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The collapse of 2+3K American plaice: was it over fishing?

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Abstract

The population of American plaice in the waters off Labrador and on the northeast Newfoundland shelf declined substantially during the mid to late 1980's, early 1990's at a time when reported catches were very low. Hutchings (1996 Can. J. Fish. Aquat. Sci. 53: 943-962) examined the overlap in distribution between American plaice and cod in research vessel survey data and concluded that unreported bycatch in the cod fishery could explain the decline of the Div. 2J portion of the Subarea 2 + Div. 3K stock of American plaice. We evaluate the method proposed by Hutchings (1996) and use reported and observer estimates of catch to investigate potential catch levels relative to survey estimates of population abundance. This method does not appear to be a good predictor of American plaice bycatch in the cod fishery as most of the regressions were not significant and it requires extrapolation well beyond the range of the data used to build the regressions. Furthermore there was little overlap between the extent of the commercial cod fishing grounds and the distribution of American plaice in the fall surveys. For this stock, catch to survey biomass ratios were low regardless of the source of information used to estimate catch and suggest an exploitation rate that should be well below sustainable levels. These analyses support the conclusion that fishing was not the cause of the decline in this population of American plaice.

Résumé

La population de plie canadienne des eaux du Labrador et du nord-est de la plate-forme de Terre-Neuve a considérablement diminué du milieu des années 80 au début des années 90, comme l'ont révélé les très faibles prises signalées. Hutchings (1996. J. can. sc. halieut. aquat. 53 : 943-962) a examiné le chevauchement de la répartition de cette plie et de la morue dans les données de relevés de recherche et a conclu que les prises accidentelles non déclarées de la pêche de la morue pourraient expliquer le déclin de la plie dans la division 2J du stock sous-zone 2 + division 3K. Le présent rapport porte sur une évaluation de la méthode proposée par Hutchings (1996). Il fait appel aux estimations des prises déclarées et aux estimations des observateurs pour établir les niveaux des prises potentielles par rapport aux estimations de l'abondance de la population issues des relevés. Cette méthode ne semble pas donner une bonne indication des prises accidentelles de plie canadienne dans les prises de morue car la plupart des régressions n'étaient pas significatives et il fallait faire une extrapolation bien au-delà de la gamme des données utilisées pour les calculer. De plus, il n'y avait que peu de chevauchement entre l'étendue de la pêche commerciale de la morue et la répartition de la plie canadienne dans les relevés d'automne. Dans le cas de ce stock, les rapports entre la biomasse des prises et la biomasse des relevés étaient faibles indépendamment de la source des renseignements utilisée pour estimer les prises, ce qui semble indiquer un taux d'exploitation nettement inférieur à un niveau durable. Ces analyses supportent la conclusion à l'effet que la pêche n'est pas à l'origine du déclin de cette population de plie canadienne.

Introduction

During the late 1980s and early 1990s there were dramatic declines in the estimated biomass of numerous fish species in the waters around Newfoundland (Atkinson 1994). The most well known of these is the northern cod (*Gadus morhua*) stock that showed large declines in the early 1990s and as of yet has shown little sign of recovery (Lilly et al. 1998). At the same time as these declines were occurring, water temperatures in the area were below normal for the longest continuous period since measurement began in 1946 (Colbourne et al. 1997). As well, there were changes in distribution of a number of species (Frank et al. 1996; Bowering et al. 1997; Morgan and Bowering 1997).

American plaice (*Hippoglossoides platessoides*) is a flatfish species that can be found throughout the northwest Atlantic and has been the most abundant flatfish in the waters around Newfoundland. The population of American plaice in the waters off Labrador and on the northeast Newfoundland shelf (Subarea 2 + Div. 3K, Fig. 1) is one of those that has shown substantial declines in population size during the mid to late 1980's early 1990's period. Concurrently the distribution changed with a higher proportion of the stock occupying deeper, warmer waters (Bowering et al. 1997). On the Grand Bank this species has been intensely exploited since the 1950's, but farther north in Subarea 2 + Div. 3K, reported catch levels have been low (Bowering and Brodie 1991; Bowering et al. 1997). In light of an average annual exploitation rate of less than 2%, Bowering et al. (1997) concluded that the collapse of the Subarea 2+Div. 3K population was not the result of fishing mortality.

Some authors conclude that the decline of northern cod can be attributed solely to over fishing (e.g. Hutchings and Myers 1994; Hutchings 1996) while others feel that changes in the abundance and/or distribution of non-commercial or lightly exploited species (such as the Subarea 2+Div. 3K American plaice stock) over a similar time period may indicate that other factors were also involved (Atkinson 1994; Frank et al. 1996; Rose et al. 2000). As part of an examination of the possible causes of the collapse of northern cod Hutchings (1996) looked at the possible impact of the bycatch of American plaice in the winter cod fishery on the Div. 2J portion of the population in Subarea 2+Div. 3K. He used fall research vessel data to examine the extent of overlap between American plaice and cod in the area of the main winter cod fishery in Div. 2J. From these results he predicted that non reported catch of American plaice in the winter cod fishery may have been substantial. He concluded that the hypothesis that fishing can not explain the decline of the Div. 2J portion of the Subarea 2 + Div. 3K stock of American plaice needs to be re-evaluated.

