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Age composition, growth and maturity of cod in inshore waters of Subdivision 3Ps as determined from sentinel surveys (1995-1997)

by

G.R. Lilly, J. Brattey and M.B. Davis

Science Branch, Department of Fisheries and Oceans
PO Box 5667, St John's, Newfoundland
Canada, A1C 5X1

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Abstract

Samples of cod (Gadus morhua) caught during sentinel surveys in Subdivision 3Ps during 1995-1997 provided information on age compositions, lengths-at-age and age at 50% maturity. Age compositions and lengths-at-age varied by gear, season, year and possibly unit area. There is a possibility that cod caught in Placentia Bay (3Psc) differ somewhat in biological characteristics from cod to the west of the Burin Peninsula (3Psa and 3Psb). Comparisons between cod sampled in the inshore during sentinel surveys and cod sampled in the offshore during research vessel bottom-trawl surveys are difficult because of differences in timing and the paucity of young fish in sentinel catches, but any differences appear to be small.

Résumé

Des échantillons de morue (Gadus morhua) prélevés au cours des relevés par pêches sentinelles dans la sous-division 3Ps de 1995 à 1997 ont permis d'obtenir des renseignements sur la composition par âges, la longueur selon l'âge et l'âge à la maturité (50 %). La composition par âges et la longueur selon l'âge variaient par engin, saison, année et, peut-être, zone unitaire. Il est possible que la morue capturée dans la baie Placentia (3Psc) présentent des caractéristiques biologiques quelque peu différentes de celles de la morue de l'ouest de la péninsule Burin (3Psa et 3Psb). La comparaison des morues des relevés côtiers par pêches sentinelles et des relevés hauturiers au chalut de fond par navires de recherche, s'avère difficile car les relevés n'ont pas été réalisés aux mêmes moments et les pêches sentinelles n'ont permis la capture que de très peu de jeunes poissons, mais les écarts semblent quand même faibles.

Introduction

Sentinel surveys for Atlantic cod (Gadus morhua) were conducted in the inshore of Subdivision 3Ps at various times from winter 1995 to autumn 1997 (Davis MS 1995; Davis and Jarvis MS 1996). Cod sampled from these surveys provide biological information on fish that are landward of the sampling conducted during the standard research vessel bottom-trawl surveys.

Catches from the sentinel surveys have been included with all other landings in the analysis of catch at age and mean weight-at-age for those fish caught in 3Ps in 1995-1997 (Shelton et al. MS 1996; Stansbury et al. MS 1998). This paper uses sentinel survey data alone to explore variability in age compositions and length-at-age associated with gear, area and time. In addition, the length-at-age and age at maturity of cod caught in the inshore are compared with those of cod caught during the offshore survey.

Materials and Methods

Surveys and sampling

Sentinel surveys were conducted by fishing enterprises operating from many communities (Fig. 1) in Subdivision 3Ps. The primary goal of these surveys was to determine catch rates on traditional fishing grounds, primarily with linetrawls and gillnets, but also to a much lesser extent with traps.

Participants

The primary collectors of data in the sentinel survey are inshore fishermen. The process of participant selection was as follows.

Through consultation with fishermen and fisheries organizations, traditional inshore fishing grounds were identified and mapped.

In the autumn of 1994, communities within the boundaries of the identified coastal areas were advised via the media and word-of-mouth of sentinel information meetings. The objective of the meetings was to present the scientific and administrative rationale and structure for the project. A representative from one or both of the project sponsoring organization and the Department of Fisheries and Oceans (DFO) Science Branch attended the meetings.

Fishermen who met eligibility criteria were invited to apply to participate in the survey. The criteria included five years as head of a fishing enterprise and a willingness to participate in a six week science training program.

Where more than one application was received from an area, the project sponsor conducted a draw or lottery to select the participant. While there was considerable interest in the project in

most areas, there were many sites from which only one application was received and others where additional canvassing was required in order to enlist participants.

In order to minimize inter-annual enterprise effects on data collection, participants are expected to remain with the survey over a number of years. It is also expected that most of the sampling activities will continue once commercial fishing activities resume and the sentinel participants will form a core of index fishermen.

Training

In order to establish a standardized data collection routine, provide a rationale for the data collection methods and establish an initial and thorough point of contact, a science training program was developed jointly by DFO and the Marine Institute of Memorial University of Newfoundland in the eighteen months prior to the start of the Sentinel Survey.

One person from each sentinel survey crew participated in a six week training course prior to commencing survey activities. The training course provided an introduction to data collection, sampling methods and tools and the use of computers and electronic oceanographic monitoring instruments. Participants also received overviews of the ocean environment, resource management and presentation/communication skills.

Sampling

In 1995, sampling ran for a maximum of thirty-five weeks. Sampling was conducted at 12 sites from February to July and 15 sites from July to December. In 1996 sampling was conducted over twelve weeks at eighteen sites. In 1997, sampling was again conducted over twelve weeks but at sixteen sites. The timing of sampling was determined after discussions with fish harvesters but was targeted for seasonally appropriate times based on historical fishing patterns. While constrained by the number of sampling weeks, an effort was made to sample during the same period each year.

Cod Traps

Three of the sites were designated for use with cod traps. The specific location of each trap site was chosen after consultation between DFO scientists, fishermen and the Fish, Food and Allied Workers Union (FFAW). Site selection was based on the need to survey throughout inshore areas and targeted historical fishing areas using the historical patterns of gear use.

Designated trap crews fished cod traps for a maximum period of five weeks and then switched to either baited linetrawls or gillnets for an additional period of seven weeks.

Trap crews fished five days per week for five weeks. Fishing days in the week were selected at the discretion of the crew and depended primarily on weather conditions. All berths selected for traps were considered prime trap locations.

When a trap was hauled, the crew noted the soak time since the previous haul and estimated how much fish had been caught. On three days each week they removed a sample of approximately 100 fish for biological sampling and released the remaining catch. Meshed fish and dead or floating fish were retained and brought ashore but were not included in the samples. While it is acknowledged that Japanese style cod traps could have higher mortalities of fish than modified Newfoundland traps, fish harvesters were asked to release as much live fish as possible.

Gillnets and Linetrawls

Both gillnet and linetrawl crews fished up to three days per week. All fish caught in gillnets and on hooks were landed.

Gillnet crews fished 2-6 fifty fathom 140 mm (5½ inch) monofilament gill nets. The nets were rigged 2-3 to a fleet. In most cases, they were fished in two nets per fleet, with one fleet fished at a control site (see below) and one fleet at each of two experimental sites. If catches exceeded 500-700 kg per week, the number of nets in a fleet was reduced. However, some consideration was given to bottom topography and net performance when reducing the number of nets in a fleet.

Linetrawl crews fished a maximum of 1000 hooks per day. These were deployed at the control site and one or two experimental sites. The number of hooks per tub was reduced if landings exceeded 500-750 kg per week

Sampling Strategy

Prior to the start of sampling with gillnets and linetrawls, a fixed (control) location on the fishing grounds was established for each site for the duration of the project. The control site was a location that was chosen to reflect average fishing activity over a fishing season. It is expected that the same control site will be occupied over years. Since fishing grounds and gear usage may change depending on season, a sentinel participant may use different gears at different times of the year, and there may be a control site for each gear type.

Each fishing day, up to half of the gear was set at the control site. The remainder (experimental) was set anywhere on the fishing grounds at the discretion of the crew. The location of each fishing set was plotted on a nautical chart. The time of the set and the soak time for the gear was recorded to the quarter hour. If high catch rates were experienced at one experimental location on a particular day, set locations were moved for the following fishing day. Environmental observations were recorded and included wind direction and speed, percent cloud cover, tide conditions, presence of invertebrates (bait) and other fish species in the area, marine mammals, sea birds and any other variable which may have influenced fishing behavior.

When the gear was retrieved, any catches from the control and experimental gear were kept separate and sampled on shore. All fish were counted, measured (fork length in cm), sexed, and examined for parasites. Otoliths were sampled based on length frequency requirements.

At selected sites, a sample of up to 100 fish was collected every other week, frozen and transported to St. John's for detailed observations (see below). All sampling information was recorded on forms similar to those used by the Port Sampling Section and on the research vessels. Otoliths were stored in manila envelopes with relevant information recorded on the outside. Fin clips were stored on blotter paper in the envelopes.

Other biological samples were collected on an "as needed" basis. These included fin clips and/or blood samples for genetic studies and liver samples for toxicological studies.

DFO staff from the Fisheries Evaluation Section and the Commercial Sampling Section provided field support through weekly visits to sites and regular phone contact. Project sponsors maintained regular contact with participants for administrative support and scientific liaison.

