Assessment of Eastern Georges Bank Cod for 2006

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ABSTRACT

Combined Canada/USA catches, which averaged about 17,500 mt between 1978 and 1992, peaked at 26,500 mt in 1982, declined to 1,800 mt in 1995, fluctuated around 3,000 mt until 2003 and subsequently declined again. Catches in 2005 were 1,200 mt, including 407 mt of discards. Canadian catches declined to 900 mt in 2005 from 1,300 mt in 2004. USA catches declined to 300 mt in 2005 from 1,100 mt in 2004.

Adult population biomass declined from 44,000 mt in 1990 to 8,500 mt in 1995, subsequently increased to 19,000 mt in 2001, and was 17,000 mt at the beginning of 2006. Recruitment at age 1 of the 2003 year class, at 7.9 million, is the first above average cohort since the 1990 year class. The 2002 and 2004 year classes, at less than 1 million each, are the lowest on record. Fishing mortality for ages 4-6 increased sharply between 1989 and 1993 from 0.5 to 1.0. In 1995, fishing mortality declined to F_{ref}=0.18, but subsequently fluctuated above F_{ref} until 2004 when it declined to 0.17 and declined further in 2005 to 0.10.

Assuming a 2006 catch equal to the 1,700 mt total quota, a combined Canada/USA catch of 2,900 mt in 2007 would result in a neutral risk (50%) that the fishing mortality rate in 2007 will exceed F_{ref}=0.18. A catch of 1,500 mt in 2007 would result in a neutral risk (50%) that the adult biomass would decrease from 2007 to 2008 and maintains the fishing mortality near F_{2005}=0.1.

RÉSUMÉ

Les prises combinées du Canada et des États-Unis, qui se sont situées en moyenne à environ 17 500 tm entre 1978 et 1992, ont culminé à 26 500 tm en 1982, chuté à 1 800 tm en 1995, fluctué alentour de 3 000 tm jusqu'en 2003 et de nouveau décliné par la suite. En 2005, ces prises étaient de 1 200 tm, dont 407 tm de rejets. Les prises canadiennes, qui avaient été de 1 300 tm en 2004, sont tombées à 900 tm en 2005. Les prises des États Unis ont décliné à 300 tm en 2005, après avoir atteint 1 100 tm en 2004.

La biomasse de la population adulte a diminué, passant de 44 000 tm en 1990 à 8 500 tm en 1995; elle a ensuite augmenté à 19 000 tm en 2001 et se chiffrait à 17 000 tm au début de 2006. Le recrutement, à l'âge 1, de la classe d'âge de 2003, dont l'effectif est de 7,9 millions de poissons, représente la première cohorte supérieure à la moyenne depuis la classe d'âge de 1990. Les classes d'âge de 2002 et 2004, qui comptent chacune moins d'un million de poissons, sont les plus basses observées à ce jour. La mortalité par pêche parmi les âges 4-6 a nettement augmenté entre 1989 et 1993, passant de 0,5 à 1,0. En 1995, elle est tombée à Fréf. = 0,18, mais elle a ensuite fluctué au-dessus de Fréf. jusqu'en 2004, année où elle est tombée à 0,17. Elle a encore reculé en 2005, pour se situer à 0,10.

Si on tient pour acquis que les prises de 2006 seront égales au quota total de 1 700 tm, des prises combinées Canada/États-Unis de 2 900 tm en 2007 correspondraient à un risque neutre (50 %) que la mortalité par pêche en 2007 soit supérieure à Fréf. = 0,18. Des prises d'environ 1 500 tm en 2007 se traduiraient par un risque neutre (50 %) que la biomasse des adultes diminue de 2007 à 2008 et maintiendraient la mortalité par pêche près de F2005 = 0,1.

Introduction

For the purpose of developing a sharing proposal and consistent management by Canada and the USA, agreement was reached that the transboundary management unit for Atlantic cod would be limited to the eastern portion of Georges Bank (DFO Statistical Unit Areas 5Zj and 5Zm; USA Statistical Areas 551, 552, 561 and 562; Figure 1; DFO 2002). This assessment applies the consensus benchmark formulation employed by Hunt et al (2005) using Canadian and USA fishery information updated to 2005, Fisheries and Oceans Canada (DFO) survey updated to 2006, National Marine Fisheries Services (NMFS) spring survey updated to 2006 and NMFS fall survey updated to 2005.

Fishery

Commercial Fishery Catches

Combined Canada/USA catches, which averaged 17,500 mt between 1978 and 1992, peaked at 26,500 mt in 1982, declined to 1,800 mt in 1995, fluctuated around 3,000 mt until 2003 and subsequently declined again. Catches in 2005 were 1,200 mt (Table 1, Figure 2).

Canadian catches peaked at 18,000 mt in 1982 and declined from 14,000 mt in 1990 to 1,100 mt in 1995 (Table 1, Figure 2). Since 1995, with reduction in cod quotas, the fishery has reduced targeting for cod through changes in fishing practices. From 1995-2004 catches fluctuated between 1,000 mt and 3,500 mt. Canadian catches declined to 900 mt in 2005 from 1,300 mt in 2004. Landings in 2005 were 630 mt, taken primarily between June and December by otter trawl and longline (Table 2). All 2005 landings were subject to dockside monitoring. As well, at sea observers monitored about 50% (by weight) of 2005 landings during January-February and 10% of landings during June-December. Discards of cod by the groundfish fishery were 200 to 400 mt during 1997-1999 (Van Eeckhaute and Gavaris 2004) and 144 mt in 2005 (Appendix A). Since 1996 the Canadian scallop fishery has not been permitted to land cod. Landings until 1995 include those catches reported by the scallop fishery. Discards of cod by the Canadian scallop fishery since 1978 ranged up to 200 mt annually (Van Eeckhaute et al 2005), and were 110 mt in 2005 (Van Eeckhaute and Gavaris 2006).

USA catches increased from 5,500 mt in 1978 to 10,500 mt in 1984, then declined and fluctuated around 6,000 mt during 1985-1993 (Table 1, Figure 2). Since December 1994, a year-round closure of Area II (Figure 1) has been in effect, with the exception of a Special Access Program in 2004. Minimum mesh size limits were increased in 1994, 1999 and in 2002. Limits on sea days, as well as trip limits, have also been implemented. USA catches during 1994-2000 ranged from between 560 mt to 1,200 mt and increased to 1,900 mt in 2003. Quotas were introduced in May 2004. USA catches declined to 300 mt in 2005 from 1,100 mt in 2004. Most of the 2005 catch was taken in the second and third quarters. Of the 124 mt landed, 87% was caught by otter trawl gear and 11% by longline. Discard to kept ratios were estimated quarterly from observed trips in the Northeast Fisheries Science Center Observer Data Base System (OBDBS) and applied to quarterly landings to estimate annual discards. Estimated discards of cod in the groundfish fishery for 1989-2004 were generally less than 100 mt annually but were 153 mt in 2005.

Size and Age Composition

The size and age composition of the 2005 landings by the Canadian groundfish fishery was derived from port and at-sea samples from all principal gears and seasons (Table 3, Figure 3). While comparison of port and at-sea length frequencies indicated discrepancies in some months for longline (Figure 4), the differences were not consistent. Landings and sampling were too limited to conclude that at-sea samples should be excluded from calculations because they were not representative of landings. Landings peaked at 58 cm (23 in) for otter trawlers (Figure 5) while longliners displayed a broad peak between 58 cm (23 in) and 80 cm (32 in). Gill-netters caught fewer cod but these fish were larger, peaking at 80 cm (32 in). Age composition was obtained by applying quarterly fishery age-length keys to the size composition. The age-length key from 2005 DFO survey, conducted in February, was used to augment the first quarter key. Two age readers were involved in processing the DFO fishery samples. Comparisons indicated good agreement (Appendix B, Table B1). Comparison of age interpretations between DFO and NMFS age readers indicated some bias, but agreement was considered satisfactory (Appendix B, Table B2).

Cod discards from the 2005 Canadian groundfish fishery were assumed to have the same size and age composition as landings since these were not considered the result of high-grade culling. The size composition of cod discards from the 2005 Canadian scallop fishery was derived from at-sea sampling. Cod discards from the scallop fishery tend to be smaller than cod caught by the groundfish fishery. Age composition of the discards was obtained by applying fishery and survey age-length keys to the size composition.

Samples from the 2005 USA fishery on eastern Georges Bank were insufficient to characterize the size composition of the landings (Table 3). Therefore, length samples from western Georges Bank were included to supplement those from eastern Georges Bank. USA fishery age samples from eastern Georges Bank were limited and were supplemented with Canadian fishery age samples (Table 3). Landings peaked at 68 cm (Figure 6).

Discards-at-length for the 2005 USA otter trawl fishery were estimated from observed trips in the OBDBS. The cod discards tend to be smaller than landed cod. Commercial fishery and NMFS survey age-length keys were then applied to discards-at-length to derive discards-at-age. Annual length-weight relationships, derived from OBDBS samples, were used in the computation of numbers discarded from weight discarded.

The 2001 year class at age 4 dominated (40% by number) the combined Canada/USA 2005 fishery age composition (Figure 7). The 2003 year class, although only partially recruited to the fishery at age 2, made the second highest contribution (17% by number) and was the dominant year class discarded. The USA groundfish fishery cod discard catch at age for 1989-2005 and the Canadian groundfish fishery and scallop fishery cod discard catch at age for 1978-2005 were included in the assessment. The discards at age were used to augment the 1978-2004 landings at age and these results were updated with the 2005 catch at age (Table 4, Figure 8).

Fishery weights at age show a declining trend starting in the early 1990s, particularly at older ages (Table 5, Figure 9). There are indications that the decline has slowed or halted in the most recent years. However, fishery weights at age remain at or near the lowest observed since 1978 for all ages.

Abundance Indices

Commercial Fishery Catch Rates

Landings of cod taken by the USA fishery on eastern Georges Bank are almost exclusively caught by otter trawl, primarily during the 2nd calendar quarter (O'Brien et al. 2002). Since 1994, the majority of USA vessels fish near the northwest corner of Closed Area II. A preliminary measure of fishery performance by otter trawl vessels was estimated by summing catch and effort for vessels in this area during 1990-2005. The data were not standardized for any variable, i.e. tonnage class, season, depth. Fishery performance (t/day fished) shows a declining trend from 1990 to 1995, an increasing trend from 1996 to 2003 and a subsequent decline during 2004-2005 (Fig.10). This catch rate series is not an indicator of abundance but reflects localized aggregations and is influenced by the movement of cod across the western boundary of the closed area.

Surveys

Surveys of Georges Bank have been conducted by DFO each year (February) since 1986 and by NMFS each autumn (October) since 1963 and each spring (April) since 1968. All surveys use a stratified random design (Figures 11 and 12). For the NMFS surveys, two vessels have been employed and there was a change in the trawl door in 1985. Vessel and door type conversion factors (Table 6), derived experimentally from comparative fishing, have been applied to the survey results to make the series consistent (Forrester et al 1997). Additionally, two different trawl nets have been used on the NMFS spring survey, a modified Yankee 41 during 1973-81 and a Yankee 36 in other years, but no conversion factors are available for cod.

The spatial distribution of cod on eastern Georges Bank, ages 3 and older, caught during the 2006 DFO survey was similar to that observed from surveys over the previous decade (Figure 13). The highest densities were observed on the northern part of the bank at depths less than 100 m. Total catch in numbers in the 2006 DFO survey declined from 2005 but remained relatively high compared to recent years (Table 7). The 2006 NMFS spring distribution was fairly dispersed (Fig 14), however, the highest percent of total cod biomass (71%) on eastern Georges Bank occurred in stratum 16, mostly in the USA portion (Fig.15). Total catch in numbers for the 2006 NMFS spring survey increased between 2005 and 2006, due in part to the 2003 year class (Table 8). The high index observed in 2004 appears to be a year effect. The 2005 NMFS autumn catch distribution was primarily along the Northern Edge (Fig. 16) and similar to the average (2000-2004) density. The highest biomasses occurred in strata 16, 17, and 21 (Fig. 17). Total catch in numbers in the 2005 NEFSC autumn survey declined from 2004 (Table 9).

Survey abundance at age (Tables 7-9, Figure 18) shows poor recruitment since the 1990 year class. The 2003 year class looks promising but it is not exceptional. There is a weak indication of increasing abundance at older ages in recent years.

Population weights at age derived from the DFO survey also display a declining trend since the early 1990s (Table 10, Figure 19) and the trend was also more pronounced at older ages. However, unlike the fishery weights at age, the decline appears more severe after 2000. Cod condition, measured as average weight at length at 3 representative length groupings, derived from the DFO survey does not show any notable trends (Figure 20).

Harvest Strategy

The Transboundary Management Guidance Committee has adopted a strategy to maintain a low to neutral risk of exceeding the fishing mortality limit reference, $F_{ref} = 0.18$. When stock conditions are poor, fishing mortality rates should be further reduced to promote rebuilding.

Estimation and Diagnostics

The state of the resource was based on results from an age structured analytical assessment (VPA) that used fishery catch statistics and sampling for size and age composition of the catch for 1978 to 2005 (including discards). The VPA was calibrated to trends in abundance from three bottom trawl survey series; NMFS spring, NMFS fall and DFO.

A consensus model formulation was established during the benchmark assessment review (O'Boyle and Overholtz, 2002). The adaptive framework, ADAPT, (Gavaris 1988) was used to implement the benchmark formulation for calibrating the virtual population analysis with the research survey data. Computational formulae used in ADAPT are described by Rivard and Gavaris (2003a). The observed data used in the model were:

$C_{a,t}$ =catch at age for ages a = 1 to 10 and time t = 1978 to 2005, where t represents the year during which the catch was taken
$I_{1,a,t}$ = DFO survey for ages a = 2 to 7 and time t = 1986.16, 1987.16… 2005.16, 2006.00
$I_{2,a,t}$ = NMFS spring survey (Yankee 41) for ages a = 1 to 8 and time t = 1978.29, 1979.29, 1980.29, 1981.29
$I_{3,a,t}$ = NMFS spring survey (Yankee 36), for ages a = 1 to 8 and time t = 1982.29, 1983.29… 2005.29, 2006.00
$I_{4,a,t}$ = NMFS autumn survey, ages a = 1 to 5 and time t = 1978.69, 1979.69… 2005.69.

The population was calculated to the beginning of 2006.00, therefore the DFO and NMFS spring survey indices for 2006 were designated as occurring at the beginning of the year, i.e. 2006.00. The benchmark formulation assumes that observation errors for the catch at age data were negligible. Observation errors for the abundance indices at age are assumed to be independent and identically distributed after taking natural logarithms of the values. Zero observations for abundance indices were treated as missing data as the logarithm of zero is not defined. The annual natural mortality rate, M, was assumed constant and equal to 0.2 for all ages in all years. Fishing mortality on age 10 for 1978 to 1999 was assumed to be equal to the population number weighted average fishing mortality on ages 8 and 9.

Estimation was based on minimization of the objective function:

$$\sum_{s,a,t}\left(lnI_{s,a,t} - \left(\hat{\kappa}_{s,a} + lnN_{a,t}\right)\right)^2$$, where s indexes survey and N is population abundance.

The estimated model parameters were:
$v_{a,t} = lnN_{a,t} = ln$ population abundance for a = 2 to 11 at time t = 2006 and for a = 11 at time t = 2001 to 2005
$\kappa_{1,a} = ln$ DFO survey catchability for a = 2 to 7
$\kappa_{2,a} = ln$ NMFS spring survey (Yankee 41) catchability for ages a = 1 to 8
$\kappa_{3,a} = ln$ NMFS spring survey (Yankee 36) catchability for ages a = 1 to 8
$\kappa_{4,a} = ln$ NMFS autumn survey catchability for ages a = 1 to 5.

Statistical properties of estimators were determined using conditional non-parametric bootstrapping of model residuals (Efron and Tibshirani 1993, Rivard and Gavaris 2003a). The population abundance estimate at age 2 at the beginning of 2006 exhibited the largest relative bias of 11%, while that for other ages/times ranged between 3% and 9%. The relative error ranged between 30% and 60% (Table 11). Survey catchability at age for the DFO and NMFS spring (Yankee 36) surveys progressively increases until about age 4 or 5 and then fluctuates. Survey catchability at age for the NMFS autumn survey is highest at age 3. While trends in the surveys are generally consistent, the survey indices exhibit high variability and the average magnitude of residuals is large. Some patterns in the residuals suggest year effects (Figures 21-25).

Retrospective analyses were used to detect any patterns to consistently overestimate or underestimate fishing mortality, biomass and recruitment relative to the terminal year estimates. The extent of the pattern for this assessment was similar to that seen in the past and was not of concern (Figures 26-27).

State of Resource

Recruitment at age 1 of the 2003 year class, at 7.9 million, is the first above average (6.4 million) cohort since the 1990 year class (Table 12, Figure 28). Prior to the 2003 year class, the 1996 and 1998 year classes, at over 4 million, were the strongest since the 1990 year class. The 2002 and 2004 year classes, at less than 1 million each, are the lowest on record.

Fishing mortality for ages 4-6 increased sharply between 1989 and 1993 from 0.5 to 1.0 (Table 13, Figure 29). In 1995, fishing mortality declined to $F_{ref}=0.18$, due to restrictive management measures, but subsequently fluctuated above F_{ref} until 2004 when it declined to 0.17 and declined further in 2005 to 0.10 (80% Confidence Interval: 0.08 – 0.13).

Adult population biomass[1] (ages 3+) declined substantially from 44,000 mt in 1990 to 8,500 mt in 1995, the lowest observed (Table 14, Figure 28). The biomass subsequently increased to 19,000 mt in 2001, declined to 13,000 mt in 2005 but increased again to 17,000 mt at the beginning of 2006 (80% Confidence Interval: 14,300 mt – 21,200 mt). Much of the increase in the late 1990's was the result of growth and survival to ages 5+ of the 1992, 1995 and 1996 year classes. The increase in 2006 was due largely to recruitment of the 2003 year class. Lower weights-at-age in the population in recent years and the generally poor recruitment have contributed to the lack of rebuilding.

Yield exceeded surplus production during the early 1990s (Figure 30). Surplus production since the mid 1990s has remained considerably lower than that prior to 1990. Growth of ages 2 to 10 has typically accounted for the greatest percentage of the production (Figure 31). Occasionally, a strong incoming year-class at age 2 makes a greater contribution to production. While there has been a tendency for greater chance of good recruitment when biomass exceeded 25,000 mt (Figure 32), there is high recruitment variability at any given biomass. Since the early 1990s, biomass has remained below 25,000 mt and recruitment has been poor.

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[1] Biomass reported in the status report (TRAC 2006) are lower due to omission of age 11 biomass.

Productivity

Age structure, fish growth, recruits per spawner, and spatial distribution reflect changes in the productive potential. In both absolute numbers and percent composition, the population age structure displays a higher abundance at older age groups compared to the mid 1990s. However, the abundance for older ages may not be well determined. Average weight at length, used to reflect condition, has been stable, but declines in weight at age have hampered biomass rebuilding. The recruit per adult biomass ratio has been generally lower than that seen prior to 1990 (Figure 33), with the exception of the 2003 year class. The spatial distribution patterns observed during the most recent bottom trawl surveys were similar to the average patterns over the previous decade. Resource productivity is currently poor due to declines in weight at age and generally low recruit per spawner ratio

Outlook

This outlook is provided in terms of consequences with respect to the harvest reference points for alternative catch quotas in 2007 (Rivard and Gavaris 2003b). Uncertainty about standing stock generates uncertainty in forecast results which is expressed here as the risk of exceeding F_{ref} =0.18. The risk calculations assist in evaluating the consequences of alternative catch quotas by providing a general measure of the uncertainties. However, they are dependent on the data and model assumptions and do not include uncertainty due to variations in weight at age, partial recruitment to the fishery, natural mortality, systematic errors in data reporting or the possibility that the model may not reflect stock dynamics closely enough.

For projections, the 2003-2005 average values were assumed for the fishery weight at age and partial recruitment pattern in 2006 and later and the 2004-2006 survey average values were assumed for beginning of year population weight at age in 2007 and later (Table 15). Assuming a 2006 catch equal to the 1,700 mt total quota, a combined Canada/USA catch of 2,900 mt in 2007 would result in a neutral risk (50%) that the fishing mortality rate in 2007 will exceed F_{ref} (Figure 34). This results in a high risk (over 75%) that the 2008 adult biomass will be lower than the 2007 adult biomass. However, the magnitude of the biomass decline is nominal and not very well determined. A catch of about 1,500 mt in 2007 would result in a neutral risk (50%) that the adult biomass would decrease from 2007 to 2008 and maintains the fishing mortality near F_{2005}=0.1. The 2003 year class is projected to make a large contribution to the fishery over the next several years.

