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Stock Composition in the 4Vn Winter Herring Fishery

by

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Abstract

This paper examined three types of information to argue that Atlantic herring (*Clupea harengus*) caught in NAFO division 4Vn during October to December should be considered as part of the 4T stock complex. First, we examined acoustic surveys conducted since 1984 to identify the location of herring schools at this time of year. We found that although herring were generally not present in southeastern 4T, they were found in 4Vn and concluded that 4Vn was an important overwintering area for 4T herring. Second, stock characteristics from herring sampled in 4Vn were compared to those in adjacent areas. These analyses showed that herring sampled from 4Vn in recent years had similar stock structure and size distribution to herring from 4T, but were very different from 4X herring. Finally, tagging studies that took place in 1977, 1978, and 1979 were re-examined. These studies indicated that most herring tagged in 4Vn were recaptured in 4T fisheries. There was no evidence to conclude that migratory patterns of herring tagged north and south of the Point Aconi Line were different. We concluded that herring overwintering in NAFO Subdivision 4Vn during November and December have closer affinity to 4T herring stocks than to herring from division 4X.

Résumé

On a examiné trois types d'information pour démontrer que le hareng de l'Atlantique (*Clupea harengus*) capturé dans la division 4Vn d'octobre à décembre doit être considéré comme faisant partie du stock de 4T. Premièrement, on a étudié les relevés acoustiques réalisés depuis 1984 pour déterminer l'emplacement des bancs de hareng à la période considérée. Il est apparu que le hareng était généralement absent du sud-est de 4T à cette période, mais qu'on en trouvait dans 4Vn, ce qui permettait de conclure que la sous-division 4Vn est une zone d'hivernage importante pour le hareng de 4T. Deuxièmement, on a comparé les caractéristiques du stock de hareng échantillonné dans 4Vn à ceux du hareng des zones adjacentes. Il ressort de cette comparaison que la structure de stock et la distribution des tailles du hareng échantillonné dans 4Vn ces dernières années étaient comparables à celles du hareng de 4T, mais très différentes de celles du hareng de 4X. Enfin, on a réexaminé les résultats d'études de marquage réalisées en 1977, 1978 et 1979. Celles-ci révélaient que la plupart du hareng étiqueté dans 4Vn était recapturé dans 4T. Rien ne démontrait que les habitudes migratoires du hareng marqué différaient selon qu'il provenait du nord ou du sud de Point Aconi. Nous en avons conclu que le hareng qui séjourne dans la sous-division 4Vn de l'OPANO au cours de novembre et de décembre présente plus d'affinité avec le hareng de 4T qu'avec celui de la division 4X.

1. Introduction

The objective of this paper is to examine the biological basis for the advice on the winter Atlantic herring (*Clupea harengus*) fishery in NAFO division 4Vn. The current advice (Anon. 1992) states that, "the fishery in this division is based upon a mixture of southern Gulf of St. Lawrence herring (division 4T), and Scotian Shelf herring (divisions 4WX) and some local stocks (4Vn)."

This advice stems from previous work (Anon. 1983) which stated that, "fish tagged in the more southern portion of Subdivision 4Vn tend to move into Division 4WX, while those tagged in the more northern portion tend to move into the Gulf of St. Lawrence. ... Results of a tagging experiment indicate that local stocks ... are exploited by the winter fishery."

A re-analysis of tagging data in 1990 found no reason to change the above conclusion (Anon. 1990).

We argue that herring caught in 4Vn during October to December should be considered as part of the 4T stock complex. Our arguments are supported by three types of information. First, we examined acoustic surveys conducted since 1984 to identify the location of herring schools at this time of year. Second, stock characteristics from herring sampled in 4Vn were compared to those in adjacent areas. Finally, tagging studies that took place in 1977, 1978, and 1979 were re-examined.

2. History of 4Vn boundaries and the winter fishery

Division 4V was split into northern and southern areas in 1958 (Halliday and Pinhorn 1990). The split was recommended because tagging experiments had shown that Atlantic cod (*Gadus morhua*) in the northern parts of 4V in winter were from the Gulf of St. Lawrence. The boundary was not made to accommodate knowledge of the movements of herring stocks.

Since 1978, the fishery has taken place mainly in November and December. Landings have occurred in January in only three years: 1980, 1981 and 1984. The fishery has been located north of the Point Aconi line since 1979. Before 1979, most of the fishery occurred south of the Point Aconi line (Sinclair et al. 1981).

3. Location of herring schools

Acoustic surveys have been conducted since 1986 in the Gulf of St. Lawrence and along the west and northeast coasts of Cape Breton from October to December (Figure 9). These surveys are described in Cairns et al. (1989), and LeBlanc et al. (1993). Surveys have also been conducted in Chedabucto Bay and along the south and eastern coasts of Cape Breton during January, every year since 1984 (Figure 10). These surveys are described by Buerkle (1992) and indicate that the only concentrations of fish likely to be found from November to January are in the Sydney Bight area and in Chedabucto Bay. Herring are generally not present in other areas. In October, small concentrations of herring were found near eastern PEI, but they were never found later in the year. It seems likely that herring from spawning grounds in the southeastern Gulf have migrated out of the Gulf and into the Sydney Bight area by early November.

The coast line of Nova Scotia, north of Chedabucto Bay, was examined in 4 of 7 years, 1984-91. Although surveys were not comprehensive, herring were not found north of Chedabucto Bay during January. There was no evidence that herring from division 4X had moved north before the end of January.

4. Stock characteristics

Since 1981, sampling of this fishery has been poor. In all but one year <150 fish were sampled from each spawning group (Table I); 150 fish being a minimum number to construct age-length keys. In some years >40% of the catch was spring spawners. Because of the poor sampling we were unable to examine age structure.

Table I Sampling in the 4Vn winter fishery

Year	Catch (tonnes)	Winter fishery Sample size Fall	Winter fishery Sample size Spring	Winter fishery Percent spring spawners	Acoustic survey Sample size	Acoustic survey Percent spring spawners
1977	7078	2651[a]		NA		
1978	2849	339[a]		41		
1979	2910	139	152	49		
1980	3851	834	404	35		
1981	3434	99	150	40		
1982	3520	175	139	44		
1983	3980	209[a]		NA		
1984	3925	395[a]		NA		
1985	3470	227[a]		NA		
1986	4352	379[a]		NA		
1987	2372	230	38	14	456	48
1988	2572	380	39	10	205	35
1989	2117	113	12	10		
1990	4711	0	0	15	136	46
1991	4967	157	39	NA	114	19
1992		400[a]		NA		

[a] - sample size of spring and fall spawners combined

NA - not available

To understand the stock composition of herring caught in the 4Vn winter fishery we examined spawning group and size distributions.

4.1 Spawning group

Spring spawners are known from herring stocks in divisions 4T and 4R and in Bras D'Or Lakes. Spring spawners were identified in 4Vn using otolith characteristics; in 4T they were identified using gonad weight. During the period 1978 to 1982 we have five estimates of spawning group for 4T and 4Vn fisheries. From 1983-86 we have no estimates of spawning group in 4Vn; from 1987-91 we have 4 estimates from commercial samples and four estimates from acoustic surveys. The eight estimates were pooled in Table II. For the two time periods, the estimated percentage of spring spawners are similar for 4T and 4Vn and equal 0% for 4X.

Table II

Years	Percent spring spawners in the catch		
Area	4T	4Vn	4X
1978-82	39	42	0
1987-91	26	23	0

4.2 Length-frequency distributions

We compared distributions and means of sample lengths among divisions and years from 1988 to 1991. A longer time period could not have been used because data were not available for 4X in 1987 or for 4W in 1992.

In division 4Vn, samples were taken from mobile gear fishery except in 1990 where there was no sampling of the commercial fishery and samples were taken from the acoustic survey.

In division 4T, 80% of the catch was taken by gill nets, therefore length frequencies were examined for both fixed and mobile gears. The purse seine fishery occurred only in the fall (July to December) and in northern 4T, which includes unit areas 4Tn, 4Tm, and 4To. Samples from the fixed gear fishery were divided into: 1) spring (January to June) gill nets south, which includes 4Tg, 4Th, and 4Tf; 2) fall gill nets north; and 3) fall gill nets south.

In Division 4W all samples were taken from the purse seine fishery during November and December. This fishery has similar timing to the 4Vn winter fishery.

