NAFO Sci. Coun. Studies, 16: 39-48

Reduction of Uncertainty Caused by Discarding in the Fisheries of the Gulf of St. Lawrence

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Abstract

Discarding of American plaice (*Hippoglossoides platessoides*) at sea is a serious problem in the Gulf of St. Lawrence and a major source of uncertainty in management of the resource. Estimates of fishing mortality based on landings-at-age rather than catch-at-age which includes discards are likely to be biased downward. A model is presented in which landings-at-age is calculated where possible to account for the differences in growth rate of the sexes, the growth rate over the year and differential selectivity of the gear types in the fishery. A method to estimate discards in the fishery using both research vessel and commercial fishery information is presented. The catch-at-age including discards is developed for the years 1976-89. The method is an economical way of reducing the uncertainty caused by discarding practices.

Introduction

An ongoing problem for many fisheries is the discarding at sea of fish of under market size. Jean (1963) estimated that up to 50%, by weight, of the American plaice (*Hippoglossoides platessoides*) catch in the Gulf of St. Lawrence was discarded. Due to their relatively large catch and their ability to select smaller fish, the mobile gear fishery accounts for the bulk of the fish that are discarded in this fishery (Halliday *et al.*, 1989). Total discards by Danish seines and otter trawls were estimated at 45% by weight and 68% by number (Halliday *et al.*, 1989). Substantial losses in potential yield have been attributed to discarding (Metuzals, MS 1985).

Estimates of fishery mortality based on landings-at-age, rather than catch-at-age which includes the discards, are likely to be biased downward. As well, lack of accounting for the effect of the fishery on the younger age groups, could result in undue exploitation of the strong year-classes before they can provide optimal yield.

The catch-at-age matrices for American plaice in NAFO Div. 4T presented from 1980 to 1989 in previous stock assessments did not include any estimate of the discarded portion of the catch. Previous catch-at-age matrices were calculated without considering the differential growth rates of the sexes. Landings-at-age matrices calculated with sexes combined result in much higher variance estimates (Tallman and Sinclair, MS 1988, MS 1989). Incorporation of an estimate of discards and sex differences in the catch-at-age matrices for American plaice would reduce the major uncertainties associated with the assessment of this stock.

Direct studies of discarding rates, though desirable, are expensive both in man-power and monetary resources. An annual requirement of resources for a direct study of discarding rates could result in a dearth of means for other projects, such as annual index of abundance surveys. In this paper, a generalized method is presented for incorporating an estimate of the discards in the catch-at-age matrix using the landings-at-age and data from annual research vessel surveys. As an illustrative example, the method is applied to recalculate the catch-at-age for the American plaice stock in Div. 4T. Such a method could be used to reduce the uncertainty associated with employing age structured models to assess fisheries where discarding occurs, without placing undue strain on other programs.

Materials and Methods

Landings-at-age

To prevent confusion, the term "landings" is used when referring to the portion of the catch that does not include an estimate of the numbers discarded at sea. "Catch" will refer to the estimates of catch that include discard estimates.

Sampling of the commercial fishery was sufficient to calculate a nominal landings-at-age for the years 1976-89. From 1976 to 1983, samples were not suffi-

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cient to allow calculation of semi-annual age-length keys. From 1984 to 1989, samples were taken from May to November when 96% of the catch was landed. The numbers of fish measured and subsampled for age determination from the 1976 through 1989 fisheries are shown in Table 1.

TABLE 1. Age-length table used in the calculation for 1976-89 catch-at-age.

Year	Table type	Gear types[a]	Period		Sample size	Catch (+)	Separated			
							Male	Female	Male	Female
1976	ALK	All gears	Jan-Dec	Length Aged	12,042 2,397	11,193	.007393	.003696	3.0561	3.2636
	LF	(10,11,12,13)	Jan-Dec	Length	3,846	7,150	.007393	.003696	3.0561	3.2636
	LF	(20,21,22,23)	Jan-Dec	Length	7,996	3,395	.007393	.003696	3.0561	3.2636
1977	ALK	All gears	Jan-Dec	Length Aged	10,260 1,800	9,230	.004435	.002426	3.1900	3.3708
	LF	(10,11,12,13)	Jan-Dec	Length	1,906	4,675	.004435	.002426	3.1900	3.3708
	LF	(20,21,22,23)	Jan-Dec	Length	8,354	4,015	.004435	.002426	3.1900	3.3708
1978	ALK	All gears	Jan-Dec	Length Aged	4,725 794	9,031	.002120	.0009928	3.3665	3.5945
	LF	(10,11,12,13)	Jan-Dec	Length	945	4,598	.002120	.0009928	3.3665	3.5945
	LF	(20,21,22,23)	Jan-Dec	Length	3,780	3,495	.002120	.0009928	3.3665	3.5945
1979	ALK	All gears	Jan-Dec	Length Aged	3,383 596	9,996	.0009339	.0006864	3.5957	3.6872
	LF	(10,11,12,13)	Jan-Dec	Length	1,578	4,463	.0009339	.0006864	3.5957	3.6872
	LF	(20,21,22,23)	Jan-Dec	Length	1,605	3,719	.0009339	.0006864	3.5957	3.6872
	LF	(41,51,53)	Jan-Dec	Length	200	721	.0009339	.0006864	3.5957	3.6872
1980	ALK	All gears	Jan-Dec	Length Aged	3,055 441	8,292	.007185	.003209	3.02359	3.2734
	LF	(10,11,12,13)	Jan-Dec	Length	1,210	3,853	.007185	.003209	3.02359	3.2734
	LF	(21,22,23)	Jan-Dec	Length	1,642	3,500	.007185	.003209	3.02359	3.2734
	LF	(40,41,42)	Jan-Dec	Length	203	222	.007185	.003209	3.02359	3.2734
1981	ALK	All gears	Jan-Dec	Length Aged	3,713 541	7,834	.008189	.004313	3.0009014	3.2004
	LF	(10,11,12,13)	Jan-Dec	Length	987	2,623	.008189	.004313	3.0009014	3.2004
	LF	(20,21,22,23)	Jan-Dec	Length	2,262	3,575	.008189	.004313	3.0009014	3.2004
1982	ALK	All gears	Jan-Dec	Length Aged	4,108 562	6,542	.012003	.004948	2.8914	3.1686
	LF	(10,11,12,13)	Jan-Dec	Length	1,624	1,459	.012003	.004948	2.8914	3.1686
	LF	(20,21,22,23)	Jan-Dec	Length	2,441	4,124	.012003	.004948	2.8914	3.1686
1983	ALK	All gears	Jan-Dec	Length Aged	9,280 980	6,094	.009960	.002109	2.8802	3.3582
	LF	(10,11,12,13)	Jan-Dec	Length	2,345	1,402	.009960	.002109	2.8802	3.3582
	LF	(20,21,22,23)	Jan-Dec	Length	6,001	4,095	.009960	.002109	2.8802	3.3582
	LF	(40,41,42)	Jan-Dec	Length	180	494	.009960	.002109	2.8802	3.3582
1984	ALK	All gears	Jan-Dec	Length Aged	13,335 639	9,599	.004012	.002271	3.2042	3.3777
	LF	(10,11,12,13)	Jan-Jul	Length	1,536	1,473	.004012	.002271	3.2042	3.3777
	LF	(20,21,22,23)	Jan-Jul	Length	1,924	1,719	.004012	.002271	3.2042	3.3777
	LF	(40,41,42,50,51,52)	Jan-Jul	Length	475	825	.004012	.002271	3.2042	3.3777
	LF	(10,11,12,13)	Aug-Dec	Length	4,576	1,949	.004012	.002271	3.2042	3.3777