Medium term projections indicate declining yield as the above average 2003 year class is fished down (Table 16). Exploitation below F_{ref} would maintain biomass at higher levels until better recruitment occurs. These results assume average recruitment of 2.5 million (1991 – 2004 year classes, excluding the 2003 year class) and constant fishing mortality rate of 0.18.

Acknowledgements

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Table 1. Catches (mt) of cod from eastern Georges Bank during 1978-2005.

Year	Canada			USA			Total
	Landings	Discards	Total	Landings	Discards	Total	
1978	8778	98	8876	5502		5502	14378
1979	5978	103	6081	6408		6408	12489
1980	8063	83	8146	6418		6418	14564
1981	8499	98	8597	8094		8094	16691
1982	17824	71	17895	8565		8565	26460
1983	12130	65	12195	8572		8572	20767
1984	5763	68	5831	10551		10551	16382
1985	10443	103	10546	6641		6641	17187
1986	8504	51	8555	5696		5696	14251
1987	11844	76	11920	4792		4792	16712
1988	12741	83	12824	7645		7645	20469
1989	7895	76	7971	6182	158	6340	14311
1990	14364	70	14435	6378	61	6439	20873
1991	13462	65	13526	6777	144	6921	20448
1992	11673	71	11744	5080	129	5209	16953
1993	8524	63	8586	4019	66	4085	12671
1994	5278	63	5340	1228	6	1234	6575
1995	1100	38	1138	665	1	666	1804
1996	1926	56	1982	773	2	775	2757
1997	2919	486	3404	557	1	558	3963
1998	1907	365	2272	795	2	797	3069
1999	1818	338	2156	1150	7	1157	3314
2000	1572	69	1641	661	11	672	2313
2001	2143	143	2285	1361	83	1444	3730
2002	1279	94	1373	1379	37	1416	2789
2003	1325	200	1525	1813	87	1900	3425
2004	1111	145	1257	980	74	1053	2310
2005	630	254	884	124	153	277	1161
Minimum	630	38	884	124	1	277	1161
Maximum	17824	486	17895	10551	158	10551	26460
Average	6768	125	6892	4243	60	4280	11172

Table 2. Nominal landings (mt) of cod from eastern Georges Bank by gear and month for Canada during 1996-2005.

Year	Gear	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1996	Gillnet						26	138	81					245
	Longline						29	389	290	91	137	66	21	1023
	Mobile	2					217	96	100	58	42	40	103	659
	Total	2					272	623	472	149	179	106	125	1926
1997	Gillnet						133	133	107	51	47			470
	Longline						177	432	385	255	132	15	21	1416
	Mobile						360	166	210	135	56	52	53	1033
	Total						670	731	703	440	235	67	74	2919
1998	Gillnet						76	90	63	25	46			300
	Longline						74	345	221	197	87	21	18	963
	Mobile						178	71	138	95	99	39	27	645
	Total					0	328	505	422	316	232	60	45	1907
1999	Gillnet						59	100	48	15	36	7	6	270
	Longline						95	288	244	152	107	27	17	929
	Mobile	3					226	156	47	72	59	38	19	619
	Total	3					379	544	339	239	201	71	42	1818
2000	Gillnet						55	76	28	24	41	9	4	238
	Longline						41	191	177	222	138	15	16	800
	Mobile	0					102	140	82	73	70	38	30	535
	Total	0					197	407	287	318	248	63	51	1572
2001	Gillnet						37	75	48	60	43	21		284
	Longline						62	212	273	282	229	62	16	1137
	Mobile						160	84	58	104	134	111	72	722
	Total						259	371	379	446	406	193	89	2143
2002	Gillnet						3	45	51	23	1	9	7	140
	Longline						2	151	199	162	127	31	30	700
	Mobile						38	87	34	78	62	55	86	439
	Total						43	283	283	263	190	95	123	1279
2003	Gillnet						6	30	31	24	3	14	1	110
	Longline						22	181	238	138	121	28	14	742
	Mobile						88	84	54	64	69	70	45	474
	Total						116	295	324	227	193	112	59	1325
2004	Gillnet						4	2	14	21	0	11	0	52
	Longline						6	85	231	168	88	96	14	688
	Mobile						78	82	50	47	56	42	16	371
	Total						88	169	294	236	144	149	30	1111
2005	Gillnet	0	0			0	11	18	0	6	0	0	0	36
	Longline	1	0			0	9	44	101	71	52	29	4	311
	Mobile	12	22			3	50	49	31	27	28	31	30	283
	Total	13	22			3	70	111	133	105	80	60	34	630

Table 3. Commercial landings length and age samples from 1978-2004 for eastern Georges Bank Canadian and USA cod fisheries. At-sea observer samples are included in Canadian length samples since 1994. USA age samples were supplemented with DFO age samples for 1996-2004 (number after supplementing shown in brackets).

	USA			Canada		
Year	Samples	Lengths	Ages	Samples	Lengths	Ages
1978	29	2047	385	29	7684	1308
1979	21	1833	402	13	3991	656
1980	16	1258	286	10	2784	536
1981	21	1615	456	17	4147	842
1982	45	4111	778	17	4756	858
1983	40	3775	903	15	3822	604
1984	44	3891	1130	7	1889	385
1985	23	2076	597	18	7644	1062
1986	27	2145	644	19	5745	888
1987	23	1865	525	33	9477	1288
1988	37	3229	797	43	11709	1984
1989	19	1572	251	32	8716	1561
1990	28	1989	287	40	9901	2012
1991	23	1894	397	45	10873	1782
1992	25	2048	445	48	10878	1906
1993	29	2215	440	51	12158	2146
1994	13	1323	260	104	25845	1268
1995	-	-	-	36	11598	548
1996	3	284[1]	74 (953)	129	26663	879
1997	80	6638[1]	55 (1299)	118	31882	1244
1998	82	7076[1]	46 (1766)	139	26549	1720
1999	70	6045[1]	250 (1168)	84	24954	918
2000	156	12219[1]	41 (1551)	107	20782	1436
2001	108	8389[1]	351 (2423)	108	18190	1509
2002	86	6306[1]	378 (1642)	91	18974	1264
2003	47	2785[1]	385 (1569)	94	20199	1070
2004	31	1872[1]	439 (1481)	127	17859	1370
2005	58	2160[1]	249(1511)	136	21942	731

[1] Includes length samples from western Georges Bank.

Table 4. Annual catch at age numbers (thousands) for eastern Georges Bank cod.

Year	Age Group										
	1	2	3	4	5	6	7	8	9	10	1+
1978	2.0	121.0	3588.0	1076.0	307.0	110.0	83.0	21.0	11.6	3.6	5327
1979	10.2	827.6	405.7	1803.7	554.1	151.5	22.4	45.8	3.8	3.1	3829
1980	1.0	994.3	1506.1	267.0	922.8	347.6	109.8	20.1	33.6	5.4	4212
1981	19.2	609.0	1457.3	1261.3	156.5	600.9	170.7	65.6	36.4	18.6	4396
1982	6.0	2692.7	1692.7	1434.7	1070.2	189.8	346.4	157.6	37.2	12.2	7665
1983	40.1	1322.4	3424.7	1477.8	467.2	283.7	31.1	71.2	38.9	5.9	7173
1984	10.1	270.6	916.5	1354.2	514.1	291.8	231.4	31.2	72.8	26.6	3744
1985	12.1	2804.8	1226.6	633.9	945.3	225.0	96.4	100.5	14.4	26.9	6095
1986	28.2	328.5	2204.8	516.9	306.3	403.1	58.4	39.3	25.9	3.6	3925
1987	14.0	3665.8	864.9	1098.9	144.0	121.0	167.0	37.0	23.6	7.6	6147
1988	9.9	317.3	3621.9	640.5	853.7	142.8	101.1	141.8	40.5	19.4	5906
1989	48.8	820.1	667.0	1827.6	191.8	311.7	55.6	24.8	50.9	11.7	4021
1990	9.0	719.5	3215.2	965.9	1199.1	116.4	122.3	10.0	14.3	22.6	6403
1991	33.3	724.1	802.4	1944.5	953.3	790.4	93.0	56.0	17.8	7.1	5434
1992	96.9	2456.9	1252.0	432.1	906.9	249.8	232.8	25.0	26.8	2.4	5686
1993	7.6	458.9	1986.2	812.3	216.1	333.7	110.6	93.6	23.2	17.4	4062
1994	2.9	187.5	488.5	753.0	246.5	40.7	58.8	26.0	20.3	1.1	1826
1995	2.0	56.5	235.2	120.1	89.1	14.4	4.2	3.0	1.5	0.0	526
1996	4.4	41.7	238.5	400.3	78.8	49.8	11.8	2.7	1.8	0.1	830
1997	3.0	136.2	213.7	412.0	461.1	111.8	55.7	18.5	3.7	0.7	1417
1998	0.6	103.2	381.1	198.1	201.2	167.0	26.2	14.9	4.7	1.1	1100
1999	3.3	63.0	540.4	364.4	110.1	61.7	52.1	12.1	2.1	4.6	1214
2000	1.8	59.6	115.8	335.9	129.5	34.6	20.2	12.2	1.8	0.3	712
2001	1.9	112.9	471.5	201.2	375.3	98.4	29.3	17.1	5.4	0.5	1314
2002	3.9	16.5	130.5	377.6	98.0	145.7	25.8	7.5	3.8	1.5	811
2003	1.8	31.6	177.9	276.5	393.6	73.0	81.9	15.9	3.1	1.2	1057
2004	2.9	13.7	132.2	152.8	134.0	128.8	32.9	22.1	4.3	0.8	625
2005	2.2	71.4	44.3	169.0	42.7	30.1	31.6	11.3	5.5	1.3	410

Table 5. Average fishery weights at age (kg) of cod from eastern Georges Bank.

Year	Age Group									
	1	2	3	4	5	6	7	8	9	10
1978	0.71	1.31	2.46	3.47	4.34	5.79	7.37	8.49	11.79	13.62
1979	0.89	1.49	2.15	4.21	4.89	7.18	9.18	10.31	11.70	14.06
1980	0.84	1.46	2.47	3.67	5.65	6.68	8.39	9.09	8.43	14.35
1981	0.88	1.50	2.36	3.42	5.21	7.22	8.57	9.89	14.17	13.57
1982	0.77	1.40	2.66	3.83	5.35	6.51	9.36	9.90	12.50	13.68
1983	0.97	1.49	2.38	3.31	4.64	6.39	7.96	10.29	11.23	12.21
1984	1.05	1.64	2.45	3.62	5.08	6.58	8.91	10.10	11.30	13.79
1985	0.91	1.42	2.09	3.89	5.09	6.41	8.10	10.24	11.42	12.72
1986	0.93	1.48	2.45	3.66	5.60	7.19	8.92	9.96	12.69	8.91
1987	0.73	1.48	2.50	4.19	5.81	7.73	8.95	10.01	11.41	13.93
1988	0.79	1.52	2.36	3.51	5.40	6.65	8.78	9.99	11.14	13.17
1989	0.81	1.62	2.27	3.77	5.40	6.69	8.22	10.72	11.67	14.14
1990	0.83	1.56	2.46	3.52	4.89	6.33	8.46	10.65	12.58	14.04
1991	1.11	1.63	2.55	3.42	4.77	5.89	7.41	10.52	9.69	14.52
1992	1.15	1.54	2.46	3.84	4.70	6.16	7.51	9.85	12.06	14.52
1993	0.88	1.57	2.31	3.08	4.50	5.73	7.08	8.88	9.70	10.86
1994	0.91	1.46	2.41	3.83	4.80	7.09	7.86	8.93	9.70	10.37
1995	0.90	1.49	2.51	3.72	5.22	6.52	11.06	10.12	10.38	14.52
1996	1.03	1.54	2.36	3.34	5.24	6.36	6.92	8.46	12.88	10.51
1997	0.98	1.50	2.23	3.34	4.25	5.80	8.05	8.33	11.87	14.52
1998	0.63	1.48	2.37	3.19	4.27	5.83	6.99	8.30	12.68	11.81
1999	0.80	1.55	2.29	3.53	4.16	6.31	6.78	8.04	12.15	13.54
2000	0.87	1.46	2.13	3.08	4.23	4.92	6.20	7.34	8.27	12.97
2001	0.88	1.49	2.33	3.00	4.05	5.12	5.08	8.02	9.22	14.81
2002	0.55	1.42	2.27	3.08	4.30	5.07	6.75	8.28	8.82	8.46
2003	0.26	1.66	2.15	2.67	3.68	4.35	5.67	7.29	7.86	9.02
2004	0.70	1.37	2.03	2.86	3.45	4.57	5.50	7.35	9.03	8.86
2005	0.33	0.96	1.68	2.47	3.68	4.70	5.12	6.99	8.33	9.26
Min.	0.26	0.96	1.68	2.47	3.45	4.35	5.08	6.99	7.86	8.46
Max.	1.15	1.66	2.66	4.21	5.81	7.73	11.06	10.72	14.17	14.81
Avg.[1]	0.43	1.33	1.96	2.67	3.60	4.54	5.43	7.21	8.41	9.04

[1] for 2003-2005

Table 6. Conversion factors used to adjust for changes in door type and survey vessel for the NMFS surveys.

Year	Door	Spring		Fall	
		Vessel	Conversion	Vessel	Conversion
1978	BMV	Albatross IV	1.56	Delaware II	1.2324
1979	BMV	Albatross IV	1.56	Delaware II	1.2324
1980	BMV	Albatross IV	1.56	Delaware II	1.2324
1981	BMV	Delaware II	1.2324	Delaware II	1.2324
1982	BMV	Delaware II	1.2324	Albatross IV	1.56
1983	BMV	Albatross IV	1.56	Albatross IV	1.56
1984	BMV	Albatross IV	1.56	Albatross IV	1.56
1985	Polyvalent	Albatross IV	1	Albatross IV	1
1986	Polyvalent	Albatross IV	1	Albatross IV	1
1987	Polyvalent	Albatross IV	1	Albatross IV	1
1988	Polyvalent	Albatross IV	1	Albatross IV	1
1989	Polyvalent	Delaware II	0.79	Delaware II	0.79
1990	Polyvalent	Delaware II	0.79	Delaware II	0.79
1991	Polyvalent	Delaware II	0.79	Delaware II	0.79
1992	Polyvalent	Albatross IV	1	Albatross IV	1
1993	Polyvalent	Albatross IV	1	Delaware II	0.79
1994	Polyvalent	Delaware II	0.79	Albatross IV	1
1995	Polyvalent	Albatross IV	1	Albatross IV	1
1996	Polyvalent	Albatross IV	1	Albatross IV	1
1997	Polyvalent	Albatross IV	1	Albatross IV	1
1998	Polyvalent	Albatross IV	1	Albatross IV	1
1999	Polyvalent	Albatross IV	1	Albatross IV	1
2000	Polyvalent	Albatross IV	1	Albatross IV	1
2001	Polyvalent	Albatross IV	1	Albatross IV	1
2002	Polyvalent	Albatross IV	1	Albatross IV	1
2003	Polyvalent	Delaware II	0.79	Delaware II	0.79
2004	Polyvalent	Albatross IV	1	Albatross IV	1
2005	Polyvalent	Albatross IV	1	Albatross IV	1
2006	Polyvalent	Albatross IV	1		

Table 7. Indices of abundance (numbers/standard tow) of eastern Georges Bank cod from the DFO survey.

Year	0	1	2	3	4	5	6	7	8	9+	Total
1986	0.00	1.78	8.19	7.41	0.77	1.60	1.03	0.51	0.08		21.37
1987	0.00	0.12	4.31	1.55	1.81	0.39	0.21	0.44	0.21	0.13	9.18
1988	0.00	0.36	1.08	12.85	1.36	2.02	0.23	0.19	0.43	0.12	18.64
1989	0.00	0.84	5.22	1.84	4.11	0.62	0.80	0.10	0.20	0.39	14.13
1990	0.05	0.25	1.91	8.36	4.70	10.60	1.29	2.63	0.35	1.46	31.60
1991	0.00	2.88	2.45	3.39	3.95	2.12	2.88	0.36	0.60	0.33	18.96
1992	0.00	0.11	4.93	2.94	0.99	1.55	1.09	0.72	0.22	0.15	12.70
1993	0.00	0.07	0.85	4.15	1.50	0.89	1.82	0.66	0.64	0.26	10.84
1994	0.00	0.03	1.51	1.66	3.10	1.15	0.44	0.88	0.20	0.35	9.32
1995	0.00	0.08	0.45	2.99	1.82	1.25	0.45	0.11	0.16	0.14	7.45
1996	0.00	0.22	0.49	4.20	10.44	3.45	2.49	1.07	0.26	0.48	23.09
1997	0.00	0.07	0.90	1.37	3.19	3.04	0.52	0.12	0.08	0.10	9.40
1998	0.00	0.01	1.40	2.00	0.78	0.76	0.57	0.13	0.07	0.05	5.78
1999	0.00	0.01	0.38	3.12	2.63	1.08	0.76	0.46	0.02	0.10	8.57
2000	0.00	0.00	1.02	3.12	11.96	5.19	2.48	1.23	0.76	0.13	25.89
2001	0.00	0.01	0.09	1.93	1.25	3.35	1.55	0.80	0.54	0.70	10.23
2002	0.00	0.00	0.28	1.15	5.05	1.67	3.09	1.10	0.45	0.35	13.15
2003	0.00	0.00	0.02	0.48	1.23	2.09	0.47	0.53	0.17	0.03	5.00
2004	0.00	1.03	0.10	0.59	0.91	1.02	0.86	0.14	0.26	0.08	4.98
2005	0.00	0.06	2.47	3.37	17.21	4.25	1.97	1.77	0.15	0.22	31.47
2006	0.00	0.00	0.10	3.55	1.66	4.23	1.86	0.55	0.51	0.36	12.82

Table 8. Indices of abundance (numbers/standard tow) of eastern Georges Bank cod from the NMFS spring survey.

Year	0	1	2	3	4	5	6	7	8	9+	Total
1978	0.67	0.12	0.00	5.09	1.11	1.65	0.28	1.29	0.11	0.13	10.44
1979	0.13	0.61	2.37	0.22	2.58	0.98	0.32	0.16	0.24	0.00	7.60
1980	0.00	0.02	4.33	4.17	0.32	3.82	0.79	0.15	0.09	0.15	13.84
1981	0.53	3.64	2.26	3.74	2.04	0.08	0.77	0.37	0.11	0.00	13.53
1982	0.00	0.79	11.99	24.58	22.87	16.98	0.00	5.56	1.32	0.22	84.30
1983	0.00	0.70	3.63	6.82	1.40	1.10	0.57	0.19	0.18	0.19	14.78
1984	0.00	0.11	0.20	0.63	0.93	0.18	0.35	0.14	0.00	0.20	2.74
1985	0.10	0.07	3.66	1.14	1.91	2.74	0.59	0.34	0.38	0.41	11.35
1986	0.00	1.12	0.61	2.04	0.54	0.77	0.97	0.04	0.20	0.26	6.53
1987	0.00	0.00	2.16	0.45	0.97	0.00	0.27	0.27	0.05	0.10	4.26
1988	0.00	0.57	0.44	5.04	0.49	0.83	0.07	0.01	0.12	0.02	7.60
1989	0.00	0.28	2.19	0.61	3.04	0.42	0.71	0.09	0.02	0.15	7.52
1990	0.04	0.08	0.67	3.14	1.09	1.18	0.28	0.31	0.03	0.04	6.89
1991	0.35	1.26	1.10	0.93	1.63	0.83	0.69	0.08	0.03	0.00	6.89
1992	0.00	0.14	1.20	0.63	0.18	0.47	0.27	0.28	0.05	0.09	3.32
1993	0.00	0.00	0.83	2.32	0.47	0.08	0.33	0.08	0.08	0.10	4.30
1994	0.00	0.10	0.37	0.29	0.35	0.08	0.02	0.06	0.00	0.01	1.30
1995	0.69	0.09	0.53	1.65	0.91	1.63	0.35	0.46	0.00	0.06	6.37
1996	0.00	0.25	0.54	1.78	2.41	0.22	0.17	0.05	0.00	0.00	5.42
1997	0.49	0.10	0.34	0.09	0.72	0.93	0.10	0.23	0.10	0.00	3.09
1998	0.10	0.00	1.99	3.80	1.91	1.88	1.17	0.06	0.06	0.00	10.98
1999	0.04	0.04	0.26	1.21	1.12	0.67	0.31	0.17	0.06	0.01	3.91
2000	0.07	0.00	0.55	1.16	2.43	0.89	0.25	0.09	0.04	0.00	5.47
2001	0.00	0.00	0.12	1.60	0.17	0.63	0.20	0.00	0.02	0.02	2.76
2002	0.07	0.00	0.23	0.90	2.08	0.34	0.41	0.12	0.00	0.00	4.15
2003	0.00	0.00	0.22	0.52	1.46	2.08	0.24	0.14	0.02	0.00	4.68
2004	0.00	0.99	0.02	1.50	3.75	3.77	2.42	0.43	0.68	0.05	13.61
2005	0.07	0.03	0.62	0.13	1.34	0.52	0.34	0.24	0.06	0.00	3.34
2006	0.00	0.07	0.13	1.72	0.74	1.82	0.61	0.27	0.14	0.00	5.50

Table 9. Indices of abundance (numbers/standard tow) of eastern Georges Bank cod from the NMFS autumn survey.