In Division 4X, samples came from the purse seine fishery during the months of September and October for all areas excluding New Brunswick. Fish taken at this time of year would have finished their season's growth, similar to the stage of growth for herring sampled in the 4Vn winter fishery.

Sample means and variances were compared using the Least Squares Means test (SAS 1989). To remove the potential problem of selective fishing for small herring, only fish > 25 cm were included in the analysis.

The results are summarized in Table III. The upper part of the table gives the mean length (cm) of herring sampled in the four divisions. The lower part of the table gives the empirical significance level (p-value) for the test that each mean length equals the 4Vn mean length. The results indicate that mean length of samples from the 4Vn fishery was not significantly different from 4T fisheries in 13 of 16 possible comparisons. By contrast mean length in the 4Vn fishery was significantly different from 4W and from 4X in all eight comparisons.

In general, herring sampled from 4Vn were the same average size as those sampled from both fixed and mobile gear fisheries in 4T. By contrast, 4Vn herring were always larger than herring sampled from 4W and 4X.

Table III Comparison of mean length of herring >25 cm sampled from fisheries in Divisions 4Vn, 4T, 4W, and 4X, 1988-1991.

Year	4Vn Mobile	4T Mobile	4T Fixed Spring North	4T Fixed Fall North	4T Fixed Fall South	4W Mobile	4X Mobile
				Mean length (cm)			
1988	31.8	32.4	32.1	32.2	32.5	30.9	30.2
1989	32.7	32.8	31.7	32.8	33.3	30.6	31.1
1990	32.4	31.4	32.5	33.3	33.6	30.7	30.4
1991	32.4	29.6	31.8	31.7	33.2	30.1	29.5
Empirical significance level (p-value) for the test *area mean length = 4Vn mean length*							
1988		0.111	0.536	0.244	0.028	0.009	0.001
1989		0.964	0.110	0.909	0.350	0.001	0.009
1990		0.062	0.977	0.107	0.016	0.001	0.001
1991		0.001	0.229	0.190	0.102	0.001	0.001

Length-frequency distributions for each gear type and division are shown for each year from 1988- to 1991 in Figure 11 to Figure 14 (at the end of the paper). The samples were aggregated without weighting by the catch.

Length-frequency distributions of aggregated samples were compared for each year using quantile-quantile plot (Q-Q plots). Q-Q plots were created using SYGRAPH (Wilkinson, 1990). A Q-Q plot is a plot of corresponding quantiles of two distributions, where the p_{th}-quantile ($0<p<1$) is the value x such that a fraction p of the observations is smaller or equal to x. For grouped data, intermediate values are obtained by interpolation. If the variables are measured on the same scale and the drawing scales are identical, two samples have the same distribution if the Q-Q plot falls on the diagonal. For example, Figure 1 shows that the length-frequency distribution from the mobile gears in 4T North and from the acoustic survey in 4Vn in 1990 are nearly identical. Figure 2 shows that the length-frequency distribution from the mobile gears in 4X and from the acoustic survey in 4Vn in 1990 are very different (the fact that the curve is below the diagonal actually indicates that the distribution from 4X is more to the left relative to that from 4Vn).

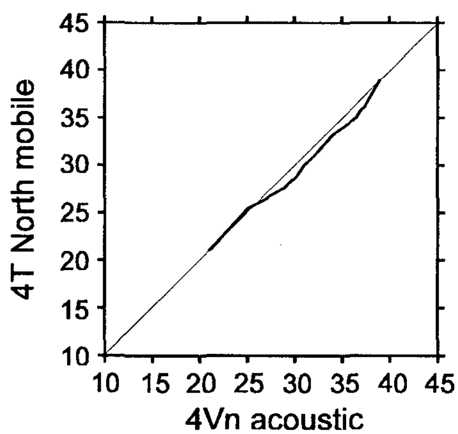

Figure 1 Q-Q plot of length frequency distributions for mobile gears in 4T north versus acoustic survey in 4Vn (1990)

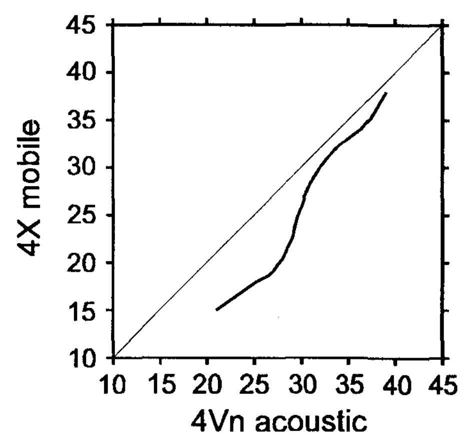

Figure 2 Q-Q plot of length frequency distributions for mobile gears in 4X versus acoustic survey in 4Vn (1990)

For each year, all possible comparisons are shown in a half-matrix of Q-Q plots (Figure 3 to Figure 6). Notice that a sample is represented on the **horizontal** axis for Q-Q plot **below** it and on the **vertical** axis for the Q-Q plots to the **left** of it. This should be kept in mind in interpreting the plots. For example, in 1991 (Figure 6), 4X mobile and 4T North fixed deviate from 4Vn in **opposite** directions.

The top cell from each figure shows that the fixed gears length distribution from 4T North and 4T South are nearly identical in all years. The Q-Q plots for the 4T division (the top 3 cells in the figures) show that samples from fixed gears and from mobile gears tend to be different, the mobile gear catching more small fish.

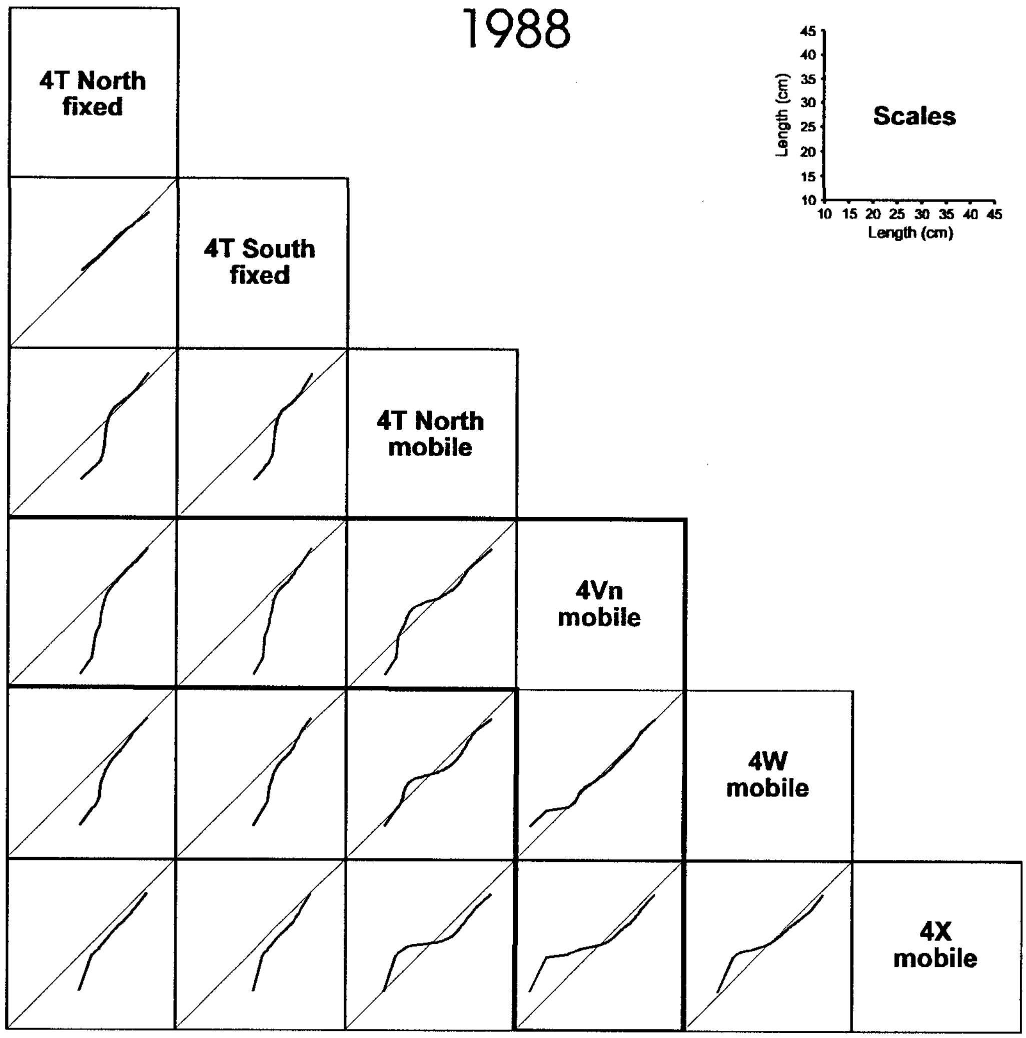

Figure 3 Half matrix of Q-Q plots comparing herring length distribution from various areas and sampling methods for 1989

The 1988 data (Figure 3) show that the 4Vn mobile gear length distribution was similar to the 4W distribution except for very small fish and, to a lesser extent, to the 4T North mobile gear distribution. Furthermore, the 4Vn and 4X distributions were different.

