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Exploitation of Atlantic cod (*Gadus morhua*) in NAFO Subdivision 3Ps: estimates from mark-recapture experiments for the October 2006 assessment

Exploitation de la morue franche (*Gadus morhua*) dans la sous-division 3Ps de l'OPANO : estimations des expériences de marquage-recapture pour l'évaluation d'octobre 2006

J. Bratney and B. Healey

Science Branch
Department of Fisheries and Oceans
P.O. Box 5667
St. John's NL
A1C 5X1

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ABSTRACT

This document provides an update of the results from a multi-year tagging study of Atlantic cod (*Gadus morhua*) in NAFO Subdiv. 3Ps, initiated during spring 1997. Since inception, a total of 66,976 cod have been tagged with single, double, or high-reward t-bar anchor tags and released at various inshore and offshore sites off southern Newfoundland (3Ps) and 13,693 (20.4%) have been reported as recaptured to 1 October 2006. During December 2005, a further 1,490 tagged cod were released in an offshore area (3Psh) with the assistance of industry. Estimates of exploitation for cod tagged in each region in each year were computed using methods we reported previously. Estimates of short-term tagging mortality, tag loss, and reporting rate were obtained and are incorporated into the estimation. No tagging has been conducted inshore since 2003, and the cod tagged inshore and captured during 2005 would typically be at least six years old; consequently, the exploitation estimates given here for inshore tagging pertain to year classes produced prior to 1999 (6+ cod) and managers should be aware that these estimates exclude cod newly recruited to the fishery (2000-2001 year classes). Also, this makes differences in exploitation rates across the time-series more difficult to interpret. Among cod tagged in Placentia Bay (3Psc) mean annual estimates of exploitation have declined from 35% in 1999 to 21% in 2005. For cod tagged in Fortune Bay (3Psb) mean annual estimates have been similar (8-12%) during 2000-2005, with tag returns indicating considerable movement of cod between Fortune Bay and Placentia Bay. For cod tagged in 3Psd (Burgeo Bank) the estimate for 2004 was 1.3%, the lowest estimate since 1998, but similar to the 2004 value (range 1.3-9.1%). Mean annual estimates of exploitation for cod tagged in offshore areas (3Psh) are marginally higher for 2005 (5.5%, compared with 1.5-3.2% during 1998-2004) but remain lower than those for inshore areas in spite of offshore landings of >6,000 t. The timing of offshore tagging in 3Psh/g was changed from April to December during 2003-2005 and a total of over 4,200 tagged cod have now been released. However, only 90 of the cod tagged offshore in December have been reported as recaptured. In terms of distribution of recaptures, results were almost identical to those for cod tagged offshore April, with recaptures taken mostly in the local offshore area (3Psh/e) and inshore within Placentia Bay (3Psc).

RÉSUMÉ

Le présent document fait le point sur les résultats d'une expérience pluriannuelle de marquage de la morue franche (*Gadus morhua*) dans la sous-division 3Ps de l'OPANO amorcée au printemps 1997. Depuis le début, 66 976 morues ont été marquées avec des étiquettes simples, doubles ou à ancrage en « T » à prime élevée et relâchées à divers endroits dans les eaux côtières et extracôtières du sud de Terre-Neuve (3Ps). De ce nombre, 13 693 recaptures (20,4 %) avaient été déclarées au 1^{er} octobre 2006. En décembre 2005, 1 490 autres morues étiquetées ont été relâchées dans un secteur extracôtier (3Psh) avec l'aide de l'industrie. On a estimé le taux d'exploitation des morues étiquetées dans chaque secteur pour chaque année à l'aide des méthodes déjà mentionnées. On a aussi évalué la mortalité à court terme due au marquage, la perte d'étiquettes et le taux de déclaration et on les a incorporés à l'estimation. Aucun marquage n'a été effectué dans les eaux côtières depuis 2003. Les morues étiquetées dans les eaux côtières et capturées en 2005 devraient donc avoir au moins six ans. En conséquence, les estimations du taux d'exploitation présentées dans le présent document pour le marquage effectué dans les eaux côtières concernent les classes d'âge antérieures à 1999 (morues de 6 ans et +); les gestionnaires doivent être conscients que ces estimations excluent les morues nouvellement recrutées à la pêche (classes d'âge 2000-2001). Une telle situation complique l'interprétation des différences dans les taux d'exploitation de la série chronologique. Parmi les morues étiquetées dans la baie de Plaisance (3Psc), les estimations annuelles moyennes du taux d'exploitation sont passées de 35 % en 1999 à 21 % en 2005. Pour les morues étiquetées dans la baie de Fortune (3Psb), les estimations annuelles moyennes ont été semblables (de 8 à 12 %) de 2000 à 2005, et les retours d'étiquettes ont révélé un mouvement considérable des morues entre la baie de Fortune et la baie de Plaisance. Dans le cas des morues étiquetées dans 3Psd (banc de Burgeo), l'estimation pour 2004 était de 1,3 %, la plus faible valeur depuis 1998, mais qui est semblable à celle de 2004 (plage de 1,3 à 9,1 %). Les estimations annuelles moyenne du taux d'exploitation des morues étiquetées dans les secteurs extracôtiers (3Psh) sont légèrement plus élevées pour 2005 (5,5 % comparativement à de 1,5 à 3,2 % de 1998 à 2004), mais demeurent plus basses que celles établies pour les secteurs côtiers, et ce, malgré des débarquements des secteurs extracôtiers supérieurs à 6 000 t. Le moment où le marquage extracôtier a été effectué dans 3Psh/g est passé d'avril à décembre en 2003-2005, et un total de plus de 4 200 morues étiquetées ont été relâchées depuis. Cependant, seulement 90 des morues étiquetées dans les eaux extracôtières en décembre ont été reprises, selon les déclarations fournies. Pour ce qui est de la répartition des recaptures, les résultats étaient presque identiques à ceux obtenus pour les morues étiquetées dans les eaux extracôtières en avril, les recaptures ayant eu lieu la plupart du temps dans le secteur extracôtier local (3Psh/e) et les eaux côtières de la baie de Plaisance (3Psc).

INTRODUCTION

A mark-recapture study of Atlantic cod (*Gadus morhua*), initiated in NAFO Subdiv. 3Ps during 1997, was updated with recaptures received up to the end of 2005 from tagged cod released in previous years. The purpose of the study is to provide information on movement patterns of 3Ps cod as well as obtain ongoing estimates of exploitation rates on different components of the stock.

Annual estimates of exploitation are given for each tagging experiment conducted in 3Ps during 1997-2005 using the methods described in Bratley and Healey (2004, 2005a, 2005b). For references on other pre- and post-moratorium cod tagging studies in 3Ps and adjacent areas see Bratley et al. 2005a, 2005b. Methods to estimate tagging mortality, tag loss, and reporting rates from our tagging data are described in Bratley and Cadigan (2004) and Cadigan and Bratley (2003, 2006).

MATERIALS AND METHODS

Methods of capture and tagging are described in detail in our previous documents (Bratley and Healey 2004, 2005a, 2005b). During 2005, cod were tagged only in the offshore (Fig. 1, 3Psg/h) during an industry trawl survey conducted in December; these cod were tagged by experienced retired DFO technicians who followed the same protocols used elsewhere in the current study. No tagging has been conducted in the inshore of 3Ps since the fall of 2003.

Reported landings of cod from 3Ps (1997-2005) and from neighbouring management areas in the northern Gulf of St. Lawrence (3Pn4RS) and eastern Newfoundland (3KL) during recent years were extracted from the Statistics Branch catch database and are summarized to aid in the interpretation of tag returns.

ESTIMATION OF EXPLOITATION RATES

The methods used to estimate exploitation rates are described in Bratley and Healey (2003, 2004). The design of the tagging study incorporates methods to estimate tagging mortality (Bratley and Cadigan 2004), tag loss and reporting rates (Cadigan and Bratley 2003, 2006). Updated estimates of tag loss and reporting rate were incorporated into the present exploitation estimates, and these showed only minor changes and are also not given here. The instantaneous rate of natural mortality (m) was assumed to be 0.2 per yr (i.e. 82% annual survival rate). Data from tag releases in 1997-2005 and recaptures obtained from 1997 until the end of 2005 were used herein. As in previous analyses we did not attempt to estimate population sizes using tag returns and commercial catches in this analysis, because typically some harvesting occurs in an area different from where fish were tagged; this makes it difficult to convert local catches to local population biomass.

Tagging experiments were conducted at many locations over several consecutive years (Table 1); thus, multiple annual estimates of exploitation are given for some locations. Note that in some years tagged fish were released during the fishery and the

first estimate of exploitation for these releases accounts for only a portion of the total exploitation in that year.

We also computed mean annual estimates of exploitation for each of the unit areas where fish were tagged. We used recaptures from the year of estimation and two preceding years in calculating these means, which were weighted by the numbers of tagged cod released (i.e. annual means for 2005 were based on recaptures from 2005, 2004 and 2003). Note that no tagging has been conducted inshore since 2003; given that cod are typically at least 4-5 years old when tagged (minimum length 45 cm) the tagged population available for recapture would now be comprised of 6+ fish and the estimates provided pertain only to the 6+ component of the population. The results presented here do not provide information on exploitation of tagged cod from year classes produced after 1999.