Handling of frozen fish

To obtain detailed information on maturity, condition and feeding of the cod, the frozen samples were transported to the Northwest Atlantic Fisheries Centre in St. John's, where they were thawed in fresh water and weighed (to the nearest 10 g) before being cut (round weight) and again after removal of the organs from the abdominal cavity (gutted weight). The stage of maturity was assessed based on visual examination of the gonads and fish were assigned to the category 'mature' or 'immature' based on criteria described by Templeman et al. (1978). The first stage in this scheme is classified as immature and all other stages show some evidence of maturing to spawn or of having spawned in the current year and are classed as mature. The 'other' or unknown' category was excluded from the analyses of maturity data. The gonad and liver were weighed (g). The stomach was weighed and put aside for detailed analysis of contents. The otoliths were saved and added to those collected in the field (Table 1). The number of fish that were sampled for length, age and body weights is provided in Table 2.

A few points are noted for those who might wish to repeat our analyses. (i) Those fish that were frozen for detailed analysis in the laboratory were not included in the length-frequencies. We have added them to the frequencies for all analyses of catch composition and length-at-age. (ii) Fishing enterprises fished at control (fixed) sites, which did not vary over time, and experimental sites, which might change on a daily basis. Information on depth and position (latitude and longitude) of fishing was recorded only on the length-frequency forms. Because the electronic record for fish taken for the detailed analysis does not indicate whether the fish was taken from the control (fixed) site or an experimental site, it is not possible at present to match each fish with a specific length-frequency. (There are also some instances where length-frequencies do not exist for the date on which the detailed sample was taken.) Hence, the depth and position at which the fish were caught is not currently available. (iii) The otolith samples came from collections made directly by fishing enterprises and from those fish that were frozen for detailed sampling in the laboratory. The electronic record for those fish sampled directly by the fishing enterprises lacks information for either the fishing enterprise or the community from which the enterprise operated. Thus, the smallest spatial area for which there is an adequate sample size for aging of fish is the commercial unit area (Fig. 2). That is, it is not possible to aggregate on the basis of community or fishing ground.

Data analyses

Age composition and length-at-age

To examine temporal and spatial variability in age composition and mean length-at-age, basic length-frequency and aging samples were combined into gear-area-time cells, where the gears were linetrawls, gillnets and traps, the areas were commercial unit areas (Fig. 2) and the time periods were one month or 2-3 adjacent months. The normal practice of weighting each length-frequency by the ratio of the landing weight to the sample weight (see, for example, Gavaris and Gavaris 1983) was not necessary for linetrawls and gillnets because the total catch was measured. In the case of traps, where usually only a sample was obtained, each frequency could have been weighted by the estimated catch, but that was not done for the present analyses. Analyses were conducted only for gear-area-time cells with an arbitrary minimum sample size of 100 aged fish. The length-frequencies and aging samples were combined into 3-cm groups before analyses. In almost all instances there were a few individuals toward either end of the length frequency that were of a length not represented in the aged sample. Therefore, the age compositions may underrepresent and possibly even miss ages toward either end of the range. In addition, the estimated length-at-age of ages toward either end of the range may not accurately reflect the length-at-age of individuals in the catch.

In the analyses of gillnet data, only length frequencies from the standard gillnet mesh size (140 mm) were selected. The mesh size is not recorded in the aging data base, so any age samples from gillnets of other mesh size could not be excluded at this time.

Age at maturity

Maturity data from the sentinel surveys were obtained from the frozen samples (Table 3) and grouped into three geographic areas; Hermitage Bay (3Psa), Fortune Bay (3Psb), and Placentia Bay (3Psc). Maturity data from spring research bottom-trawl surveys in the offshore of Subdivision 3Ps from 1995 to 1997 were examined for comparison. Fish in the research vessel samples were examined fresh. For those samples collected from the sentinel survey during August -December, one year was added to the age and the year because the fish collected at that time were maturing to spawn in the following calendar year. Sentinel samples collected during the autumn were therefore compared with sentinel and bottom-trawl samples from the following spring.

The methodology used here to analyze maturity data was essentially as described by Morgan and Hoenig (1997), Morgan and Shelton (MS 1995) and Morgan and Brattey (1997). Because of the length-stratified collection of otoliths during research vessel surveys, the calculation of proportion mature at age included a weighting by the female population number at length (Morgan and Hoenig 1997). The sentinel data were also collected in a length-stratified manner so the proportions were weighted by the length frequency of the catch. Estimates of the observed proportion mature at age were tabulated. Age at 50% maturity (A50) and 95% confidence limits were produced using Probit analyses with a logit link function (SAS Institute Inc. 1989).

Parameter estimates and their standard errors are also given using the numbers of otoliths as the sample size.

Results

Age composition of the catch

The age-composition of the catch may vary depending on the type of gear and the time and location of deployment. The influence of gear type on age composition may be explored by deploying various gears at the same time and place, but this has not yet been done within the sentinel survey program. However, some appreciation of the possible magnitude of the variability may be obtained by examining the data available from trap, linetrawl and gillnet catches in summer and early autumn in 3Psc in 1996. The length frequencies from these gears were dissimilar, with traps and linetrawls having relatively broad distributions characterized by long descending tails and gillnets having narrower distributions (Fig. 3). Average fish size increased from trap (49 cm) to linetrawl (56 cm) to gillnet (64-66 cm) (Table 4). Age compositions were also dissimilar, with trap taking the youngest fish, dominated by 4-year-olds, and gillnets taking the oldest fish, dominated by 6- and 7-year-olds (Table 4). The 1989 year-class, which appears from most analyses to be strong relative to adjacent year-classes (Stansbury et al. MS 1998), was weakly represented in the trap catch (7%) but represented about one third of the gillnet catch.

To examine temporal variability in catch at age by a given gear, age compositions were calculated for periods of 1 month or 2 adjacent months for linetrawl catches in 3Psa and 3Psb (Tables 5 and 6) and gillnet catches in 3Psc (Table 7). The age compositions varied somewhat over periods of just 2-3 months. For example, in the 1995 linetrawl catches in 3Psa and 3Psb, the contribution of age 5 fish decreased and the contribution of age 8 fish increased in May-June compared to both the previous winter and the following autumn. Such changes may be due to several factors. For example, fish move about over time, so that the survey at a specific site may not necessarily exploit the same group of fish during adjacent months. In addition, the sampling pattern within each unit area may vary over time, so that the contribution by each community to the total catch and the age sample may vary among months. Variability over longer time periods is also apparent. On a seasonal basis, there was an increase in the representation of younger fish in the autumn compared to the previous winter-spring. This is probably due primarily to growth of individual fish. On the time-scale of years, it is possible to see the entry and passage of specific year-classes. For example, the contribution of the 1992 year-class increased during the three years of study whereas the contribution of the 1989 year-class decreased.

To examine spatial variability in catch at age, data from linetrawl catches were aggregated for the months September to November for each of the three commercial unit areas in each year (Table 8; Fig. 4). The 1989 year-class was more prominent in the west (3Psa) than in the east (3Psc).

Length-at-age

The influence of gear type on estimates of length-at-age is illustrated with data from 3Psc in 1996 (Table 4; Fig. 5). Lengths-at-age estimated from trap data were smaller than comparable estimates from linetrawl data. Much of the difference in this example may be due to individual fish growth between July when the trap catches were taken and September-October when the linetrawl catches were taken. Estimates of length-at-age from gillnet catches were higher than estimates from linetrawl catches. This is thought to be due primarily to the selection by gillnets for larger fish of a cohort, especially at ages 5-6, but there is also the possibility that gillnets were set at depths where larger fish were present.

An introduction to seasonal changes in length-at-age is available from the sampling of linetrawl catches in 1995. It was expected that repeated sampling within the inshore environment might reveal the seasonal pattern of growth in length, but in both 3Psa and 3Psb there was an apparent decline in mean length-at-age for several age-groups during spring (Tables 5 and 6). This may be caused by the movement of different groups of fish into or out of the areas, or may simply be an artifact of the sampling.

To examine spatial variability in length-at-age, data from linetrawl catches were aggregated for the months September to November for each of the three commercial unit areas and each year (Table 8). There is an indication that length-at-age is very similar in 3Psa and 3Psb but greater in 3Psc (Fig. 6).

To determine whether lengths-at-age of the cod caught in the inshore by sentinel surveys were different from those of cod caught in the offshore by the research trawl (Lilly MS 1998), data were selected from sampling in spring 1995, which is the only period when the sentinel surveys were operating at the same time as the offshore survey. Lengths-at-age from cod in the offshore were very similar to those of cod taken by linetrawls, and both were less than those of cod caught in gillnets (Fig. 7).

