

Cod (*Gadus morhua*) Migrations in the Gulf of St. Lawrence and Areas South of Newfoundland

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Abstract

During the years 1975, 1976, 1980 and 1982 cod (*Gadus morhua*) tagging experiments were conducted, inside the Gulf of St. Lawrence and outside in areas south of Newfoundland, by French scientists from IFREMER St. Pierre and Miquelon laboratory, in order to study the population distribution and migration and to complement the experiments carried out by Canadian scientists. The analysis from all recoveries and results from these experiments are presented here. The relevance is that the comparison with the Canadian results would lead to a better understanding of the cod stock exchanges in the area.

The migratory patterns were believed to be mainly a response to seasonal environmental condition changes. In winter the cod were noted to migrate from the central Gulf of St. Lawrence southwards to outside areas, and the reverse process occurred in spring. On St. Pierre Bank most of migrations were observed to take place to and from the offshore and inshore waters. Most of the cod on St. Pierre Bank were believed to remain in the area. Although some exchanges with the Grand Bank cod population were noted, the level of this migratory process which was variable from year to year seemed generally low.

Key words: Cod, distribution, environment, migration, Northwest Atlantic

Introduction

Cod has been the main fishery resource exploited in the Northwestern Atlantic. The impact of this activity on the regional economy has always been strong, and efficient management of the fisheries has been, and is still a main goal. Through history, one of the objectives of scientists has been to provide the managers a better description of the cod distribution in the area. For this purpose the cod populations exchanges and their migratory patterns in western Gulf of St. Lawrence and/or areas south of Newfoundland (Fig. 1) has been studied and numerous tagging experiments have been conducted by Canadian scientists (Thompson, 1943; Templeman and Fleming, 1962; Templeman, 1962, 1974, 1979; Lear, MS 1984, MS 1988a and MS 1988b).

During the years 1975, 1976, 1980 and 1982, tagging experiments were also conducted by the Institut Français de Recherche pour l'Exploitation de la Mer (IFREMER) laboratory of St. Pierre and Miquelon. These data are considered here to supplement the Canadian studies. During 1975 and 1976 the tagging experiments were carried out mainly in the Gulf of St. Lawrence (Div. 4R) and neighbouring areas (Subdiv. 3Pn) and on the northern part of St. Pierre Bank (Subdiv. 3Ps). First results and conclusions were presented by Minet (MS 1975 and MS 1977). In the last 2 years, 1980 and 1982, tagging was conducted exclusively on St. Pierre Bank (Subdiv. 3Ps).

An analysis of all recoveries from these four experiments is presented here. Deductions are then made of the cod migration patterns in the Gulf of St. Lawrence and areas south of Newfoundland by integrating these with results from previous studies. The interpretations of migration patterns and the apparent abundance levels are discussed in relation to cod stock assessments for the areas.

Material and Methods

Tagging periods were selected based on the knowledge on cod biology, and fisheries information obtained from the fishermen. In the Gulf of St. Lawrence, Subdiv. 3Pn and northern part of St. Pierre Bank, tagging was carried out in winter, when cod were distributed along the Newfoundland coast. On St. Pierre Bank tagging was conducted in autumn when cod were distributed in the shallow waters of the bank.

Tagging by the IFREMER laboratory was carried out during the four surveys, February 1975 (Div. 4R, Subdiv. 3Pn and Subdiv. 3Ps, when 465, 206 and 199 cod respectively were tagged), January to March 1976 (Div. 4R, Subdiv. 3Pn and Subdiv. 3Ps, when 1 496, 1 462 and 35 cod respectively were tagged), October 1980 (Subdiv. 3Ps, when 958 cod were tagged) and October 1982 (Subdiv. 3Ps, when 1 492 cod were tagged). A bottom trawl (Lofoten type, 50 mm mesh size) was used to catch cod, the tows were 30 mins duration. To avoid scaling and crushing of the cod while hauling, they were only

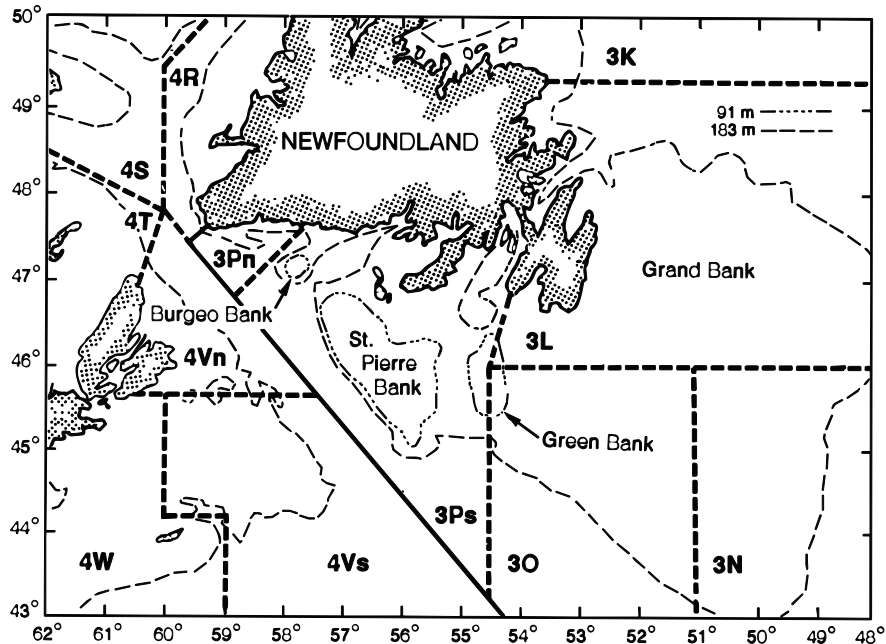


Fig. 1. Location of the banks in the tagging areas.

collected when their abundance in catches and the level of by-catch were low (Minet, MS 1975). The cod were placed in tanks with running water and observed for 1 hour. Then only fishes still in good condition were tagged using yellow flag tags. The tags were placed between the first and the second dorsal fins. After tagging, cod were put in other tanks for 30 min to be sure of their good conditions before returning them to the sea.