Year						Age Group					
	0	1	2	3	4	5	6	7	8	9+	Total
1978	0.20	2.74	0.10	5.45	0.75	0.10	0.11	0.14	0.00	0.00	9.60
1979	0.33	3.07	3.06	0.21	2.73	0.45	0.09	0.04	0.02	0.03	10.02
1980	0.57	1.42	0.74	1.17	0.04	0.33	0.03	0.03	0.04	0.00	4.36
1981	0.61	4.28	2.18	1.68	0.48	0.03	0.05	0.00	0.00	0.10	9.41
1982	0.00	0.98	1.29	0.10	0.11	0.00	0.00	0.05	0.00	0.00	2.52
1983	1.65	0.12	0.33	1.24	0.04	0.00	0.00	0.00	0.04	0.00	3.43
1984	0.05	3.25	0.22	1.18	1.89	0.05	0.07	0.00	0.00	0.02	6.73
1985	2.23	0.38	1.79	0.29	0.04	0.00	0.02	0.00	0.00	0.01	4.75
1986	0.21	5.41	0.08	0.37	0.00	0.00	0.01	0.00	0.00	0.00	6.09
1987	0.28	0.23	1.52	0.22	0.18	0.00	0.00	0.00	0.00	0.01	2.45
1988	0.17	1.01	0.32	2.12	0.18	0.48	0.00	0.09	0.05	0.00	4.44
1989	0.57	1.03	2.40	0.40	1.09	0.14	0.04	0.00	0.00	0.00	5.68
1990	0.35	0.72	0.87	1.42	0.21	0.36	0.05	0.00	0.03	0.00	4.01
1991	0.00	0.35	0.14	0.16	0.02	0.05	0.00	0.00	0.00	0.00	0.72
1992	0.00	0.37	1.31	0.28	0.00	0.07	0.02	0.00	0.00	0.00	2.04
1993	0.00	0.15	0.19	0.29	0.03	0.00	0.00	0.00	0.00	0.00	0.65
1994	0.02	0.14	0.52	0.41	0.26	0.02	0.05	0.00	0.00	0.00	1.43
1995	0.40	0.05	0.23	0.56	0.09	0.05	0.01	0.00	0.00	0.00	1.40
1996	0.02	0.56	0.15	0.56	0.41	0.10	0.05	0.00	0.00	0.00	1.85
1997	0.00	0.26	0.68	0.27	0.15	0.20	0.05	0.00	0.00	0.00	1.62
1998	0.00	0.23	1.16	1.06	0.17	0.22	0.00	0.00	0.05	0.00	2.89
1999	0.00	0.03	0.03	0.45	0.22	0.06	0.00	0.00	0.00	0.00	0.78
2000	0.00	0.10	0.37	0.12	0.16	0.08	0.00	0.00	0.00	0.00	0.83
2001	0.04	0.13	0.19	0.46	0.07	0.14	0.02	0.02	0.00	0.00	1.08
2002	0.22	0.18	1.14	1.28	4.48	0.31	0.38	0.03	0.00	0.00	8.02
2003	0.14	0.00	0.04	0.18	0.13	0.03	0.00	0.01	0.00	0.00	0.52
2004	0.03	0.76	0.12	1.51	0.70	0.98	0.79	0.19	0.05	0.05	5.18
2005	0.04	0.05	0.91	0.21	0.45	0.08	0.00	0.02	0.00	0.00	1.76

Table 10. Average weight at age (kg) for eastern Georges Bank cod from the DFO survey.

Year	1	2	3	4	5	6	7	8	9	10	11
						Age Group					
1978[1]	0.12	0.83	1.74	2.79	4.29	6.16	7.43	8.47	11.10	12.26	16.15
1979[1]	0.12	0.83	1.74	2.79	4.29	6.16	7.43	8.47	11.10	12.26	16.15
1980[1]	0.12	0.83	1.74	2.79	4.29	6.16	7.43	8.47	11.10	12.26	16.15
1981[1]	0.12	0.83	1.74	2.79	4.29	6.16	7.43	8.47	11.10	12.26	16.15
1982[1]	0.12	0.83	1.74	2.79	4.29	6.16	7.43	8.47	11.10	12.26	16.15
1983[1]	0.12	0.83	1.74	2.79	4.29	6.16	7.43	8.47	11.10	12.26	16.15
1984[1]	0.12	0.83	1.74	2.79	4.29	6.16	7.43	8.47	11.10	12.26	16.15
1985[1]	0.12	0.83	1.74	2.79	4.29	6.16	7.43	8.47	11.10	12.26	16.15
1986	0.12	0.81	1.70	2.78	4.20	6.22	7.31	9.31	13.86	14.15	16.15
1987	0.15	0.85	1.70	2.69	5.67	7.49	7.48	6.66	10.10	7.00	16.15
1988	0.13	0.93	1.79	3.02	4.17	6.27	8.44	8.72	12.33	14.16	11.40
1989	0.13	0.83	1.71	2.76	4.31	6.43	7.62	7.81	11.32	10.30	14.72
1990	0.19	0.79	1.84	2.90	4.36	6.00	8.59	9.52	13.49	14.41	16.51
1991	0.09	0.90	1.95	3.17	4.24	4.90	7.54	10.06	9.97	15.50	13.49
1992	0.12	0.82	1.94	2.88	4.19	5.89	6.58	8.60	9.91	11.95[2]	24.60
1993	0.07	0.95	1.84	2.92	4.44	5.81	6.75	7.40	9.28	8.41	21.63[2]
1994	0.06	0.66	1.41	2.65	3.99	7.61	7.70	8.66	8.87	11.77	21.63[2]
1995	0.17	0.78	1.54	2.11	3.29	5.00	6.33	7.92	11.89	14.99	18.65
1996	0.05	0.76	1.56	2.56	4.00	6.11	5.55	12.03	11.92	13.79	19.75
1997	0.11	0.72	1.68	2.17	3.19	6.39	6.74	10.74	9.44	16.59	17.67[2]
1998	0.08	0.61	1.29	2.22	3.09	4.64	5.77	8.40	8.21	8.25	15.59
1999	0.16	1.03	1.33	2.18	2.98	4.65	6.93	11.00	8.45	11.28	11.93
2000	0.08[2]	0.91	1.59	2.30	3.12	4.60	6.51	8.28	11.52	13.88	10.62
2001	0.01	0.68	1.40	2.44	3.59	5.14	6.91	7.47	10.25	9.85	11.76
2002	0.01[2]	0.42	1.17	2.31	3.59	4.41	5.95	8.44	10.00	11.84	15.76
2003	0.01[2]	0.18	1.03	1.79	3.09	3.48	5.24	6.81	7.66	10.44[2]	14.33[2]
2004	0.02	0.23	1.45	2.34	3.66	4.26	4.59	6.77	10.54	9.03	14.33[2]
2005	0.01	0.59	1.17	1.71	2.83	3.21	3.86	5.72	5.91	4.61	12.90
2006	0.01[2]	0.32	1.14	1.46	2.52	3.21	4.35	4.68	5.67	6.83	5.99
Min.	0.01	0.18	1.03	1.46	2.52	3.21	3.86	4.68	5.67	4.61	5.99
Max.	0.19	1.03	1.95	3.17	5.67	7.61	8.59	12.03	13.86	16.59	24.60
Avg.[3]	0.01	0.38	1.25	1.84	3.00	3.56	4.27	5.73	7.37	6.83	11.07

[1] average of 1986 to 1995, except age 11 which is average of 1988 to 1995
[2] average of adjacent years
[3] for 2004-2006

Table 11. Statistical properties of estimates for population abundance (numbers in thousands) and survey calibration constants for eastern Georges Bank cod obtained from a bootstrap with 1000 replications.

Parameter	Estimate	Standard Error	Relative Error	Bias	Relative Bias
N[2001 11]	88	37	0.423	5	0.053
N[2002 11]	36	21	0.592	3	0.084
N[2003 11]	81	48	0.592	6	0.072
N[2004 11]	88	39	0.449	6	0.066
N[2005 11]	105	45	0.426	6	0.061
N[2006 2]	527	269	0.511	58	0.110
N[2006 3]	5602	2282	0.407	361	0.065
N[2006 4]	498	190	0.381	42	0.085
N[2006 5]	989	330	0.334	72	0.073
N[2006 6]	677	201	0.297	25	0.037
N[2006 7]	439	141	0.321	13	0.030
N[2006 8]	334	127	0.380	19	0.058
N[2006 9]	92	43	0.466	6	0.069
N[2006 10]	220	95	0.432	13	0.060
N[2006 11]	116	51	0.441	9	0.076
DFO 2	0.266	0.056	0.210	0.006	0.021
DFO 3	1.053	0.230	0.219	0.026	0.025
DFO 4	1.805	0.364	0.201	0.040	0.022
DFO 5	2.393	0.498	0.208	0.034	0.014
DFO 6	2.412	0.498	0.206	0.055	0.023
DFO 7	2.310	0.504	0.218	0.046	0.020
NMFS spring Y41 1	0.026	0.012	0.467	0.002	0.076
NMFS spring Y41 2	0.385	0.250	0.649	0.056	0.145
NMFS spring Y41 3	0.472	0.248	0.525	0.059	0.126
NMFS spring Y41 4	0.465	0.228	0.490	0.046	0.099
NMFS spring Y41 5	0.741	0.387	0.522	0.064	0.086
NMFS spring Y41 6	0.818	0.453	0.554	0.105	0.129
NMFS spring Y41 7	1.331	0.671	0.504	0.110	0.083
NMFS spring Y41 8	1.430	0.802	0.561	0.158	0.110
NMFS spring Y36 1	0.042	0.009	0.208	0.001	0.014
NMFS spring Y36 2	0.183	0.034	0.185	0.002	0.013
NMFS spring Y36 3	0.491	0.091	0.186	0.008	0.017
NMFS spring Y36 4	0.828	0.147	0.177	0.003	0.004
NMFS spring Y36 5	0.995	0.188	0.189	0.013	0.013
NMFS spring Y36 6	0.852	0.163	0.192	0.013	0.015
NMFS spring Y36 7	0.799	0.160	0.201	0.017	0.021
NMFS spring Y36 8	0.646	0.147	0.227	0.028	0.044
NMFS autumn 1	0.096	0.017	0.178	0.001	0.012
NMFS autumn 2	0.128	0.022	0.171	0.001	0.006
NMFS autumn 3	0.244	0.043	0.176	0.003	0.012
NMFS autumn 4	0.170	0.031	0.180	0.001	0.003
NMFS autumn 5	0.187	0.037	0.197	0.003	0.015

Table 12. Beginning of year population abundance (numbers in thousands) for eastern Georges Bank cod.

| Year | Age Group | | | | | | | | | | | |
	1	2	3	4	5	6	7	8	9	10	11	1+
1978	11131	2210	10563	3506	991	307	279	56	26	9	0	29078
1979	9504	9112	1700	5432	1905	536	152	154	27	11	4	28538
1980	9231	7772	6714	1028	2830	1062	303	105	85	19	6	29154
1981	17355	7557	5467	4143	601	1490	558	149	68	39	10	37438
1982	6287	14192	5638	3167	2260	352	682	304	64	23	16	32984
1983	4581	5142	9196	3097	1312	895	119	250	108	19	8	24727
1984	13532	3715	3022	4462	1217	655	478	70	140	54	10	27355
1985	4532	11070	2797	1652	2438	536	276	185	29	50	20	23586
1986	21113	3699	6543	1194	785	1150	238	139	62	11	17	34952
1987	7027	17261	2733	3381	515	368	581	142	79	28	6	32120
1988	13649	5741	10835	1461	1782	293	193	325	83	43	16	34422
1989	3960	11166	4414	5624	624	697	112	68	140	32	18	26855
1990	5813	3198	8402	3013	2965	339	293	42	33	69	16	24183
1991	9315	4751	1971	4001	1601	1355	173	130	26	15	36	23373
1992	2691	7597	3237	896	1541	464	407	59	56	5	6	16958
1993	3906	2115	4016	1530	348	456	157	126	26	22	2	12706
1994	2752	3191	1319	1517	529	93	79	31	21	1	3	9537
1995	2074	2251	2444	643	570	213	40	13	3	0	0	8249
1996	3144	1696	1792	1789	418	386	161	29	8	1	0	9424
1997	4732	2570	1351	1252	1105	271	271	121	21	5	1	11700
1998	1731	3872	1981	914	656	492	122	172	83	14	3	10039
1999	4351	1417	3077	1279	570	356	253	76	127	64	11	11581
2000	2753	3560	1103	2032	720	367	236	160	52	102	48	11134
2001	2500	2253	2860	799	1362	473	270	175	120	41	84	10935
2002	2644	2045	1742	1917	473	778	299	194	128	93	33	10347
2003	924	2162	1659	1309	1230	299	506	221	152	101	75	8639
2004	7917	755	1741	1198	823	654	179	340	167	122	82	13978
2005	576	6479	606	1306	843	553	420	117	259	133	99	11391
2006	2500	469	5240	456	917	652	426	315	86	207	107	11376

Table 13. Annual fishing mortality rate for eastern Georges Bank cod.

Year	Age Group										
	1	2	3	4	5	6	7	8	9	10	4-6
1978	0.00	0.06	0.47	0.41	0.41	0.50	0.39	0.53	0.65	0.57	0.42
1979	0.00	0.11	0.30	0.45	0.38	0.37	0.18	0.39	0.17	0.36	0.43
1980	0.00	0.15	0.28	0.34	0.44	0.44	0.51	0.24	0.57	0.38	0.42
1981	0.00	0.09	0.35	0.41	0.34	0.58	0.41	0.65	0.88	0.72	0.44
1982	0.00	0.23	0.40	0.68	0.73	0.88	0.81	0.83	1.00	0.86	0.71
1983	0.01	0.33	0.52	0.73	0.49	0.43	0.34	0.38	0.50	0.41	0.62
1984	0.00	0.08	0.40	0.40	0.62	0.67	0.75	0.67	0.83	0.78	0.47
1985	0.00	0.33	0.65	0.54	0.55	0.61	0.48	0.89	0.77	0.88	0.56
1986	0.00	0.10	0.46	0.64	0.56	0.48	0.31	0.37	0.61	0.44	0.56
1987	0.00	0.27	0.43	0.44	0.37	0.45	0.38	0.34	0.40	0.36	0.43
1988	0.00	0.06	0.46	0.65	0.74	0.76	0.84	0.65	0.76	0.67	0.70
1989	0.01	0.08	0.18	0.44	0.41	0.67	0.77	0.51	0.51	0.51	0.46
1990	0.00	0.28	0.54	0.43	0.58	0.47	0.61	0.30	0.63	0.45	0.51
1991	0.00	0.18	0.59	0.75	1.04	1.00	0.88	0.64	1.38	0.76	0.87
1992	0.04	0.44	0.55	0.75	1.02	0.88	0.97	0.62	0.73	0.67	0.91
1993	0.00	0.27	0.77	0.86	1.11	1.55	1.42	1.60	2.92	1.82	1.03
1994	0.00	0.07	0.51	0.76	0.69	0.63	1.60	2.20	6.24	3.83	0.74
1995	0.00	0.03	0.11	0.23	0.18	0.07	0.12	0.28	0.89	0.39	0.18
1996	0.00	0.03	0.16	0.28	0.23	0.14	0.08	0.10	0.28	0.14	0.25
1997	0.00	0.06	0.19	0.44	0.59	0.56	0.23	0.17	0.19	0.17	0.51
1998	0.00	0.03	0.23	0.26	0.39	0.42	0.23	0.08	0.06	0.08	0.34
1999	0.00	0.05	0.21	0.36	0.22	0.19	0.21	0.14	0.01	0.07	0.30
2000	0.00	0.02	0.12	0.20	0.21	0.10	0.09	0.06	0.02	0.00	0.19
2001	0.00	0.06	0.20	0.32	0.34	0.24	0.11	0.10	0.02	0.01	0.32
2002	0.00	0.01	0.08	0.24	0.25	0.21	0.09	0.04	0.03	0.00	0.23
2003	0.00	0.02	0.12	0.25	0.41	0.29	0.17	0.07	0.02	0.01	0.33
2004	0.00	0.02	0.08	0.14	0.18	0.22	0.20	0.06	0.02	0.01	0.17
2005	0.00	0.01	0.08	0.14	0.05	0.06	0.08	0.09	0.02	0.01	0.10

Table 14. Beginning of year population biomass (thousands of mt) for eastern Georges Bank cod.

Year	Age Group												
	1	2	3	4	5	6	7	8	9	10	11	1+	3+[1]
1978	1376	1836	18395	9770	4247	1889	2073	473	294	111	2	40468	37255
1979	1175	7570	2961	15138	8165	3302	1133	1303	300	139	68	41254	32509
1980	1141	6457	11692	2864	12131	6546	2250	886	943	229	104	45244	37645
1981	2146	6278	9521	11545	2578	9179	4148	1266	750	484	168	48064	39640
1982	777	11791	9818	8827	9687	2168	5069	2571	708	281	253	51951	39383
1983	566	4272	16016	8630	5622	5515	885	2113	1201	234	128	45183	40345
1984	1673	3086	5262	12436	5214	4038	3555	589	1559	659	167	38240	33480
1985	560	9197	4871	4603	10452	3305	2050	1567	323	615	326	37870	28113
1986	2555	2982	11123	3323	3298	7151	1739	1298	861	156	276	34761	29225
1987	1054	14589	4649	9079	2924	2758	4342	947	796	194	94	41426	25783
1988	1713	5342	19341	4413	7431	1835	1629	2839	1026	615	181	46364	39309
1989	534	9290	7526	15515	2688	4486	855	531	1581	330	268	43605	33780
1990	1123	2519	15487	8735	12935	2034	2513	403	451	991	260	47451	43809
1991	800	4260	3847	12671	6791	6633	1306	1309	256	226	486	38584	33524
1992	331	6217	6266	2578	6457	2733	2677	507	559	63	137	28527	21978
1993	275	2003	7372	4464	1545	2648	1062	934	241	188	48	20779	18501
1994	176	2106	1864	4018	2108	709	608	270	186	14	64	12122	9840
1995	350	1766	3774	1357	1877	1065	253	102	33	0	0	10578	8462
1996	144	1281	2791	4581	1671	2360	895	347	94	13	0	14177	12752
1997	527	1852	2265	2718	3526	1735	1830	1304	200	80	12	16051	13671
1998	135	2370	2555	2025	2024	2283	705	1445	680	116	51	14389	11884
1999	679	1458	4104	2788	1698	1655	1753	840	1077	717	126	16894	14757
2000	229	3221	1757	4673	2247	1691	1537	1326	595	1422	509	19205	15755
2001	25	1542	3997	1953	4886	2430	1863	1307	1231	401	984	20618	19051
2002	34	866	2047	4421	1700	3431	1777	1639	1278	1106	517	18816	17917
2003	12	389	1713	2339	3801	1042	2648	1505	1167	1057	1076	16748	16347
2004	123	172	2533	2808	3015	2788	824	2304	1757	1101	1172	18595	18301
2005	7	3846	708	2239	2388	1776	1618	671	1528	612	1278	16672	12819
2006	34	152	5967	667	2307	2095	1853	1475	486	1412	643	17092	16906

[1] Biomass reported in the status report (TRAC 2006) are lower due to omission of age 11 biomass.