This paper re-examines the potential impact of fishing on Subarea 2 + Div. 3K American plaice. We evaluate the method proposed by Hutchings (1996) and use reported and observer estimates of catch to investigate potential catch levels relative to survey estimates of population biomass.

Materials and Methods

Three sources of data were used in this study, fall and winter survey data and observer catch/effort records from commercial fisheries. Fall groundfish surveys by Canadian research vessels towing bottom trawls have been conducted in Division 2J since 1977 and Division 3K since 1978, using a stratified-random survey design (Doubleday 1981). We examined data from surveys conducted mainly during November-December from 1978-1992. The entire series of surveys was conducted using an Engel 145 high-rise otter trawl equipped with a small mesh liner (30 mm stretched mesh) in the codend. Sets were 30 minutes in duration at 3.5 knots. We used the data from all successful survey sets.

From 1986-90 the Department of Fisheries and Oceans conducted surveys directed at northern cod in the January to March period, using the research vessel *Gadus Atlantica*. In most years, sets were carried out in both Divs. 2J and 3K. In some years, many of the sets were part of stratified random trawl surveys, while in other years, objectives included delineation of cod concentrations in the offshore fishing grounds by acoustics and trawling, mesh selection studies, collection of biological samples, and cod tagging. The fishing gear used (with the exception of mesh selection studies) was the same as that used in the autumn surveys. Sets were generally 30 minutes in duration, although this was not possible in some instances due to high cod densities and the capacity of the trawl. We examined all 235 sets (101 from Div. 2J and 134 from Div. 3K) from the 1986-1990 surveys in which numbers and weights of cod and plaice in the catches were recorded.

Observer estimates of catch and discards of American plaice from commercial fisheries in the area were available for the 1980 to 1992 period. Observers are contracted by Fisheries and Oceans to collect information on all aspects of the fishing operations of individual vessels while at sea. Their duties include the collection of geo-referenced catch and effort data and other details of the capture of fish and invertebrates. Catch is recorded by species, including the amount discarded, on a set by set basis using quantitative estimation techniques described in Kulka and Firth (1987). The degree of observer coverage varied with directed species and time. It averaged 20-40% for the cod directed fishery from 1980-1986. It was 100% for the cod and shrimp fisheries from 1987. For other groundfish directed fishing coverage averaged 57-75% for non-Canadian vessels from 1980-1986 and 100% from 1987. For Canadian vessels directed for groundfish species other than cod it averaged 15-30% over the entire time period. There was no observer coverage for vessels of less than 500 tons (Kulka and Firth 1987).

Following the method of Hutchings (1996) we conducted regressions between catch (kg) of American plaice and cod in the fall research vessel survey for each year from 1978 to 1992 in Div. 2J and 3K. These regressions were used to estimate the biomass of American plaice caught in the cod fishery by using the catch of cod by commercial offshore mobile gear as the predictor of American plaice bycatch. Only data from the main area of the winter cod fishery in Div. 2J and 3K were used (Wroblewski et al. 1995). For Div 2J these were the same as those used by Hutchings (1996) in his analyses of data from 1981 to 1992. Analyses of data from the fall survey were used to predict catch of American plaice in the cod fishery using catch of cod in offshore mobile gear in that Division, in that year. The catch of cod is that reported in Lilly et al. (1998). A new 'predicted' estimate of catch of American plaice was calculated as the catch reported from non-cod fisheries plus that predicted in the cod fishery from the regressions. Since the cod fishery occurred in the winter and the surveys were conducted in the fall, regression results in year n were also used to predict the catch of American plaice in the cod fishery using the catch of cod in year n+1. This was then added to the reported catch of American plaice in the non-cod fisheries to produce a second ‘predicted’ estimate of catch. In both cases the larger of the ‘predicted’ or reported catch was taken as the estimate of catch for a given year.

Observer data were used to estimate the amount of American plaice caught in the non-plaice directed fisheries. This estimate includes both kept and discarded American plaice. Catches of American plaice in the shrimp fishery were taken from Kulka (1995). These estimates were compared to the reported catch of American plaice from the observed fisheries and the larger of the two was taken as the estimate of catch from the non-plaice directed fisheries. Estimates of American plaice discards from the observed American plaice directed fishery were added to the reported catch of American plaice from this fishery. These two estimates were added to the reported catch of American plaice from the non-observed fleet sectors to produce an ‘observer’ estimate of catch.

To evaluate the potential impact of the fishery on this population ratios of catch to survey biomass (C/B) index were calculated as proxies for exploitation rate (e.g. De Cardenas and Junquera 1998, Bowering et al. 1997). C/B ratios were calculated from the reported, predicted and observer catch estimates. Since the surveys took place in the fall and the bulk of the fishery occurred in the winter, two types of C/B ratios were calculated for each estimate of catch. Ratios were calculated using the catch in year n and the survey biomass in year n (post fishery ratios) and C/B ratios were also calculated using the survey biomass in year n and the catch in year n+1 (pre fishery ratios).

