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

by

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ABSTRACT

Discarding of American plaice at sea is a serious problem in the Gulf of St. Lawrence and a major source of uncertainty in management of the resource. This paper presents a landings at age that 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 to 1989. The method is an economical way of reducing the uncertainty caused by discarding practices.

SPECIAL SESSION ON MANAGEMENT UNDER UNCERTAINTIES
RELATED TO BIOLOGY AND ASSESSMENTS

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 per cent, by weight, of the American plaice 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 per cent by weight and 68 per cent by number (Halliday et al. 1989). Substantial losses in potential yield have been attributed to discarding (Metuzals 1985).

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

The catch at age matrices for American plaice in NAFO Division 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 1988, 1989). Incorporation of an estimate of discards and sex differences into the catch at age for American plaice would reduce the major uncertainties associated with the assessment of this stock.

Direct studies of discarding rates, though desireable, 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 I present a generalized method for incorporating an estimate of the discards into the catch at age matrix using the landings at age and data from annual research vessel survey. As an illustrative example I will apply the method to re-calculate the catch at age for the American plaice stock of NAFO Division 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 I will use the term, "landings", 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 to 1989. From 1976 to 1983 samples were not sufficient 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 sub-sampled for age determination from the 1976 through 1989 fisheries are shown in Table 1.

Semi-annual age-length keys were prepared for the periods before and after July 31. 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 1989). As well, the partition provided the best balance of landings, ages and lengths sampled within the major gear types (Table 2). I assumed that age at length was unaffected by gear sampled and combined otoliths within each half of the year to make the semi-annual keys.

The length frequencies by gear and semi-annual 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 period (Table 1). Sampled gears were grouped in the following categories: 1) trawls, side and stern otter trawls and pair trawls ; 2) seines, Danish and Scottish; 3) gillnets and longlines.

All calculations of age-length keys and landings by gear the entire year or within semi-annual 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 the total

landings over sampled landings. Examples of how landings at age by sex, gear type and/or semi-annual period are combined and prorated for the unsampled landings are given in Tallman and Sinclair (1988, 1989).

Catch at Age

The stratified-random bottom trawl survey carried out by research vessels in NAFO Div. 4T during September of each year since 1971 (Halliday and Koeller 1981) supplied the raw data for the calculations (Fig. 1). The survey trawl was equiped with small mesh liners of 32mm in the lengthening piece and 6mm in the codend (Halliday and Koeller 1971). According to Clay (1979) this should retain 50 per cent of the plaice of 7 cm in length. However, Halliday et al. (1989) noted that survey catches had a modal length of 22 cm suggesting that fish smaller than this may not have been fully recruited to the gear. Even so, over the size range expected in commercial catches (greater than 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 of American plaice of 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

$$\text{Theoretical length frequency distribution} = \sum_{j}\sum_{i} N_i P_{ji} Q_j$$

where:

N_i = mean number per tow in stratum "i"

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"

I will use the terms "theoretical catch" to describe the catch calculated form RV data that is 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 an selectivity ogive (Table 3) to the sexed length frequency distribution (Figure 3). Ogives varied according to the year to correspond to the mesh size regulation at the time. The standard mesh size limit for mobile gear was 110mm in 1976, 120mm from 1977 to 1980 and 130mm from 1981 to the present (Clay et al. 1984). The ogives used were those calculated by Clay et al. (1984) (Table 3, Figure 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 (Figure 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 (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 35cm 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 (Figure 3). This figure was used to scale the length frequency of the theoretical catch to the landings.

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 gives a flow chart of the process and shows the calculations made on the RV population length frequency for 1983.

RESULTS AND DISCUSSION

The combined landings at age for 1976 to 1989 are shown in Table 4. The matrix shows some strong year classes apparently recruiting to the fishery in the late 1970's. In the 1980's recruitment appears to be much less.

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

The discards at age for 1976 to 1989 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 rather large the discarding rate of roughly 83.5 per cent in numbers in 1976 corresponds well with the value of 76 per cent 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 (1985) for 1984. The calculated value for 1980 of 60 % may be compared to 45.8 % recorded by Cliche (1981). When I limited the discard estimates 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 1985, 1980 - Cliche 1981) show that: 1) the range of ages where discarding occurs is quite similar between the calculated and empirical methods of estimation; 2) the calculated % discarded declines much more gradually than the empirical values (Figure 5). The % 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 than should be being assigned to the older age groups. This in turn might account for the apparent over-estimation of the overall % 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 over-estimated.

Ideally, one should the 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 under-estimate 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 changes in discarding practices because the available 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 NAFO Division 4T cod. Preliminary results of applying the model to NAFO Division 4T cod suggest that the model is sensitive enough to give 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 to make a qualitative estimate of discarding. If the estimates calculated here are any indication, discarding is severe and on-going in this fishery.

