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Decision rules for overwintering herring fisheries

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Abstract

A computer simulation model demonstrates the risk of over-exploitation to small stocks in overwintering herring fisheries that take place where mixtures of large and small stocks occur. This model leads to the general principles that (1) if mixing of stocks is random, then (a)exploitation on average will be equal among all stocks, (b) exploitation rates will be more variable on the smaller stocks, but (2) if fishing occurs where small stocks are concentrated; exploitation rates much higher than expected will occur on the small stocks.

These principles were used, in combination with fishery and research survey results to develop decision rules for the 4Vn overwinter herring fishery. The first rule determines that the overwinter catch is not to exceed recent average landings, because these levels have not been detrimental to local spawning components. The second determines that the starting date should be November 1, because results of acoustic and bottom trawl surveys indicate that the migration of 4T herring is well established by this date. The third, is that no more than 10% of the catch by number can be below 24.5 cm fork length, as this limit has been effective in keeping the landings of immature herring to less than 10% and a higher percentage of the immature herring are likely to be of local origin than adults. The fourth rule concerns fishing area, which was not able to be defined using the data analyzed to date and was identified as an item to be determined among science, management, and industry.

Résumé

Un modèle informatique permet de simuler le risque de surexploitation des petits stocks de hareng qui existe au moment de la pêche d'hiver qui porte sur un mélange de stocks importants et petits. Le modèle permet de définir des principes généraux : 1) si le mélange des stocks est aléatoire, a) l'exploitation moyenne sera également répartie entre les stocks et b) les taux d'exploitation seront plus variables chez les petits stocks et 2) si la pêche est effectuée aux endroits où les petits stocks sont concentrés, des taux d'exploitation beaucoup plus importants que prévus seront exercés sur ces stocks.

Ces principes ont été utilisés, de pair avec les résultats de la pêche et de relevés de recherche, pour l'élaboration de règles de décision s'appliquant à pêche d'hiver du hareng en 4Vn. La première règle stipule que les prises d'hiver ne doivent pas excéder la valeur moyenne des débarquements récents car ces derniers n'ont pas été nuisibles aux composantes de géniteurs locales. La deuxième fixe au 1er novembre la date d'ouverture car les relevés acoustiques et par chalut de fond montrent que la migration du hareng de 4T est déjà bien en cours à cette date. La troisième stipule qu'au plus 10 % des poissons capturés ne peuvent avoir une longueur à la fourche inférieure à 24,5 cm car cette limite s'est avérée efficace pour maintenir à moins de 10 % les captures de harengs immatures et que l'augmentation de ce pourcentage s'expliquerait sans doute par des harengs d'origine locale plutôt que par des adultes. La quatrième règle porte sur la zone de pêche qui n'a pu être délimitée à l'aide des données analysées jusqu'à maintenant. La zone devra donc être définie par les scientifiques, les gestionnaires et les représentants de l'industrie.

Introduction

There are three areas where herring have been harvested in mixed-stock overwintering aggregations in the Maritimes Region in recent years; 4Vn, Chedabucto Bay, and Halifax. The biological objective, to keep exploitation rates within $F_{0.1}$ or other conservation targets on all stocks in these fisheries, is similar in each area. $F_{0.1}$ fishing mortality targets are usually in the range of 20% to 25% for herring stocks in the Maritimes Region.

The typical situation encountered in these fisheries is that a large stock migrates into the overwintering area which also has one or more smaller stocks, either originating within the area or migrating from another area. In order to attain the objective of keeping fishing mortality within target limits for all stocks, it is important to understand the exploitation rates expected on each stock component in the overwintering area. In particular, it is important to identify the situations which lead to very high exploitation rates on the smaller, more vulnerable populations. These rates would then be added to the exploitation rates experienced by these stocks in other fisheries.

Once these situations are identified, specific rules governing the conditions under which a fishery proceeds can be established. Specific operational considerations to ensure that the large stock predominates in the catch include: allocations, size, opening times, and closed areas. The objective is to establish the rules for the fishery before it begins and to have easily identified criteria for any in-season alterations in fishing. The results of the fishery would then be evaluated against the objectives for that year at a stock assessment review meeting, and any changes required to meet those objectives would be suggested. Similarly, if new evidence came to light that would indicate new areas of fishing opportunities, these would be considered in the decision rules for the next year. Some general principles and a specific example for deriving decision rules in the 4Vn overwintering fishery are examined in this report

General Principles

General principles concerning the exploitation of fish from two or more stocks were derived using a simple computer simulation. Two conditions were examined. In the first, two stocks, one large ('migrating') and one smaller ('local') stock were assumed to be randomly mixed in the fishing area. In the second, fishing occurred in an area where the small stock was concentrated. In both cases, catches were made in groups of 40t for each stock and the TAC is set to some percentage of the larger stock, for example 5% (Appendix 1).

In the first situation, where fishing occurs in an area where the stocks are in proportion to their relative population size, the computer model is similar to having a group of black and white marbles completely mixed throughout a jar. If black represents the migrating stock, then there are many more black marbles than white ones. Samples picked from this random mixture would produce numbers of each type according to their relative proportions. In this situation the TAC is set on the basis of the more numerous migrating stock and equal exploitation rates would be expected on each group. To extend the marble analogy, the proportion of marbles seclected from each group would be equal.

