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Cod in NAFO Divisions 2J3KL

by

C. A. Bishop, J. T. Anderson, E. Colbourne, G. R. Lilly, R. A. Myers, G. A. Rose, D. E. Schneider and D. E. Stansbury

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

Introduction

Prior to the 1960s the Div. 2J3KL cod stock supported fisheries catching from 200 000 to 300 000 tons annually. During the 1960s good recruitment along with high exploitation rates saw catches averaging about 580 000 tons (Table 1; Fig.1). However, the stock was in a period of decline from the 1960s until the mid-1970s. Reduced exploitation and some improved recruitment after that time allowed the stock to increase until the mid-1980s, although it has subsequently declined. Research survey data would suggest that the decline occurred earlier in the north (Div. 2J) and has been substantial each year since about 1990. The 1994 assessment of the stock was unable to determine the absolute stock level but considered that it was at an all time low.

In an effort to provide further understanding of the population dynamics and biology of this cod stock, information available since that time, as well further analysis on previously existing data, are summarized in the Sections that follow. This summary represents a synthesis by the authors of the content and subsequent discussion of papers presented at an April 1995 Newfoundland Regional Groundfish Stock Assessment meeting at which time the status of the Div. 2J3KL cod stock was reviewed.

Physical Environment

Since the relatively warm period from the early-1950s to late-1960s the oceanic conditions in the Newfoundland region have been characterized by three cold periods; early-1970s, mid-1980s and the early-1990s. During 1991 the total heat content of the water column was the lowest ever recorded on the Newfoundland shelf. These cold episodes resulted from the large scale winter atmospheric circulation over the Northwest Atlantic which brought cold Arctic air further south than normal resulting in increased ice cover and a colder and fresher water mass on the Newfoundland shelf.

During 1994 the annual air temperatures had increased in comparison to recent years. However, seasonally, the winter temperatures were below normal causing ice to form early, be of greater areal extent and last longer than normal off northern Newfoundland and southern Labrador although ice conditions off southern Newfoundland at the beginning of April were less than recent years (Colbourne, 1995). As a result ocean temperatures on the Newfoundland shelf measured at Station 27 were below normal during the winter over all depths but by July they had warmed to 2.0°C above normal in the upper water column and increased to near normal in the bottom layers by late-autumn. The summer area of the CIL along the Bonavista transect has returned to near normal but remained above normal across Hamilton Bank and the Grand Bank. The July-August upper layer (0-50 m) was fresher than normal in 1994.

Ocean conditions in 1994 were closer to the long term average than in recent years. This may be beneficial for biotic factors such as growth rates.

Stock Structure

Cod in Div. 2J3KL are considered as a stock complex in which the existence of substocks or stock components has long been suspected. Most attempts to distinguish individual components have been complicated because of extensive annual migrations undertaken within the stock, particularly the inshore-offshore migration.

Recent research with micro-satellite DNA and antifreeze protein levels indicate that cod overwintering in a sound in Trinity Bay are genetically distinguishable from cod overwintering offshore along the shelf-break of the Grand Bank (Ruzzante *et al.*, 1995). This difference occurs even though cod from the two areas intermingle during most of summer and fall as a result of the inshore feeding migration by offshore individuals. This observation is consistent with previous work by Templeman (1979) and general observations by fishermen as to seasonal differences in characteristics of their catches.

Similar analyses to determine differences between offshore components throughout their range have not been conclusive. There were differences in interpretation of results with the methodology used in the analysis as well as between the years being compared. Some of the problems encountered may have been related to timing of sampling or to movements of cod within the area. The identification of substocks or stock components would be important for the future management of this stock. The fishery should be managed to prevent any over exploitation of a stock component.

Spatial Patterns of abundance and distribution

Temporal Changes

A more southerly distribution of cod, three years of age and older has been reported previously (Bishop *et al.*, 1993; Hutchings and Myers, 1994; Lilly, 1994; Rose *et al.*, 1994; Taggart *et al.*, 1994). This reportedly began in 1989 (deYoung and Rose, 1993). Different reasons for the southward shift in distribution have been hypothesized: 1) it is a direct result of colder ocean climate conditions; 2) it is a direct result of changes in the more southerly distribution of capelin; 3) the changing pattern in distribution is not a 'shift' but a result of high fishing mortality in the northern areas; 4) it is a combination of fishing mortality and ocean climate factors.

Recent work examining fishing mortality based on tagging data for the period 1954-1991 concluded that fishing mortality was higher in Div. 3K than in Div. 3L (Myers *et al.*, 1995b). There was no comparable tagging data in Div. 2J in the late-1980s and early-1990s with which to make a similar comparison. Higher fishing mortality in more northerly areas is consistent with the three hypotheses stated above. The lack of comparable data from Div. 2J and the observation that cod straddled the Div. 3K/3L border during the late-1980s limit the interpretation of these results.

Acoustic data collected within the "Bonavista Corridor", which straddles the boundary of Div. 3K and 3L, from 1983-1994 demonstrated an increase in density within the study area during 1990-92, compared to 1983-89 and 1993 (Fig. 2). These results are consistent with the hypothesis that there was an increase in local density during 1990-92, in association with the decline of cod abundance in the north (Div. 2J3K). The decline in local density in 1993 was hypothesized to result from a further southward shift in distribution of cod to the north cape of the Grand Bank, outside Canada's 200-mile limit. Density continued to decline within the study area in 1994 .

Mean catch at two traps sites indicated a trend of decreasing catch rate in Div. 3K compared to Div. 3L from 1992-94, consistent with a southerly shift in the juvenile population, as observed for adults (Table 2). For 1992 and 1993 there was a decrease in the proportion of young juvenile cod (ages 1 and 2) compared to older juveniles (ages 3 and 4) from south to north in trap catches (Fig. 3).

Changing Distributions in 1994

An acoustic survey in June 1994 observed cod within four areas, ranging from the north cape of the Grand Bank in the south to Hawke Channel in the north (Fig. 4). This was the first year that some of these areas were surveyed, such as Hawke Channel, whereas other areas, such as the north cape of the Grand Bank, were surveyed previously. Also it should be noted that many areas within the Div. 2J3KL area were not covered by this survey. Estimates of cod densities were highest on the north cape of the Grand Bank and in Hawke Channel and lower in the Notre Dame Channel and St. Anthony Basin areas. Cod densities were very low compared to previous observations made during spring acoustic sampling. Although analyses have not been completed there appear to be differences in age structure between regions, where cod were significantly older in the north (Hawke Channel), comprising both juveniles and adults (mean age >4 years). In the southern regions cod averaged <4 years age. Cod were in lowest condition (K_f) in the southern most region the north cape of the Grand Bank. Adults sampled in the Hawke Channel region were largely spent, indicating that spawning occurred prior to June.

Pelagic juvenile cod were found extensively over the NE Newfoundland Shelf during late-August, demonstrating that successful spawning of cod occurred in spring off southern Labrador in 1994 (Anderson and Dalley, 1995b). This observation agrees with the June acoustic survey which only found adult cod only in the north (Hawke Channel). Comparisons to previous surveys are restricted by the fact the 1994 survey was the first time coverage was extended to the north. Comparing similarly surveyed areas offshore in 1994 to 1993 indicates there were more pelagic offshore juvenile cod in 1994. Pelagic juvenile cod were distributed throughout the surveyed inshore areas during 1994, consistent with previous surveys.

Juvenile Cod

Juvenile cod surveys conducted between 1992-94 demonstrated that cod, ages 0-3 years, occurred throughout the inshore areas along the east coast of Newfoundland (Schneider *et al.*, 1995; Dalley and Anderson, 1995; Anderson and Dalley, 1995b).

Pelagic and demersal juvenile cod surveys demonstrated strong cross-shelf gradients in abundance, where the inshore areas typically have the highest concentrations (Dalley and Anderson, 1995; Anderson and Dalley, 1995b). With the exception of 1994, the spatial distribution of pelagic juvenile cod was largely confined to the inshore areas. This distribution was confirmed by demersal sampling conducted in the same year after the cod had settled. In the 1994 pelagic juvenile survey cod were sampled abundantly offshore (Anderson and Dalley, 1995b). Demersal sampling in the late-fall of 1994 did not sample 0-group cod on the bottom offshore (Dalley and Anderson, 1995). It was not possible to ascertain if the pelagic juvenile cod sampled offshore in 1994 migrated inshore or remained undetected offshore during their first winter of life.

Beach seine sampling has demonstrated the abundant occurrence of 0-group and 1-group cod below the inter-tidal range to depths of 5-7 m (Schneider *et al.*, 1995). A nearshore trawling experiment carried out in November 1993 demonstrated that 0-group and 1-group cod were abundant out to depths of 40 m, approximately 2-3 km from shore (Anderson and Dalley, 1995a). Older cod (ages 2 and 3) were less abundant at depths <40 m and more abundant at greater depths.

