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Seasonal migration patterns of Atlantic cod (*Gadus morhua*) in NAFO subdivision  
3Ps based on tagging experiments during 1997-98

by

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## Abstract

Migration patterns based on recaptures of cod tagged in the inshore of Subdivision 3Ps and adjacent areas (inshore southern 3L) during 1997 and both inshore and offshore areas of 3Ps during 1998 are described. Cod tagged in Halibut Channel (N=1842) during April 1998 were recaptured offshore in small numbers throughout the year mostly within 50 nm of the tagging site; however, there were four recaptures in Placentia Bay during July-September indicating a portion of this offshore stock component moved inshore during summer. Cod tagged in the Hermitage Channel south of Burgeo Bank during early April were recaptured either inshore along the south coast of Newfoundland eastward to southern 3L, or north and westward to 3Pn4RS. Recaptures of spawning cod tagged in Fortune Bay during May 1998 came mostly from within Fortune Bay itself, with smaller numbers of recaptures westward along the south coast or eastward into western Placentia Bay; there were no recaptures from offshore 3Ps or inshore 3L, suggesting that these were predominantly an inshore south coast stock. Spawning and pre-spawning cod tagged at the head of Placentia Bay during 1997 and 1998 dispersed widely throughout the bay during the summer and in both years a portion migrated eastward across the stock boundary into southern 3L, approximately as far north as the eastern side of Trinity Bay. These cod appeared to migrate back into Placentia Bay during fall. The tag returns indicate that the 1998 summer and fall fishery in Placentia Bay exploited a complex mixture of stock components that included fish from Burgeo Bank, Halibut Channel, and Fortune Bay as well as 'local' fish. The numbers of Placentia Bay-tagged cod recaptured per unit weight of catch was compared between Placentia Bay and adjacent areas in southern 3L (St. Mary's Bay and southern Avalon, eastern Avalon, and Conception Bay). The comparison suggests that a substantial portion of the catch from southern 3L during 1998 was fish of 3Ps origin. In contrast, Placentia Bay-tagged cod were extremely rare further north in 3L (western Trinity Bay and Bonavista Bay) and in 3K in spite of considerable landings (>2,000mT).

## Résumé

Les régimes migratoires, déterminés à partir des recaptures de morues marquées dans la partie côtière de la sous-division 3Ps et dans les zones voisines (partie côtière sud de 3L) en 1997, et dans les zones côtière et hauturière de 3Ps en 1998, sont décrits. Des morues marquées dans le chenal Halibut (N=1842) en avril 1998 ont été recapturées au large en petits nombres tout au long de l'année et la plupart l'ont été à moins de 50 milles marins du lieu de marquage, mais quatre morues ont été recapturées dans la baie Placentia de juillet à septembre, ce qui indique qu'une partie de cette composante du stock hauturier s'était déplacée vers la côte au cours de l'été. Les morues marquées dans le chenal Hermitage, au sud du banc Burgeo au début d'avril, ont été recapturées soit en zone côtière, le long de la côte sud de Terre-Neuve en direction est, vers la partie sud de 3L, ou au nord en direction ouest vers 3Pn4Rs. Les recaptures de géniteurs marqués dans la baie Fortune en mai 1998 ont surtout été faites dans la baie Fortune elle-même, mais certaines morues ont été recapturées vers l'ouest le long de la côte sud ou vers l'est dans la partie ouest de la baie Placentia. Aucune capture n'a été faite dans la partie hauturière de 3Ps ou dans la partie côtière de 3L, ce qui porte à croire qu'il s'agit surtout d'un stock côtier de la côte sud. Les géniteurs et pré-géniteurs marqués au fond de la baie Placentia en 1997 et 1998 se sont largement dispersés dans toute la baie pendant l'été et, au cours de ces deux années, une partie de ces morues s'est déplacée vers l'est et a traversé la limite du stock pour atteindre le sud de 3L, presque autant au nord que la partie est de la baie Trinity. Il semble que ces morues soient retournées dans la baie Placentia à l'automne. Les étiquettes récupérées montrent que la pêche d'été et d'automne de 1998 faite dans la baie Placentia exploitait un mélange complexe de composantes de stocks englobant des poissons du banc Burgeo, du chenal Halibut, de la baie Fortune, en plus de poissons « indigènes ». Le nombre de morues marquées dans la baie Placentia recapturées par unité de poids des captures a été comparé entre la baie Placentia et les zones voisines du sud de 3L (baie St. Mary's et sud d'Avalon, est d'Avalon et baie Conception). Cette comparaison porte à croire qu'une partie appréciable des captures du sud de 3L effectuées en 1998 était formée de poissons originaires de 3Ps. Au contraire, les morues marquées dans la baie Placentia étaient extrêmement rares plus au nord dans 3L (ouest de la baie Trinity et baie Bonavista) ainsi qu'en 3K cela en dépit d'importants débarquements (>2 000 tonnes métriques).

## Introduction

The cod stock inhabiting NAFO subdivision 3Ps consists of a complex mixture of sub-components whose movement patterns are poorly understood (Thompson 1943; Templeman and Fleming 1962; Templeman 1974, 1979; Lear 1984, 1988; Moguedet 1994; Brattey 1996; Lawson et al. 1998). This document summarizes information on the spatial and temporal distribution of tag returns from cod tagged and released in subdivision 3Ps during 1997 and 1998 and recaptured during the commercial fisheries in 1997 and 1998. Movement patterns based on tagging and recaptures received up to the end of 1997 are given in Lawson et al. (1998). Further analyses of data from recaptures of these tagged cod are given elsewhere (Brattey and Cadigan 1998; Lawson et al. 1998; Cadigan and Brattey 1999a, b).

## Methods

The methodology and a description of the 1997 tagging experiments is given in detail in Brattey and Cadigan (1998). Briefly, cod caught with handlines (inshore) or an otter trawl (offshore) in excellent condition were and measured and tagged with either one or two spaghetti t-bar tags and released close to the capture site. All tags were coded with a unique serial number and return address and a reward was paid for returning the tags. The tagging program was advertised widely among those participating in the fishery.

During 1998 over 9,000 cod were tagged and released at various inshore and offshore sites in 3Ps (Table 1; Fig 1) using the same methodology as was used in 1997. Most of the tagging was done in early spring (April and May) on spawning and pre-spawning aggregations prior to the opening of the directed cod fishery on June 28<sup>th</sup> 1998. Some cod were also tagged in eastern and inner Placentia Bay during October after most of the quota had been caught. A wide range of sizes of cod encompassing the entire size range caught during the commercial fishery was tagged (45 cm to >100 cm).

## Results

### Commercial fishery landings

Interpretation of the tag returns requires information on the spatial and temporal distribution of catches. Monthly reported landings by statistical area for the 1998 fisheries in 3Ps are summarized in Table 2; descriptions of the 1997 fishery and landings are given elsewhere (Kulka et al. 1998; Brattey and Cadigan 1998). Table 2 includes estimates of reported landings from commercial, sentinel, by-catch and recreational fisheries. A competitive fishery with quotas for July-August, September-October, and November-December was fished by the inshore sector west of the Burin Peninsula and in 3Psd, whereas individual boat quotas, taken mainly during July and September-November, were fished in Placentia Bay. Reported monthly landings in 3Ps during January - June 1998 were generally small (<228 t), but increased in July with the opening of the directed cod fishery. Catches were highest in Placentia Bay in most months and ranged from 187 t in December to 2255 t in July. Monthly landings from the inshore sector tended to decline in a westerly direction toward Fortune Bay (3Psb) and Hermitage Bay (3Psa). Offshore landings occurred mostly in the fall as the French and Canadian mobile fleet directed their effort mainly in 3Psf and 3Psh (south-east St. Pierre Bank and Halibut Channel). Further information on the 1998 commercial fishery in 3Ps is given in Kulka et al. (1999). Corresponding landings for the inshore of NAFO Divs. 3K and 3L are given in Brattey (1999).

### Annual recaptures of tagged cod

The total numbers of tagged cod reported as recaptured from tagging experiments in 1997 and 1998 is summarized in Table 3. There were considerable numbers of recaptures during both years. A total of 675 cod tagged in 1997 were reported as recaptured up to the end of 1998 and a total of 510 cod tagged in 1998 were reported as recaptured during the same period. For the 1997 tagging experiments with release sites at

the mouth of Placentia Bay (i.e. Iona Islands, Lord's Cove, Oderin Bank, St. Bride's), there were more recaptures in 1998 than in 1997; however, the converse was true for 1997 experiments with release sites at the head of Placentia Bay (i.e. Bar Haven, Clattice Harbour). Offshore tagging experiments (all conducted in 1998) generated substantially fewer recoveries than inshore ones.