All recoveries, from the tagging year until the last year of reported recaptures, had recorded location and date of the recovery and length, weight and sex of the fish.

Results and Discussion

The major proportion of tagged cod was between 45 and 75 cm in length (Fig. 2). The number of recoveries by quarter, year and areas are presented in Tables 1 to 8 for each NAFO Division and Subdivision where a tagging experiment was conducted.

During the 4 years, about 6 000 cod were tagged. Percentage of the total number recovered by division and year varied between 2 and 13%. The recovery rates were low when the number of cod tagged were low (<200), for example in 1975 and 1976 for the tagging conducted in Subdiv. 3Ps. This relationship has been observed in other migration studies (Templeman, 1962, 1974, 1979).

The migration of each cod from the position of tagging to the position of recovery over the years was plotted for each tagging experiment (Fig. 3–9).

Observed patterns show that for the tagging experiments in the Gulf of St. Lawrence (Div. 4R), the recoveries of the first quarter were most important in the south neighbouring area just outside the Gulf (Subdiv. 3Pn). Some recoveries were also recorded on Burgeo Bank (Subdiv. 3Ps) but these were at a lower recovery level. The percentage of recaptures outside the Gulf of St. Lawrence decreased as the year progressed, and in the third quarter all recoveries were inside the Gulf of St. Lawrence where the tagging was done (Tables 1–2).

Conversely, from the taggings just outside the Gulf of St. Lawrence in winter the percentages of recoveries were lower inside the Gulf than outside, the tagging area and the northern part of Subdiv. 3Ps. Most of these recoveries in Subdiv. 3Ps were observed on Burgeo Bank, and for a large part along the south coast of Newfoundland. The percentage of recaptures inside the Gulf of St. Lawrence increased as the year progressed and was optimal in spring and/or summer (Tables 3–4).

The results of the latest two tagging experiments clearly indicated that in winter the cod had migrated from the north and the centre of the Gulf of St. Lawrence to the south along the west coast of Newfoundland and to the mouth of the Gulf. This

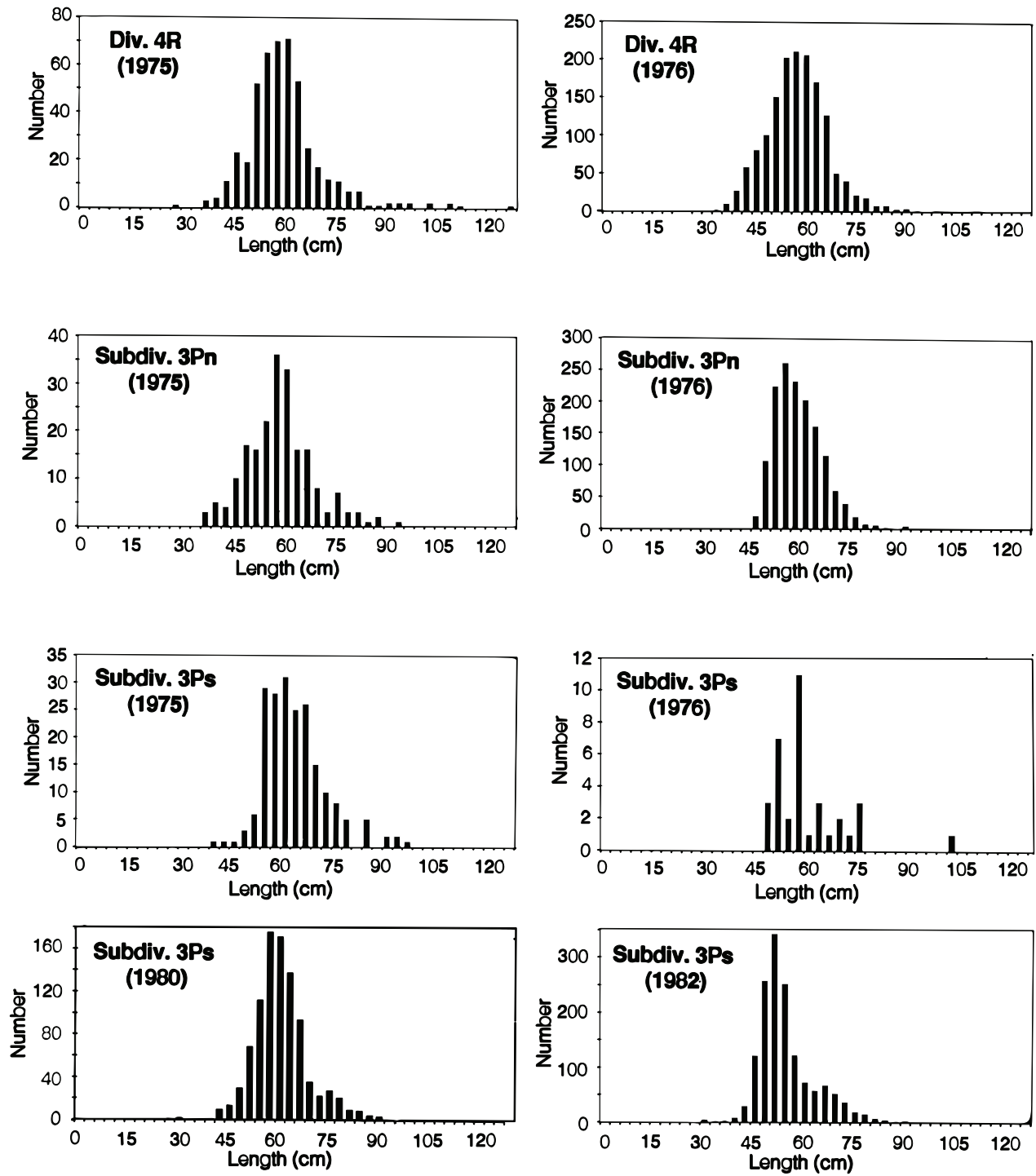


Fig. 2. Length distribution of cod tagged in the Gulf of St. Lawrence (Div. 4R) and areas south of Newfoundland (Subdiv. 3Pn and 3Ps) in 1975, 1976, 1980 and 1982.