Table 15. Projection inputs for eastern Georges Bank cod.

						Age Group					
	1	2	3	4	5	6	7	8	9	10	11
Natural Mortality											
2006-2010	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Fishery Partial Recruitment (2003-2005 average)											
2006-2010	0.01	0.09	0.5	1	1	1	0.85	0.5	0.1	0.05	0.05
Fishery Weight at Age (2003-2005 average)											
2006-2010	0.43	1.33	1.96	2.67	3.60	4.54	5.43	7.21	8.41	9.04	13.31
Population Beginning of Year Weight at Age (2004-2006 DFO survey average)											
2007-2011	0.01	0.38	1.25	1.84	3.00	3.56	4.27	5.73	7.37	6.83	9.44

Table 16. Deterministic projection results for eastern Georges Bank cod.

						Age Group							
	1	2	3	4	5	6	7	8	9	10	11	1+	3+
Projected Population Numbers (thousands)													
2007	2500	2044	380	4036	330	664	472	314	243	69	168		
2008	2500	2043	1647	284	2760	226	454	332	235	195	56		
2009	2500	2043	1646	1232	195	1887	154	319	248	189	158		
2010	2500	2043	1646	1232	843	133	1291	109	239	200	153		
2011	2500	2043	1646	1232	842	576	91	907	81	192	162		
Fishing Mortality													
2006-2010	0.002	0.016	0.09	0.18	0.18	0.18	0.153	0.09	0.018	0.009	0.009		
Projected Population Biomass (mt)													
2007	34	780	477	7426	992	2366	2015	1798	1788	474	1589		18925
2008	34	779	2065	523	8289	805	1939	1900	1732	1331	532		19117
2009	34	779	2064	2268	584	6723	659	1828	1830	1290	1495		18740
2010	34	779	2065	2266	2531	474	5508	621	1761	1362	1448		18036
2011	34	779	2065	2267	2530	2053	388	5193	599	1311	1530		17934
Projected Catch Numbers (thousands)													
2006	3	5	283	48	96	68	38	17	1	1	1		
2007	4	30	30	604	49	99	61	25	4	1	1		
2008	4	30	129	43	413	34	59	26	4	2	0		
2009	4	30	129	185	29	283	20	25	4	2	1		
2010	4	30	129	184	126	20	166	8	4	2	1		
Projected Catch Biomass (mt)													
2006	1	6	553	127	346	310	208	122	8	10	8	1700	1693
2007	2	40	58	1612	178	452	331	177	33	5	18	2905	2864
2008	2	40	252	114	1490	154	318	187	32	14	6	2607	2566
2009	2	40	251	492	105	1283	108	180	34	14	17	2526	2484
2010	2	40	251	492	455	90	904	61	32	15	17	2359	2318
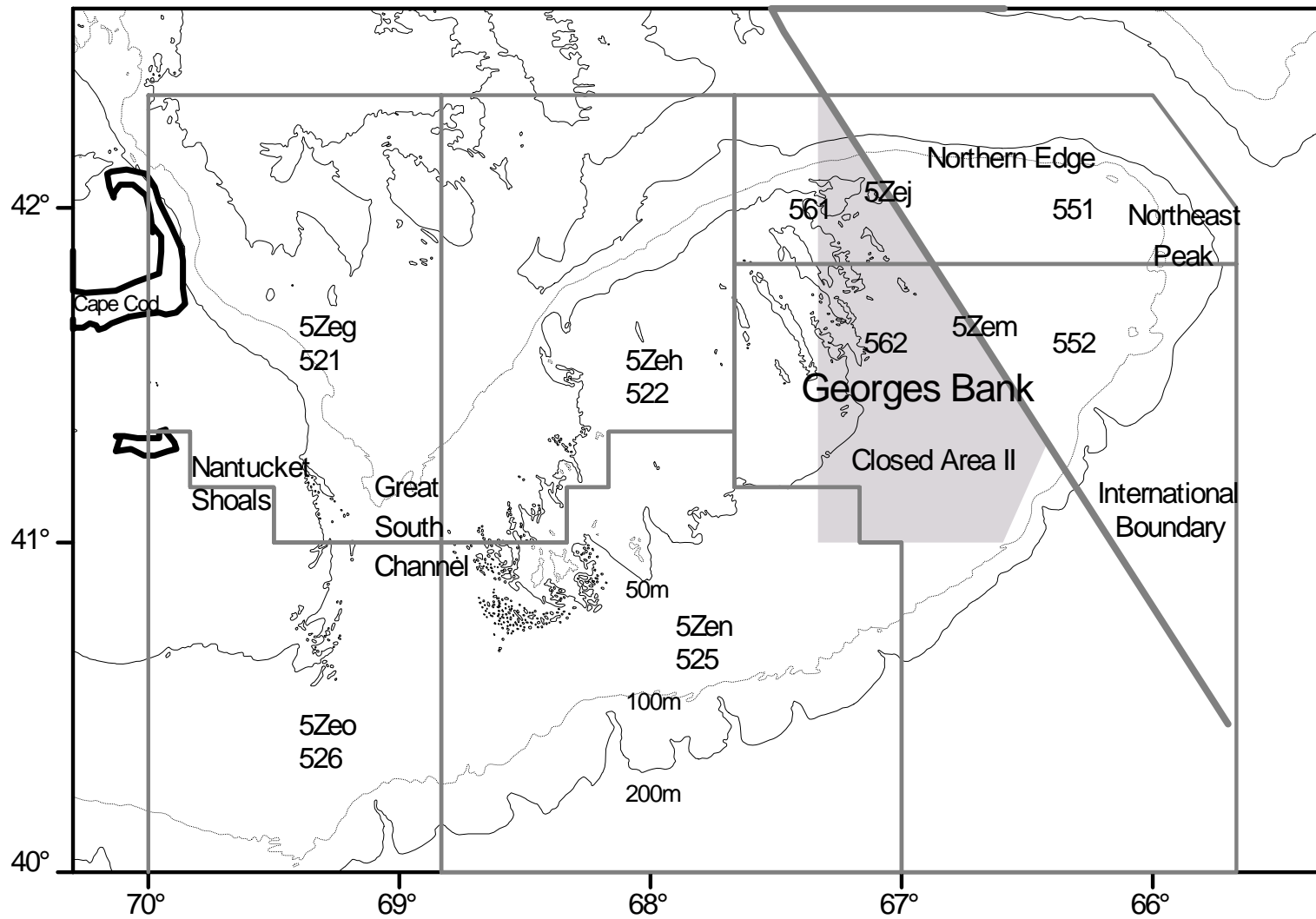
Figure 1. Fisheries statistical unit areas in NAFO Subdivision 5Ze.
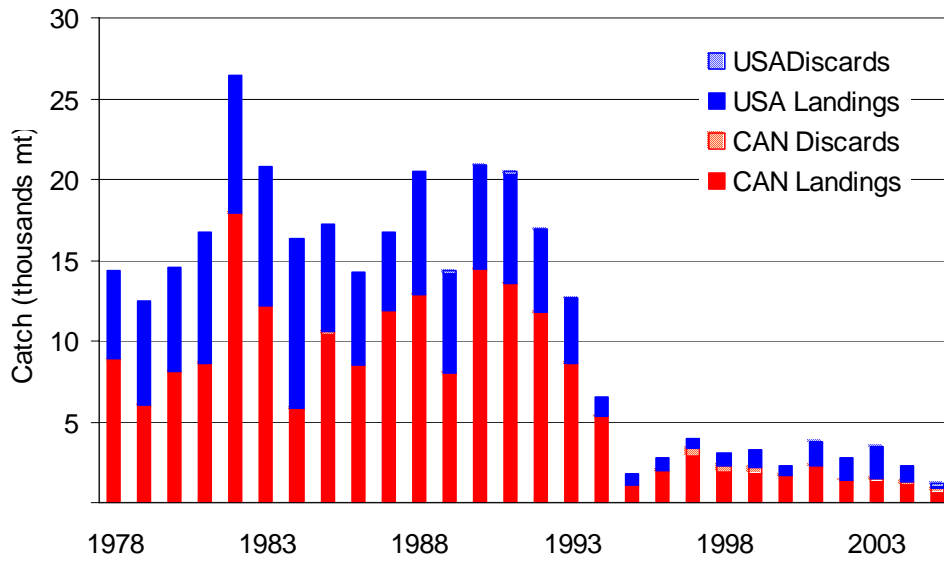
Figure 2. Catches (mt) of cod from eastern Georges Bank during 1978-2005.
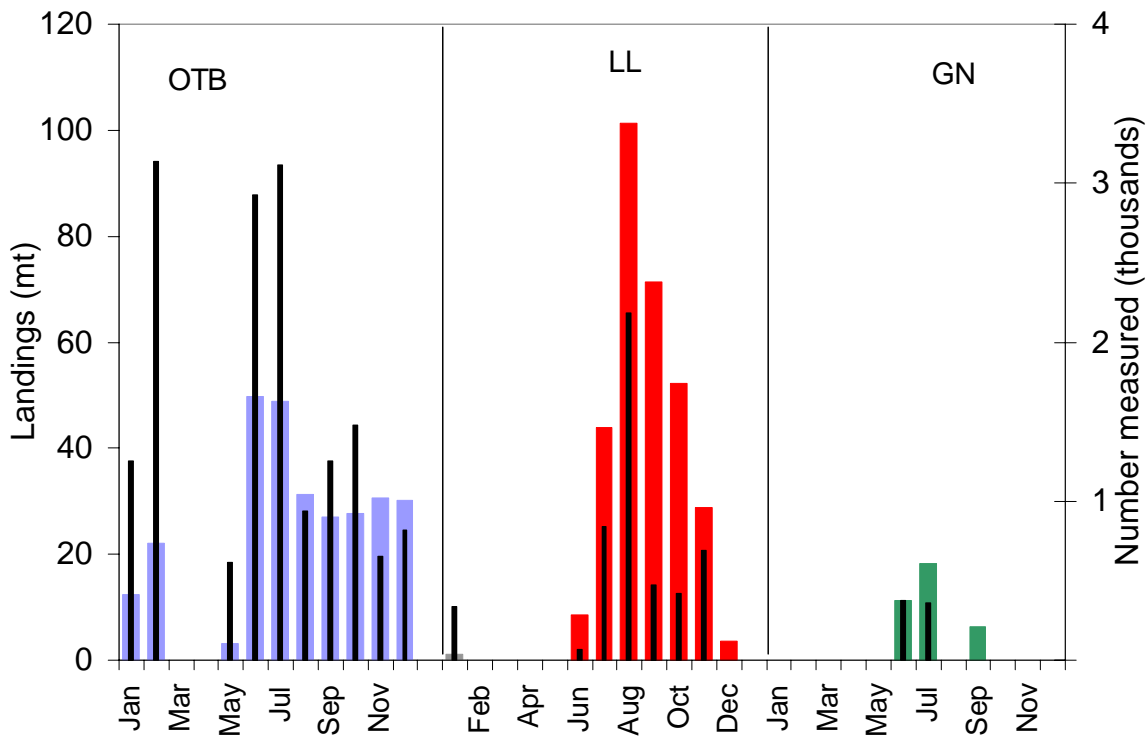
Figure 3. Landings (wide bars) and sampling (narrow dark bars) of cod by gear and month from the 2005 Canadian groundfish fishery on eastern Georges Bank.
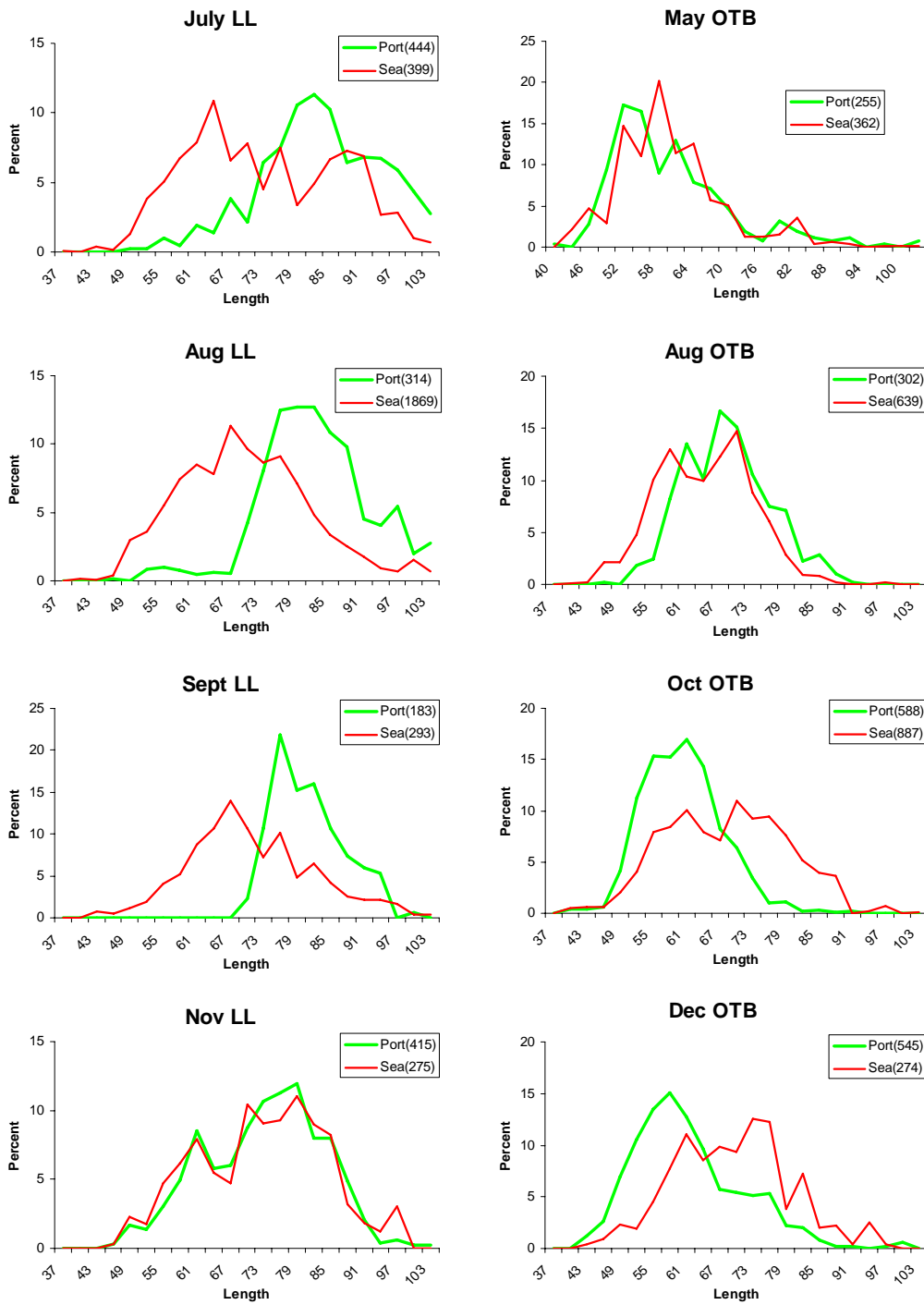
Figure 4. Comparison of cod length composition from port and sea sampling for the 2005 Canadian fishery on eastern Georges Bank.
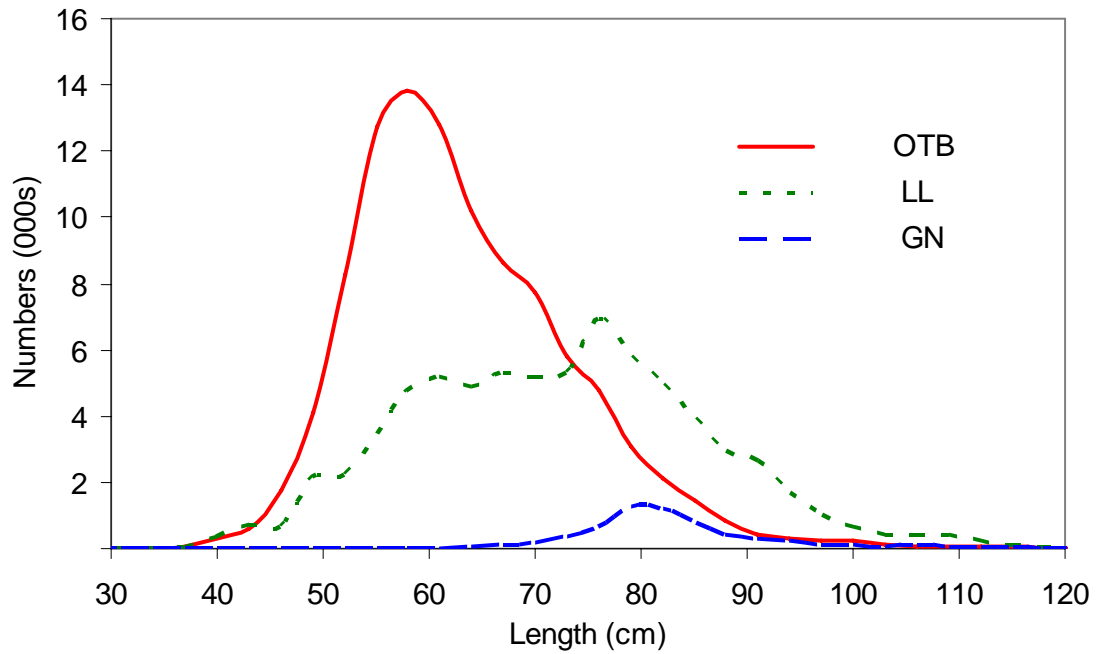
Figure 5. Cod landings at length by gear from the 2005 Canadian groundfish fishery on eastern Georges Bank.
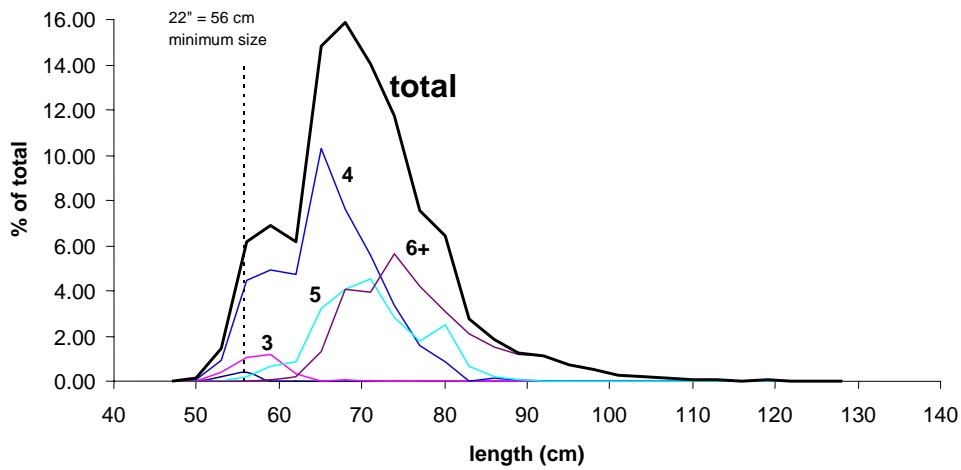
Figure 6. Length composition of cod landings by age group for the 2005 USA fishery on eastern Georges Bank.
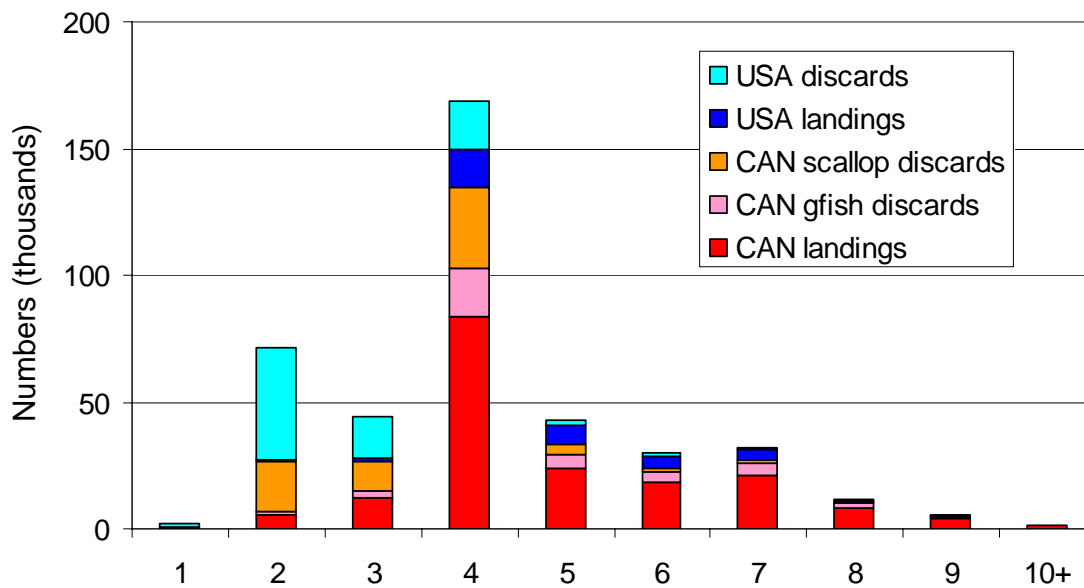
Figure 7. Catch at age for landings and discards of cod from the 2005 fisheries on eastern Georges Bank.