Many of the tagging experiments now have long (> 6 yrs) times at liberty and some of the earliest experiments likely have relatively few tagged cod still available for recapture, due to the combined effects of fishing, natural mortality, and tag loss. The remaining tagged cod from these experiments would also be typically >10 years old, given that they are usually at least age 4 at the time of tagging. The low numbers of tagged cod available for recapture from these older experiments has the potential to cause computational difficulties, i.e. when a tag type was returned from an experiment where the estimated number of that tag type still available for recaptures was small, i.e. <1. To address this problem, during estimation we flagged the number of instances where the remaining numbers of cod tagged with a particular tag type declined to <1, and also flagged instances where more tagged cod were recaptured within a year than were estimated to be available. If such events occurred frequently and involved multiple recaptures across several experiments it could imply that the assumed rate of natural mortality, the estimated rate of tag loss, or estimated reporting rate was incorrect (too high). In the present analyses there were no experiments where the estimated number of a particular tag type declined to <0, but there were several experiments where the estimated number available for recapture declined to <1. These typically involved experiments with small numbers of releases of one or more tag types and long (>5 yr) times at liberty. Consequently, we feel that the estimates we used for tagging mortality, tag loss and reporting rate, and our assumed rate of natural mortality seem reasonable.

RESULTS

SPATIAL AND TEMPORAL DISTRIBUTION OF COD LANDINGS

Reported landings of cod by unit area for NAFO Subdiv. 3Ps from 1997-2005 are summarized in Table 2A and Fig. 2. In most years there were substantial landings (>1,000 t) throughout the stock area except in 3Psg and 3Psd; that latter unit area is closed to directed cod fishing for much of the year. There have been no major changes in the distribution of landings over the past 3-4 years. Highest landings (33-51% of the entire TAC) have come from Placentia Bay (3Psc) (Fig. 2). In terms of percentage, landings from Placentia Bay have declined marginally whereas those of some offshore areas have increased by a corresponding amount. In the offshore, landings have mostly been highest in 3Psf/h, which includes the southern Halibut Channel and the

eastern portions of St. Pierre Bank (see Fig. 1). Note that the total annual catches reported herein for some years exclude catches where unit area was not reported and are therefore slightly lower than the totals reported in Brattey et al. (2005, 2006).

Reported annual landings by unit area for management areas adjacent to 3Ps are reported in Table 2B (NAFO Div. 3KL) and Table 2C (Subdiv. 3Pn and Div. 4RS). The TAC's in these adjacent management units have been smaller than those in 3Ps (typically 3,000-9,000 t). In most years, the highest landings per unit area from the northern Gulf stock have come from Subdiv. 3Pn, and unit areas 4Ra and 4Rb. From the northern cod stock area (Div. 2J+3KL), highest landings have come well to the north of 3Ps from unit areas 3Ki, 3La and 3Lb; annual landings in each of the unit areas in southern 3L (3Lf/j/q) have typically been low (<700 t). A moratorium on directed cod fishing in both of these adjacent management areas was re-introduced during 2003-04 and is clearly reflected in the lower landings. However, in 2004-05 the fishery on the northern Gulf stock was reopened with a TAC of 3,500 t and this was increased to 5,000 t in 2005-06; the spatial distribution of landings in 2005 in 3Pn4RS is similar to that for the 1997-2002 period.

NUMBERS OF RECAPTURES

A matrix of the numbers of tagged cod reported as recaptured annually (for all tag types combined) to 2005 is given by tagging experiment in Table 3. As in previous years, there have been substantial numbers of recaptures from most inshore tagging experiments, particularly those conducted in Placentia Bay during spring and fall. Offshore tagging (Halibut Channel, Hermitage Channel, Burgeo Bank, NW St. Pierre Bank) has tended to generate substantially fewer recaptures. Tags have been returned from some experiments for 6-7 years after release, although the numbers of returns have declined to zero in some of the earliest experiments conducted in 1997 and 1998.

EXPLOITATION ESTIMATES

Annual estimates of exploitation (expressed as % of available numbers harvested) for each tagging experiment are summarized and grouped by unit area of release in Table 4. Note that the values for years prior to 2005 have been revised slightly from those reported in Brattey and Healey (2005b); these differences reflect slight changes in the estimates of reporting rate and recovery of a few additional tags recovered in previous years but returned in 2005.

Among cod tagged in Placentia Bay, annual estimates of exploitation have been much higher than those for cod tagged in other regions of the stock area, particularly during 1999 and 2000 when both the overall TAC and landings in Placentia Bay were highest (see Fig. 2). Annual estimates increased from 14 to 15% exploitation during 1997-98 to a maximum of 34.4% during 1999 followed by a decline during subsequent years. The mean annual estimate of exploitation in 2005 for cod tagged in Placentia Bay (21%) is similar to that estimated for 2002-04, although the present estimates are for slightly older (6+) fish.

Note that not all of the exploitation of cod tagged in 3Psc occurs in Placentia Bay itself (see Fig. 3) there is movement into Fortune Bay as well as northward into southern 3L and more rarely offshore onto St. Pierre Bank and Halibut Channel. Also, the 2005 exploitation estimates from cod tagged in 3Psc prior to the spring of 1999 are based on very few recaptures (<5) and are consistently low; this may reflect growth and reduced selection of the available tagged fish from these experiments; most of these fish may have grown beyond the optimum selection size of gillnets which account for most of the catch. These older recaptures were therefore not included when calculating annual means. There are few or no recaptures from some of the oldest tagging experiments (1997 and 1998), suggesting that the tagged population from these experiments has now declined to very low numbers; this is not surprising given that any survivors would mostly be at least 12 years old and they have been fished quite heavily for the past several years.

Among cod tagged in Fortune Bay (3Psb), annual estimates for 2005 showed little variation, ranging from 7.6 to 9.9% and the annual average for 2005 was similar to that estimated for previous years. Recaptures show extensive movement of cod between Fortune Bay and Placentia Bay (Fig. 4). The number of cod tagged has been too low in the western portion of the inshore (i.e. 3Psa) to draw firm conclusions about exploitation of cod tagged in that region.

Among cod tagged in 3Psd since 1998, estimates of exploitation have been consistently low and notably lower than those observed in 3Psc and 3Psb, with annual means ranging from 9.1% in 1999 to only 1.9% in 2005. The individual estimates for both 2003 and 2004 were all low (1.9- 2.1%). Some of the cod tagged in this region in recent years have been recaptured in western 3Ps or in 3Pn4RS (Fig. 5); however, reopening of the northern Gulf cod fishery with landings of 3,500 t in 2004 and 4,300 t in 2005 has not resulted in a notable increase in exploitation rate of cod tagged in 3Psd. Management measures have reduced the winter cod landings from 3Psd (and 3Psa) in recent years (see Table 2).

Mean annual estimates of exploitation have consistently been lowest among cod tagged in Halibut Channel (3Psh) during April, with little variation among individual experiments (1.7-3.6% during 1998-2004) in spite of substantial landings. The estimates for 2005 (5.5%) are somewhat higher than those of preceding years, but are again low relative to inshore areas; the slight increase could be partly due to the higher catch in offshore areas. In 2003-05, tagging was conducted in 3Psh and or 3Psg in December to improve the coverage of this offshore region; however, only about 90 recaptures have been reported up to the end of 2005. The numbers and locations of recapture are similar to those observed for cod tagged in this region in April (see Table 3 and Figs. 6 and 7). Notably, there have been no reported recaptures from the northern Gulf stock area. Most recaptures have come from the winter otter trawl fishery close to where tagged cod were released, from the summer inshore fishery in Placentia Bay, or the late summer-early fall gillnet fishery on southern St. Pierre Bank.

DISCUSSION

We emphasize that our 2005 results pertain mostly to the 6+ portion of the 3Ps cod stock because no inshore tagging has been conducted since the fall of 2003 and at that time tagged cod would typically be at least 4 years old. The exploitation rate on 4 and 5 year old cod that are newly recruited to the fishery during 2005 cannot be determined from the tagging data presented here. The fishery in the past three years (2003-05) has mostly exploited the relatively strong 1997 and 1998 year classes which in 2005 were 7 and 8 years old, respectively (Bratney et al. 2005, 2006). Subsequent year classes (2000-02) appear to be relatively weak (Bratney et al. 2005, 2006); consequently, fisheries managers should be aware that as the 1997 and 1998 year classes age and grow beyond the main selection size of gillnets, the fishery will switch to these weaker incoming year classes which could result in a rapid increase in fishing mortality. A resumption of tagging in the inshore would be beneficial and could provide estimates of harvest rates on these incoming year classes.

Our findings agree with results given in Bratney and Healey (2004, 2005b), and indicate restricted mixing of cod from different portions of the 3Ps stock area as well as higher exploitation of adult cod tagged inshore, particularly in Placentia Bay. These complex migration patterns and stock structure may have some influence on the various abundance indices that are available for the stock (Bratney et al. 2005) and add uncertainty to any sequential population analyses of the stock as a whole. The limited mixing of inshore cod in particular make it difficult to determine whether inshore indices are reflecting trends in the stock as a whole or mainly of inshore components of the stock. Trends in the indices differ between inshore and offshore and are difficult to reconcile with the tagging results. Tagging suggests low exploitation in the offshore yet the two offshore abundance indices have declining trends in recent years. In contrast, inshore indices (sentinel) have been stable for several years (albeit at a lower level than when the fishery opened in 1997), but tagging suggests that in some inshore area such as Placentia Bay exploitation has consistently been relatively high. At present, these results remain enigmatic and difficult to explain.