In the second situation, where fishing occurs where the local stock is concentrated and for example, there are equal numbers of migrating and local stocks then the numbers of migrating and local stocks harvested would be equal. However, because the local stock is much smaller than the migrating stock and the TAC is based on the larger migrating stock, exploitation rates or the proportion of the smaller population harvested would be much greater than in the first situation. The computer model is used to determine the relative difference and potential impact on small local stocks from fishing in these two types of conditions.

The model deomonstrates that in the first situation, on average, equal exploitation rates occur regardless of the relative sizes of the two stocks. On average, if the TAC is 5% of the large stock the exploitation rate on the small stock will also be 5% (Fig. 1). As the relative size of the larger stock increases, the variation around the exploitation rate of the small stock also increases so that occasionally, very large exploitation rates occur, on the small stock, that are 20% or more. The variation seems to level off or increase very slowly as the stock ratios increase past 8:1. The purpose of this example is not to predict precisely what will happen, but to provide an illustration of the risk involved in proceeding with any mixed stock fishery under ideal conditions (Fig. 1). Very low exploitation rates on the small stock will also occur. For example, at stock ratios of 16:1, the exploitation rate on the small stock will be zero about 30% of the time (Fig. 2).

The second condition represents a more dangerous situation for the smaller stock, that is if fishing occurs in an area where the small stock is concentrated while the TAC is set to the size of the larger stock.

For example, suppose the ratio of the large stock to the small stock is 16:1 but fishing occurs where the ratio between the two stocks is 1:1 and the fishery proceeds until the TAC is caught. In this situation, the average exploitation rate that would be expected on the small stock would be about 40% with a range between 10% and 75% (Fig. 3). Very few exploitation rates lower than the target will occur (Fig. 4).

These results illustrate the following general principles:

I. If mixing of stocks is random:

A. Exploitation rates will on average be equal among all stocks, regardless of number of stocks.

B. Exploitation rates will be more variable on the smaller stock(s).

II. If fishing occurs where small stocks are concentrated; exploitation rates much higher than expected will occur on the small stocks.

Thus, formulating and evaluating decision rules requires understanding the relative sizes of the contributing stocks, areas where small stocks are concentrated, and differences in biological characteristics so that stock mixtures can be evaluated.

A specific example: 4Vn

The above principles will be referred to when formulating decision rules for the 4Vn overwintering fishery. The objective in this case is to provide information that would allow managers to formulate rules and permit the fishery to proceed without interruption until the allocation was caught. The effect of these rules, with respect to the principles defined above, would be evaluated as part of the assessment process at the end of the year. Any necessary adjustments in the rules would be made in light of that assessment. Detailed information on the analyses contributing to the development of these rules can be found in Claytor (1997).

Decision Rule 1: How many fish to catch?

Overwinter catch not to exceed recent average landings, for example 1990-1996.

Since 1983, fishing by large seiners has been restricted to the northern portion of 4Vn with the intent of directing this fishery primarily towards the 4T migrating stock. Thus, average landings during this period by all gear sectors are an indication of the fishing effects on stocks contributing to this fishery (Table 1). The presence of a high proportion of 11+ herring (Fig. 5), although their stock origin has not been identified, in local coastal fall fisheries and the continued presence of local fisheries suggest that fishing levels, since 1983, have not been detrimental to local spawning components.

The average reported landings of fixed local gears during this time was 100 tonnes. Much of the local herring fisheries direct for bait and a large portion of the catch has remained unreported and unknown. Potential removals by local fisheries, however, may be as high as 3500 tonnes (Claytor 1997).

These average levels of removal, while a weak biological rationale for advising on harvest levels, form the basis for current advice on catch allocations in this area until additional information becomes available on 4Vn spawning components.

Decision Rule 2: When to start?

Starting date: November 1.

The starting date should reflect a time when the migration of the 4T stock has proceeded to the extent that the risk of over-exploitation on smaller stocks is minimized. Results of acoustic and bottom trawl surveys indicate that, since 1984, the migration is well-established by November 1, and that this would be an appropriate starting date (Table 2). Test fisheries or surveys would provide more precise indicators of annual trends in migration timing.

In some years, the migration appears to make an appreciable start by mid-October but other years this is not the case. Two years, 1991 and 1992, were the peak abundance years for the 4T stock, yet the abundance of herring in 4Vn by mid-October was considerably different (Table 2).

Major biomass concentrations in 4Vn during October and November are in Aspy Bay and St. Ann's Bank. Concentrations in the north are always greatest after November 1, indicating that the 4T migration has been consistently advanced after November 1 (Fig. 6).

Decision Rule 3: Size of fish in catch?

No more than 10% of catch by number can be below 24.5 cm fork length.

In 4Vn, a higher percentage of the immature herring are likely to be of local origin than adults. A likely reason for this higher percentage is that 4T immature herring are known to overwinter in 4T, or at least migrate to 4Vn later than 4T adult herring. This differing migration pattern results from anti-freeze proteins in juvenile 4T herring that allow them to live under the ice in the Gulf of St. Lawrence during the winter (Chadwick et al. 1990). Thus, a size limit is an additional criteria that can be used to reduce exploitation of local immature herring.