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Table 1. Age-length table used in the calculation for 1976 to 1989 catch at age

YEAR	TABLE TYPE	GEARS	PERIOD		SAMPLE SIZE	CATCH	SEPARATED a male	SEPARATED a female	SEPARATED b male	SEPARATED b female
1976	ALK	ALL GEARS	JAN-DEC	LENGTH AGED	12042 2397	11193	.007393	.003696	3.0561	3.2636
	LF	(10,11,12,13)	JAN-DEC	LENGTH	3846	7150	.007393	.003696	3.0561	3.2636
	LF	(20,21,22,23)	JAN-DEC	LENGTH	7996	3395	.007393	.003696	3.0561	3.2636
1977	ALK	ALL GEARS	JAN-DEC	LENGTH AGED	10260 1800	9230	.004435	.002426	3.1900	3.3708
	LF	(10,11,12,13)	JAN-DEC	LENGTH	1906	4675	.004435	.002426	3.1900	3.3708
	LF	(20,21,22,23)	JAN-DEC	LENGTH	8354	4015	.004435	.002426	3.1900	3.3708
1978	ALK	ALL GEARS	JAN-DEC	LENGTH AGED	4725 794	9031	.002120	.0009928	3.3665	3.5945
	LF	(10,11,12,13)	JAN-DEC	LENGTH	945	4598	.002120	.0009928	3.3665	3.5945
	LF	(20,21,22,23)	JAN-DEC	LENGTH	3780	3495	.002120	.0009928	3.3665	3.5945
1979	ALK	ALL GEARS	JAN-DEC	LENGTH AGED	3383 596	9996	.0009339	.0006864	3.5957	3.6872
	LF	(10,11,12,13)	JAN-DEC	LENGTH	1578	4463	.0009339	.0006864	3.5957	3.6872
	LF	(20,21,22,23)	JAN-DEC	LENGTH	1605	3719	.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	3055 441	8292	.007185	.003209	3.02359	3.2734
	LF	(10,11,12,13)	JAN-DEC	LENGTH	1210	3853	.007185	.003209	3.02359	3.2734
	LF	(21,22,23)	JAN-DEC	LENGTH	1642	3500	.007185	.003209	3.02359	3.2734
	LF	(40,41,42)	JAN-DEC	LENGTH	203	222	.007185	.003209	3.02359	3.2734

Table 1. Age-length table used in the calculation for 1976 to 1989 catch at age

YEAR	TABLE TYPE	GEARS	PERIOD		SAMPLE SIZE	CATCH	SEPARATED a male	SEPARATED a female	SEPARATED b male	SEPARATED b female
1981	ALK	ALL GEARS	JAN-DEC	LENGTH AGED	3713 541	7834	.008189	.004313	3.0009014	3.2004
	LF	(10,11,12,13)	JAN-DEC	LENGTH	987	2623	.008189	.004313	3.0009014	3.2004
	LF	(20,21,22,23)	JAN-DEC	LENGTH	2262	3575	.008189	.004313	3.0009014	3.2004
1982	ALK	ALL GEARS	JAN-DEC	LENGTH AGED	4108 562	6542	.012003	.004948	2.8914	3.1686
	LF	(10,11,12,13)	JAN-DEC	LENGTH	1624	1459	.012003	.004948	2.8914	3.1686
	LF	(20,21,22,23)	JAN-DEC	LENGTH	2441	4124	.012003	.004948	2.8914	3.1686
1983	ALK	ALL GEARS	JAN-DEC	LENGTH AGED	9280 980	6094	.009960	.002109	2.8802	3.3582
	LF	(10,11,12,13)	JAN-DEC	LENGTH	2345	1402	.009960	.002109	2.8802	3.3582
	LF	(20,21,22,23)	JAN-DEC	LENGTH	6001	4095	.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	13335 639	9599	.004012	.002271	3.2042	3.3777
	LF	(10,11,12,13)	JAN-JULY	LENGTH	1536	1473	.004012	.002271	3.2042	3.3777
	LF	(20,21,22,23)	JAN-JULY	LENGTH	1924	1719	.004012	.002271	3.2042	3.3777
	LF	(40,41,42,50,51,52)	JAN-JULY	LENGTH	475	825	.004012	.002271	3.2042	3.3777
	LF	(10,11,12,13)	AUG-DEC	LENGTH	4576	1949	.004012	.002271	3.2042	3.3777
	LF	(20,21,22,23)	AUG-DEC	LENGTH	3328	1983	.004012	.002271	3.2042	3.3777
	LF	(40,41,42,50,51,52)	AUG-DEC	LENGTH	1496	1466	.004012	.002271	3.2042	3.3777
1985	ALK	ALL GEAR	JAN-JULY	LENGTH AGED	4111 938	4423	.003172	.002338	3.2905	3.3835
	ALK	ALL GEAR	AUG-DEC	LENGTH AGED	3378 612	5067	.003172	.002338	3.2905	3.3835
	LF	(10,11,12,16)	JAN-JULY	LENGTH	1306	1891	.003172	.002338	3.2905	3.3835
	LF	(21,22,23)	JAN-JULY	LENGTH	2263	1784	.003172	.002338	3.2905	3.3835
	LF	(41,42,51)	JAN-JULY	LENGTH	542	694	.003172	.002338	3.2905	3.3835
	LF	(10,11,12,16)	AUG-DEC	LENGTH	549	2208	.003172	.002338	3.2905	3.3835
	LF	(21,22,23)	AUG-DEC	LENGTH	2646	2086	.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-JULY	LENGTH AGED	11479 803	3961	.01070	.004858	2.9310	3.1875
	ALK	ALL GEARS	AUG-DEC	LENGTH AGED	8274 489	3252	.01070	.004858	2.9310	3.1875
	LF	(11,12,16)	JAN-JULY	LENGTH	2429	1524	.01070	.004858	2.9310	3.1875
	LF	(20)	JAN-JULY	LENGTH	7302	1921	.01070	.004858	2.9310	3.1875
	LF	(50)	JAN-JULY	LENGTH	1195	513	.01070	.004858	2.9310	3.1875
	LF	(11,12,16)	AUG-DEC	LENGTH	3784	1178	.01070	.004858	2.9310	3.1875
	LF	(20)	AUG-DEC	LENGTH	3901	1542	.01070	.004858	2.9310	3.1875
	LF	(50)	AUG-DEC	LENGTH	589	458	.01070	.004858	2.9310	3.1875