Our estimates of overall exploitation for cod tagged in the Burgeo region (3Psd) continue to be low and suggest that cod present in this area at the time of tagging, irrespective of their stock affinity, have not been heavily exploited. Any removals of migrant 3Pn4RS cod tagged in 3Psd in the past few management years will therefore be small and have little influence on the dynamics of that stock. Reopening of the northern Gulf cod fishery in 2004-05 and the ongoing fishery in 2005-06 to date appears to have had little influence on estimates of exploitation rate for cod tagged in 3Psd. Some cod in 3Ps are also known to migrate into southern 3L in some years rendering them vulnerable to fisheries in that area; however, landings have been restricted in 3L in the past few years and only a few cod tagged in 3Ps were recaptured in 3L during 2005.

Compared with many other regions in 3Ps, the estimates of exploitation for the offshore areas continue to be low, in spite of substantial offshore landings of over 6,000 t per annum in the past several years (Fig. 2). In previous analyses (Bratney and Healey 2004, 2005b) concerns were expressed that the estimates for the offshore may be more uncertain because of the sparseness of the tagging coverage, depth of capture of cod for tagging, and limited spatial extent of activity in the offshore fishery. We have

attempted to address some of this uncertainty by conducting more tagging offshore during December rather than April for a third time (2003-05) as part of the industry trawl survey (see McClintock 2003). Results to date show a marginally higher exploitation rate of these cod (5.5%) compared to those tagged offshore during 1998-2004, but otherwise agree with findings from spring tagging, with most recaptures taken offshore near the tagging site, on southeastern St. Pierre Bank, or inshore in Placentia Bay.

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Table 1. Summary of details for cod tagging experiments conducted in NAFO Subdiv. 3Ps during 1997-2005 (PB=Placentia Bay, FB=Fortune Bay, HB=Hermitage Bay).

Year & expt no.	DFO Stat. area	Area of release	Dates	Gear	Depth (m)	Number tagged	Mean length (cm)
1997-001	3Psc	Bar Haven, NW PB	9-12 Apr.	handline	48-60	996	62.1
1997-002	3Psc	Clattice Hbr., NW PB	10 Apr.	handline	58-60	966	52.3
1997-004	3Psc	Bar Haven, NW PB	17-18 May	handline	50	817	65.0
1997-005	3Psc	St. Bride's, SE PB	25-28 May	handline	40	709	66.4
1997-006	3Psc	Oderin Bank, W PB	24-26 Jun.	handline	40	963	58.9
1997-008	3Psc	Lord's Cove, SW PB	25 Jun.-18 Jul.	trap/handline	18-40	793	53.5
1997-015	3Psc	Iona Islands, E PB	6-8 Nov.	handline	30-50	778	61.3
1998-001	3Psh	Halibut Channel	2-5 Apr.	otter trawl	181-307	1,842	63.9
1998-002	3Psd	Hermitage Channel	5-7 Apr.	otter trawl	231-344	1,352	53.9
1998-003	3Psc	Bar Haven, NW PB	22-25 April	handline	21-50	2,073	61.0
1998-004	3Psc	Paradise Sound, W PB	27-29 April	otter trawl	151-206	1,212	60.8
1998-005	3Psc	Wareham Rock, NW PB	May 1-3	handline	41-53	1,037	61.9
1998-006	3Psb	Pool's Cove, FB	May 20-29	handline	67	938	57.5
1998-007	3Psc	Bar Haven, NW PB	19-24 Oct.	h'line/otter trl.	41-60	511	60.3
1998-008	3Psc	Eastern Channel, PB	17-22 Oct.	handline	52-80	883	58.8
1999-003	3Psb	South of Pass Island, FB	8 Apr.	otter trawl	211-217	1,293	57.0
1999-004	3Psc	head of Placentia Bay	29 Apr.-7 May	handline	20-70	2,422	63.2
1999-002	3Psd	Hermitage Channel	4-7 Apr.	otter trawl	192-322	464	59.8
1999-001	3Psh	Halibut Channel	1-3 Apr.	otter trawl	149-239	1,808	68.0
1999-039	3Psc	head of Placentia Bay	8-17 Nov	h'line/otter tr'l	50	2,152	63.0
1999-043	3Psa	Hermitage Bay	30 Nov-1 Dec	handline	50	57	52.9
2000-001	3Psh	Halibut Channel	1-7 Apr	otter trawl	203-259	1,044	85.8
2000-003	3Psd	Burgeo Bank	4-Apr	otter trawl	212-318	5	77.0
2000-004	3Psb	Pass Island	5-7 Apr	otter trawl	136-220	1,665	53.1
2000-006	3Psb	Pool's Cove, FB	17-19 Apr	line-trawl	60-112	752	55.0
2000-007	3Psc	inner Placentia Bay	26 Apr - 6 May	handline	16-50	2,494	60.5
2000-008	3Psc	inner Placentia Bay	27 Apr - 4 May	otter trawl	30-107	528	59.2
2000-033	3Psc	Bar Haven, PB	5-12 Nov.	handline	33-55	1,165	59.0
2000-034	3Psc	Saturday Ledge, PB	10-12 Nov.	otter trawl	35-55	792	58.7
2000-035	3Psc	Eastern Channel, PB	13-15 Nov.	handline	35-63	1,212	58.7
2001-001	3Psb	Pool's Cove, FB	9-11 Jan.	handline	55-92	200	57.5
2001-002	3Psb	Pool's Cove, FB	9-11 Jan.	linetrawl	73-92	388	56.1
2001-003	3Psh	Halibut Channel	12-14 Apr.	otter trawl	170-248	1,144	80.8
2001-006	3Psd/a	Burgeo Bank	15-17 Apr.	otter trawl	179	999	53.8
2001-007	3Psd	NW St. Pierre Bank	16-17 Apr.	otter trawl	186-193	666	89.0
2001-008	3Psb	Pass Island, FB	18 Apr.	otter trawl	178-224	477	54.8
2001-009	3Psb	Fortune Bay	25-26 Apr.	handline	50-185	60	52.8
2001-010	3Psc	inner Placentia Bay	28 Apr.-6 May	otter trawl	35-230	1,704	57.1
2001-011	3Psc	inner Placentia Bay	28 Apr.-7 May	handline	30-60	2,273	58.7
2002-001	3Psb	Pool's Cove, FB	8-10 Jan.	handline	31-69	408	54.2
2002-002	3Psb	Pool's Cove, FB	8-10 Jan.	linetrawl	60-76	223	55.4
2002-003	3Psh	Halibut Channel	11-18 Apr.	otter trawl	150-279	1,509	56.5
2002-004	3Psb	Pass Island, FB	13-14 Apr.	otter trawl	219-239	1,792	54.0
2002-006	3Psd	SE Burgeo Bank	14-15 Apr.	otter trawl	136-369	963	64.8
2002-007	3Psc	inner Placentia Bay	27 Apr.-7 May	handline	20-45	1,832	55.5
2002-008	3Psc	inner Placentia Bay	28 Apr.-7 May	otter trawl	17-48	1,399	56.4
2002-012	3Psb	Grand Bank, FB	18 Jun.	handline	67	138	52.0
2002-024	3Psc	inner Placentia Bay	12-18 Nov.	handline	29-51	1,676	55.6
2003-002	3Psh	Halibut Channel	12-13 Apr.	otter trawl	184-295	133	53.4
2003-003	3Psb	Pass Island, FB	14-15 Apr.	otter trawl	208-231	1,481	52.2
2003-004	3Psd	Burgeo Bank	15-16 Apr	otter trawl	277-347	878	63.0
2003-005	3Psc	Placentia Bay	28 Apr.-11 May	handline	14-70	3,427	55.5
2003-006	3Psb	Fortune Bay	16-22 Jun.	hand-line	39-80	1,384	54.0
2003-007	3Psb	Fortune Bay	16-22 Jun.	h'line/otter trawl	34-160	630	54.4
2003-008	3Psc	Placentia Bay	11-18 Nov.	handline	39-65	1,645	55.4
2003-009	3Psc	Placentia Bay	18-19 Nov.	otter trawl	74-145	634	53.6
2003-010	3Psh	Halibut Channel	9-10 Dec.	otter trawl	150-161	488	60.4
2003-011	3Psg	South St. Pierre Bank	10-Dec.	otter trawl	123-138	511	59.8
2004-002	3Psh	Halibut Channel	12-14 Dec.	otter trawl	138-157	1,747	61.7
2005-010	3Psh	Halibut Channel	16-17 Dec	otter trawl	139-149	1,490	64.9

Table 2A. Reported landings of cod from unit areas in NAFO Subdiv. 3Ps during 1997-2005.

Year	3Psa	3Psb	3Psc	3Psd	3Pse	3Psf	3Psg	3Psh	Totals
1997	1,191	1,791	4,956	256	110	90	0	1,314	9,708
1998	1,573	2,428	7,102	1,274	698	1,108	377	4,713	19,274
1999	2,697	3,206	11,654	873	360	2,856	804	2,109	24,558
2000	1,718	2,263	8,774	249	1,003	3,183	156	7,742	25,087
2001	1,273	2,398	5,853	343	262	1,404	120	3,349	15,002
2002	1,353	2,302	4,892	356	1,389	1,144	92	3,292	14,819
2003	1,328	2,536	4,825	234	1,401	1,358	171	3,408	15,261
2004	1,403	2,113	4,388	429	831	1,239	202	3,809	14,414
2005	1,286	2,070	4,175	512	1,303	1,922	130	3,326	14,724

Table 2B. Reported landings of cod from inshore unit areas in NAFO Divs. 3KL during 1998-2005. Most of the landings in 3Lb during 2003 were from a fish kill in Smith Sound, Trinity Bay during April. Total reported offshore landings have been < 50 t per annum.