[a] Gear types: 10 = Otter trawl, 11 = Otter trawl-side, 12 = Otter trawl-stern, 13 = Midwater trawl, 16 = Bottom pair trawl, 20 = Danish seine (charters), 21 = Danish seine, 22 = Scottish seine, 23 = Pair seine, 31 = Purse seine, 33 = Purse seine - 2 vessels, 40 = Gillnets, 41 = Set gillnets, 42 = Drift gillnets, 50 = Longlines, 51 = Set lines, 52 = Drift lines.

TABLE 1. (Continued).

Year	Table type	Gear types[a]	Period		Sample size	Catch	Separated			
							Male	Female	Male	Female
	LF	(20,21,22,23)	Aug-Dec	Length	3,328	1,983	.004012	.002271	3.2042	3.3777
	LF	(40,41,42,50,51,52)	Aug-Dec	Length	1,496	1,466	.004012	.002271	3.2042	3.3777
1985	ALK	All gear	Jan-Jul	Length Aged	4,111 938	4,423	.003172	.002338	3.2905	3.3835
	ALK	All gear	Aug-Dec	Length Aged	3,378 612	5,067	.003172	.002338	3.2905	3.3835
	LF	(10,11,12,16)	Jan-Jul	Length	1,306	1,891	.003172	.002338	3.2905	3.3835
	LF	(21,22,23)	Jan-Jul	Length	2,263	1,784	.003172	.002338	3.2905	3.3835
	LF	(41,42,51)	Jan-Jul	Length	542	694	.003172	.002338	3.2905	3.3835
	LF	(10,11,12,16)	Aug-Dec	Length	549	2,208	.003172	.002338	3.2905	3.3835
	LF	(21,22,23)	Aug-Dec	Length	2,646	2,086	.003172	.002338	3.2905	3.3835
	LF	(41,42,51)	Aug-Dec	Length	183	717	.003172	.002338	3.2905	3.3835
1986	ALK	All gears	Jan-Jul	Length Aged	11,479 803	3,961	.01070	.004858	2.9310	3.1875
	ALK	All gears	Aug-Dec	Length Aged	8,274 489	3,252	.01070	.004858	2.9310	3.1875
	LF	(11,12,16)	Jan-Jul	Length	2,429	1,524	.01070	.004858	2.9310	3.1875
	LF	(20)	Jan-Jul	Length	7,302	1,921	.01070	.004858	2.9310	3.1875
	LF	(50)	Jan-Jul	Length	1,195	513	.01070	.004858	2.9310	3.1875
	LF	(11,12,16)	Aug-Dec	Length	3,784	1,178	.01070	.004858	2.9310	3.1875
	LF	(20)	Aug-Dec	Length	3,901	1,542	.01070	.004858	2.9310	3.1875
	LF	(50)	Aug-Dec	Length	589	458	.01070	.004858	2.9310	3.1875
1987	ALK	All gears	Jan-Jul	Length Aged	8,680 923	4,119	.006390	.0021	3.7540	3.4010
	ALK	All gears	Aug-Dec	Length Aged	10,616 1,445	3,675	.0006390	.0021	3.7540	3.4010
	LF	(11,12,16)	Jan-Jul	Length	1,632	1,706	.0006390	.0021	3.7540	3.4010
	LF	(20)	Jan-Jul	Length	5,628	1,538	.0006390	.0021	3.7540	3.4010
	LF	(40&50)	Jan-Jul	Length	1,420	851	.0006390	.0021	3.7540	3.4010
	LF	(11,12,16)	Aug-Dec	Length	2,746	1,473	.0006390	.0021	3.7540	3.4010
	LF	(20)	Aug-Dec	Length	5,692	1,540	.0006390	.0021	3.7540	3.4010
	LF	(40&50)	Aug-Dec	Length	2,178	692	.0006390	.0021	3.7540	3.4010
1988	ALK	All gears	Jan-Jul	Length Aged	9,026 436	3,352	.0010	.0013	3.5270	3.6280
	ALK	All gears	Aug-Dec	Length Aged	8,585 523	3,355	.0010	.0013	3.5270	3.6280
	LF	(11,12,15,16)	Jan-Jul	Length	2,520	847	.0010	.0013	3.5270	3.6280
	LF	(21,22,23,31,33)	Jan-Jul	Length	4,906	1,559	.0010	.0013	3.5270	3.6280
	LF	(41,42,51)	Jan-Jul	Length	1,600	918	.0010	.0013	3.5270	3.6280
	LF	(11,12,15,16)	Aug-Dec	Length	1,518	1,721	.0010	.0013	3.5270	3.6280
	LF	(21,22,23,31,33)	Aug-Dec	Length	6,765	1,181	.0010	.0013	3.5270	3.6280
	LF	(41,42,51)	Aug-Dec	Length	302	27	.0010	.0013	3.5270	3.6280
1989	ALK	All gears	Jan-Jul	Length Aged	8,226 1,205	2,596	.003868	.003322	3.2276	3.2730
	ALK	All gears	Aug-Dec	Length Aged	7,580 1,041	2,391	.003868	.003322	3.2276	3.2730