The size restriction in effect for 1996 was that no more than 10% of the catch by number could be below 24.5 cm fork length. This size restriction is the same as in 4T. This restriction was a change from previous years when the 10% limit was based on 26.5 cm fork length.

Landings of immature herring in 1996 were 285 tonnes, about 7% of the total catch by biomass and number. This level is above the average from 1992 to 1995 (Table 3).

The maximum size for immature herring in the 1996 catch was 28.5 cm total length but most were below 27.0 cm total length (70%). Of the herring below 28.5 cm total length, 20% were immature (Fig. 7).

The 1996 size limit was effective in keeping the landings of immature herring to less than 10%.

Decision Rule 4: Fishing Area?

Restrict fishing to area of 4T winter distribution, position of boundary to be determined among science, management, and industry.

Fishery location and size of aggregations are two ways in which fishing area can affect the stock composition of the catch. For example, the risk to small stocks could be reduced by limiting fishing activity to areas where small portions of large aggregations could be harvested rather than large portions of small aggregations

Large seiner fishing activity in 4Vn concentrated entirely in the northern portion of the fishing area from 1991 to 1995. During this time, over 90% of the catch was fall spawners. In 1996, a similar percentage of fall spawners was caught in Aspy Bay to the end of November. When the fishery moved further south a higher percentage of spring spawners occurred in the catch (Fig. 8).

This higher concentration of spring spawners could occur for two reasons. Either, it was in an area where 4T spring spawners predominate, or was an area where spring spawners from local, primarily Bras d'Or stocks, were concentrated. If the situation was one of concentration of local stocks, high exploitation rates would be expected.

Of the 167 tonnes of spring spawners caught in the southern area, 64 tonnes were positively identified as 4T origin based on a qualitative examination of otolith characteristics. The remaining 103 tonnes could not be identified as either 4T or local stocks (Table 4).

The age structure of spring spawners caught in this area indicated a similarity with spring spawners caught earlier in the season in the northern part of the fishing area. This similarity, while suggesting a predominance of 4T spring spawners in this catch, does not guarantee a reduction in the risk to local spring stocks from continual fishing in this area.

An examination of previous years fishing and surveys to determine the consistency of spring spawner distribution is important for two reasons. First, the high risk to small stocks when fishing in areas where they might be concentrated and, second, the accounting of the 4Vn allocation against the 4T fall spawner component because of the high percentage of fall spawners typically seen in this fishery.

References

Chadwick, E.M.P., D.K. Cairns, H.M.C. Dupuis, K.V. Ewart, M.H. Kao, and G.L. Flecther. 1990. Plasma antifreeze levels reflect the migratory behaviour of Atlantic herring (*Clupea harengus harengus*) in the southern Gulf of St. Lawrence. Can. J. Fish. Aquat. Sci. 47:1534-1536.

Claytor, R.R.. 1997. 4Vn large seiner fishery in 1996. DFO Canadian Stock Assessment Secretariat Res. Doc. in preparation.