Changes in Maturity, Weight, Age Composition and Condition

Observations from autumn and spring surveys indicate that both males and females have shown an increasing proportion mature at younger age and smaller size since 1990-91 with the Jan. 1, 1995 estimates being the highest in the time series (Morgan and Shelton, 1995). The trends observed were evident in all Divisions (Fig. 5).

Micro-otolith age determination of pelagic juvenile cod demonstrated that cod larvae hatched primarily in June 1994, with an extrapolated spawning period which would have occurred during May, and possibly late-April. There was no evidence of spawning after this time in 1994. This observation contrasts with samples from 1992 and 1993 which demonstrated that successful spawning occurred primarily during June and July.

Condition factors as measured by body weight relative to length fluctuated without apparent trend from 1977 until 1989 after which they declined through 1992 in Div. 2J and to a lesser extent in Div. 3K. There was no apparent decline in Div. 3L (Bishop *et al.*, 1995). This pattern was supported by estimates of the overall level of feeding of cod during the same time period, particularly for Div. 2J (Lilly, 1995b). However, the declining trend in condition appears reversed in 1993 and 1994. This was not reflected in feeding success data for the same period.

Changes in growth rate and proportion mature at age are important in the determination of the amount of recruitment necessary for spawner biomass replacement i.e. for year-classes to produce sufficient spawner biomass to equal that of their parents. Using the most recent assessment results, obtained using the ADAPT framework, it was concluded that the decrease in recruitment and growth over the 1980s played a major role in the stock decline (Shelton, 1995).

The growth rate of Atlantic cod populations is strongly related to age at maturity and this is influenced by temperature (Myers *et al.*, 1995a).

During the food and subsistence fishery in Div. 2J3KL in 1994 it was generally observed by fishermen that cod were of average condition. There were some reports of 'thin' fish observed in some areas during the similar 1993 fishery (Kulka *et al.*, 1995) but the extent of these observations are unknown.

Autumn survey average lengths and weights at age for the dominant age groups (4-7) declined for most years from the late-1970s to early-1980s until 1992 with declines most pronounced in Div. 2J. The 1993 and 1994 values have shown general increases (Bishop *et al.*, 1995). Cod older than age 7 were virtually absent in the autumn surveys of 1993 and 1994 (Tables 3-6).

The Fishery in 1994

The food fishery was generally considered a 'failure' i.e. catch rates were low and cod generally small (Kulka *et al.*, 1995). The catch totalled 1 308 tons and was taken mainly in Div. 3L (367 tons) and Div. 3K (932 tons).

Catch beyond the 200-mile limit in 1994 was estimated by the surveillance Branch of DFO to be about 50 tons.

Fishing Mortality

The history of exploitation of Div. 2J3KL cod since 1954 as estimated from tag return data from 122 tagging experiments was presented (Myers *et al.*, 1995b). Very high rates of exploitation in the late-1980s and early-1990s were estimated. This would be consistent with the hypothesis that these populations collapsed because of overfishing. The fishing mortality in the early- and mid-1980s was generally higher than that estimated from the VPA. The fishing mortalities estimated in the late-1980s to 1991 were very high, above 1, and similar to those estimated from VPA. The fishing mortalities were high even if the assumed natural mortality was 0.5 for the period.

A separate analysis of inshore components of the Div. 2J3KL stock complex using tagging data (Myers and Barrowman, 1995) indicated that the fishing mortality has been very high on the inshore components of the cod stocks since 1948, when the estimated fishing mortality was greater than 0.5. These results are consistent with the hypothesis that inshore stocks have been virtually eliminated by overfishing. There is a need to define inshore stocks and to institute conservation measures specific to inshore populations.

Estimates of the recorded by-catch of the cod in the shrimp fishery appeared to be small (Kulka, 1995). The Nordmore grate was mandatory in 1994 in some areas which reduced the by-catch.

An analysis of the ratio of the catch to estimated biomass from the research survey indicated; 1) that the fishing mortality from the very limited food fishery and offshore foreign catch is significant, and 2) the high fishing mortality estimated by other methods were not observed (Fig. 6). This analysis suggests that efforts should continue toward reducing fishing mortality until the stock recovers.

Predator-prey and Competition Interactions

Cod are eaten by a variety of predators, including seabirds, squid and various fish, including cod itself (cannibalism), but the non-human predator of greatest concern in recent years is the harp seal. The harp seal population has been increasing and is now estimated to number about 4.8 million (Stenson *et al.* 1995). Although cod is a minor component (3%) of the harp seal diet. It is estimated that harp seals consumed between 46 000 to 140 000 tons annually in Div. 2J3KL. Most of these cod are juveniles of ages 1 and 2. The impact of this removal on the dynamics of the cod stock has not been assessed.

Harp seals fed primarily on capelin prior to the mid-1980s, but since that time have preyed mainly on Arctic cod (Stenson and Lawson, 1995). Such changes could be related to changes in abundance or distribution of either prey. The biomass of Arctic cod, estimated from autumn bottom-trawl surveys, was relatively low until 1984, but has been generally higher and more variable since 1985 (Lilly, 1995). The abundance of capelin has been difficult to determine in the 1990s because of the divergence between estimates from acoustic surveys, which declined substantially after 1989, and various inshore indices, which did not reflect such a decline (Carscadden, 1995). However, there was no decline in capelin biomass in the mid-1980s which might account for the change in seal diet. Both capelin and Arctic cod on the Northeast Newfoundland Shelf experienced an eastward shift in the 1990s, with the change being more pronounced in capelin (Lilly, 1995). It is not known if such changes influenced the feeding of seals. In 1994 harp seals consumed an estimated 735 000 to 1.7 million tons of Arctic cod and 288 000 to 1.0 million tons of capelin (Stenson *et al.*, 1995).

The biological interactions among capelin, Arctic cod, cod and seals may be complex. Capelin is consumed by the other three species. Arctic cod is consumed by seals and cod. Cod is consumed by seals and by larger congeners. In addition, capelin, Arctic cod and juvenile cod have similar food requirements, so there is potential for competition among them.

Feeding

The temporal pattern of change in stomach contents of cod has varied by Division (Fig. 7), (Lilly, 1995). In Div. 2J, the average quantity of capelin in stomachs was nil or low during 1991-1994, reflecting the absence or low abundance of capelin in Div. 2J as determined during acoustic surveys. The condition (somatic and liver indices) of the few cod remaining in Div. 2J also declined in 1991 and 1992, but the somatic condition index recovered in 1993 and 1994. The liver index was not yet available for 1993 and 1994.

In Div. 3K, the average quantity of capelin and other food in stomachs was relatively high in 1993, but the quantity of capelin declined in 1994. There was no corresponding decline in somatic condition. In Div. 3L, neither stomach contents nor somatic condition declined in 1993 and 1994.

Changes in Co-occurring Groundfish Species

Witch flounder biomass estimates from Div. 2J3KL have declined from 45 000 tons in 1983-84 to an all time low of 900 tons in 1994 (Bowering, 1995). American plaice biomass from Div. 2-3K has also declined over the same temporal period from approx. 120 000 tons in 1982-83 to 5 000 tons in 1994, as well, the lowest in the time series (Brodie *et al.*, 1995). The depth distribution of witch and plaice has changed from the 1980s to the 1990s with the proportion of the biomass increasing since 1989 in deeper water. The age composition of American plaice has narrowed from a maximum age in fall surveys of 16 in 1989 to a maximum age of 12 in 1993. Age compositions were not available for witch for the past two years but previous analysis have shown a decline in maximum age from 26 in the mid-1970s, to 17 in 1981, and further to 14 from 1986-92.

The declining biomass trends in these two species in NAFO Div. 2J3K cannot be explained by the removals of the commercial fishery. The ratio of annual catch/RV biomass, a proxy for exploitation rate, never exceeded 9% for American plaice. The situation is not as clear for witch because of uncertainties with survey coverage of the stock area and a fishery concentrating on pre-spawning aggregations.

There are similarities in the abundance and distribution patterns of cod, American plaice, and witch. All have shown declining trends over the same time period and a tendency to be found in deeper water. Unlike cod, there is no evidence for a change to a more southerly distribution for plaice.

Recruitment Trends

Recruitment to fishable sizes (ca age 3) was compared using research surveys and reconstruction of recruitment for catch data (VPAs). In 6 different stocks from 1980 onward the VPA based trend in recruitment declined, while the research vessel estimates did not decline (Myers *et al.*, 1995a). This can result from increased discarding and high-grading, such that juvenile fish are under-estimated by VPA reconstruction. In each of the 6 stocks, high juvenile mortality was associated with high adult mortality, consistent with the hypothesis of discarding. Based on VPA reconstruction calibrated against research surveys (ADAPT) recruitment fell below replacement levels in the early-1980s (Shelton, 1995). The recruitment required to replace spawner stock rose during this period due to increased fishing mortality and declining weights-at-age.