Year	3Ka	3Kd	3Kh	3Ki	3La	3Lb	3Lf	3Lj	3Lq	Totals
1998	5	122	661	1,331	1,113	649	411	402	147	4,840
1999	24	205	1,100	2,299	1,462	1,686	702	698	268	8,444
2000	13	57	204	1,188	1,477	1,442	398	451	211	5,441
2001	27	184	440	1,117	1,546	2,042	592	486	434	6,868
2002	8	37	133	444	1,150	1,503	304	288	285	4,153
2003	4	6	14	32	74	853	19	11	28	1,041
2004	1	4	26	119	161	140	70	86	23	629
2005	12	33	133	326	188	217	127	132	35	1,220

Table 2C. Reported landings of cod from unit areas in NAFO Subdiv. 3Pn and Divs. 4RS during 1997-2005.

Year	3PN	4Rd	4Rc	4Rb	4Ra	4Sv	4Sw	4Sxyz	Totals
1997	2,006	299	593	600	806	141	327	20	4,792
1998	870	636	281	367	387	61	476	33	3,111
1999	1,165	944	908	1,478	1,551	124	632	88	6,890
2000	1,478	800	728	1,439	1,215	180	660	140	6,640
2001	1,740	717	995	1,269	1,310	252	570	81	6,934
2002	1,713	591	795	1,377	1,172	123	686	69	6,526
2003	35	59	14	55	20	19	60	13	276
2004	727	335	288	609	569	97	433	54	3,112
2005	812	783	441	698	967	278	293	21	4,294

Table 3. Annual summary of reported recaptures (all tag types combined) for cod tagged and released in NAFO Subdiv. 3Ps during 1997-2005 (PB=Placentia Bay, FB=Fortune Bay, HB=Hermitage Bay) and recaptured during 1997-2006.

Year & expt no.	DFO Stat. area	Area of release	Dates of release	Number tagged	Reported recaptures										
					1997	1998	1999	2000	2001	2002	2003	2004	2005	unk'n	
1997-001	3Psc	Bar Haven, NW PB	9-12 Apr.	996	78	69	72	36	8	3	1	0	1	10	
1997-002	3Psc	Clattice Hbr., NW PB	10 Apr.	966	91	42	54	26	7	5	5	0	0	6	
1997-004	3Psc	Bar Haven, NW PB	17-18 May	817	103	43	84	49	5	5	0	1	0	8	
1997-005	3Psc	St. Bride's, SE PB	25-28 May	709	27	46	86	43	8	1	1	1	0	7	
1997-006	3Psc	Oderin Bank, W PB	24-26 Jun.	963	16	57	36	16	10	1	1	1	0	6	
1997-008	3Psc	Lord's Cove, SW PB	25 Jun.-18 Jul.	794	28	69	50	26	13	3	2	0	0	3	
1997-015	3Psc	Iona Islands, E PB	6-8 Nov.	784	0	39	89	32	9	2	0	0	1	7	
Total					6029	343	365	471	228	60	20	10	3	2	3
1998-001	3Psh	Halibut Channel	2-5 Apr.	1842	.	24	23	16	7	4	2	0	2	3	
1998-002	3Psd	Hermitage Channel	5-7 Apr.	1352	.	39	50	20	10	3	0	2	1	4	
1998-003	3Psc	Bar Haven, NW PB	22-25 April	2073	.	125	313	143	35	9	4	1	1	18	
1998-004	3Psc	Paradise Sound, W PB	27-29 April	1212	.	152	192	101	20	4	6	1	0	17	
1998-005	3Psc	Wareham Rock, NW PB	May 1-3	1037	.	81	208	93	25	6	6	2	1	14	
1998-006	3Psb	Pool's Cove, FB	May 20-29	938	.	87	91	43	25	13	3	2	1	1	
1998-008	3Psc	Bar Haven, NW PB	19-24 Oct.	511	.	6	80	39	22	9	3	1	0	1	
1998-009	3Psc	Eastern Channel, PB	17-22 Oct.	883	.	29	103	86	38	19	6	2	0	12	
Total					9848	543	1060	541	182	67	30	11	6	70	
1999-001	3Psh	Halibut Channel	1-3 Apr.	1808	.	.	39	46	20	14	6	4	0	2	
1999-002	3Psd	Hermitage Channel	4-7 Apr.	464	.	.	29	12	2	6	1	0	0	0	
1999-003	3Psb	South of Pass Island, FB	8 Apr.	1293	.	.	76	60	31	18	5	3	0	2	
1999-004	3Psc	head of Placentia Bay	29 Apr.-7 May	2422	.	.	402	276	110	34	14	2	4	34	
1999-039	3Psc	head of Placentia Bay	8-17 Nov	2152	.	.	68	371	124	44	10	4	2	31	
1999-043	3Psa	Hermitage Bay	30 Nov-1 Dec	57	.	.	1	6	2	1	0	1	0	1	
Total					8196	.	615	771	289	117	36	14	6	70	
2000-001	3Psh	Halibut Channel	1-7 Apr	1044	.	.	.	2	12	2	2	2	1	0	
2000-003	3Psd	Burgeo Bank	4-Apr	5	.	.	.	0	0	0	0	0	0	0	
2000-004	3Psb	Pass Island	5-7 Apr	1665	.	.	.	92	45	46	28	7	4	2	
2000-006	3Psb	Pool's Cove, FB	17-19 Apr	752	.	.	.	60	63	34	19	4	2	6	
2000-007	3Psc	inner Placentia Bay	26 Apr - 6 May	2494	.	.	.	314	273	107	28	10	12	32	
2000-008	3Psc	inner Placentia Bay	27 Apr - 4 May	528	.	.	.	66	42	26	15	5	1	6	
2000-033	3Psc	Bar Haven, PB	5-12 Nov.	1165	.	.	.	43	153	40	15	11	2	10	
2000-034	3Psc	Saturday Ledge, PB	10-12 Nov.	792	.	.	.	41	80	45	17	3	3	12	
2000-035	3Psc	Eastern Channel, PB	13-15 Nov.	1212	.	.	.	50	129	40	30	4	7	12	
Total					9657	.	.	668	797	340	154	46	32	80	
2001-001	3Psb	Pool's Cove, FB	9-11 Jan.	200	.	.	.	.	25	14	8	3	0	1
2001-002	3Psb	Pool's Cove, FB	9-11 Jan.	388	.	.	.	.	52	27	12	4	3	3
2001-003	3Psh	Halibut Channel	12-14 Apr.	1144	.	.	.	.	10	13	7	2	6	1
2001-006	3Psd/a	Burgeo Bank	15-17 Apr.	999	.	.	.	.	56	32	7	8	9	1
2001-007	3Psd	NW St. Pierre Bank	16-17 Apr.	666	.	.	.	.	25	9	3	1	3	4
2001-008	3Psb	Pass Island, FB	18 Apr.	477	.	.	.	.	14	15	10	2	1	1
2001-009	3Psb	Fortune Bay	25-26 Apr.	60	.	.	.	.	4	5	2	2	0	0
2001-010	3Psc	inner Placentia Bay	28 Apr.-6 May	1704	.	.	.	.	217	175	85	21	20	26
2001-011	3Psc	inner Placentia Bay	28 Apr.-7 May	2273	.	.	.	.	326	190	70	18	13	25
2001-025	3Psa	Ramea	1 Aug.	7	.	.	.	.	0	1	0	0	0	0
2001-027	3Psc	inner Placentia Bay	22 Nov.	350	.	.	.	.	5	48	19	6	4	3
Total					8268	.	.	.	734	529	223	67	59	65	
2002-001	3Psb	Pool's Cove, FB	8-10 Jan.	408	.	.	.	.	.	35	37	10	5	3
2002-002	3Psb	Pool's Cove, FB	8-10 Jan.	222	.	.	.	.	.	31	19	4	3	1
2002-003	3Psh	Halibut Channel	11-18 Apr.	1509	.	.	.	.	.	13	14	9	6	0
2002-004	3Psb	Pass Island, FB	13-14 Apr.	1792	.	.	.	.	.	47	36	25	7	0
2002-006	3Psd	SE Burgeo Bank	14-15 Apr.	963	.	.	.	.	.	13	7	4	6	0
2002-007	3Psc	inner Placentia Bay	27 Apr.-7 May	1832	.	.	.	.	.	219	197	65	24	11
2002-008	3Psc	inner Placentia Bay	28 Apr.-7 May	1399	.	.	.	.	.	188	172	53	35	14
2002-012	3Psb	Grand Bank, FB	18 Jun.	138	.	.	.	.	.	9	4	5	1	0
2002-024	3Psc	inner Placentia Bay	12-18 Nov	1676	.	.	.	.	.	71	189	102	47	8
Total					9939	.	.	.	.	626	675	277	134	37
2003-002	3Psh	Halibut Channel	12-13 Apr.	133	.	.	.	.	.	.	2	1	1	0
2003-003	3Psb	Pass Island, FB	14-15 Apr.	1481	.	.	.	.	.	.	58	50	49	2
2003-004	3Psd	Burgeo Bank	15-16 Apr	878	.	.	.	.	.	.	9	12	4	0
2003-005	3Psc	Placentia Bay	28 Apr.-11 May	3427	.	.	.	.	.	.	476	295	166	27
2003-006	3Psb	Fortune Bay	16-22 Jun.	1384	.	.	.	.	.	.	80	84	44	3
2003-007	3Psb	Fortune Bay	17-27 Jun.	630	.	.	.	.	.	.	17	20	17	0
2003-008	3Psc	inner Placentia Bay	11-18 Nov	1645	.	.	.	.	.	.	37	138	88	10
2003-009	3Psc	inner Placentia Bay	18-19 Nov	634	.	.	.	.	.	.	6	24	35	7
2003-010	3Psh	Halibut Channel	9-10 Dec.	488	.	.	.	.	.	.	1	6	9	0
2003-011	3Psg	South St. Pierre Bank	10-Dec.	511	.	.	.	.	.	.	0	10	8	0
Total					11211	.	.	.	.	.	686	640	421	49
2004-002	3Psh	Halibut Channel	12-14 Dec	1747	.	.	.	.	.	.	.	1	54	0
2005-010	3Psh	Halibut Channel	16-17 Dec	1490	.	.	.	.	.	.	.	.	1	0

Table 4. Annual estimates of exploitation (harvest rates) by experiment for cod tagged in NAFO Subdiv. 3Ps during 1997-2004. Recaptures were adjusted to account for reporting rate and releases were adjusted to account for tagging mortality, tag loss and assumed natural mortality (0.2 per year). Dark shaded cells represent estimates for experiments conducted during the fishing season and account for only a portion of exploitation in the year of release. Boxed cells (light shading) indicate values used to compute annual means for each area of release. See text for further details.

