

Discarding of Cod (*Gadus morhua*) in the Northern Cod and Northern Shrimp Directed Trawl Fisheries, 1980–94

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Abstract

Since the 1960s, trawlers have fished the offshore banks of the Labrador and Northeast Newfoundland Shelves for cod (*Gadus morhua*). As well, shrimp (*Pandalus* sp.) have been fished in the deep channels off Newfoundland and Labrador since the late-1970s. The shrimp gear captures incidental species including small cod that are of no commercial value to this sector. Cod, discarded from both fisheries were generally under-recorded in the fishing logs. Landings data, used as input for the assessment of the stock does not include the discard component and thus is biased. Concerns have frequently been expressed about the level of discarding from the directed offshore fisheries for cod and shrimp. However, the winter cod and shrimp directed fisheries have been observed since 1980, providing the opportunity to quantify discarding. This analysis derives amounts discarded based on observed catches adjusted to landings, estimates numbers-at-age from length samples obtained by observers, and examines spatial patterns of discarding for the period 1980–94. Discarding from the cod directed fishery was the larger component, accounting for an average of 92% of the weight of total discards annually. For both fisheries combined, total estimated discards peaked in 1986 at 9 403 tons (10 211 389 fish) but declined to low levels by 1992 when the cod directed fishery was closed. A gear attachment, the Nordmore grate was introduced in the shrimp fishery in 1993 causing a further reduction in cod by-catch and discards. The total in 1994 was 57 396 fish, a fraction of the numbers from the mid-1980s. Prior to 1987, much of the discarding occurred along the shelf edge where fishing effort was highest. After 1986, discarding was more prevalent shoreward, where cod tended to be smaller, away from the areas of greatest fishing effort.

Key words: discards, north-east Newfoundland and Labrador shelves, northern cod, shrimp

Introduction

Atlantic cod (*Gadus morhua*) in NAFO Divisions 2J, 3K and 3L on the north-east Newfoundland and Labrador Shelf comprised Atlantic Canada's most important groundfish resource for more than 400 years. During most of that period, the fishery was prosecuted near shore. A significant increase in catch and fishing effort resulted from the introduction of an offshore cod fishery during the 1960s and 1970s, primarily on the outer slopes of Hamilton, Belle Isle and Funk Island Banks (Fig. 1). This contributed to a decline in biomass in the late-1970s. After some growth of the stock, it continued to be the primary resource for both the inshore and offshore groundfish sectors into the 1980s. Bishop *et al.* (MS 1993) noted that a decline in abundance of cod became evident in the autumn of 1990, after which the biomass declined rapidly. The fishery, with a peak catch of 268 677 tons in 1988 was closed in 1992. As well, shrimp (*Pandalus* sp.) were fished since the late-1970s off Labrador in Cartwright and Hawke Channels and in St. Anthony Basin within Div. 2J and 3K (Fig. 1). This fishery took incidental

catches of small cod (Kulka, MS 1995), of no commercial value to this sector.

Among the many reasons cited for the decline of northern cod is the unreported catch including fish discarded at sea. Discarding, the selective removal (by size or other selection criteria) of whole fish from the catch for return to the sea, generally occurs because of unmarketability. Only fish rejected whole are classified as discards, not parts of fish returned to the sea during production. Dumping is the non-selective process of returning whole or partial (unculled) catches to the sea and this occurs when amounts caught exceed quotas or processing capacity of the vessel. In either case, chance of survival for the fish is small given the damaging effects of the gear and the handling on board of the fish during production. Throughout the rest of this paper, both dumping and discarding are referred to as discarding, when they are not specifically differentiated.

Prior to 1980, fishing logs were the only source of information on discarding of fish. Stevenson