Maturity

Age at maturity of cod by unit area and year, with a comparison of data from the spring offshore survey with sentinel sampling is given in Tables 9-11. Estimates of A_{50} for female cod were in general slightly higher for female cod compared to males (males mature at younger ages). The estimates ranged from 4.2 to 5.2 for males and from 4.2 to 5.1 for females with no indication of marked annual changes for either sex within the 3 yr time period. Many estimates from the sentinel survey are influenced by small sample sizes and lack of fish in the younger ages; consequently the model in some instances could not be fitted or parameter estimates have high standard errors. There is some indication of a decline in A_{50} from west to east in the sentinel survey samples; however, in most years the confidence intervals for A_{50} overlap, suggesting no major differences in maturity schedules between inshore areas or between the sentinel and trawl survey areas. Age at maturity remains low for the 3Ps stock relative to the values observed up to the mid-1980's (Brattey and Morgan MS 1996).

Discussion

Sampling during sentinel surveys has provided an opportunity for studying various aspects of the biology of cod in inshore waters of 3Ps during the moratorium years of 1995 and 1996 and at the same sites after fishing reopened in 1997. The sampling in 1995 was particularly informative because fishing operated over much of the calendar year and provided seasonal information on age compositions and lengths-at-age (present study) and condition and feeding (Lilly MS 1996). Fishing was much more limited in time in 1996 and 1997, so that data from 3Ps as a whole were much less informative about seasonal changes. Data from specific sites were even more limited. It may also be noted that the predominance of linetrawl and 140 mm gillnet in sentinel surveys has resulted in relatively few fish being caught at younger ages, so that it is difficult to obtain reliable estimates of age at maturity.

There is evidence of differences between fish caught to the west of the Burin Peninsula (3Psa and 3Psb) and fish caught in Placentia Bay (3Psc). The 1989 year-class seems to be more prominent in the west. In addition, cod in the west appear to grow more slowly, mature at a later age, and have lower condition in winter (Lilly MS 1996). These biological differences should be examined more thoroughly, both to determine if the differences are persistent over time and to improve our understanding of stock structure and productivity. One potential artifact that must be examined is the possibility that the higher proportion of mature fish at ages 4-6 in 3Psc may be caused in part by the selection of the faster growing fish within each year-class by the gillnets, which contributed more to the sampling in 3Psc than elsewhere.

Comparisons between fish caught inshore in the sentinel survey and fish caught offshore in the research vessel survey are difficult because of the difference in survey timing (April offshore and mainly summer/autumn inshore) and the paucity of small/young fish in the sentinel samples. Nevertheless, it appears that any differences between cod caught inshore and cod caught offshore are small.

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Table 1. Number of cod sampled for length and age from catches in the 3Ps sentinel surveys, by gear, year, commercial unit area and month. There are additional samples to be added for 1997.

Year	Unit	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Trap														
1996	3Psc						43	179						222
1997	3Psc							30						30
Total							43	209						252
Linetrawl														
1995	3Psa		46	61	182	185	55			90	51	82	26	778
	3Psb		24	118	159	243	155	25			117	209	112	1162
	3Psc			1		16	6		54		183	34	4	298
1996	3Psa							61	66	217	186	47	44	621
	3Psb	58								40	218	77	70	463
	3Psc	2							40	106	96			244
1997	3Psa	80	63	9						40	71			263
	3Psb	33												33
	3Psc						37							37
Total		173	133	189	341	444	253	86	160	493	922	449	256	3899
Gillnet														
1995	3Psb							71						71
	3Psc			64	19	199	183	94	77	38	78	159	57	968
1996	3Psb									60	73			133
	3Psc	100	47				4	166	71	114	47	94	102	745
1997	3Psc	56				61	55	95	61	49				377
Total		156	47	64	19	260	242	426	209	261	198	253	159	2294

Table 2. Number of cod sampled for length, age and body weight from catches in the 3Ps sentinel surveys, by gear, year, commercial unit area and month. There are additional samples to be added for 1997.

Year	Unit	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Trap														
1996	3Psc							29						29
Total								29						29
Linetrawl														
1995	3Psa		46	61	182	185	55			28	24	82	26	689
	3Psb		24	118	159	243	155	25			117	209	112	1162
	3Psc			1		16	6				136	34	4	197
1996	3Psa									81	76			157
	3Psb	58									102	77	36	273
	3Psc	2												2
1997	3Psa		21	9						40	71			141
	3Psb	33												33
Total		93	91	189	341	444	216	25		149	526	402	178	2654
Gillnet														
1995	3Psc			64	19	199	183	94		38	78	123	57	855
1996	3Psc	100	47					80	15	24	17	44	73	400
1997	3Psc					19		56		49				124
Total		100	47	64	19	218	183	230	15	111	95	167	130	1379

Table 3. Numbers of cod sampled for age and maturity during the Sentinel survey in NAFO subdiv. 3Ps.

Year	Gear	Area	Community	Month											
				Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
95	Line trawl	3Psa	Francois	0	22	21	61	74	16	0	0	28	0	31	26
			Ramea	0	24	40	121	111	39	0	0	0	24	51	0
		3Psb	Harbour Breton	0	0	16	45	75	96	25	0	0	44	112	20
			Rencontre	0	24	47	67	111	11	0	0	0	29	51	67
			Seal Cove	0	0	55	47	55	48	0	0	0	44	46	25
		3Psc	Arnold's Cove	0	0	1	0	16	6	0	0	0	2	4	4
			Lord's Cove	0	0	0	0	0	0	0	0	0	29	0	0
			Placentia	0	0	0	0	0	0	0	0	0	46	30	0
			Red Harbour	0	0	0	0	0	0	0	0	0	59	0	0
	Gill net	3Psc	Fox Harbour	0	0	0	0	4	33	34	0	0	0	0	0
			Little Harbour	0	0	8	0	77	73	0	0	12	39	34	23
			Lord's Cove	0	0	0	0	0	0	0	0	0	21	0	0
			Monkstown	0	0	3	19	80	27	12	0	16	18	0	0
			North Harbour	0	0	49	0	35	24	32	0	0	0	89	34

cont'd:

Table 3. Cont'd.

Year	Gear	Area	Community	Month											
				Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
			Placentia	0	0	4	0	0	0	0	0	0	0	0	0
			St. Bride's	0	0	0	0	3	26	6	16	0	10	0	0 0
1996	Line trawl	3Psa	Ramea	0	0	0	0	0	0	0	0	81	76	0	0
		3Psb	Harbour Breton	0	0	0	0	0	0	0	0	0	76	0	0
			Rencontre	58	0	0	0	0	0	0	0	0	26	77	36
		3Psc	Arnold's Cove	2	0	0	0	0	0	0	0	0	0	0	0
	Gill net	3Psc	Little Harbour	0	0	0	0	0	0	45	0	0	17	18	21
			North Harbour	100	47	0	0	0	0	0	0	0	0	26	52
			St. Bride's	0	0	0	0	0	0	35	15	24	0	0	0
	Cod trap	3Psc	Little Harbour	0	0	0	0	0	0	29	0	0	0	0	0
1997	Line trawl	3Psa	Ramea	0	21	9	0	0	0	0	0	40	71	0	0
		3Psb	Rencontre	33	0	0	0	0	0	0	0	0	0	0	0

Table 3. Cont'd.

Year	Gear	Area	Community	Month											
				Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1997	Gill net	3Psc	Monkstown	0	0	0	0	19	0	26	0	21	0	0	0
			St. Bride's	0	0	0	0	0	0	30	0	28	0	0	0

Table 4. Age composition and mean length-at-age of cod sampled from the catch from three gears in the sentinel survey in unit area 3Psc in summer and early autumn of 1996. Also provided for each gear-time cell are the mean and the 10th and 90th percentiles of the lengths of the fish, the number of fish aged, the number of fish caught, and the number of fish that were not assigned an age when the age-length key was applied to the length composition because they were of a length not represented in the aged sample. The highlighted cells in the age compositions indicate the 1989 year-class and highlighted cells in the lengths-at-age indicate values based on fewer than 5 aged fish.

	Trap	Linetrawl	Gillnet	
Age	July	Sep-Oct	Jul-Aug	Sep-Oct
Age composition of catch				
2		0.1		
3	3.9	5.6	0.2	0.1
4	52.3	27.5	1.0	0.3
5	12.9	20.3	6.0	9.5
6	19.7	23.3	38.2	48.3
7	**7.4**	**13.4**	**37.9**	**32.3**
8	2.1	6.0	11.4	7.4
9	1.5	3.3	4.4	1.0
10	0.3	0.6	0.6	0.6
11				0.2
12			0.3	0.4
13			0.0	
14		0.0		
Mean length-at-age				
2		**33.3**		
3	37.2	41.9	**42.6**	**39.4**
4	43.8	47.6	51.9	**52.3**
5	51.2	53.6	58.0	61.1
6	56.3	59.2	62.2	63.9
7	60.1	67.0	65.7	67.6
8	63.2	70.6	67.5	71.7
9	67.1	72.6	68.3	82.7
10	**64.0**	**74.5**	78.9	84.5
11				**81.8**
12			**80.7**	**73.0**
13			**103.0**	
14		**112.0**		
Mean length	48.9	56.2	64.2	65.7
10th - 90th	40-61	44-70	58-71	60-72
No. of fish aged	179	202	237	161
No. of fish caught	4454	9308	12151	5575
No. not represented	5	5	2	1

Table 5. Age composition and mean length-at-age of cod sampled from the linetrawl catch in the sentinel survey in unit area 3Psa during various months of 1995-1997. Also provided for each year-month cell are the mean and the 10th and 90th percentiles of the lengths of the fish, the number of fish aged, the number of fish caught, and the number of fish that were not assigned an age when the age-length key was applied to the length composition because they were of a length not represented in the aged sample. The highlighted cells in the age compositions indicate the 1989 year-class and highlighted cells in the lengths-at-age indicate values based on fewer than 5 aged fish.