Table 1 cont. Age-length table used in the calculation for 1976 to 1989 catch at age

YEAR	TABLE TYPE	GEARS	PERIOD		SAMPLE SIZE	CATCH	SEPARATED a male	SEPARATED a female	SEPARATED b male	SEPARATED b female
1987	ALK	ALL GEARS	JAN-JULY	LENGTH AGED	8680 923	4119	.0006390	.0021	3.7540	3.4010
	ALK	ALL GEARS	AUG-DEC	LENGTH AGED	10616 1445	3675	.0006390	.0021	3.7540	3.4010
	LF	(11,12,16)	JAN-JULY	LENGTH	1632	1706	.0006390	.0021	3.7540	3.4010
	LF	(20)	JAN-JULY	LENGTH	5628	1538	.0006390	.0021	3.7540	3.4010
	LF	(40&50)	JAN-JULY	LENGTH	1420	851	.0006390	.0021	3.7540	3.4010
	LF	(11,12,16)	AUG-DEC	LENGTH	2746	1473	.0006390	.0021	3.7540	3.4010
	LF	(20)	AUG-DEC	LENGTH	5692	1540	.0006390	.0021	3.7540	3.4010
	LF	(40&50)	AUG-DEC	LENGTH	2178	692	.0006390	.0021	3.7540	3.4010
1988	ALK	ALL GEARS	JAN-JULY	LENGTH AGED	9026 436	3352	.0010	.0013	3.5270	3.6280
	ALK	ALL GEARS	AUG-DEC	LENGTH AGED	8585 523	3355	.0010	.0013	3.5270	3.6280
	LF	(11,12,15,16)	JAN-JULY	LENGTH	2520	847	.0010	.0013	3.5270	3.6280
	LF	(21,22,23,31,33)	JAN-JULY	LENGTH	4906	1559	.0010	.0013	3.5270	3.6280
	LF	(41,42,51)	JAN-JULY	LENGTH	1600	918	.0010	.0013	3.5270	3.6280
	LF	(11,12,15,16)	AUG-DEC	LENGTH	1518	1721	.0010	.0013	3.5270	3.6280
	LF	(21,22,23,31,33)	AUG-DEC	LENGTH	6765	1181	.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-JULY	LENGTH AGED	8226 1205	2596	.003868	.003322	3.2276	3.2730
	ALK	ALL GEARS	AUG-DEC	LENGTH AGED	7580 1041	2391	.003868	.003322	3.2276	3.2730
	LF	(11,12,16)	JAN-JULY	LENGTH	1761	884	.003868	.003322	3.2276	3.2730
	LF	(21,22,23)	JAN-JULY	LENGTH	6061	1193	.003868	.003322	3.2276	3.2730
	LF	(41,50,51)	JAN-JULY	LENGTH	404	4909	.003868	.003322	3.2276	3.2730
	LF	(11,12,16)	AUG-DEC	LENGTH	1756	1047	.003868	.003322	3.2276	3.2730
	LF	(21,22,23)	AUG-DEC	LENGTH	5602	1078	.003868	.003322	3.2276	3.2730
	LF	(41,50,51)	AUG-DEC	LENGTH	222	247	.003868	.003322	3.2276	3.2730

(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 AGED AND MEASURED IN 1989

		MONTH								
		APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	TOTAL
GEAR										
GILLNETS	MEAS	30	228	.	83	.	.	.	.	341
	AGED	13	26	.	26	.	.	.	.	65
LONGLINE	MEAS	.	.	.	63	.	222	.	.	285
	AGED	.	.	.	34	.	47	.	.	81
SEINES	MEAS	.	1723	3182	1156	2563	919	1396	724	11663
	AGED	.	231	468	153	359	152	175	90	1628
TRAWLS	MEAS	.	375	1049	337	838	218	700	.	3517
	AGED	.	57	149	48	122	27	69	.	472
TOTAL	N	1	11	18	10	16	7	9	3	75