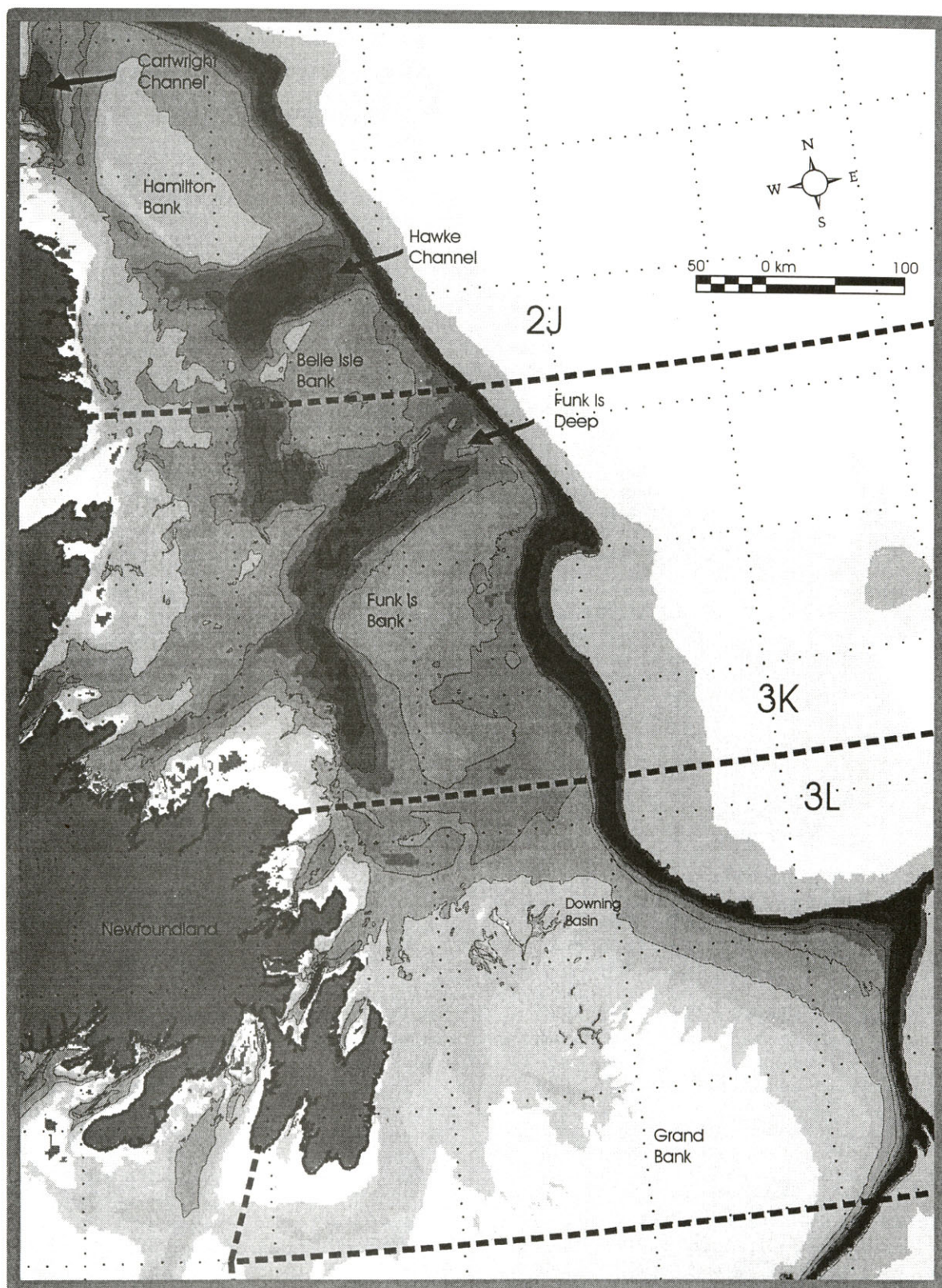


Fig. 1. Map of the Labrador and northeast Newfoundland Shelf showing NAFO Divisions, banks, channels and bathymetry.

(MS 1978) examined some of these records but concluded that they were incomplete. Before the mid-1980s, there was little incentive to record discards in the fishing logs. Comparisons of log and observer data for the cod directed fishery for 1981 to 1985 (Kulka and Stevenson, MS 1986) and from the shrimp fishery, particularly in earlier years (Kulka, MS 1995) confirmed that discarded or dumped fish were greatly under-reported in fishing logs. Thus, observer data was chosen as the most reliable source of information on discarding. Since 1980, observers on a portion of the offshore fleets estimated and measured fish caught and discarded. Mandatory use of fishery observers for both fisheries since 1987, and a specific requirement of observers to quantify all species by fishing set, has yielded a very detailed data set on discard levels for the cod and shrimp directed trawl fisheries.

Although cod was discarded from both of the cod and shrimp directed fisheries, this source of mortality was not accounted for in the assessment of northern cod. Landing statistics, the basis for catch data as input into the assessment does not include amounts discarded and thus, fishing mortality is underestimated. Limited information on discard weights collected by fishery observers from earlier years has been reported by Kulka (MS 1982, MS 1984, MS 1985, MS 1986 a and b, and MS 1989) and Kulka and Stevenson (MS 1986). The purpose of this paper is to examine in more detail, discarding for the observed offshore shrimp and cod directed trawl fisheries, from 1980 to 1994. Discards from other gears, by-catch of cod from trawl fisheries other than shrimp and cod, and discards from the inshore sector are not included. This study provides amounts (weight), size of fish discarded, estimates of numbers-at-age for the offshore cod and shrimp fisheries, examines spatial patterns in discarding over time and addresses the potential impact of these removals on the population.

Methods

Information gathered by fishery observers from offshore (vessel class 4+) trawler fleets of all countries directing for northern cod and northern shrimp in Div. 2J, 3K and 3L (Fig. 1) was used to examine discarding practices by those fleets from 1980 to 1994. Observers stationed on board a portion of the trawl fleet estimated, for each set, the catches of cod, including amount kept and discarded, using the methods of Kulka and Firth (1987). These data were used to calculate total discard weights and numbers when adjusted to the landing statistics. Up to 1986, observers were deployed to a portion of the cod and shrimp fleet. Although coverage of the two fleets was mandatory for the winter fishery (December to May) after 1987, occasional sets were missed since only one

observer was deployed per vessel and fishing was a 24-hour operation. Also, due to logistic problems in deploying observers, not all trips were covered after 1987. Coverage outside 200 miles was limited and is not included in this study.

Discarding of fish varies greatly among vessels and may be handled by the crew in a variety of ways on a particular vessel. Based on prior knowledge of vessel production and layout, instructions to observers during briefings on discard observation strategies were tailored to individual vessels and even different production shifts on the same vessel. Factors such as discard sites, processing area layout, crew habits, discard practices and levels of discarding were taken into account when quantifying discards.

Discard observation sites were combined where possible, to minimize the number of locations at which observations had to be made thus maximizing amount of fish viewed, weighed or counted. For example, if all fish to be discarded merged at one location before going overboard, this is where the fish were counted or collected for weighing. Also, time spent viewing discards was greatest where the discard rate was highest. However, observation time was allocated to each discard site and covered the entire processing period because discard rates varied among sites and during processing. The objective was for the observed periods to be representative of the entire processing period in terms of discard practices

Estimating discards was accomplished by either weighing or counting fish, or a combination of both (Fig. 2) depending on vessel conditions and amounts discarded. The general principle was to use the most direct method possible to estimate discards. With respect to weighing, the most direct method was applied where amounts were small. If the entire discarding period could not be observed, the total amount discarded was estimated by subsampling. A count of baskets of discard fish was collected for the portion of the discarding period observed, then extrapolated to the total processing period. A weighed sample of baskets allowed conversion of basket counts to weights.

