



Fisheries and Oceans Pêches et Océans
Canada Canada

Secrétariat canadien pour l'évaluation des stocks
Document de recherche 99103

Canadian Stock Assessment Secretariat
Research Document 99/103

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Stock structure and seasonal migration patterns of Atlantic cod (*Gadus morhua*) based on
inshore tagging experiments in Divs. 3KL during 1995-97

by

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Research documents are produced in the official language in which they are provided to the Secretariat.

ISSN 1480-4883
Ottawa, 1999

Canada

Abstract

During 1995-1997, a total of 11,975 cod were tagged with t-bar anchor tags and released at various inshore locations in Divs. 3KL from statistical area 3Kd (Northern Peninsula) southward to 3Lq (St. Mary's Bay). Most tagging was conducted during July-September and the spatial extent of coverage varied among years. Tagged cod were reported as recaptured mainly during the sentinel survey (1996-1998), summer recreational fisheries (1996 and 1998), a fall inshore "index" fishery (1998 only), and during by-catch from fisheries directed at other species such as herring, lumpfish, and winter flounder. A total of 504 tagged cod have been reported as recaptured up to the end of 1998. The results indicate that the inshore of 3KL is inhabited by at least two groups of cod: (1) a resident inshore group that inhabits northern 3L and 3K from approximately western Trinity Bay northward, and (2) a migrant group from 3Ps. The migrant group may constitute the bulk of inshore cod inhabiting southern 3L (eastern Trinity Bay southward) during summer and early fall, but only a small proportion of cod in northern 3L and 3K. There appears to be considerable seasonal movement along the inshore with a counter-clockwise, northward movement of some inshore cod around the eastern portion of insular Newfoundland during summer. A southward return migration presumably occurs in late fall and early winter, but this could not be confirmed from tag returns due to lack of fishing activity at that time of year. Inshore-offshore movement of tagged cod may also have occurred, but such movement could not be detected due to the lack of offshore fishing activity associated with the moratorium on northern (2J-3KL) cod.

Résumé

De 1995 à 1997, 11 975 morues au total ont été marquées au moyen d'étiquettes en « t » puis relâchées à divers endroits de la zone côtière des divisions 3KL, de la zone statistique 3Kd (péninsule Northern) vers le sud à la 3Lq (baie Ste-Marie). La majeure partie du marquage a pris place de juillet à septembre, et la superficie couverte a varié d'une année à l'autre. Les captures de morues marquées ont été signalées principalement pendant les pêches sentinelles (1996 et 1998), les pêches récréatives estivales (1996 et 1998), une pêche repère en zone côtière (1998 seulement) et lors de prises accidentelles de pêches dirigées sur d'autres espèces telles le hareng, la poule de mer et la plie rouge. Un total de 504 morues marquées avaient été déclarées recapturées à la fin de 1998. Les résultats indiquent qu'au moins deux groupes de morues cohabitent dans la zone côtière de 3KL, soit un groupe local côtier qui fréquente une zone au nord de 3L et de 3K, s'étendant vers le nord à partir d'une ligne située à l'ouest environ de la baie de la Trinité, et un second groupe qui migre dans ce secteur à partir de 3Ps. Ce second groupe pourrait constituer la majeure partie de la morue fréquentant le secteur côtier au sud de 3L (depuis l'est de la baie de la Trinité vers le sud) en été et tôt en automne, mais une faible proportion seulement de la morue du nord des divisions 3L et 3K. Il semble y avoir des migrations saisonnières considérables le long de la zone côtière, dont un mouvement estival de certaines morues côtières procédant vers le nord et dans le sens contraire des aiguilles d'une montre autour de la portion orientale de l'île de Terre-Neuve. On présume une migration inverse, vers le sud, qui se produit à la fin de l'automne ou au début de l'hiver, mais, compte tenu du peu d'activités de pêche à ce moment de l'année, il a été impossible de confirmer cette hypothèse sur la base des étiquettes retournées. Une migration des morues marquées aurait également pu se produire depuis la côte vers le large, mais elle n'a pu être détectée, faute d'activité de pêche hauturière, étant donné le moratoire sur la pêche de la morue du Nord (2J-3KL).

Introduction

Over the past 10 years, the abundance and distribution of northern cod (NAFO Divs. 2J-3KL) has changed dramatically. Aggregations of adult cod have been observed in some inshore areas throughout the year, but cod in the traditional offshore over-wintering and spawning grounds have continued to decline in abundance and show a truncated age distribution with few fish older than age 5 (Lilly et al. 1999). In light of these changes, there is an urgent need for new information on the origins and migration patterns of the adult cod currently occupying the inshore. The present paper summarizes information on the geographic distribution of recaptures from cod tagging experiments conducted in the inshore of 3KL during 1995-1997. Further analyses of these data, in conjunction with tagging experiments on cod in NAFO subdivision 3Ps, are presented elsewhere (Brattey and Cadigan 1998; Lawson et al. 1998; Brattey et al. 1999; Cadigan and Brattey 1999). Data from cod tagging experiments conducted in Newfoundland Region prior to 1994 are summarized in Taggart et al. (1995).

Materials and Methods

Between December 1995 and the autumn of 1997, a total of 11,975 cod were measured (nearest cm), tagged with uniquely numbered t-bar anchor tags, and released at various inshore locations in Divs. 3K and 3L (Fig. 1). Most of the tagging was done in summer and fall. Cod released during 1995 were tagged with single yellow tags, whereas cod tagged in 1996 as part of the sentinel fishery program were tagged with single red t-bar tags. In 1997 and 1998, a new quantitative tagging study was initiated (for details see Brattey and Cadigan 1998) and cod were tagged with single yellow, double yellow, or single pink. Various monetary rewards, depending on the number of tags and their colour, were paid to encourage fishers to send in tags and relevant information from recaptured cod.

Results

Fishing activity

Monthly reported landings for 1996-1998 by statistical area for 3K and 3L are summarized in Tables 1 and 2. The 1996 catch for September does not include a substantial recreational fishery catch estimated at approximately 1000 t from Divs. 3KL which could not be partitioned among statistical areas.

Compared to pre-moratorium years, reported landings were generally small throughout the 3yr period of the study. In all three years there was little or no reported catch between December and the following April or May. In June and July sentinel fisheries typically began and small landings (generally < 50 t) were reported. Recreational fisheries also contributed to landings in August and September in 1996 and 1998. Reported catches in 1998 from 3Ki southward were relatively high during August-October due to combined catches from the recreational and index fisheries. In most years, reported landings were higher in 3Ki (Fogo), 3La (Bonavista Bay), and 3Lb (Trinity Bay) relative to areas to the north or south.

Annual recaptures of tagged fish

Recaptures of tagged cod are summarized by year and area of release in Table 3. The numbers of recaptures were consistent with the landings. In most areas recaptures were lower in 1997 when there was no recreational or index fishery and highest in 1998 when combined index and recreational fisheries landed approximately 1500 t and 2300 t in 3K and 3L, respectively, during August-October (Tables 1, 2). Higher percentages of recaptures from tagging in southern 3L (i. e. 3Lj, 3Lq) were due mostly to recoveries from the reopened commercial cod fishery in adjacent 3Ps. The proportion of cod tagged in each area that were recaptured was variable, but typically ranged from 0 to 3%.