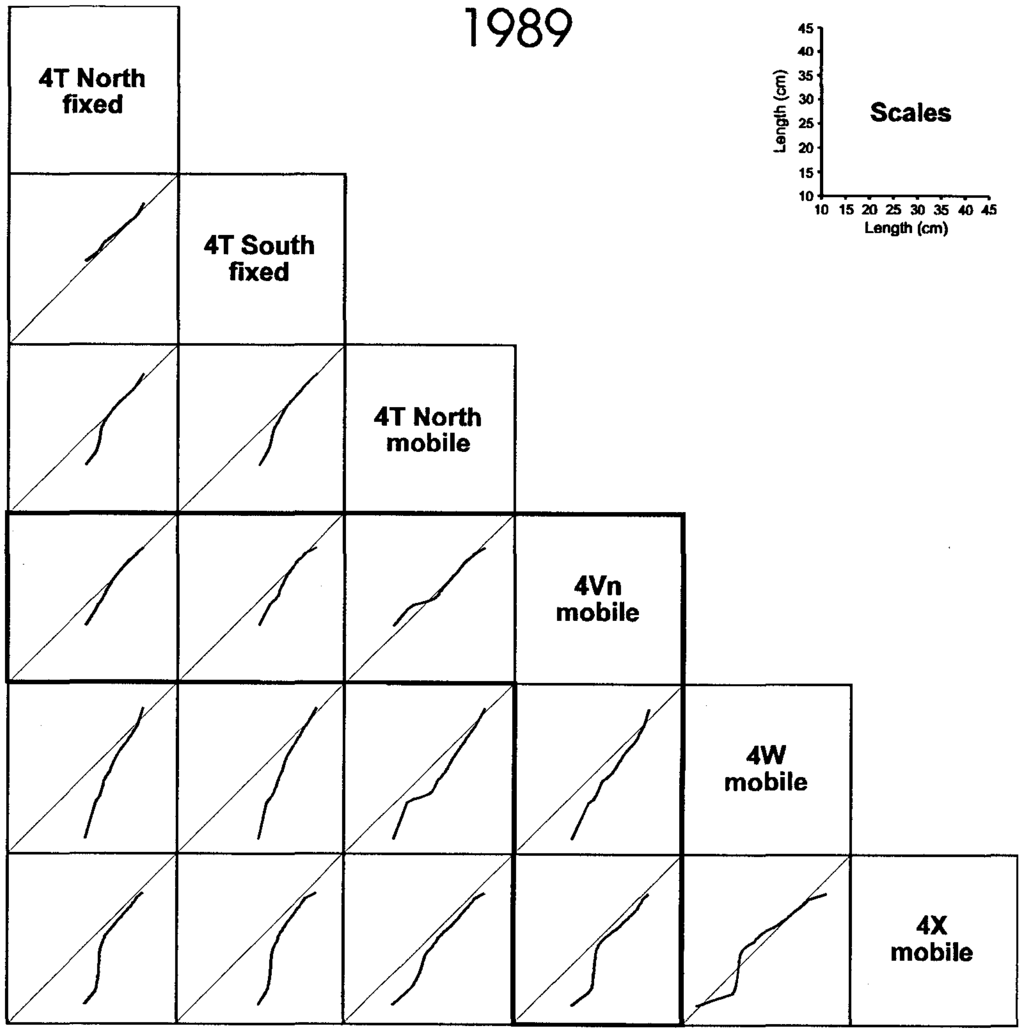

Figure 4 Half matrix of Q-Q plots comparing herring length distribution from various areas and sampling methods for 1989

The 1989 data (Figure 4) showed that the 4Vn mobile gear length distribution was similar to the 4T distributions and very different from the 4X distribution.

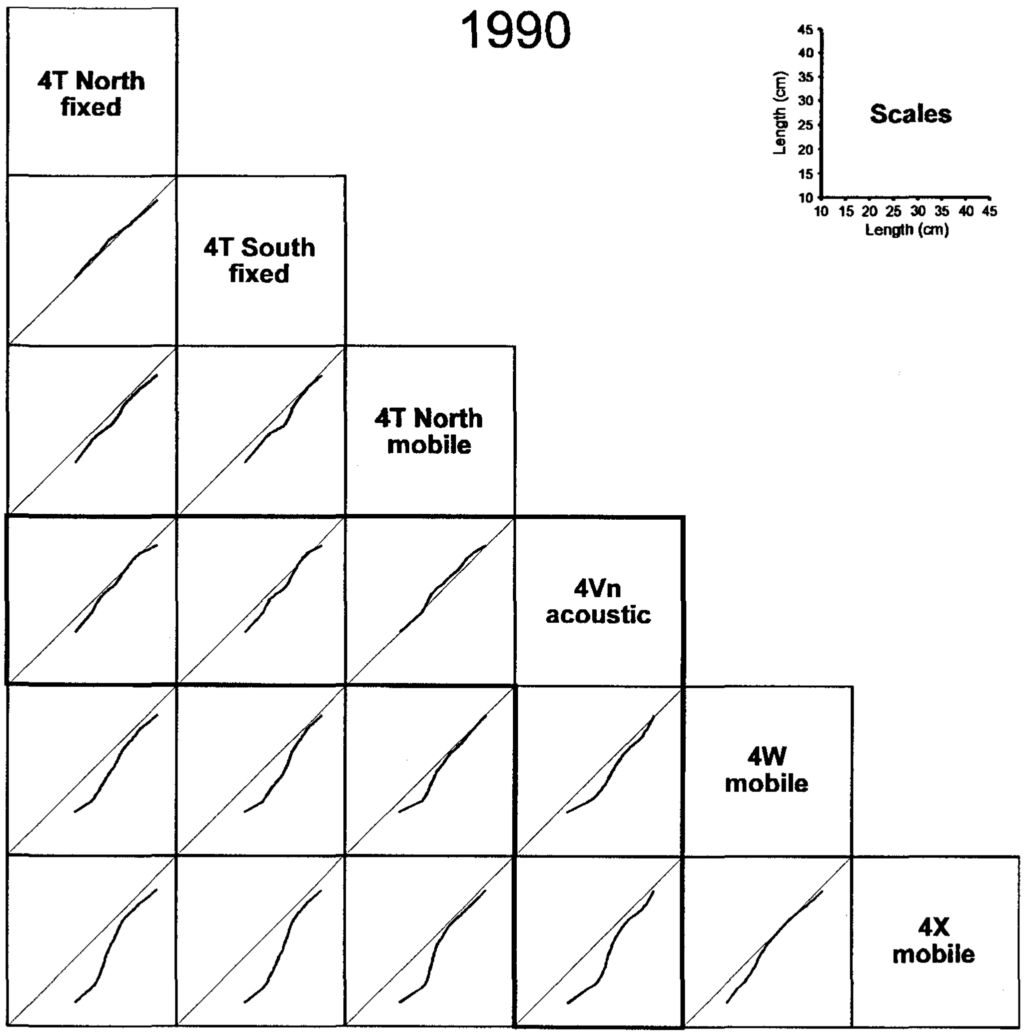

Figure 5 Half matrix of Q-Q plots comparing herring length distribution from various areas and sampling methods for 1990

The 1990 data (Figure 5) showed that the 4Vn acoustic gear length distribution was similar to the 4T distribution but different from the 4X distribution.