Where weighing was not possible, discarded fish were counted then converted to weight by multiplying by the average weight of discarded individuals. Random samples of discarded fish from the set were weighed and measured and their mean length was calculated. A length/weight table was used to calculate average discard weight. Typical circumstances involved discarding at more than one location. Thus, the entire discarding period could not be observed at each site. For this situation, discard estimates were obtained by counting the

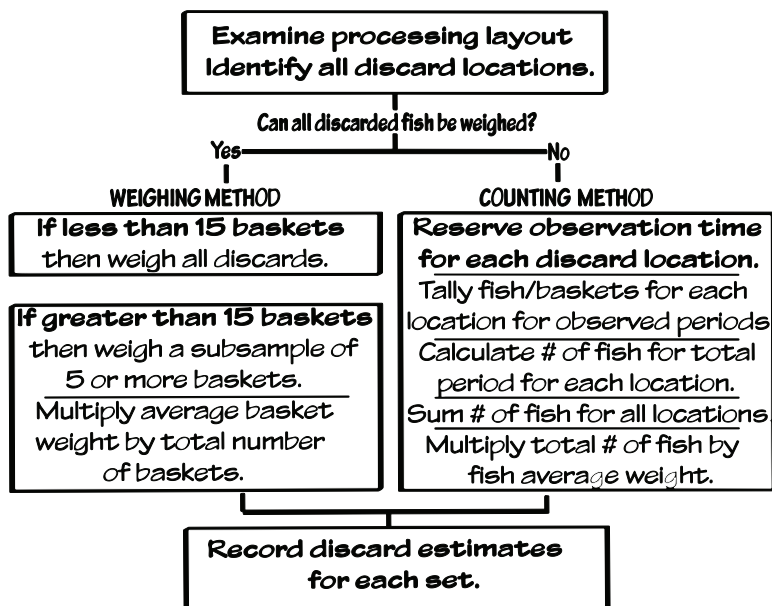


Fig. 2. Flow chart of discard estimation strategies used by fishery observers.

discards for part of the discarding period at each site, then extrapolating these counts to the total period. This total was then multiplied by the average weight of discarded individuals to obtain total discard weight for the species. Whether the discards were weighed or counted, amount viewed, counted or weighed was maximized. All sites were observed and observations were spread over the entire production period. Observed periods at each discard site were adjusted to the entire period then added across all sites.

Only sets where the observer estimated catch and discards were used in this study to calculate percent of cod discarded. To account for unobserved sets, total discard amounts were estimated by multiplying the ratio of landings to observed kept weights by observed discard weight. For the cod directed fishery, this was done by NAFO Division by month (the finest breakdown available from the landing statistics) and for the shrimp fishery, it was done by shrimp ground (refer to Fig. 1 and Table 1). Where observed catch exceeded reported landings, observed figures were used. Length samples of discards were collected from each vessel and these data were used to convert discard weight to numbers-at-length. Age-length keys from research vessel surveys for the appropriate areas were used to calculate numbers-at-age since commercial landing keys did not cover the lower end of the discard sizes.

Latitude, longitude and date recorded with each set provided a detailed time and geo-reference. Spatial variation in discarding for the cod directed fishery was examined by calculating the proportion of cod discarded for each set then transforming these point data to surfaces using potential mapping, similar to the methods described in Kulka *et al.* (1995) and Wroblewski *et al.* (1995). The resulting surface is a discard intensity plot differentiating level of discarding and a standard error plot showing variation in discarding over the extent of the fishing grounds. The years 1980 to 1986, prior to mandatory reporting of discards, and 1987–92, when discards were deducted from the allocation, were combined and compared.

Results

Table 1 shows that discarding of cod increased annually from 1980 to 1987, then declined to low levels by 1992. For the cod directed fishery, total discarding was generally highest in the winter months in Div. 3K, which corresponded to area of greatest fishing effort, along with Div. 2J, where catch-per-set was greatest and where fish were smaller. Unlike the Canadian fleet, the foreign vessels generally discarded little cod. Foreign effort was phased out during the 1980s. Therefore, in the earlier years, discard rates were lower in Div. 2J corresponding to where most of the foreign effort took place. For the domestic fleet, discard rates

Weight Discarded (tons)														
Cod Directed					Shrimp Directed					Numbers				
Year	Div.	Div.	Div.	Total	Cartwright	Hawke	St. Anth.	St. Anth.	Funk Is.	Total	Both			
	2J	3K	3L		Channel	Channel	East	West			Fisheries	Directed	Fisheries	
1980	55.7	76.2	22.8	154.7	31.7					31.7	186.4	124 081	27 860	151 941
1981	329.9	241.8	-65.5	637.2	18.9	47.6				66.5	703.7	776 260	67 580	900 341
1982	965.1	581.9	236.7	1 783.7	5.9					5.9	1 789.6	2 107 224	9 220	2 116 444
1983	1 577.2	1 344.9	641.6	3 563.7	0.0					0.0	3 563.7	3 224 708	0	3 224 708
1984	528.5	3 185.0	1 740.5	5 453.9	1.1					1.1	5 455.0	5 224 741	1 719	5 226 460
1985	83.3	5 545.7	1 333.7	6 962.7	0.4					0.4	6 963.2	5 953 800	625	5 954 425
1986	529.3	6 054.9	2 746.0	9 330.1	72.8					72.8	9 402.9	10 097 621	113 768	10 211 389
1987	1 747.0	2 013.5	665.1	4 425.6	4.6	215.5	91.5			311.6	4 737.3	4 416 849	348 245	4 765 094
1988	1 310.7	967.8	560.5	2 839.0	1.3	121.8	23.1	14.9	257.9	419.0	3 258.0	3 339 565	3 142 446	6 432 011
1989	1 088.5	973.2	519.8	2 581.5	26.2	103.5	36.4	53.5	280.7	500.3	3 081.8	3 018 173	1 435 815	4 453 988
1990	950.6	573.5	1 339.8	2 864.0	14.7	24.0	60.8	61.9	227.1	388.4	3 252.4	3 486 868	1 257 283	4 744 151
1991	23.0	492.0	444.0	959.0	6.4	383.7	35.8	68.0	64.1	558.0	1 517.0	1 151 877	1 106 472	2 258 349
1992	0.0	73.1	377.9	451.0	7.6	124.4	10.6	18.8	70.9	232.3	683.3	561 399	565 056	1 126 455
1993				0.0	2.8	40.9	2.3	0.5	0.0	46.5	46.5		180 723	180 723
1994				0.0	9.6	8.7	2.8		0.9	22.0	22.0		57 396	57 396
Avg.	706.8	1 701.8	822.6	2 800.4	13.6	118.9	24.5	44.2	128.8	177.1	2 977.5	43 483 166	8 176 089	51 659 255