	1995					1996			1997	
Age	Feb-Mar	Apr	May	Sep-Oct	Nov-Dec	Jul-Aug	Sep	Oct	Jan-Feb	Sep-Oct
Age composition of catch										
2							0.1	0.9		0.4
3	0.6	0.3		3.5	3.9	1.6	2.9	5.2	0.2	4.0
4	1.7	2.0	1.9	8.2	6.9	6.5	6.7	10.0	5.2	22.3
5	22.8	15.4	16.8	21.9	17.7	7.3	7.1	11.8	18.3	16.6
6	**53.6**	**56.7**	**52.2**	**55.4**	**52.1**	17.2	18.6	21.9	20.2	16.6
7	11.5	14.1	14.7	6.7	13.3	**45.0**	**49.6**	**39.4**	23.0	16.7
8	6.0	6.1	10.8	3.1	5.1	12.0	7.3	5.5	**23.6**	**22.9**
9	3.2	3.7	3.7	0.2	0.9	6.5	5.8	4.4	6.5	0.4
10	0.4	1.0		0.7		1.5	1.8	1.0	2.2	
11	0.3					1.7	0.1		0.7	
12		0.9				0.8				
13				0.2			0.1			
14										
Mean length-at-age										
2							**28.0**	**32.6**		**37.0**
3	**30.3**	**37.0**		36.8	38.5	**38.5**	38.9	39.9	**34.0**	38.5
4	**38.9**	43.0	**44.8**	44.0	46.7	44.5	45.0	45.7	41.0	46.7
5	48.5	47.7	49.8	50.0	52.2	50.1	49.7	51.0	51.5	51.9
6	58.0	56.1	57.2	59.5	56.5	61.1	56.0	58.3	56.8	57.2
7	61.6	59.0	63.2	65.3	63.7	64.3	63.9	64.0	61.0	59.1
8	63.7	64.2	66.1	73.3	61.6	65.7	63.7	66.1	67.9	64.7
9	63.7	68.6	65.8	**85.0**	**58.0**	68.1	68.7	67.6	66.1	**82.0**
10	**76.0**	**65.7**		**70.0**		63.8	71.2	**72.8**	**75.3**	
11	**79.0**					**70.4**	**94.0**		**67.0**	
12		**70.0**				**88.0**				
13				**85.0**			**103.0**			
14										
Mean length	56.3	56.5	58.3	56.4	56.6	61.8	60.0	58.3	59.6	55.4
10th - 90th	45-68	46-67	48-70	45-69	44-70	48-77	47-75	44-74	47-73	43-68
No. of fish aged	107	182	185	141	108	127	217	186	143	111
No. of fish caught	1528	2391	3858	7942	6261	4812	6088	4255	443	2979
No. not represented	33	62	75	43	262	20	27	23	1	46

Table 6. Age composition and mean length-at-age of cod sampled from the linetrawl catch in the sentinel survey in unit area 3Psb during various months of 1995-1996. Also provided for each year-month cell are the mean and the 10th and 90th percentiles of the lengths of the fish, the number of fish aged, the number of fish caught, and the number of fish that were not assigned an age when the age-length key was applied to the length composition because they were of a length not represented in the aged sample. The highlighted cells in the age compositions indicate the 1989 year-class and highlighted cells in the lengths-at-age indicate values based on fewer than 5 aged fish.

	1995							1996	
Age	Mar	Apr	May	Jun	Oct	Nov	Dec	Oct	Nov-Dec
Age composition of catch									
2						0.1		0.2	
3	1.0	2.3	0.69		5.7	4.6	4.1	2.5	5.28
4	4.2	6.9	2.15	2.7	11.5	7.2	11.3	16.8	16.61
5	28.3	33.6	21.08	18.0	37.9	26.1	37.2	13.5	17.57
6	**43.3**	**34.3**	**47.39**	**40.4**	**22.4**	**34.4**	**31.2**	26.0	28.13
7	14.2	9.5	13.97	11.2	16.7	12.6	7.2	**21.8**	**23.05**
8	6.5	10.2	11.87	22.1	5.7	10.5	8.2	10.0	4.04
9	1.7	2.4	1.63	3.8		1.7	0.1	5.0	3.45
10	0.8	0.8	1.02	0.2	0.1	2.2	0.8	1.9	0.74
11				1.5		0.6		1.9	0.74
12			0.2	0.2				0.3	0.27
13								0.2	
14									0.08
Mean length-at-age									
2						25.7		**31.0**	
3	**30.0**	**31.9**	**35.9**		38.5	38.2	39.1	38.0	41.4
4	**37.4**	39.3	40.2	**42.1**	44.9	46.1	47.0	44.6	46.7
5	46.7	46.8	46.9	48.8	53.3	52.9	54.1	51.5	55.3
6	55.5	54.3	54.5	56.8	60.0	57.7	59.7	58.3	58.7
7	61.6	59.0	58.8	62.4	63.6	65.8	60.4	64.6	62.8
8	63.8	61.2	62.2	65.4	64.6	65.1	63.6	65.6	70.4
9	**64.0**	**58.2**	68.9	76.1		**67.9**	**103.0**	70.1	72.3
10	**76.8**	**76.0**	**70.6**	**94.0**	**94.0**	**66.4**	**67.0**	67.5	**79.7**
11				**83.5**		**73.0**		70.0	83.7
12			**79.0**	**94.0**				**87.8**	**91.0**
13								**79.0**	
14									**88.0**
Mean length	54.3	51.9	54.5	59.2	55.6	57.1	56.0	57.7	57.5
10th - 90th	42-67	41-63	45-66	47-75	43-68	46-69	46-67	44-73	45-70
No. of fish aged	118	159	243	155	117	209	112	218	147
No. of fish caught	1190	1509	5613	2743	5063	8591	6768	5743	16337
No. not represented	22	16	30	72	40	46	69	2	27

Table 7. Age composition and mean length-at-age of cod sampled from the gillnet catch in the sentinel survey in unit area 3Psc during various months of 1995-1997. Also provided for each year-month cell are the mean and the 10th and 90th percentiles of the lengths of the fish, the number of fish aged, the number of fish caught, and the number of fish that were not assigned an age when the age-length key was applied to the length composition because they were of a length not represented in the aged sample. The highlighted cells in the age compositions indicate the 1989 year-class and highlighted cells in the lengths-at-age indicate values based on fewer than 5 aged fish.

	1995					1996				1997	
Age	May	Jun	Jul-Aug	Sep-Oct	Nov-Dec	Jan-Feb	Jul-Aug	Sep-Oct	Nov-Dec	May-Jun	Jul-Aug
Age composition of catch											
2											
3	0.0		0.0	0.1	0.1	0.0	0.2	0.1	0.2		0.1
4		0.0	0.0	0.7	0.5	1.7	1.0	0.3	2.1	0.4	1.2
5	6.8	12.8	21.2	8.4	29.4	1.8	6.0	9.5	11.8	6.1	18.9
6	**34.5**	**41.0**	**40.6**	**50.6**	**38.8**	18.6	38.2	48.3	36.6	9.2	21.7
7	33.5	29.2	24.4	23.5	20.6	**44.1**	**37.9**	**32.3**	**33.5**	54.4	33.9
8	21.3	11.0	12.6	15.1	9.7	15.5	11.4	7.4	13.1	**20.0**	**17.7**
9	3.0	4.1	1.3	1.1	0.9	17.7	4.4	1.0	2.6	6.5	5.2
10	0.3	2.0		0.6	0.1		0.6	0.6	0.1	2.1	0.3
11	0.3					0.7		0.2	0.1	1.1	0.9
12							0.3	0.4		0.1	
13	0.2						0.0				
14											
Mean length-at-age											
2											
3	**34.0**		**37.0**	**40.0**	44.1	**31.0**	**42.6**	**39.4**	40.9		37.4
4		**43.0**	**43.0**	**50.9**	52.7	40.0	51.9	**52.3**	56.5	**53.8**	52.1
5	61.0	57.6	58.2	60.7	62.8	49.4	58.0	61.1	60.7	60.1	57.3
6	62.3	60.4	61.0	64.2	66.1	62.2	62.2	63.9	65.2	63.2	59.1
7	65.0	63.2	63.7	66.4	67.6	66.2	65.7	67.6	67.9	63.9	63.5
8	68.5	67.2	65.0	65.8	69.8	66.6	67.5	71.7	69.6	67.1	68.4
9	73.5	69.4	**64.9**	79.6	75.8	70.8	68.3	82.7	75.1	72.5	71.3
10	**76.0**	71.4		**81.6**	**82.0**		78.9	84.5	**92.3**	80.0	**73.0**
11	**76.0**					**86.4**		**81.8**	**86.0**	**85.4**	**88.3**
12							**80.7**	**73.0**		**91.0**	
13	**85.0**						**103.0**				
14											
Mean length	64.8	62.1	61.7	64.8	65.9	65.7	64.2	65.7	66.2	65.3	62.9
10th - 90th	59-71	56-69	55-68	59-71	60-72	59-73	58-71	60-72	60-73	59-72	55-71
No. of fish aged	199	183	171	116	216	147	237	161	196	116	156
No. of fish caught	3342	5450	8641	8952	14254	4114	12151	5575	17844	4331	1781
No. not represented	33	52	39	42	65	3	2	1	4	2	9