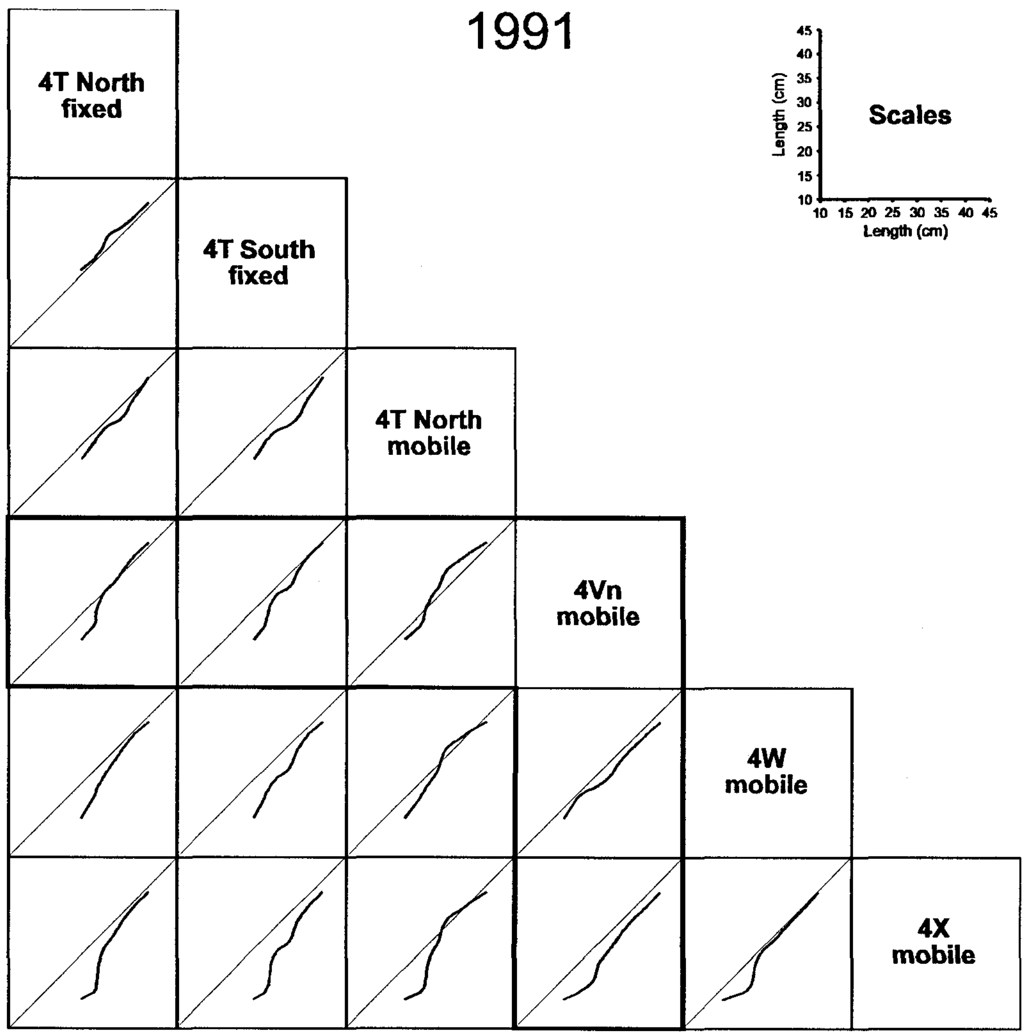

Figure 6 Half matrix of Q-Q plots comparing herring length distribution from various areas and sampling methods for 1991

The 1991 data (Figure 6) showed that the 4Vn mobile gear length distribution was most similar to the 4W mobile and 4T North fixed gear distributions.

In general, the 4Vn distributions were most closely associated with the 4T north mobile gear distributions but they also resembled the 4W distribution in two of four years.

5. Tagging studies

5.1 Background

Stock origin of herring overwintering in 4Vn was explored in a series of tagging experiments, 1977 to 1979 (Stobo 1982, 1983 and W. Stobo, S. Courtenay and J. Gagné, unpublished data). Fish were tagged in division 4Vn during the winter fishery using purse seiners. Tagging data are presented in the following documents: Sinclair et al. (1981) summarizes the type of gear where tags were recovered; Stobo (1982) summarizes the month and number of tags by NAFO Division; exact locations of tag recaptures were provided by W. Stobo (unpublished data).

Preliminary analyses of tag recaptures were presented by Stobo et al. (unpublished data). There were several limitations with these analyses. First a few tags of questionable origin were included in the analysis. Second, tags were combined over years, and it was not possible to examine any annual variation in tag recaptures. Third, there was no analysis of tags applied north and south of the Point Aconi Line. Finally, the analyses did not account for the two spawning stocks in 4T. Ideally, tag recapture rates should be analyzed separately for spring and fall spawners.

Dealing first with questionable tags. In 4X, most tags were recovered from purse seine fisheries located in southwest Nova Scotia and near Digby. The project leader, W. Stobo, said that recoveries from southwest Nova Scotia could also include herring that were caught in 4Vn but trucked to plants near Yarmouth. There was no way of identifying these tags. The following tags were excluded from recoveries in 4X. Four tags recovered near Halifax, probably at Herring Cove, which is on the border between 4X and 4W. Three tags recovered near Berwick and Kentville, which does not border on the sea. And finally, one tag recovered near Sable Island, which is outside 4X. Weighting of tag returns by landings was done only for the purse seine fisheries in 4X. A summary of tag recaptures by Division is in Table IV. Note that the column 4XW includes the 8 tag recoveries excluded from 4X and from 4W. The column 4Vn includes all tags recovered in this area.

In this analysis, we attempt to address some of the shortcomings of the previous studies. We have examined tag returns separately for each tagging year, 1977, 1978, and 1979. Recovery years (first, second, and third year after tagging) were also treated separately. In addition, tags applied north and south of the Point Aconi Line were treated separately; we test the hypothesis that there was no difference in return rate of tags applied in the two locations. Therefore we have a total of 12 experiments that are summarized in Table IV.

Table IV Tag recovery according to Division, tagging year and season and recovery year

				Tag recaptures					
Tagging year	Tagging location	Number tagged	Recovery year	4T Spring	4T Fall	4X	4W	4XW	4Vn
1977	South	3082	1	0	1	9	5	19	13
			2	1	0	0	0	0	3
			3	1	0	0	0	0	0
1978	North	1888	1	8	2	0		0	
			2	1	0	0		0	
			3	0	0	0		0	
1978	South	2106	1	2	1	0		0	
			2	2	0	0		0	
			3	0	0	0		0	
1978	Both	3994	1	10	3	0	13	13	70
			2	3		0	2	2	8
			3	0	0	0	0	0	0
1979	North	10705	1	33	18	4	16	21	64
			2	4	7	3	0	5	1
			3	0	1	0	0	0	0
Total				**52**	**30**	**16**	**36**	**60**	**159**

North refers to tags applied north of the Point Aconi Line.
South refers to tags applied south of the Point Aconi Line.

The most contentious aspect of tagging studies is to assume that the chance of recovering a tag is equal in all areas. Location of tag recaptures in 4T is summarized by gear type in Table V. Tag return rates varied greatly among fisheries. More than half of the tags were recovered in the spring fishery by mobile gear. This fishery had return rates 14 times greater than the fall mobile fishery, 7 times greater than the spring fixed-gear fishery, and more than 2 times greater than the fall fixed-gear fishery.

Table V Tag recapture rate according to gear and season

Fishery	Proportion of tag recaptures (%)	Proportion of total catch (%)	Proportion of spring spawners (%)
Spring mobile	55	21	54
Spring fixed	8	20	95
Fall mobile	15	42	27
Fall fixed	22	17	5
TOTAL	**100**	**100**	**100**

It is not known why the fisheries had such different recapture rates. Reasons would include: gear selectivity, on-board processing of fish, tag loss, tagging mortality, and of course reporting rates. One reason that might explain the higher capture rate in the spring is that many tagged fish were < 30 cm and therefore less likely to be caught in gill nets. It is also possible that addition over time of herring overwintering in other areas, possibly the Laurentian Channel, would dilute the tagged-to-untagged ratio (S. Courtenay, pers. comm.). Because of the high variation in reporting rate, weighting of tag returns was done using exploitation rates in the spring purse seine fishery only; we assumed that reporting rates were similar for both 4T and 4X.

5.2 Weighting returns

A simple model for the expected number of tags recovered in a region is:

$$E(TRec_G) = C_G \times ExR_G \times FR_G \times TRel$$

where

G = the region (i.e. G="4T", G="4X", etc.)

$TRec_G$ = Number of tags recovered in region G

C_G = A factor depending on unknowns, like reporting rate

ExR_G = The exploitation rate

FR_G = The fraction of the 4Vn stock migrating to region G

$TRel$ = The number of tags released in 4Vn.