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

	COD END MESH SIZE (mm)					
LENGTH (cm)	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

Table 4. ESTIMATED LANDINGS AT AGE (,000) for 4T Plaice from 1976 to 1989

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	1380	2101	2002	1202	615	190	46	286	798	464	769	483	234	921
8	2371	2253	3837	4682	1129	461	378	417	782	680	1322	527	484	1119
9	2142	1884	2671	5723	2771	717	1061	529	960	728	1349	574	768	1531
10	2400	1625	2612	3926	2640	1564	1682	843	1557	1161	1193	794	739	1018
11	2036	1295	2144	2379	2279	1190	1482	1107	1823	1664	1505	784	822	828
12	2818	1706	1470	1534	2722	1417	1489	1454	1628	2098	1677	868	980	669
13	1466	902	1383	1051	2322	944	1027	1476	1009	1769	1572	1094	800	577
14	796	594	720	988	1663	1314	735	873	1299	1560	1016	984	968	443
15	397	289	542	309	1586	2047	413	600	883	1112	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	1286	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	17921	14822	19124	22843	19358	13627	9488	9796	13296	13669	13188	10028	9240	9071

Table 5. CV (/100) FOR LANDINGS OF 4T PLAICE FROM 1976 TO 1989.

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	0.07	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. NAFO Division 4T American plaice discards at age ('000) for 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	1521	322	217	98	179	166	32	168	217	444	716	159	115	399
5	14303	4445	1318	722	951	384	738	1022	610	1663	1370	1539	893	2396
6	29268	12192	3646	2983	2714	2663	1300	3235	1560	2146	3107	5968	4000	4718
7	19802	17997	8130	6894	7424	5861	3219	3629	2854	2832	4622	8971	3954	10080
8	9635	9249	5823	7202	9572	7505	6754	7089	3446	3832	3313	8673	5826	8273
9	8262	3395	1711	3141	4825	7063	5742	10569	4625	3177	3227	7708	3995	6866
10	5020	1640	979	1094	1942	4925	4287	7758	6018	3136	1868	6370	1862	4972
11	2524	791	388	438	469	2165	1458	9142	2531	3750	2334	5410	1452	2565
12	953	385	59	158	157	997	202	4494	2371	2935	3703	4618	1224	2341
13	0	103	27	45	75	103	8	1037	1010	2211	2253	2134	1011	1571
14	223	0	0	12	27	75	0	278	223	1746	1640	1753	971	1066
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	91590	50550	22298	22788	28335	32057	23754	48597	25584	29093	30013	54830	25721	46252

Table 7. NAFO Division 4T Catch at age ('000) including discards for 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	1521	325	226	100	179	166	32	172	263	462	716	160	138	410
5	14340	4544	1560	722	951	384	738	1150	805	1752	1395	1587	953	2489
6	29725	12793	4422	3456	2795	2704	1325	3412	1916	2238	3504	6107	4232	5099
7	21182	20098	10132	8096	8039	6051	3265	3915	3652	3296	5391	9454	4188	11001
8	12006	11502	9660	11884	10701	7966	7132	7506	4228	4512	4635	9200	6310	9392
9	10404	5279	4382	8864	7596	7780	6803	11098	5585	3905	4576	8282	4763	8397
10	7420	3265	3591	5020	4582	6489	5969	8601	7575	4297	3061	7164	2601	5990
11	4560	2086	2532	2817	2748	3355	2940	10249	4354	5414	3839	6194	2274	3393
12	3771	2091	1529	1692	2879	2414	1691	5948	3999	5033	5380	5486	2204	3010
13	1466	1005	1410	1096	2397	1047	1035	2513	2019	3980	3825	3228	1811	2148
14	992	594	720	1000	1690	1389	735	1151	1522	3306	2656	2737	1939	1509
15	446	312	542	310	1586	2197	427	693	922	1727	1672	1869	1156	940
16	407	239	144	209	713	949	324	468	459	1117	1135	1173	836	572
17	364	201	102	127	462	1286	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	109473	65004	41412	45663	47693	45684	32926	58382	38880	42762	43201	64858	34961	55323