[a] Gear types: 10 = Otter trawl, 11 = Otter trawl-side, 12 = Otter trawl-stern, 13 = Midwater trawl, 16 = Bottom pair trawl, 20 = Danish seine (charters), 21 = Danish seine, 22 = Scottish seine, 23 = Pair seine, 31 = Purse seine, 33 = Purse seine - 2 vessels, 40 = Gillnets, 41 = Set gillnets, 42 = Drift gillnets, 50 = Longlines, 51 = Set lines, 52 = Drift lines.

TABLE 1. (Continued).

Year	Table type	Gear types[a]	Period		Sample size	Catch	Separated			
							Male	Female	Male	Female
1989	LF	(11,12,16)	Jan-Jul	Length	1,761	884	.003868	.003322	3.2276	3.2730
	LF	(21,22,23)	Jan-Jul	Length	6,061	1,193	.003868	.003322	3.2276	3,2730
	LF	(41,50,51)	Jan-Jul	Length	404	4,909	.003868	.003322	3.2276	3.2730
	LF	(11,12,16)	Aug-Dec	Length	1,756	1,047	.003868	.003322	3.2276	3.2730
	LF	(21,22,23)	Aug-Dec	Length	5,602	1,078	.003868	.003322	3.2276	3.2730
	LF	(41,50,51)	Aug-Dec	Length	222	247	.003868	.003322	3.2276	3.2730

[a] Gear types: 10 = Otter trawl, 11 = Otter trawl-side, 12 = Otter trawl-stern, 13 = Midwater trawl, 16 = Bottom pair trawl, 20 = Danish seine (charters), 21 = Danish seine, 22 = Scottish seine, 23 = Pair seine, 31 = Purse seine, 33 = Purse seine - 2 vessels, 40 = Gillnets, 41 = Set gillnets, 42 = Drift gillnets, 50 = Longlines, 51 = Set lines, 52 = Drift lines.

TABLE 2. Numbers of American plaice (*Hippoglossoides platessoides*) measured and aged in 1989. (N = the number of samples)

Gear		Month								
		Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Total
Gillnets	Measured	30	228	—	83	—	—	—	—	341
	Aged	13	26	—	26	—	—	—	—	65
Longlines	Measured	—	—	—	63	—	222	—	—	285
	Aged	—	—	—	34	—	47	—	—	81
Seines	Measured	—	1,723	3,182	1,156	2,563	919	1,396	724	11,663
	Aged	—	231	468	153	359	152	175	90	1,628
Trawls	Measured	—	375	1,049	337	838	218	700	—	3,517
	Aged	—	57	149	48	122	27	69	—	472
Total	N	1	11	18	10	16	7	9	3	75

Semiannual age-length keys were prepared for the periods before and after 31 July 1989. This split provided the best balance for the temporal aspects of the fishery which began in April and closed by the end of November (Tallman and Sinclair, MS 1989). As well, the partition provided the best balance of landings, age and lengths sampled within the major gear types (Table 2). It was assumed that age-at-length was unaffected by gear sampled, and combined otolith readings within each half of the year were used to make the semiannual keys.

The length frequencies by gear, and semiannual period weighted by the corresponding landings, were used with the appropriate age-length key to obtain the landings-at-age by gear and half year periods (Table 1). Sampled gears were grouped in the following categories: (1) trawls consisting of side and stern otter trawls and pair trawls; (2) seines consisting of Danish and Scottish seines; and (3) gillnets and longlines.

All calculations of age-length keys and landings by gear, for the entire year or within semiannual periods, were done for each sex separately. The landings-at-age for males, females and juveniles were combined to give the overall landings-at-age for a gear type.

The software program AGELEN (Wright, MS 1990) was used to perform the calculations. AGELEN is based on the ALSYS-X system used by the Department of Fisheries and Oceans, Scotia-Fundy Region. The input parameters to the program are listed by year in Table 1. Unsampled landings were incorporated by multiplying the landings-at-age for sampled gears by the ratio of total landings over sampled landings. Examples of how landings-at-age by sex, gear type and/or semiannual period are combined and prorated for the unsampled landings are given in Tallman and Sinclair (MS 1988, MS 1989).