Recaptures of cod tagged in 1995 and 1996

The geographic distribution of recaptures from cod tagged in each area is shown in Figs. 2-10; only recaptures with exact latitude and longitude are shown and these accounted for approximately 95% of the total recaptures.

Cod tagged in the Bay Verte Peninsula area and at Conche on the northern Peninsula in 1996 (Fig. 2) were mostly recaptured in White Bay and around the Bay Verte Peninsula during the year of release, but there were recaptures from the Gulf of St. Lawrence in subsequent years indicating that some of these cod had migrated through the Strait of Belle Isle. A single cod was recaptured off the south coast.

Cod tagged in the Fogo-Twillingate area (Fig. 3) during July and September 1996 were mostly recaptured in the local area on the northward side of the islands where tagging took place, but there was some movement southward to Bonavista Bay in all three years and also westward to Notre Dame Bay in 1998. In general the recaptures are indicative of fairly local residency, but with significant numbers moving to adjacent bays and statistical areas. There was one long-distance migrant recovered from 3Psc.

Cod tagged in Bonavista Bay in 1996 were mostly recaptured within the same bay throughout the three year recapture period (Fig 4). There are a few recaptures southward only as far as western Trinity Bay and in 1998 northward to Fogo and Notre Dame Bay. However, there were no recaptures from areas further south in 3L or from 3Ps.

Most of the tagging experiments were conducted in summer, but a large batch of cod were tagged in late fall (December) 1995 in three arms in western Trinity Bay. Many of these were recaptured in the local area, even 2.5 yrs later (Fig. 5); however, in all years there were considerable numbers of recaptures from southern Bonavista Bay and further north in 3Ki. Similar to the Bonavista Bay tagging, there was no recaptures from areas further south in 3L. There was a single recapture from the Strait of Belle Isle in Div. 4R. Most of the cod in Fig. 5 were tagged in Smith Sound and the results demonstrate movement of cod out of Smith Sound presumably during late spring or summer with dispersal along the inshore mostly in a northerly direction.

Release of tagged cod in western Trinity Bay (Smith Sound) during 1996 generated recaptures mostly in the western side of Trinity Bay with single recaptures northward to Bonavista Bay and Notre Dame Bay (Fig. 6A). In contrast, recaptures from 1996 taggings in eastern Trinity Bay came from the local area in the year of release but included three recaptures off the south coast and one from Conception Bay. These recaptures are consistent with the hypothesis the fish tagged on the eastern side of Trinity Bay, which were released during July and August, included some summer migrants from 3Ps. These fish presumably returned south during the winter of 1996-1997 and were captured during the commercial fishery in 3Ps which reopened on May 19th, 1997 before these cod had resumed their northward summer migration. Some of the tagged cod had clearly migrated northward in 1998 with one recapture from the Twillingate area. There was a notable absence of southerly recaptures during 1998 from both the western and eastern Trinity Bay tagging, in spite of the more substantial catch from the recreational and index fisheries during August-October in that year.

Release of tagged cod off the eastern Avalon during July-October 1996 generated few recaptures in the year of tagging (Fig. 7), probably because most cod were released after the September recreational fishery that year. However, in 1997 there were many recaptures from Placentia Bay, the eastern Avalon, and Conception Bay. Recaptures during 1998 showed a similar pattern to those seen in 1997, but included one recapture from Fortune Bay and two from areas further north in 3L. These recaptures are also consistent with the hypothesis that the tagged fish included many migrants from 3Ps, particularly Placentia Bay, and that these cod were returning southward during the late fall of 1996 with some recaptured during the reopened commercial fishery in 3Ps in the spring of 1997.

Recaptures of cod tagged in 1997

Cod tagged south of Fogo during July 1997 were recaptured mostly during 1998 and were dispersed widely eastward to Notre Dame Bay and south to Bonavista Bay (Fig. 8). The pattern of recaptures was consistent with the 1996 tagging, showing considerable movement of cod between these three areas.

Recaptures of cod tagged in southern Bonavista Bay during July 1997 (Fig. 9) were similar to those observed from 1996 tagging in this area. There was a cluster of recaptures close to the tagging sites along with some movement south mainly to western Trinity Bay, as well as northward dispersal to Fogo. There was a single recapture from 3Psc.

Cod tagged in St. Mary's Bay during June 1997 (Fig. 10) gave no recoveries with specific positions during 1997; all recaptures shown are from 1998. Recaptures were widely dispersed, with several recaptures in 3L during July-September as far north as Bonavista Bay. Most of the fall recaptures came from 3Ps (Placentia Bay) and included one offshore recapture from Halibut Channel. Recaptures from a fall 1997 tagging in St. Mary's Bay (not shown) were mostly obtained in 1998 from southern 3L, but included one recapture from Placentia Bay and one from Bonavista Bay.

There were only 14 recaptures from 788 cod tagged in NW Arm in Trinity Bay during May 1997 (not shown) and these came from the local area or northward to Bonavista Bay.

There were very few recaptures from a July-August 1997 tagging of 88 cod off Ferryland (3Lj)(not shown); three were caught in the vicinity of the tagging site and one in Placentia Bay.

Conclusions

In general, the recaptures of tagged cod from these experiments suggest that the inshore of 3KL is inhabited by at least two groups of cod: (1) a resident inshore group that inhabits northern 3L and 3K from approximately western Trinity Bay northward, and (2) a migrant group from 3Ps. The migrant group may constitute the bulk of inshore cod inhabiting southern 3L (eastern Trinity Bay southward) during summer and early fall, but only a small proportion of cod in northern 3L and 3K. There is no indication of a significant overwintering population of inshore cod in southern 3L, judging by the lack of catch in this area and absence of reports of overwintering concentrations that have been commonly reported further north adjacent to deep fjords (Lilly et al. 1999). The contribution of offshore cod to the inshore of 3KL in recent years remains difficult to determine; however, the low offshore biomass combined with the rarity of fish ≥ 5 yr old in the offshore contrasts with the age composition of inshore catches (Lilly et al. 1998, 1999) and suggests that inshore populations currently consist mostly of resident inshore cod and migrants from 3Ps.

There appears to be considerable exchange of cod along the inshore between the Fogo area (3Ki), Bonavista Bay (3La), and western Trinity Bay (3Lb). Many of the summer taggings in 3K and 3L also generated small numbers of recaptures in 3Ps, suggesting that cod populations in the inshore of 3K and northern 3L during summer also included some long-distance seasonal migrants from the south coast. However, from taggings in Placentia Bay during early spring (April-May) most of these 3Ps migrants were recaptured south of Trinity Bay (see Bratley et al. 1999).