tended to be lower later in the year. The domestic summer/autumn fishery occurred to the south on the Grand Banks where catch rates were lower and fish were larger. For the offshore cod directed fishery, from 155 tons (124 081 fish) in 1980, discarding peaked in 1986 at 9 330 tons or 10 097 621 fish then declined to 451 tons (561 399 fish) in 1992, the last year of the directed fishery.

Cod by-catch from the shrimp fishery is categorized by fishing ground within Div. 2J and 3K. The fishery for shrimp was limited before 1986 to the more northerly areas, namely Cartwright and Hawke Channels in NAFO Div. 2J (refer to Fig. 1). Discards increased proportionately with the catches of shrimp as effort spread southward and peaked in 1988 as the shrimp fishery spread to more southerly locations. The cod by-catches were highest in Hawke Channel and Funk Island Deep with these areas contributing to most of the shrimp fishery discarding, particularly between 1987 and 1991. Nearly all by-caught cod in this fishery were discarded in later years but about 15% (the larger fish) was kept in earlier years, before 1988.

Discarding from both fisheries dropped off sharply after 1991 as the cod fishery was closed (February 1992) and gear attachments on shrimp nets were used to exclude cod by-catch. Only 22 tons (57 396 small cod from the shrimp fishery) of discards was observed in 1994. Preliminary results for 1995 show a similar level.

Spatial variation in discarding for the cod directed fishery was highly variable over the extent of the fishing grounds depending on fleet, (foreign or domestic), individual vessel habits, size of catch and average size of fish in the catch. Prior to mandatory observer coverage and the requirement to count discards against the allocation in 1987 (Fig. 3a), high discarding was most extensive along the shelf edge in Div. 3K corresponding to where catch rates were highest and where most of the domestic fishing effort occurred. Extent of discarding was less extensive in Div. 3L due to smaller catch per set and larger fish, and very limited in Div. 2J given the greater foreign fleet component in that area. Variance, depicted by standard error in Fig. 3b for 1980–86, shows that where standard error was high closely matched locations of high discard rate shown in Fig. 3a. That is, where discarding was high, it was also more variable. After 1986 (Fig. 3c), extent of high discarding was reduced and distributed more shoreward where smaller fish were caught, away from the main concentration of fishing effort. Variance during this period (Fig. 3d) was homogeneous over most of the grounds and lower than 1980–86. Spatial differences in discard rates

for the shrimp fishery was a function of local cod densities in the deep channels and this varied among areas, seasons and years.

Figure 4 shows numbers of discarded cod at length by year from the two fisheries for 1980–94. Most of the fish discarded from the directed cod fishery were between 25 and 50 cm. Average size of discards from the cod directed fishery (Fig. 5) varied over time, increasing during the early-1980s then declining after 1987. This pattern was likely related in part to a corresponding increase (to 1985) then decrease in dumping where fish of all sizes were discarded. Shrimp fishery discards were a minor component before 1988 and consisted of a mix of smaller fish averaging 28 cm and ranging from 15 to 40 cm. Except for 1987, shrimp fishery by-catch discards were smaller in size than the discards from the cod fishery because of the smaller mesh used (Fig. 5). Size of shrimp fishery discards was fairly consistent over time except in 1987 when large concentrations of older fish were encountered in Hawke Channel and St. Anthony Basin. Nearly all cod caught in this fishery were discarded and as the cod fishery declined, it became an increasingly greater component of the total discards of cod.

Numbers of cod discarded at age from both fisheries is shown in Fig. 6. Nearly all 6+ fish were retained in all years. Older fish, mainly 4- and 5-year-olds dominated in the years prior to 1992 with a minor component of 3- and 6-year-olds. Some fish were retained in all size and age groups but an increasing proportion of younger and smaller fish caught were discarded. An expanding shrimp fishery discarding younger fish and closure of the cod fishery led to a greater proportion of 2- and 3-year-olds discarded in the later years. Table 2 summarizes the numbers-at-age combined for both fisheries.

Figure 7a shows that average age of discards dropped over time as shrimp fishery discards became an increasingly important component. Overall, 74% of discards were aged 4 and 5 and nearly all (98%) were less than 6 years old. Figure 7b compares, using the ADAPT framework model, population numbers and total catch numbers to the amounts discarded from the offshore directed cod and shrimp fisheries. In the peak year, they represented 6.5% of the total offshore catches and 1% of the population. Due to a declining population after 1985, and an increase in total discards up to 1986, the weight of discarded cod as a percent of the population biomass increased steadily from 1980 to 1990, with the exception of the peak discard year in 1986. Thereafter, it declined to near zero.