Catch-at-age

The stratified-random bottom trawl surveys carried out by research vessels (RV) in Div. 4T during September of each year since 1971 (Halliday and Kohler, 1981) supplied the raw data for the calculations (Fig. 1). The survey trawl was equipped with small mesh liners of 32 mm in the lengthening piece and 6 mm in the codend (Halliday and Koeller, MS 1971). According to Clay (1979), this should retain 50% of the American plaice of 7 cm in length. However, Halliday *et al.* (1989) noted that survey catches had a model length of 22 cm, suggesting that fish smaller than this may not have

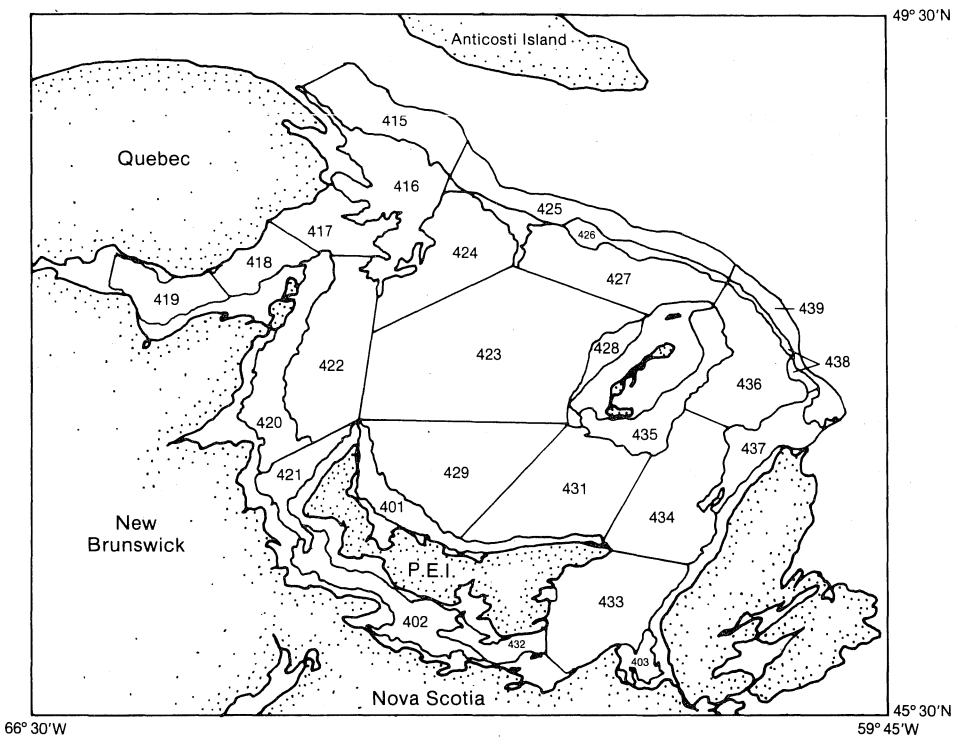

Fig. 1. The southern Gulf of St. Lawrence showing the stratification scheme used for groundfish surveys of the Canadian Department of Fisheries and Oceans, Gulf Region. Stratification was based on depth contours.

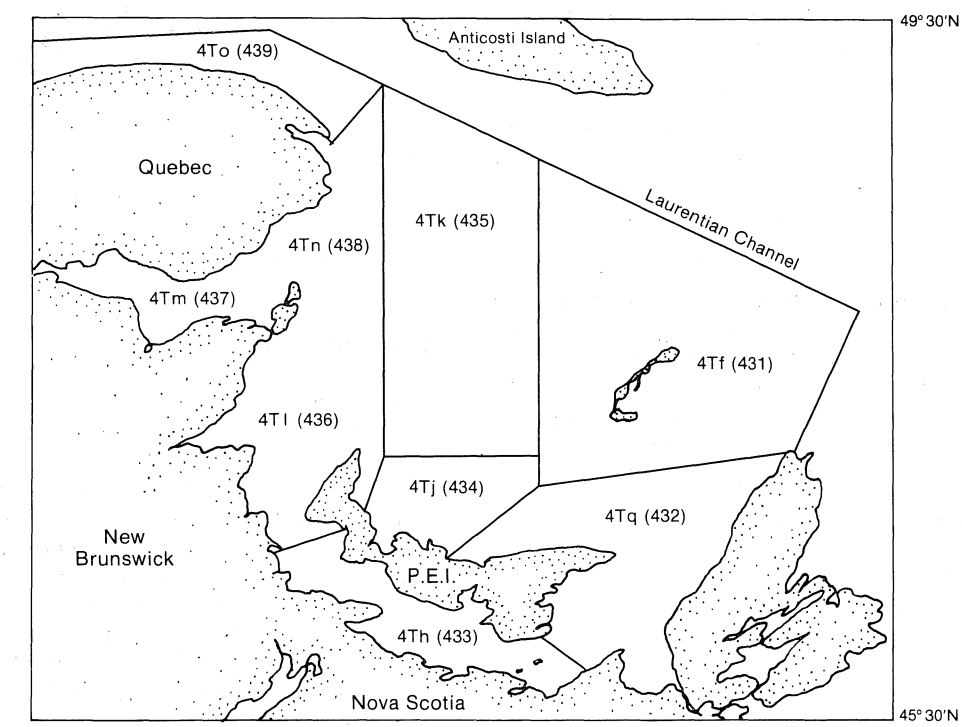

Fig. 2. Statistical subareas within NAFO Division 4T in the southern Gulf of St. Lawrence.

TABLE 3. Selection ogives for American plaice (*Hippoglossoides platessoides*) as calculated by computer (sine) simulation (Clay *et al.*, MS 1984). Values are the percentages of fish of a particular length that are retained by the net.

Length (cm)	Codend mesh size (mm)					
	60	90	100	110	120	130
12	0.0					
13	3.8					
14	23.8					
15	53.4					
16	81.9					
17	98.4	0.0				
18	100.0	2.2	0.0			
19		11.7	0.1			
20		27.1	4.0	0.0		
21		46.2	13.7	0.7		
22		65.8	27.9	5.8	0.0	
23		83.0	44.8	15.4	1.8	0.0
24		95.0	62.4	28.5	7.6	0.2
25		99.9	78.5	43.8	16.9	3.1
26		100.0	91.0	59.7	29.0	9.2
27			98.4	74.6	42.9	18.2
28			100.0	87.0	57.4	29.5
29				95.7	71.2	42.2
30				99.8	83.3	55.4
31				100.0	92.6	68.3
32					98.3	79.9
33					100.0	89.3
34						96.1
35						99.6
36						100.0

been fully recruited to the gear. Even so, over the size range expected in commercial catches (>20 cm), the survey probably gives an unbiased estimate of the population size structure available to commercial gear.