### **Recaptures from inshore tagging in 1997**

The distribution of recaptures from cod tagged at the head of Placentia Bay during 1997 was similar in both 1997 and 1998 (Fig. 2), with many recaptures throughout the inner bay, and down the eastern side. In both years there was a cluster of recaptures off St. Bride's, as well as several recaptures from the inshore of southern 3L. There were more recaptures from 3L in 1998, probably because of the substantial increase in landings associated with the recreational and "index" fisheries in the fall of 1998 (see Brattey 1999). A small number of cod tagged at the head of Placentia Bay were recaptured offshore during 1998, in the Halibut Channel and from the south-western slope of the Grand Bank. There was little evidence of much westerly movement of cod tagged in Placentia Bay, in spite of the substantial landings (see Table 2).

Recaptures of cod tagged off St. Bride's in 1997 showed a somewhat different pattern of recoveries (Fig. 3); there was only a single recovery north of 3Lq and many recaptures from the vicinity of the tagging site during 1997 and 1998. The recaptures from the head of Placentia Bay were mostly obtained during fall.

Recaptures of cod tagged on Oderin Bank (Fig. 4) were widely distributed, occurring in Fortune Bay, eastern and central Placentia Bay, and inshore southern 3L; there were also some offshore recaptures from St. Pierre Bank and central Halibut Channel. Cod tagged off Lord's Cove on the Burin Peninsula gave a broadly similar pattern of recoveries, but with no offshore recaptures and more recaptures from the local area and around the Burin Peninsula (Fig. 5).

### **Recaptures from offshore tagging in 1998**

Cod tagged in Halibut Channel (Fig. 6) during April 1998 were recaptured offshore in small numbers throughout the year mostly within 50 nm of the tagging site; however, several were also recaptured in Placentia Bay during July-September indicating that a portion of this offshore stock component moved inshore during summer. There was also one recapture from Conception Bay during summer and one from offshore in Div. 3O where there was no directed cod fishery.

Cod tagged in Hermitage Channel south of Burgeo Bank (Fig. 7) during April were recaptured either inshore along the south coast of Newfoundland eastward to southern 3L, or west and northward into 3Pn-4Rs. A notable finding was several tag returns from Placentia Bay during fall, indicating that cod from the Burgeo Bank area contributed to substantial landings reported for Placentia Bay during fall (Table 2). The tag returns also show that some cod in the Burgeo Bank area during early April 1998 migrated out of the stock area and contributed to catches in the adjacent management unit (3Pn-4RS). The stock origin of these fish remains a contentious issue; some of the cod captured during tagging were spawning in the local area and by definition would be part of the 3Ps stock; however, many females were maturing to spawn later in spring and their stock affinity remains unknown.

### **Recaptures of offshore cod within Placentia Bay**

There have been several tagging experiments in offshore areas of 3Ps over the past 5 decades and many of these have generated recaptures in Placentia Bay (Taggart et al. 1996). To investigate the timing of arrival and duration of residency of these fish in Placentia Bay, the cumulative daily recaptures from within Placentia Bay (3Psc) were plotted (Fig. 8A). These analyses show that the offshore cod arrive in Placentia Bay as early as April and May in some years, but the bulk of the recaptures are taken from mid to late June and early July through to September in most years. In 1954, tagging was conducted later in the spring and

the recaptures in Placentia Bay were delayed to the latter part of July and continued through November. The 1998 tagging in the Burgeo Bank/Hermitage Channel area generated several recaptures in early July suggesting that these fish had already arrived in Placentia Bay when the 1998 commercial fishery opened.

A similar pattern was observed for cod tagged on northern St. Pierre Bank, with recoveries in Placentia Bay beginning in late May or mid-June and continuing through October and November (Fig. 8B).

For Halibut Channel tagging (Fig. 8C) there are few data; however, tagging in 1963 generated recaptures in Placentia Bay during May-August. The 1998 tagging experiment generated recaptures from early July until December.

In general, these tagging experiments suggest that fish tagged on the offshore areas of 3Ps in traditional over-wintering areas contribute to inshore catches throughout the summer and fall period, with the timing of arrival inshore varying among years. The results also suggest that over-wintering cod from the Halibut Channel do not contribute to inshore catches west of the Burin Peninsula.

### **Recaptures from inshore tagging in 1998**

Spawning cod tagged in Fortune Bay during late May were recaptured mostly within Fortune Bay itself, but with some recoveries westward along the south coast and eastward to the western side of Placentia Bay; (Fig. 9). There were no recaptures from eastern Placentia Bay in spite of substantial landings. These results suggest that these fish were predominantly an inshore south coast stock component and to date none of these cod have been recaptured in offshore areas in 3Ps or inshore southern 3L.

There were substantial numbers of recoveries from cod tagged at the head of Placentia Bay (Fig. 10). Most were obtained from the inner portion of Placentia Bay during summer or the eastern and inner side of the bay during fall. With the increased fishing effort in 3L from the recreational and test fisheries during August-October 1998, there were many more recoveries in southern 3L during 1998 than were observed during 1997. Recaptures in 3L extended as far north as southern and western Trinity Bay.

Cod tagged in the fall of 1998 in the eastern side of Placentia Bay while the fishery was in progress were captured north of the tagging area, indicating that tagged cod were moving into the bay as fall progressed (Fig. 11).

### **Recaptures of Placentia Bay cod per unit weight of catch**

Using monthly reported catches and numbers of tagged cod reported as recaptured from tagging of cod at the head of Placentia Bay during fall 1997 (expt. 9715) and spring 1998 (expts. 9803, 9804, 9805) information on the relative abundance of Placentia cod in different areas was obtained (Fig. 12). Within Placentia Bay, the densities of tagged cod (expressed as numbers of tagged fish per 50 t of reported catch) were high during May and June (55.3 and 19.6 tags per 50 t) when catches were small (9 and 15 t) and limited to by-catch and sentinel fishery landings. However, during July when the commercial fishery opened and landings were substantial (>2,000 t), the densities of tagged cod dropped to approximately 2 tagged cod per 50 t of catch. The decline is consistent with the arrival of cod from elsewhere; recaptures from other experiments reported here (Figs. 6, 7) suggest that at least a portion of these migrants came from offshore areas within 3Ps. Although landings fluctuated considerably subsequent to July, densities of locally tagged cod within Placentia Bay itself remained fairly stable at approximately 2 tagged fish per 50 t catch. Over the corresponding time period, there were recoveries of Placentia Bay-tagged cod throughout southern 3L as far north as Trinity Bay. In St. Mary's Bay and the eastern Avalon, densities of the Placentia Bay-tagged cod were comparable to or slightly higher than those observed in Placentia Bay itself. These results suggest that a substantial portion of the cod captured in these areas were of 3Ps origin, though not necessarily from Placentia Bay alone. Many of the tagged cod were spawning and the tag recaptures indicate that a portion of the 3Ps stock subsequently undergoes a summer migration counter-clockwise around the Avalon Peninsula

into the adjacent management unit (see Cadigan and Bratley 1999). The densities of Placentia Bay-tagged cod tended to decline in a south to north direction through Div. 3L and Placentia Bay cod were rare in catches from Trinity Bay (3La), Bonavista Bay (3Lb), and in 3K where landings were substantial (see Bratley 1999). These results indicate that the substantial catch of cod in the inshore of northern 3L and 3K probably consisted mostly of local inshore cod, along with a few seasonal migrants from 3Ps. Recaptures of cod tagged within northern 3L and 3K during 1995-1997 also support this suggestion (Bratley 1999).

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Table 1. Summary of details for cod tagging experiments conducted in NAFO subdiv. 3Ps and Divs 3KL during 1997-1998.

DFO Stat.	Year &				Depth	Number	Mean
area	expt no.	Location	Dates	Gear	(m)	tagged	length (cm)
3Psc	9701	Bar Haven, NW Placentia Bay	9-12 Apr.	handline	48-60	996	62.1
	9702	Clattice Hbr., W Placentia Bay	10 Apr.	handline	58-60	966	52.3
	9704	Bar Haven, NW Placentia Bay	17-18 May	handline	50	817	65.0
	9705	St. Bride's, SE Placentia Bay	25-28 May	handline	40	709	66.4
	9706	Oderin Bank, W Placentia Bay	24-26 Jun.	handline	40	963	58.9
	9708	Lord's Cove, SW Placentia Bay	25 Jun.-18 Jul.	trap/handline	18-40	793	53.5
	9715	Iona Islands, E Placentia Bay	6-8 Nov.	handline	30-50	778	61.3
3Psb	9806	Poole's Cove, Fortune Bay	20-29 May	handline	69	938	57.5
3Psc	9803	Bar Haven, NW Placentia Bay	22-25 April	handline	21-50	207 3	61.0
	9804	Paradise Sound, W Placentia Bay	27-29 April	otter trawl	151-206	1212	60.8

cont'd:-



Table 1. Cont'd.