Table 8. Age composition and mean length-at-age of cod sampled from the linetrawl catch in the sentinel survey in unit areas 3Psa, 3Psb and 3Psc during the autumn (September – November) of 1995-1997. Also provided for each year-area cell are the mean and the 10th and 90th percentiles of the lengths of the fish, the number of fish aged, the number of fish caught, and the number of fish that were not assigned an age when the age-length key was applied to the length composition because they were of a length not represented in the aged sample. The highlighted cells in the age compositions indicate the 1989 year-class and highlighted cells in the lengths-at-age indicate values based on fewer than 5 aged fish.

	1995			1996			1997
Age	3Psa	3Psb	3Psc	3Psa	3Psb	3Psc	3Psa
Age composition of catch							
2		0.1	0.2	0.6	0.2	0.1	0.4
3	4.1	4.6	4.5	3.9	3.5	4.5	4.0
4	8.8	8.9	9.6	8.6	13.6	23.2	22.3
5	18.6	30.5	36.1	10.2	14.7	19.0	16.6
6	**52.2**	**30.7**	**31.4**	19.2	28.9	24.9	16.6
7	10.1	13.3	8.2	**44.8**	**22.1**	**16.4**	16.7
8	4.8	9.1	6.5	6.6	8.9	7.3	**22.9**
9	0.7	1.1	3.1	4.7	5.1	3.9	0.4
10	0.4	1.4	0.0	1.3	1.2	0.7	
11		0.3	0.3	0.1	1.5		
12					0.2		
13	0.2			0.1	0.1		
14						0.0	
Mean length-at-age							
2		25.6	**37.0**	31.5	**30.2**	**33.2**	**37.0**
3	37.8	38.5	42.2	39.5	39.9	42.1	38.5
4	44.7	45.5	50.9	45.1	44.9	47.7	46.7
5	50.6	52.8	56.8	50.5	52.1	54.1	51.9
6	58.8	58.3	62.4	56.8	58.4	59.8	57.2
7	64.6	64.9	67.1	64.1	63.2	67.2	59.1
8	68.3	65.4	67.0	65.5	65.7	70.3	64.7
9	**66.6**	**67.9**	67.1	68.2	69.6	72.4	**82.0**
10	**70.0**	66.1	**94.0**	73.2	68.6	**74.4**	
11		**73.0**	**70.0**	**94.0**	72.6		
12					**86.9**		
13	**85.0**			**103.0**	**79.0**		
14						**112.0**	
Mean length	56.5	56.5	59.2	59.1	57.6	57.7	55.4
10th - 90th	45-69	45-68	50-69	45-74	44-71	45-71	43-68
No. of fish aged	223	326	217	450	335	202	111
No. of fish caught	13089	15633	18342	12321	17425	13969	2979
No. not represented	76	40	19	27	12	7	46

Table 9. Observed proportion mature at age of female and male Atlantic cod (Gadus morhua) in NAFO subdiv. 3Ps during 1995 spawning year. A50=median age at maturity (years); L95% and U95%=lower and upper 95% confidence intervals. Parameter estimates of the logit model are shown: Int=intercept, SE=standard error, n=number of fish examined, dot=no fish sampled, n/f indicates model could not be fitted.

Females

	Inshore sentinel (spring 95)			Offshore trawl survey (spring 95)
Age	3Psa	3Psb	3Psc	3Ps
2	.	.	.	0
3	0	0	0	0
4	0	0	0.50	0
5	0.51	0.67	0.92	0.51
6	0.79	0.89	1	0.79
7	0.93	0.98	1	0.97
8	0.96	0.98	1	0.96
9	1	1	1	1
10	1	1	1	1
11	1	1	1	1
12	1	1	.	1
A50	5.07	4.73	4.18	5.17
L 95%	4.69	4.42	2.58	4.92
U 95%	5.32	4.94	4.60	5.37
Slope	1.38	1.70	3.30	1.68
SE	0.21	0.23	1.13	0.23
Int	-6.97	-8.05	-13.82	-8.68
SE	1.38	1.23	5.58	1.26
n	307	408	262	288

Males

	Inshore sentinel (spring 95)			Offshore trawl survey (spring 95)
Age	3Psa	3Psb	3Psc	3Ps
2	.		.	0
3	0	0.23	.	0
4	0.39	0.44	.	0.31
5	0.68	0.73	0.96	0.70
6	0.83	0.94	1	0.91
7	0.96	0.98	1	0.94
8	0.91	1	1	1
9	1	1	1	1
10	1	1	1	1
11	.	.	1	1
12	.	.	.	1
A50	4.24	4.23	n/f	4.60
L 95%	2.40	3.72	n/f	4.28
U 95%	4.85	4.54	n/f	4.84
Slope	0.92	1.46	n/f	1.68
SE	0.25	0.23	n/f	0.23
Int	-3.89	-6.18	n/f	-7.74
SE	1.46	1.21	n/f	1.17
n	222	314	319	307

Table 10. Observed proportion mature at age of female and male Atlantic cod (Gadus morhua) in NAFO subdiv. 3Ps during 1996 spawning year. A50=median age at maturity (years); L95% and U95%=lower and upper 95% confidence intervals. Parameter estimates of the logit model are shown: Int=intercept, SE=standard error, n=number of fish examined, dot=no fish sampled, n/f indicates model could not be fitted.

Females

	Inshore sentinel (fall 95)			Offshore trawl survey (spring 96)	Inshore sentinel (spring 96)		
Age	3Psa	3Psb	3Psc	3Ps	3Psa	3Psb	3Psc
2	.	.	.	0	.	.	.
3	0	0	0	0	.	.	0
4	0.1	0	0.00	0.01	.	0	0.03
5	0.36	0.06	0.81	0.39	.	0.58	0.80
6	0.88	0.90	1	0.74	.	0.72	0.96
7	0.93	1.00	1	0.92	.	1	1
8	1.00	1.00	1	1	.	1	1
9	1	1	1	1	.	.	1
10	.	1	1	1	.	.	.
11	.	1	1	1	.	.	1
12	.	.	.	.	.	.	1
A50	5.19	5.04	n/f	5.54	.	5.36	4.76
L 95%	4.33	4.84	n/f	5.32	.	4.23	4.51
U 95%	5.65	5.23	n/f	5.74	.	6.00	5.01
Slope	1.73	3.02	n/f	1.98	.	2.21	3.70
SE	0.42	0.46	n/f	0.21	.	0.80	0.77
Int	-8.97	-15.21	n/f	-10.98	.	-11.84	-17.50
SE	2.51	2.36	n/f	1.21	.	4.53	3.69
n	85	221	254	415	.	27	142

Males

	Inshore sentinel (fall 95)			Offshore trawl survey (spring 96)	Inshore sentinel (spring 96)		
Age	3Psa	3Psb	3Psc	3Ps	3Psa	3Psb	3Psc
2	.	.	.	0	.	.	.
3	0	0.00	0	0	.	.	0
4	0.00	0.01	0.32	0.21	.	0.20	0.25
5	0.48	0.56	0.73	0.60	.	1	0.61
6	0.89	0.90	0.97	0.93	.	1	0.97
7	0.96	,98	1	0.93	.	1	1
8	1.00	1	1	1	.	1	1
9	1	1	1	1	.	.	1
10	1	1	1	1	.	.	.
11	.	1	1	1	.	.	1
12	.	1	1	1	.	.	.
A50	5.19	5.09	4.44	4.88	.	n/f	4.61
L 95%	4.57	4.87	3.95	4.66	.	n/f	4.26
U 95%	5.62	5.30	4.77	5.11	.	n/f	4.92
Slope	2.07	2.57	2.26	1.76	.	n/f	2.18
SE	0.49	0.37	0.45	0.17	.	n/f	0.43
Int	-10.74	-13.07	-10.03	-8.58	.	n/f	-10.06
SE	2.75	1.92	2.24	0.83	.	n/f	2.07
n	75	217	216	418	.	30	116

Table 11. Observed proportion mature at age of female and male Atlantic cod (Gadus morhua) in NAFO subdiv. 3Ps during 1997 spawning year. A50=median age at maturity (years); L95% and U95%=lower and upper 95% confidence intervals. Parameter estimates of the logit model are shown: Int=intercept, SE=standard error, n=number of fish examined, dot=no fish sampled, n/f indicates model could not be fitted.