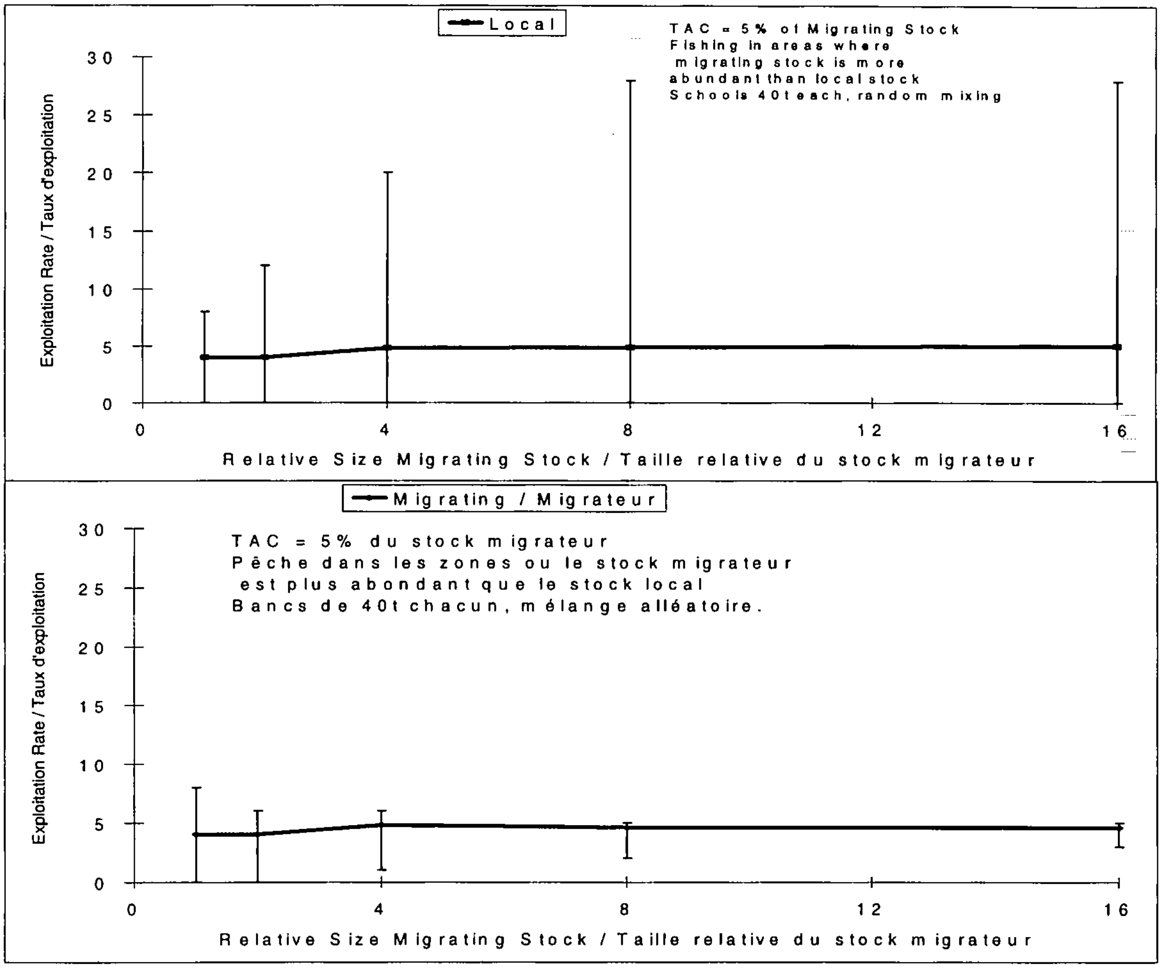


Fig. 1 Average exploitation rate (line) and variation expected around exploitation rates (vertical lines) in areas where stock mixtures are made up of a large and a small stock with the large stock equal to, or up to 16X greater than the small stock.

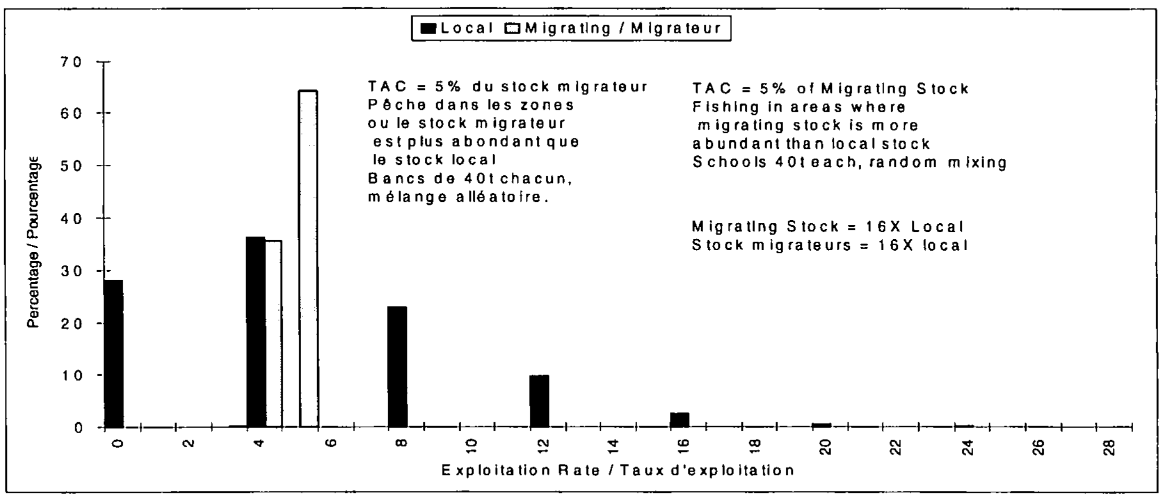
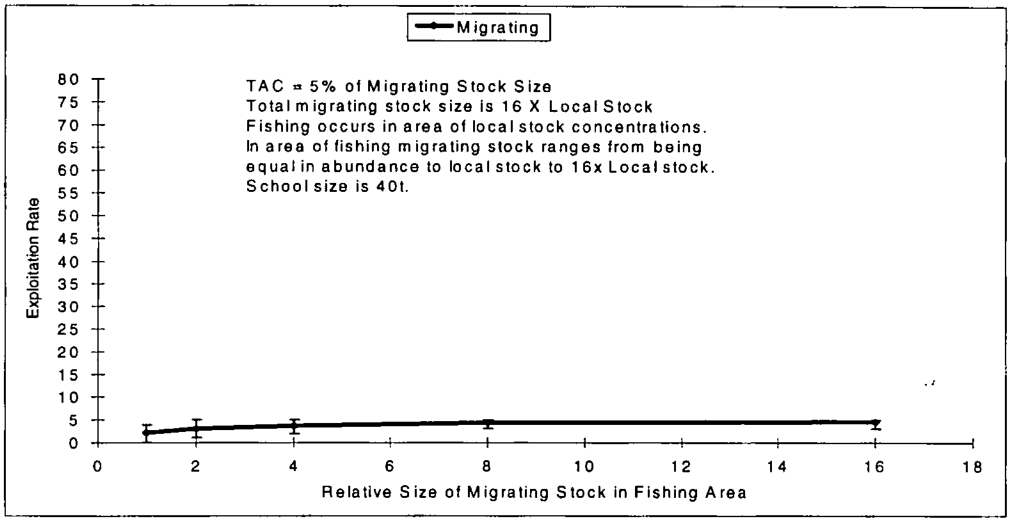


Fig. 2. Distribution of exploitation rates expected in small and large stocks from scenario described in Fig. 1.