DFO Stat.	Year &				Depth	Number	Mean
area	expt no.	Location	Dates	Gear	(m)	tagged	length (cm)
	9805	Wareham Rock, NW Placentia Bay	May 1-3	handline	41-53	1037	61.9
	9808	Bar Haven, NW Placentia Bay	19-24 Oct.	h' line/otter trl.	41-60	511	60.3
	9809	Eastern Channel, Placentia Bay	17-22 Oct.	handline	52-80	883	58.8
3Psd	9802	Hermitage Channel/Burgeo Bank	5-7 Apr.	otter trawl	231-344	1352	53.9
3Psh	9801	Halibut Channel	2-5 Apr.	otter trawl	181-307	1842	63.9

Table 2. Reported monthly landings (t) of cod by statistical area from NAFO Subdivision 3Ps during 1998.

Year	Month	Inshore			Offshore					Totals
		3Psa	3Psb	3Psc	3Psd	3Pse	3Psf	3Psg	3Psh	
1998	1	0.017	4.078	17.039	0.005	0	0	0	0	21.139
	2	0.097	2.227	0	16.051	0	0.25	0.010	0.904	19.539
	3	0	0	46.483	0.198	0.026	0.469	3.023	66.123	116.322
	4	6.357	64.241	0.440	4.554	0	0.289	8.347	143.221	227.449
	5	3.900	10.508	10.342	2.109	0	0	12.676	47.911	87.446
	6	19.705	67.404	77.435	0	0	0	0	1.570	166.114
	7	258.167	1086.039	2254.552	210.928	0.018	0	0	4.968	3814.672
	8	103.148	87.947	565.346	43.291	0.032	0	0	36.161	835.925
	9	659.506	717.079	1036.995	426.813	86.973	179.915	34.436	371.905	3513.622
	10	6.184	2.434	1608.576	0.536	10.996	425.024	45.282	440.929	2539.961
	11	603.830	705.555	1312.608	189.821	71.734	130.705	67.064	967.482	4048.799
	12	42.672	5.417	186.990	18.609	0.562	14.524	0.179	162.999	431.952

Table 3. Annual summary of reported recaptures for cod tagged and released in NAFO subdiv. 3Ps during 1997-1998.

Year	Statistical area	Location	Number released	Recaptured		
				1997	1998	unknown
1997	3Psc	Bar Haven, PB	1813	180	102	1
		Clattice H'br, PB	966	90	40	0
		Iona Islands, PB*	784	0	32	0
		Lord's Cove, Burin Pen.	794	26	66	0
		Oderin Bank, PB	963	16	54	0
		St. Bride's, PB	709	27	40	1
1998	3Psb	Poole's Cove, FB	939	.	85	0
	3Psc	Bar Haven, PB	2073	.	115	0
		Bar Haven, PB*	511	.	6	0
		Eastern Channel, PB*	883	.	26	0
		Paradise Sound, PB	1212	.	143	0
		Wareham Rock, PB	1037	.	74	0
	3Psd	Hermitage Channel	1353	.	38	0
	3Psh	Halibut Channel	1842	.	23	0

\* cod tagged and released during fall after most of quota for that year was caught.

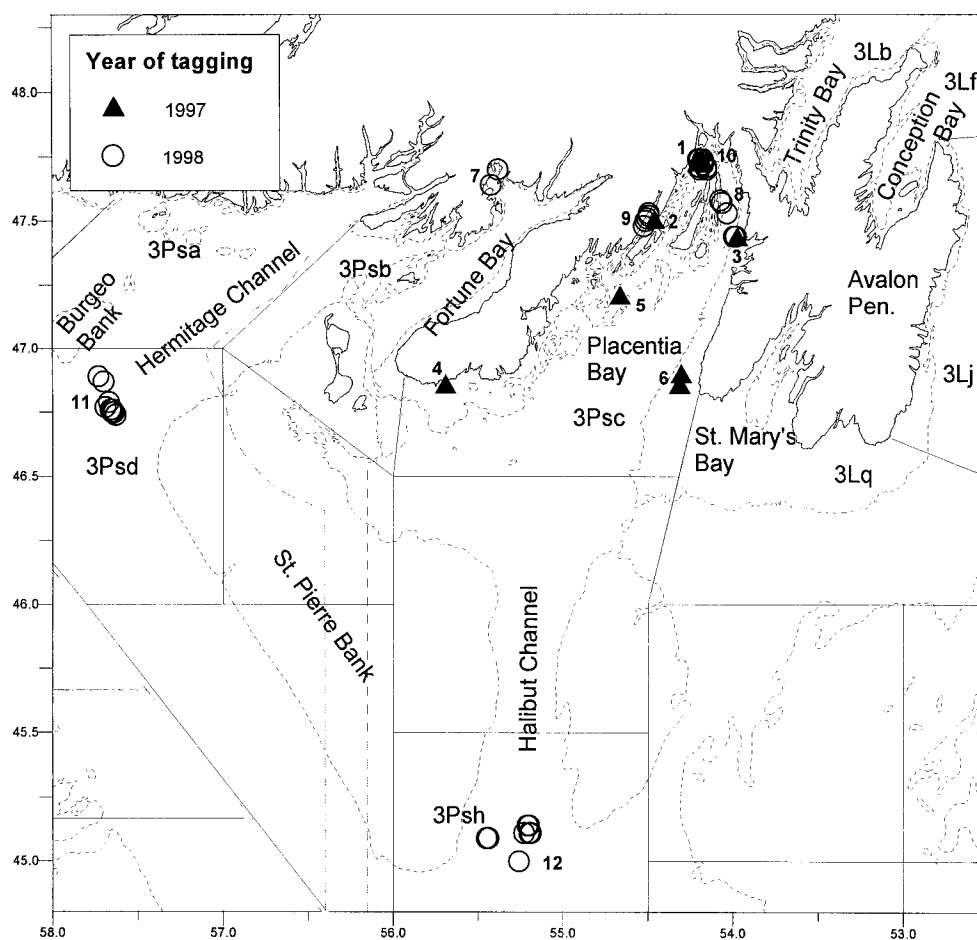


Fig. 1. Locations where cod were tagged and released in NAFO subdivision 3Ps during 1997-1998 (1=Bar Haven, 2=Clattice Harbour, 3=Iona Islands, 4=Lord's Cove, 5=Oderin Bank, 6=St. Bride's, 7=Poole's Cove, 8=Eastern Channel, 9=Paradise Sound, 10=Wareham Rock, 11=Hermitage Channel, 12=Halibut Channel. Solid lines are NAFO statistical area boundaries (i.e. 3Psc, 3Lq, etc.) and dashed lines are French economic zone and 200 m depth contour.