A number of analyses were conducted to evaluate the degree of overlap between the distribution of cod and American plaice. The ratio of weight of American plaice to cod in survey catches was calculated for catches of cod less than 100 kg, between 100 and 1000 kg and greater than or equal to 1000 kg from both the fall and winter survey data. This was to indicate whether large catches of American plaice co-occurred with large catches of cod. The degree of overlap between cod and American plaice was further explored by comparing information on the area of the cod fishery and the distribution of American plaice. The area of the cod fishery for all years combined was defined using potential mapping in SPANS and the observer data to draw a boundary around all observed cod sets over all years (Kulka 1998). The distribution of American plaice and cod from the fall survey was overlaid on this map. The area within the cod fishing ground each year was stratified based on density of fishing effort using the same potential mapping technique. Fifteen fishing density strata were created (areas of low to high number of sets fished per square km from the observer data). Fall survey data were then overlaid on these strata and the average American plaice catch in kg per tow for sets in the fall survey that fell into each stratum was calculated. The average cod catch per hour in the commercial fishery in each of these fishing density strata was also calculated. Finally, the trend in the American plaice population index from the entire Div. 2J3K area was examined relative to the trend in only the area of the main cod fishery (as defined by Wroblewski et al. 1995) as well as the percentage of the population that was in the cod fishing area.

Results

The results for the regressions of American plaice catch on cod catch in the fall surveys and the catches predicted from these regressions are shown in Table 1. Only six of 30 regressions were significant and only two of these had an r^2 of 0.4 or greater. In 21 instances there was a positive relationship between American plaice and cod catch in the survey. In nine of these positive relationships, reported catch of American plaice in the cod fishery was greater than predicted. In total, 17 of 30 regressions predicted less catch of American plaice than was actually reported from the cod fishery. We obtained different results than Hutchings (1996) for 3 years (1984,1986, 1990). Differences in regressions are due to discrepancies between the data used in Hutchings (1996) and the final edited data used in this study (J.A. Hutchings, Dept. of Biology, Dalhousie University, Halifax, NS, Canada, pers. com.).

Catch/biomass ratios were small regardless of the method used to estimate catch. If only reported catch was used, the average C/B ratio was 3% with a maximum of 8% for the pre fishery ratio and an average of 4% and a maximum of 9% for the catch to biomass ratio using catch and biomass from the same year (Figure 2). C/B ratios using catch in the cod fishery as predicted from regressions of fall survey data had an average of 5% and a maximum of 17% for the pre fishery ratios and an average of 6% and a maximum of 18% for the post fishery ratios. These are the only instances of C/B ratios exceeding 10% and are a result of the large prediction of American plaice catch in the cod fishery from the non-significant 1987 regression for Div. 2J. If the ratio was calculated using catch estimated from the observer data the average was 4% and the maximum was 9% for the pre fishery calculations and the average was 5% and the maximum 10% for the post fishery ratios. Ratios calculated using the reported catch and the observer data showed an increasing trend from the mid-1980's to 1988 or 1989. The ratios calculated using the predicted estimates of catch also showed an increase from the mid-1980's but with a large peak in 1987.

In both the fall and winter surveys, large catches of American plaice and cod did not co-occur (Table 2). Sets with large catches of cod contained little American plaice. The largest sets of cod in the fall surveys contained only 1.2% American plaice by weight and in the winter surveys (corresponding to the time of the main fishery for cod) they contained less than 0.2%.

The distribution of the cod fishing grounds relative to the distribution of American plaice from the fall survey shows little overlap between the two. The exceptions are in the 1989-91 period when the cod fishery in Div. 2J occurred more shoreward and shallower than usual and overlapped somewhat the main area of American plaice abundance in that area (Figure 3).

Catch rate of cod in the commercial fishery was highest where the density of fishing was greatest (Figure 4). In most years the catch rate of American plaice from the fall survey was highest where commercial effort for cod was sparse and very low where commercial effort was concentrated. American plaice catch in the survey was very low in areas with fishing densities of 10-15. These areas accounted on average for 80% of the cod fishing effort. This indicates that there would be little opportunity for bycatch of American plaice in the area most heavily fished during the cod fishery.

Trends in the index of American plaice biomass inside and outside of the area of the cod fishery were different (Figure 5). The biomass outside of the cod fishing area showed a steady decline from 1983. In the area of the cod fishery, the biomass showed a large increase from 1985 to 1986, remained fairly stable from 1987 to 1991 and then decreased sharply to 1992. Before 1990, the percentage of the total American plaice population in the cod fishing area was low, averaging 5%. From 1990 to 1992 the total population was much reduced and the percentage of the population in the area of the cod fishery was much larger averaging 25%.

Discussion

The population of American plaice off Labrador and northeast Newfoundland declined dramatically during a period of low reported catch and minimal directed fishing (Bowering et al. 1997). Directed fisheries for American plaice in this area were not large since there were larger quotas for this species available in more southern areas, closer to the home ports of most trawler fleets in the Newfoundland area. Other fisheries occurred in the general area during this time and as pointed out by Hutchings (1996) there was the potential for these fisheries to have an impact on this stock through catch and discards. For example, there are little or no reports of catch from the shrimp fishery in the landings statistics although observer information indicates that there was bycatch of American plaice (ranging from 0 to 228 t annual between 1980-94) in this fishery (Kulka 1995). To date such information has not been included in the assessment of this stock or the evaluation of the impact of fishing on this stock.