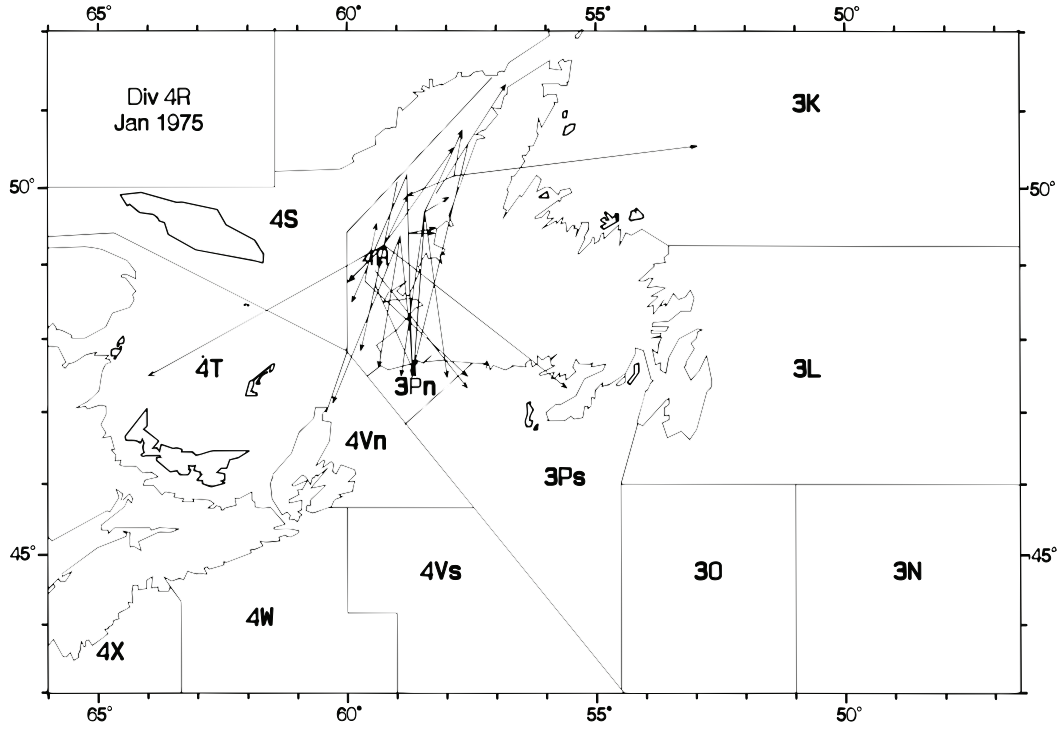


Fig. 3. IFREMER tagging January 1975: tagging in Div. 4R, all recaptures.

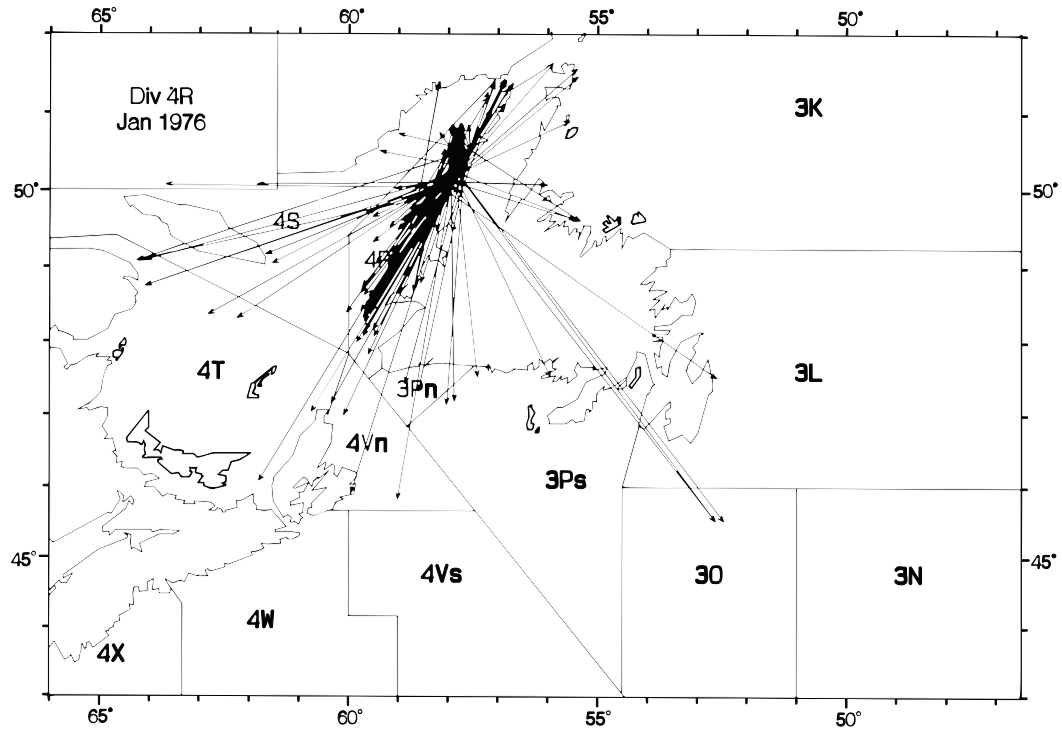


Fig. 4. IFREMER tagging January 1976: tagging in Div. 4R, all recaptures.