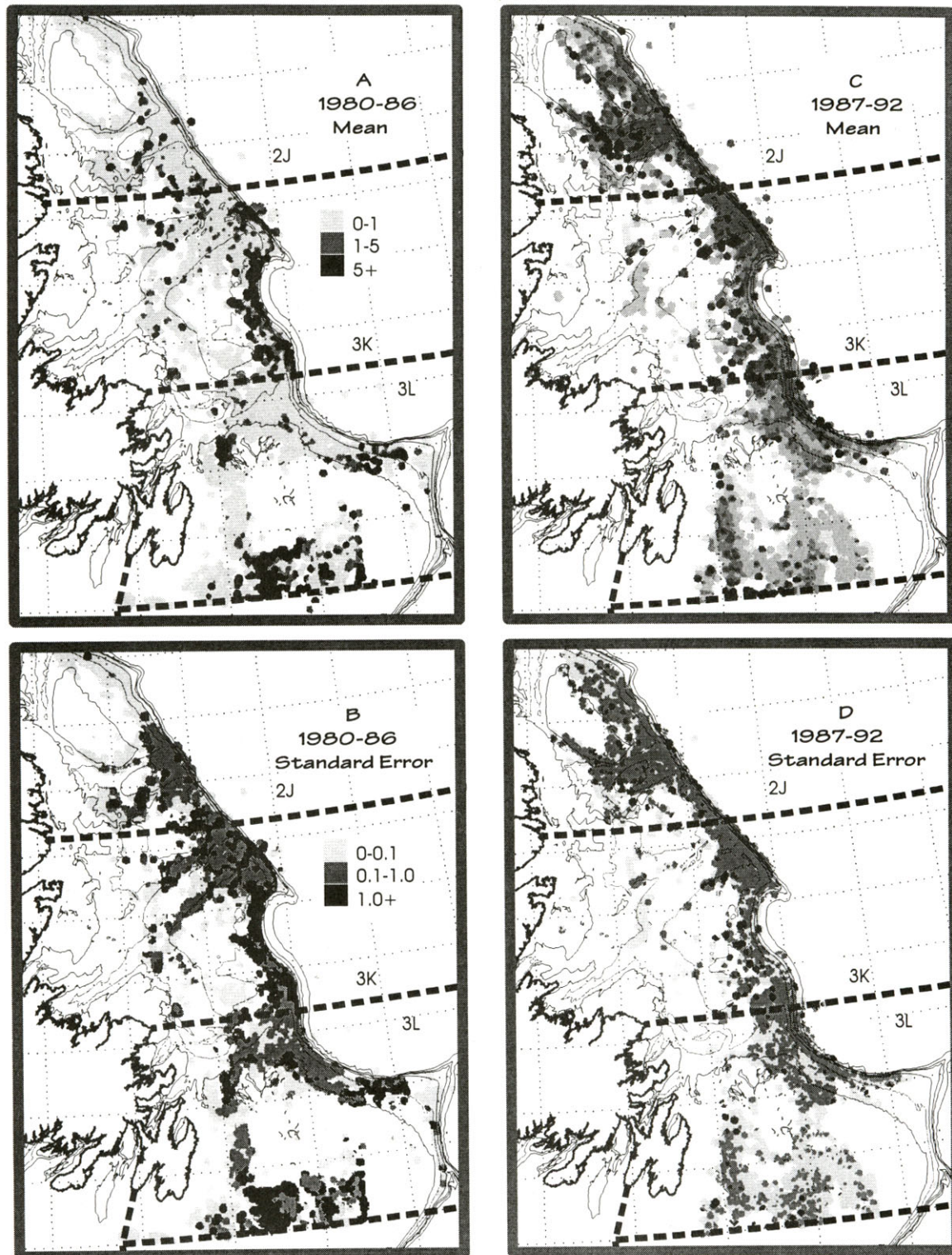


Fig. 3. Spatial distribution of cod discarding for the offshore cod directed trawl fishery from potential mapping: (A) mean of discard rate for 1980-86 where light grey areas show where discarding was 0-1% of the catch, medium, 2-5% and black where discarding exceeded 5%; (B) standard error of percent discarded for 1980-86 where light grey was 0-0.1, medium, 0.1-1.0 and black, +1.0%; (C) mean of discard rate for 1987-92; and (D) standard error of percent discarded for 1987-92.