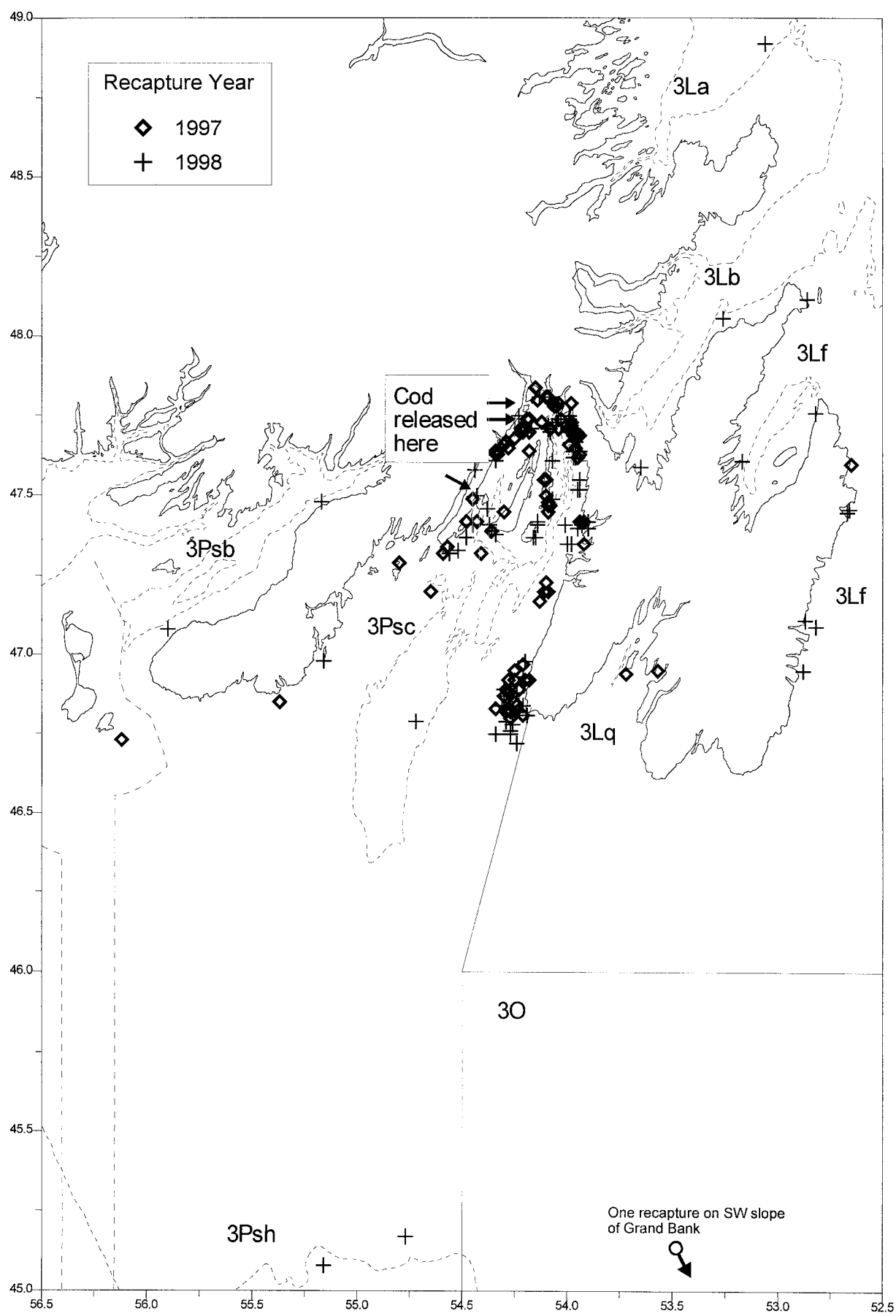


Fig. 2. Reported recapture positions for cod tagged and released at three sites at the head of Placentia Bay during April 9-May 11, 1997 (N=2779).

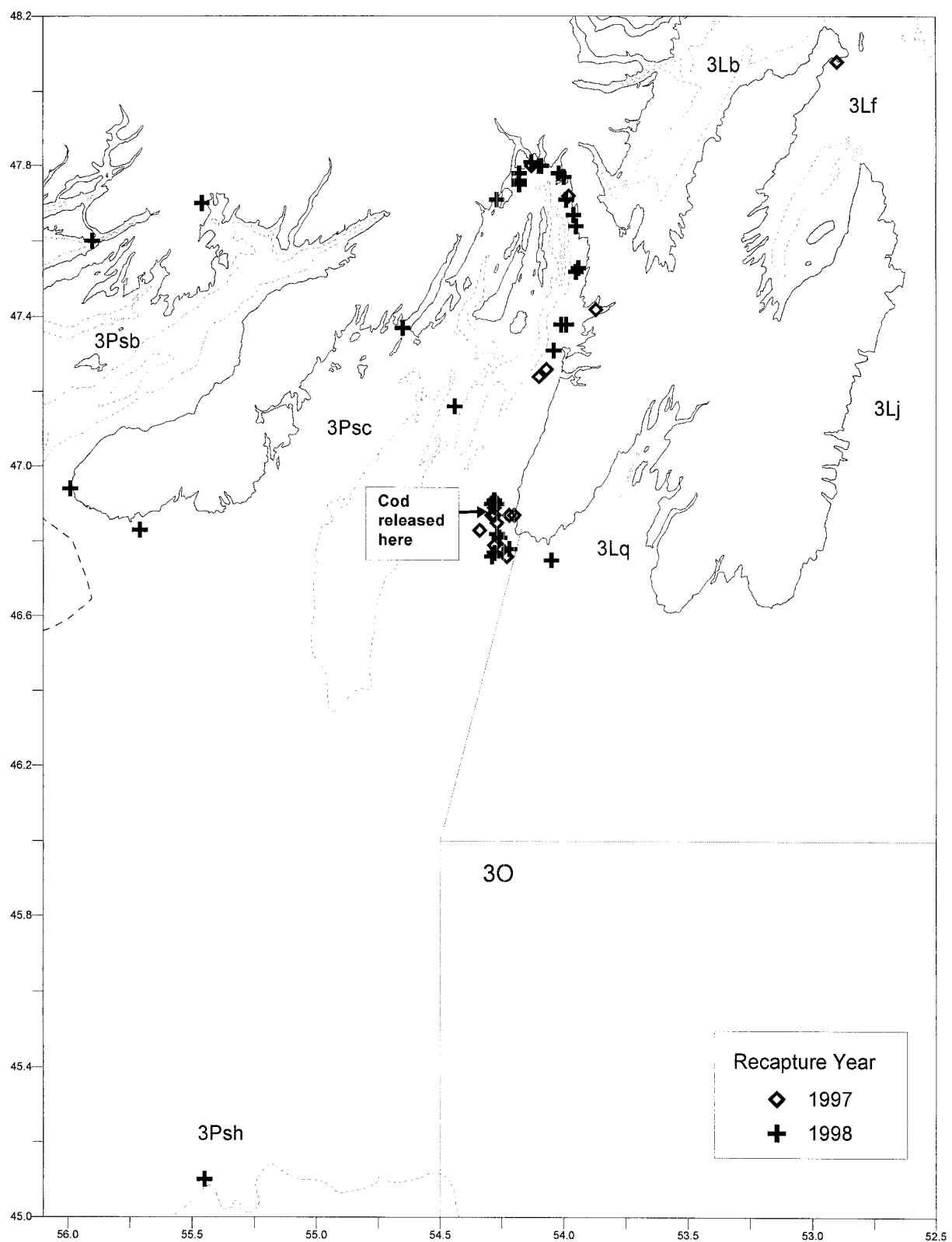


Fig. 3. Reported recapture positions for cod tagged off St. Bride's, Placentia Bay on May 25-28, 1997 (N=709).

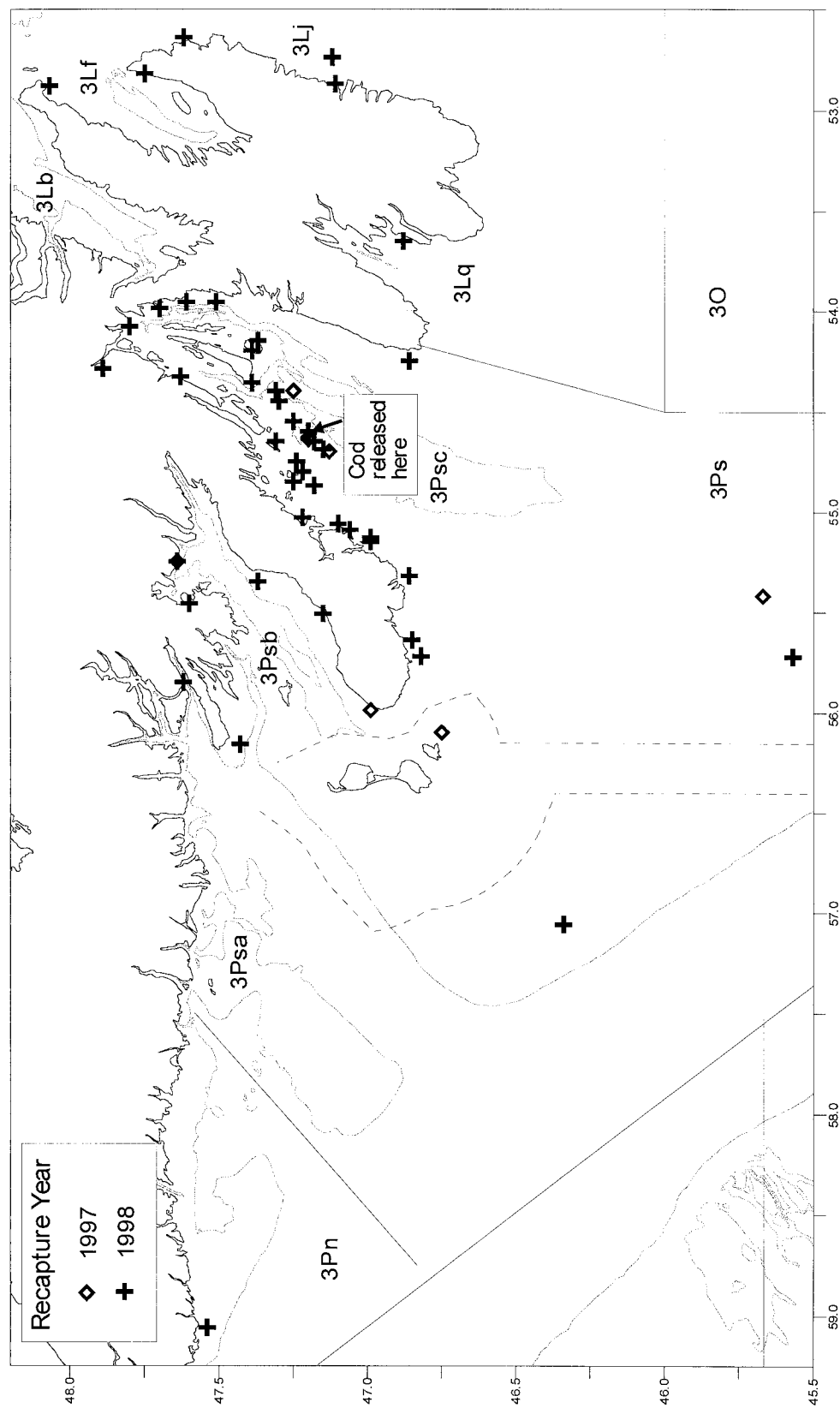


Fig. 4. Reported recapture positions for cod tagged at Oderin Bank, Placentia Bay during 24-26 June 1997 (N=963).