The recaptures from this study and from tagging in 3Ps (Bratley et al. 1999) suggest a seasonal counter-clockwise and northward migration of some cod around the eastern portion of insular Newfoundland during summer. Many of the recaptures in 3KL during 1998 were from the fall index fishery and were north of the release location (see Figs. 2, 3, 4, 6, 7, 9) or were from cod tagged in 3Ps during spring (Bratley et al. 1999). There is less evidence for northward movement in the 1996 or 1997 recaptures, but the fishery occurred soon after release in 1996 and there were few recaptures in 1997 making the comparison among years more difficult. Nonetheless, the results suggest a considerable movement northward of some inshore

cod during 1998. A northward seasonal movement along the inshore is consistent with the findings of Taggart (1997) for cod tagged offshore in 2J-3KL prior to 1992; after migrating inshore these cod showed a seasonal movement northward in late summer and fall before returning to the offshore. A southward return migration of inshore cod presumably occurs in late fall and early winter, but this could not be confirmed from tag returns reported here due to lack of inshore fishing activity at that time of year.

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Acknowledgements:

I thank the sentinel and commercial fishers and staff of the Fisheries Evaluation, Gadoids, and Commercial Sampling Sections of DFO for conducted the tagging experiments; C. George, D. Porter, S. Moulton, and J. Maddock for collating recapture information. I also gratefully acknowledge the assistance of Fisheries Officers in implementing the tagging program. George Lilly provided helpful comments on the manuscript.

Table 1. Reported monthly landings (t) of cod from the inshore of NAFO Div. 3K during 1996-1998 by statistical area. (The landings for September 1996 exclude part of an estimated recreational fishery catch of approximately 1,000 t for Divs. 3KL combined; this catch could not be broken down by statistical area). Months with no reported landings are omitted.

Year	Month	3Ka	3Kd	3Kh	3Ki	Total
1996	5	0.000	0.000	0.349	0.485	0.834
	6	0.000	0.064	2.596	6.251	8.911
	8	1.365	7.309	43.941	16.008	68.623
	9	0.795	2.357	8.684	9.336	21.172
	10	0.185	0.653	2.868	3.169	6.875
	11	0.000	0.208	0.005	5.216	5.429
	12	0.000	0.000	0.122	0.000	0.122
	Total		3.853	14.518	81.309	73.451
1997	1	0.000	0.000	0.182	0.000	0.182
	5	0.000	0.000	0.000	3.566	3.566
	6	0.070	0.025	3.543	26.622	30.260
	7	1.701	1.147	19.023	25.189	47.060
	8	0.347	2.872	10.716	10.437	24.372
	9	1.073	4.567	20.328	12.022	37.990
	10	0.112	1.425	5.958	6.234	13.729
	11	0.000	0.000	4.809	1.071	5.880
Total		3.303	10.036	64.559	85.141	163.039
1998	5	0.000	0.000	0.000	2.964	2.964
	6	0.000	0.000	2.000	17.947	19.947
	7	0.000	0.000	0.000	0.013	0.013
	8	0.000	0.000	0.951	23.856	24.807
	9	2.809	50.581	382.430	619.756	1055.576
	10	0.836	53.842	189.922	277.404	522.004
	Total		3.645	104.423	575.303	941.940

Table 2. Reported monthly landings (t) of cod from the inshore of NAFO Div. 3L during 1996-1998 by statistical area. (The landings for September 1996 exclude part of an estimated recreational fishery catch of approximately 1,000 t for Divs. 3KL combined; this catch could not be broken down by statistical area). Months with no reported landings are omitted.

Year	Month	3La	3Lb	3Lf	3Lj	3Lq	Total
1996	4	0.118	0.038	0.000	1.380	0.000	1.536
	5	0.709	1.139	0.096	0.000	0.011	1.955
	6	1.665	4.655	1.295	9.468	0.384	17.467
	7	25.974	35.423	8.560	16.683	24.079	110.719
	8	9.504	12.717	14.347	15.168	12.213	63.949
	9	1.761	9.721	4.276	8.034	6.743	30.535
	10	0.703	5.812	1.107	2.481	3.662	13.765
	11	0.000	6.505	0.000	0.154	0.000	6.659
	12	0.000	0.000	0.000	0.245	6.716	6.961
	Total	40.434	76.010	29.681	53.613	53.808	253.546
1997	4	0.000	0.109	0.000	0.000	0.000	0.109
	5	16.954	17.968	0.014	0.000	16.822	51.758
	6	27.842	26.836	0.244	0.000	1.230	56.152
	7	24.313	25.468	1.862	4.475	20.853	76.971
	8	16.891	37.651	6.934	9.876	4.364	75.716
	9	5.811	13.606	6.861	8.708	6.413	41.399
	10	4.604	6.456	3.727	1.805	13.100	29.692
	11	1.362	0.215	3.877	0.000	4.356	9.810
	12	0.120	0.000	0.000	0.000	0.000	0.120
	Total	97.897	128.309	23.519	24.864	67.138	341.727
1998	1	0.000	0.000	0.174	0.000	0.000	0.174
	5	4.123	0.013	0.000	0.000	0.000	4.136
	6	16.694	11.444	1.653	2.861	2.595	35.257
	7	14.099	16.268	17.132	35.078	23.808	106.395
	8	387.504	168.566	81.468	62.417	29.205	729.160
	9	439.349	311.314	208.595	126.634	37.084	1122.986
	10	132.418	134.082	101.513	131.288	38.606	537.917
	11	1.366	0.526	0.460	0.043	0.455	2.850
	12	0.000	5.000	0.007	0.000	0.000	5.007
	Total	995.553	647.213	411.002	358.321	131.753	2543.882

Table 3. Annual summary of recaptures by statistical area of release for cod tagged in the inshore of NAFO Divs. 3KL during 1995-1997.

Year	Area	Number released	Year of recapture				
			1995	1996	1997	1998	unknown
1995	3Lb	2046	0	28	20	39	2
1996	3Kd	175	-	3	0	0	0
	3Kh	843	-	30	5	11	0
	3Ki	1169	-	25	7	24	1
	3La	1257	-	16	10	24	1
	3Lb	977	-	14	5	16	1
	3Lf	119	-	0	0	2	0
	3Lj	1936	-	8	21	26	0
1997	3Ki	260	-	-	1	15	0
	3La	778	-	-	1	32	1
	3Lb	788	-	-	2	12	0
	3Lj	308	-	-	9	7	0
	3Lq	1319	-	-	19	60	1