There will be annual random variation in FR_G and C_G and estimation error in ExR_G. It is probable that tags were less likely to be recovered in gill nets than other gears. Processors believe that herring landed by gillnet are in worse condition than those landed by other gears. However, although >40% of the 4T catch and <2% of the 4X catch was taken with gillnets, there was no quantitative evidence that the factor C_G is different between the two regions. Therefore, we assume that it is equal (i.e., $C_{4T} = C_{4X}$).

After rearranging, we obtain the following relationship:

$$FR_G \approx TRec_G \, / \, (C_G \times ExR_G \times TRel)$$

The ratio $Q=FR_{4X}/FR_{4T}$ is of interest. After simplification using the assumption that $C_{4X} = C_{4T}$, we obtain the relation:

$$Q = \frac{FR_{4X}}{FR_{4T}} \approx \frac{TRec_{4X} \, / \, (C_{4X} \times ExR_{4X} \times TRel)}{TRec_{4T} \, / \, (C_{4T} \times ExR_{4T} \times TRel)} = \frac{TRec_{4X} \, / \, ExR_{4X}}{TRec_{4T} \, / \, ExR_{4T}}$$

The fraction of the stock migrating to each region (relative to the total of the migration to both regions but excluding migrations to other regions) can be estimated by:

$$FR_{4T} \approx \frac{1}{1+Q} \quad \text{and} \quad FR_{4X} \approx \frac{Q}{1+Q}$$

The above estimators essentially use tag returns weighted by exploitation rate.

Table VI Estimation of the proportion of the 4Vn fishery migrating to 4T vs 4X.

Tagging year	Tagging location	Recovery year	Proportion of stocks migrating to 4T (vs 4X)	
			Without weighting	Weighted by exploitation rate
1977	South	1	0.10	0.18
1977	South	2	1.00	1.00
1977	South	3	1.00	1.00
1978	North	1	1.00	1.00
1978	North	2	1.00	1.00
1978	North	3		
1978	South	1	1.00	1.00
1978	South	2	1.00	1.00
1978	South	3		
1979	North	1	0.93	0.90
1979	North	2	0.79	0.70
1979	North	3	1.00	1.00

Table VI shows the estimates of FR_{4T} using tags returns weighted by exploitation rates for each of the 10 valid samples (two sets gave no returns). We observed that weighting by exploitation rate changes the estimates for three of the 10 sets. The estimate of the fraction of the stock migrating to 4T decreases for two sets and increases for one set. In all cases, the change is less than 10%. In view of the uncertainty in the estimate of the exploitation rate and for the sake of simplicity, we pursue the analysis without weighting.

5.3 Tag recovery rate

Our next analysis tested for consistency in recovery rates: Were recovery rates comparable for the 12 tagging experiments? Table VII shows the recovery rate for each sample. Figure 7 (a) shows the recovery rates versus the recovery year. The model above suggests that we should consider the logarithm of the recovery rate; Figure 7 (b) showed that the resulting model was satisfactory. Fitting a regression line to Figure 7 (b) showed that approximately 78% fewer tags were recovered in the second year compared to the first and that again 78% fewer tags were recovered in the third year compared to the second. Furthermore, the residuals were well behaved, showing that the all recovery rates were regular (i.e. there were no outliers). In this regard, it would be fair to say that unknown factors like tag return rate did not vary throughout the study and results from the 12 experiments could be examined separately.

Table VII Total tag recovery rates

Tagging			Recovery			
Year	Location	Number	Year	Number	Rate	Ln(rate)
1977	South	3082	1	10	0.00324	-5.731
1977	South	3082	2	1	0.00032	-8.033
1977	South	3082	3	1	0.00032	-8.033
1978	North	1888	1	10	0.00530	-5.241
1978	North	1888	2	1	0.00053	-7.543
1978	North	1888	3	0	0.00000	
1978	South	2106	1	3	0.00142	-6.554
1978	South	2106	2	2	0.00095	-6.959
1978	South	2106	3	0	0.00000	
1979	North	10705	1	55	0.00514	-5.271
1979	North	10705	2	14	0.00131	-6.639
1979	North	10705	3	1	0.00009	-9.278

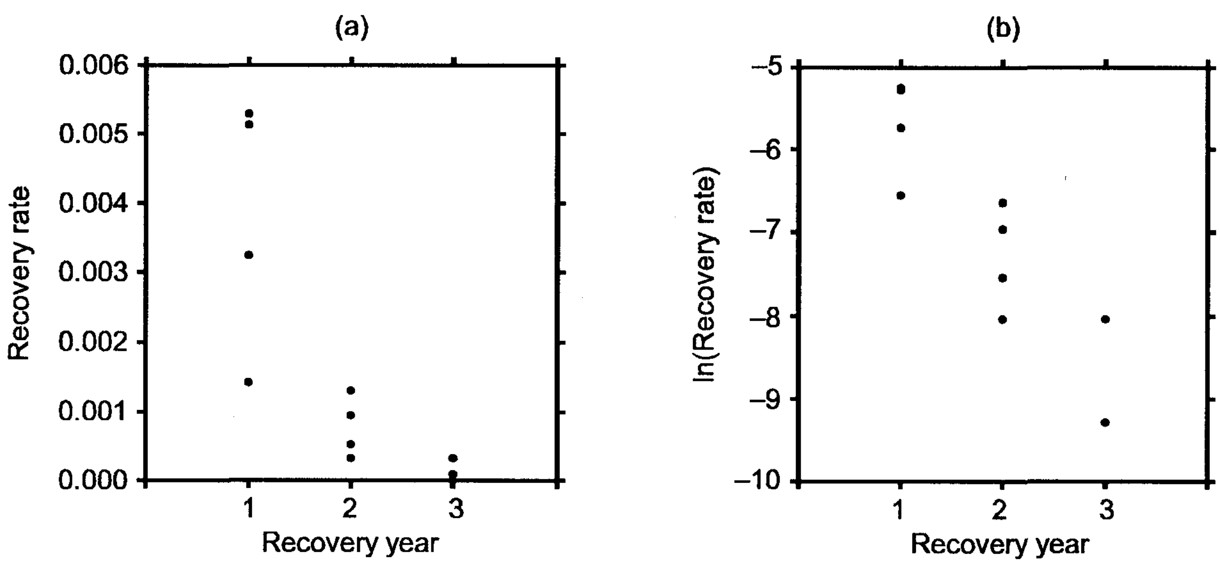

Figure 7 Recovery rates versus recovery year (raw and log scales)

5.4 Identifying outliers

The current biological advice on stock mixtures in 4Vn (Anon. 1992) is influenced greatly by results of the first return year of the 1977 tagging experiment. Because this experiment is only one of 12 experiments, it was important to test if the results were outliers. A box-and-whisker plots gives a "rule of thumb" to identify "outside" and "far out" values, e.g. outliers (Tukey, 1977). Tukey's definition is based on hinges and the H-spread. The following description is sufficiently close for our purpose.

All values in the 2nd and 3rd quartile of a distribution are considered "regular". A value in the first quartile is considered

"regular" if it is within 1.5 times the interquartile range from the 25th centile

"outside" if it is more than 1.5 times and less than 3 times the interquartile range from the 25th centile; they are often shown as asterisks on box-and-whisker plots

"far out" if it is more than 3.0 times the interquartile range from the 25th centile; they are often shown as dots on box-and-whisker plots.

The same terms are applied symmetrically to values in the 4th quartile.

In a box-and-whisker plot, the box shows (approximately) the 1st quartile and 3rd quartile. A line within the box shows the median (in the figure below, the median and the 3rd quartile are equal). The whiskers spread out to the last "regular" values on each side of the box (in the figure below, the last regular values equal their corresponding quartiles).

Figure 8 shows a box-and-whisker plot of the 10 unweighted estimates of the proportion of the stock migrating to 4T (compare to 4X). The asterisk identifies the 11th value (0.79) as "outside" and the dot identifies the 1st value (0.10) as "far out". (The box-and-whisker plot for weighted estimates is also shown for comparison.)