Abundance estimates from the fall survey declined for fish at ages 2, 3 and 4 in 1994, compared to 1993 and 1992 in Div. 2J3KL (Bishop *et al.*, 1995). This points to a continuing decline in recruitment to fishable size classes due to weak year-classes in 1990-1992.

Pre-recruit juveniles have been measured at the pelagic stage from 1991-1994 (Anderson and Dalley, 1995b), at age 0+ to 2+ in the coastal zone (depth = 0-10 m) from 1959-1964 and 1992-1994 (Schneider *et al.*, 1995), and at ages 0+ to 3+ from the shelf break shoreward to depths of ca 40 m (Dalley and Anderson, 1995).

A number of different indices of trends in year-class strength now exist: pelagic density and distribution (Anderson and Dalley, 1995b), beach seine surveys of demersal fish in shallow water (Schneider *et al.*, 1995), Campelen trawl surveys in deeper water (Dalley and Anderson, 1995).

The 1994 year-class appears to be stronger than the 1993 and 1992 year-classes, based on several different indices at age 0+ (Table 7). The 1993 also appears to be stronger than the 1992 year-class, based on indices at age 0+ and at age 1+ (Table 8). In most instances the 1991 year-class ranked lowest in abundance. It will be at least 3 years until it is known whether this trend is reflected in the RV survey. The beach seine survey can be used to reliably track relative cohort strength (Schneider *et al.*, 1995), with precision similar to that of the fall research survey. The precision of the other indices needs to be evaluated.

Biomass trends

Autumn research vessel survey estimates of biomass and abundance in Div. 2J3KL have shown severe declines in recent years and the 1994 point estimate is the lowest in the series (Bishop *et al.*, 1995). No aggregations of fish were found.

Estimates from spring research vessel surveys in Div. 3L have also declined substantially in recent years with the 1993 and 1994 being at similar but low levels (Bishop *et al.*, 1995).

Anecdotal information from the food fishery in September of 1994 indicated that there were no areas with reports of "good" catch rates comparable to that experienced in the years prior to 1992 (Kulka *et al.*, 1995)

The June 1994 acoustic survey had no large catches comparable to those obtained during 1990-1993 surveys. No high density aggregations of adults were located as had been the case in previous years.

Given the levels of precision in spring and autumn surveys it is not possible to conclude that the change in biomass and abundance from 1993 to 1994 was significant. However, all indices indicate that this stock is still at an extremely low level.

Summary

The Div. 2J3KL cod stock remains at a very low level, probably in the order of 1% of that in the early-1980s. The stock consists mainly of young fish with virtually none older than age 7. The stock reduction since the moratorium has occurred although catches have been much reduced. The majority of the catch since the moratorium have come from inshore areas where it has been shown that separate stock components are likely to exist, mainly in the deep water bays.

The reasons for the drastic decline in this stock remain unresolved. Hypotheses suggest a variety of potential causes, such as, adverse environmental conditions, underestimation of fishing mortality, and increased predation. Although water temperatures were anomalously low during the early-1990s, there are indications of a return to more normal conditions. Analysis of tagging concluded, as did previous results from VPA analysis, that fishing mortality in the late-1980s and early-1990s was high, assuming a constant rate of natural mortality. Since the moratorium, fishing mortality would have been reduced in the offshore areas as catches were very small. By-catch mortality of cod in the northern shrimp fishery declined from 1992-94 with the introduction of the Nordmore grate. Harp seal numbers have increased substantially since the early-1980s and their consumption of cod as well as other fish species has increased.

Since 1990-91 cod have shown an increasing proportion mature at younger ages with the proportion for 1994

being the highest in the time series. This may be a response to population declines. Estimates of the abundance of pre-recruits (ages 0-2) have been obtained in recent years using a variety of indices. The abundance in 1994 at age 0 was greater than in 1992 and 1993.

Prognosis

All the indices available indicate that this stock is at an extremely low level. The reasons for the drastic decline in recent years remain unresolved. Stock reduction since the moratorium has occurred although catches have been much reduced. Projections of recovery time are not possible until there is evidence of the presence and survival of a substantial year-class. The increasing trend in pre-recruit indices is encouraging but it is premature to base any predictions on their strengths.

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Table 1. Historical catches of cod from NAFO Divisions 2J3KL for the period 1959-94.

	2J					3K					3L					2J3KL				
	Offshore mobile gear					Offshore mobile gear					Offshore mobile gear									
Year	Can.	Other	Total	Fixed gear	Total	Can.	Other	Total	Fixed gear	Total	Can.	Other	Total	Fixed gear	Total	Total Canada	Total fixed gear	Total offshore mobile gear	Total	TAC
1959	-	46372	46372	17533	63905	-	97678	97678	56264	153942	4515	51515	56030	85695	141725	164007	159492	200080	359572	-
1960	1	164036	164037	15418	179455	53	69855	69908	47676	117584	7355	60213	67568	94192	161760	164695	157286	301513	458799	-
1961	1	243147	243148	17545	260693	-	60574	60574	31159	91733	4675	70318	74993	70659	145652	124039	119363	378715	498078	-
1962	-	226841	226841	23424	250265	-	45554	45554	42816	88370	4383	87463	91846	72271	164117	142894	138511	364241	502752	-
1963	1	197868	197869	23767	221636	-	79331	79331	47486	126817	4446	83015	87461	73295	160756	148995	144548	364661	509209	-
1964	13	197359	197372	14787	212159	-	121423	121423	40735	162158	10158	142370	152528	75806	228334	141499	131328	471323	602651	-
1965	-	246650	246650	25117	271767	21	50097	50118	26467	76585	7353	130387	137740	58943	196683	117901	110527	434508	545035	-
1966	39	226244	226283	22645	248928	13	58907	58920	32208	91128	8253	120206	128459	55990	184449	119148	110843	413662	524505	-
1967	28	217255	217283	27721	245004	114	78687	78801	24905	103706	13478	200343	213821	49233	263054	115479	101859	509905	611764	-
1968	4650	355108	359758	12937	372695	1849	119778	121627	40768	162395	15784	211808	227592	47332	274924	123320	101037	708977	810014	-
1969	30	405231	405261	4328	409589	56	80949	81005	24923	105928	18255	151945	170200	67973	238173	115565	97224	656466	753690	-
1970	-	212961	212961	1963	214924	92	78274	78366	21512	99878	14471	137840	152311	53113	205424	91151	76588	443638	520226	-
1971	-	154700	154700	3313	158013	31	61506	61537	21111	82648	11976	148766	160742	38115	198857	74546	62539	376979	439518	-
1972	-	149435	149435	1725	151160	7	133369	133376	14054	147430	4380	109052	113432	46273	159705	66439	62052	396243	458295	-
1973	1123[a]	52985	54108	3619	57727	108	159653	159761	13190	172951	1258	97734	98992	24839	123831	44137	41648	312861	354509	666000
1974	-	119463	119463	1804	121267	19	149189	149208	10747	159955	880	67918	68798	22630	91428	36080	35181	337469	372650	657000
1975	410	78578	78988	3000	81988	189	112678	112867	15518	128385	670	53770	54440	22695	77135	42482	41213	246295	287508	554000
1976	94	30691	30785	3851	34636	771	79540	80311	20879	101190	2187	40998	43185	35209	78394	62991	59939	154281	214220	300000
1977	525	39584	40109	3523	43632	1051	26776	27827	28818	56645	5362	26799	32161	40282	72443	79561	72623	100097	172720	160000
1978	4682	17546	22228	6638	28866	7027	6373	13400	29623	43023	9213	12263	21476	45194	66670	102377	81455	57104	138559	135000
1979	9194	6537	15731	8445	24176	21579	16890	38469	27018	65487	14184	12693	26877	50359	77236	130779	85822	81077	166899	180000
1980	13592	7437	21029	17210	38239	21920	6830	28750	37015	65765	15523	13963	29486	42298	71784	147558	96523	79265	175788	180000
1981	22125	4760	26885	14215	41100	23112	3847	26959	23002	49961	21760	15070	36830	42821	79651	147035	80038	90674	170712	200000
1982	58384	8923	67307	14429	81736	8881	4074	12955	42141	55096	27192	9271	36463	56479	92942	207506	113049	116725	229774	230000
1983	37281	4158	41439	10743	52182	31623	2815	34438	40681	75119	39125	10920	50044	54999	105043	214452	106423	125922	232345	260000
1984	10754	1259	12013	13150	25163	48114	11059	59173	35143	94316	49620	13944	63564	49428	112992	206209	97721	134750	232471	266000
1985	1541	5	1546	10209	11755	72111	9714	81825	30368	112193	39112	28927	68039	39306	107345	192647	79883	151410	231293	266000
1986	4627	7373	12011	12567	24578	58239	2226	60465	28539	89004	55117	51555	106672	31263	137935	190352	72369	179137	251506	266000
1987	38216	3620	41836	16139	57975	39240	6119	45359	27141	72500	43185	25883	69068	35467	104535	199388	78747	156263	235010	256000
1988	41468	9	41477	17112	58589	40260	50	40310	33820	74130	59107	26748	85855	50103	135958	241870	101035	167642	268677	266000
1989	33584	1014	34598	22920	57518	37280	1194	38474	20711	59185	40943	36540	77483	59238	136721	214676	102869	150555	253424	235000
1990	17863	689	18493	14332	32884	26893	883	27691	27577	55353	33371	26456	59827	70624	130451	190660	112533	106155	218688	199262
1991	635	84	719	2195	2914	29505	1009	30514	13318	43832	30146	49660	79806	44317	124123	120116	59830	111039	170869	190000
1992	-	-	-	19	19	584	273	857	899	1756	16418	14610	31028	10876	36904	28796	11794	31885	43679	-
1993	-	-	-	14	14	-	-	-	547	547	2	2425[a]	2426	3384	5810	9000[b]	9000[b]	2425	11425	-
1994	-	-	-	9	9	-	-	-	367	367	-	50[a]	50	932	982	1308	1308	50	1358	-

[a]Surveillance catch estimate.
[b]This includes a further 5053 t catch estimated from the recreational fishery additional to that recorded in DFO statistical records.