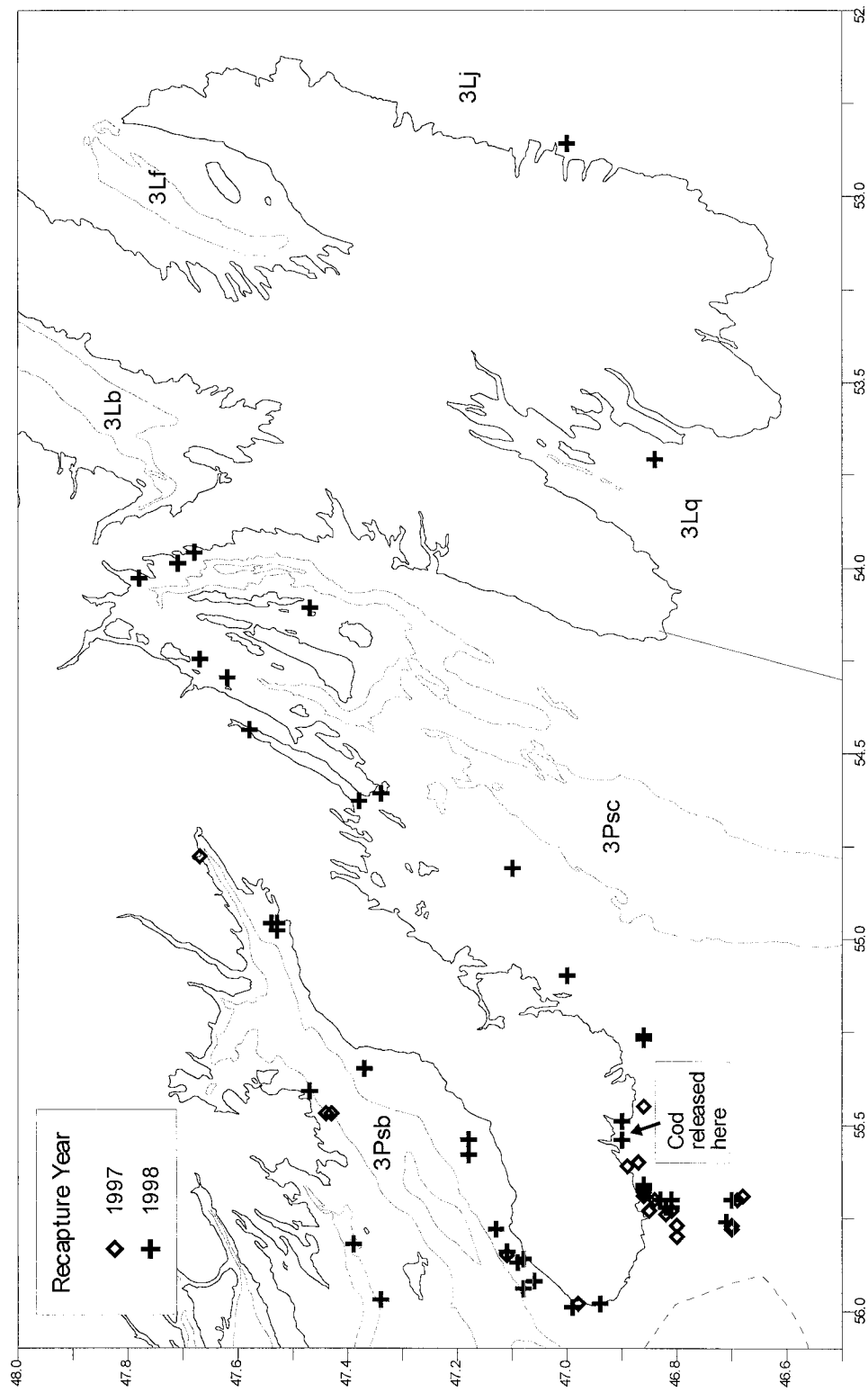


Fig. 5. Reported recapture positions for cod tagged at Lord's Cove, Burin Peninsula during 25 June-18 July 1997 (N=793).



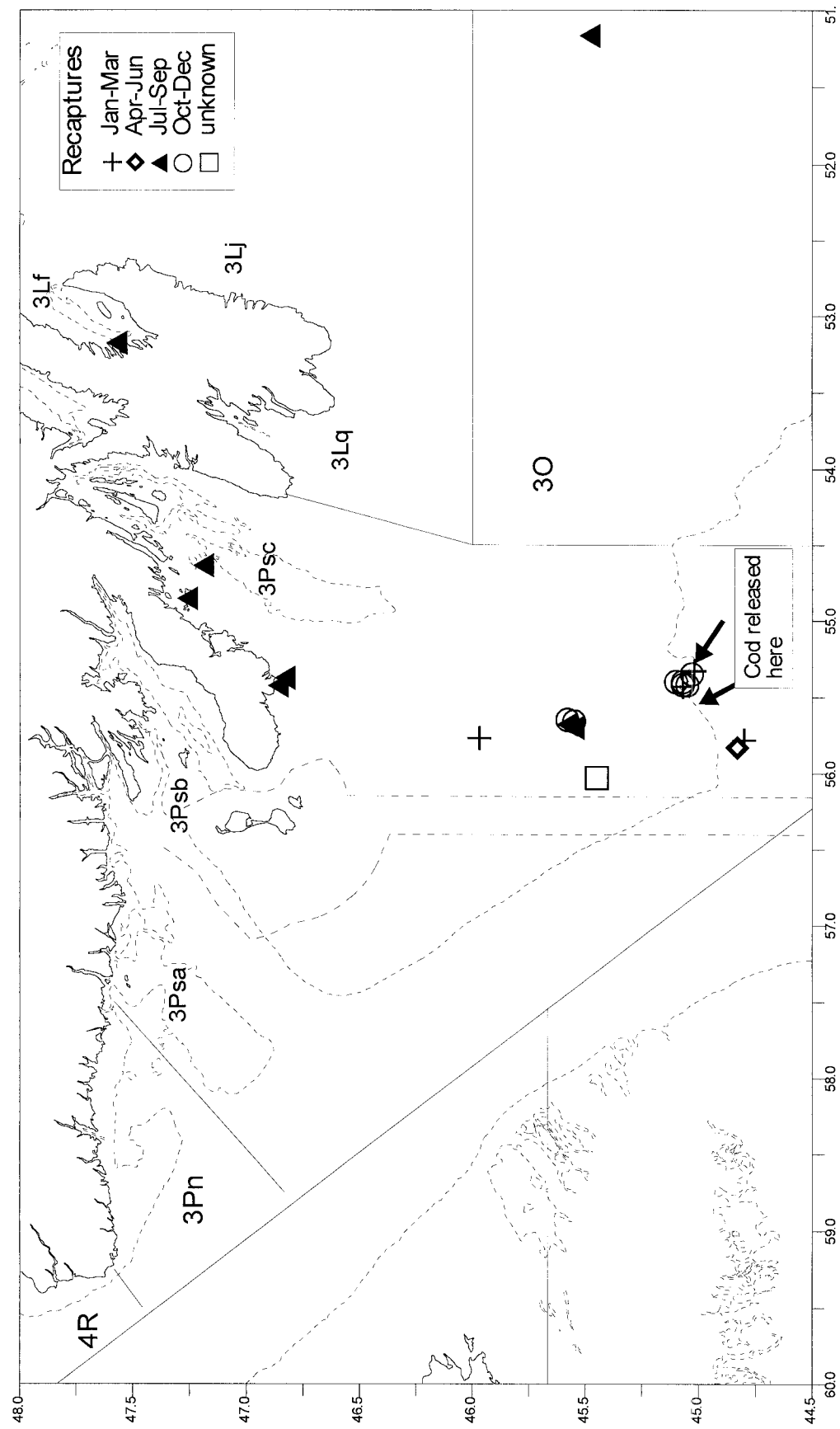


Fig. 6. Reported recapture positions by season for cod tagged and released in 3Psh (Halibut Channel) during 2-5 April 1998 (N=1842).