DFO Stat. area	Year & expt no.	Area of release	Dates	Number tagged	Reported annual landings (t)									
					9,045	19,694	28,111	25,100	15,460	14,819	15,260	14,414	14,768	
					Exploitation rates (% harvested)									
					1997	1998	1999	2000	2001	2002	2003	2004	2005	
3Psa	1999-043	Hermitage Bay	30 Nov-1 Dec	57	.	.	4.0	22.1	18.9	23.9	0.0	24.9	0.0	
"	2001-025	Ramea	1-Aug	7	.	.	.	.	0.0	41.1	0.0	0.0	0.0
Annual mean exploitation								22.1	18.9	15.7	0.0	22.1	0.0	
3Psb	1998-006	Poole's Cove, FB	20-29 May	938	.	12.1	24.7	15.3	17.9	13.1	1.8	5.4	0.0	
"	1999-003	Pass Island, FB	8-Apr	1293	.	.	10.8	10.8	8.2	6.3	2.3	2.0	0.0	
"	2000-004	Pass Island	5-7 Apr	1665	.	.	.	8.4	5.9	8.8	6.7	2.9	2.1	
"	2000-006	Poole's Cove, FB	17-19 Apr	752	.	.	.	13.6	19.4	18.1	13.3	5.7	2.9	
"	2001-001	Poole's Cove, FB	9-11 Jan	200	.	.	.	.	26.3	25.8	29.6	16.7	0.0
"	2001-002	Poole's Cove, FB	9-11 Jan	388	.	.	.	.	29.6	28.5	20.7	10.8	12.0
"	2001-008	Pass Island, FB	18-Apr	477	.	.	.	.	4.6	6.5	6.6	1.6	1.0
"	2001-009	Fortune Bay	25-26 Apr	60	.	.	.	.	10.5	16.6	10.3	16.0	0.0
"	2002-001	Poole's Cove, FB	8-10 Jan	408	.	.	.	.	.	20.0	31.0	16.1	11.4
"	2002-002	Poole's Cove, FB	8-10 Jan	222	.	.	.	.	.	29.4	32.6	13.7	13.9
"	2002-004	Pass Island, FB	13-14 Apr	1792	.	.	.	.	.	3.9	4.2	3.8	1.4
"	2002-012	Grand Bank, FB	18-Jun	138	.	.	.	.	.	9.6	6.2	11.6	3.3
"	2003-003	Pass Island, FB	14-15 Apr	1481	.	.	.	.	.	.	6.2	7.4	9.8
"	2003-006	Fortune Bay	16-22 Jun	1384	.	.	.	.	.	.	8.2	12.8	9.9
"	2003-007	Fortune Bay	16-22 Jun	630	.	.	.	.	.	.	3.9	6.8	7.6
Annual mean exploitation						12.1	16.6	11.3	11.3	11.8	10.7	8.4	9.4	
3Psc	1997-001	Bar Haven, NW PB	9-12 Apr	996	14.6	19.3	31.1	17.8	11.9	6.8	0.0	0.0	5.7	
"	1997-002	Clattice Hbr., NW PB	10-Apr	966	12.0	9.8	20.9	14.5	6.9	5.5	5.1	0.0	0.0	
"	1997-004	Bar Haven, NW PB	17-18 May	817	17.4	13.2	33.9	37.0	0.0	4.3	0.0	0.0	0.0	
"	1997-005	St. Bride's, SE PB	25-28 May	709	6.8	18.1	55.1	59.0	12.2	24.9	0.0	0.0	0.0	
"	1997-006	Oderin Bank, W PB	24-26 Jun	963	2.6	12.0	14.5	7.1	7.6	0.0	0.0	0.0	0.0	
"	1997-008	Lord's Cove, SW PB	25 Jun-18 Jul	793	6.7	22.9	29.8	22.8	8.9	11.2	0.0	0.0	0.0	
"	1997-015	Iona Islands, E PB	6-8 Nov	778	0.0	12.8	40.1	19.2	11.1	6.2	0.0	0.0	0.0	
"	1998-003	Bar Haven, NW PB	22-25 Apr	2073	.	10.1	37.7	25.4	9.8	2.7	2.3	0.0	1.8	
"	1998-004	Paradise Sound, W PB	27-29 Apr	1212	.	21.6	40.3	41.0	16.9	2.5	14.9	4.1	0.0	
"	1998-005	Wareham Rock, NW PB	1-3 May	1037	.	13.8	48.0	45.2	18.3	3.6	12.2	12.1	0.0	
"	1998-008	Bar Haven, NW PB	19-24 Oct	511	.	2.4	38.6	25.4	41.9	19.4	8.0	11.8	0.0	
"	1998-009	Eastern Channel, PB	17-22 Oct	883	.	4.6	28.4	31.3	26.8	26.0	16.3	6.1	0.0	
"	1999-004	inner Placentia Bay	29 Apr-7 May	2422	.	.	33.8	33.5	26.8	13.9	8.1	1.5	4.3	
"	1999-039	inner Placentia Bay	8-17 Nov	2152	.	.	5.8	38.5	27.4	16.6	5.3	3.7	1.1	
"	2000-007	inner Placentia Bay	26 Apr - 6 May	2494	.	.	.	21.2	29.6	18.0	7.2	3.9	5.6	
"	2000-008	inner Placentia Bay	27 Apr - 4 May	528	.	.	.	19.0	22.9	20.5	20.6	7.9	3.5	
"	2000-033	Bar Haven, PB	5-12 Nov	1165	.	.	.	5.3	30.9	16.7	8.6	8.6	2.4	
"	2000-034	Saturday Ledge, PB	10-12 Nov	792	.	.	.	8.9	27.3	26.6	16.8	4.4	5.4	
"	2000-035	Eastern Channel, PB	13-15 Nov	1212	.	.	.	6.8	26.4	15.4	15.8	3.2	7.5	
"	2001-010	inner Placentia Bay	28 Apr-6 May	1704	.	.	.	.	22.4	29.1	24.2	10.1	12.8
"	2001-011	inner Placentia Bay	28 Apr-7 May	2273	.	.	.	.	24.5	24.2	15.3	5.3	5.1
"	2001-027	western Channel, PB	22-23 Nov	350	.	.	.	.	2.3	34.1	26.6	13.3	12.4
"	2002-007	inner Placentia Bay	27 Apr - 7 May	1832	.	.	.	.	.	19.8	29.4	17.0	8.9
"	2002-008	inner Placentia Bay	28 Apr - 7 May	1399	.	.	.	.	.	22.7	36.1	21.5	21.9
"	2002-024	inner Placentia Bay	12-18 Nov	1676	.	.	.	.	.	6.8	29.0	27.4	22.0
"	2003-005	inner Placentia Bay	28 Apr-11 May	3427	.	.	.	.	.	.	22.3	24.4	20.9
"	2003-008	inner Placentia Bay	11-18 Nov	1645	.	.	.	.	.	.	3.8	20.9	21.3
"	2003-009	inner Placentia Bay	18-19 Nov	634	.	.	.	.	.	.	1.8	10.7	18.7
Annual mean exploitation					14.5	14.8	34.6	31.3	26.7	21.8	24.9	21.9	20.8	
3Psd	1998-002	Hermitage Channel	5-7 Apr	1352	.	5.1	8.7	3.9	3.5	1.1	0.0	1.2	1.0	
"	1999-002	Hermitage Channel	4-7 Apr	464	.	.	10.4	6.5	1.3	5.8	1.1	0.0	0.0	
"	2001-006	Burgeo Bank	15-17 Apr	999	.	.	.	.	12.1	9.6	2.3	4.0	6.5
"	2001-007	NW St. Pierre Bank	16-17 Apr	666	.	.	.	.	6.3	4.1	1.7	0.5	1.9
"	2002-006	SE Burgeo Bank	14-15 Apr	963	.	.	.	.	.	2.5	1.9	1.2	3.2
"	2003-004	Burgeo Bank	15-16 Apr	878	.	.	.	.	.	.	1.9	3.1	1.3
Annual mean exploitation						5.1	9.1	4.6	7.9	5.6	2.0	2.1	1.3	
3Psh	1998-001	Halibut Channel	2-5 Apr	1842	.	2.1	3.1	2.8	1.0	0.5	0.6	0.0	0.6	
"	1999-001	Halibut Channel	1-3 Apr	1808	.	.	4.0	6.3	3.4	2.8	1.2	1.5	0.0	
"	2000-001	Halibut Channel	1-7 Apr	1044	.	.	.	0.4	2.5	0.4	0.4	1.1	0.7	
"	2001-003	Halibut Channel	12-14 Apr	1144	.	.	.	.	1.5	2.4	1.6	0.6	2.1
"	2002-003	Halibut Channel	11-18 Apr	1509	.	.	.	.	.	1.5	1.8	1.5	1.6
"	2003-002	Halibut Channel	12-13 Apr	133	.	.	.	.	.	.	2.3	1.6	2.4
"	2003-010	Halibut Channel	9-10 Dec.	488	.	.	.	.	.	.	0.3	2.6	5.3
3Psg	2003-011	South St. Pierre Bank	10-Dec.	511	.	.	.	.	.	.	0.0	4.0	4.0
3Psh	2004-002	Halibut Channel	12-14 Dec.	1747	.	.	.	.	.	.	.	0.0	6.0
"	2005-010	Halibut Channel	16-17 Dec	1490	.	.	.	.	.	.	.	.	0.1
Annual mean exploitation						2.1	3.5	3.6	2.6	1.5	1.7	2.2	5.5	