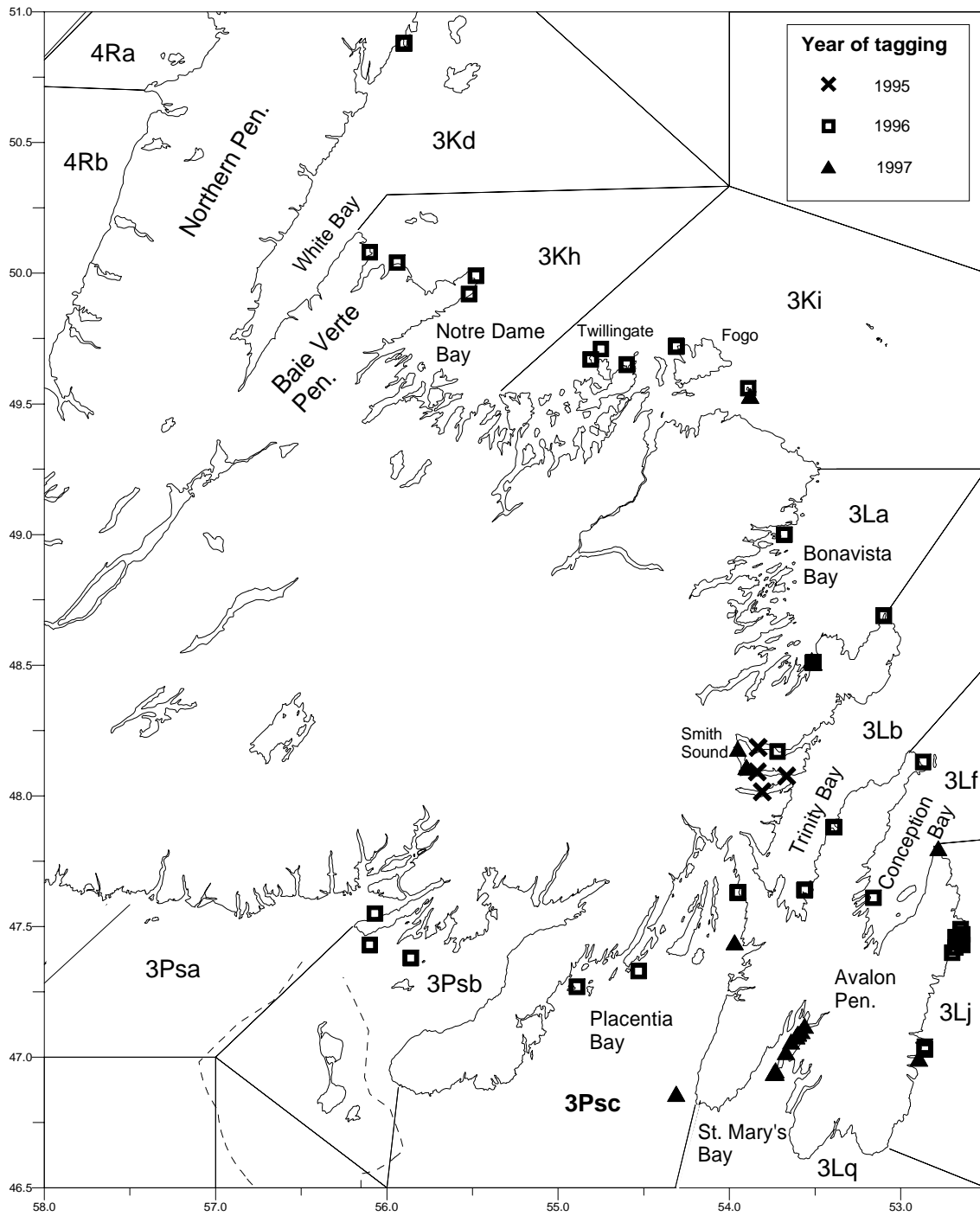


Fig. 1. Locations of inshore sites where cod were tagged and released in NAFO Divs. 3KL during 1995-1997. Solid lines are boundaries of NAFO statistical areas; dashed line is French economic zone.

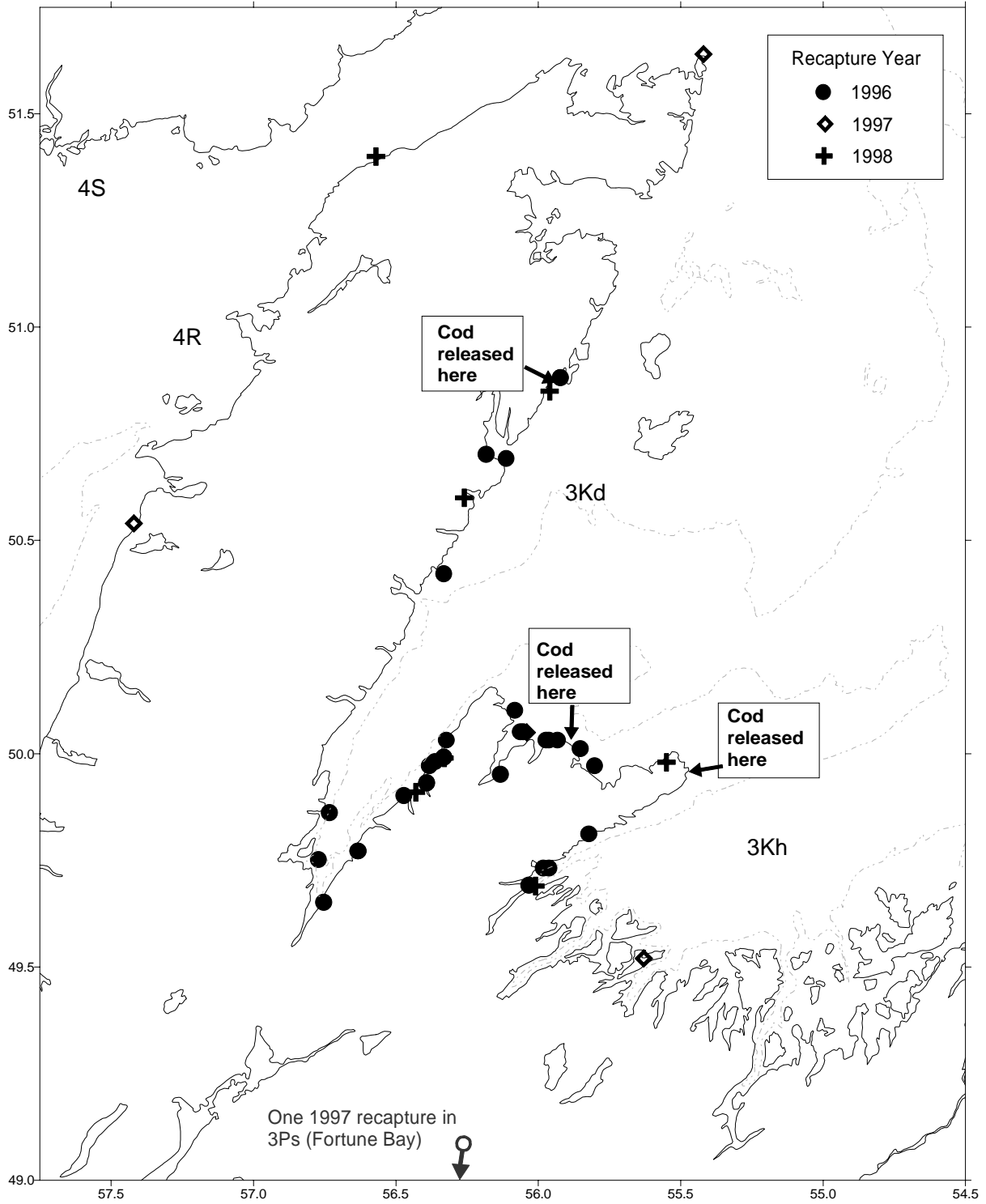


Fig. 2. Reported recapture positions for cod tagged and released in 3Kh (Bay Verte Peninsula) during 16-26 July 96 (N=843) and 3Kd (Conche) during 16-18 Sept 96 (N=175).