The method of Hutchings (1996) is not a good predictor of American plaice bycatch in the cod fishery. Few of the regressions were actually significant and the r^2 values were low. Further, it is inappropriate to make predictions using values that are well outside of the range of the data used to produce the regressions (Zar, 1984), in this case using tens of thousands of tons of commercial catch in regressions built using survey sets with less than five tons of catch. There was little overlap between the distribution of the main commercial cod fishery and the distribution of American plaice in the fall surveys. The cod fishery generally occurred on the seaward slopes of the banks while the bulk of the biomass of American plaice was found in shallower waters. There were exceptions to this, in particular in 1989-92 when the cod fishery occurred in an area of higher American plaice abundance. Observer information indicates that bycatch of American plaice was higher in those years.

Catch to research vessel biomass ratios can be used as a proxy for exploitation rate (e.g. De Cardenas and Junquera, 1998, Bowering et al. 1997). For this stock, the C/B ratio was low regardless of the source of information used. The C/B ratio calculated using reported catch is less than 10% in all years. If the ratio is calculated including the predicted catch of American plaice in the cod fishery as described by Hutchings (1996) then the highest value is 18%. The incorporation of observer information on catch and discards leads to a maximum C/B ratio of 10%. Yield per recruit analyses of this stock indicate that the $F_{0.1}$ level is 0.3, an exploitation rate of 24% at a natural mortality of 0.2 (Brodie and Pitt 1982). These C/B ratios suggest an exploitation rate that should be well below sustainable levels and too low to have caused the observed decline in population biomass.

The observer data, including information on discards, provides perhaps the most reliable estimate of catch. However, prior to 1987 the level of observer coverage was lower and there is no observer coverage of smaller vessels. This fleet of vessels less than 500t caught as much as 70% of the reported catch of American plaice in some years (average 45%). It is therefore possible that even the estimate of catch from the observer data is low. We increased the estimate of catch from the observer data in the pre 1987 period and the reported catch from the smaller vessels over the entire 1978-92 period by a factor of 5 and recalculated the post fishery C/B ratios. Even these highly inflated estimates of catch produced C/B ratios for the 1978-92 period of only 17% and 13% during the period of major population decline. There were only 3 years (1978, 1979, 1985) when this estimate of C/B exceeded the $F_{0.1}$ level of 24%.

There is no virtual population analysis (VPA) for this stock because of difficulties in fitting the catch data to the survey data and a lack of sampling of the commercial catch in some years when catches were very low. C/B ratios provide only a proxy for exploitation rate. However, the survey index would have to over estimate the actual population size by at least a factor of 2.5 to result in C/B ratios in the range of the $F_{0.1}$ for this stock. Further the biomass index in Div. 2J3K declined by 100,000 tons from 1983-90, a time when the largest estimates of catch totalled only 30,000 tons.

Bowering et al. (1997) examined changes in distribution, abundance, various biological parameters, age structure and reported catch to biomass ratios. They were unable to determine a cause for the decline of this stock but concluded that fishing mortality was not a likely cause. This study also found C/B ratios well below what was thought to be sustainable for this stock as well as little overlap between the distribution of American plaice and the major fishery in the area. These analyses support the conclusion of Bowering et al. (1997) that the decline of the Subarea 2+3K population of American plaice was not the result of over exploitation.

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Table 1. Results of regressions between weight of American plaice and cod in the survey catch in year *n*. Also shown are the catches of American plaice predicted from these regressions to occur in the cod fishery in year *n* and *n+1*. Reported catch of American plaice is for year *n*. All catches are in metric tons.

Year	Regression	P	r^2	Predicted year *n*	Predicted year *n+1*	Reported catch in cod fishery	Total Reported catch
2J							
1978	Y=0.03x+0.64	0.10	0.65	667	473	60	145
1979	Y=-0.01x+6.91	0.48	0.09	0	0	207	221
1980	Y=0.00x+5.73	0.88	0.01	0	0	106	142
1981	Y=0.06x-1.10	0.001*	0.77	1612	4037	54	96
1982	Y=0.08+0.63	0.001*	0.29	5385	3315	188	204
1983	Y=0.18-0.05	0.0004*	0.40	7458	2162	75	168
1984	Y=0.03x+1.14	0.36	0.03	362	48	72	92
1985	Y=-0.04x+2.74	0.70	0.01	0	0	22	34
1986	Y=0.005x+7.2	0.89	0.001	75	224	36	100
1987	Y=0.17+2.7	0.44	0.02	7371	7054	105	239
1988	Y=0.03x+0.35	0.004*	0.34	1245	1039	96	106
1989	Y=0.02x+3.4	0.20	0.07	696	365	1737	3225
1990	Y=0.02x+1.3	0.10	0.12	363	15	797	991
1991	Y=-0.01x+5.22	0.40	0.03	0	0	59	69
1992	Y=-0.62x+2.65	0.18	0.07	0	0	-	5
3K							-
1978	Y=0.01x+7.09	0.84	0.002	141	392	571	3327
1979	Y=-0.01x+7.02	0.48	0.03	0	0	685	2733
1980	Y=-0.01x+5.59	0.56	0.02	0	0	1064	4862
1981	Y=0.01x+3.26	0.20	0.04	273	133	672	7411
1982	Y=0.01x+2.64	0.12	0.04	132	347	430	1588
1983	Y=0.01x+2.43	0.31	0.02	347	594	434	1341
1984	Y=0.01x+2.60	0.37	0.02	594	818	486	1029
1985	Y=0.01x+2.52	0.37	0.01	821	681	97	708
1986	Y=-0.0004x+9.44	0.80	0.003	0	0	985	2914
1987	Y=0.0005x+4.96	0.91	0.0002	28	25	231	823
1988	Y=0.05x+4.59	0.16	0.06	2020	1931	245	797
1989	Y=-0.0001x+5.64	0.94	0.0002	2	0	260	1014
1990	Y=0.002x+3.80	0.04*	0.09	59	65	109	816
1991	Y=0.002x+3.46	0.12	0.03	64	5	78	428
1992	Y=0.01x+1.19	0.0002*	0.11	10	0	-	97