A sexed length frequency distribution was calculated from the RV database to provide an estimate of the mean number-per-tow in each stratum for each sex and length category within sex, that was available to the fishing fleet in any given year.

The fleet does not fish with uniform intensity in all areas. For each NAFO unit area, the mean number-per-tow of each stratum in the unit area was multiplied by the proportion of the unit area that the stratum occupied (Fig. 2). A total for each unit area was calculated by summing numbers within each. The theoretical population distribution in each unit area was weighted by the percentage of commercial fishery landings.

To summarize mathematically:

for i strata and j unit areas

Theoretical length frequency distribution

$$\sum_{ji}\sum N_i P_{ji} Q_j$$

where:

N_i = mean number-per-tow in stratum i

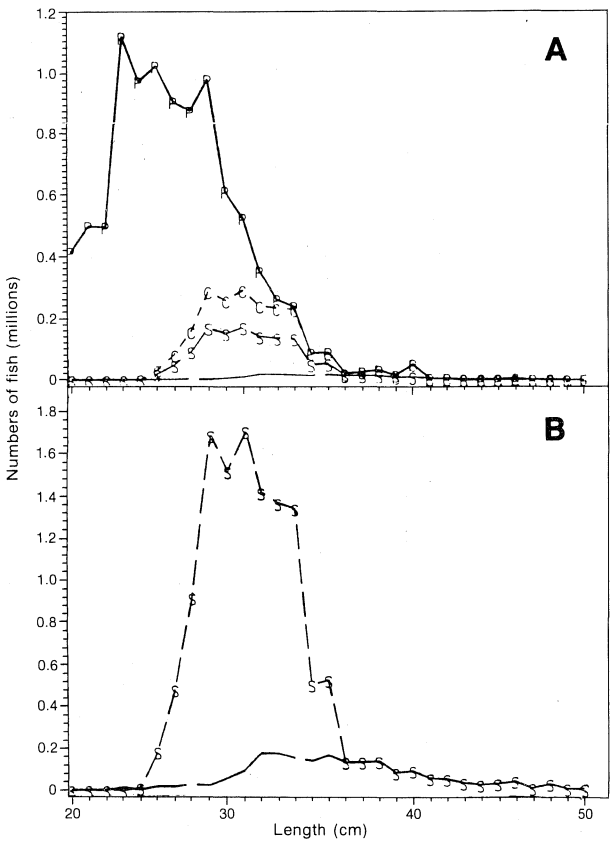

Fig. 3. Schematic diagram (**A**) shows the relative magnitudes of the theoretical population (P), theoretical catch (C), scaled catch (S) and landings by length of male American plaice (*Hippoglossoides platessoides*) in 1984 as calculated by the discarding model. Catch is in numbers. (**B**) shows a comparison of scaled catch(s) and landings-at-length where the area below the scaled catch curve and above the landings curve represents the discarded portion of the total catch.

P_{ji} = proportion of unit area j that is made up of stratum i

Q_j = proportion of catch that is from unit area j

The term "theoretical catch" is used to describe the catch calculated from RV data that was unscaled to landings and "catch" to describe the catch derived from the addition of the discards calculated from the RV data to the commercial landings calculated using AGELEN.

A theoretical distribution of catch-at-length for a given mesh size was calculated by applying a selectivity ogive (Table 3) to the sexed length frequency distribution (Fig. 3). Ogives changed in different years to correspond to the mesh size regulation at the time. The standard mesh size limit for mobile gear was 110 mm in 1976, 120 mm from 1977 to 1980 and 130 mm from 1981 to the present (Clay *et al.*, MS 1984). The ogives used were those calculated by Clay *et al.* (MS 1984) (Table 3, Fig. 4).

The resulting theoretical catch-at-length distribution was scaled to the landings by the ratio of the area under the curve of landings to that of theoretical catch (Fig. 3). The domain of the scaling factor was chosen to reflect lengths above which the research vessel catch and the commercial catch would be unbiased by differential availability of flounder to the net and the discarding practices. Chouinard and Metuzals (MS 1985) found that less than 5% of the numbers caught were discarded in the 40 cm length group. Halliday *et al.* (1989) suggested that the majority of fish 35 cm and below were discarded. To be as conservative as possible a lower bound of 40 cm was chosen. An upper bound of length was chosen (60 cm) beyond which it was thought that sampling would be sporadic (Fig. 3). This figure was used to scale the length frequency of the theoretical catch to the landings.

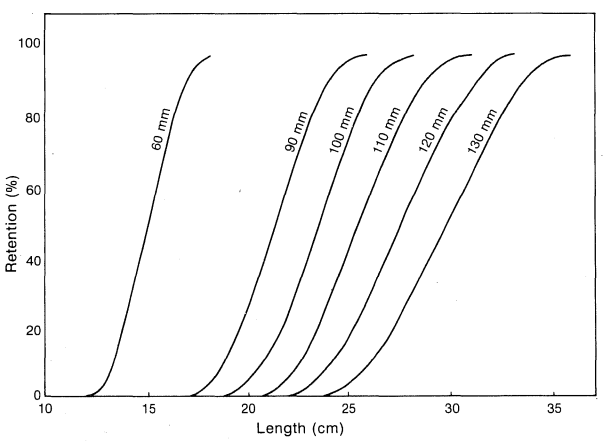

Fig. 4. The selectivity ogives for American plaice (*Hippoglossoides platessoides*) for six different codend mesh sizes (from Clay *et al.*, MS 1984).

The following calculations were made on the lengths below 40 cm of the theoretical catch. The landings-at-length were assumed to be the minimum appropriate estimate of catch. To estimate discards, the landings-at-length were subtracted from the catch-at-length. Age-length keys for the new length frequency of the catch (<40 cm) were made for each sex using a version of the RVAN program (Clay, 1990) written in the SAS language. The length frequency of the discards of each sex was used with the appropriate age-length key calculated from the RV data to obtain the discards-at-age by sex.