Table 2 Annual Mean Catch rates From Japanese Pelagic Traps in NAFO Divisions 3K and 3L.

	Herring Neck 3K	Holyrood 3L
1992	5.72	4.71
1993	5.24	6.67
1994	1.39	12.99

Table 3. MEAN NUMBERS PER TOW OF COD AT AGE FROM AUTUMN RV SURVEYS IN DIVISION 2J.

	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
1	0.00	0.36	0.00	1.06	1.99	0.52	0.06	0.03	0.08	0.75	0.24	0.12	0.01	0.00	0.00	0.01
2	0.31	1.54	4.16	3.09	14.10	5.30	1.51	2.28	0.41	2.55	12.85	1.39	1.29	0.06	0.33	0.10
3	1.37	1.32	3.06	18.26	16.83	16.75	9.06	8.49	1.93	2.63	8.09	8.64	3.35	0.85	0.18	0.19
4	11.46	4.48	2.29	6.42	25.91	16.55	22.07	31.24	4.43	4.62	5.87	4.06	16.09	0.47	0.33	0.11
5	16.81	20.37	4.22	4.47	16.46	26.70	13.65	70.31	24.93	7.74	5.69	2.14	5.48	1.07	0.11	0.07
6	16.19	20.80	17.01	4.28	8.85	10.19	16.54	41.29	25.16	25.28	7.85	1.50	0.99	0.14	0.13	0.01
7	2.31	12.34	15.23	13.24	4.54	2.46	7.32	21.61	7.37	29.34	13.26	1.07	0.56	0.01	0.01	0.03
8	0.73	1.79	9.63	11.65	12.34	1.55	1.26	8.71	5.29	5.49	9.01	1.96	0.35	0.00	0.00	0.00
9	0.50	0.52	2.00	7.91	5.61	3.50	0.86	0.72	2.21	3.91	1.28	0.97	0.26	0.00	0.00	0.00
10	0.28	0.38	0.51	1.33	3.56	1.50	1.18	0.66	0.38	1.92	0.67	0.21	0.14	0.00	0.00	0.00
11	0.28	0.24	0.08	0.36	0.74	0.66	0.43	0.60	0.05	0.31	0.33	0.06	0.02	0.00	0.00	0.00
12	0.11	0.29	0.14	0.17	0.24	0.32	0.22	0.35	0.18	0.14	0.11	0.04	0.03	0.00	0.00	0.00
13	0.04	0.09	0.15	0.10	0.11	0.05	0.03	0.11	0.08	0.08	0.00	0.00	0.01	0.00	0.00	0.00
14	0.08	0.31	0.21	0.22	0.13	0.02	0.02	0.11	0.09	0.02	0.00	0.00	0.01	0.00	0.00	0.00
1+	50.47	64.82	58.68	72.55	111.40	86.10	74.21	186.50	72.57	84.78	65.25	22.16	28.59	2.60	1.09	0.52
2+	50.47	64.46	58.68	71.49	109.41	85.58	74.15	186.47	72.49	84.03	65.01	22.04	28.58	2.60	1.09	0.51
3+	50.16	62.92	54.52	68.40	95.31	80.27	72.65	184.19	72.08	81.49	52.16	20.65	27.29	2.54	0.76	0.41
4+	48.79	61.61	51.46	50.14	78.49	63.52	63.59	175.70	70.16	78.85	44.07	12.02	23.94	1.69	0.58	0.22
5+	37.33	57.12	49.17	43.72	52.57	46.97	41.52	144.46	65.72	74.23	38.20	7.96	7.84	1.22	0.25	0.11
6+	20.52	36.76	44.95	39.25	36.12	20.26	27.87	74.15	40.80	66.49	32.51	5.82	2.36	0.15	0.14	0.04

Table 4. MEAN NUMBERS PER TOW (ADJUSTED FOR MISSING STRATA) OF COD AT AGE FROM AUTUMN RV SURVEYS IN DIVISION 3K.

	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
1	0.00	0.18	0.01	0.22	0.83	0.26	0.01	0.35	0.38	1.14	1.79	1.08	0.02	0.03	0.01	0.01
2	0.13	1.01	1.25	1.71	3.36	3.23	0.65	2.41	0.90	2.43	14.36	3.82	2.05	0.34	0.56	0.05
3	2.13	1.37	5.14	1.66	7.29	5.58	2.96	4.84	2.15	4.12	15.80	18.77	5.59	0.95	0.55	0.26
4	14.46	1.98	3.22	4.72	6.17	9.64	4.56	24.10	3.88	3.18	15.91	18.07	24.42	0.78	0.48	0.12
5	23.80	11.16	3.51	4.65	10.88	7.77	6.21	29.07	9.38	3.91	11.98	12.00	17.25	1.78	0.15	0.08
6	14.15	12.19	11.72	2.61	3.33	7.98	3.09	20.18	7.26	5.36	10.53	8.75	5.92	0.66	0.18	0.01
7	3.63	2.64	8.48	5.50	2.25	2.96	2.98	10.33	3.48	2.89	11.60	6.01	2.32	0.13	0.05	0.02
8	1.82	1.27	2.63	5.36	3.96	1.48	0.92	6.22	2.44	0.97	6.62	6.65	0.93	0.03	0.01	0.02
9	0.44	0.47	0.48	1.56	3.07	2.37	0.69	2.37	1.25	0.46	3.00	2.17	0.55	0.00	0.00	0.00
10	0.38	0.32	0.23	0.60	1.07	1.43	0.64	0.79	0.62	0.27	2.18	0.66	0.25	0.00	0.00	0.00
11	0.26	0.03	0.19	0.16	0.38	0.59	0.54	0.98	0.32	0.07	0.94	0.24	0.01	0.00	0.00	0.00
12	0.06	0.19	0.19	0.07	0.16	0.28	0.16	0.68	0.17	0.09	0.35	0.06	0.02	0.00	0.00	0.00
13	0.04	0.07	0.06	0.06	0.07	0.10	0.06	0.25	0.11	0.03	0.26	0.00	0.01	0.00	0.00	0.00
14	0.12	0.13	0.11	0.12	0.23	0.21	0.05	0.18	0.23	0.07	0.17	0.00	0.01	0.00	0.00	0.00
1+	61.43	33.02	37.22	29.01	43.04	43.88	23.52	102.75	32.58	24.99	95.49	78.29	59.34	4.70	1.99	0.57
2+	61.43	32.84	37.21	28.79	42.21	43.62	23.51	102.40	32.20	23.85	93.70	77.21	59.32	4.67	1.98	0.56
3+	61.30	31.83	35.96	27.08	38.85	40.39	22.87	99.99	31.30	21.41	79.35	73.39	57.27	4.33	1.42	0.51
4+	59.18	30.46	30.83	25.42	31.56	34.82	19.90	95.15	29.15	17.30	63.54	54.62	51.68	3.38	0.87	0.25
5+	44.71	28.48	27.60	20.70	25.38	25.17	15.34	71.05	25.27	14.12	47.63	36.55	27.26	2.60	0.39	0.13
6+	20.91	17.32	24.09	16.05	14.51	17.40	9.13	41.98	15.89	10.22	35.65	24.54	10.01	0.82	0.24	0.05

Table 5L MEAN NUMBERS PER TOW (ADJUSTED FOR MISSING STRATA) OF COD AT AGE FROM AUTUMN RV SURVEYS IN DIVISION 3L.