Females

	Inshore sentinel (fall 96)			Offshore trawl survey (spring 97)	Inshore sentinel (spring 97)		
Age	3Psa	3Psb	3Psc	3Ps	3Psa	3Psb	3Psc
2	.	.	.	0	.	.	.
3	0	.	.	0	.	.	.
4	0	0.09	0.00	0.23	0	.	1.00
5	0.75	0.64	0.53	0.73	0.69	.	1.00
6	0.95	1	1	0.89	1	.	1.00
7	1	0.97	1	1	1	.	1
8	1	1	1	1	1	.	1
9	1	1	1	1	.	.	1
10	1	1	1	1	1	.	.
11	.	.	.	1	.	.	1
12	.	1	.	.	.	.	.
A50	4.84	4.81	n/f	4.64	n/f	.	n/f
L 95%	3.92	4.43	n/f	4.29	n/f	.	n/f
U 95%	5.47	5.15	n/f	5.05	n/f	.	n/f
Slope	3.99	2.26	n/f	2.45	n/f	.	n/f
SE	1.77	0.57	n/f	0.52	n/f	.	n/f
Int	-19.33	-10.89	n/f	-11.35	n/f	.	n/f
SE	8.66	2.81	n/f	2.35	n/f	.	n/f
n	86	111	85	150	17	0	39

Males

	Inshore sentinel (fall 96)			Offshore trawl survey (spring 97)	Inshore sentinel (spring 97)		
Age	3Psa	3Psb	3Psc	3Ps	3Psa	3Psb	3Psc
2	.	.	.	0	.	.	.
3	.	0	.	0.07	.	.	.
4	0.24	0	0.53	0.22	0	.	.
5	0.55	0.73	0.57	0.72	0.76	.	1.00
6	1	0.82	0.91	1	1	.	1.00
7	1	0.99	1	1	1	.	1
8	1	1	1	1	1	.	1
9	1	1	1	1	.	.	1
10	1	1	1	1	.	.	1
11	1	1	.	.	.	.	1
12	.	.	.	.	.	.	.
A50	4.69	4.83	4.52	4.46	n/f	.	n/f
L 95%	4.07	4.26	2.81	4.13	n/f	.	n/f
U 95%	5.21	5.20	5.13	4.91	n/f	.	n/f
Slope	2.22	1.98	1.75	2.15	n/f	.	n/f
SE	0.7	0.5	0.55	0.41	n/f	.	n/f
Int	-10.42	-9.56	-7.91	-9.58	n/f	.	n/f
SE	3.38	2.61	3.03	1.72	n/f	.	n/f
n	71	103	88	165	13	0	36

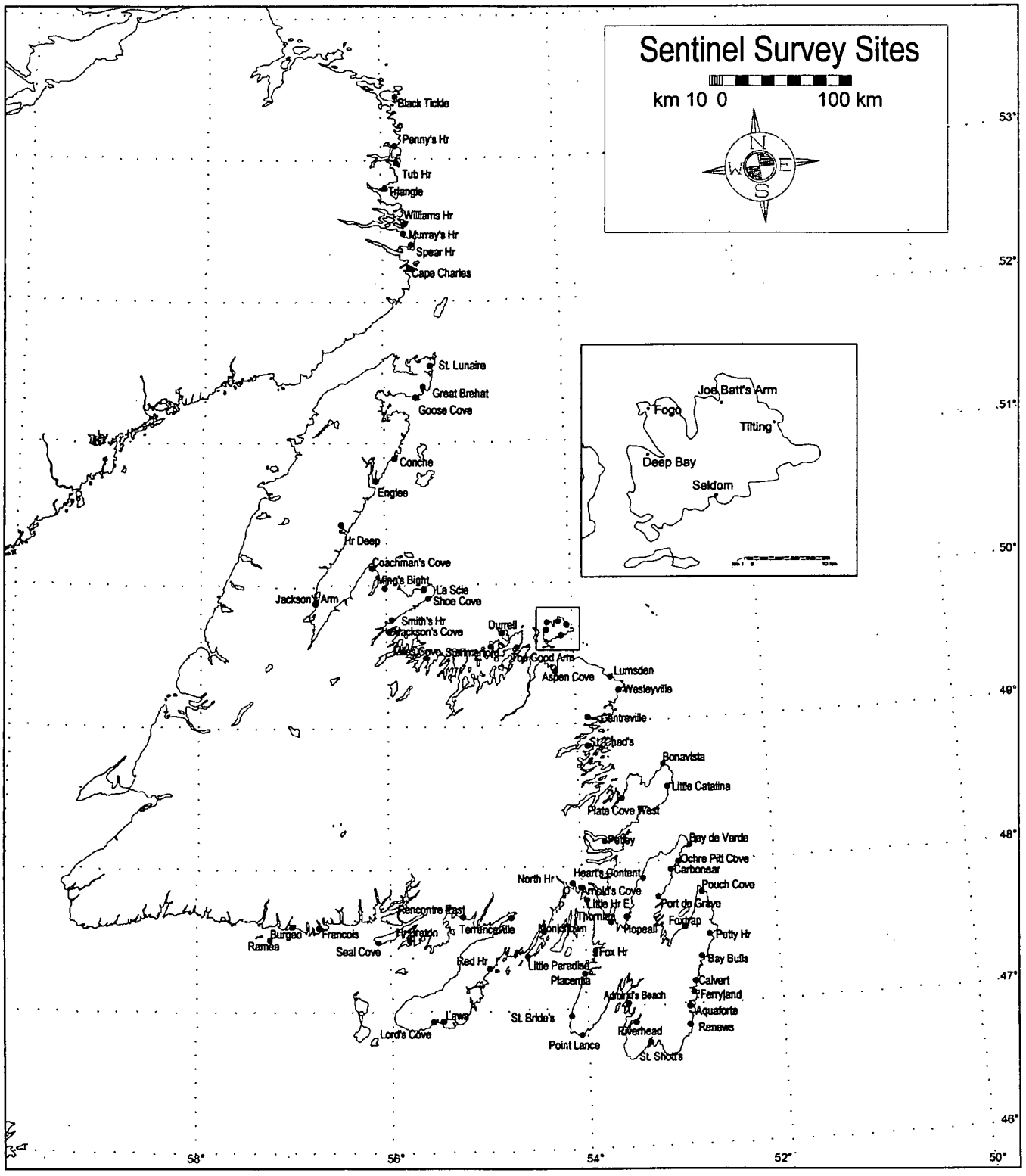

Fig. 1. Sentinel survey sites.