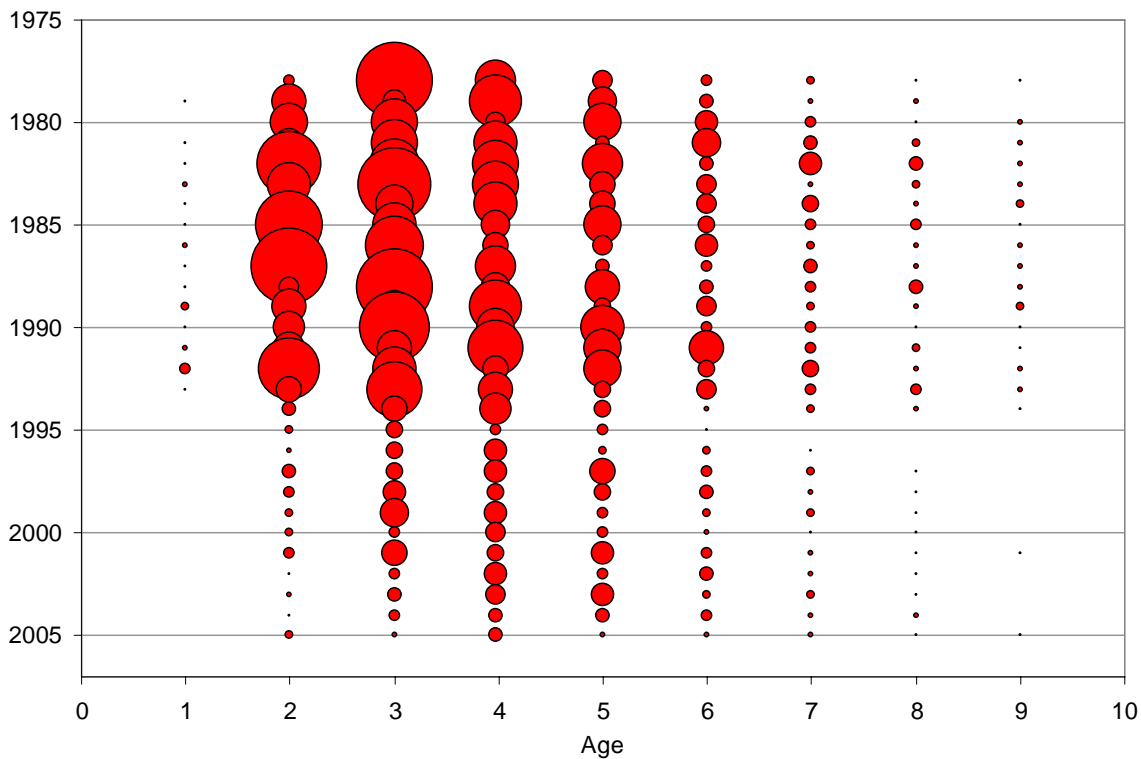
Figure 8. Total catch at age (numbers) of cod from eastern Georges Bank for 1978 to 2005. The bubble area is proportional to magnitude.
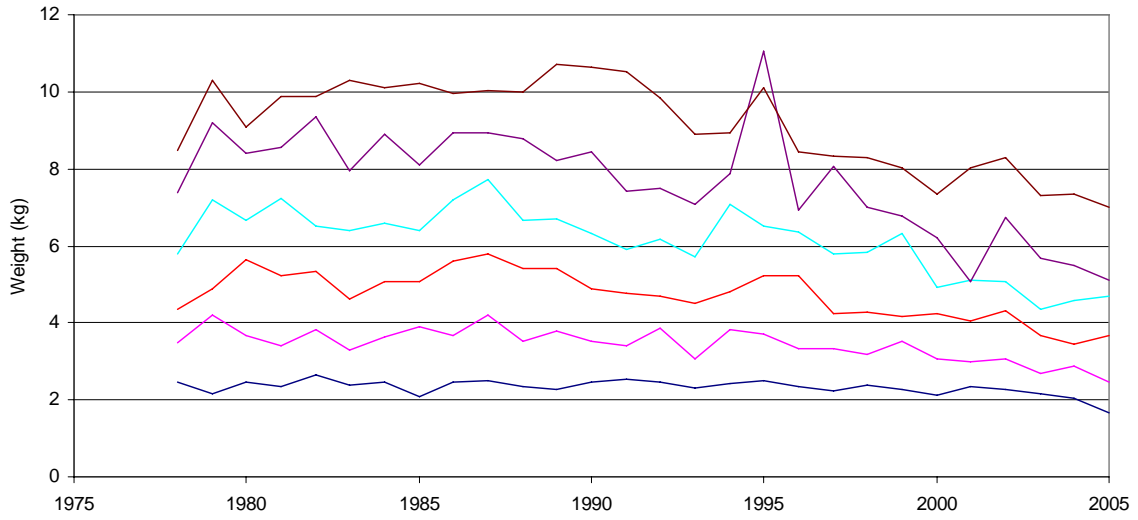
Figure 9. Average weights at ages 3 to 8 of cod from the eastern Georges Bank fishery for 1978 to 2005.
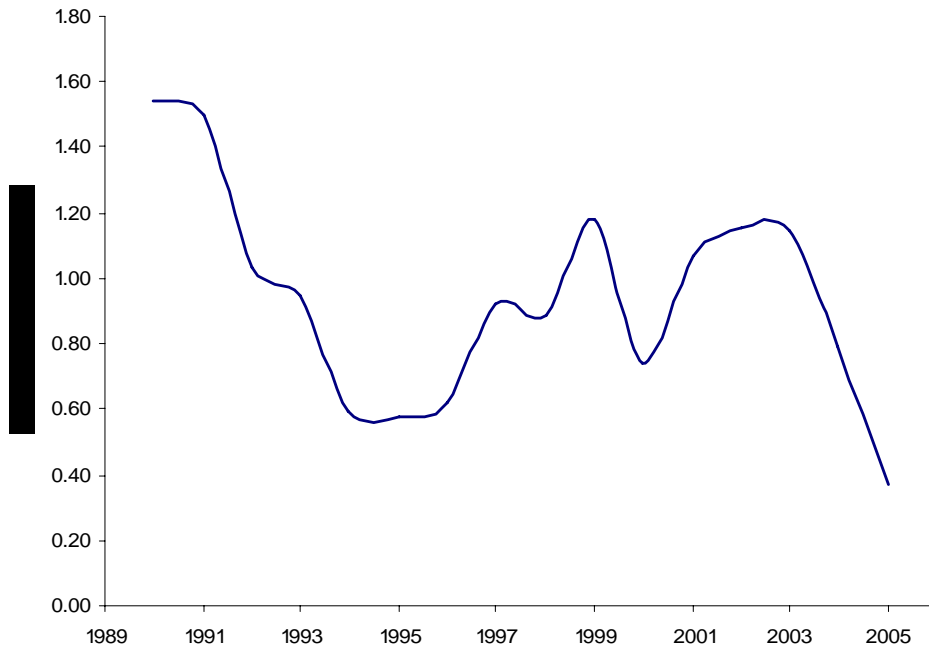
Figure 10. Nominal catch rate (mt/day) of cod from the eastern Georges Bank USA fishery.
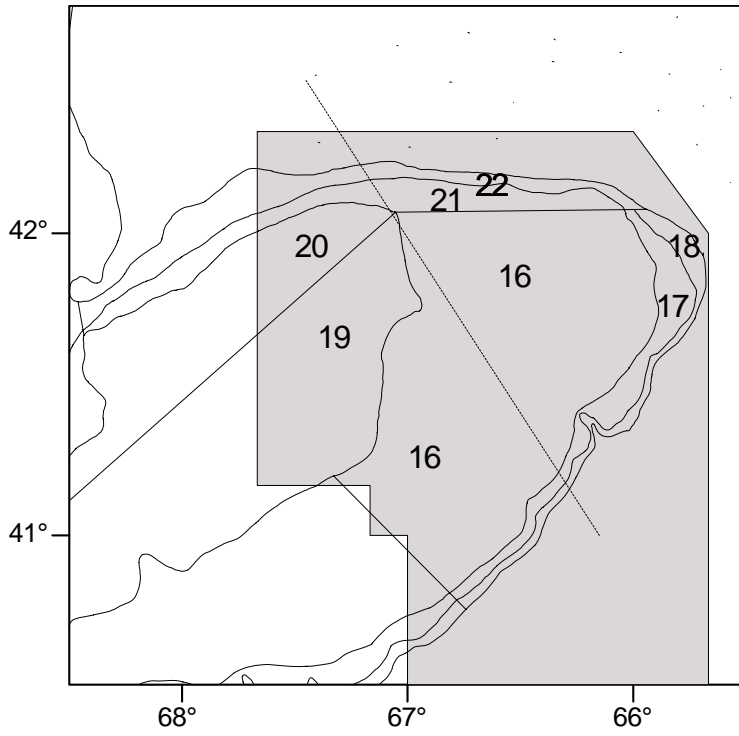
Figure 11. Stratification used for NMFS surveys. The eastern Georges Bank management unit is indicated by shading.
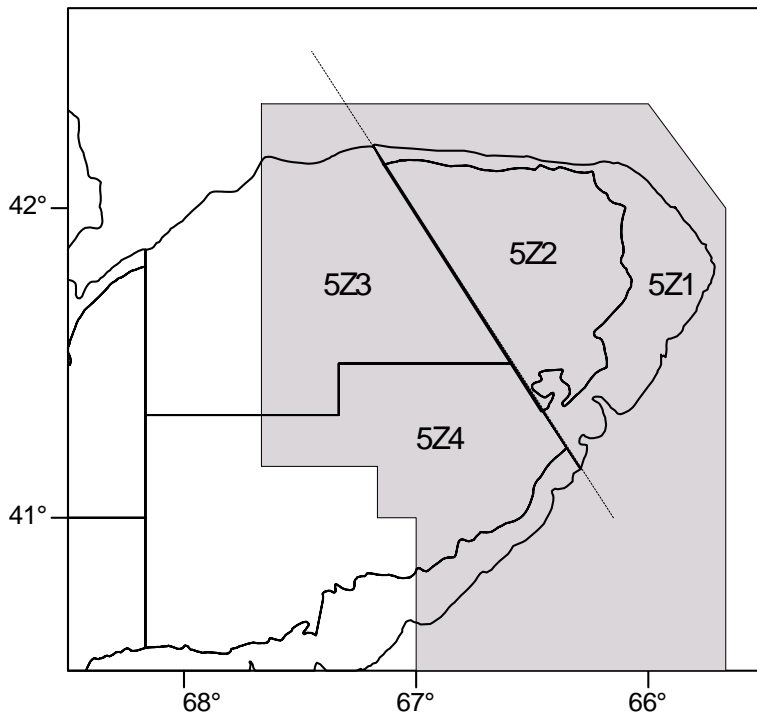
Figure 12. Stratification used for the DFO survey. The eastern Georges Bank management unit is indicaded by shading.
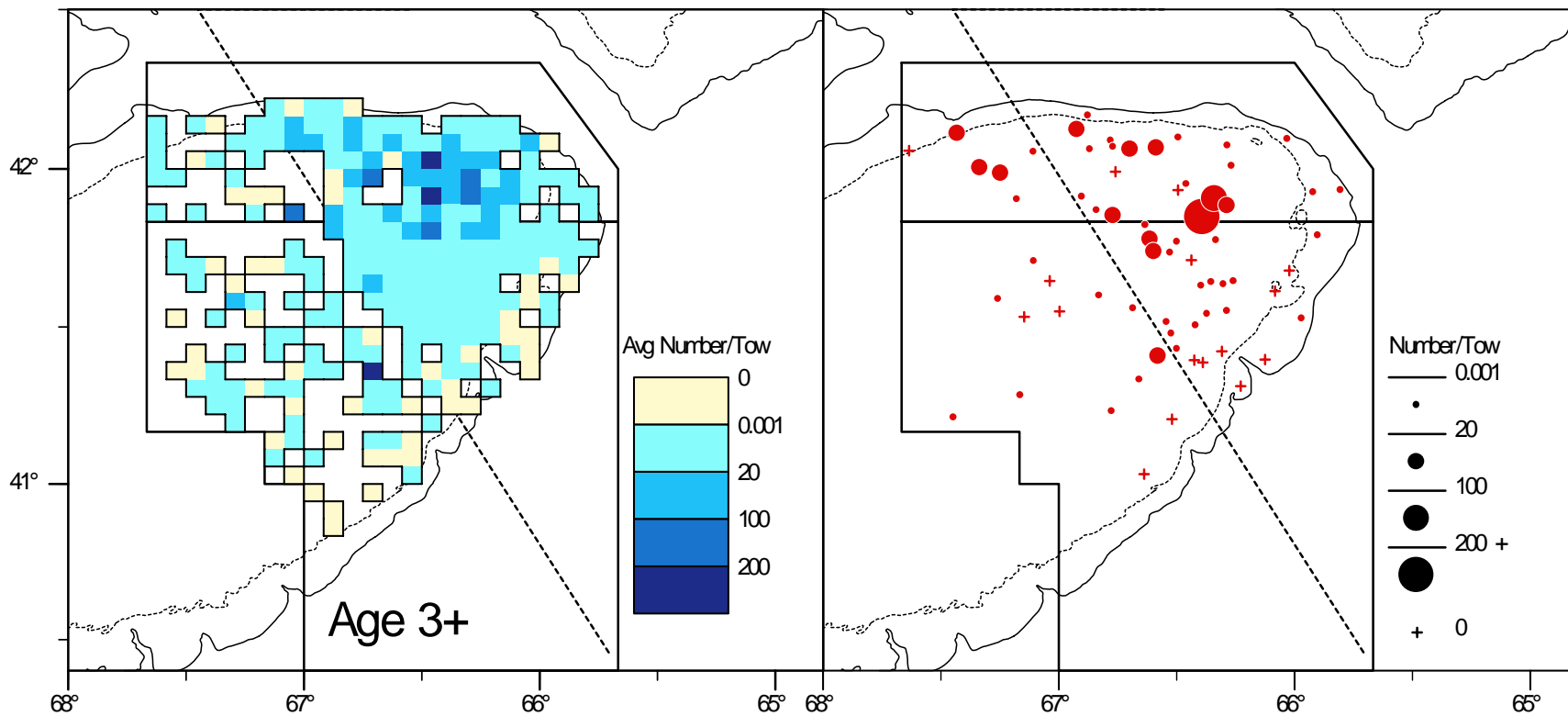
Figure 13. Spatial distribution of cod on eastern Georges Bank from the DFO survey for 2006 (right panel) compared to the average for 1996-2005 (left panel).
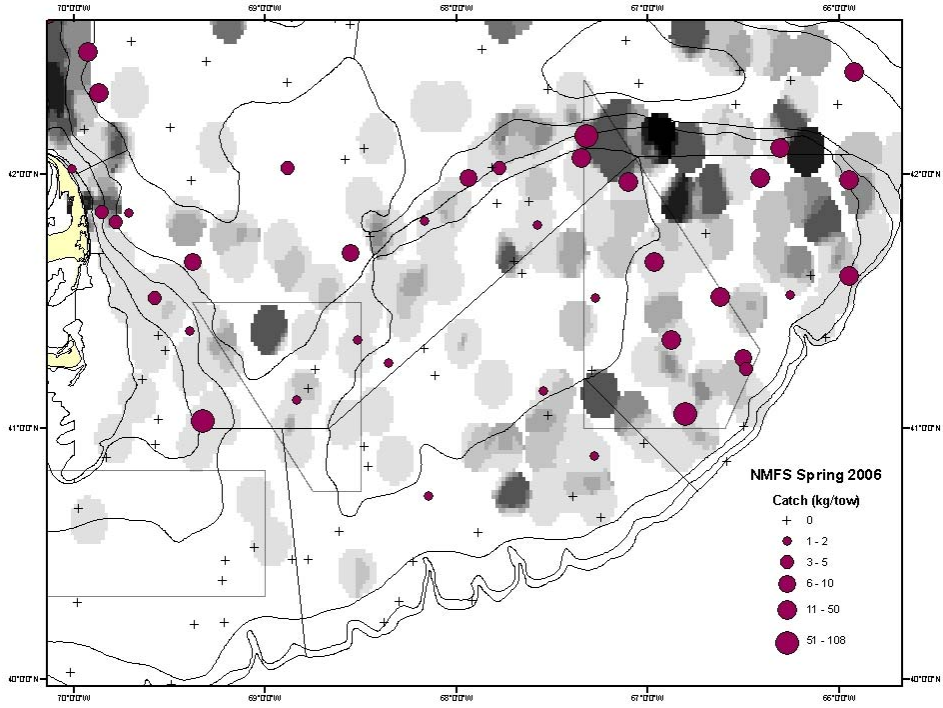
Figure 14. Spatial distribution of cod from 2006 NMFS spring survey, shown as solid circles, compared to 2001 - 2005, shown as shading.
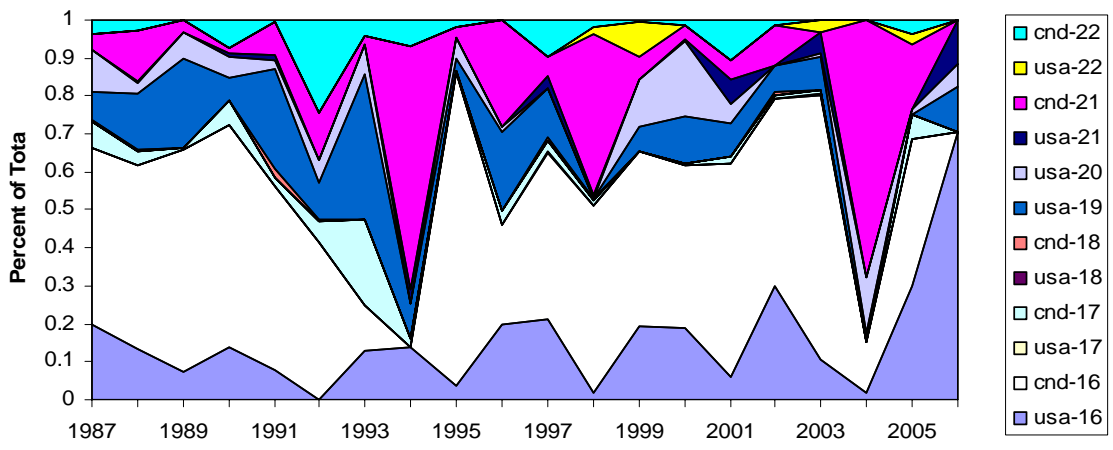
Figure 15. Distribution of eastern Georges Bank cod by strata for the NMFS spring survey.
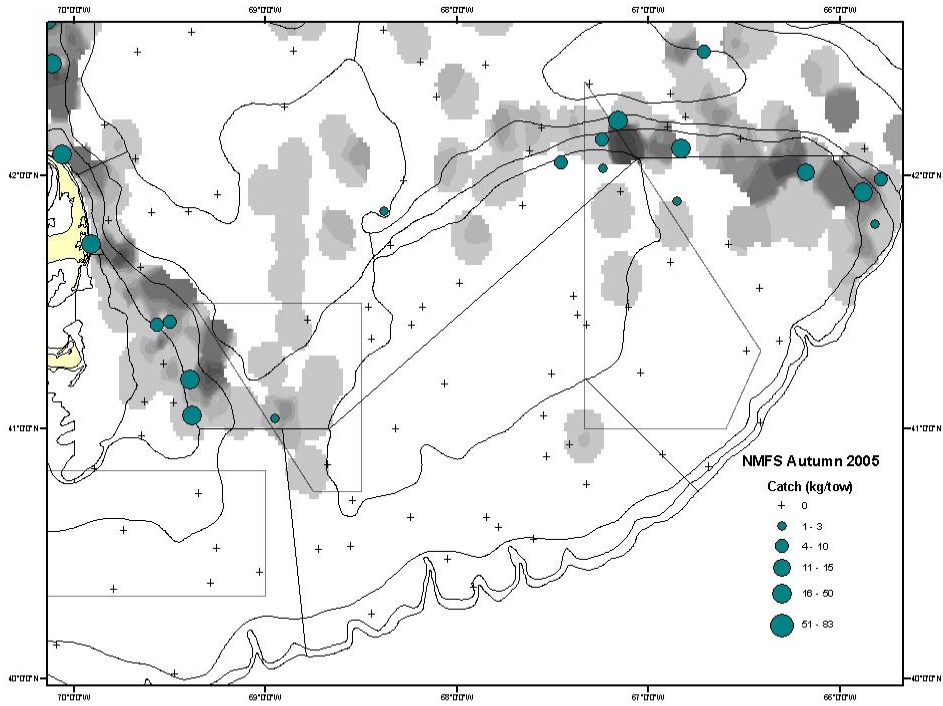
Figure 16. Spatial distribution of cod from the 2005 NMFS autumn survey, shown as solid circles, compared to 2000 - 2004, shown as shading.
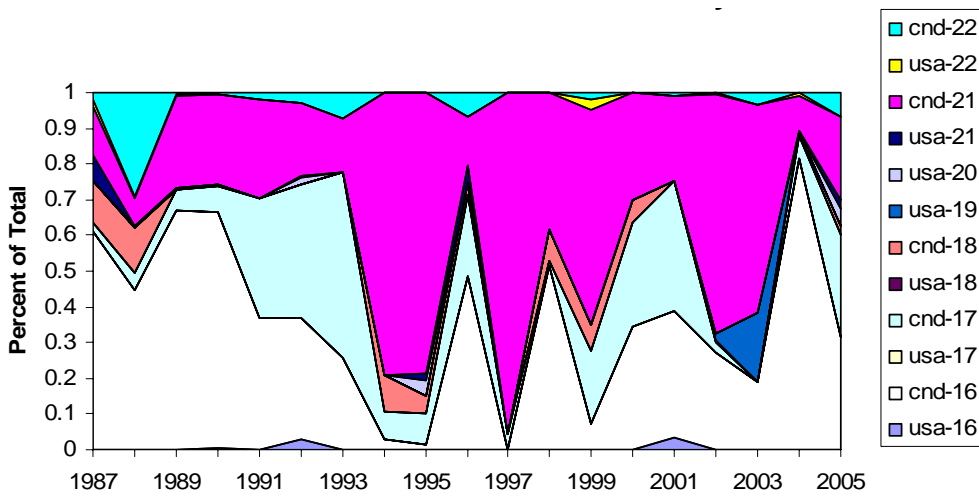
Figure 17. Distribution of eastern Georges Bank cod by strata for the NMFS autumn survey.
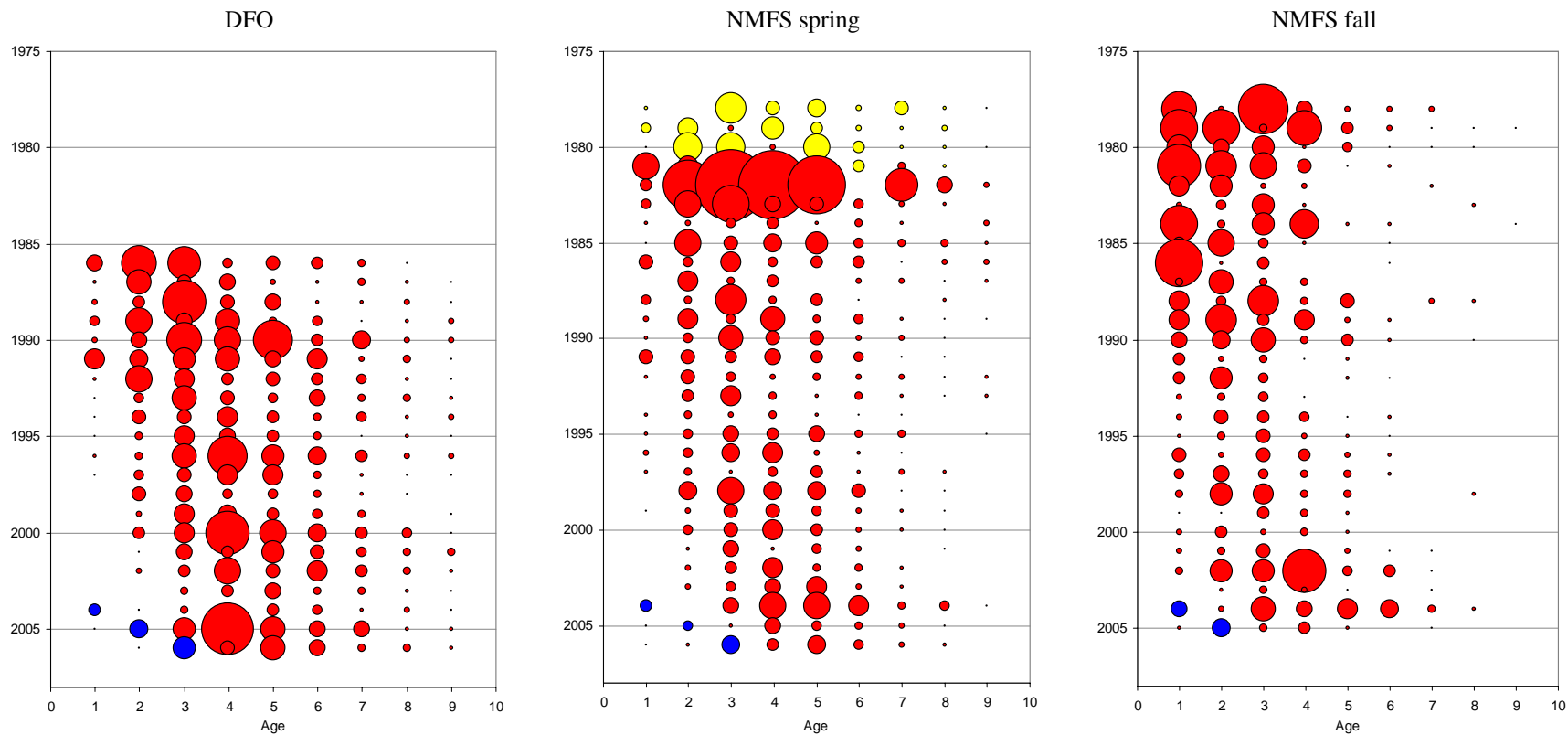
Figure 18. Survey abundance at age (numbers) of eastern Georges Bank cod. The bubble area is proportional to magnitude within each survey. Conversion factors to account for changes in door type and survey vessel were applied to the NMFS surveys. The NMFS spring survey was conducted using a modified Yankee 41 during 1978 to 1981 (pale bubbles). The 2003 year class is identified.
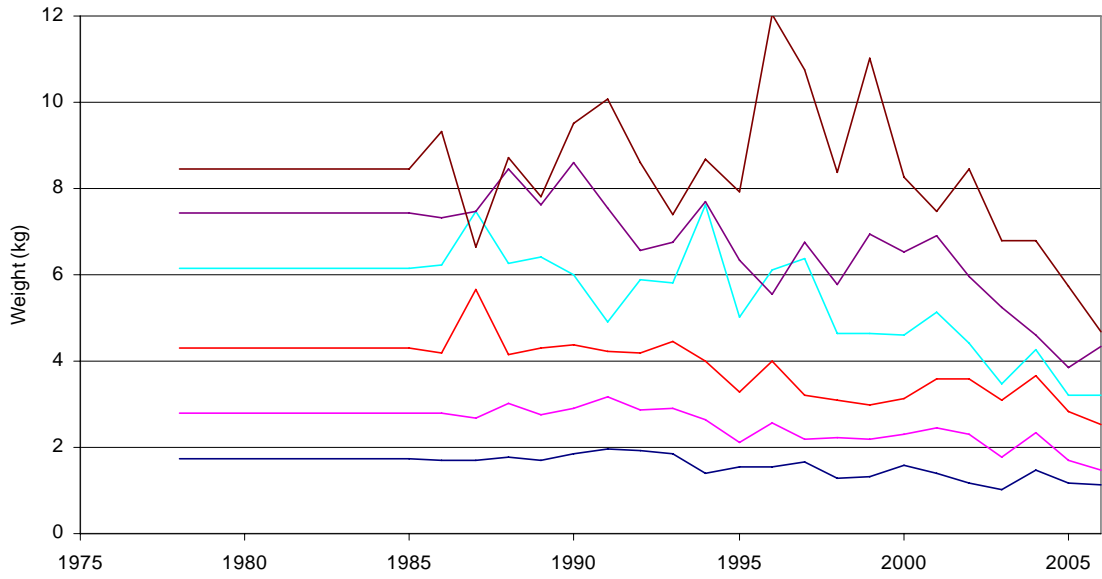
Figure 19. Average weights of eastern Georges Bank cod at ages 3 to 8 from the DFO survey. The average of 1986 to 1995 was used for 1978 to 1985 to calculate biomass.
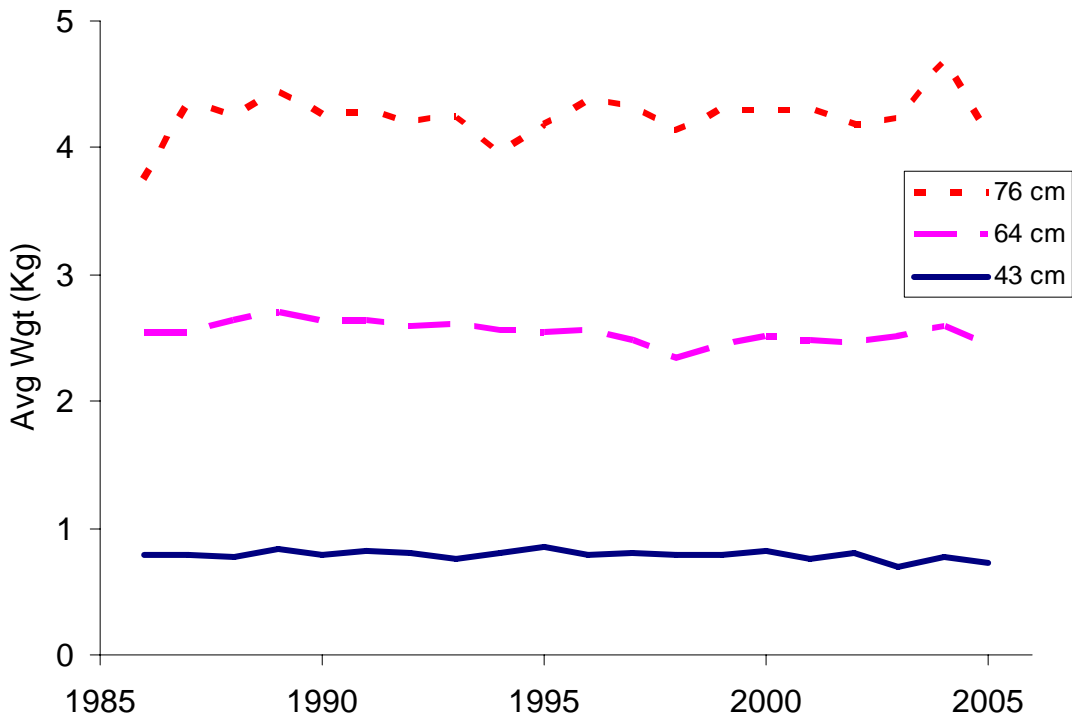
Figure 20. Condition, measured as average weight at three representative length groupings (center of 3 cm grouping used in label), for eastern Georges Bank cod from the DFO survey.
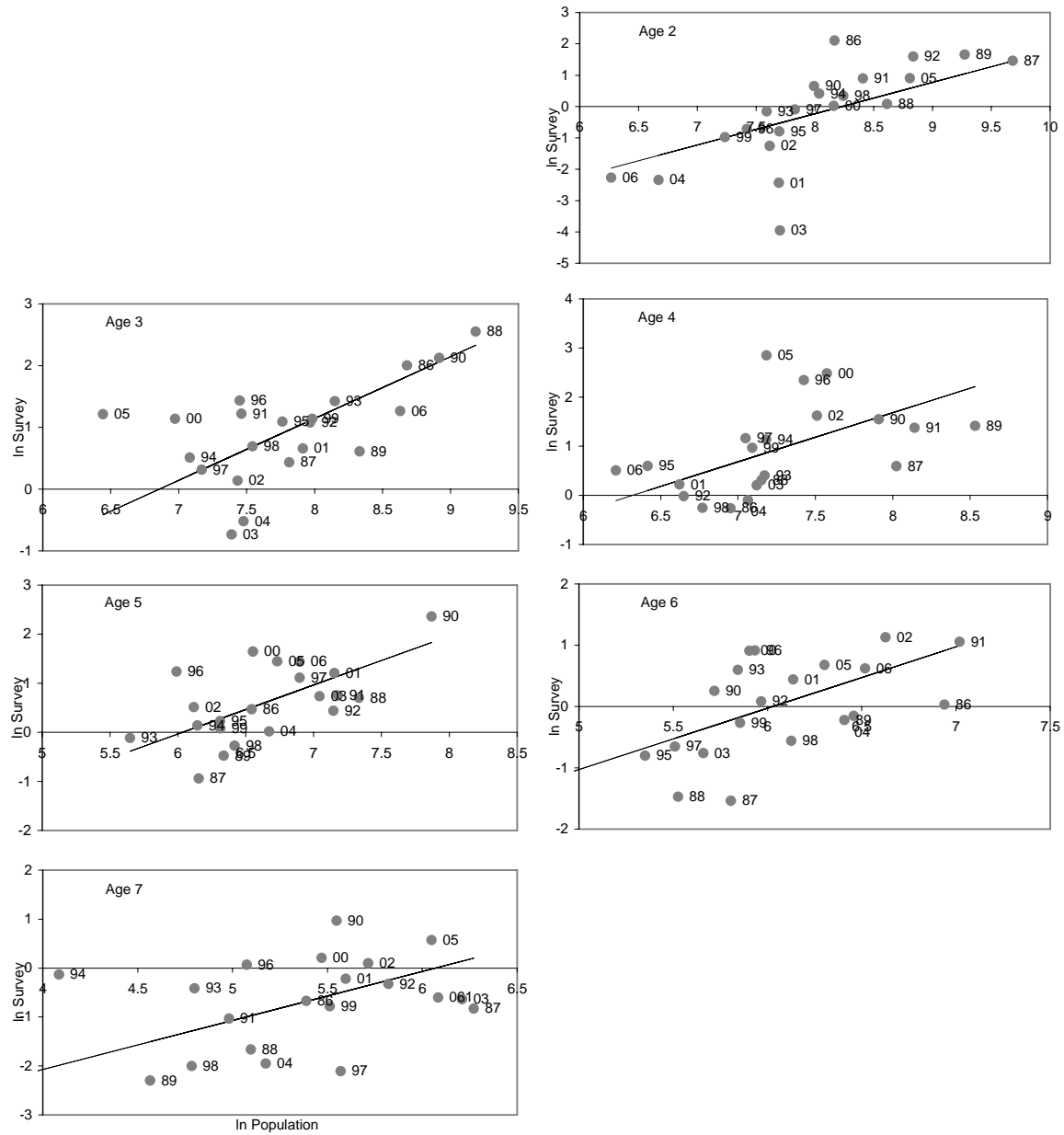
Figure 21. Observed and predicted *ln* DFO survey abundance versus *ln* population abundance for eastern Georges Bank cod.
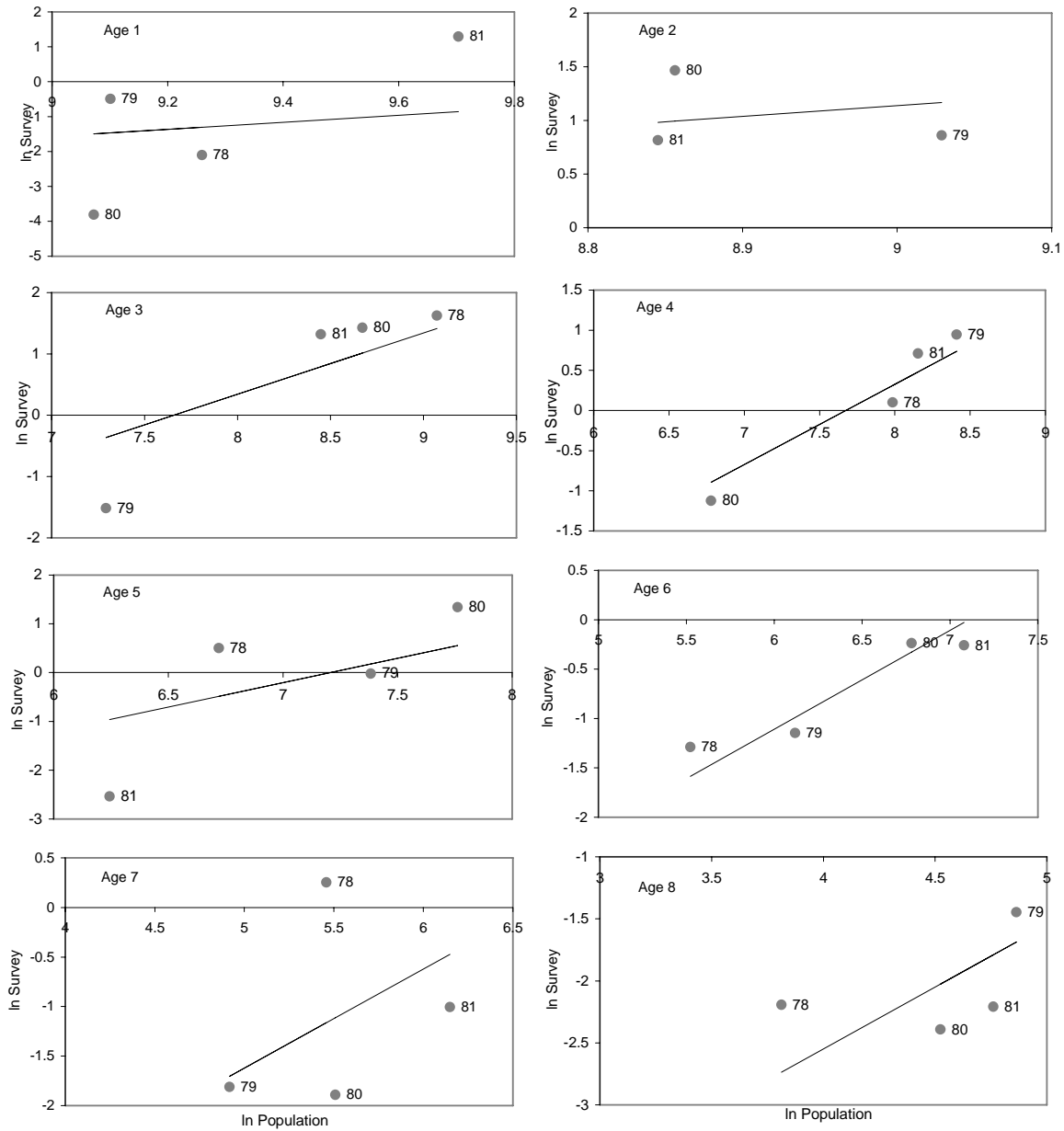
Figure 22. Observed and predicted *ln* NMFS spring Yankee 41 survey abundance versus *ln* population abundance for eastern Georges Bank cod.
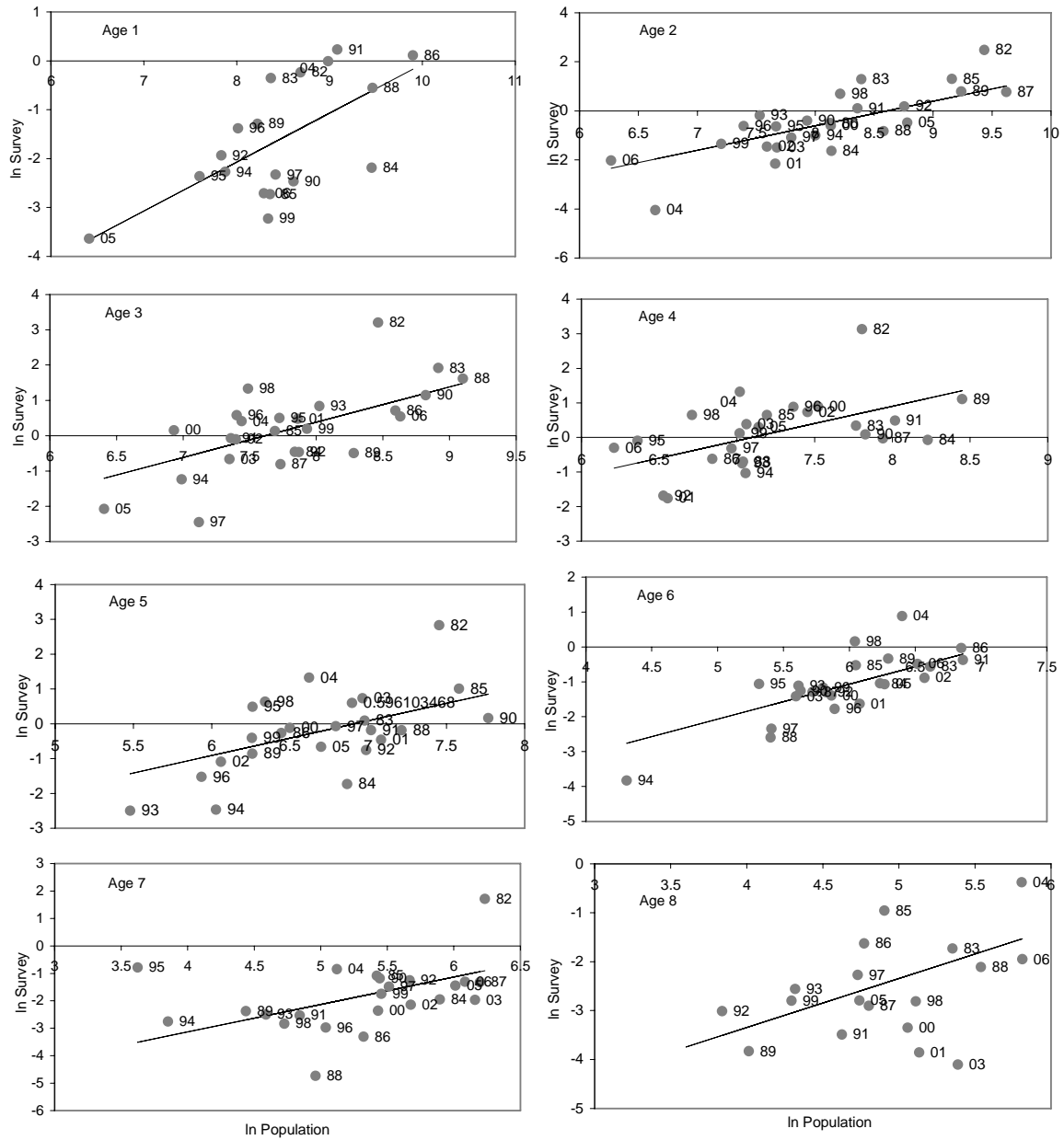
Figure 23. Observed and predicted *ln* NMFS spring Yankee 36 survey abundance versus *ln* population abundance for eastern Georges Bank cod.