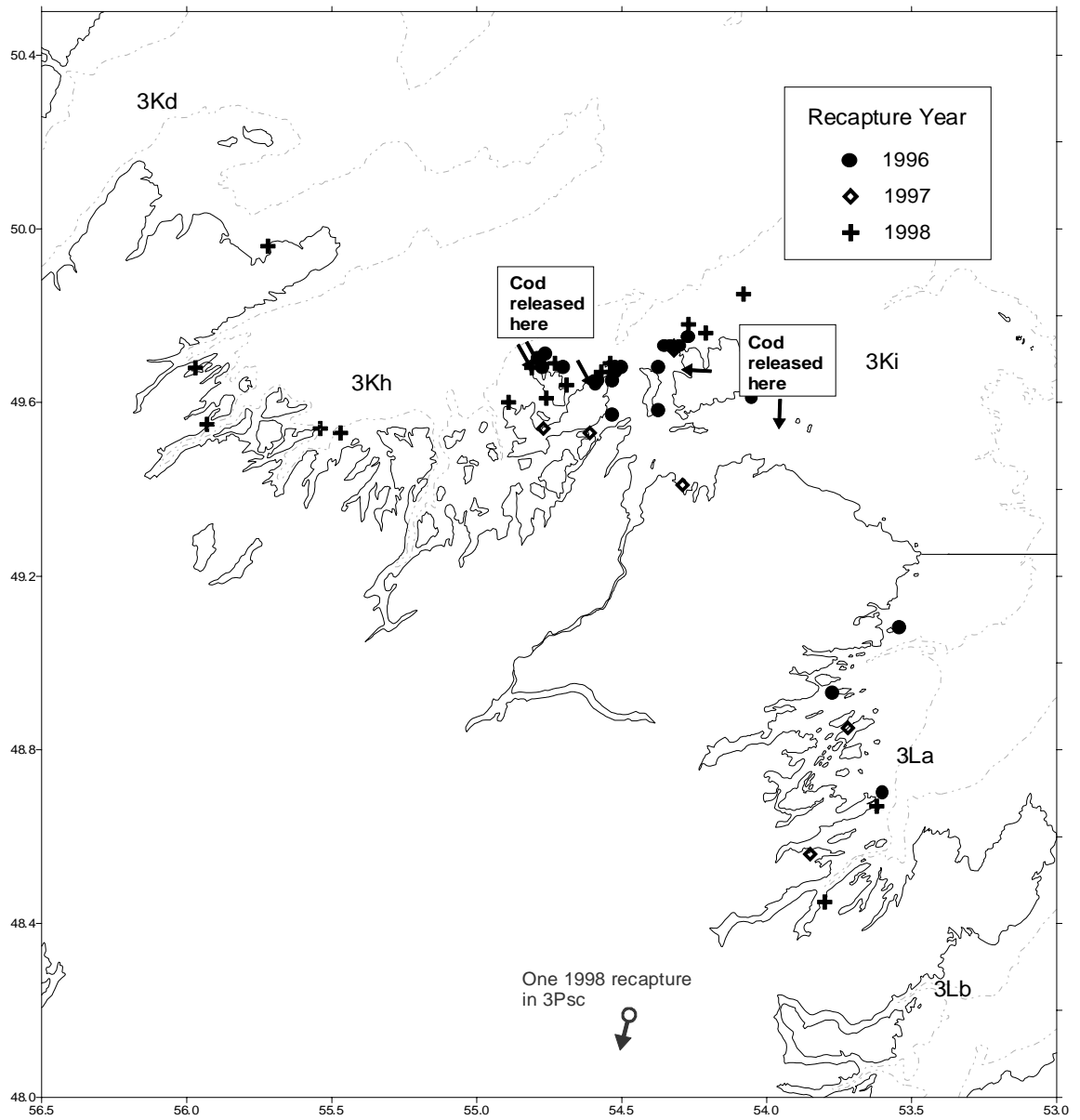


Fig. 3. Reported recapture positions for cod tagged and released in 3Ki (Fogo-Twillingate) during 3-26 July and 17 Sept 1996 (N=1169). Solid straight line is NAFO Div. boundary.