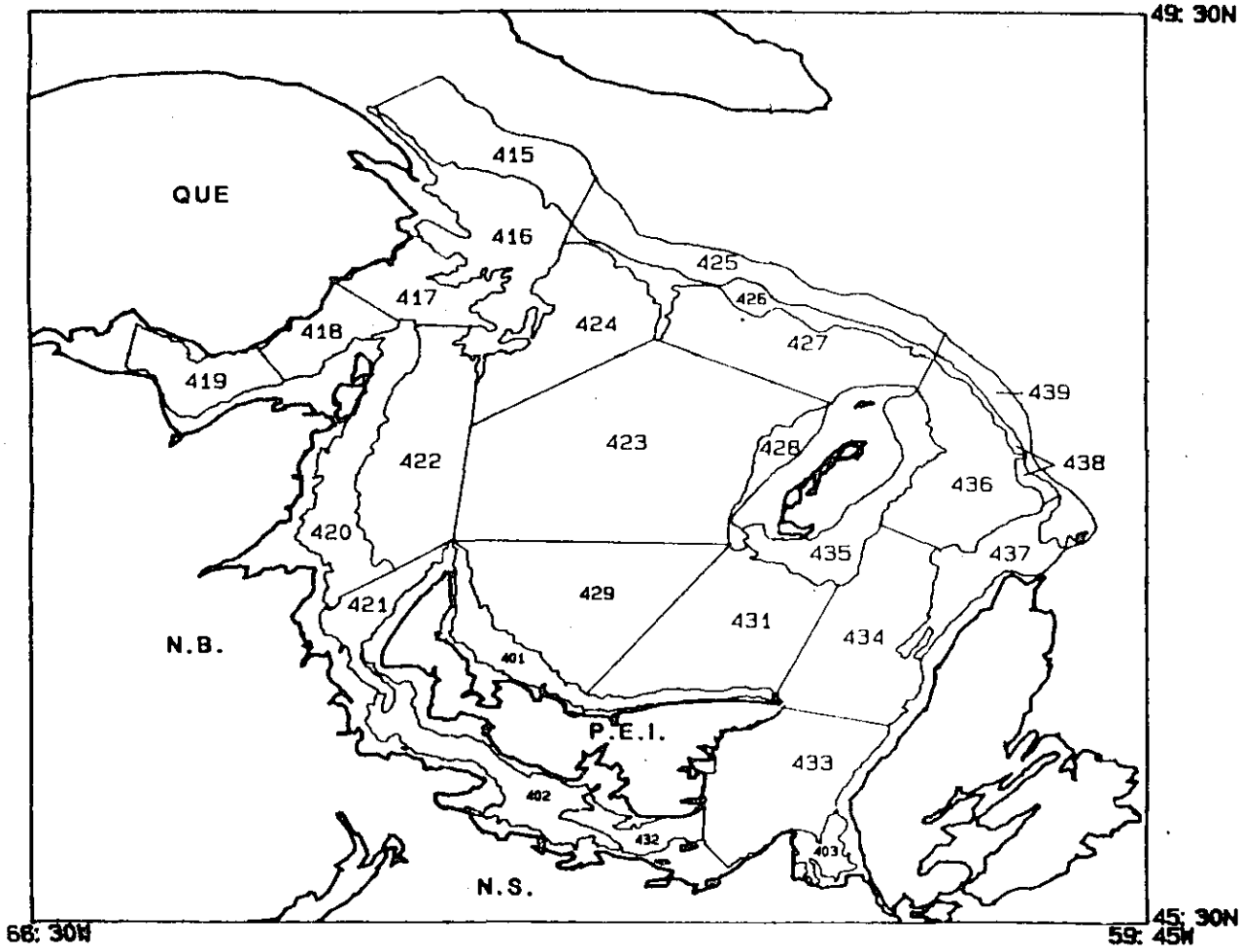


Figure 1. The southern Gulf of St. Lawrence showing the stratification scheme used for groundfish surveys of the Gulf Region, Canadian Department of Fisheries and Oceans. Stratification was based on depth contours.