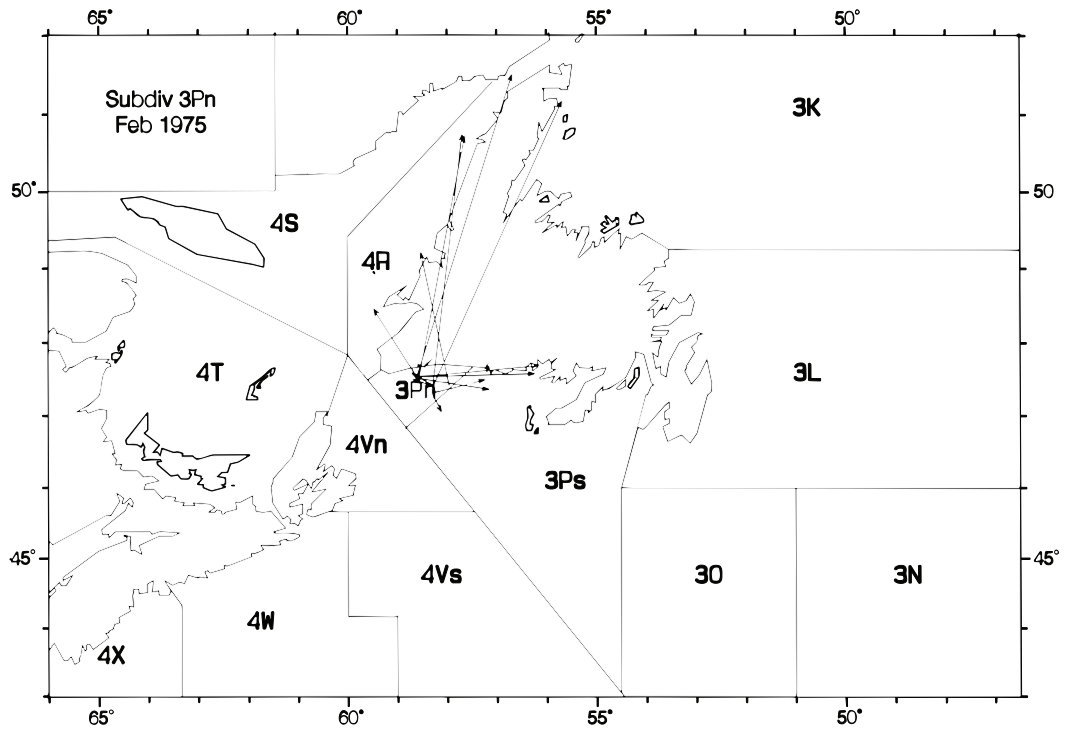


Fig. 5. IFREMER tagging February 1975: tagging in Subdiv. 3Pn, all recaptures.

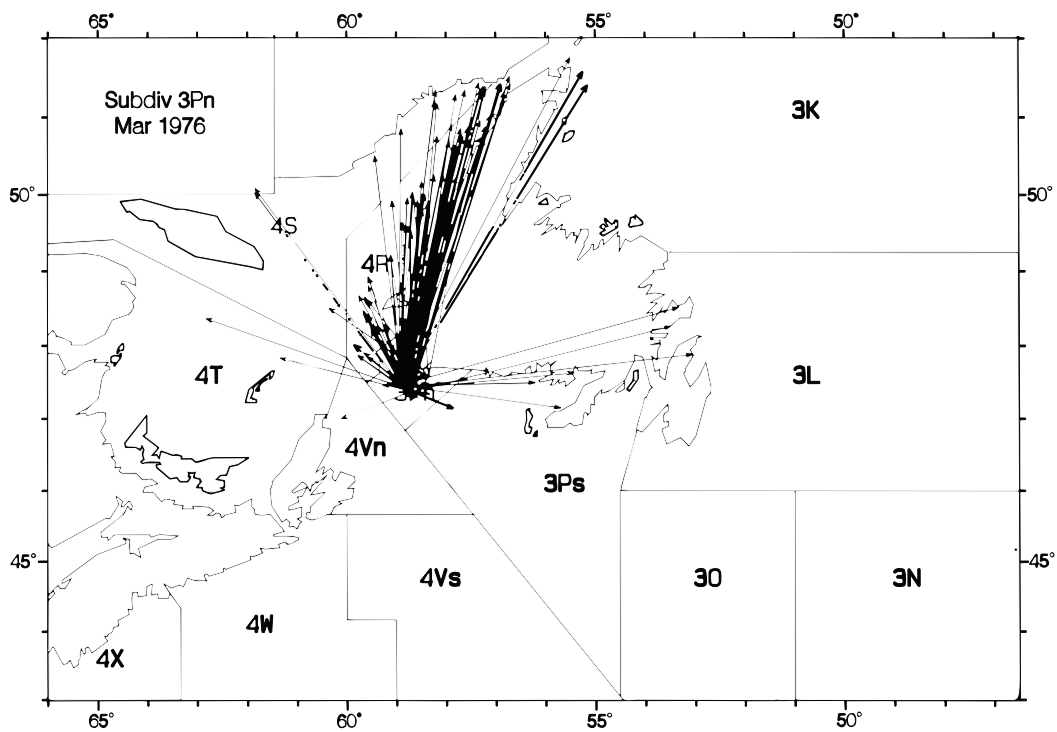


Fig. 6. IFREMER tagging March 1976: tagging in Subdiv. 3Pn, all recaptures.