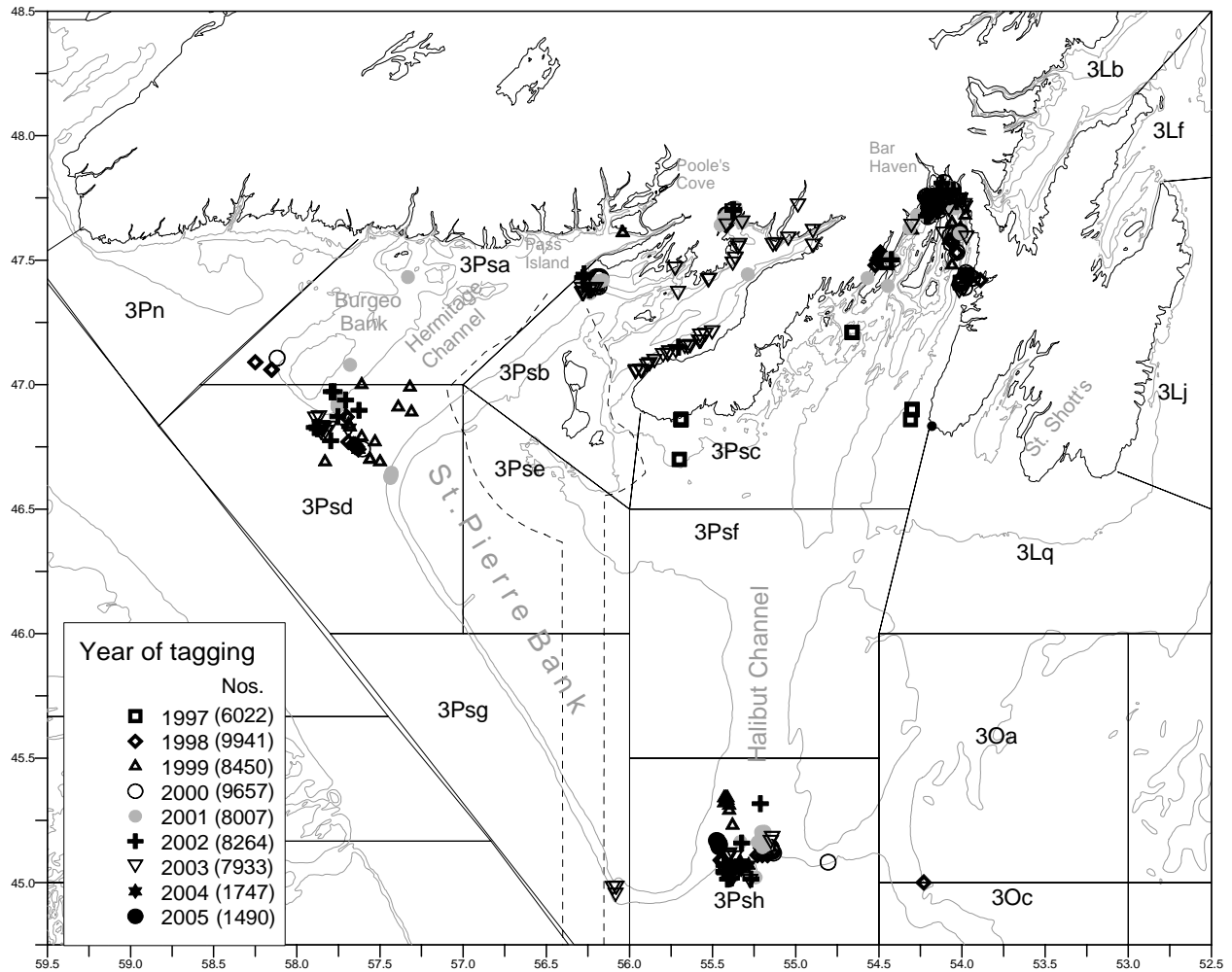


Fig. 1. Locations and total numbers of cod tagged each year off southern Newfoundland during 1997-2005, boundaries of unit areas, 100 m and 200 m depth contours (grey lines), and boundary of French economic zone (dashed line).

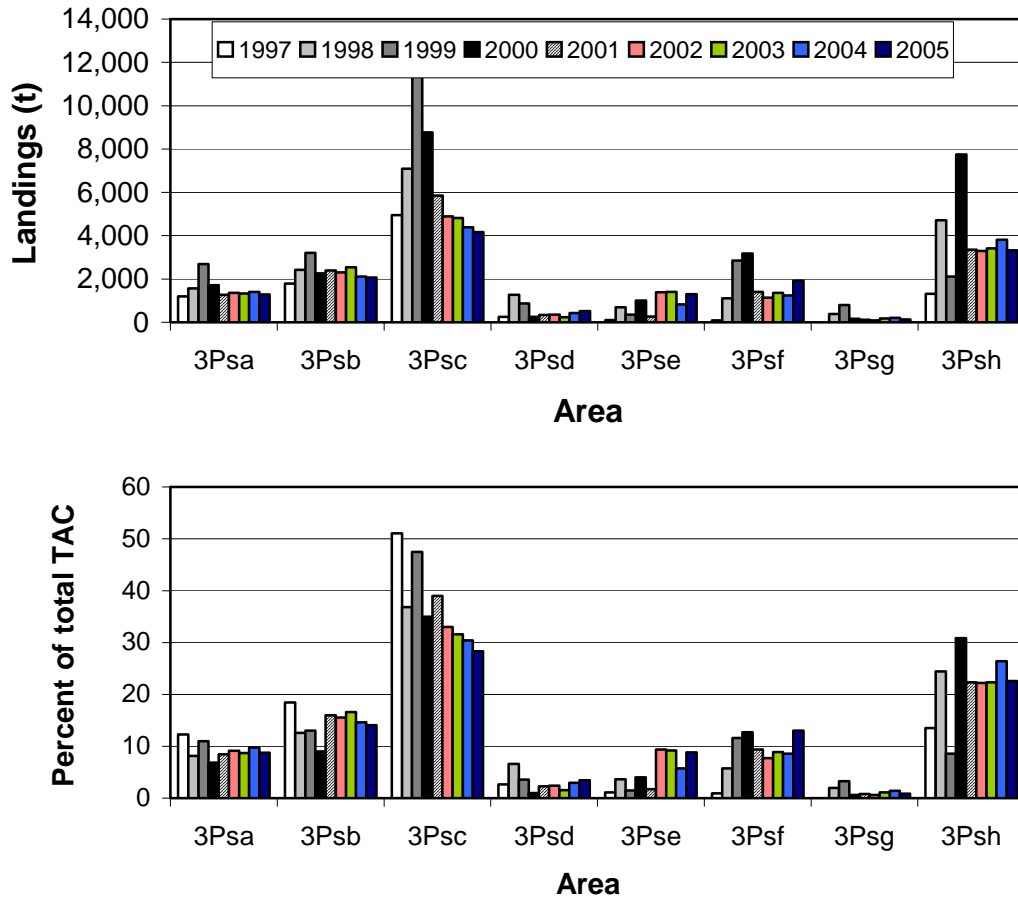


Fig. 2. Annual reported landings of cod by unit area from NAFO Subdiv. 3Ps during 1997-2005.