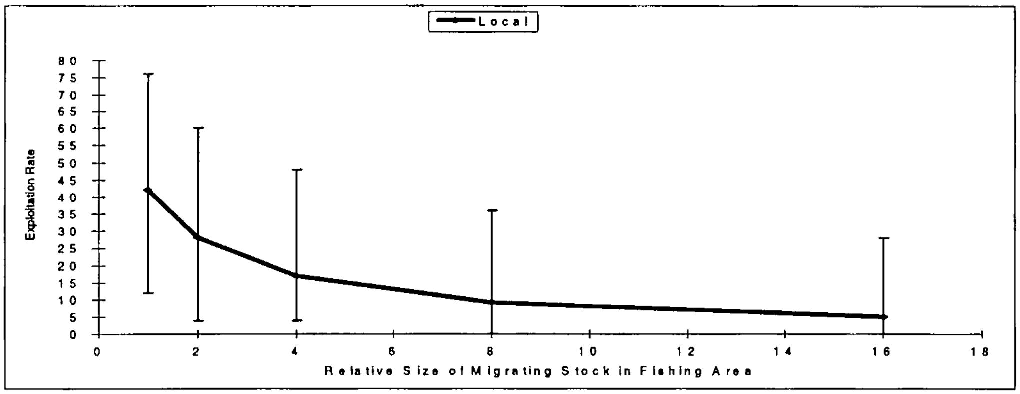


Fig. 3 Average exploitation rates and variation around exploitation rates if the TAC is set to the size of the large stock that is 16X the small stock but fishing occurs in an area where stock sizes range form equal to 16X greater for the large stock.

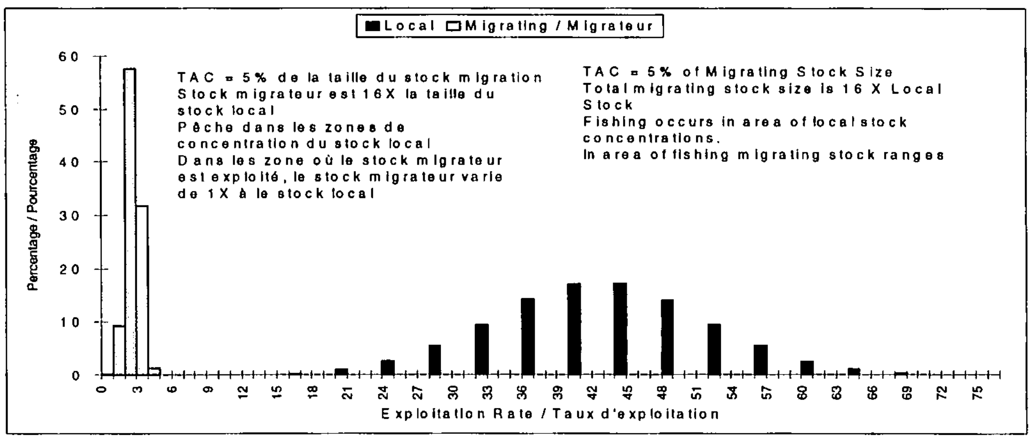


Fig. 4. Distribution of exploitation rates for large and small stocks under scenario described in Fig. 3.