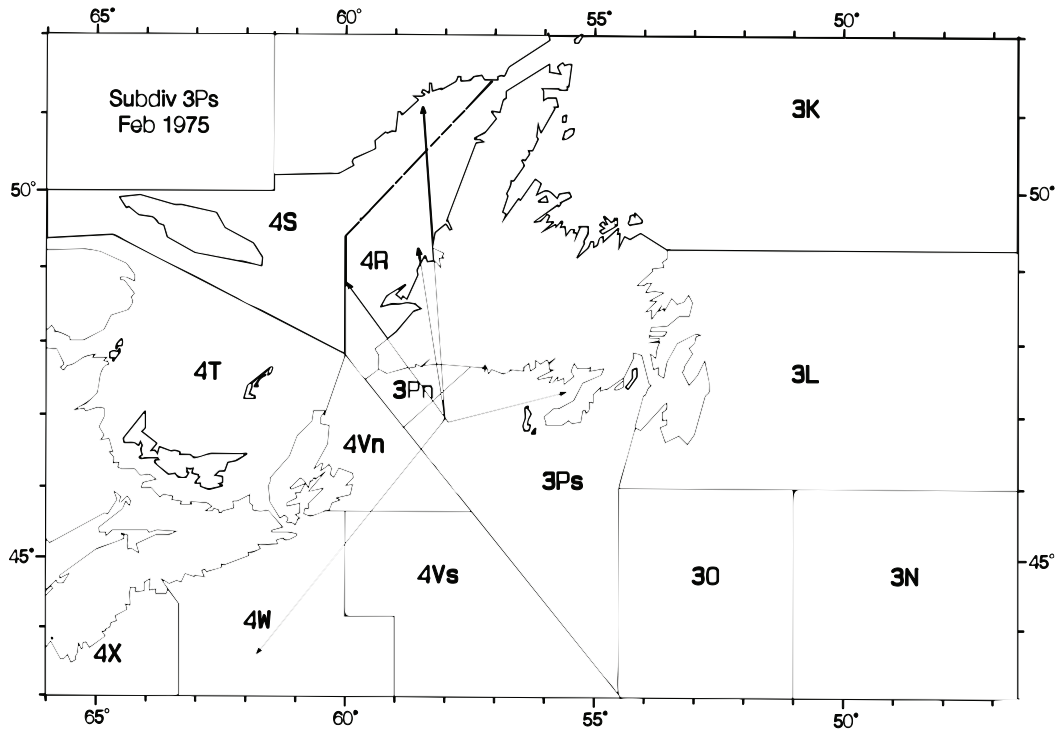


Fig. 7. IFREMER tagging February 1975: tagging in Subdiv. 3Ps, all recaptures.

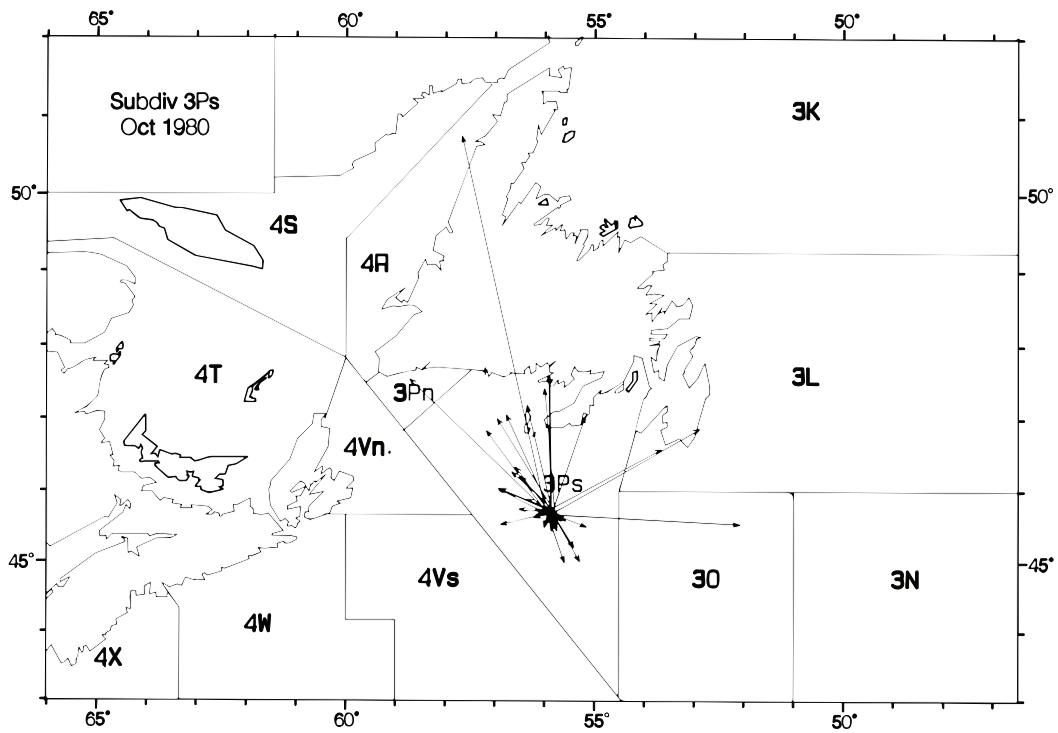


Fig. 8. IFREMER tagging October 1980: tagging in Subdiv. 3Ps, all recaptures.