	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
1	0.37	0.41	0.65	0.36	0.01	0.04	0.16	0.05	0.02	0.03	0.05	0.01	0.00	0.00
2	0.36	2.74	3.58	7.58	1.22	1.15	2.77	1.68	0.70	0.69	0.80	0.39	0.25	0.02
3	6.29	1.97	13.64	11.43	9.65	2.53	2.02	4.54	4.08	6.03	1.58	2.99	0.89	0.07
4	2.62	6.60	5.27	18.89	12.84	11.82	3.91	2.38	3.68	14.08	4.41	4.58	1.39	0.14
5	2.49	2.80	7.61	5.18	10.91	10.19	9.43	4.96	1.89	9.71	4.49	4.43	0.62	0.09
6	3.72	2.07	1.41	10.52	5.17	10.44	7.13	6.09	2.56	5.60	2.59	2.78	0.30	0.04
7	5.24	1.72	1.36	1.69	3.43	3.27	3.33	4.62	2.60	3.88	0.46	0.73	0.06	0.02
8	0.97	1.56	2.36	1.18	0.71	2.47	1.31	2.16	0.99	3.05	0.25	0.06	0.01	0.00
9	0.20	0.29	1.27	1.03	0.81	0.96	1.00	1.03	0.71	1.69	0.25	0.04	0.00	0.00
10	0.07	0.09	0.45	1.08	0.40	0.38	0.10	0.54	0.21	0.67	0.09	0.03	0.00	0.00
11	0.04	0.05	0.13	0.43	0.29	0.48	0.13	0.13	0.08	0.31	0.07	0.01	0.00	0.00
12	0.03	0.06	0.06	0.25	0.11	0.26	0.22	0.10	0.04	0.20	0.02	0.02	0.00	0.00
13	0.12	0.06	0.19	0.18	0.07	0.18	0.18	0.13	0.03	0.10	0.01	0.00	0.00	0.00
1+	22.51	20.42	37.97	59.78	45.62	44.17	31.70	28.41	17.60	46.04	15.08	16.07	3.52	0.38
2+	22.14	20.01	37.31	59.42	45.61	44.12	31.54	28.36	17.58	46.01	15.03	16.06	3.52	0.38
3+	21.78	17.27	33.73	51.85	44.39	42.97	28.77	26.68	16.89	45.32	14.22	15.67	3.27	0.36
4+	15.50	15.29	20.09	40.42	34.74	40.44	26.75	22.15	12.80	39.29	12.65	12.68	2.38	0.29
5+	12.88	8.70	14.82	21.53	21.90	28.62	22.83	19.77	9.12	25.21	8.24	8.10	0.99	0.15
6+	10.39	5.89	7.22	16.35	10.99	18.44	13.41	14.81	7.23	15.50	3.75	3.67	0.37	0.06

Table 6 . MEAN NUMBERS PER TOW OF COD FROM AUTUMN RV SURVEYS IN DIV. 2J3KL.

	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
1	0.41	0.27	0.16	0.51	1.04	0.36	0.02	0.14	0.21	0.59	0.66	0.40	0.03	0.01	0.00	0.01
2	0.32	3.00	1.59	2.49	6.09	5.57	1.10	1.85	1.56	2.14	8.25	1.91	1.34	0.29	0.37	0.05
3	1.94	2.48	5.11	5.88	12.31	10.79	7.27	4.77	2.04	3.93	8.98	10.93	3.35	1.78	0.60	0.16
4	11.78	3.83	2.74	5.93	10.65	15.23	12.35	20.70	4.03	3.20	8.30	12.95	13.97	2.30	0.83	0.13
5	16.79	13.23	3.26	3.83	10.88	11.34	10.01	31.29	13.23	5.29	6.20	8.61	9.00	2.72	0.34	0.08
6	10.53	13.31	9.67	2.79	3.88	9.59	7.28	21.29	11.61	10.57	6.52	5.64	3.31	1.42	0.22	0.02
7	2.27	4.99	8.78	5.82	2.44	2.30	4.24	10.14	4.38	10.13	8.23	3.90	1.10	0.35	0.04	0.02
8	0.92	1.19	3.66	5.31	5.35	1.37	0.92	5.26	2.67	2.58	4.84	3.98	0.50	0.04	0.01	0.01
9	0.31	0.37	0.74	2.59	2.94	2.09	0.78	1.37	1.38	1.55	1.62	1.68	0.35	0.02	0.00	0.00
10	0.26	0.23	0.23	0.57	1.42	1.30	0.67	0.58	0.34	0.79	0.98	0.55	0.16	0.01	0.00	0.00
11	0.19	0.11	0.10	0.16	0.36	0.54	0.41	0.68	0.17	0.15	0.43	0.23	0.04	0.00	0.00	0.00
12	0.06	0.16	0.11	0.09	0.14	0.28	0.15	0.42	0.19	0.11	0.16	0.12	0.02	0.01	0.00	0.00
13	0.04	0.05	0.10	0.07	0.13	0.12	0.06	0.19	0.13	0.08	0.10	0.04	0.01	0.00	0.00	0.00
1+	45.80	43.21	36.23	36.03	57.63	60.87	45.25	98.68	41.96	41.11	55.29	50.93	33.18	8.96	2.41	0.48
2+	45.39	42.94	36.08	35.52	56.58	60.51	45.23	98.54	41.74	40.53	54.62	50.53	33.15	8.94	2.41	0.47
3+	45.07	39.94	34.49	33.03	50.49	54.94	44.13	96.69	40.18	38.38	46.37	48.62	31.81	8.65	2.03	0.42
4+	43.13	37.47	29.38	27.16	38.18	44.15	36.86	91.92	38.14	34.46	37.39	37.70	28.46	6.87	1.43	0.26
5+	31.35	33.64	26.64	21.23	27.53	28.93	24.52	71.22	34.11	31.26	29.09	24.75	14.49	4.57	0.61	0.13
6+	14.57	20.41	23.38	17.40	16.66	17.59	14.50	39.93	20.88	25.97	22.89	16.14	5.49	1.85	0.27	0.05

Table 7. Ranking of year-class strength based on different pre-recruit indices for different ages. BS - beach seine surveys; DS - demersal juvenile cod surveys; PS - pelagic juvenile cod surveys. In - refers to Inshore; Off - refers to offshore.

Year-Class	AGE (years)												
	0					1			2			3	
	BS	DS		PS		BS	DS		BS	DS		DS	
	In	In	Off	In	Off	In	In	Off	In	In	Off	In	Off
1989	-	-	-	-	-	-	-	-	-	-	-	1	2
1990	-	-	-	-	-	-	-	-	2	2	1	3	1
1991	-	-	-	-	-	3	3	1	3	3	2	2	3
1992	3	3	1.5	2	2	2	2	3	1	1	3	-	-
1993	2	2	1.5	3	3	1	1	2	-	-	-	-	-
1994	1	1	3	1	1	-	-	-	-	-	-	-	-

Table 8. Abundance indices of year-class strength based on different pre-recruit indices at different ages. BS - beach seine surveys (mean cod/tow); DS - demersal juvenile cod surveys (cod/tow); PS - pelagic juvenile cod surveys (cod/10,000 m^3). In - refers to Inshore; Off - refers to offshore.

Year-Class	AGE (years)												
	0					1			2			3	
	BS	DS		PS		BS	DS		BS	DS		DS	
	In	In	Off	In	Off	In	In	Off	In	In	Off	In	Off
1989	-	-	-	-	-	-	-	-	-	-	-	5.40	5.54
1990	-	-	-	-	-	-	-	-	0.39	32.28	6.26	0.88	6.63
1991	-	-	-	-	-	3.95	64.40	3.28	0.23	4.68	6.21	3.08	2.41
1992	9.62	8.64	0.03	1.07	1.03	9.99	83.64	1.45	0.94	52.54	6.07	-	-
1993	13.0	20.64	0.03	1.05	1.02	16.5	137.9	2.69	-	-	-	-	-
1994	19.8	60.92	0.02	1.51	1.14	-	-	-	-	-	-	-	-