Table 2. Ratio of weight of American plaice to weight of cod with increasing levels of cod catch. Data are taken from all successful fall sets in Div. 2J and 3K from 1978 to 1992 and for all successful winter sets from those divisions from 1986 to 1990.

Cod catch (kg)	Number of sets	Ratio of American plaice to cod (%)
Fall Surveys		
< 100	2965	63.02
≥ 100 and < 1000	625	14.54
≥ 1000	42	1.18
Winter Surveys		
< 100	135	30.12
≥ 100 and < 1000	34	1.75
≥ 1000 and < 10,000	47	0.17
≥ 10,000	19	0.02

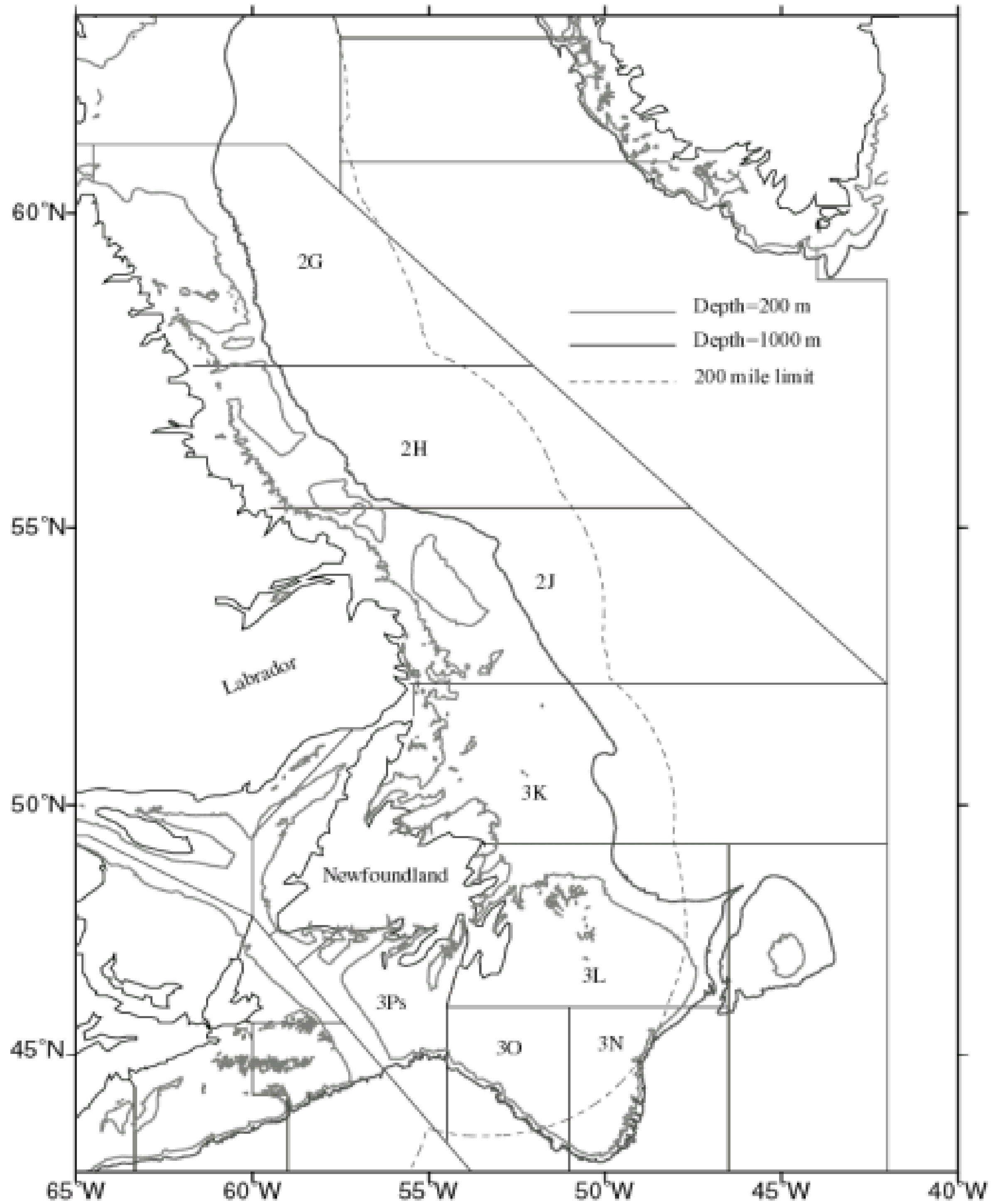

Figure 1. Map showing the location of Subarea 2 and Division 3K. The 200 and 1000 m depth contours and Canada's 200 mile limit are also shown.