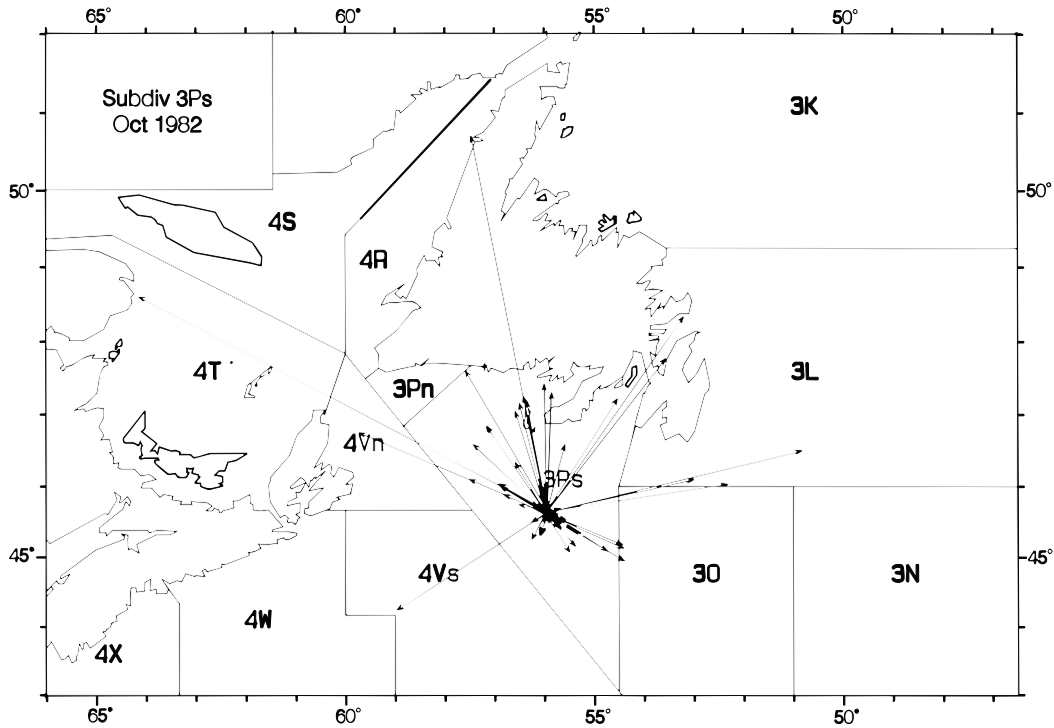


Fig. 9. IFREMER tagging October 1982: tagging in Subdiv. 3Ps, all recaptures.

TABLE 1. Number of recoveries by year, quarter and NAFO area, from cod tagging experiments in the Gulf of St. Lawrence (Div. 4R) in 1975 (Feb); total tagged = 465.

Year of recapture	Quarter I		Quarter II		Quarter III		Quarter IV		Total by Area	
	No.	Area	No.	Area	No.	Area	No.	Area	No.	Area
1975	1	4R	3	4R	2	4R	6	4R		
	1	3Pn	2	3Pn	1	4T	3	3Pn		
			1	3Ps			1	3Ps		
							1	4T		
1976	3	3Pn	4	4R	1	4R	5	4R		
	1	3Ps					3	3Pn		
	1	4Vn					1	3Ps		
							1			
1977	1	4R	1	4R			2	4R		
1978	1	3Pn	1	4R			1	4R		
	1	3Ps					1	3Pn		
							1	3Ps		
1979	1	4R	1	4R			2	4R		
			1	3Pn			1	3Pn		
			1	3K			1	3K		
Total	5	3Pn	10	4R	3	4R	16	4R		
	3	4R	3	3Pn	1	4T	8	3Pn		
	2	3Ps	1	3Ps			3	3Ps		
	1	4Vn	1	3K			1	3K		
							1	4T		
						1	4Vn			

TABLE 2. Number of recoveries by year, quarter and NAFO area, from cod tagging experiments in the Gulf of St. Lawrence (Div. 4R) in 1976 (Jan); total tagged = 1 496.

Year of recapture	Quarter I		Quarter II		Quarter III		Quarter IV		Total by Area	
	No.	Area	No.	Area	No.	Area	No.	Area	No.	Area
1976	8	4R	42	4R	28	4R	3	4R	81	4R
	3	3Pn	4	4S	5	4T	1	4Vn	8	4T
	1	3Ps	3	4T	1	3K			5	4S
					1	4S			3	3Pn
									1	3Ps
									1	3K
									1	4Vn
1977	4	4R	21	4R	7	4R			32	4R
	1	4Vn	1	4S	4	4S			5	4S
			1	4T	1	4T			2	4T
			1	4Vn	1	3K			2	4Vn
			1	3K					2	3K
		1	3M					1	3M	
1978	6	4R	11	4R	14	4R	1	3L	31	4R
	1	4S	1	4T	3	3K			3	3K
	1	4Vs	1	3O	2	3O			3	3O
			1	3Ps					1	4S
									1	4T
									1	3L
								1	3O	
								1	3Ps	
1979	2	4R	1	4R	1	4R	1	4R	5	4R
	1	4S			1	3K			1	4S
					1	3L			1	3K
									1	3L
1980	1	4R					1	4R	2	4R
1981	4	4R	1	4R	1	4R			6	4R
					1	3K			1	3K
					1	3Ps			1	3Ps
Total	25	4R	76	4R	51	4R	5	4R	157	4R
	3	3Pn	5	4S	7	3K	1	4Vn	12	4S
	2	4S	5	4T	6	4T	1	3L	11	4T
	1	4Vn	1	4Vn	5	4S			8	3K
	1	4Vs	1	3K	2	3O			3	3Pn
	1	3Ps	1	3O	1	3L			3	4Vn
			1	3Ps	1	3Ps			3	3Ps
									3	3O
									2	3L
								1	4Vs	

migration could possibly extend to the south coast of Newfoundland and/or Burgeo Bank. In spring and summer, the migration pattern reversed and cod moved into the Gulf of St. Lawrence from Burgeo Bank.

This migratory process has been described by Templeman (1962, 1974, 1979), Minet (MS 1975, MS

1977), Bertrand (MS 1989). All these authors point out a migration from the Gulf of St. Lawrence to southern neighbouring areas, and conclude that their presence in Subdiv. 3Ps, only on Burgeo Bank, is a result of cod coming from the Gulf of St. Lawrence in the winter. They also report only a portion of these cod return to their original area of distribution. Analysis of length at 50% maturity, meristic

TABLE 3. Number of recoveries by year, quarter and NAFO area, from cod tagging experiments outside the Gulf of St. Lawrence (Subdiv. 3Pn) in 1975 (Feb); total tagged = 206.

