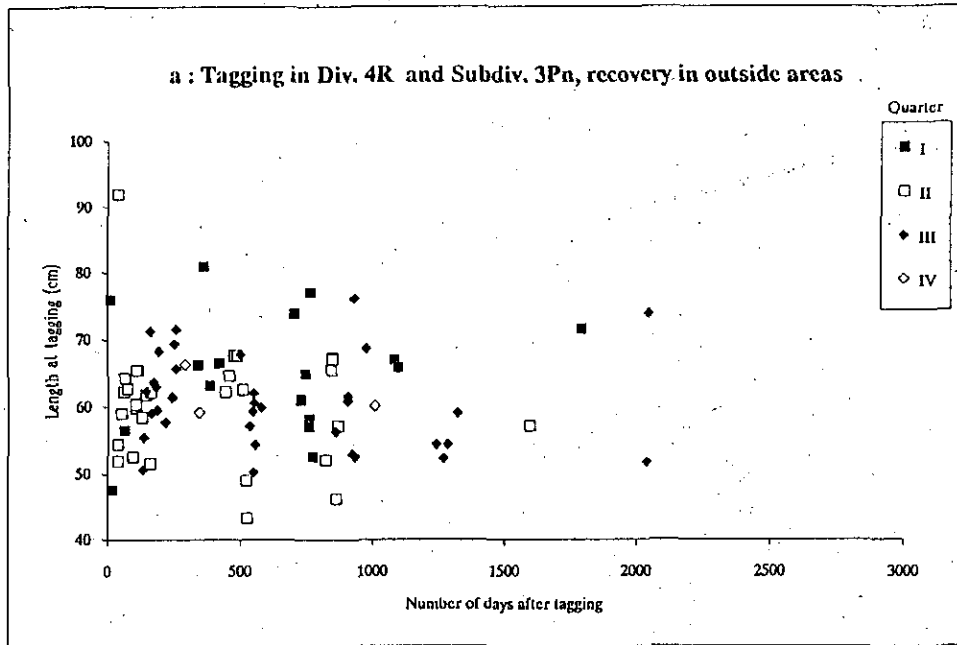


Figure 12. Relation between elapsed time - tagging / recovery - and length of cod tagged in the Gulf of St-Lawrence area (a) and on St-Pierre Bank (b).