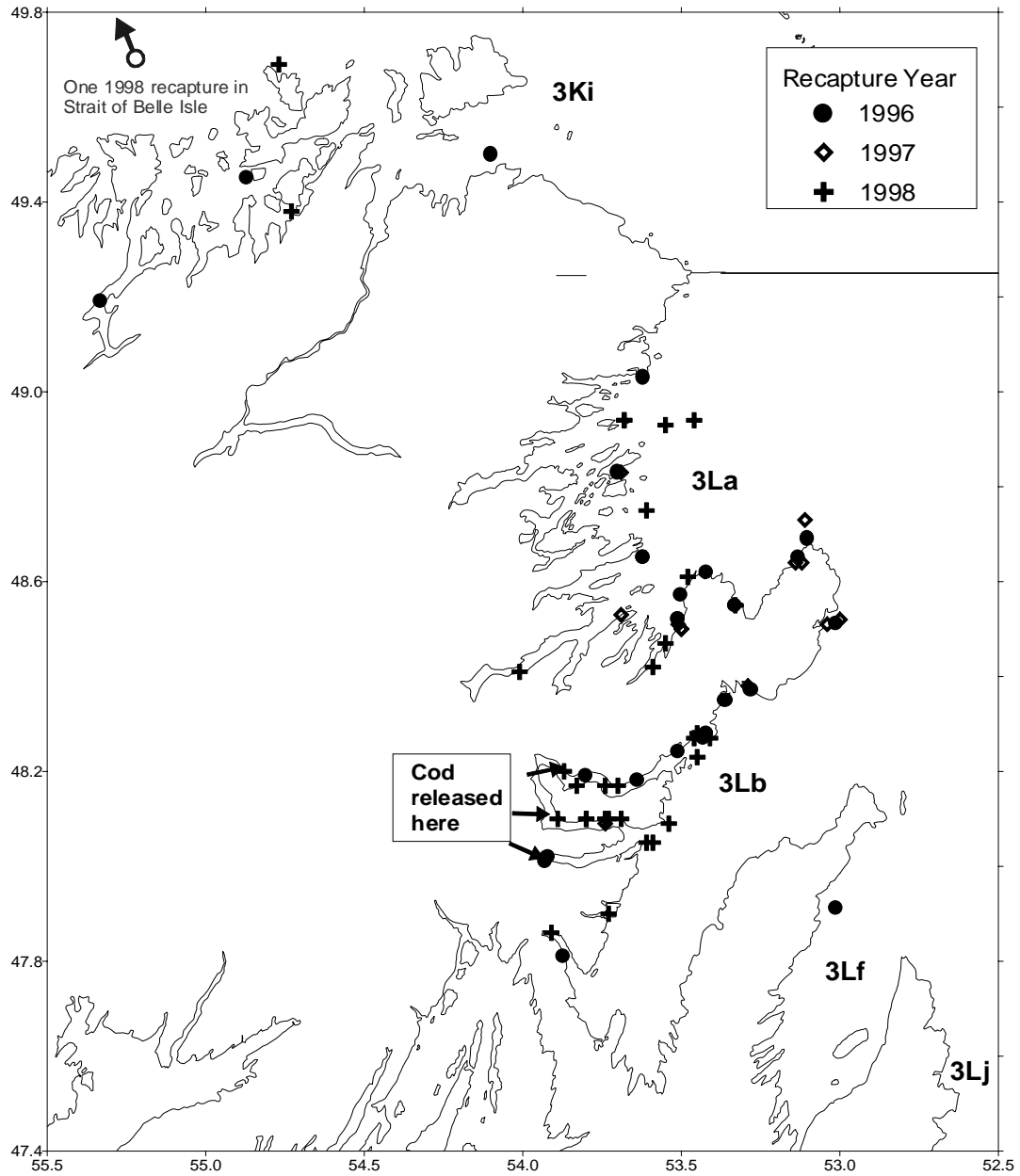


Fig. 5. Reported recapture positions for cod tagged in 3Lb (Smith Sound, NW Arm, and SW Arm, Trinity Bay) during December 1995 (N=2046).

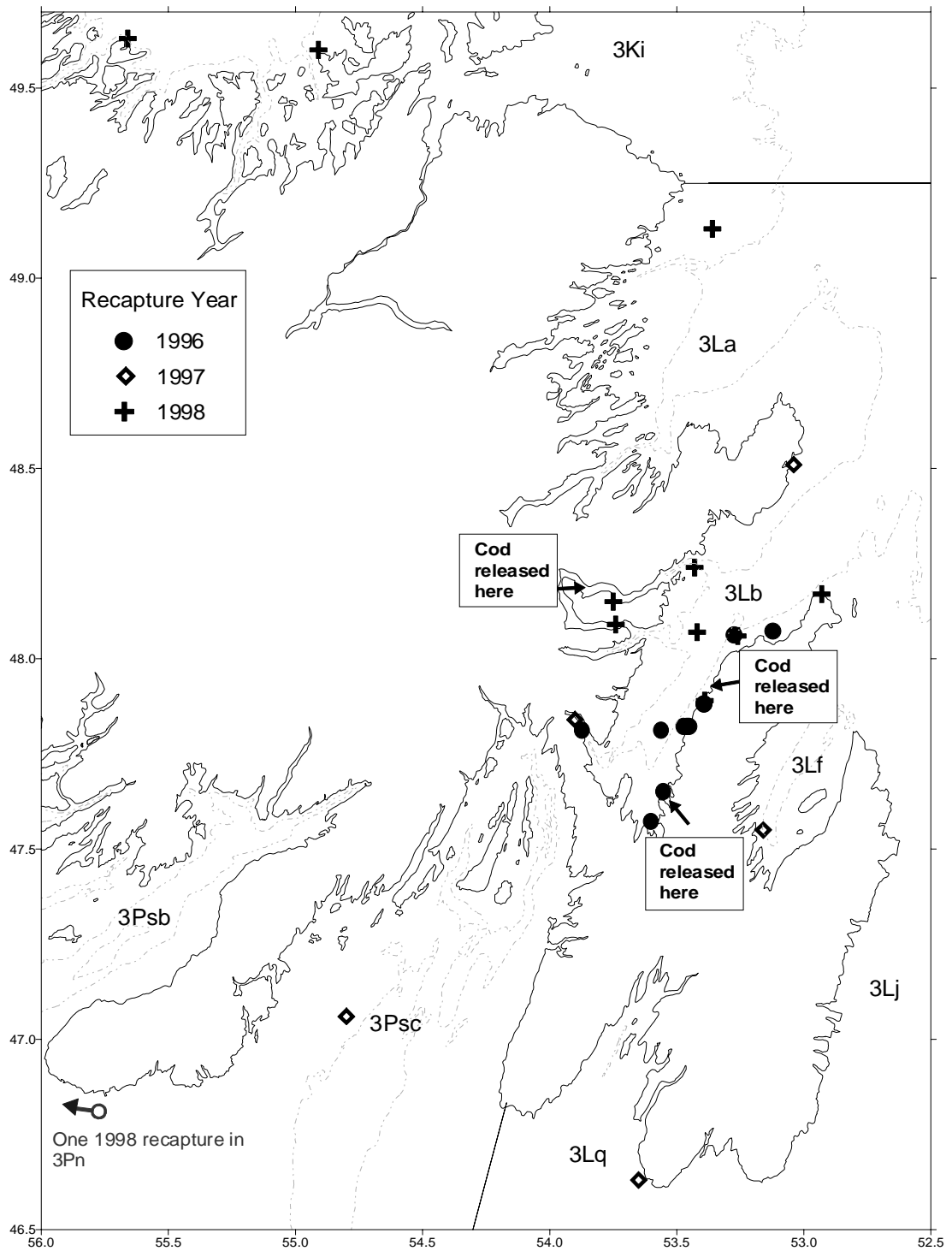


Fig. 6. Reported recapture positions for cod tagged and released in 3Lb (Trinity Bay) during 5 July - 9 Aug 1996 (N=977).