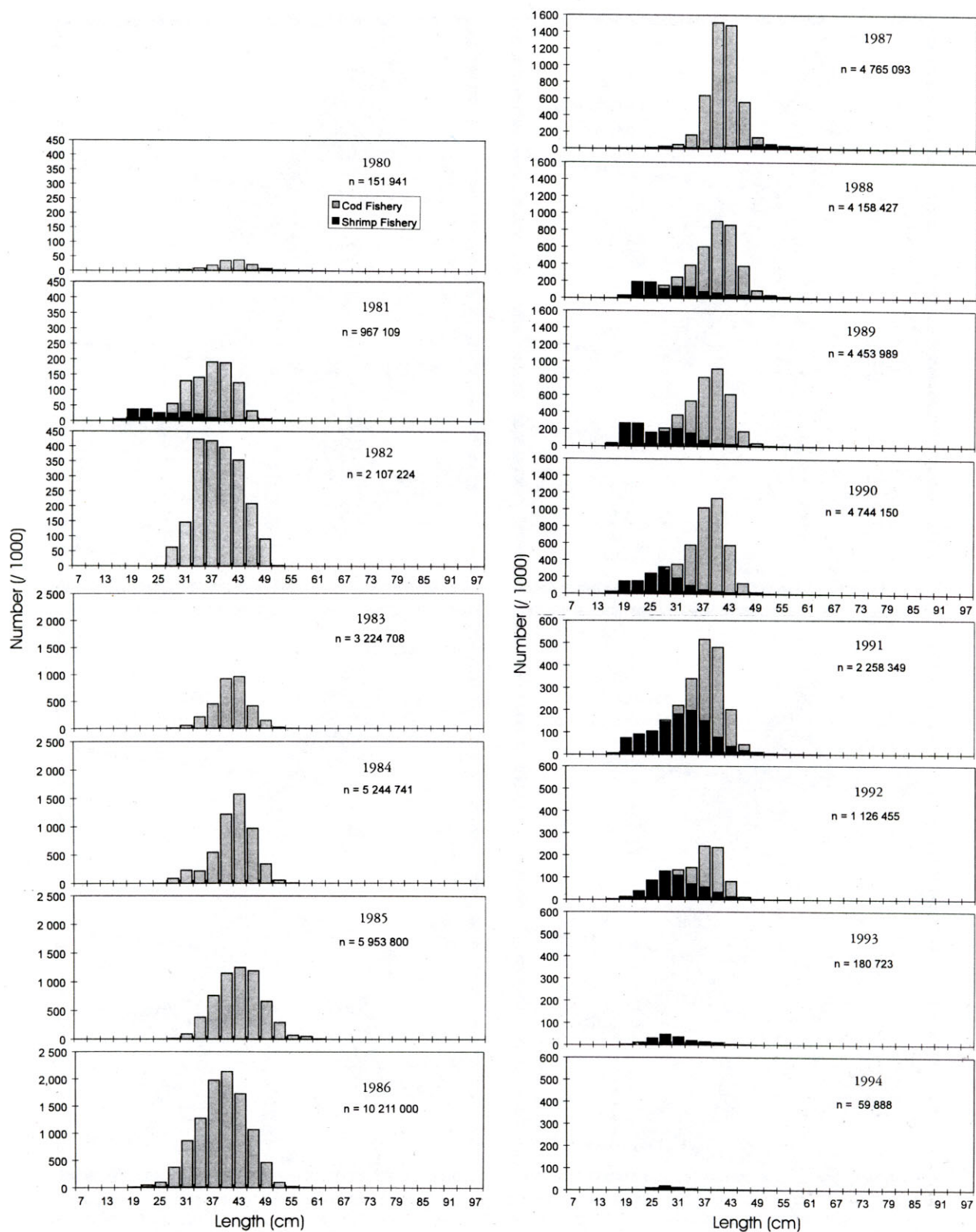


Fig. 4. Numbers of cod discarded at length from the offshore cod and shrimp directed fisheries: (A) 1980-86, and (B) 1987-94.

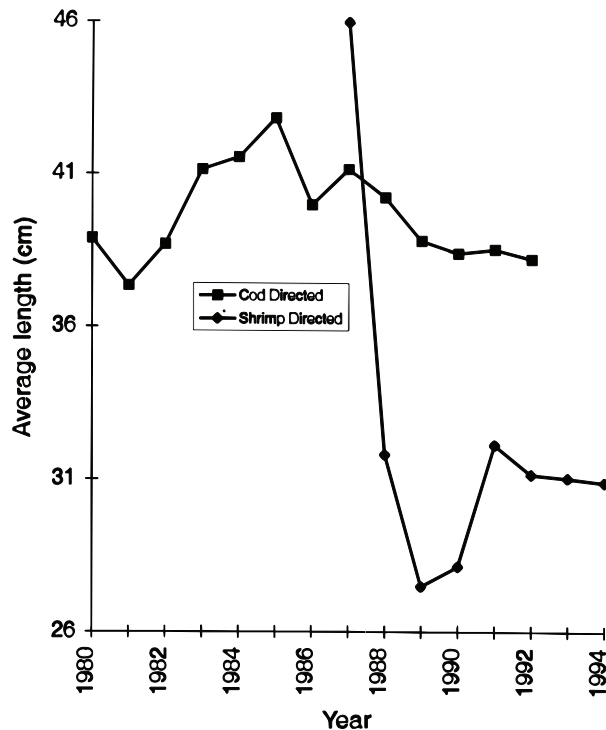


Fig. 5. Average length of cod discarded from the offshore cod and shrimp directed fisheries.

Discussion

Several factors contributed to the increasing discard rates of the early-1980s observed on most Canadian vessels and to a limited extent on some foreign vessels. Some vessels tended to discard more than others. Observed vessel averages varied between 1 and 22% discarding in 1986, the peak year, but such factors as variable market requirements, size of catch, fish size, among others caused considerable variation within and among vessels, and over area and time. The more extreme actions of certain vessels led to reports of dumping far exceeding the observed average.

Increasingly dense schools of fish encountered in the directed winter fishery resulted in larger catches. Catch per set increased from 1981 and peaked in 1984 and 1985 in Div. 2J, often exceeding the processing capacity of the vessels during that period. On some vessels, portions of some sets were dumped if the previous set was not completely processed before the next set was brought aboard. Although somewhat different among vessels, average optimum catch-per-set for processing was 12 tons, to allow production of one set to be completed before the next set was on

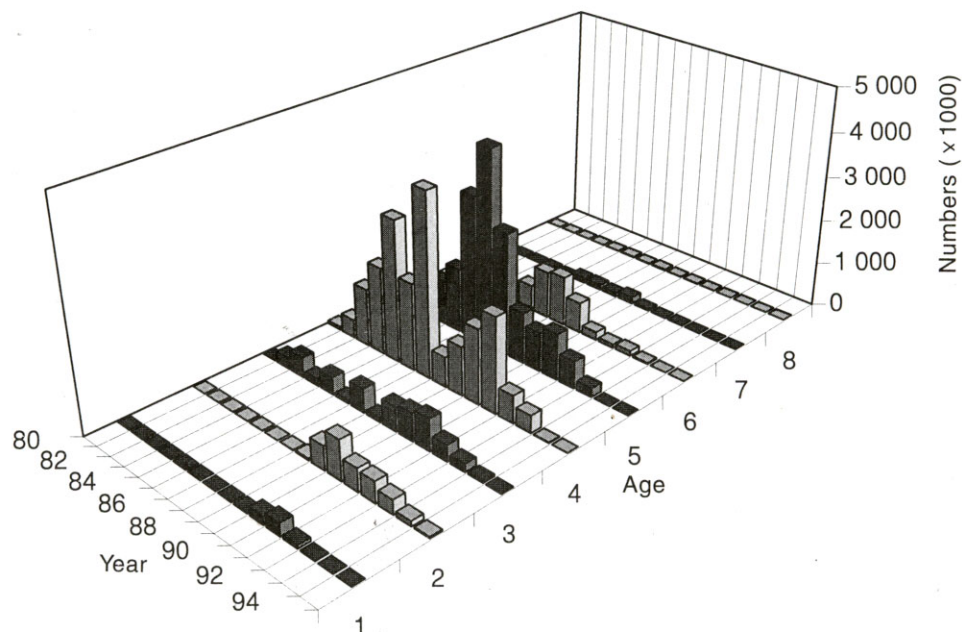


Fig. 6. Numbers of cod discarded at age for the offshore cod and shrimp directed fisheries in Div. 2J, 3K and 3L.