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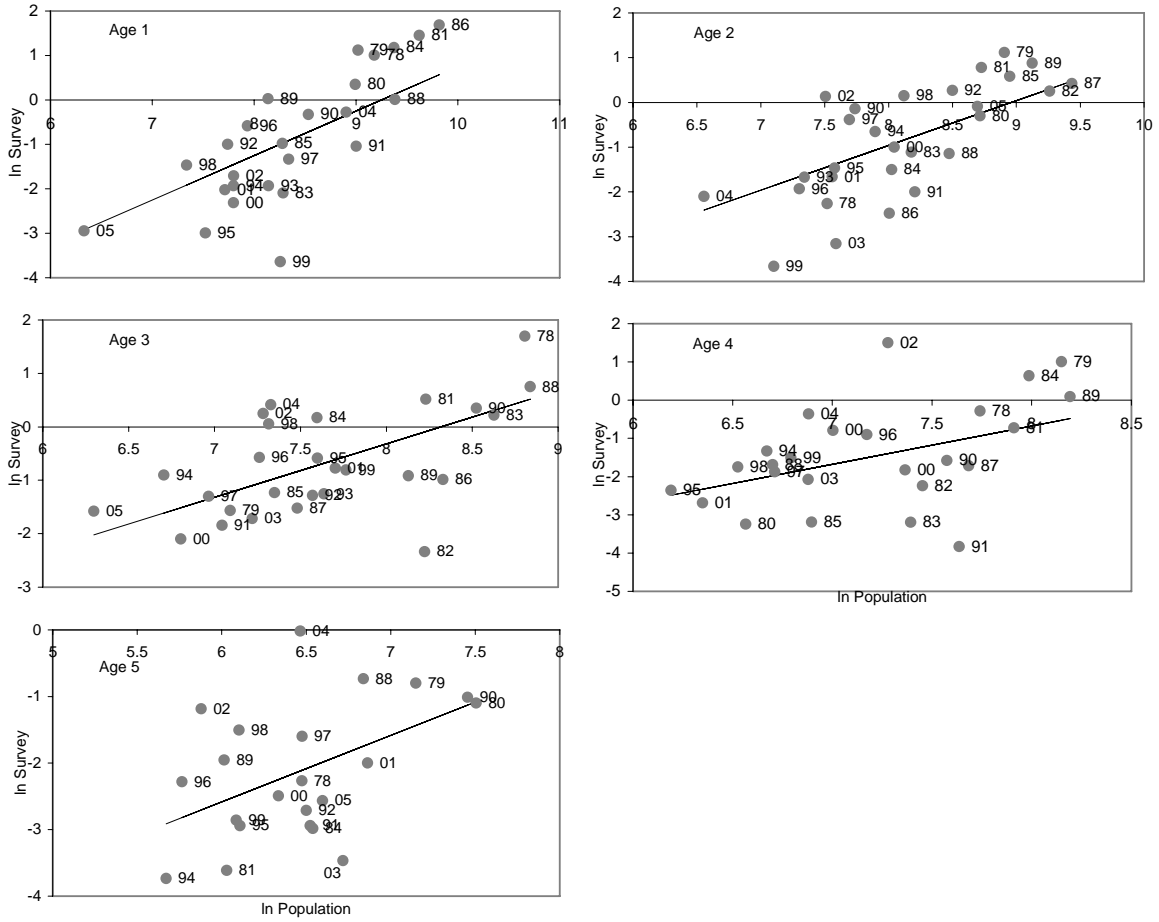
Figure 24. Observed and predicted *ln* NMFS autumn survey abundance versus *ln* population abundance for eastern Georges Bank cod.
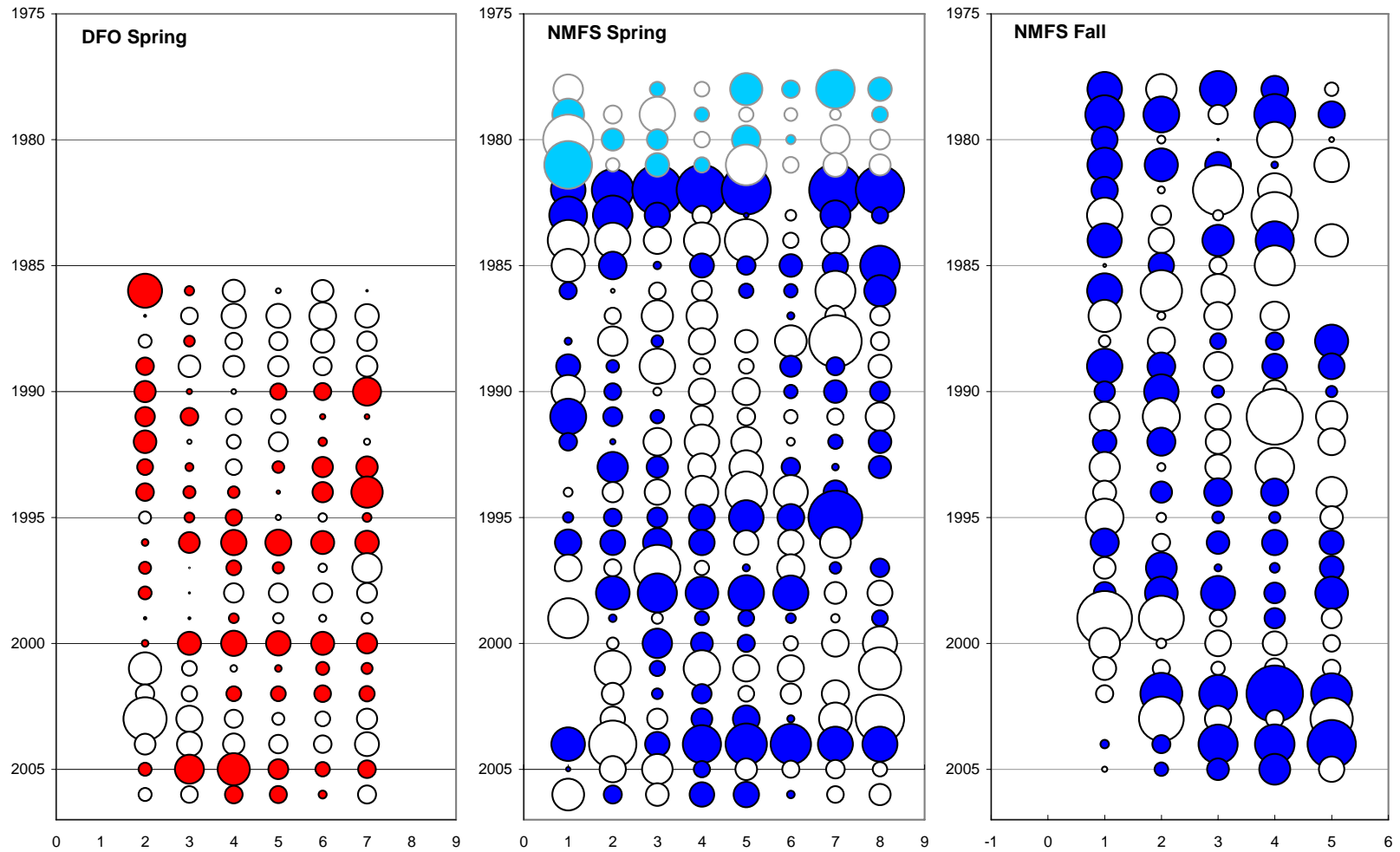
Figure 25. Residuals by year and age group from survey indices for eastern Georges Bank cod. Solid bubbles indicate positive values, open bubbles indicate negative values and bubble area is proportional to magnitude. The NMFS spring survey was conducted using a modified Yankee 41 during 1978 to 1981 (pale bubbles).