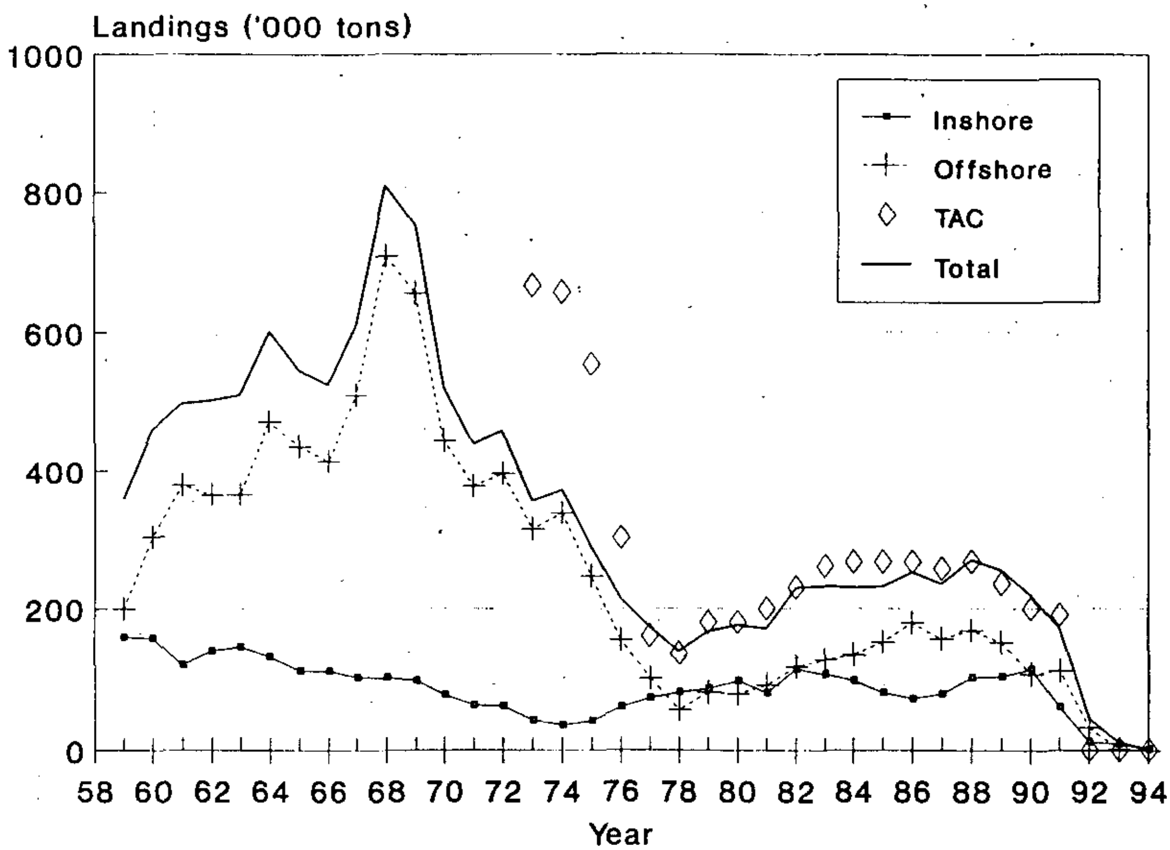
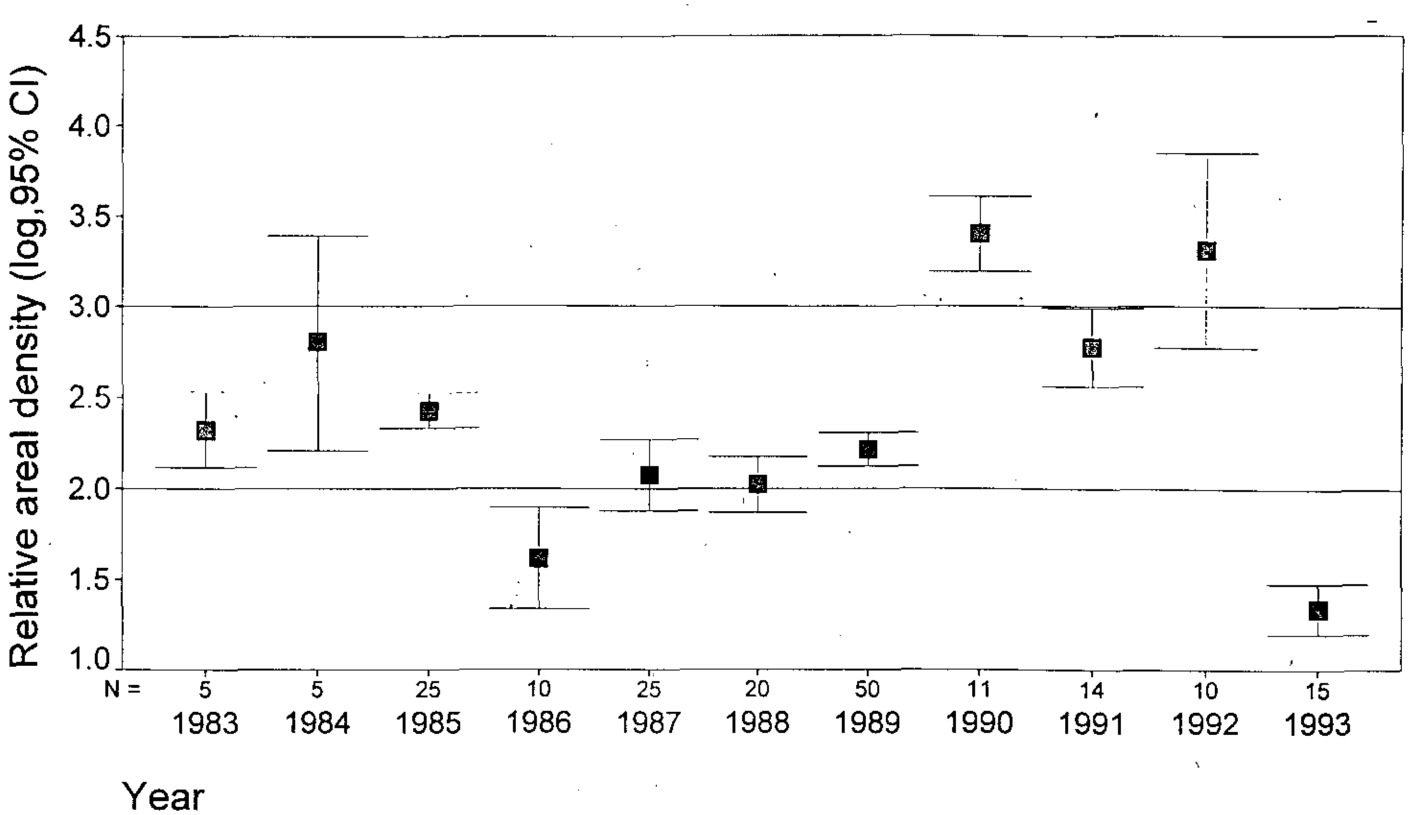


Figure 1. Cod in Divisions 2J3KL: Inshore and offshore landings and TAC's.



Acoustic counting method

Fig. 2. Relative acoustic areal densities of cod measured within aggregations located in the Bonavista Corridor area (northern 3L, southern 3K) in June, 1983-1993. Densities are mean counts from randomly chosen blocks within the aggregations. Counting method was modified duration-in-beam method. All identified aggregations sampled independently with trawls.