The discarded catch and the landings were summed to give the catch-at-age. Figure 3 demonstrates graphically the curves of theoretical population, theoretical catch, landings, catch and discards.

Results and Discussion

The combined landings-at-age for 1976–89 are shown in Table 4. The matrix shows some strong year-classes apparently recruiting to the fishery in the late-1970s. In the 1980s recruitment appears to be much less.

TABLE 4. Estimated landings-at-age for American plaice (*Hippoglossoides platessoides*) in Div. 4T from 1976 to 1989.

	Year													
Age	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	0	3	9	2	0	0	0	4	46	18	0	1	23	11
5	37	99	242	0	0	0	0	128	195	89	25	48	60	93
6	457	601	776	473	81	41	25	177	356	92	397	139	232	381
7	1,380	2,101	2,002	1,202	615	190	46	286	798	464	769	483	234	921
8	2,371	2,253	3,837	4,682	1,129	461	378	417	782	680	1,322	527	484	1,119
9	2,142	1,884	2,671	5,723	2,771	717	1,061	529	960	728	1,349	574	768	1,531
10	2,400	1,625	2,612	3,926	2,640	1,564	1,682	843	1,557	1,161	1,193	794	739	1,018
11	2,036	1,295	2,144	2,379	2,279	1,190	1,482	1,107	1,823	1,664	1,505	784	822	828
12	2,818	1,706	1,470	1,534	2,722	1,417	1,489	1,454	1,628	2,098	1,677	868	980	669
13	1,466	902	1,383	1,051	2,322	944	1,027	1,476	1,009	1,769	1,572	1,094	800	577
14	796	594	720	988	1,663	1,314	735	873	1,299	1,560	1,016	984	968	443
15	397	289	542	309	1,586	2,047	413	600	883	1,112	798	958	828	391
16	407	231	144	209	713	949	324	468	459	817	551	699	789	352
17	334	201	102	127	462	1,286	34	447	560	531	329	664	433	243
18	207	237	109	28	97	803	255	297	378	258	179	337	368	200
19	267	157	66	57	106	203	43	338	267	297	162	315	232	86
20	165	171	33	44	133	280	24	115	197	138	136	295	205	88
21	98	44	95	71	39	221	73	74	57	70	119	164	81	56
22	75	20	0	17	0	0	35	105	24	60	34	118	73	31
23	26	10	113	7	0	0	27	17	18	28	25	87	47	18
24	14	17	29	0	0	0	11	3	0	15	18	45	50	6
25	11	0	0	14	0	0	6	16	0	20	6	24	24	6
26	6	14	15	0	0	0	2	11	0	0	6	26	0	3
Total	17,921	14,822	19,124	22,843	19,358	13,627	9,488	9,796	13,296	13,669	13,188	10,028	9,240	9,071

The coefficients of variation (CV) of the landings-at-age matrix are shown in Table 5.

The discards-at-age for 1976–89 are shown in Table 6. As one would expect, the range of lengths is less than the landings-at-age but the number of ages where discarding occurs is quite broad (on average ages 4 to 15).

The catch-at-age including discards is shown in Table 7. While some of the increases appear to be rather large, the discarding rate of roughly 83.5% in

TABLE 5. Coefficients of variation (/100 m) for landings of American plaice (*Hippoglossoides platessoides*) in Div. 4T from 1976 to 1989.

	Year													
Age	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
4	0	0	0	0	0	0.847	0	0	0.126	0.198	0	0.000	0.043	0.030
5	0.313	0.185	0.365	0	0	0.387	0	0.076	0.299	0.193	0.273	0.188	0.132	0.066
6	0.118	0.128	0.234	0.290	0.820	0.340	0.398	0.140	0.210	0.198	0.172	0.116	0.157	0.042
7	0.071	0.079	0.129	0.153	0.204	0.268	0.413	0.133	0.070	0.106	0.122	0.062	0.140	0.040
8	0.054	0.079	0.096	0.081	0.152	0.167	0.174	0.110	0.097	0.088	0.082	0.062	0.097	0.027
9	0.058	0.085	0.128	0.072	0.097	0.132	0.105	0.108	0.082	0.087	0.087	0.059	0.084	0.026
10	0.053	0.086	0.118	0.082	0.116	0.107	0.077	0.086	0.068	0.069	0.078	0.050	0.081	0.020
11	0.056	0.091	0.129	0.110	0.125	0.082	0.088	0.081	0.062	0.054	0.073	0.050	0.074	0.025
12	0.044	0.064	0.139	0.130	0.110	0.118	0.092	0.072	0.064	0.047	0.063	0.049	0.069	0.021
13	0.059	0.081	0.151	0.139	0.136	0.143	0.115	0.076	0.075	0.048	0.059	0.041	0.077	0.025
14	0.074	0.086	0.116	0.127	0.171	0.128	0.132	0.102	0.074	0.052	0.071	0.043	0.068	0.025
15	0.093	0.082	0.161	0.179	0.175	0.118	0.177	0.139	0.094	0.056	0.067	0.044	0.072	0.026
16	0.081	0.093	0.324	0.216	0.197	0.149	0.203	0.169	0.194	0.066	0.069	0.049	0.071	0.031
17	0.087	0.089	0.481	0.219	0.274	0.140	0.193	0.172	0.183	0.078	0.084	0.049	0.104	0.032
18	0.108	0.092	0.307	0.446	0.431	0.171	0.220	0.219	0.199	0.109	0.112	0.066	0.123	0.041
19	0.095	0.107	0.362	0.388	0.482	0.297	0.489	0.207	0.223	0.111	0.101	0.068	0.151	0.046
20	0.117	0.087	0.551	0.422	0.703	0.331	0.560	0.333	0.310	0.174	0.127	0.070	0.174	0.036
21	0.153	0.220	0.236	0.401	0	0.231	0.422	0.333	0.577	0.237	0.122	0.093	0.265	0.036
22	0.197	0.311	0	0.589	0.281	0.244	0.400	0.352	0.739	0.252	0.166	0.103	0.274	0.052
23	0.282	0.406	0.308	0.885	0.618	0.389	0.687	0.672	0.661	0.486	0.215	0.122	0.346	0.020
24	0.369	0.314	0.379	0	0	0.297	0.960	0.970	0	0.522	0.202	0.176	0.390	0.029
25	0.353	0	0	0.586	0	0.597	0.769	0.711	0	0.615	0.271	0.211	0.504	0.036
26	0.577	0.317	0.508	0	0	0.457	0	0.914	0	0	0.370	0.245	0	0.059
27	0	0	0	0	0	0	0	0	0	0	0.000	0.253	0	0.021
28	0	0	0	0	0	0	0	0	0	0	0.822	0.284	0	0.040
29	0	0	0	0	0	0	0	0	0	2.995	0.385	0.220	0	0
30	0	0	0	0	0	0	0	0	0	0	0.305	0.000	1.243	0.010