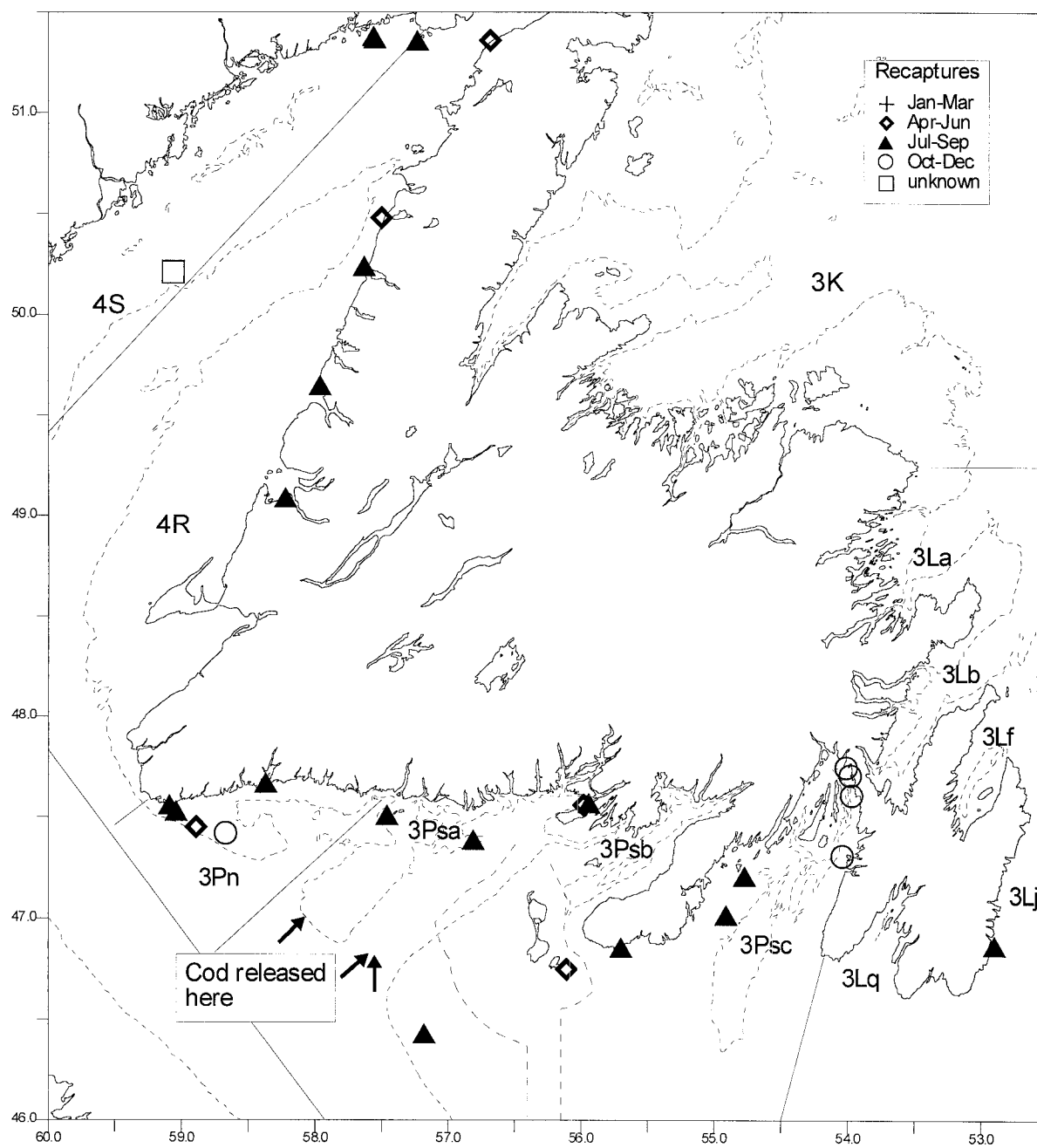


Fig. 7. Reported recapture positions for cod tagged and released in Burgeo Bank / Hermitage Channel area during 5-7 April 1998 (N=1352).

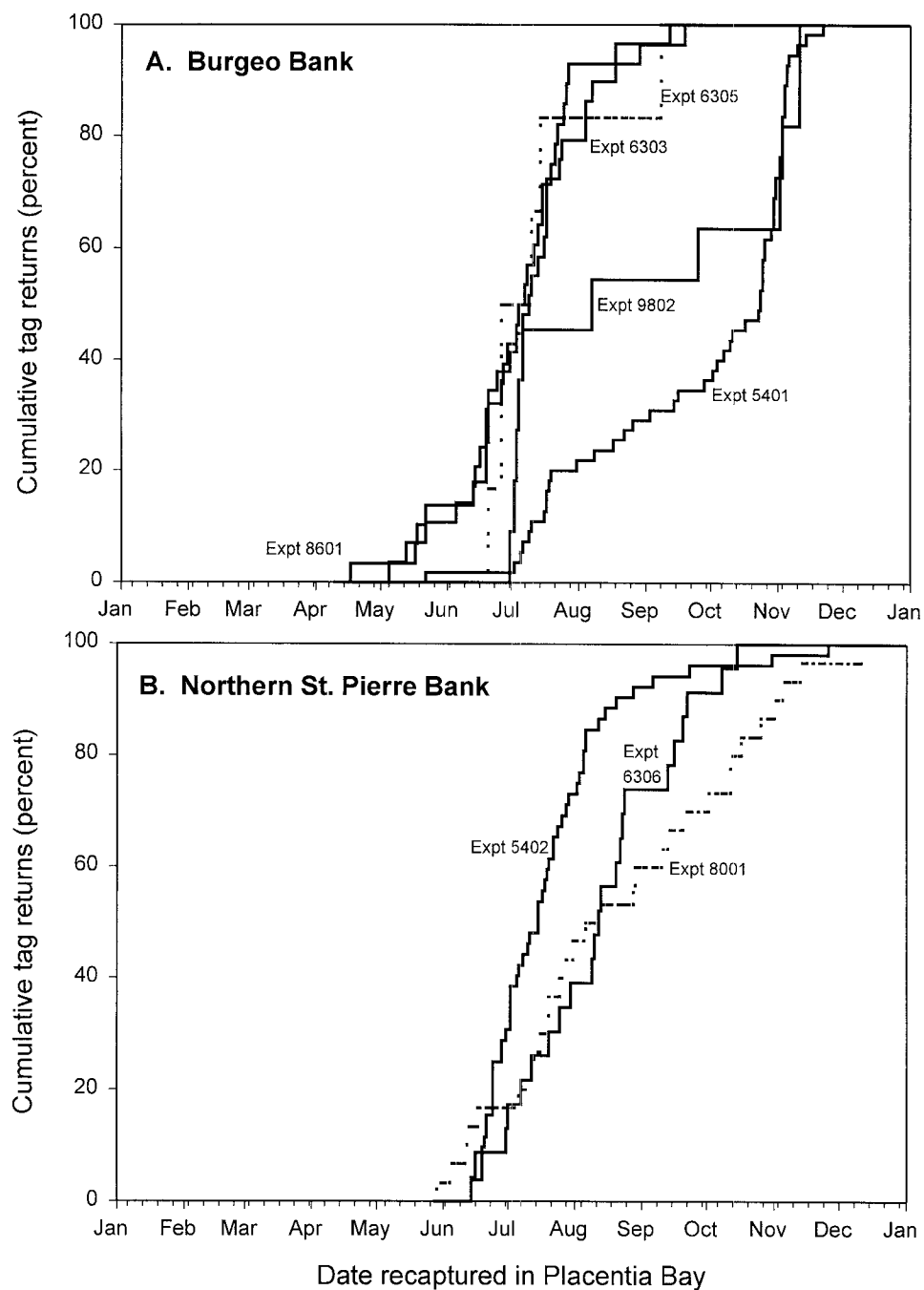


Fig. 8. Recaptures of tagged cod in Placentia Bay from tagging experiments in offshore areas of NAFO subdivision 3Ps.