TABLE 2. Numbers of discards from the cod and shrimp directed fisheries in Div. 2J, 3K and 3L, by age.

Year	Discard Age-group (years)											Total
	1	2	3	4	5	6	7	8	9	10	11+	
1980	0	0	0	60 369	49 273	7 831	68	0	0	0	0	124 081
1981	0	3 026	249 251	408 524	96 194	19 547	3 599	0	0	0	0	780 141
1982	0	0	447 424	1 284 176	302 991	67 290	5 209	134	0	0	0	2 107 224
1983	0	45	157 092	1 939 526	989 955	118 733	14 518	3 475	1 136	228	0	3 224 708
1984	0	925	396 004	3 154 599	1 430 782	251 973	1 073	9 285	100	0	0	5 244 741
1985	0	62	84 133	1 936 741	3 232 521	573 057	107 142	14 570	2 360	3 215	0	5 953 800
1986	0	9 674	537 680	4 075 233	4 406 498	1 053 066	108 652	6 769	273	634	118	10 198 597
1987	11 759	39 204	96 809	673 300	2 723 640	1 107 711	80 670	20 805	7 240	2 543	1 412	4 765 093
1988	17 257	535 703	545 495	1 092 489	1 131 458	678 534	148 652	6 227	2 028	402	182	4 158 427
1989	187 669	887 234	622 664	1 666 380	869 880	179 174	31 761	8 557	484	127	59	4 453 989
1990	284 928	511 453	709 224	2 114 216	1 027 604	85 363	5 580	3 626	1 868	217	70	4 744 150
1991	80 388	468 579	363 299	615 885	609 638	112 240	7 255	675	244	95	51	2 258 349
1992	14 189	315 446	180 622	386 419	201 927	26 336	1 260	254	3	0	0	1 126 455
1993	3 469	117 247	45 367	12 113	1 207	1 144	124	51	0	0	0	180 723
1994	2 668	33 911	14 896	3 952	1 751	82	120	16	0	0	0	57 396
Total	602 326	2 922 509	4 456 501	19 423 922	17 075 318	4 282 081	515 684	74 445	15 735	7 462	1 892	49 377 875

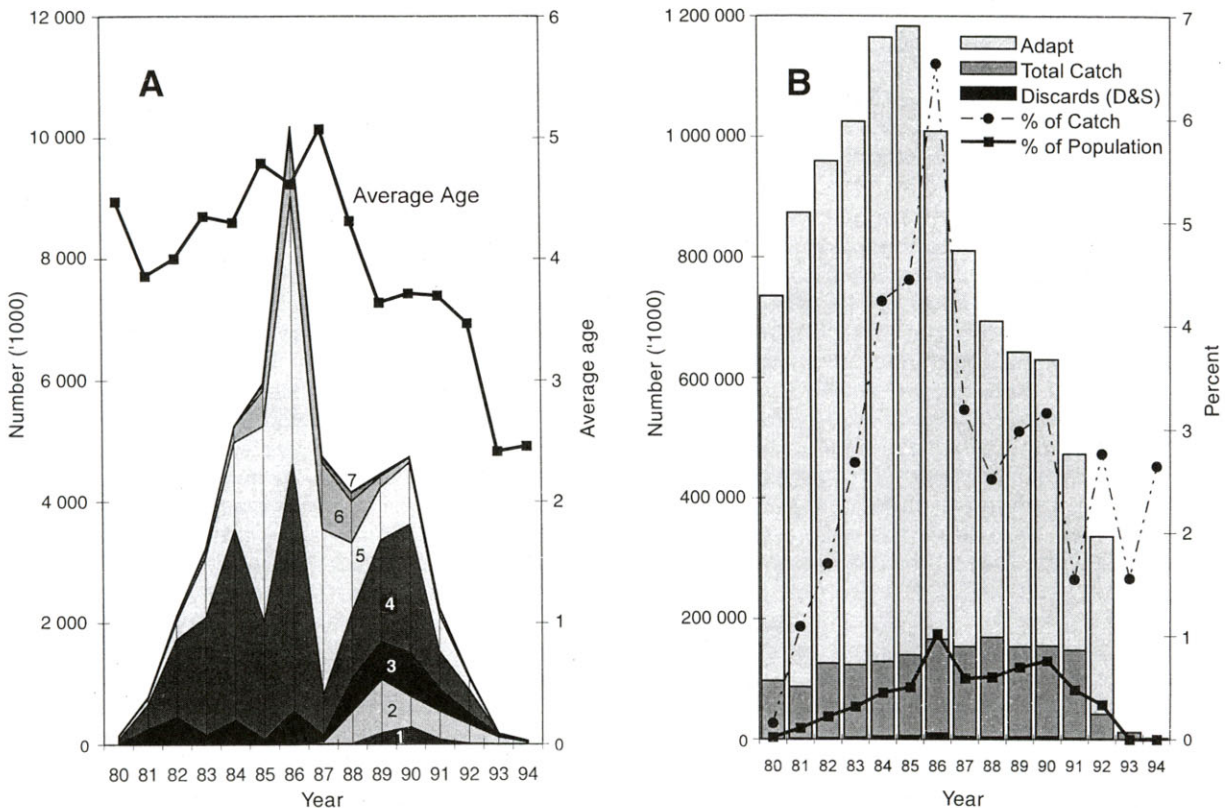


Fig. 7. Cod discards from the offshore northern cod and shrimp directed trawl fisheries: (A) shows numbers discarded by year. Sub-portions of the area graph denote numbers-at-age. The line graph shows average of discards by year. (B) shows numbers discarded (Cod Directed (D) and Shrimp fisheries (S)) in comparison to population numbers calculated from ADAPT model and reported offshore catch while the lines show discards percentages of the same.

board. Percentage of sets exceeding 12 tons increased from about 2.5% of sets in 1980, peaking in 1985 at 18%. Catches exceeding 25 tons were not uncommon for limited areas and times, particularly in Div. 2J and 3K in the mid-1980s. As well, trip limits imposed by the companies resulted in some portion of final sets of some trips being dumped as vessels topped up before returning to port. The result was increased dumping during the winter, a consequence of catches greater than processing capacity and trip limits. The summer fishery, prosecuting less dense concentrations of fish, had lower discard rates. As well, many foreign vessels, active in the early-1980s, particularly in Div. 2J discarded fewer fish. Their on-board cutting, filleting and fish meal machinery could process small fish and their processing capacity could handle large catches.