TABLE 6. Discards-at-age for American plaice (*Hippoglossoides platessoides*) in Div. 4T from 1976 to 1989.

	Year													
Age	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	47	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	69	0	68	0	0	124
4	1,521	322	217	98	179	166	32	168	217	444	716	159	115	399
5	14,303	4,445	1,318	722	951	384	738	1,022	610	1,663	1,370	1,539	893	2,396
6	29,268	12,192	3,646	2,983	2,714	2,663	1,300	3,235	1,560	2,146	3,107	5,968	4,000	4,718
7	19,802	17,997	8,130	6,894	7,424	5,861	3,219	3,629	2,854	2,832	4,622	8,971	3,954	10,080
8	9,635	9,249	5,823	7,202	9,572	7,505	6,754	7,089	3,446	3,832	3,313	8,673	5,826	8,273
9	8,262	3,395	1,711	3,141	4,825	7,063	5,742	10,569	4,625	3,177	3,227	7,708	3,995	6,866
10	5,020	1,640	979	1,094	1,942	4,925	4,287	7,758	6,018	3,136	1,868	6,370	1,862	4,972
11	2,524	791	388	438	469	2,165	1,458	9,142	2,531	3,750	2,334	5,410	1,452	2,565
12	953	385	59	158	157	997	202	4,494	2,371	2,935	3,703	4,618	1,224	2,341
13	0	103	27	45	75	103	8	1,037	1,010	2,211	2,253	2,134	1,011	1,571
14	223	0	0	12	27	75	0	278	223	1,746	1,640	1,753	971	1,066
15	49	23	0	1	0	150	14	93	39	615	874	911	328	549
16	0	8	0	0	0	0	0	0	0	300	584	474	47	220
17	30	0	0	0	0	0	0	36	11	139	268	142	40	108
18	0	0	0	0	0	0	0	0	0	109	23	0	3	4
19	0	0	0	0	0	0	0	0	0	39	43	0	0	0
20	0	0	0	0	0	0	0	0	0	19	0	0	0	0
21	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22	0	0	0	0	0	0	0	0	0	0	0	0	0	0
23	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0	0	0	0	0
26	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	91,590	50,550	22,298	22,788	28,335	32,057	23,754	48,597	25,584	29,093	30,013	54,830	25,721	46,252

TABLE 7. Catch-at-age including discards for American plaice (*Hippoglossoides platessoides*) in Div. 4T from 1976 to 1989.

	Year													
Age	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	47	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	69	0	68	0	0	124
4	1,521	325	226	100	179	166	32	172	263	462	716	160	138	410
5	14,340	4,544	1,560	722	951	384	738	1,150	805	1,752	1,395	1,587	953	2,489
6	29,725	12,793	4,422	3,456	2,795	2,704	1,325	3,412	1,916	2,238	3,504	6,107	4,232	5,099
7	21,182	20,098	10,132	8,096	8,039	6,051	3,265	3,915	3,652	3,296	5,391	9,454	4,188	11,001
8	12,006	11,502	9,660	11,884	10,701	7,966	7,132	7,506	4,228	4,512	4,635	9,200	6,310	9,392
9	10,404	5,279	4,382	8,864	7,596	7,780	6,803	11,098	5,585	3,905	4,576	8,282	4,763	8,397
10	7,420	3,265	3,591	5,020	4,582	6,489	5,969	8,601	7,575	4,297	3,061	7,164	2,601	5,990
11	4,560	2,086	2,532	2,817	2,748	3,355	2,940	10,249	4,354	5,414	3,839	6,194	2,274	3,393
12	3,771	2,091	1,529	1,692	2,879	2,414	1,691	5,948	3,999	5,033	5,380	5,486	2,204	3,010
13	1,466	1,005	1,410	1,096	2,397	1,047	1,035	2,513	2,019	3,980	3,825	3,228	1,811	2,148
14	992	594	720	1,000	1,690	1,389	735	1,151	1,522	3,306	2,656	2,737	1,939	1,509
15	446	312	542	310	1,586	2,197	427	693	922	1,727	1,672	1,869	1,156	940
16	407	239	144	209	713	949	324	468	459	1,117	1,135	1,173	836	572
17	364	201	102	127	462	1,286	34	483	571	670	597	806	473	351
18	207	237	109	28	97	803	255	297	378	367	202	337	371	204
19	267	157	66	57	106	203	43	338	267	336	205	315	232	86
20	165	171	33	44	133	280	24	115	197	157	136	295	205	88
21	98	44	95	71	39	221	73	74	57	70	119	164	81	56
22	75	20	0	17	0	0	35	105	24	60	34	118	73	31
23	26	10	113	7	0	0	27	17	18	28	25	87	47	18
24	14	17	29	32	0	0	11	3	0	15	18	45	50	6
25	11	0	0	14	0	0	6	16	0	20	6	24	24	6
26	6	14	15	0	0	0	2	11	0	0	6	26	0	3
Total	109,473	65,004	41,412	45,663	47,693	45,684	32,926	58,382	38,880	42,762	43,201	64,858	34,961	55,323

numbers in 1976 corresponds well with the value of 76% given by Halliday *et al.* (1989) for that year. The estimate of 62% discarded catch by numbers is very close to the 61.8% recorded by Chouinard and Metuzals (MS 1985) for 1984. The calculated value for 1980 of 60% may be compared to 45.8% recorded by Cliche (MS 1981). When the discard estimates were limited to the unit areas surveyed by Cliche (areas 4Tf, 4Tk, 4Tl, 4Tn) the overall rate was 46%.