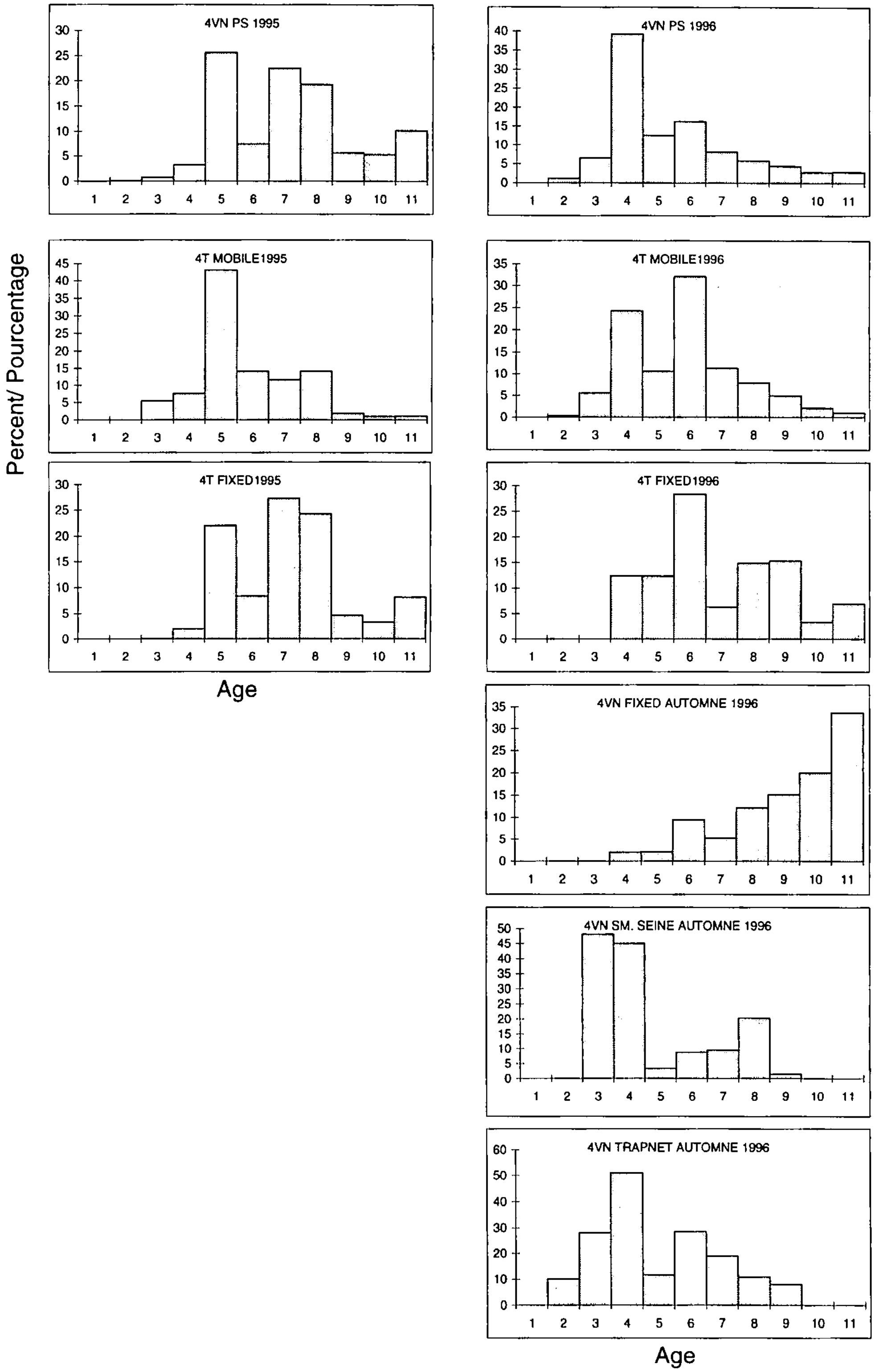


Fig. 5. Comparison of fall spawner catches in purse seine (mobile) and inshore (fixed) gears in 4T and 4Vn in 1995 and 1996.

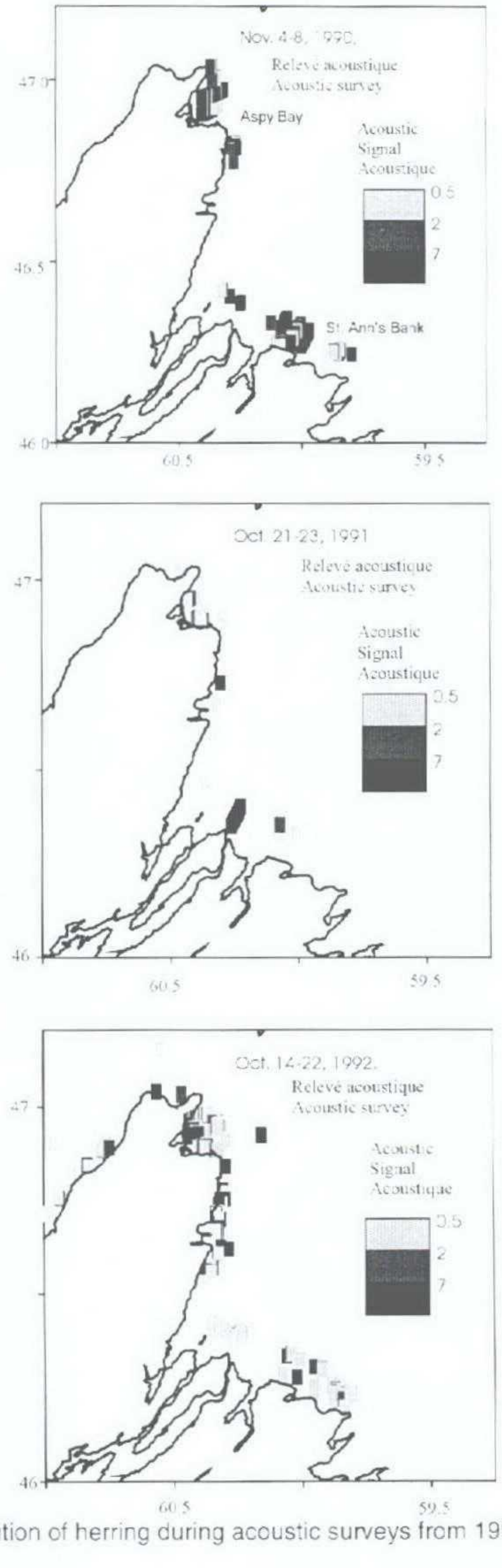


Fig. 6. Distribution of herring during acoustic surveys from 1990-1992 in 4Vn.