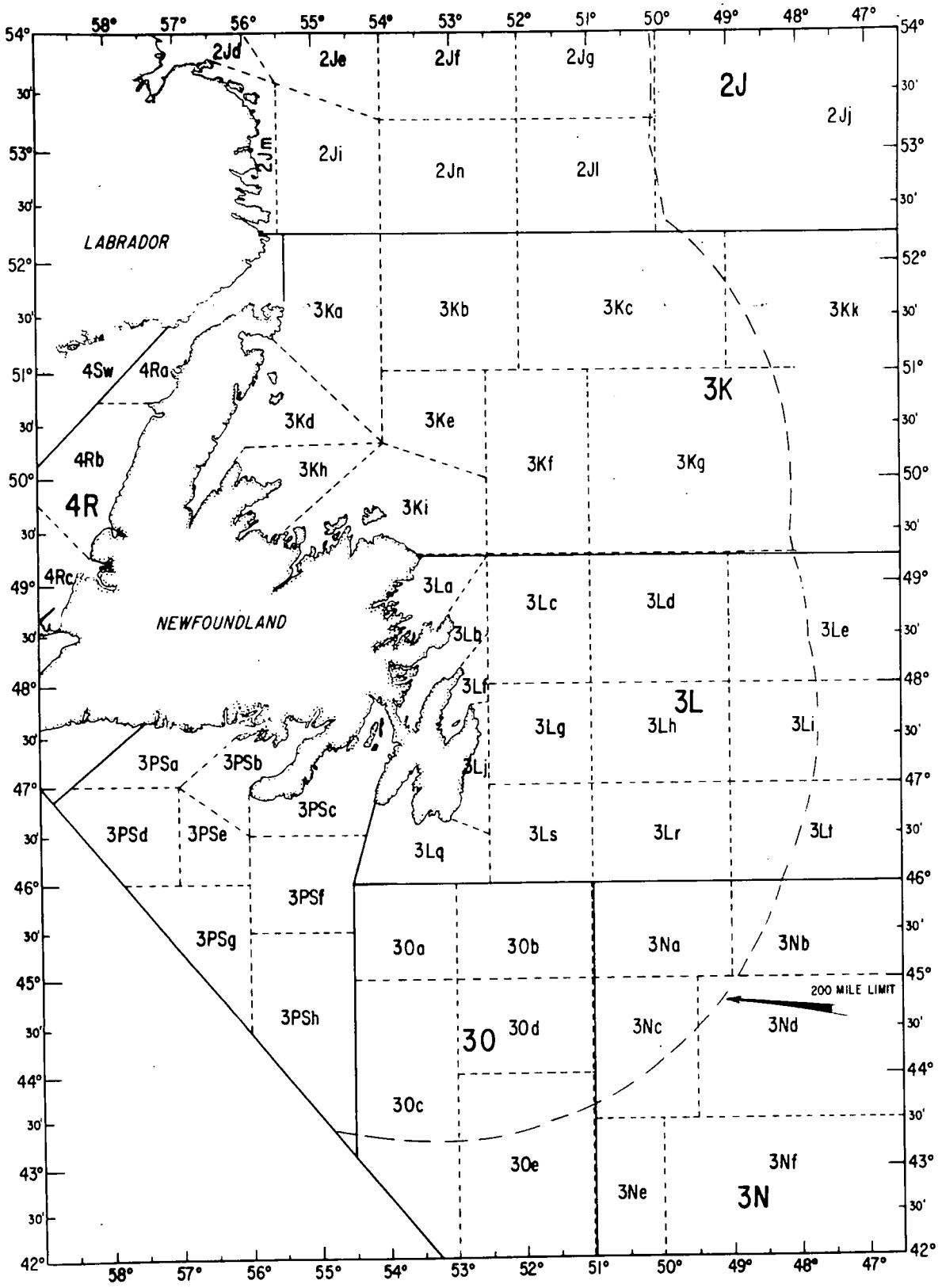

Fig.2. Commercial fishery statistical unit areas.

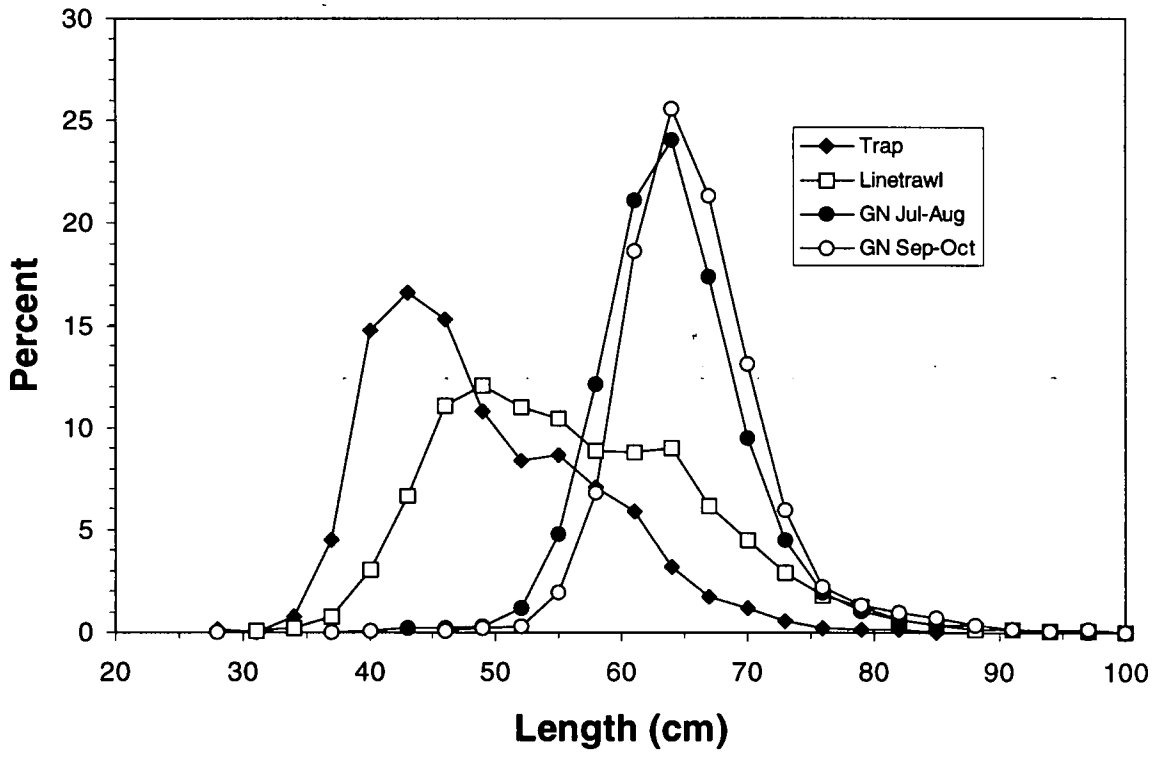

Fig. 3. Length frequency distributions of cod sampled from the catch from three gears in the sentinel survey in unit area 3Psc in summer and early autumn of 1996.

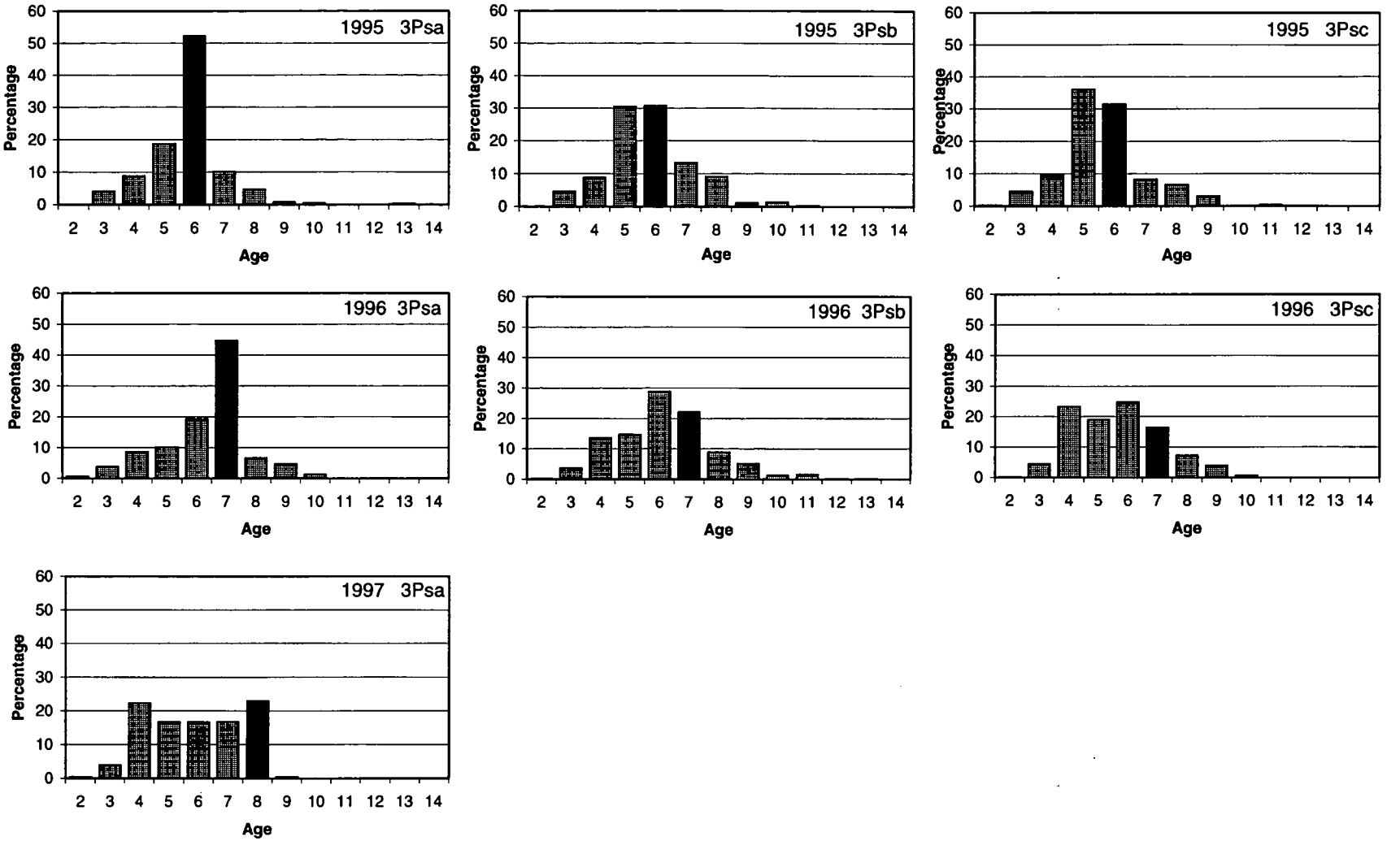

Fig. 4. Age compositions of cod determined from sampling of the linetrawl catch in the sentinel survey in unit areas 3Psa, 3Psb and 3Psc in the autumn (September – November) of 1995-1997. Sampling of the 1997 catch has not been completed. The 1989 year-class is highlighted in black.