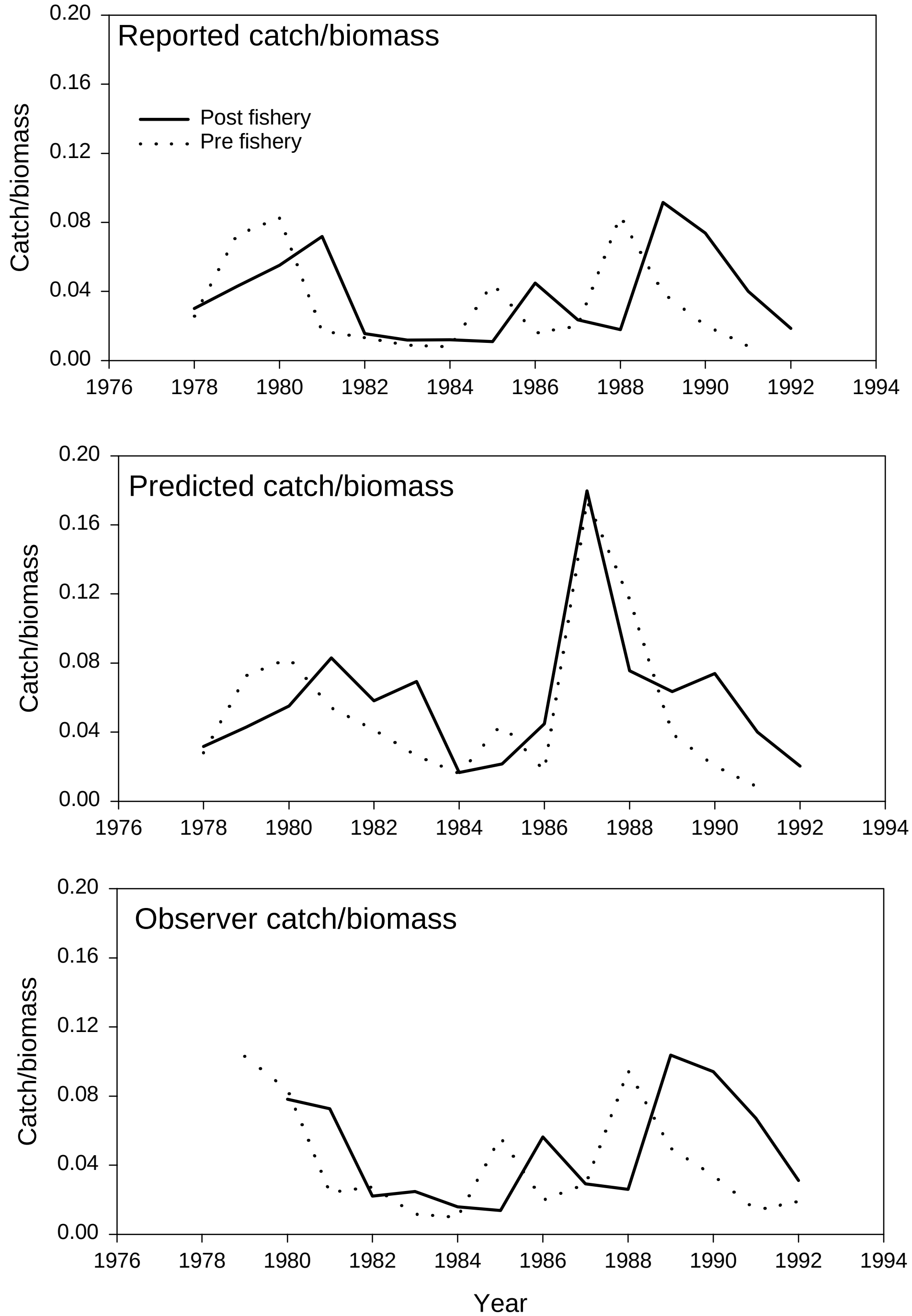

Figure 2. Catch to survey biomass ratios calculated using the reported, predicted and observer estimates of catch. The pre-fishery ratios are calculated using the survey biomass in year n and the catch in year n+1. The post-fishery ratios are calculated using both the survey biomass and catch in year n.