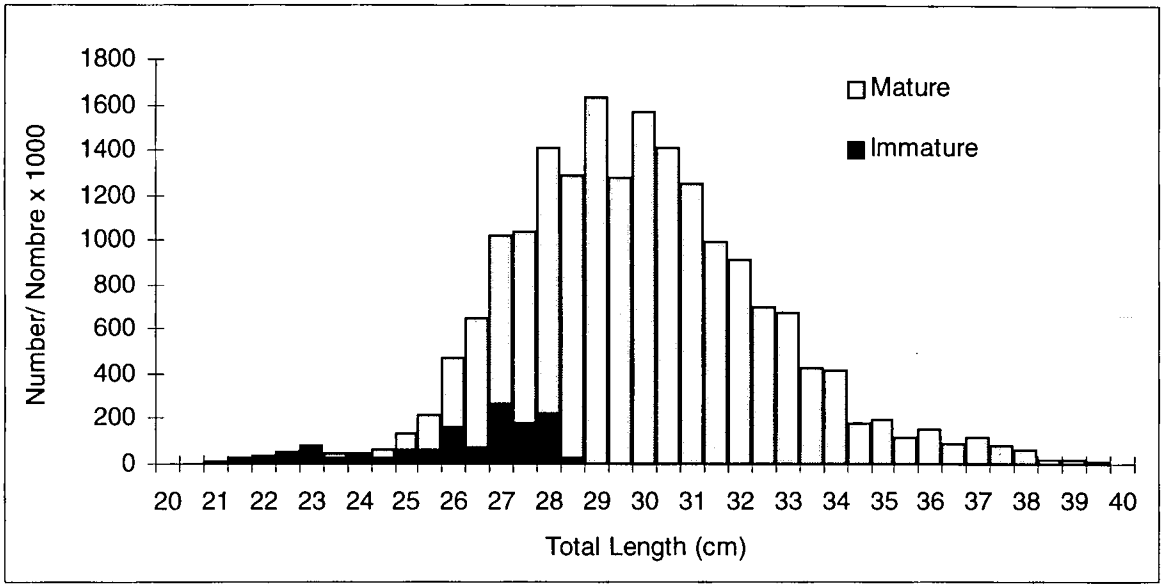


Fig. 7. Length frequency distribution of total catch by large seiners in 4Vn, 1996.

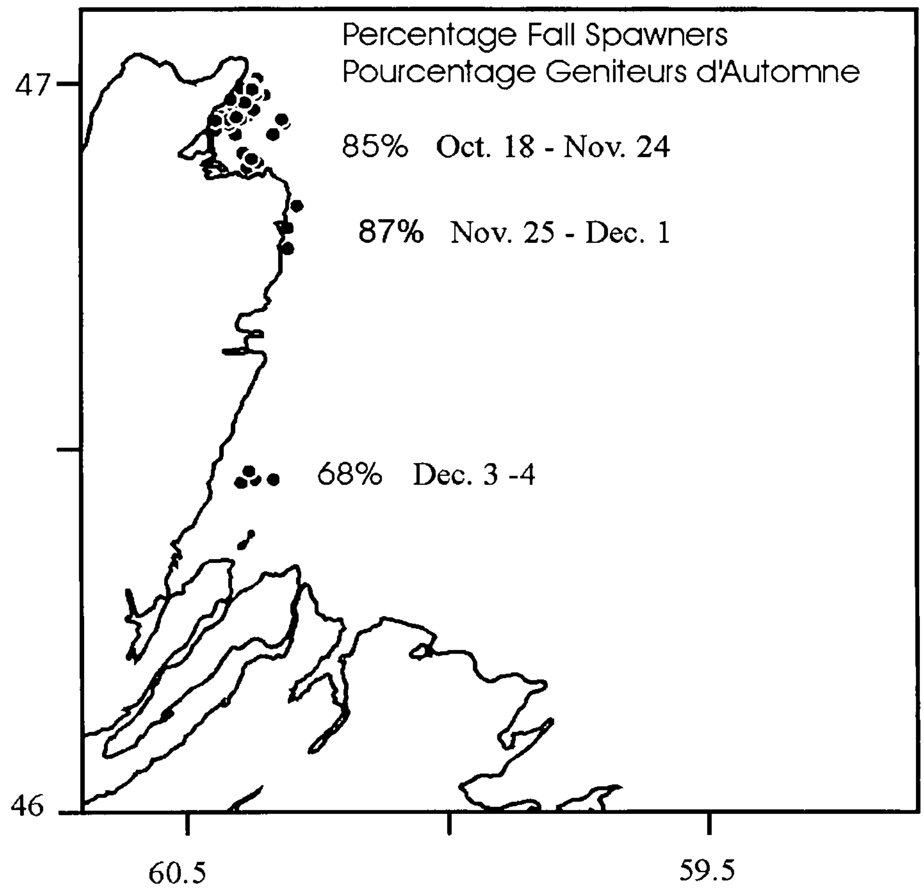


Fig. 8. Percentage of fall spawners in large seiner catch in 4Vn, 1996, by date and area.

Table 1. Large seiner fleet catches in 4Vn by spawning group from 1978 to 1996.

Year	Spawning Group Fall	Spring	Total	TAC	Percent Fall
78	1833	808	2641	8000	69
79	1418	1496	2913	3000	49
80	2981	870	3852	4500	77
81	2120	1162	3282	3000	65
82	2150	1373	3523	3000	61
83	2808	1167	3976	5000	71
84	3000	1004	4005	3500	75
85	2822	778	3600	3500	78
86	3105	1214	4319	4200	72
87	2093	279	2372	4200	88
88	2438	138	2576	4200	95
89	1959	159	2117	4200	93
90	3942	721	4663	4200	85
91	3871	921	4792	4200	81
92	3955	292	4247	4200	93
93	3722	219	3940	4200	94
94	2968	276	3244	4200	91
95	3990	153	4142	4200	96
96	3543	734	4276	6423	83
Ave. 78-96	2843	724	3567		80
Ave. 83-96	3158	575	3734		85
Ave. 91-95	3701	372	4073		91
Ave. 90-96	3713	474	4186		89

Table 2. Biomass estimates in tonnes from July and September bottom trawl surveys and October - December acoustic surveys in 4Vn from 1970-1996.