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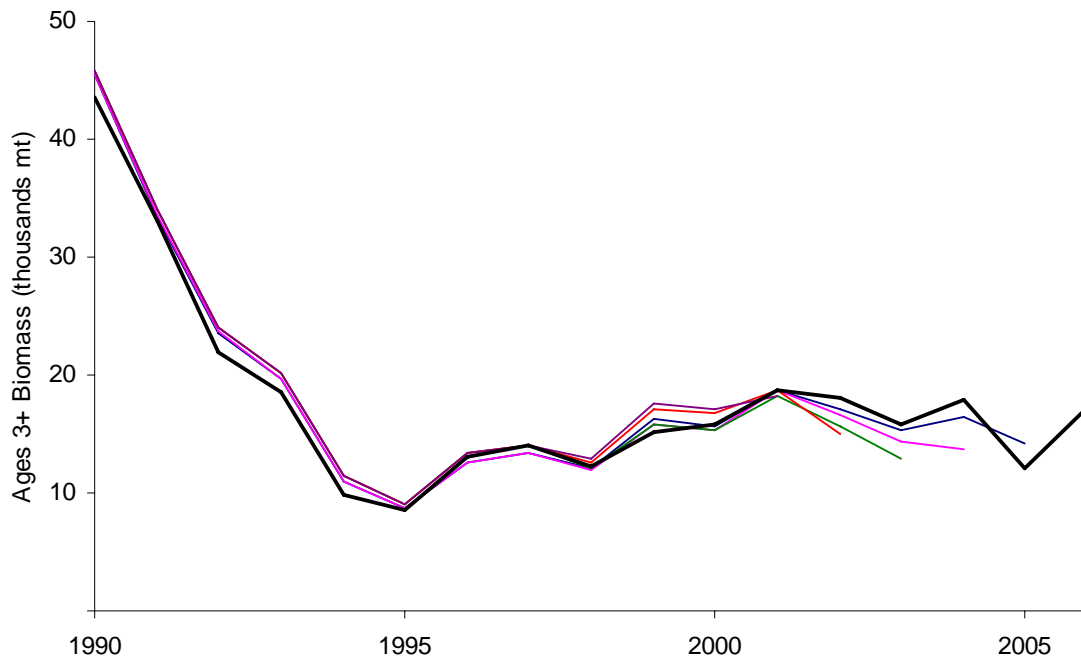
Figure 26. Retrospective pattern for ages 3+ biomass of eastern Georges Bank cod.
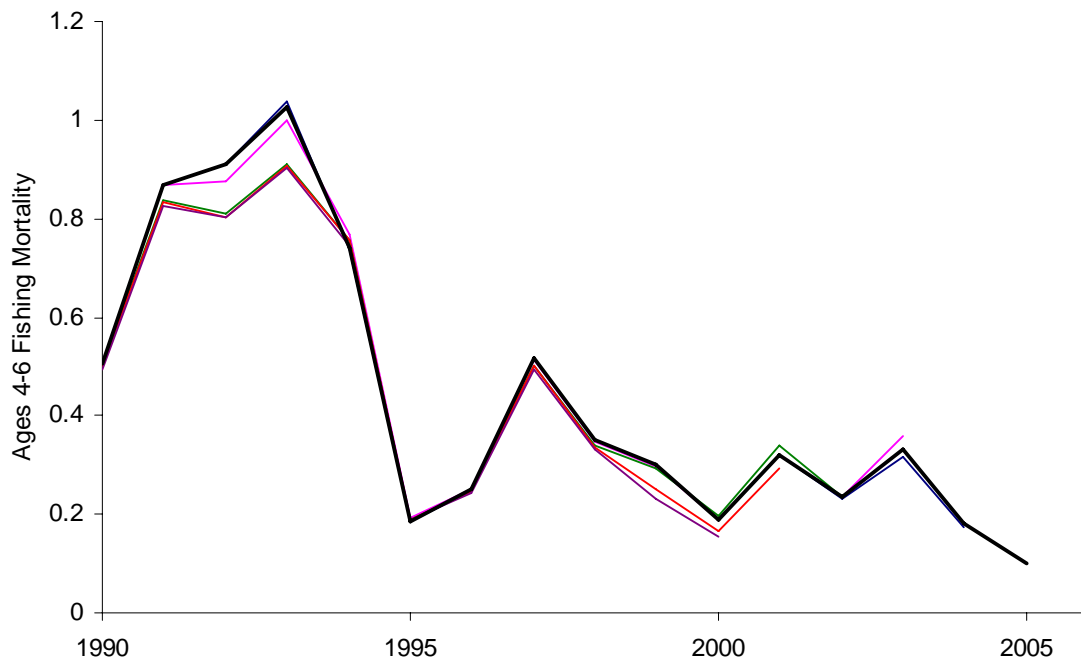
Figure 27. Retrospective pattern for ages 4-6 fishing mortality rate of eastern Georges Bank cod.
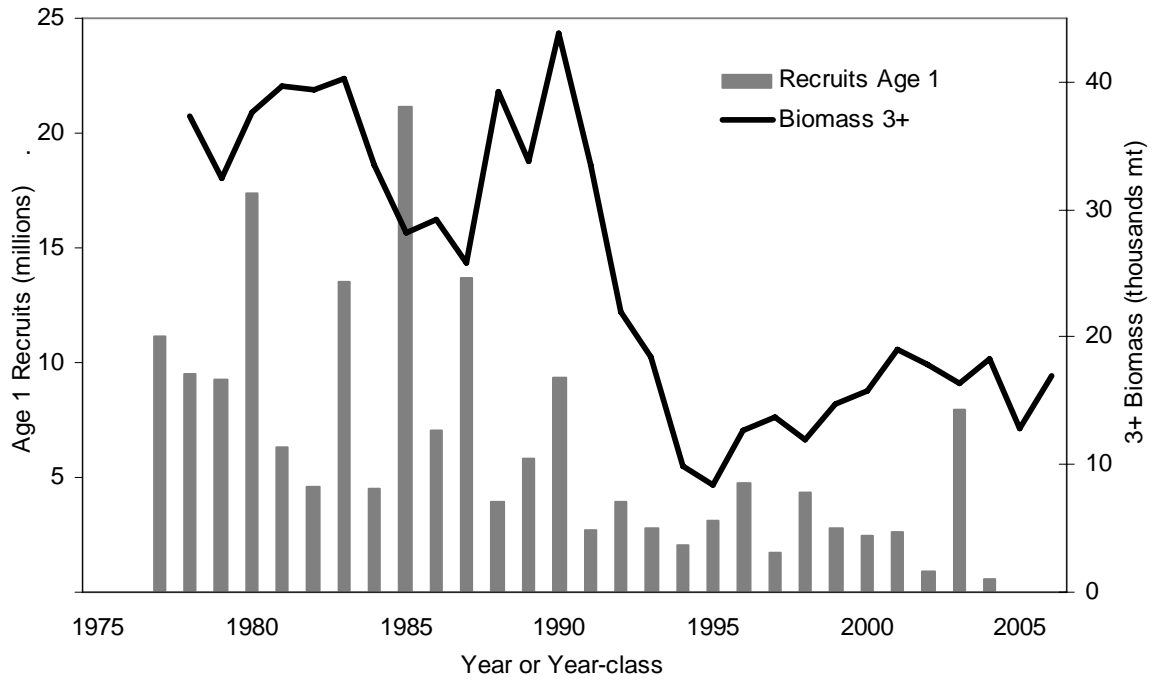
Figure 28. Adult biomass (ages 3+) and year class abundance at age 1 for eastern Georges Bank cod.
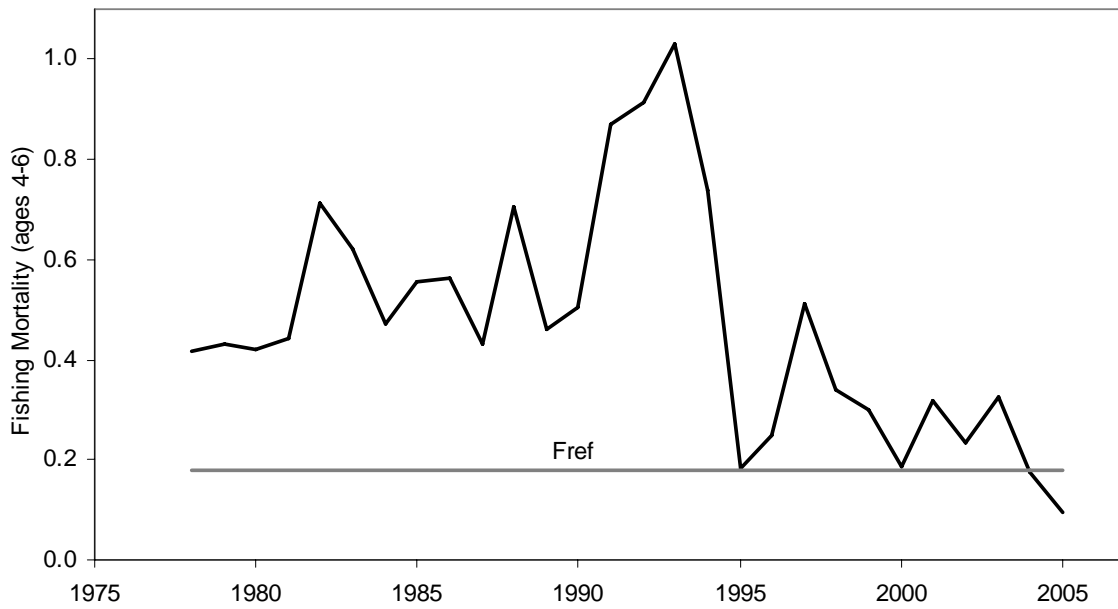
Figure 29. Fishing mortality rate at ages 4 to 6 for eastern Georges Bank cod. The established fishing mortality threshold reference, $F_{ref}=0.18$, is indicated.
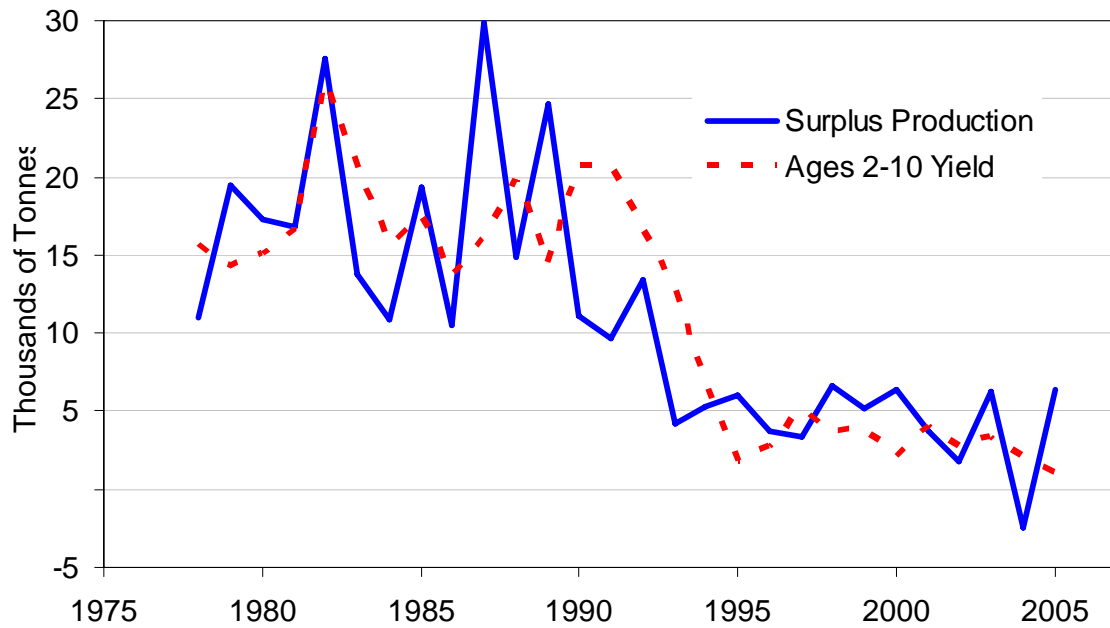
Figure 30. Surplus production of eastern Georges Bank cod compared to harvested yield.
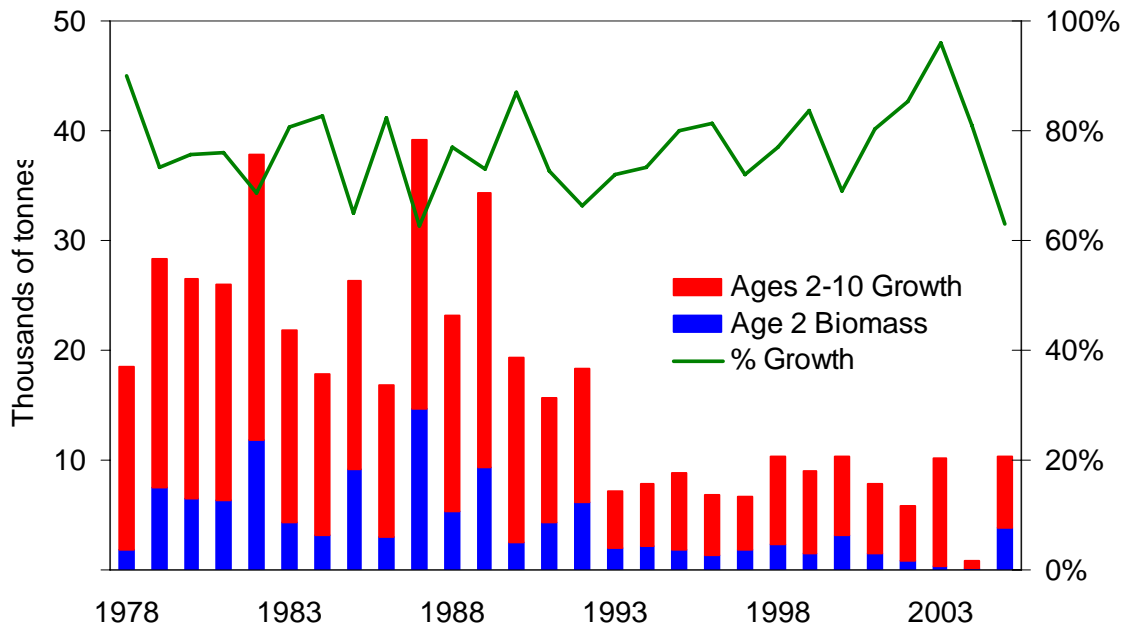
Figure 31. Components of annual production for eastern Georges Bank cod attributable to growth of ages 2 to 10 and to the amount contributed from incoming year classes at age 2.
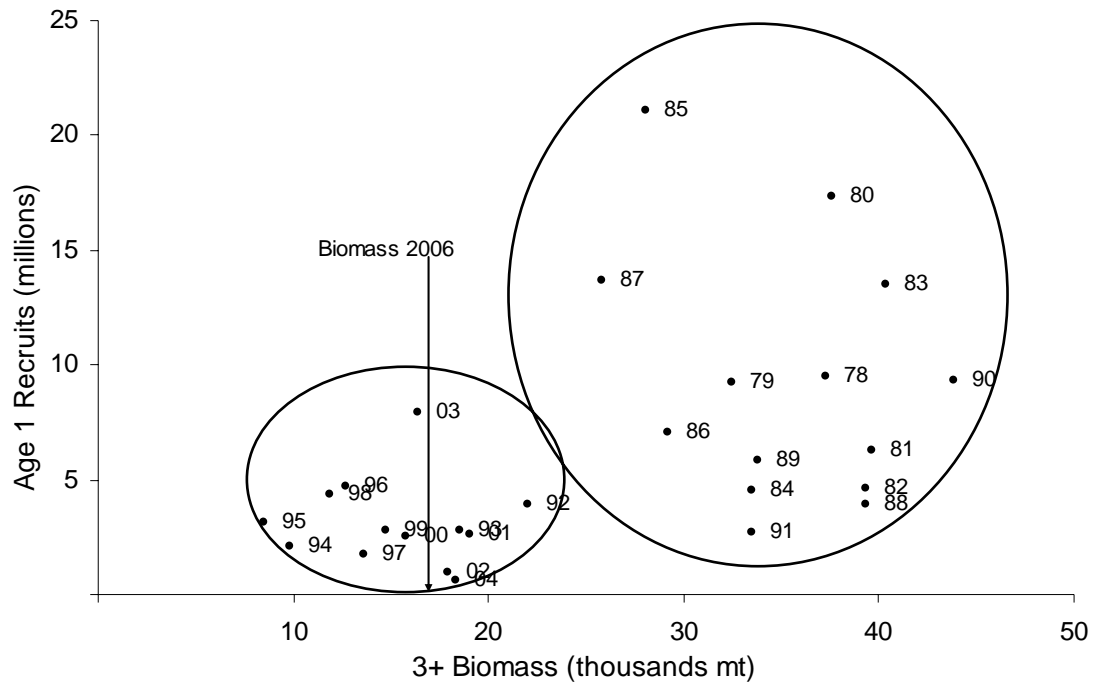
Figure 32. Relationship between adult biomass (ages 3+) and recruits at age 1 for eastern Georges Bank cod.
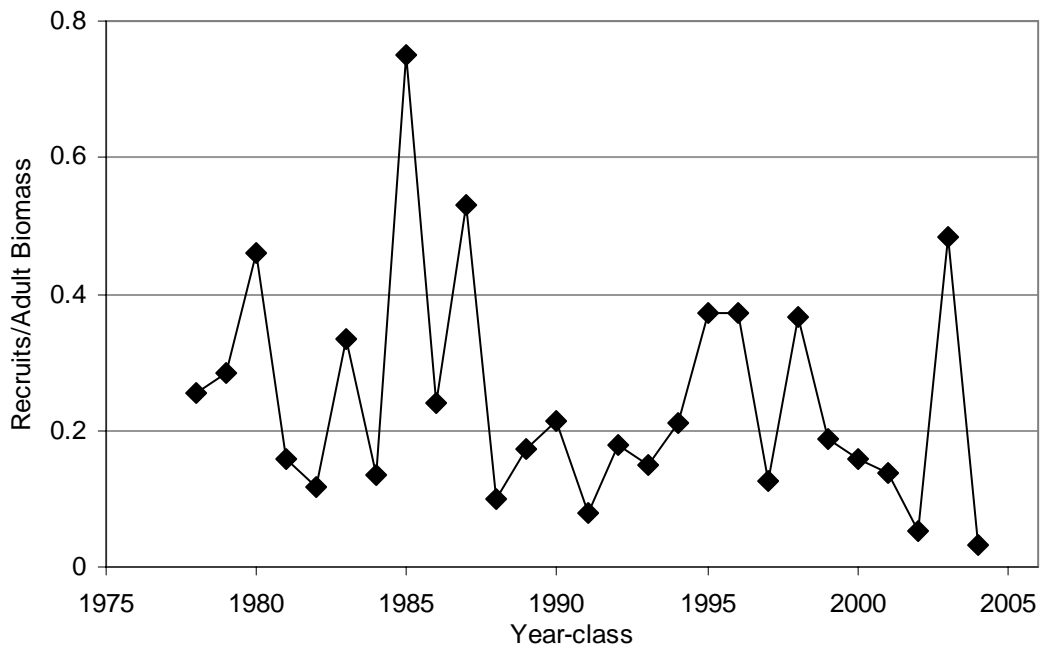
Figure 33. Ratio of recruits at age 1 to adult biomass (ages 3+) for eastern Georges Bank cod.
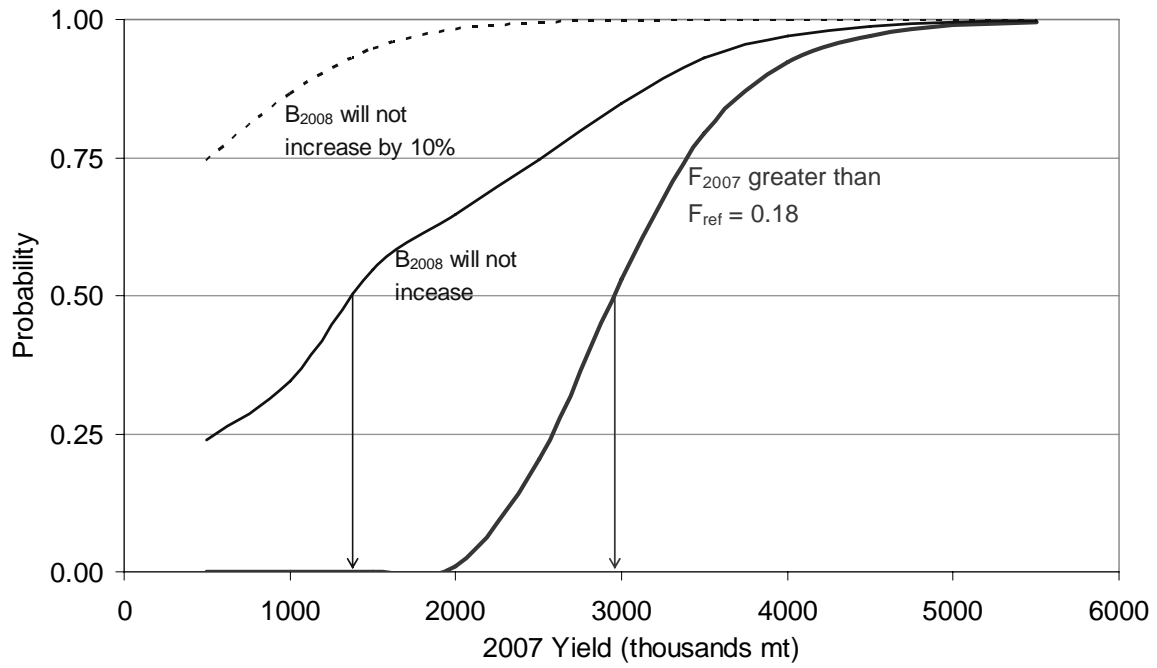
Figure 34. Risk of 2007 fishing mortality exceeding $F_{ref} = 0.18$ and risk of biomass not increasing or not increasing by 10% for alternative total yields of eastern Georges Bank cod.