Year of recapture	Quarter I		Quarter II		Quarter III		Quarter IV		Total by Area	
	No.	Area	No.	Area	No.	Area	No.	Area	No.	Area
1975	1	3Ps	1	3Pn	1	4R			1	3Pn
									1	3Ps
									1	4R
1976			1	3Ps	1	3Ps			2	3Ps
1977	2	3Ps	1	3K					2	3Ps
	2	4R	1	4R					3	4R
	1	3Pn							1	3K
									1	3Pn
1978			1	3Pn					1	3Pn
1980	1	4R							1	4R
Total	3	3Ps	2	3Pn	1	3Ps			5	4R
	2	4R	1	3Ps	1	4R			5	3Ps
	1	3Pn	1	3K					3	3Pn
			1	4R					1	3K

characters and parasitic infestation, essentially by nematodes, also confirm this pattern (Templeman *et al.*, 1957; Mabeau *et al.*, MS 1986; Bishop *et al.*, MS 1988).

Lear (MS 1988a, MS 1988b) confirmed the observations of Templeman (1962), pointing out the migration of cod from Subdiv. 3Pn and Burgeo Bank to shallow waters along the south coast of Newfoundland, as it is observed in this study. An analysis of the fishing activity of the French trawler fleet in the Gulf of St. Lawrence in winter during the period 1978–89 (Fréchet, MS 1990) also described this cod migration, but only inside the Gulf. Gascon *et al.* (MS 1990) attempted to quantify this migration, particularly the proportion of cod leaving the Gulf. They observed similar results to Templeman (1974, 1979), estimating the proportion to be between 2.3–2.7% for the period 1954–55 and 10–12% for the period 1962–66, with only about 10% returning to the Gulf.

The magnitude of this migration, is variable from year to year and depends on the abundance of the cod stock in the Gulf of St. Lawrence and on a combination of various factors such as hydrological conditions relating to the presence of ice in winter, food and predators. For example in the years 1984 and 1986, large concentrations were noted on the western slope of Burgeo Bank in winter from bottom trawl surveys (Moguedet, MS 1991a). It was then assumed that a large proportion of these cod were

from the Gulf of St. Lawrence (Moguedet, MS 1991a and MS 1991b). The tag return probability, while depending on the abundance of migrating cod and a combination of various above mentioned factors, in addition depend on the fishing activities on Burgeo Bank. It is therefore difficult to draw conclusions and quantify the annual level of mixing of cod stocks in this area. It becomes more difficult especially if the migration involves only a part of the population, for example the mature individuals (hypothetically). It would then depend on the abundance of some cohorts and the fishing activity interaction on those cohorts.

Recovery numbers from tagging experiments conducted in Subdiv. 3Ps in the winters of 1975 and 1976 were low (Tables 5–6). This was essentially due to the small numbers of cod tagged in comparison to the stock size, so an analysis of the migration patterns in winter was difficult.

A very large percentage (70–100%) of recoveries from tagging experiments conducted on St. Pierre Bank in the Subdiv. 3Ps in autumn, were reported from this same Subdivision (Tables 7 and 8). Similar patterns were observed by Lear (MS 1988a and MS 1988b). Some of them were from coastal waters, others from deeper waters and the migration rate to the Grand Bank was higher than the migratory rate to the Gulf of St. Lawrence and neighbouring areas (Subdiv. 3Pn). A quarterly analysis of the migration from St. Pierre Bank did not show

TABLE 4. Number of recoveries by year, quarter and NAFO area, from cod tagging experiments outside the Gulf of St. Lawrence (Subdiv. 3Pn) in 1976 (Mar); total tagged = 1 462.

Year of recapture	Quarter I		Quarter II		Quarter III		Quarter IV		Total by Area	
	No.	Area	No.	Area	No.	Area	No.	Area	No.	Area
1976	11	3Pn	35	4R	9	4R	3	4R	49	4R
	2	4R	3	3Pn	4	4S	1	4Vn	14	3Pn
	1	3Ps	3	3Ps	2	3Ps			6	3Ps
			2	4T					6	4S
			2	4S					2	4T
			1	3K					1	3K
								1	4Vn	
1977	10	4R	9	4R	10	4R			29	4R
	4	3Pn	2	3Pn	1	4S			6	3Pn
	1	3Ps	1	3L					1	3L
								1	3Ps	
								1	4S	
1978	2	4R	8	4R	2	4S			11	4R
	2	3Pn	2	3Pn	1	4R			4	3Pn
	2	3Ps	1	3L					4	4S
	1	4S	1	4S					2	3Ps
								1	3L	
1979	3	4R			3	4R			6	4R
					1	3K			1	3K
					1	3L			1	3L
1981	1	4Vn			4	4R			4	4R
									1	4Vn
Total	17	3Pn	52	4R	27	4R	3	4R	99	4R
	17	4R	7	3Pn	7	4S	1	4Vn	24	3Pn
	4	3Ps	3	3Ps	2	3Ps			11	4S
	1	4S	3	4S	1	3K			9	3Ps
	1	4Vn	2	4T	1	3L			3	3L
			2	3L					2	4T
			1	3K					2	3K
								2	4Vn	

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 autumn and winter in the Gulf of St. Lawrence. This was not confirmed by the recoveries obtained from the 1982 tagging experiment.

Recoveries of cod tagged in Subdiv. 3Ps collected 1 000 days and more after tagging were mainly mature individuals (>60 cm length). This was not so clearly observed for cod tagged inside the Gulf of St. Lawrence (Fig. 10).

These two tagging experiments conducted on St. Pierre Bank in the autumn of 1980 and 1982,

clearly pointed out that a cod population was distributed mainly in this area. Similar patterns have been observed by Templeman (1962, 1974, 1979), Templeman and Fleming (1963). Here, the major migratory process takes place from offshore areas to inshore coastal waters and then the reverse occurs with season changes. This was described by Templeman (1962). As it was noted on Burgeo Bank in winter, largest cod concentrations have also been identified in western and south slopes of St. Pierre Bank in winter. From recoveries reported from a tagging experiment conducted in 1986, Lear (MS 1988b) concluded that these large concentrations were generally living offshore, only migrating to shallow waters in the south and central parts of the

TABLE 8. Number of recoveries by year, quarter and NAFO area, from cod tagging experiments on the St. Pierre Bank (Subdiv. 3Ps) in 1982 (Oct); total tagged = 1 492.