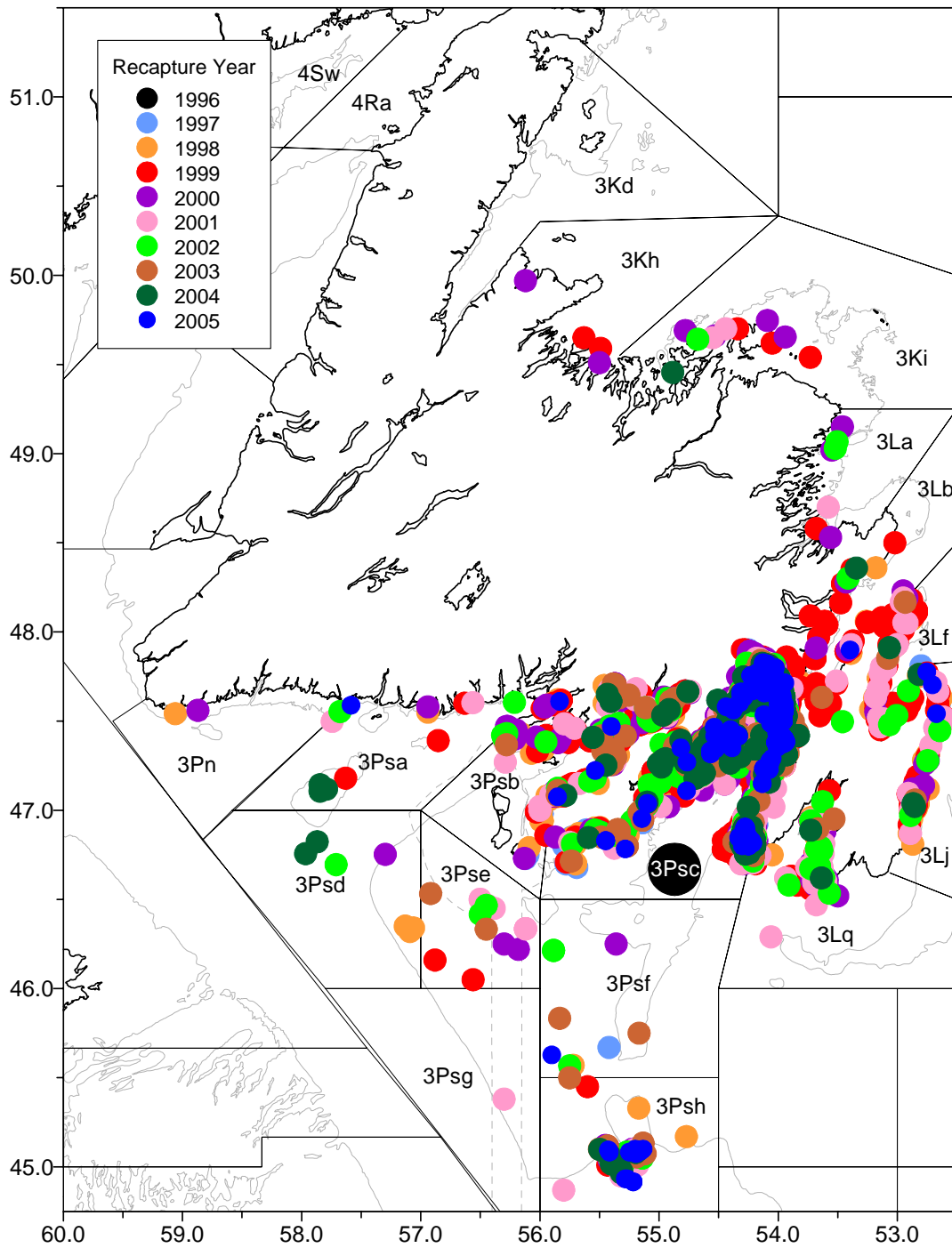


Fig. 3. Reported recapture positions for cod tagged and released in 3Psc (Placentia Bay) during 1996-2005 (>9,000 recaptures). Boundaries of statistical unit areas (solid lines), the 200 m depth contour (grey line) and French economic zone surrounding St. Pierre and Miquelon (dashed line) are also shown.

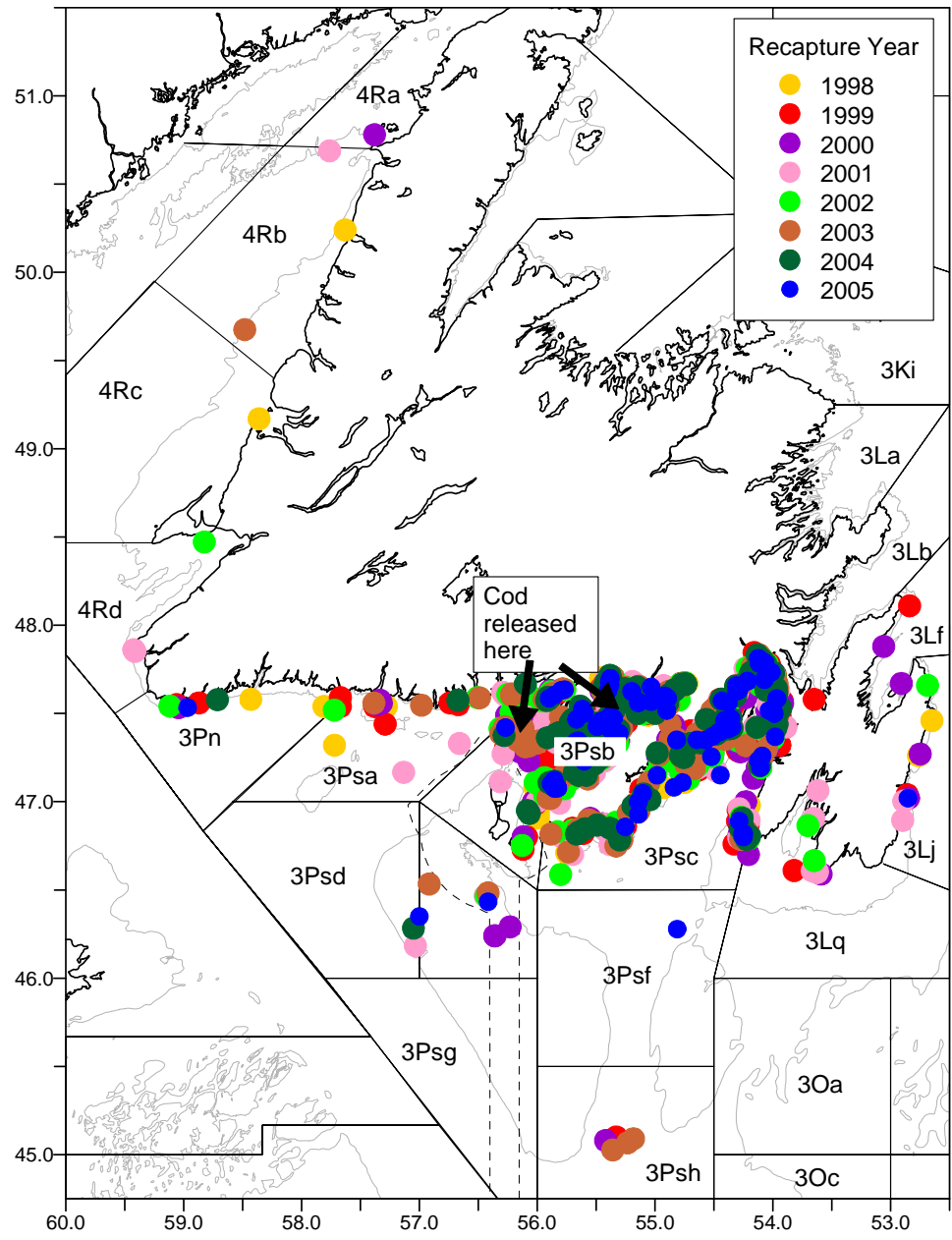


Fig. 4. Reported recapture positions for cod tagged and released in 3Psb (Fortune Bay) during 1999-2004 (>1,500 recaptures). Boundaries of statistical unit areas (solid lines), the 200 m depth contour (grey line) and French economic zone surrounding St. Pierre and Miquelon (dashed line) are also shown.