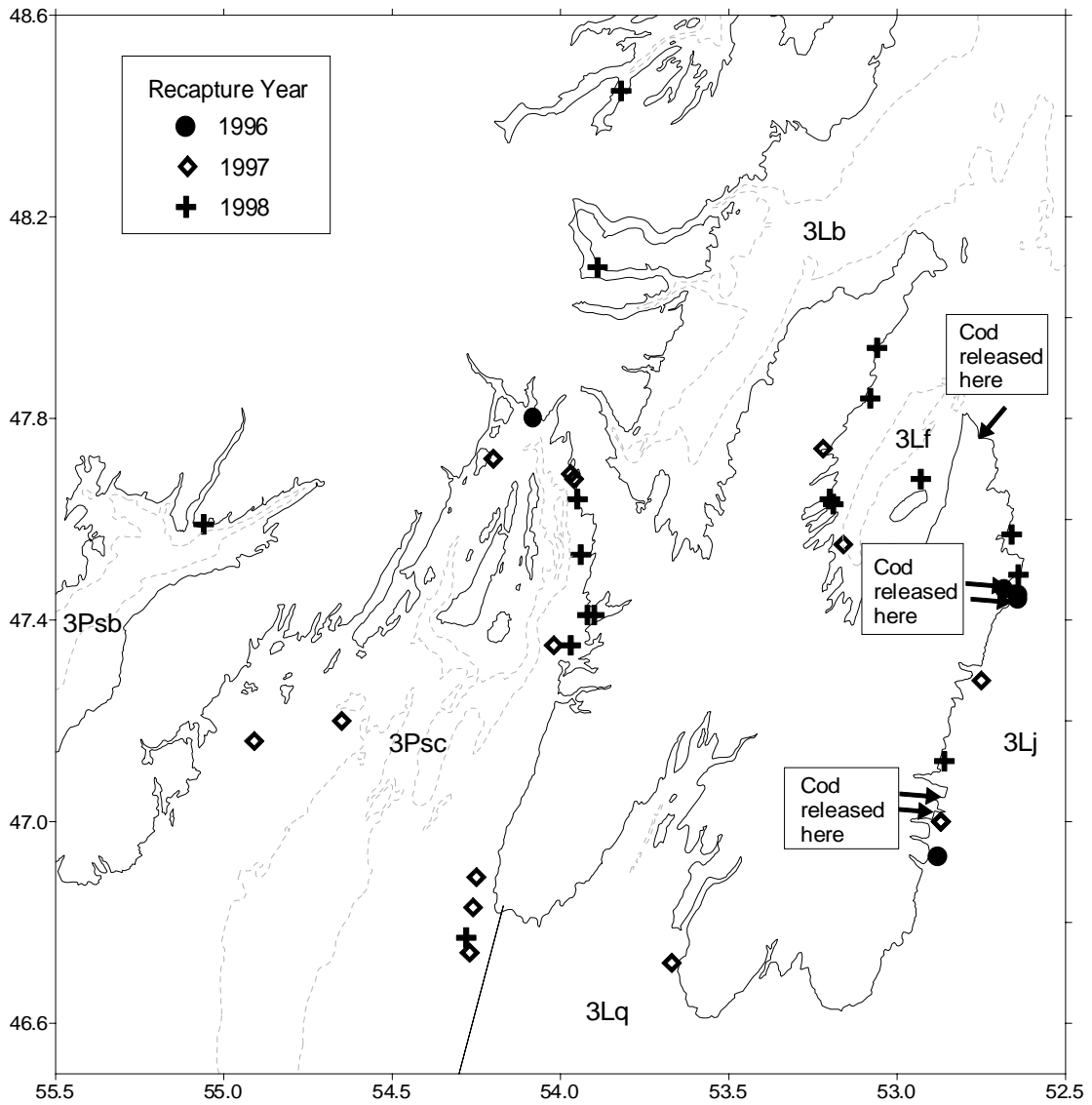


Fig. 7. Reported recapture positions for cod tagged and released in 3Lj (Pouch Cove, Petty Harbour, Ferryland, and Calvert) during July-Oct 1996 (N=1936).

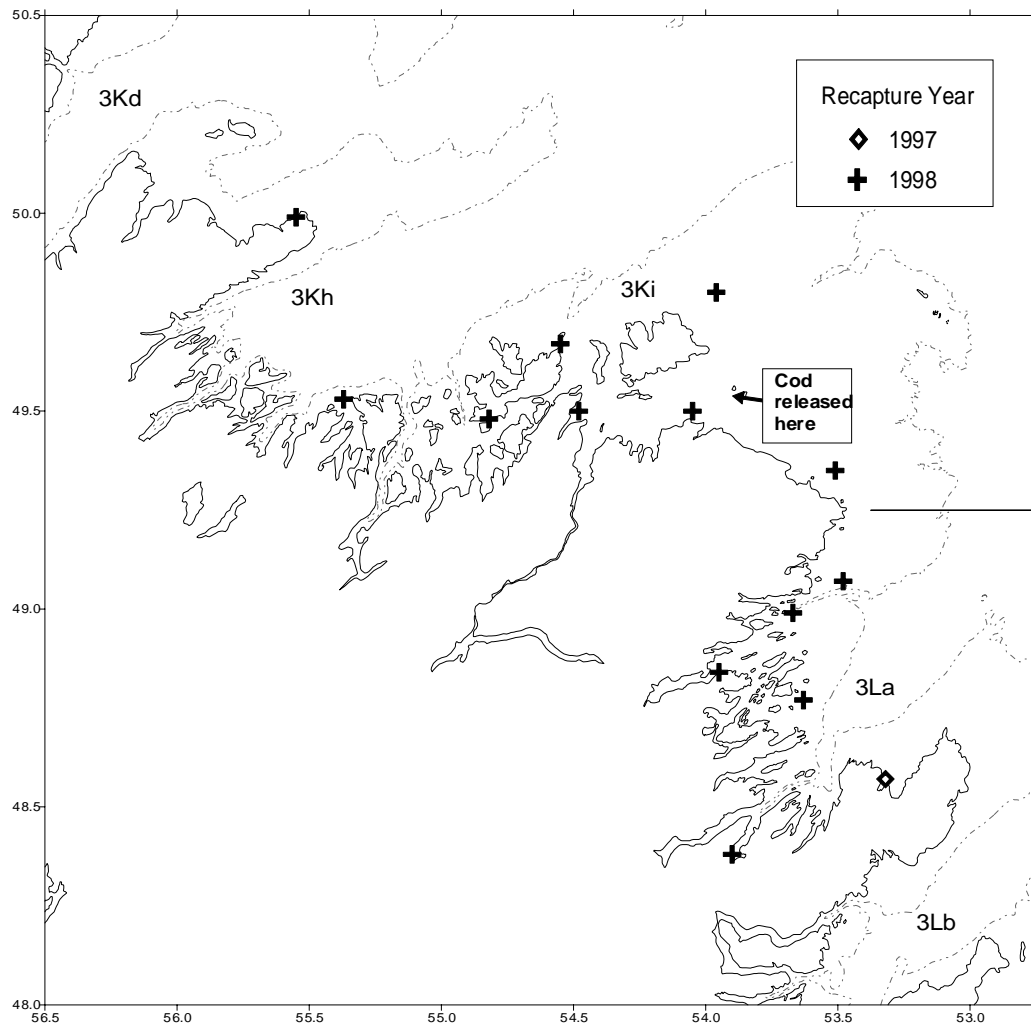


Fig. 8. Reported recapture positions for cod tagged and released in 3Ki (off Aspen Cove) during July 1997 (N=260).