Year of recapture	Quarter I		Quarter II		Quarter III		Quarter IV		Total by Area	
	No.	Area	No.	Area	No.	Area	No.	Area	No.	Area
1982							5	3Ps	5	3Ps
1983	1	3Ps	7	3Ps	3	3Ps	18	3Ps	29	3Ps
	1	4V			3	3L	2	3L	5	3L
							1	3O	1	4V
									1	3O
1984	2	3Ps	2	3Ps	2	3Ps	4	3Ps	10	3Ps
					1	4T			1	4T
1985	4	3Ps	2	3Ps	1	4R	2	3Ps	8	3Ps
	1	4Vs							1	4R
									1	4Vs
1986	1	3Ps	1	3Ps					2	3Ps
	1	3O							1	3O
Total	8	3Ps	12	3Ps	5	3Ps	29	3Ps	54	3Ps
	1	3O			3	3L	2	3L	5	3L
	1	4V			1	4R	1	3O	2	3O
	1	4Vs			1	4T			1	4R
									1	4T
									1	4V
									1	4Vs

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 of the cod population (7–10%) of St. Pierre Bank could migrate to the Grand Bank. This was also noted by Moguedet (MS 1991b).

On the other hand, from the four tagging experiment results presented here no migration was observed from St. Pierre Bank to Burgeo Bank. All recoveries were observed in the northern part of the St. Pierre Bank.

Conclusions

From these results it can be concluded that in some years a large part of the cod population in the Gulf of St. Lawrence migrates in winter from the central and northern areas southward and to areas outside of Rose Blanche, Subdiv. 3Pn and Burgeo Bank, Subdiv. 3Ps. The reverse process takes place at spring and summer. The migration intensity is variable from year to year. Cod distributed at the limit of the Gulf of St. Lawrence also migrates to coastal areas of Newfoundland.

On St. Pierre Bank, most of the migrations take place from offshore to inshore waters and reverse. They are also related to hydrological conditions, primarily water temperatures. It is known that food availability also plays an important role. These migratory patterns were observed by Templeman (1962, 1974, 1979) and Templeman and Fleming (1963). They stated that a large complex cod stock is distributed in the Gulf of St. Lawrence (Div. 4R, 4S) and the nearest outside areas (Subdiv. 3Pn, north of Subdiv. 3Ps Burgeo Bank and coastal areas south of Newfoundland).

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

This study points out the various exchanges between cod populations in the area. The high vari-

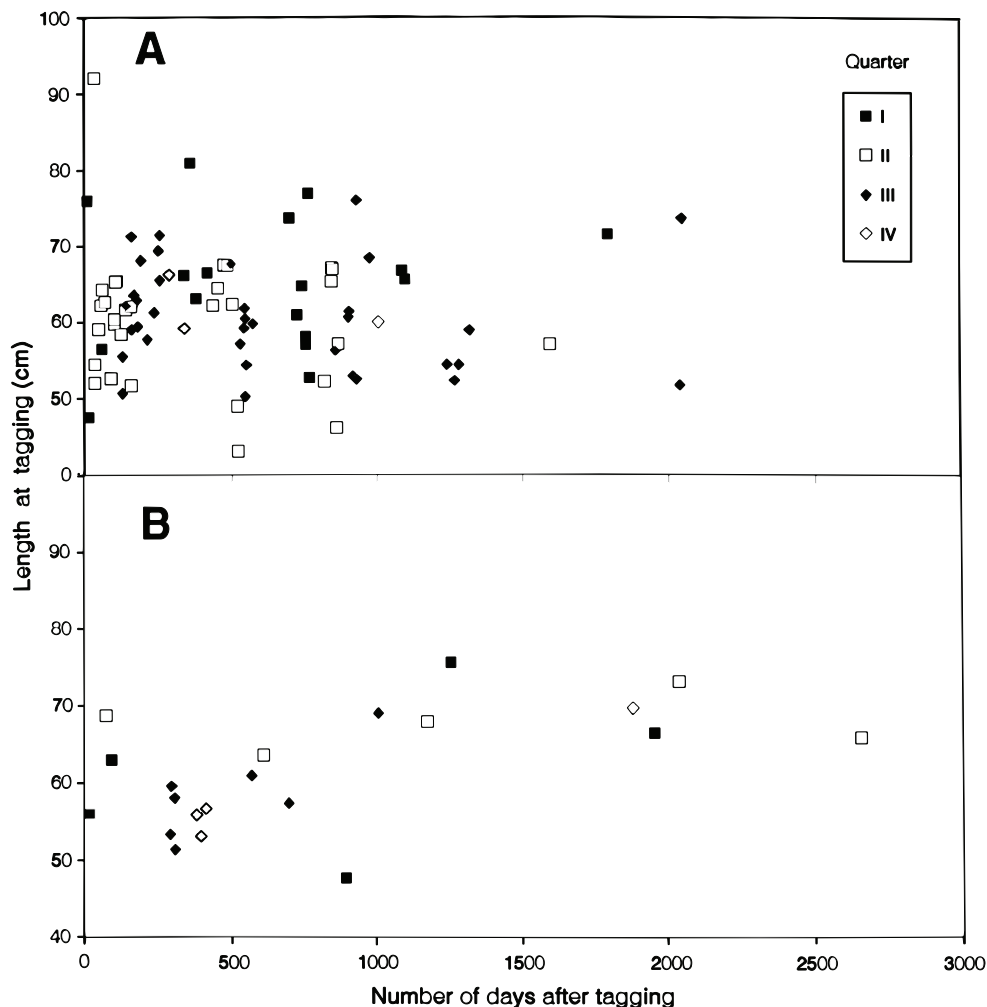


Fig. 10. Relation between elapsed time – tagging/recovery – and length of cod tagged in the (A) Gulf of St. Lawrence area and (B) on St. Pierre Bank.

ability of migratory rates, depending mainly on environmental conditions, prevents 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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