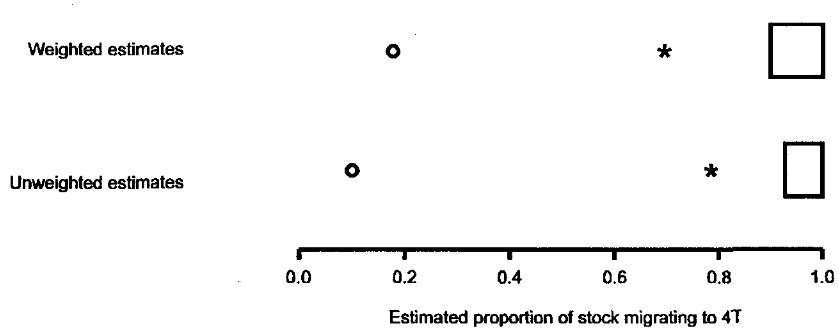

Figure 8 Compatibility of tagging experiments

Under the hypothesis of equal exploitation rates in 4T and 4X, if n tags are recovered in 4T and 4X, the number k of tags recovered in 4T follows a binomial distribution with parameters n and $p=FR_{4T}/(FR_{4T} + FR_{4X})$. We have computed the exact confidence interval for the proportion p of the population migrating to 4T versus 4X using the number k of tags in each sample. The confidence interval was computed using the method described in (Box, Hunter, Hunter, 1978, p. 131). Results are shown in Table VIII. There was a strong consistency between the samples, except for the first one.

Table VIII The 95% confidence interval for the proportion of the stock migrating into 4T.

Tagging year	Tagging location	Recovery year	Confidence interval for the proportion of stock migrating to 4T vs 4X	
			Lower bound	Upper bound
1977	South	1	0.003	0.445
1977	South	2	0.025	1.000
1977	South	3	0.025	1.000
1978	North	1	0.692	1.000
1978	North	2	0.025	1.000
1978	North	3		
1978	South	1	0.292	1.000
1978	South	2	0.158	1.000
1978	South	3		
1979	North	1	0.824	0.980
1979	North	2	0.492	0.953
1979	North	3	0.025	1.000

The box-and-whisker plot and the comparison of confidence intervals suggested that the first sample should be considered as an outlier.

5.5 Hypothesis testing

We have tested the hypothesis that fish tagged in 4Vn stocks migrate equally to 4T and 4X versus the alternative hypothesis that these fish migrate preferentially to 4T. Using a randomization test (Edgington, 1987) on the 12 samples, we found that the null hypothesis was rejected with a p-value of 0.048.

5.6 Combining the samples

Combining all the samples directly (without any weighting) gives an estimate of 0.837 and a confidence interval from 0.748 to 0.904 for the proportion of fish overwintering in 4Vn that migrated to 4T.

If we consider that the first sample is an outlier and remove it, the estimate becomes 0.920 and the confidence interval is from 0.843 to 0.967. There was no evidence that this proportion was different for tags applied north and south of the Point Aconi Line.

5.7 Combining 4X and 4W

One could suppose that the 4X and 4W are actually a single region which we refer to as 4XW. Using this supposition allows one to combine tags recovered in divisions 4X and 4W. The proportion of 4Vn stock migrating to 4T would be 0.75.

Table IX Estimation of the proportion of the 4Vn fishery migrating to 4T vs 4X.

Tagging year	Tagging location	Recovery year	Proportion of stocks migrating to 4T (vs 4XW)
1977	South	1	0.07
1977	South	2	1.00
1977	South	3	1.00
1978	North	1	1.00
1978	North	2	0.60
1978	North	3	
1978	South	1	0.50
1978	South	2	1.00
1978	South	3	
1979	North	1	0.72
1979	North	2	0.69
1979	North	3	1.00

6. Discussion

The evidence examined in this paper suggests that herring overwintering in NAFO Subdivision 4Vn during November and December have closer affinity to 4T herring stocks than to herring from Division 4X. Acoustic surveys conducted at this time of year showed that although herring were generally not present in southeastern 4T, they were found in 4Vn. This observation indicated that 4Vn is an important overwintering area for 4T herring.

Analyses of stock characteristics showed that herring sampled from 4Vn in recent years had similar stock structure and size distribution to herring from 4T, but were very different from 4X herring.

Finally, analysis of tagging studies conducted during the late 1970's indicated that most herring tagged in 4Vn were recaptured in 4T fisheries. There was no evidence to conclude that migratory patterns of herring north and south of the Point Aconi Line were different.

Sydney Bight is not the only mixing area for herring outside the Gulf of St. Lawrence. 4T herring are also captured in Chedabucto Bay (Stobo 1982). During this tagging study, approximately 12% of tags applied in Chedabucto Bay during winter were recovered from 4T fisheries in the first year after tagging.

Tagging of southern Gulf gaspereau stocks, a species closely related to herring, showed more dramatic migration into 4W. Of the 6660 gaspereau tagged during 1980 in homewater streams near Pictou, more than one third of tags were recovered in Chedabucto Bay (4W) and one tag was recovered in 4X (Crawford and Tully 1989). Thus, the capture of 4T herring in Chedabucto Bay could be as likely as the capture of 4X herring in Sydney Bight.

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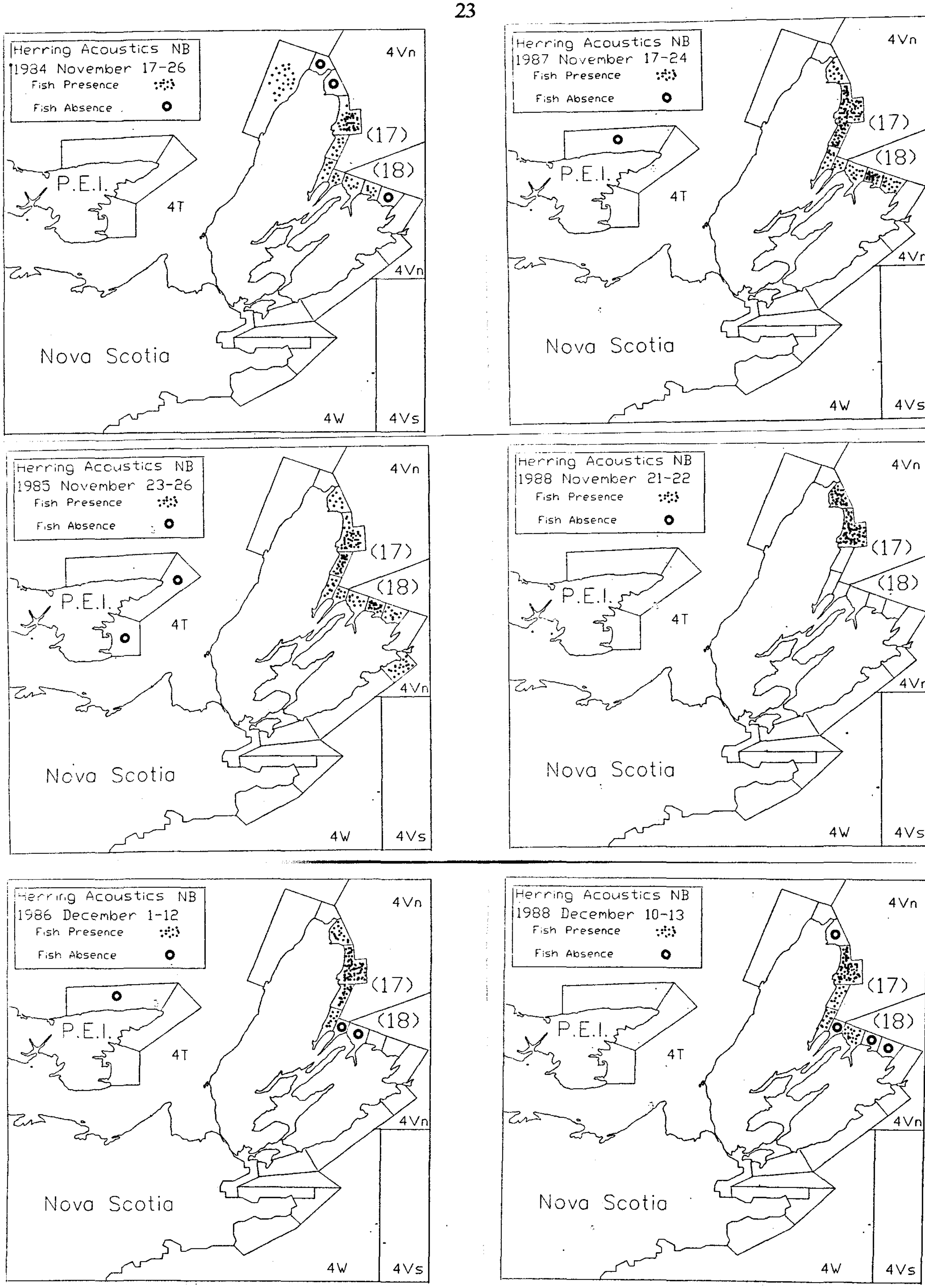