Appendix A

Discards from the groundfish fishery in 2005

Discards from the groundfish fishery in 2005 were derived using a similar model to that described by Van Eeckhaute and Gavaris (2004). Define the parameter *m* as,

$$\frac{C_c}{C_o} \bigg/ \frac{L_c}{L_o} = m \, ,$$

where C_c is the observed catch of cod, C_o is the observed catch of haddock plus pollock, L_c is the unobserved landings of cod and L_o is the unobserved landings of haddock plus pollock. Assuming that haddock and pollock are not discarded, since those quotas are not considered limiting, the observed catch of haddock plus pollock is equal to the unobserved landings of haddock plus pollock.

$$C_o = L_o$$

Simplifying shows that the weight of cod caught may be derived from the amount of cod landed if the parameter *m* is known,

$$C_c = mL_c \, .$$

We require an estimate of the parameter *m*, referred to hereafter as the landings multiplier. An estimator of the landings multiplier and its standard error was obtained using the multiplicative model described by Van Eeckhaute and Gavaris (2004).

The 2005 groundfish fishery on eastern Georges Bank is usefully classified based on main species into three types, cod-haddock, pollock and yellowtail flounder. When the main species was pollock or yellowtail flounder, few cod were caught. Eastern Georges Bank has been partitioned into five zones for monitoring purposes (Figure A1). Most of the cod is caught in zones A and B. A small amount of cod is caught by gillnet and handline. The bottom otter trawl (OTB) fisheries were partitioned into two groups depending on participation in the Temporary Vessel Replacement Program (TVRP), non-TVRP and TVRP, and the longline (LL) fisheries were partitioned into three vessel size based groups, <45 ft, 45-65 ft and 65-100 ft. There were few trips for the LL 45-65 ft and for LL 65-100 ft sectors and at-sea monitoring was very limited. Almost 85%, 525 mt of the 630 mt landed, was caught by the OTB non-TVRP, OTB TVRP and LL <45 ft cod-haddock fisheries in zones A and B. The fisheries during 2005 were conducted during January and February and from June to December. During the fourth quarter of 2005, it became apparent that the cod quota would not limit harvesting the entire haddock quota. Indeed, several vessels sought cod when fishing during the fourth quarter. At-sea monitoring was limited in the fourth quarter and was not considered representative of fleet behavior. Given that there was not an incentive to discard cod, it was assumed that cod were not discarded during the fourth quarter. Therefore, discard analyses were conducted only for the LL <45 ft, OTB non-TVRP and OTB TVRP cod-haddock fisheries in zones A and B during quarters 1-3. There were a few exploratory trips during May of 2005 but these were not included.

Discard multipliers were derived by zone and quarter for the three fleets, LL <45 ft, OTB non-TVRP and OTB TVRP (Table A1). There is a great deal of variation in the cod:haddock+pollock ratios, resulting in imprecise estimates of discard multipliers. Given

the uncertainty, a hypothesis of no discarding could not be rejected for the LL <45 ft sector or for the first quarter fisheries by the OTB. To overcome some of the variability, discard multipliers for the OTB non-TVRP and OTB TVRP were pooled over quarters 2-3 and zones A-B. These multipliers were applied against the unobserved landings of cod from these zones and for these quarters to obtain a total discard estimate of 144 mt (Table A2).

Table A 1. Discard multipliers for Canadian groundfish fleets fishing eastern Georges Bank in 2005 by zone and quarter. Values in italics signify where a hypothesis of no discarding was not rejected.

	Zone A			Zone B		
	Q1	Q2	Q3	Q1	Q2	Q3
LL <45 ft			*0.89±0.32*			*1.31±0.42*
OTB non-TVRP	*0.15±0.14*		1.91±0.57	*1.29±0.39*	2.22±0.67	2.11±0.50
OTB TVRP		0.05±0.05	1.20±0.88	*1.37±0.81*	2.96±1.62	3.10±1.50

Table A 2. Discard estimates from the Canadian groundfish fishery in 2005.

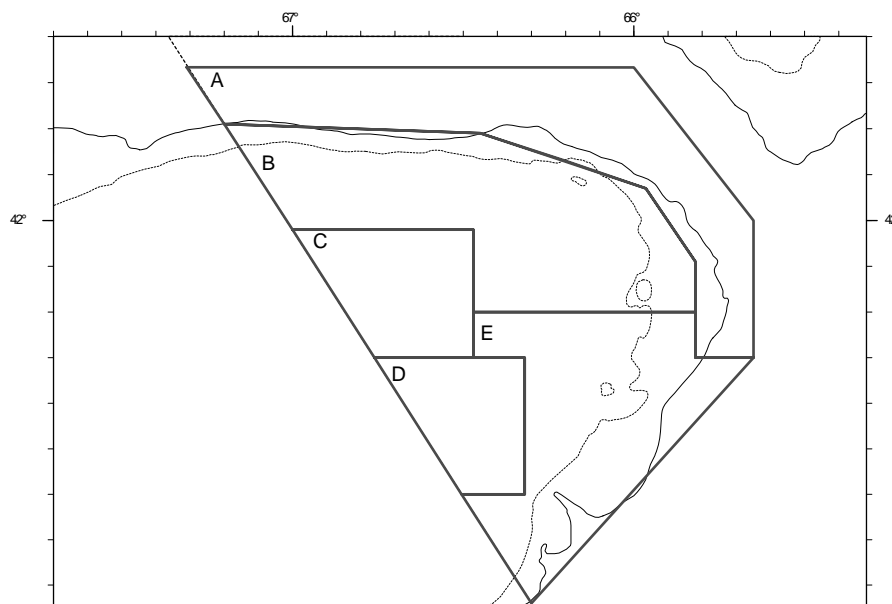|	Unobserved Landings (mt)	Multiplier	± S. E.	Discards
OTB non-TVRP	94	2.13	±0.35	**107**
OTB TVRP	25	2.52	±0.86	**37**
Total				**144**

Figure A 1. Zones used for monitoring purposes of Canadian fisheries on eastern Georges Bank.

Appendix B

Table B 1. Inter-reader agreement matrix for the DFO age readers Bette Hatt and Laura Brown using eastern Georges Bank cod otoliths from the 2004 Canadian fishery and the 2005 DFO survey.

	BH								
LB	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**Total**
2	6	1							7
3	1	51	1		1				54
4			47	2					49
5			2	23	2				27
6				2	48	1			51
7					4	9	3		16
8						2	20		22
9							2	8	10
Total	7	52	50	27	55	12	25	8	**236**

CV=1.63

90% Agreement

	DIFF		
	-1	**0**	**1**
	13	212	11

Table B 2. Inter-reader agreement matrix for the DFO cod age reader versus the NMFS cod age reader, Bette Hatt and Nina Shepherd respectively, using eastern Georges Bank cod otoliths from the 2003 Canadian fishery, the 2004 DFO survey, the 2004 USA fishery and the 2004 NMFS fall survey.

	DFO								
NMFS	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**Total**
1	7								7
2	1	2							3
3			35	3	1				39
4				38	3				41
5				1	37	5	1	1	45
6					2	40	4		46
7						2	7	2	11
8							1	6	7
Total	8	2	35	42	43	47	13	9	**199**

CV=2.27

88% Agreement

	DIFF		
	-1	**0**	**1**
	7	172	20