	Trawl Biomass		Acoustic	
Year	July	Sep	Biomass	Dates
70	6155			
71	2459			
72	1835			
73	10968			
74	No Est.			
75	739			
76	0			
77	667			
78	31			
79	0			
80	No Sets			
81	0			
82	0			
83	0			
84	1940		75724	Nov 17-26
85	0		106865	Nov 23-26
86	230		127708	Dec 1-12
87	39345		443058	Nov 17-24
88	81		172886	Nov 21-22
89	0			No survey
90	9		135249	Nov 4-8
91	4997		4418	Oct. 21-23
92	0		44845	Oct. 14-22
93	417		12512	Oct 15-20
94	8788	8773		No survey
95	1773	5201	5295	Sep 24-26
96	0		21804	Oct. 14-16

Table 3. Landings of immature herring by large seiners in 4Vn, 1992-1996.

Year	Immature (t)
92	59
93	26
94	308
95	0
96	285
Ave. 92-95	98

Table 4. Number (x 1000) and biomass (t) of catch on Dec. 3-4 near St. Anns Bay by large seiners by spawning group and stock origin.

	Number	Wt (kg)	Lth (cm)	Biomass
Fall Spawners				
Immature	153	0.1255	26.3	19
Maturing	113	0.1780	29.7	20
Spawning	0	0.0000	0.0	0
Spent	1705	0.1865	30.0	318
Total				357
Spring spawners 4T				
Immature	18	0.1080	24.8	2
Maturing	303	0.2050	29.6	62
Total				64
Spring spawners Unknown				
Immature	13	0.1010	24.4	1
Maturing	447	0.2267	30.6	101
Total				103
Spring Spawner Total				167
Printemps + Automne				524

Appendix 1. Example of program used to investigate exploitation rates on local and migrating stocks. In this example, the area where fishing occurs has equal numbers of local and migrating fish, even though the total migrating stock is 16 times the size of the local stock.

```
'loccond.bas
' estimates exploitation rates for migrating and local
' stocks using various school sizes and population sizes

CLS

NumSim = 10000

'OPEN "M1611r.txt" FOR OUTPUT AS #1
OPEN "EM16s40b.txt" FOR OUTPUT AS #2

MigSchSize = 40
LocSchSize = 40
LocPop = 1000
MigPop = LocPop * 16
EffMigPop = LocPop


Tac = MigPop * .05

NumMigSch = EffMigPop / MigSchSize
NumLocSch = LocPop / LocSchSize
TotSch = NumMigSch + NumLocSch

ProbLoc = NumLocSch / TotSch

catch = Tac / MigSchSize
catch = INT(catch) + 1

PRINT "Migrating School Size", MigSchSize
PRINT "Local School Size", LocSchSize
PRINT "Eff Migrating Population Size", EffMigPop
PRINT "Local Poplation Size", LocPop

PRINT "TAC", Tac

PRINT "Number of Migrating Schools", NumMigSch
PRINT "Number of Local Schools", NumLocSch
PRINT "Total Schools", TotSch

PRINT "Probability of catching local school", ProbLoc

PRINT "Catch", catch

INPUT y$

DIM BinLoc(0 TO 100)
DIM BinMig(0 TO 100)
FOR i = 0 TO 100
 BinLoc(i) = 0
 BinMig(i) = 0
'  PRINT i, BinLoc(i), BinMig(i)
```

```
NEXT i
'input y$

FOR j = 1 TO NumSim
 LocCat = 0
 MigCat = 0

FOR i = 1 TO catch
 IF RND <= ProbLoc THEN
  LocCat = LocCat + 1
  ELSE MigCat = MigCat + 1
 END IF
NEXT i

'CLS

LOCATE 1, 5
PRINT "Simulation", j
'PRINT "Local Schools Caught", LocCat
'PRINT "Migrating Schools Caught", MigCat
LocER = ((LocCat * LocSchSize) / LocPop) * 100
MigER = ((MigCat * MigSchSize) / MigPop) * 100
IntLer = INT(LocER)
IntMer = INT(MigER)
'PRINT "Local ER", LocER
'PRINT "Integer Local ER", IntLer
'PRINT "Migrating ER", MigER
'PRINT "Integer Migrating ER", IntMer

FOR b = 0 TO 100
 IF IntLer = b THEN BinLoc(b) = BinLoc(b) + 1
 IF IntMer = b THEN BinMig(b) = BinMig(b) + 1
 IF IntLer > 100 THEN BinLoc(100) = BinLoc(100) + 1
 IF IntMer > 100 THEN BinMig(100) = BinMig(100) + 1
NEXT b

'WRITE #1, j, LocER, MigER

'INPUT y$
'cls
NEXT j
CLS
INPUT y$

FOR b = 0 TO 100
  PRINT b, BinLoc(b), BinMig(b)
  WRITE #2, b, BinLoc(b), BinMig(b)
NEXT b

'CLOSE #1
CLOSE #2
```