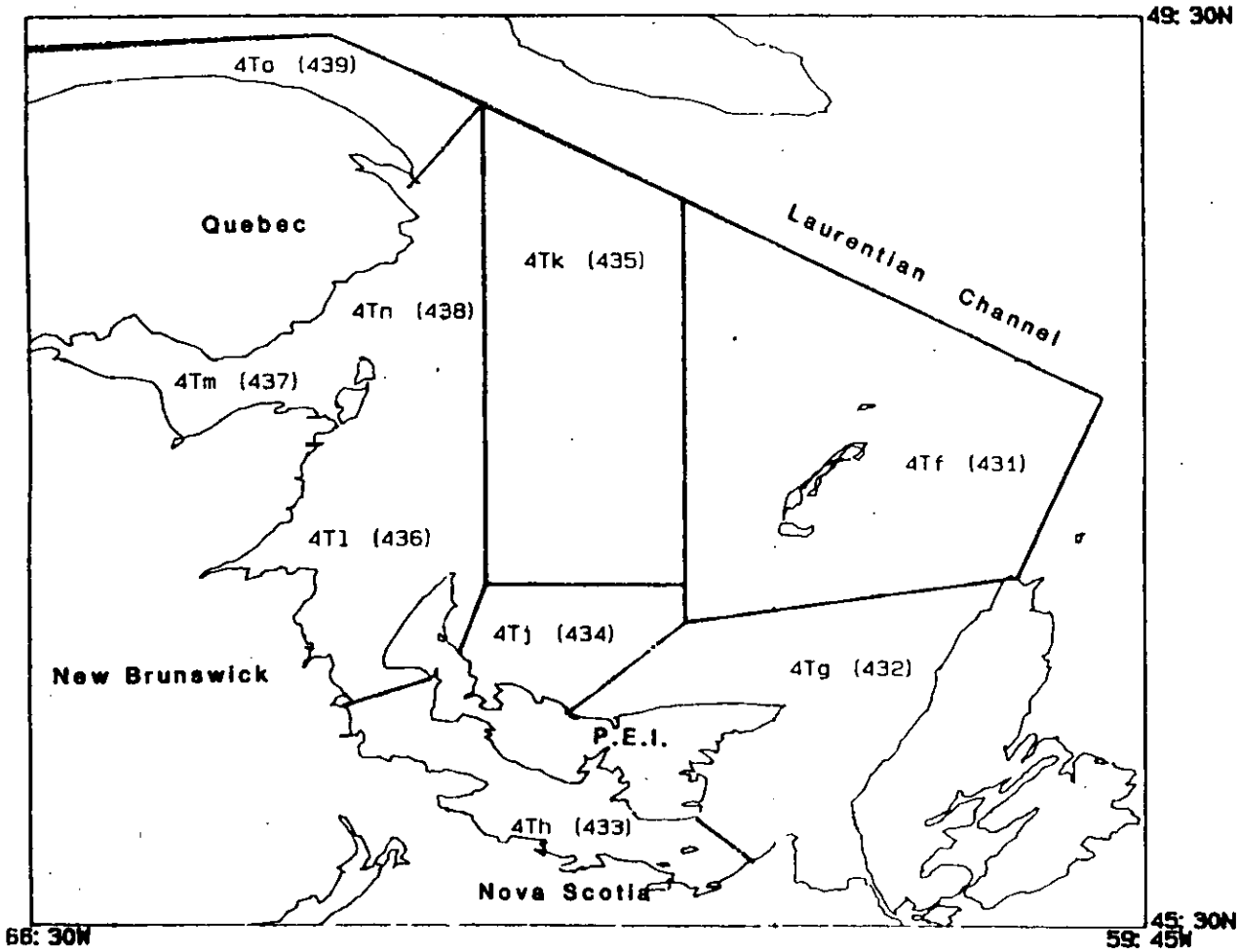
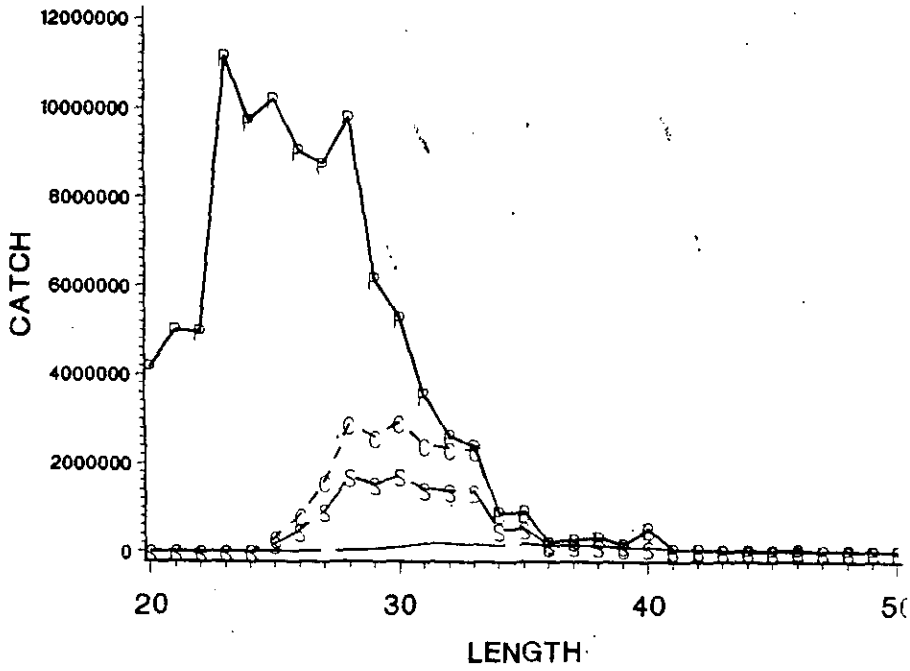


Figure 2. Statistical sub-areas within NAFO Division 4T in the southern Gulf of St. Lawrence.

Theoretical population (P), theoretical catch (C), scaled catch (S) and landings at length in 1984.



Scaled catch (S) and landings at length in 1984.