Figure 9 Results of acoustic surveys conducted in the Gulf of St. Lawrence and along the west and northeast coasts of Cape Breton from October to December

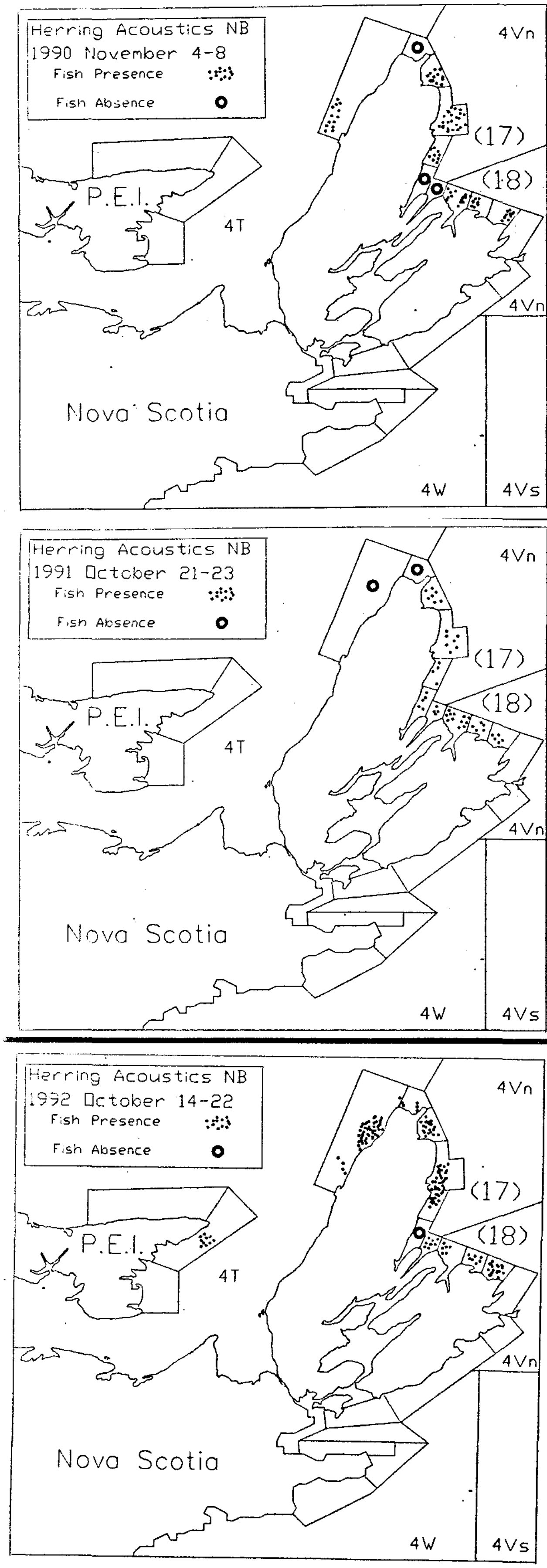

Figure 9 Results of acoustic surveys conducted in the Gulf of St. Lawrence and along the west and northeast coasts of Cape Breton from October to December (suite)

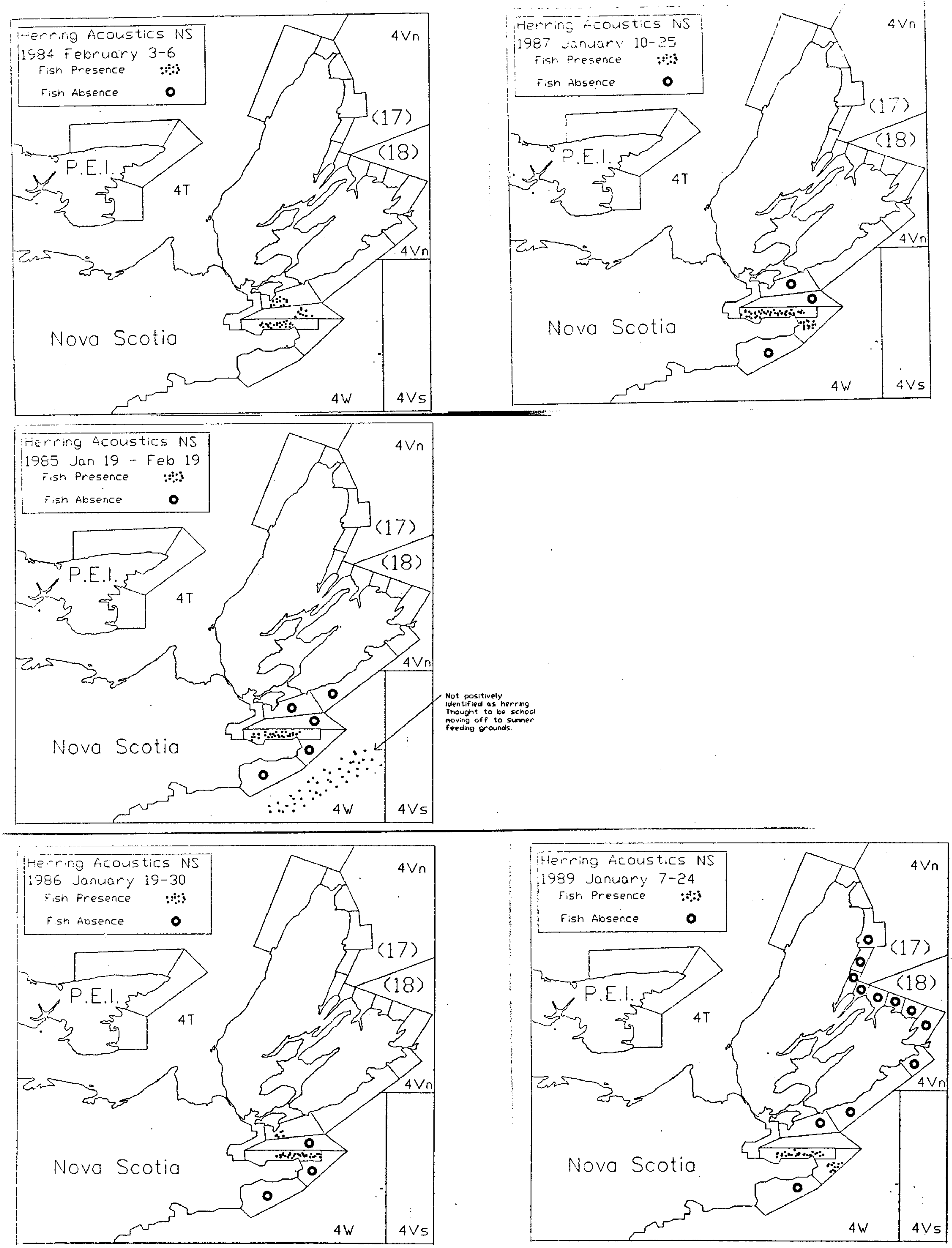

Figure 10 Results of acoustic surveys conducted in Chedabucto Bay and along the south and eastern coasts of Cape Breton during January