The inclusion of discards improves the consistency in the matrix compared to the landings-at-age. The ages of full recruit appears to be between ages 7 to 9 compared to 12 or 13 for the landings-at-age matrix.

Comparisons of the ratio-at-age between observed and the calculated values (1976 - Halliday *et al.*, 1989; 1984 - Chouinard and Metuzals, MS 1985; 1980 - Cliche, MS 1981) show that: (1) the range of ages where discarding occurs is quite similar between the calculated and empirical methods of estimation; and (2) the calculated percentage discarded declines much more gradually than the empirical values (Fig. 5). The percentage discarded calculated is substantially higher in both years from age 8 or 9 onward. This suggests that the length range used (1 to 39 cm) may be somewhat too broad, resulting in more discards estimated at length between 30 and 39 cm than there should be, and hence more fish being assigned to the older age groups than should be. This in turn might account for the apparent over-estimation of the overall percentage discards by number compared to the empirical observations.

The method is heavily dependent on the scaling factor. It has been observed that RV surveys do not seem to capture as high a percentage of the older age-classes compared to the commercial fleet (A. Sinclair, Canadian Department of Fisheries and Oceans, Quebec Region, pers. comm.). If so, the scaling factor would be biased upward and the total number of discards would be overestimated.

Ideally, one should calculate the discards in each unit area separately and sum these for the estimate of discards at age. To do this, one could apply the selectivity ogive to the research population in each area and then scale the length frequency by the landings in each area to get the catch. Unfortunately, the number of samples taken is insufficient to have separate analyses by sex, gear type, time period and unit area. Such an analysis would involve splitting roughly 5,000 to 15,000 lengths taken per annum into 106 cells. At present, sampling is barely sufficient to account for the three major gear groupings, sex differences and growth from one half of the year to the next.

On the other hand, empirical studies may underestimate the amount of discarding because fishermen involved in a study are likely to consciously or unconsciously fish to reduce the number of small fish that they catch when government personnel are watching (G. Chouinard, Canadian Department of Fisheries and Oceans, Gulf Region, pers. comm.).

It is difficult to evaluate how sensitive the method is to change in discarding practices because the available

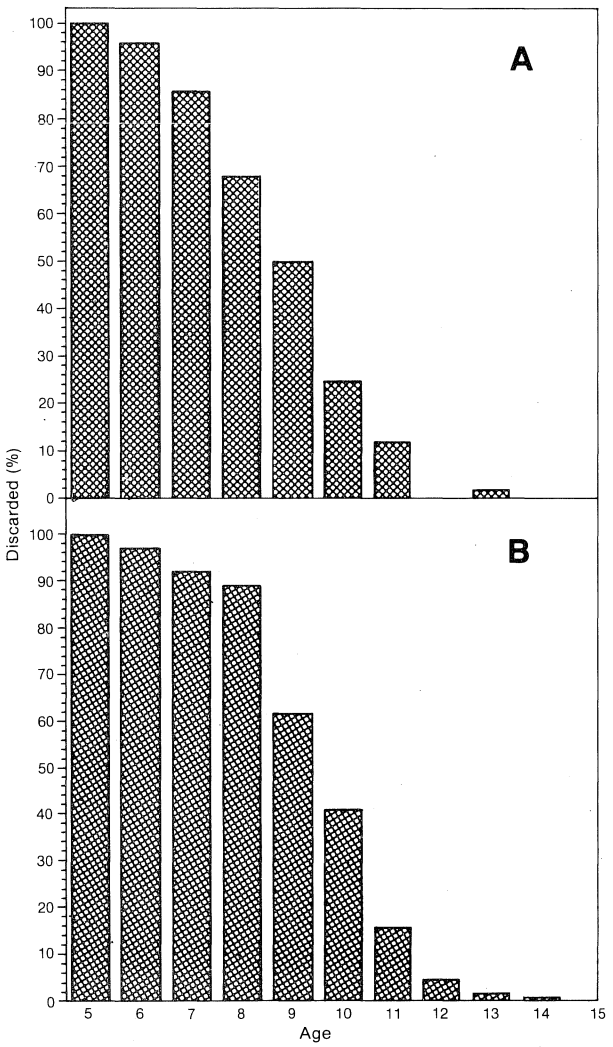

Fig. 5. The percent of American plaice (*Hippoglossoides platessoides*) discarded-at-age from (**A**) empirical studies and (**B**) calculated from the discarding model.

empirical studies do not vary greatly in the amount of discarding (46 to 68%). However, the results do seem to track the changes consistently (empirical studies — 68% in 1976, 46% in 1980, 62% in 1984 *versus* calculated estimate — 76% in 1976, 46% in 1980, 62% in 1984). A possible test of the sensitivity of the model would be to use RV and commercial landings and discard data from fisheries where discarding is thought to be infrequent, such as in Div. 4T cod. Preliminary results of applying the model to cod in Div. 4T suggest that the model is sensitive enough to given reasonable estimates of discarding in this type of fishery.

Conclusion

The method estimates a discarding rate comparable to empirical estimates. The model overestimated discards in 1976. However, the method did give high values during years where discarding was high and so may be useful for making qualitative estimates of discarding. If the estimates calculated here are any indication, discarding is severe and on-going in this fishery.

Acknowledgements

A. Sinclair, G. Chouinard and D. Swain provided much appreciated input into this work. Isabelle Forrest-Gallant provided valuable technical assistance during the course of the work.

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