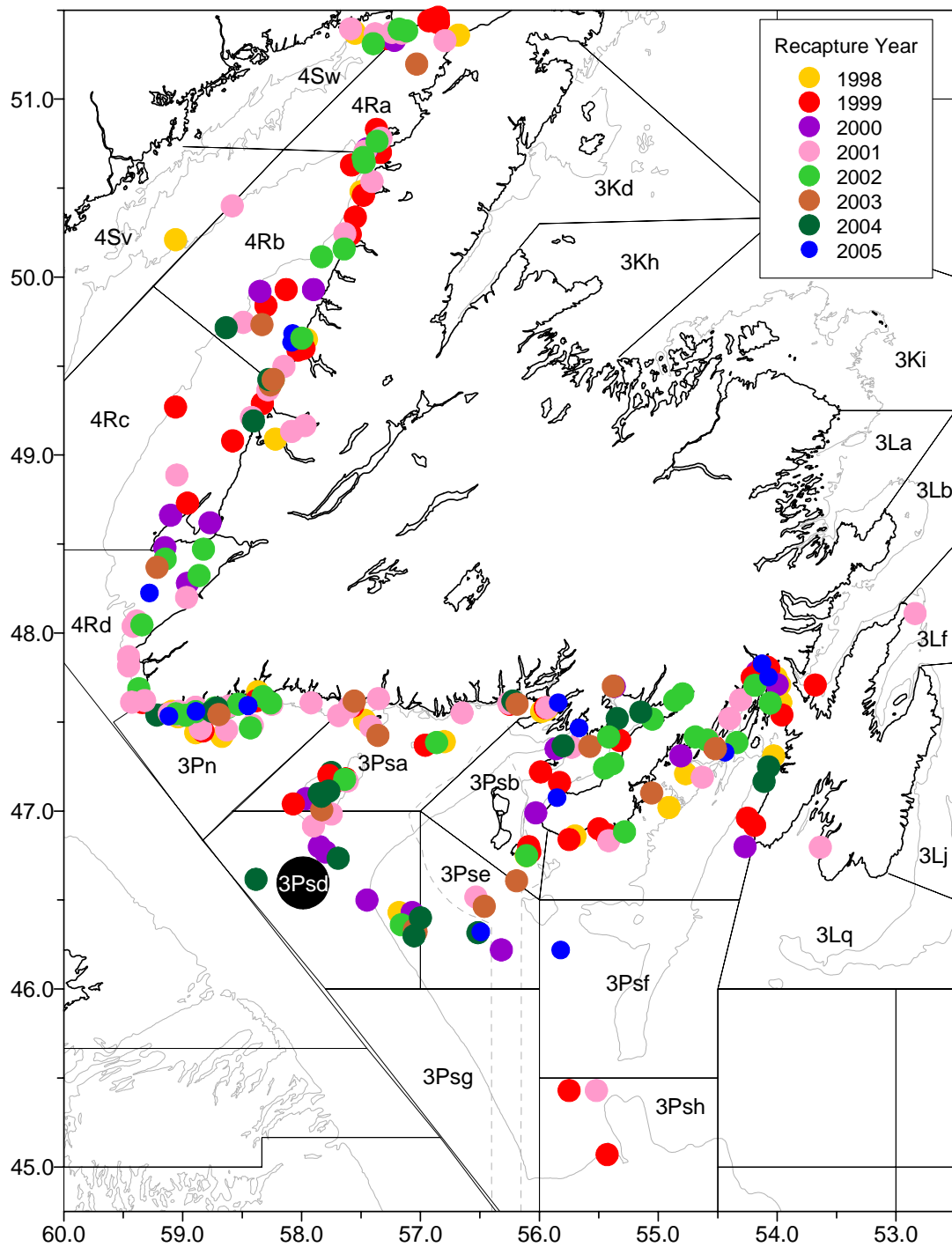


Fig. 5. Reported recapture positions for cod tagged and released in 3Psd (Burgeo Bank) during 1998-2003 (~277 recaptures). Boundaries of statistical unit areas (solid lines), the 200 m depth contour (grey line) and French economic zone surrounding St. Pierre and Miquelon (dashed line) are also shown. Returns from cod tagged on NW St. Pierre Bank are excluded.

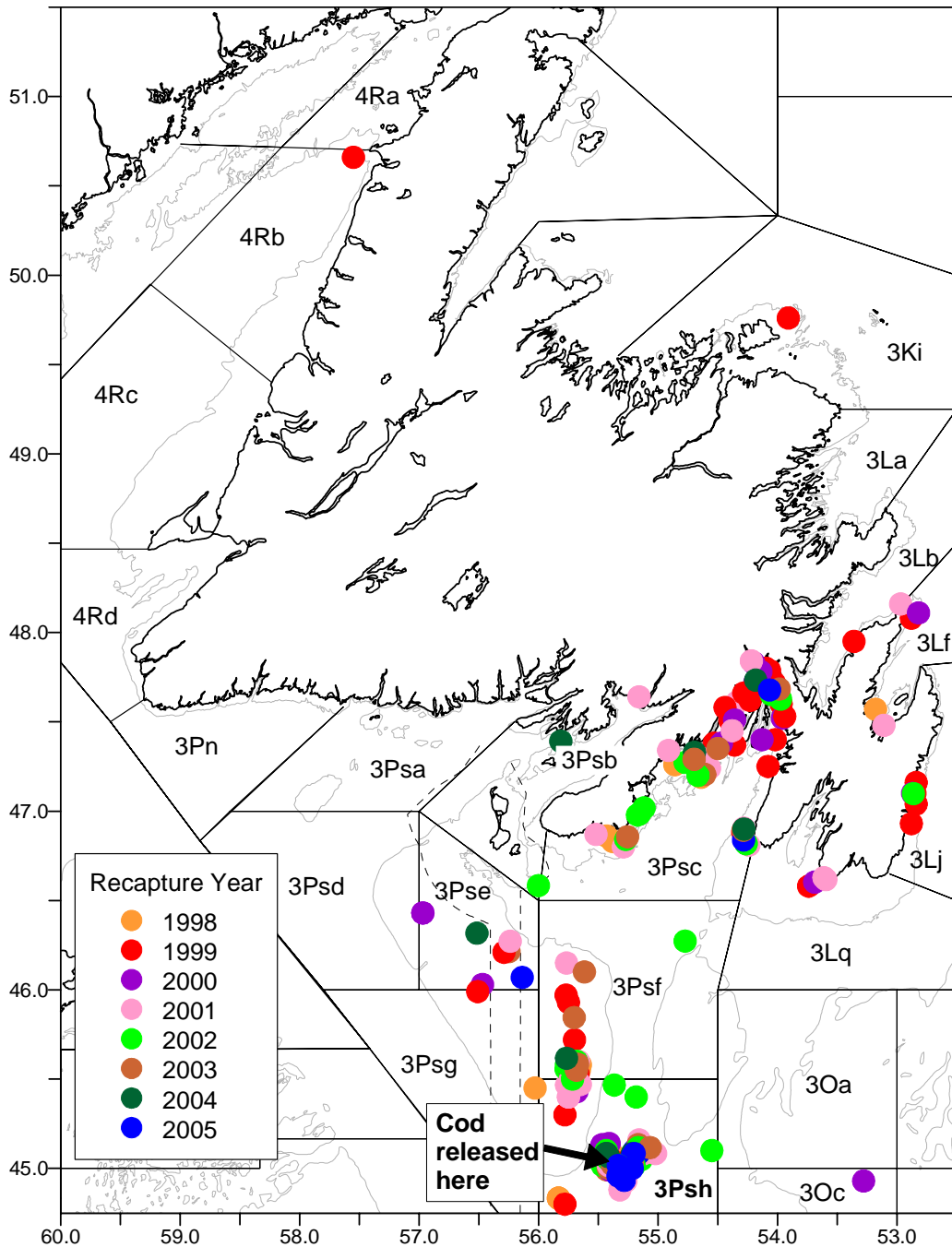


Fig 6. Reported recapture positions for cod tagged and released in 3Psh (Halibut Channel) during April 1998-2003 (~226 recaptures). Boundaries of statistical unit areas (solid lines), 200 m depth contour (grey lines), and French economic zone surrounding St. Pierre and Miquelon (dashed line) are also shown.

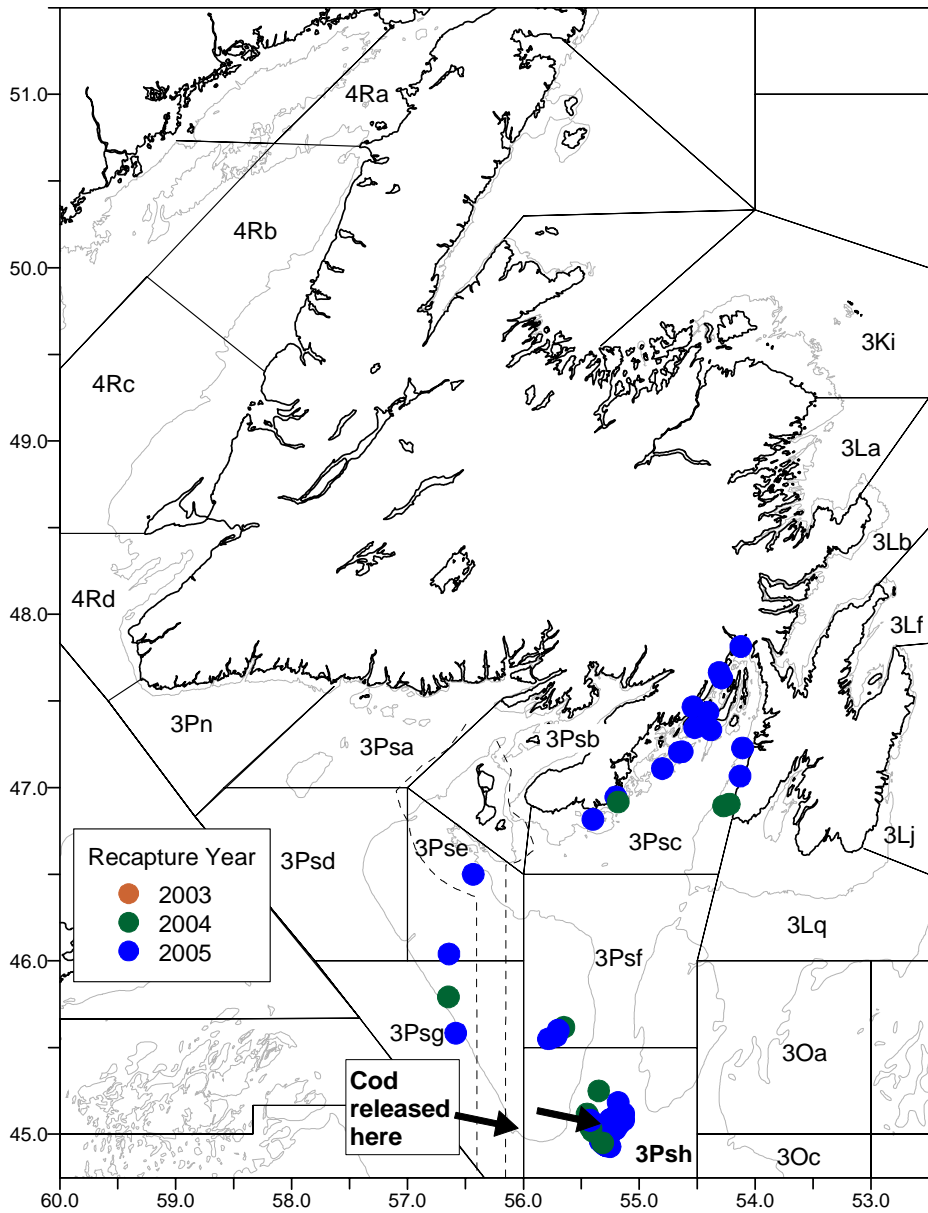


Fig 7 . Reported recapture positions for cod tagged and released in 3Psg/h (Halibut Channel) during December 2003-2005 (~75 recaptures). Boundaries of statistical unit areas (solid lines), 200 m depth contour (grey lines), and French economic zone surrounding St. Pierre and Miquelon (dashed line) are also shown.