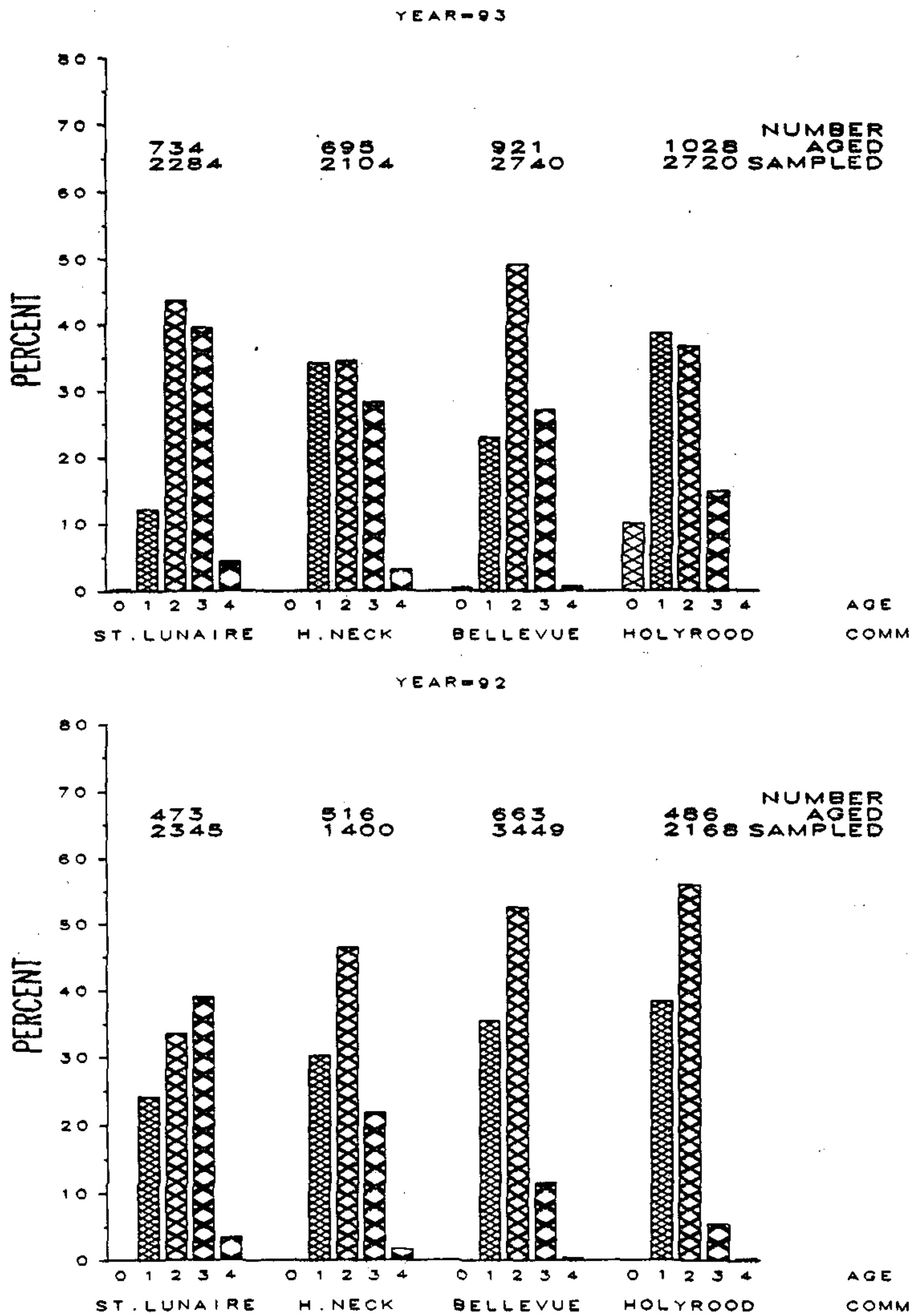


Fig. 3. Catch age composition from Japanese pelagic traps from 4 sites in Div. 3K (St. Lunaire, Herring Neck) and Div. 3L (Bellevue, Holyrood) in 1992, 1993.

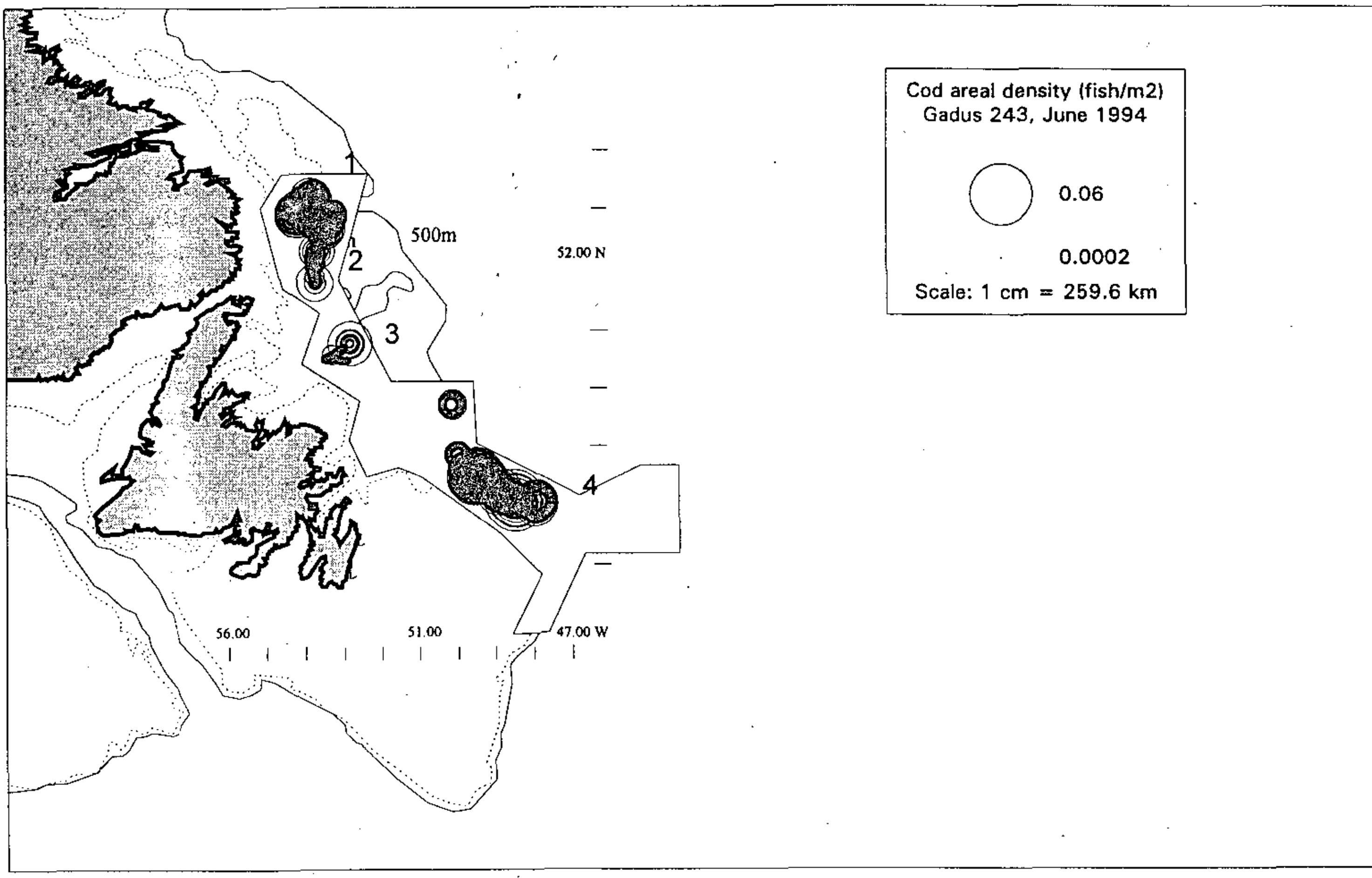


Fig. 14. Map of acoustic density distribution of cod within survey area (outlined) in June 1994. Numerals indicate four discrete aggregations: 1) Hawke Channel; 2) St. Anthony Basin; 3) Notre Dame Channel; and 4) north Cape of Grand Bank.

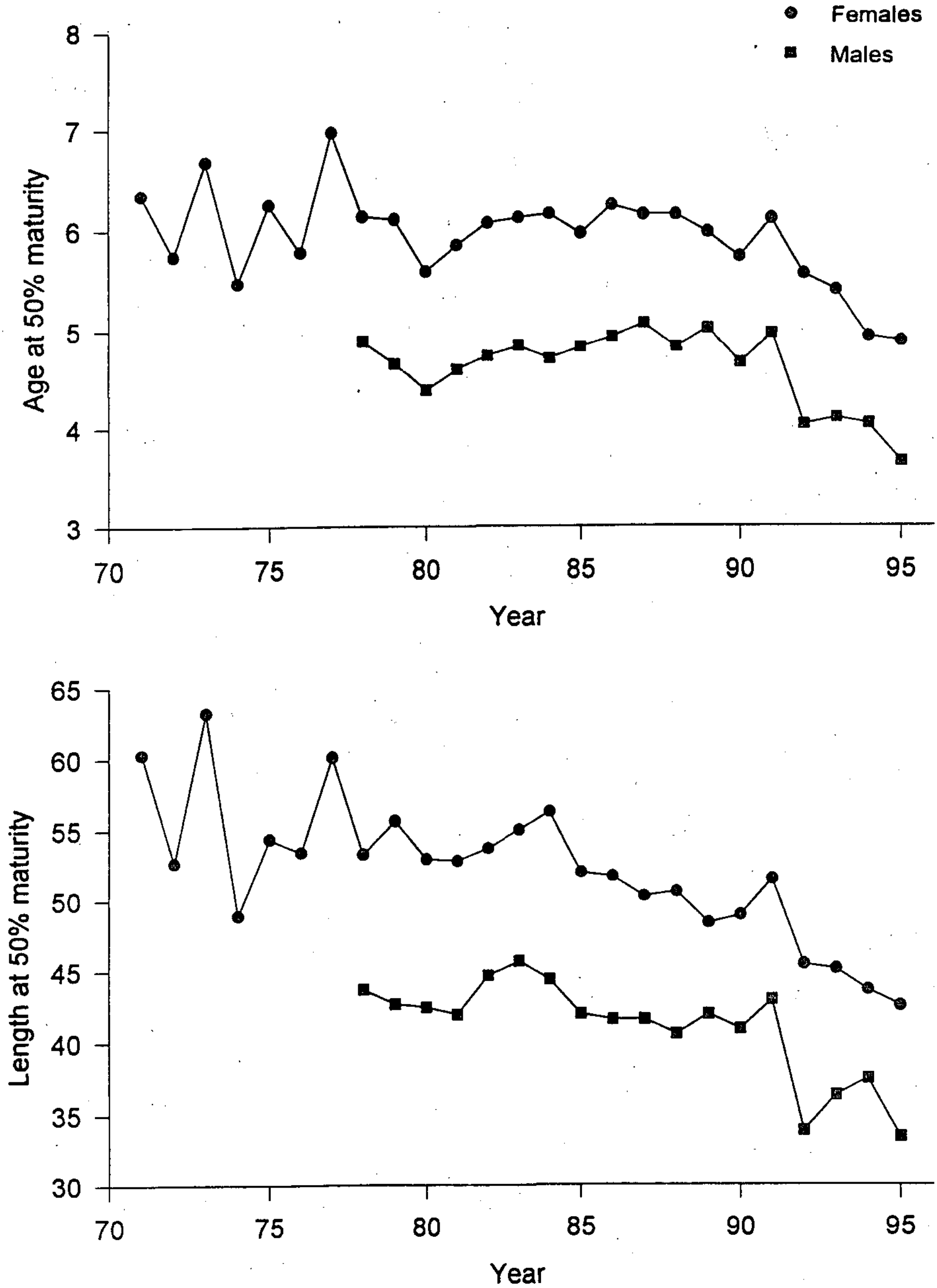


Figure 5 . Age and length at 50% maturity (Jan.1) for cod in Div. 2J3KL.