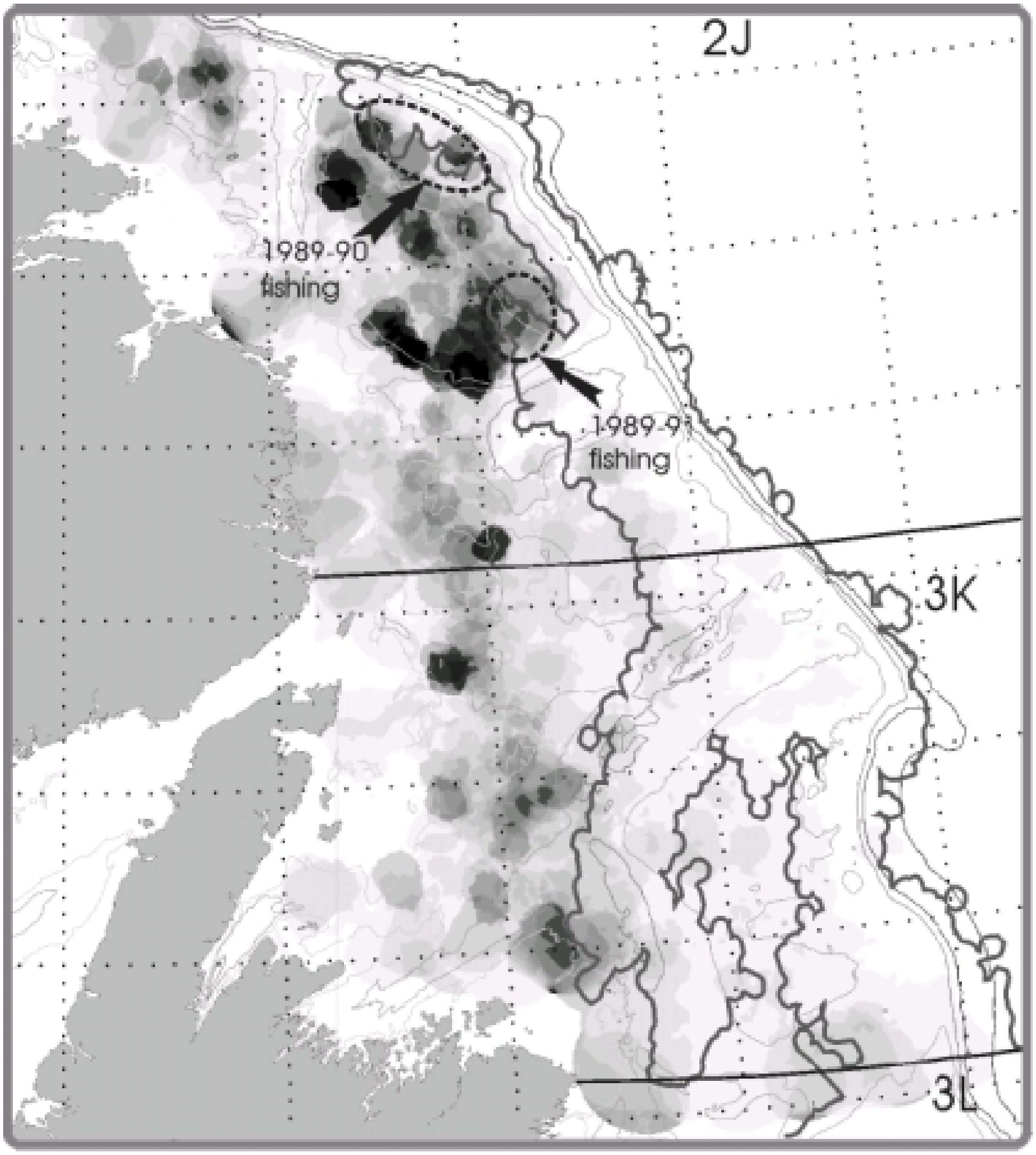

Figure 3. Distribution of American plaice based on combined 1978-92 fall research vessel survey data. Darker grey shading indicates higher density of fish. The solid line shows the perimeter of the entire area fished for cod from 1980 to 1992 (the commercial offshore fishing grounds). The ovals indicated by the dashed lines give the location of the cod fishing grounds in the 1989/90 and 1990/91 fishing seasons.