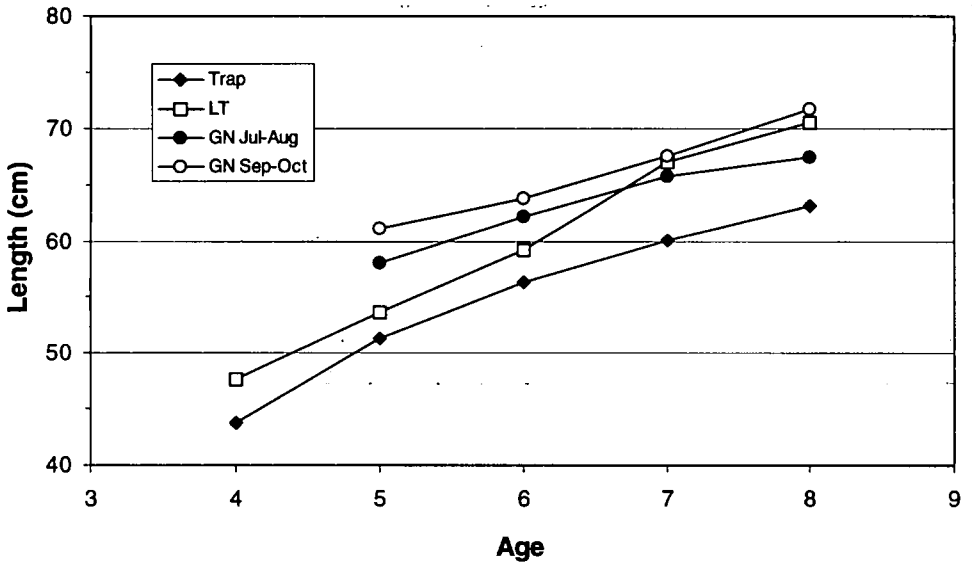

Fig. 5. Mean length-at-age of cod determined from sampling of the catch from three gears in the sentinel survey in unit area 3Psc in summer and early autumn of 1996.

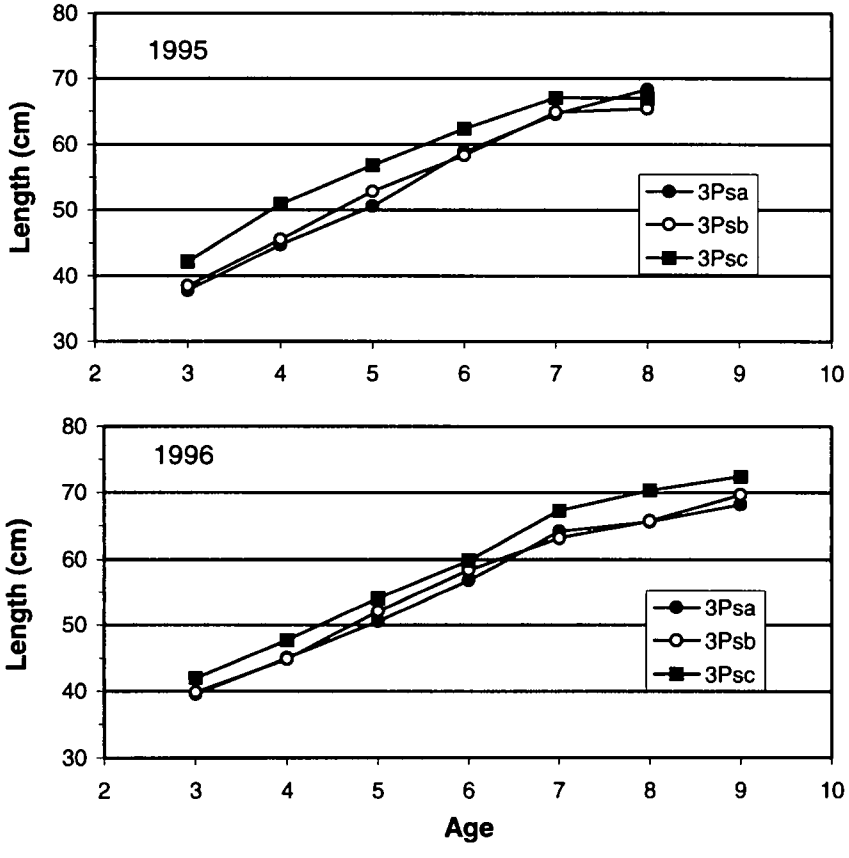

Fig. 6. Mean length-at-age of cod determined from sampling of the linetrawl catch in the sentinel survey in unit areas 3Psa, 3Psb and 3Psc in the autumn (September – November) in 1995 and 1996.

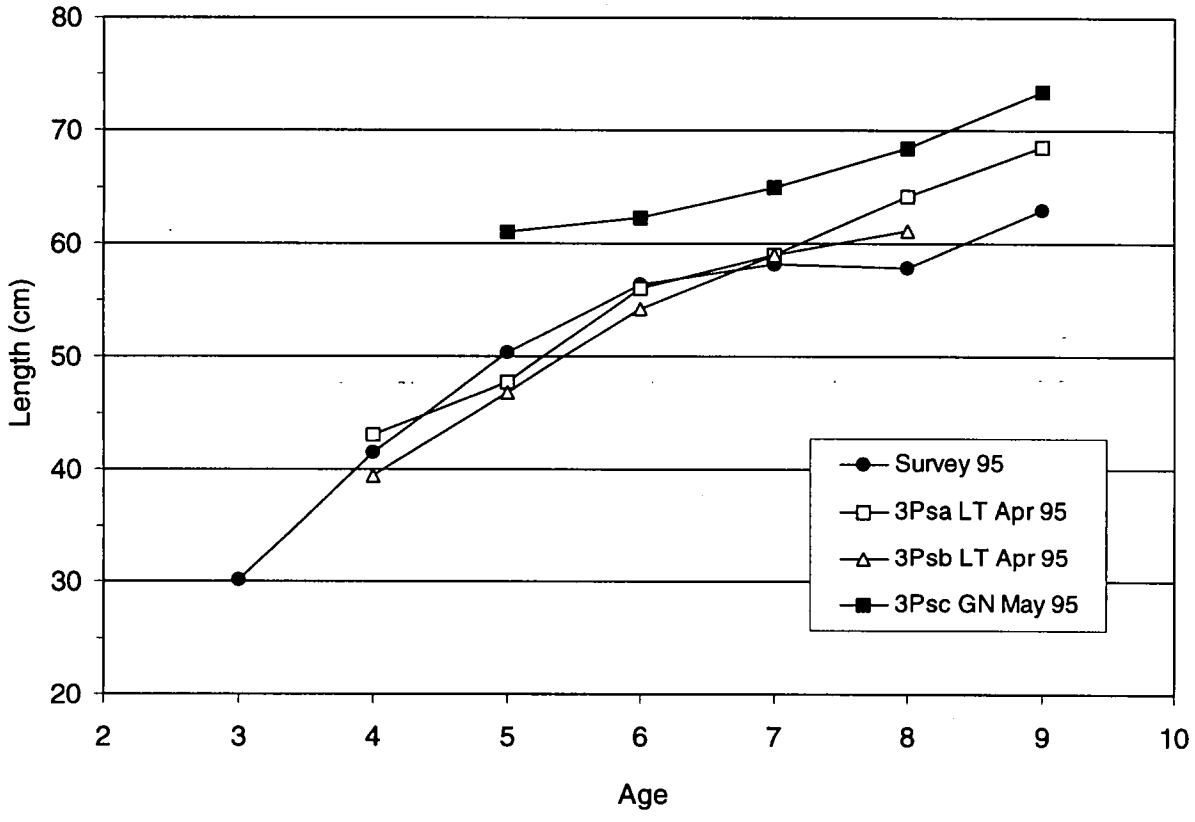

Fig. 7. Comparison between the mean length-at-age of cod sampled during the research bottom-trawl survey in the offshore of 3Ps in spring 1995 and cod sampled during sentinel surveys conducted at approximately the same time in nearshore waters of unit areas 3Psa, 3Psb and 3Psc.