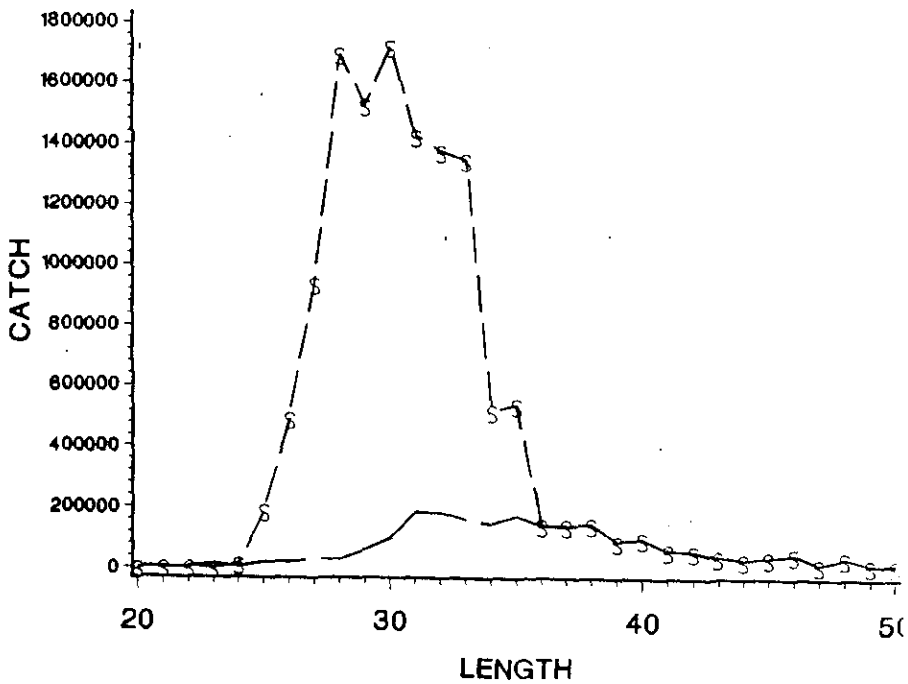


Figure 3. Schematic to show the relative magnitudes of the 'theoretical population', 'theoretical catch', 'scaled catch' and landings by length of male American plaice in 1984 as calculated by the discarding model. Catch is in numbers. The area below the scaled catch curve and above the landings curve represents the discarded portion of the total catch.

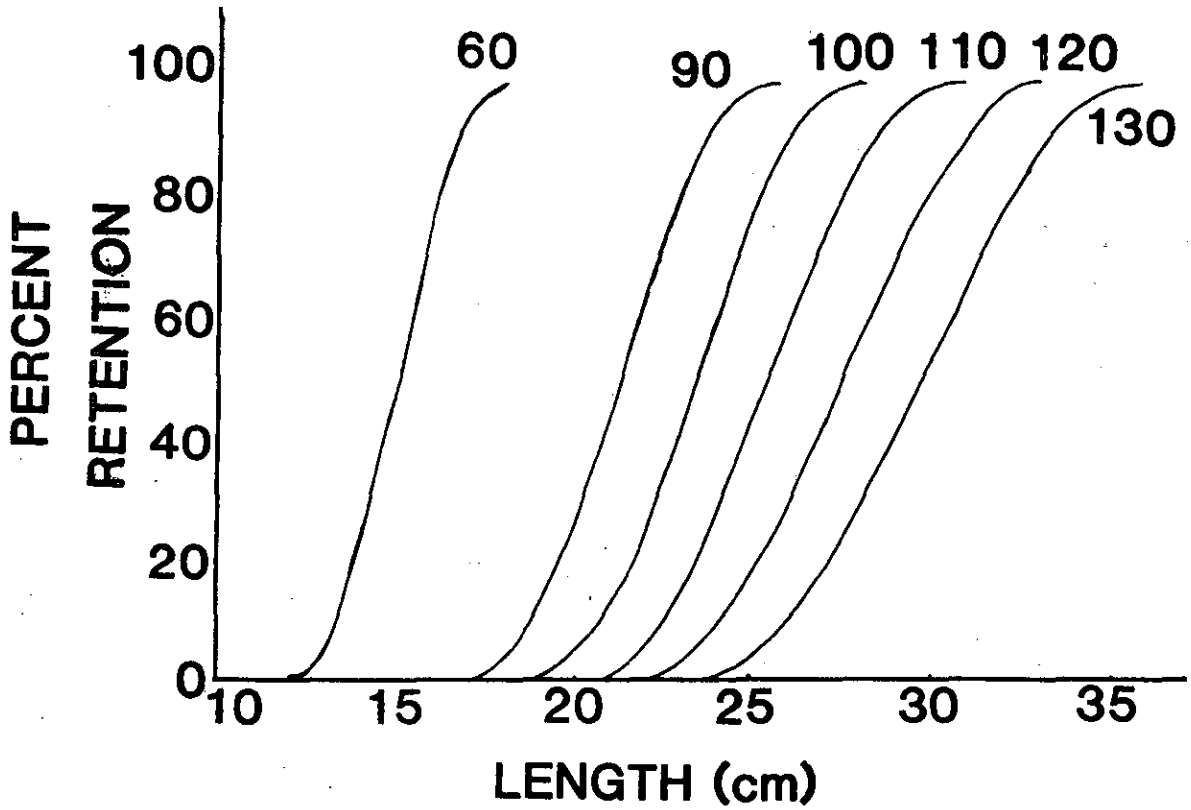
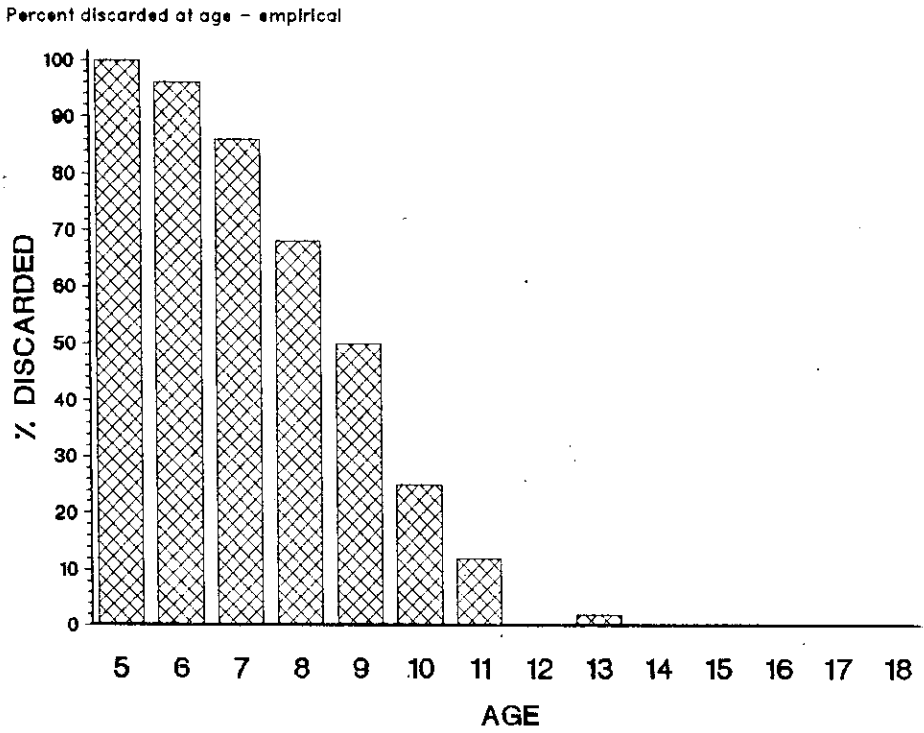