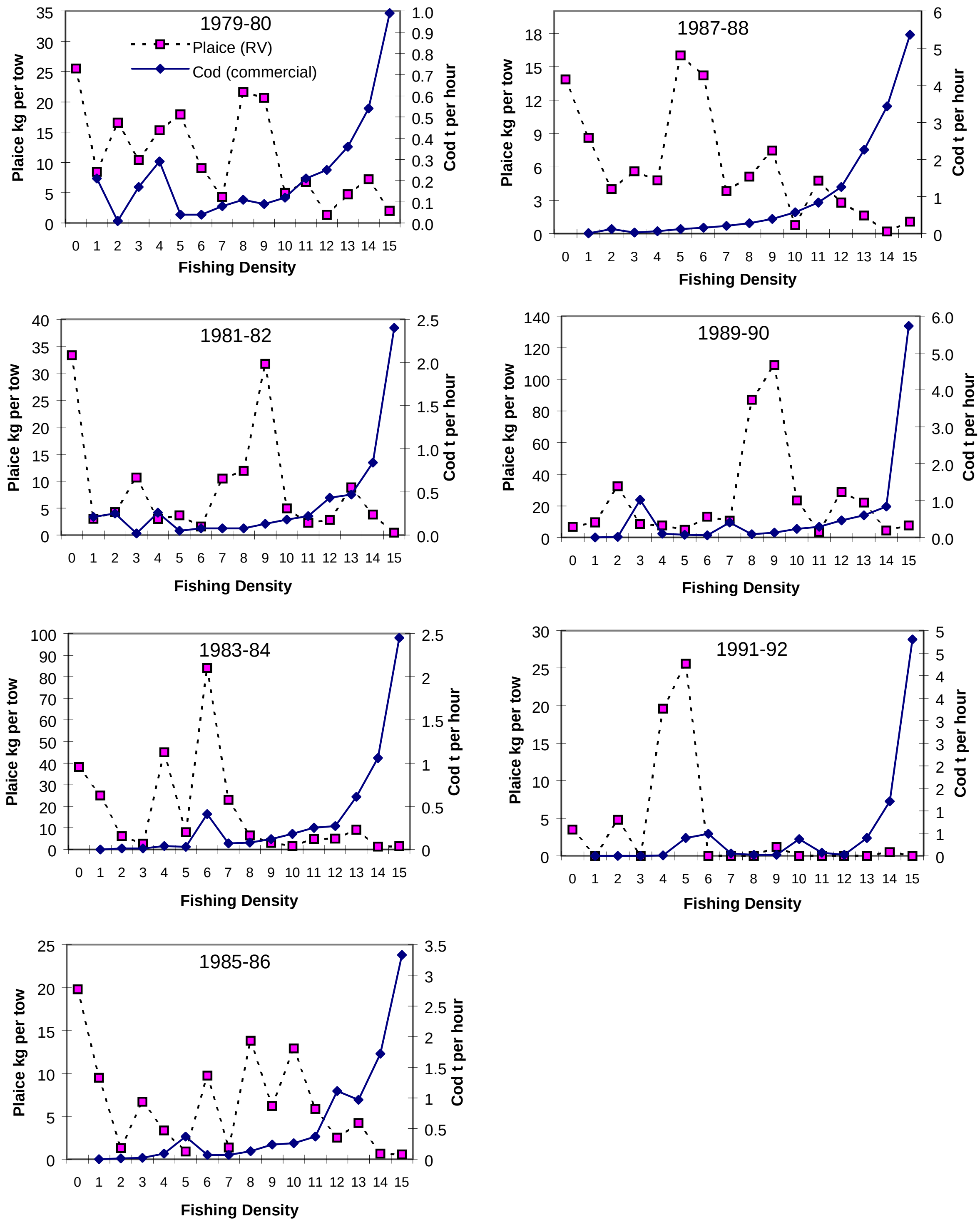

Figure 4. Catch of American plaice from the fall research vessel surveys of year n (Kg/tow) and catch rate of cod from the commercial fishery in year n+1 (tons/hr) in relation to fishing density. Zero represents the area outside of the cod fishing grounds, 1 to 15 represent increasingly more intensely fished cod fishing areas as determined by the number of commercial fishing sets per square km. Only every second year is shown but intervening years show similar patterns.

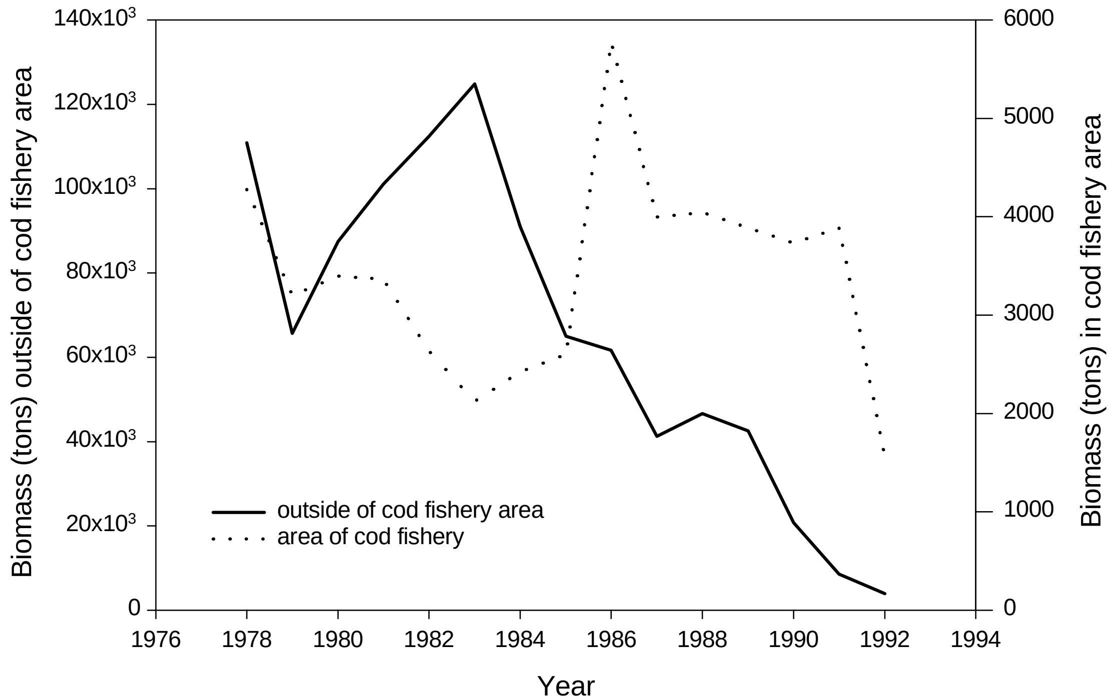

Figure 5. Research vessel survey indices of biomass of American plaice from 1978-1992 inside and outside of the main area of the commercial cod fishery.