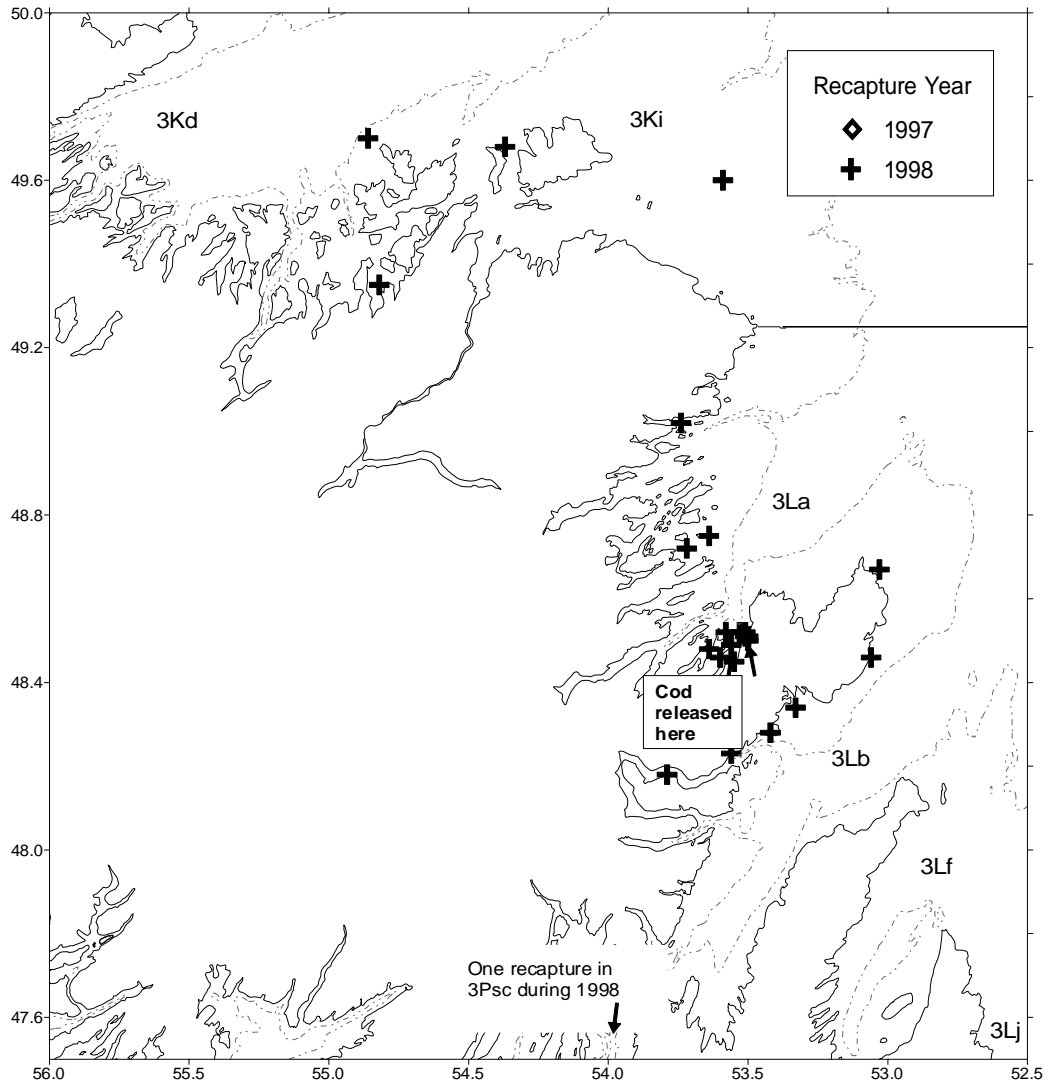


Fig. 9. Reported recapture positions for cod tagged and released in 3La (Plate Cove and Open Hall, Bonavista Bay) during July 1997 (N=778).

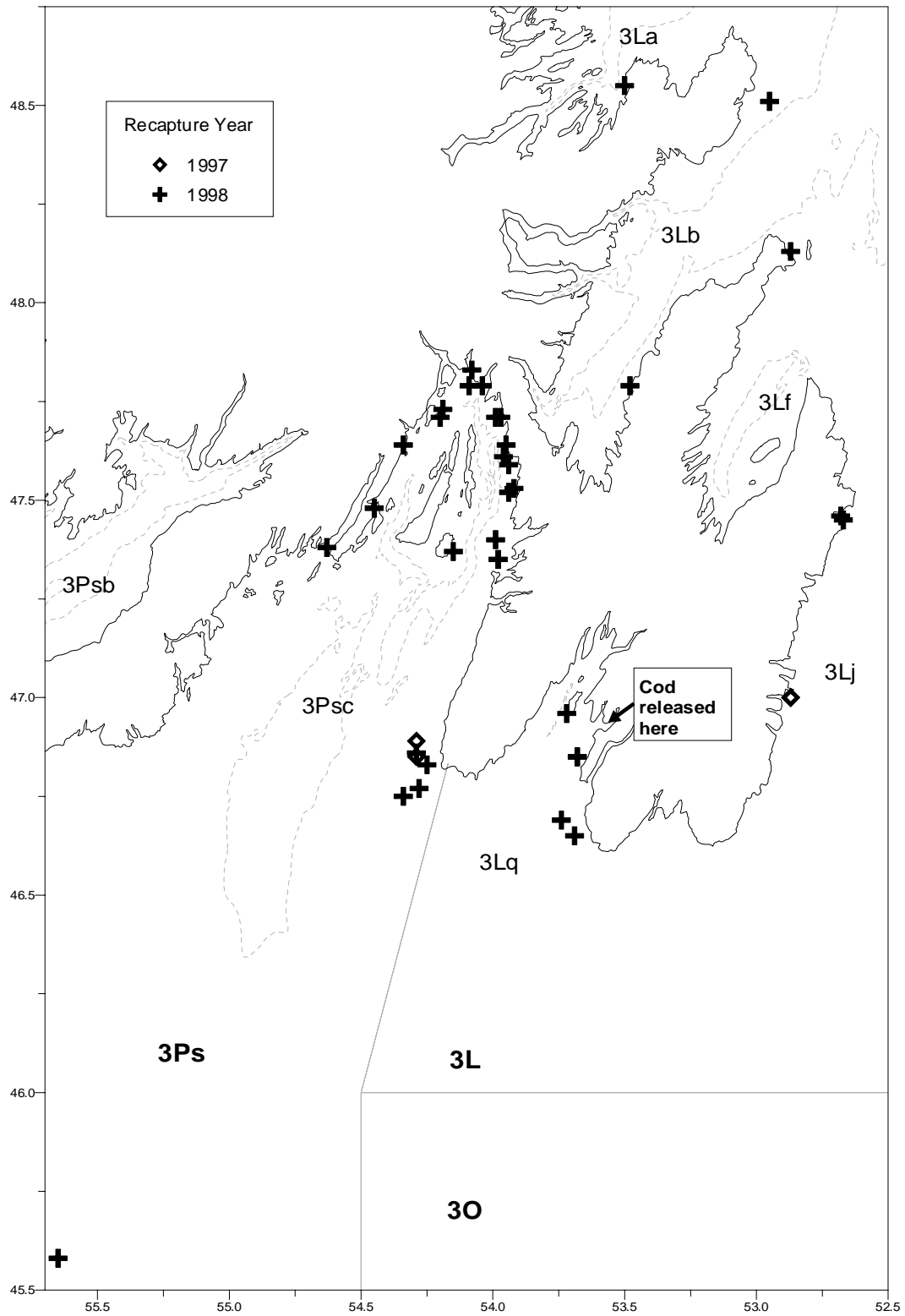


Fig. 10. Reported recapture positions for cod tagged in 3Lq (Riverhead, St. Mary's Bay) during 25-26 June 1997 (N=701).