Figure 4. The selectivity ogives for American plaice for 60, 90, 100, 110, 120 and 130 mm mesh nets (from Clay et al. 1984).



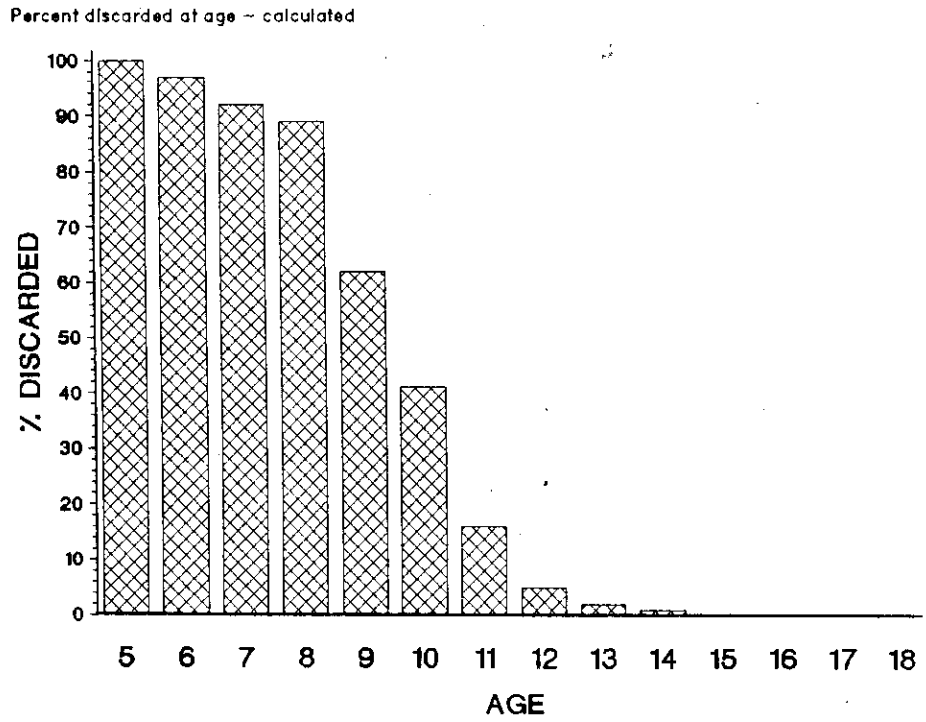


Figure 5. The percent discarded at age from empirical studies and calculated from the discarding model.