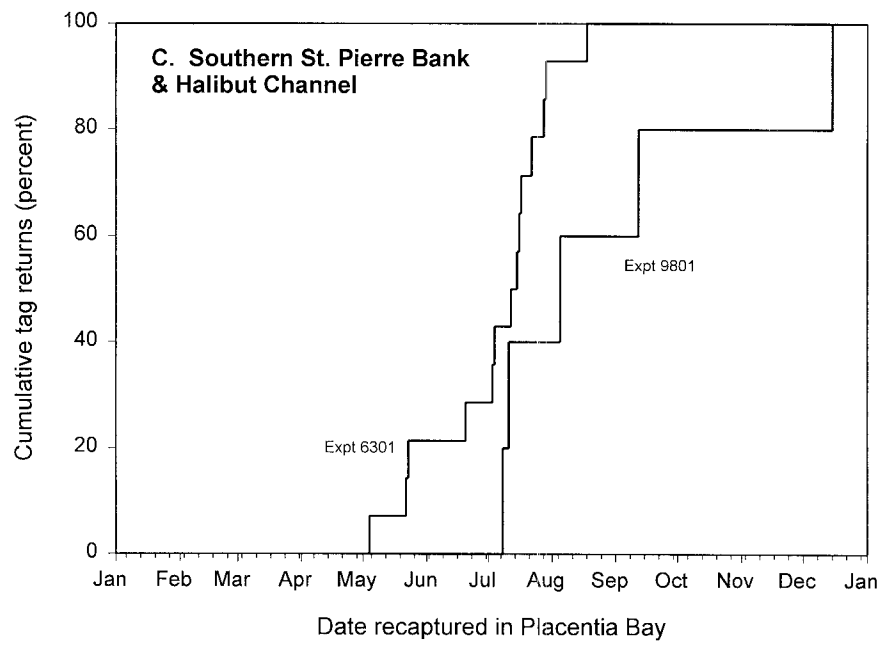


Fig. 8. Cont'd.

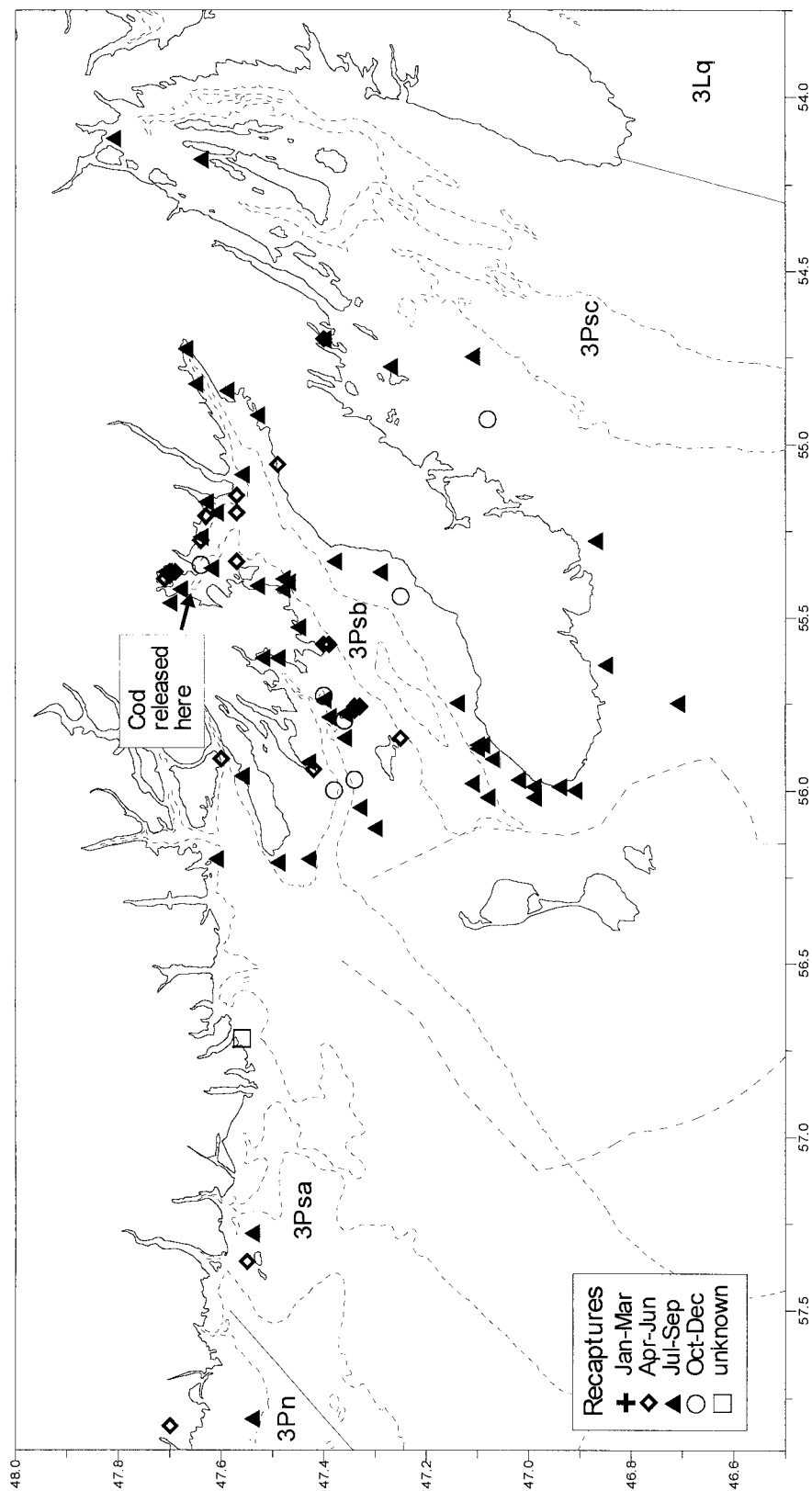


Fig. 9. Reported recapture positions by season for cod tagged near Poole's Cove, Fortune Bay during 20-29 May 1998 (N=938).

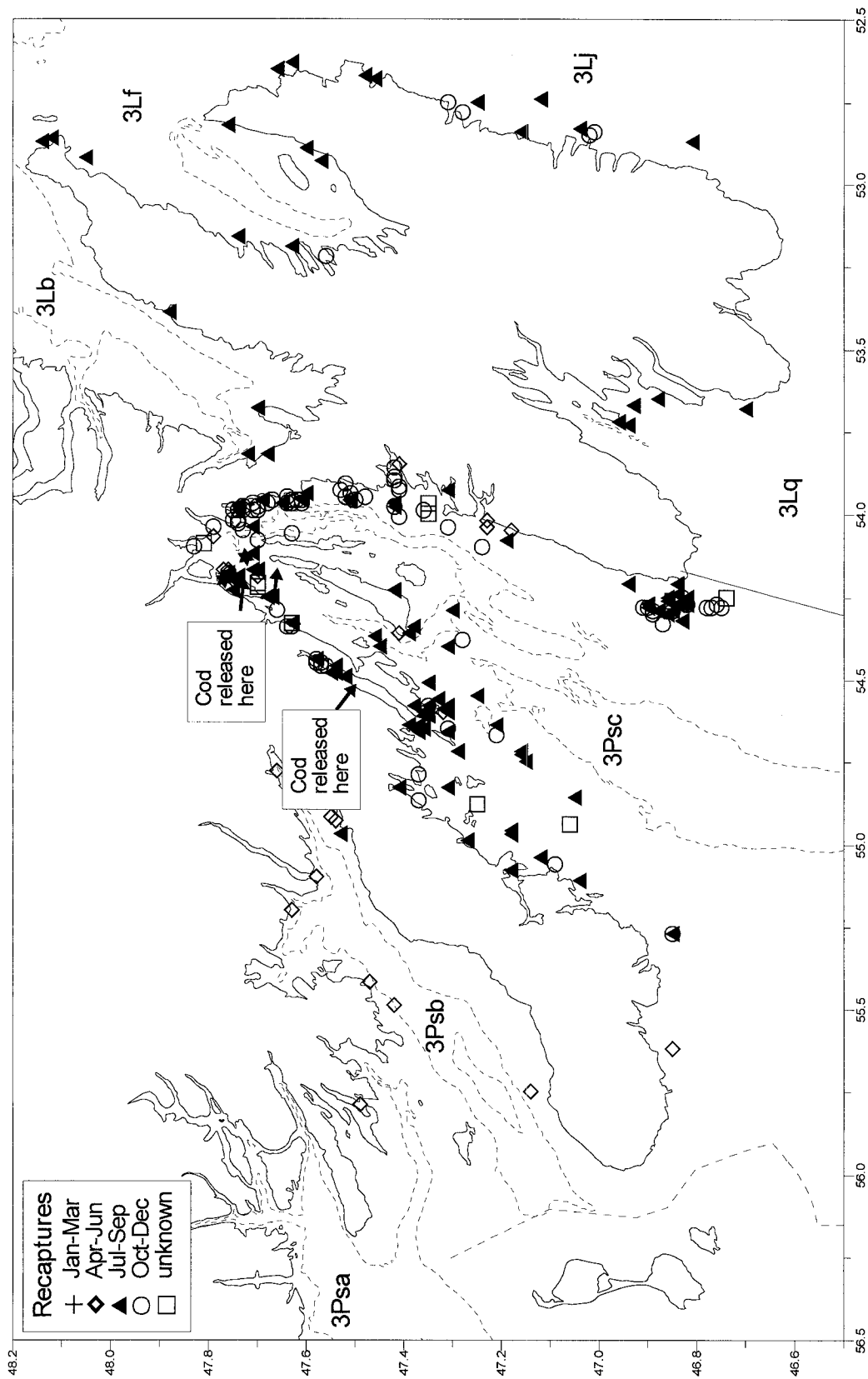


Fig. 10. Reported recapture positions by season for cod tagged at three sites at the head of Placentia Bay during April 22-May 3, 1998 (N=4322).