A greater portion of small, unmarketable fish taken by the Canadian fleet particularly in the northern part of Div. 3K and shoreward also contributed to the increasing discard rate observed

during the early- to mid-1980s. These smaller fish were of less value in the market and plant machinery was less capable of efficiently handling fish less than about 41 cm (16 inches). However, the separation of discards at sea was not a knife edge process and did not result in the retainment of all fish greater than 41 cm and the disposal of all other sizes. Rather, a decreasing proportion in each size category was discarded, from 100% of fish less than about 37 cm to less than 1% for 50 cm fish.

Discarding diminished for a number of reasons after 1986 (Kulka, MS 1989). The industry took several steps to reduce catch size and increase fish size. To reduce the large catches caused by increasing density of fish schools that occurred in the early- to mid-1980s, tow length was reduced from an average 5.1 hours in 1980 to 1.5 hours in 1987–88. As a result, catch-per-set was reduced, decreasing the need to dump fish. Also, density of the schools to the north started to decline after the mid-1980s, resulting in smaller catches. After 1986, most larger fish that came on board were retained

because catch-per-set no longer exceeded processing capacity. Also, smaller fish were retained as markets were found for these fish. On the other hand, about 2–4% of the catch continued to consist of fish too small for the markets and plant machinery and these continued to be discarded.

Technology changes through the 1980s also contributed significantly to the lower catch-per-set with time. Gear configuration and vessel production/storage was altered to allow the handling of larger catches while reducing catch size and increase average size of fish caught. First appearing in 1983 and increasing to 78% usage in 1988, windows cut in the codend were designed to release a portion of the catch beyond a certain level while the gear was still in the water. However, this modification may have also had a negative effect, i.e. some loss of fish through the window as the gear was brought aboard. Some of these lost fish may not have survived. Mesh size was increased from 128 mm in 1980 to 137 mm in 1987–88. A change to square mesh from diamond before 1985 facilitated the release of more small fish. Introduction of SCANMAR to detect when the net was full to capacity likely led to the shorter tow lengths observed. Increased processing capacity through containerization increased optimum catch size and allowed larger catches to be retained.

Regulations requiring that discarded fish be deducted from the quota were introduced in 1987. Coupled with mandatory observer coverage to monitor discarding, and the decreasing catch-per-set was a strong incentive not to dump fish. Unlike previous years, discarded fish were lost revenue. Due to the decreasing set length, technological changes and less dense schools of fish, discarding dropped after 1986. Mandatory observer coverage made it more difficult to discard without those discards being recorded and applied to the quota. Following the moratorium on the directed fishery for cod in 1992, and introduction of the Nordmore grate in 1993 that allowed the live escapement of most cod from the shrimp gear (Kulka, MS 1995), amounts discarded dropped to low levels.

Discarding is only one form of under-reported fishing mortality and the offshore cod and shrimp trawl fleets are just two of a number sectors for which discarding is generally not included in the official catch statistics. The magnitude of under-reported catches from other sectors (non-inclusion of discards in the landing statistics or non-reporting of landed fish) remains unknown because these sectors were not monitored. The results of this study address one aspect of non-recorded fishing mortality by providing estimates of total discards for the offshore cod and shrimp fleet. It is

reasonable to assume that the estimates obtained after 1986 are close to reality for the reasons discussed above, particularly because of high observer coverage. Before 1986, if discarding on unobserved vessels was greater, then the numbers presented in this paper should be regarded as minimum estimates.

Observer narrative reports suggest that discarding on unobserved vessels was higher than those observed, although the exact difference cannot be determined. Considering that discarding from the offshore cod and shrimp directed fisheries based on observed vessels is equivalent to about 6.5% by weight of total reported offshore landings (all gears and all fisheries including other groundfish) in the peak year, or about 1% of the population, it would not seem to be a major contributor to cod mortality. Even if discarding on unobserved vessels were several times the amounts reported in this paper for the years prior to 1987, offshore discards would still be a minor contributor to mortality compared to reported catch. Thus, if unreported mortality from commercial fishing was a major contributor to the decline of northern cod, particularly after 1986 when observer coverage was mandatory, then other sectors would have had to contribute substantially more in terms of unreported mortality. However, there are no reliable data to confirm if this was the case. Although a relatively minor component, most offshore discards were 2–5 year old fish and therefore, the impact would be focused on those younger, pre-recruit year-classes.

Three other sources of discarding remain unquantified. First, for the by-catch from other trawl fisheries, a portion of cod by-catch was discarded. A preliminary examination of the data from these fisheries showed that for most fisheries the discard rate and absolute amounts were low, because cod was usually more valuable than the directed species and amounts by-caught were relatively low. Second, some discarding was done for other offshore gears but they were a much smaller fishery and discards associated with them would be correspondingly small. Limited data exists for these non-cod directed trawl fisheries and other offshore gears and these amounts should be quantified. Third, for the inshore sector, which was a complex set of fisheries made up of a variety of gears and extending along the northeast coast of Newfoundland and Labrador, there exists no reliable source of data. Less direct methods will be required to attempt to examine discarding practises and under-reporting for these fisheries.

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