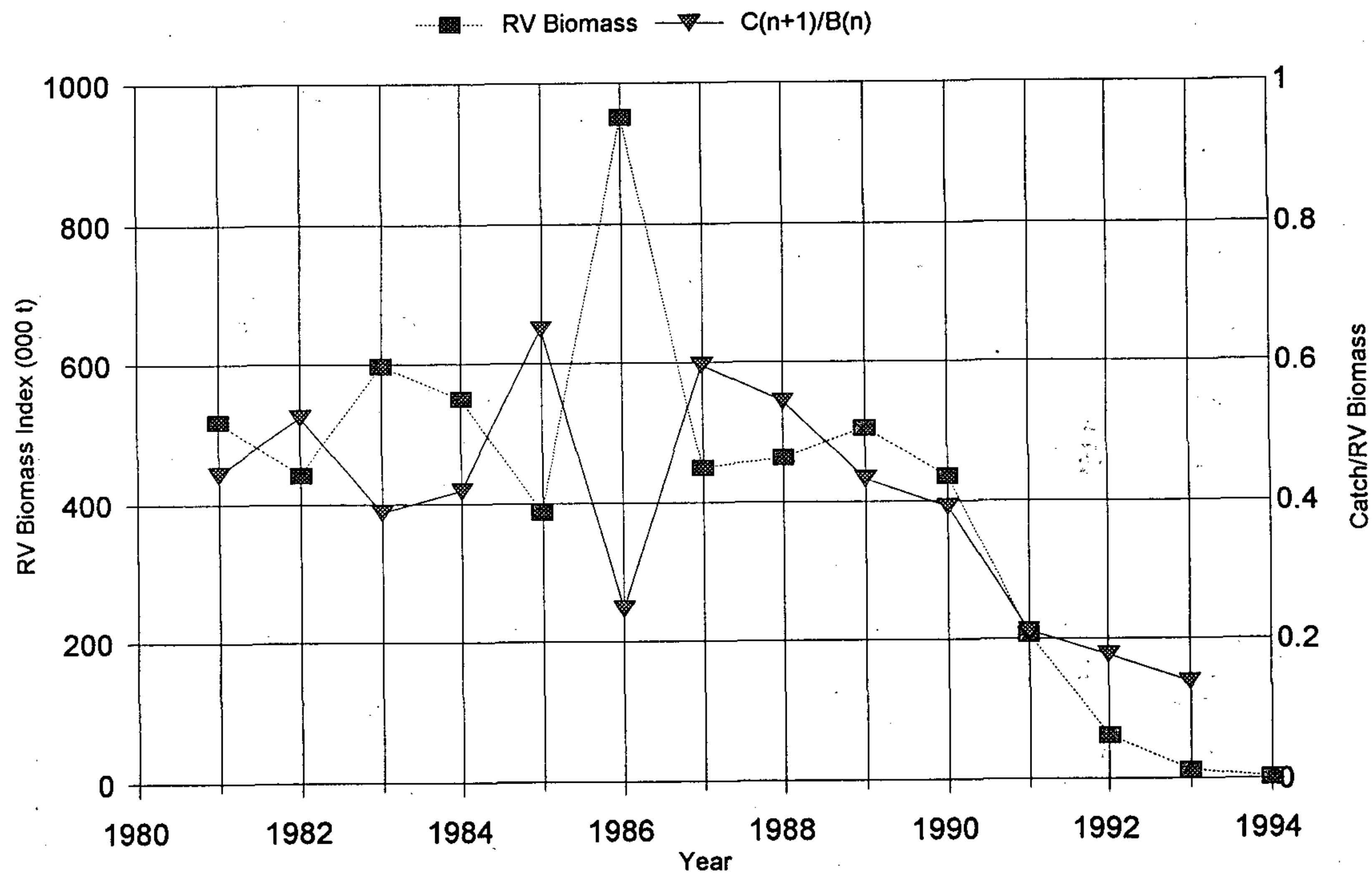


**Fig.6. 2J3KL Cod : Catch/RV Biomass
(catch yr n+1 & biomass end of yr n)**

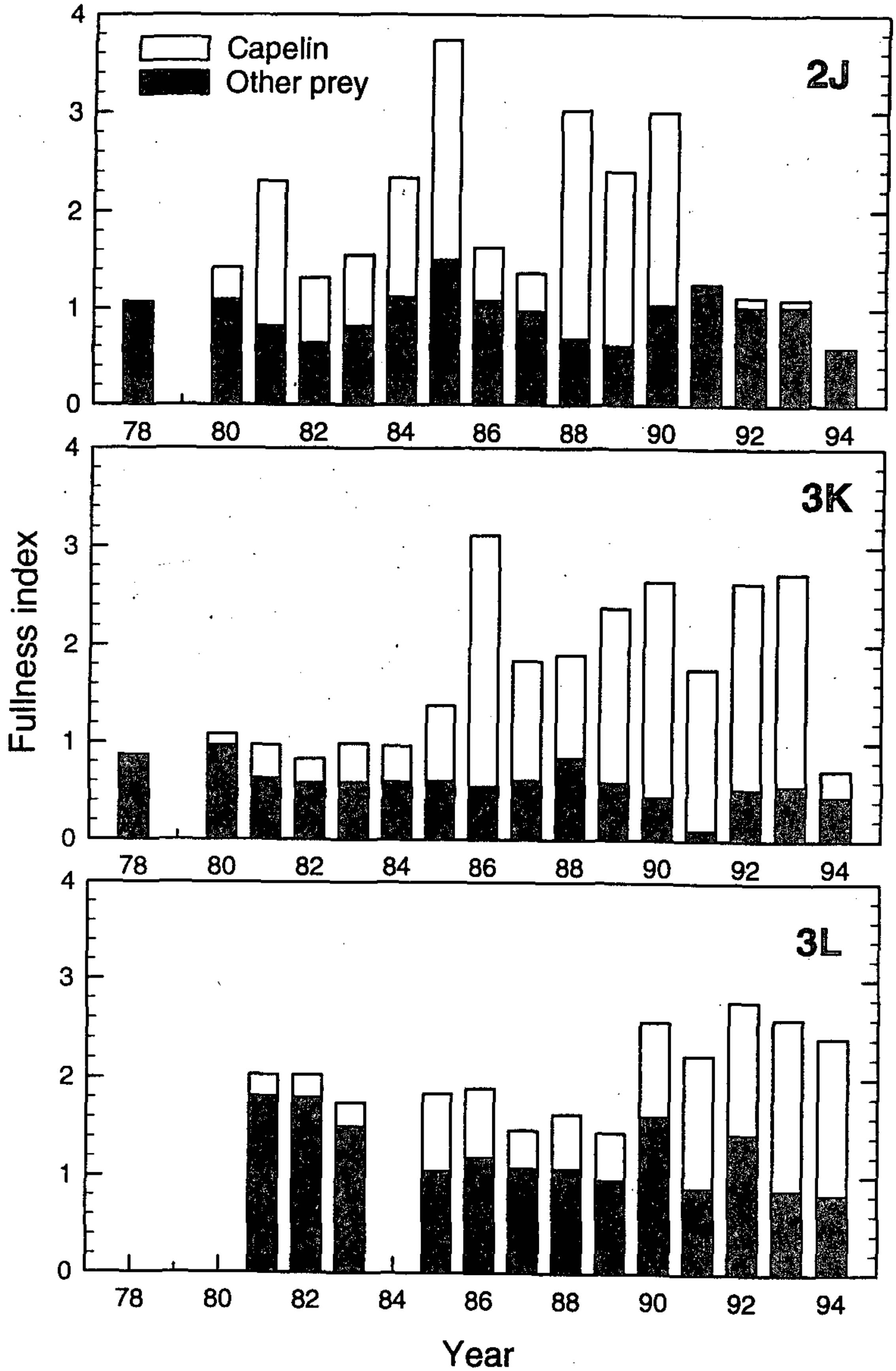


Fig. 7 . Mean stomach fullness index of cod (36-71 cm only) by Division and year. The fullness index is partitioned into capelin and all other prey combined. Updated from Lilly (1993) and Taggart et al. (1994).