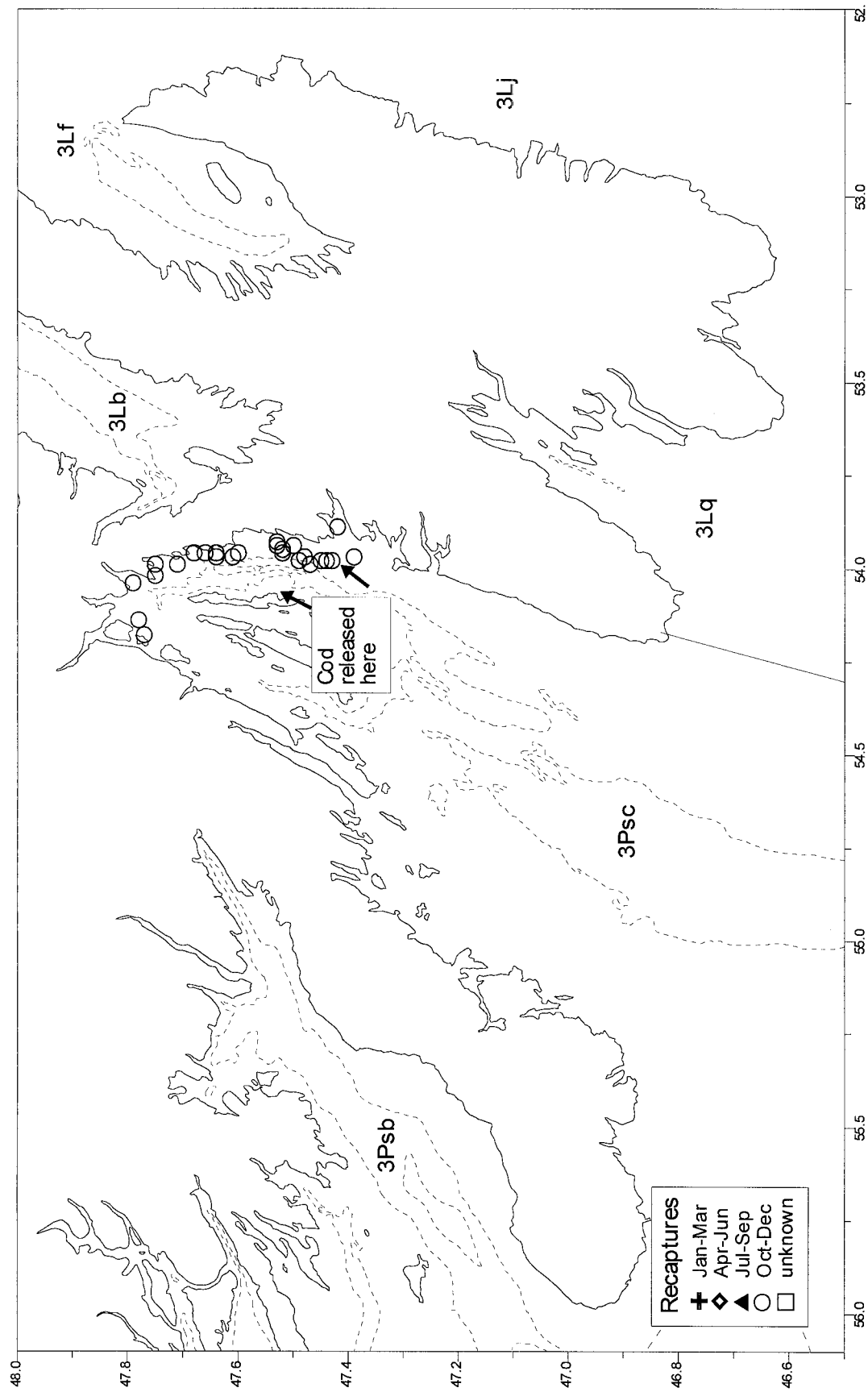


Fig. 11. Reported recapture positions by season for cod tagged in the eastern channel of Placentia Bay during 10-21 October 1998 (N=883).

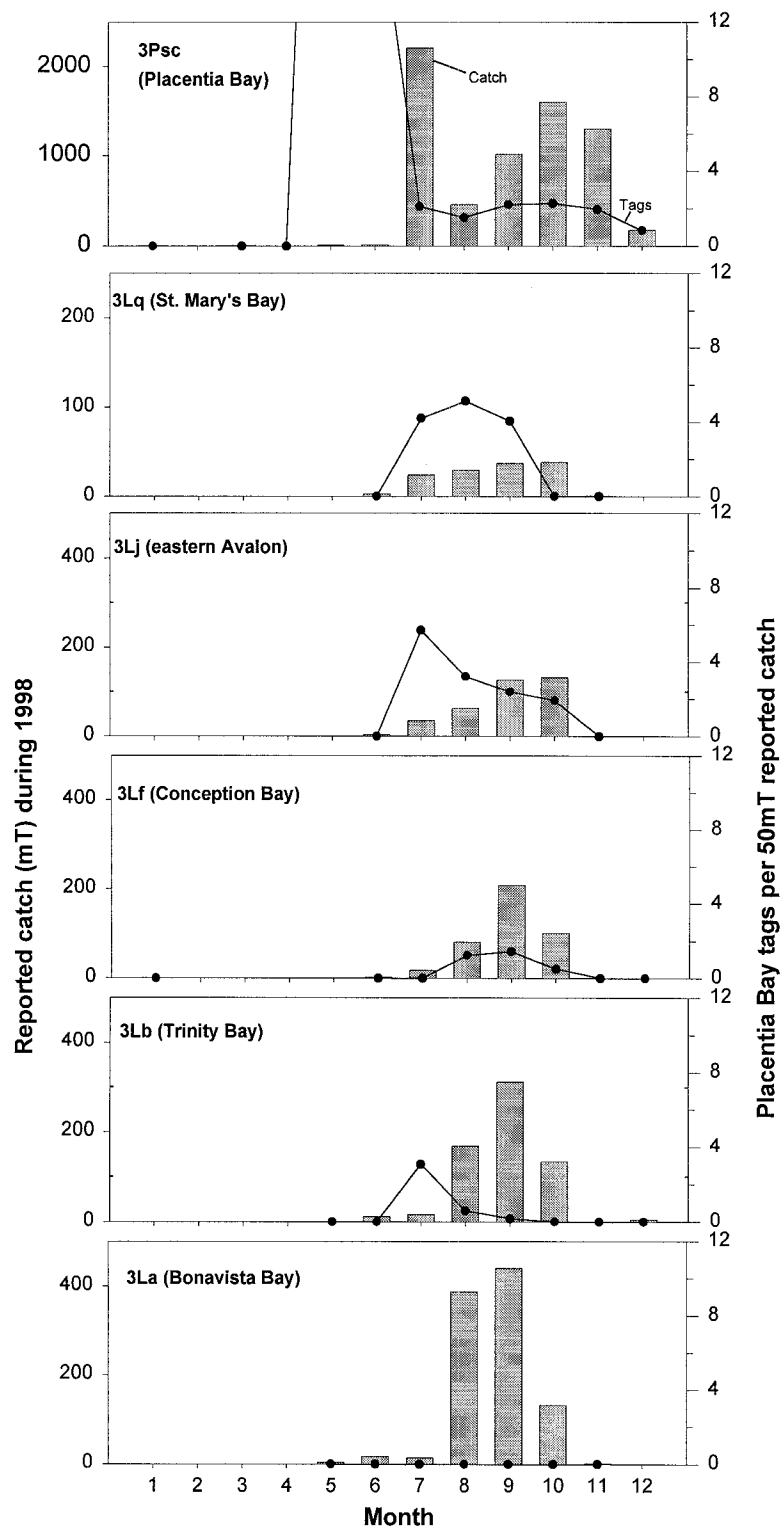


Fig. 12. Recaptures per unit weight of catch for cod tagged in Placentia Bay (N=5100) during fall 1997 and spring 1998 and recaptured during commercial fisheries in 3Ps and 3L during 1998.