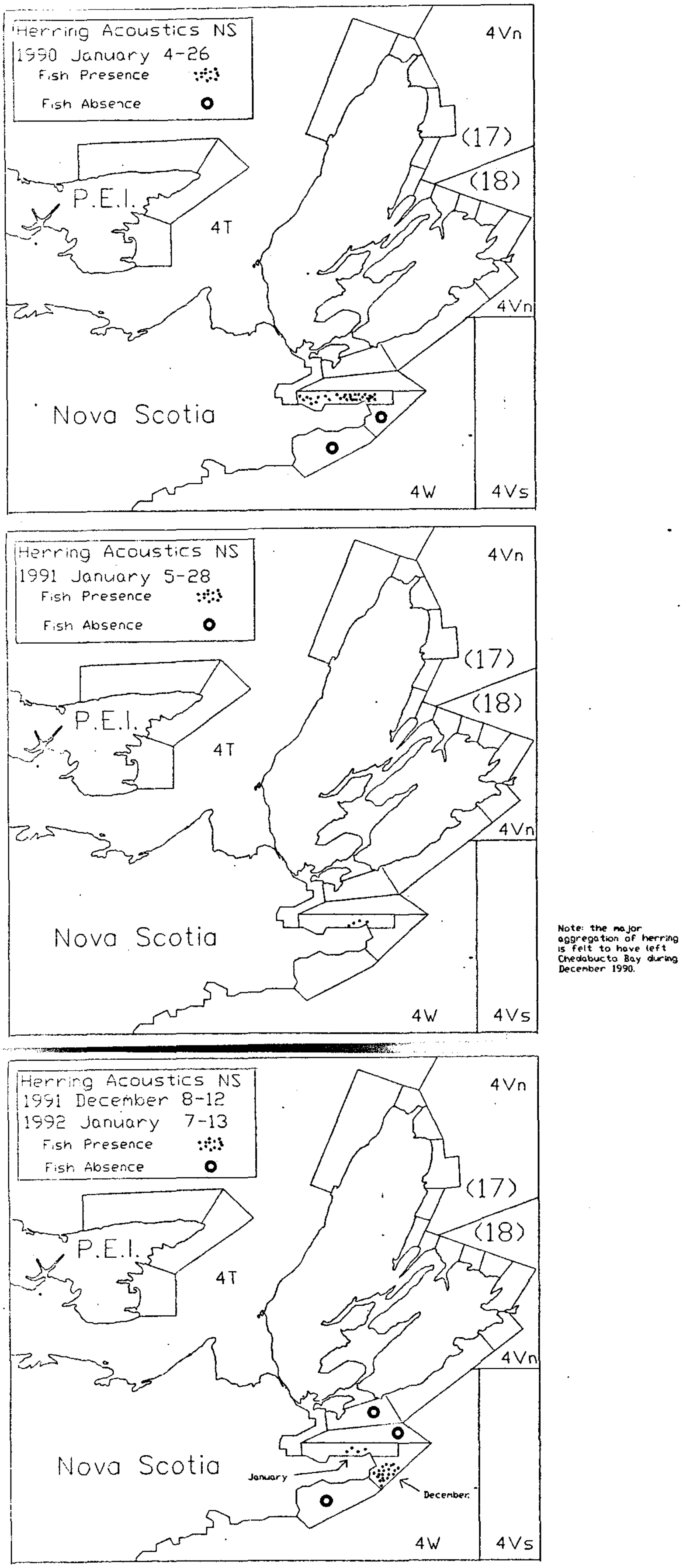

Figure 10 Results of acoustic surveys conducted in Chedabucto Bay and along the south and eastern coasts of Cape Breton during January (suite)

1988 herring proportional length frequencies

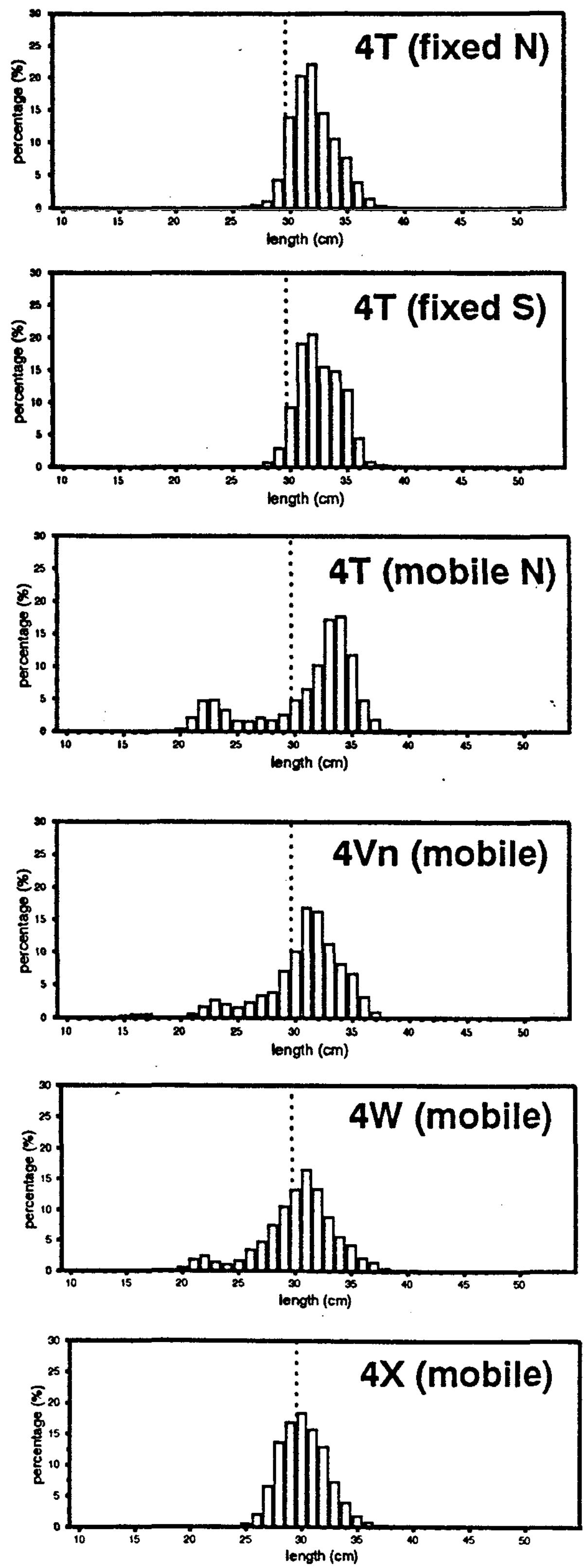

Figure 11 Histogram of herring length according to division and gear - 1988

1989 herring proportional length frequencies

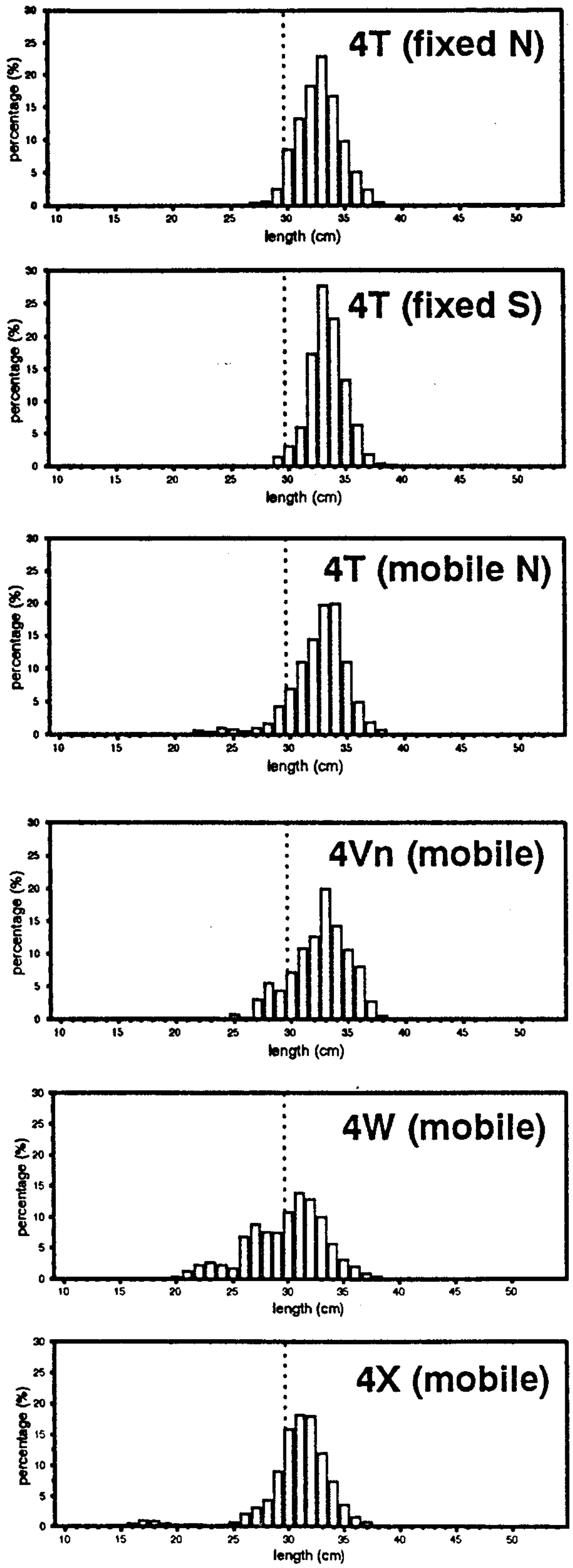

Figure 12 Histogram of herring length according to division and gear - 1989

1990 herring proportional length frequencies

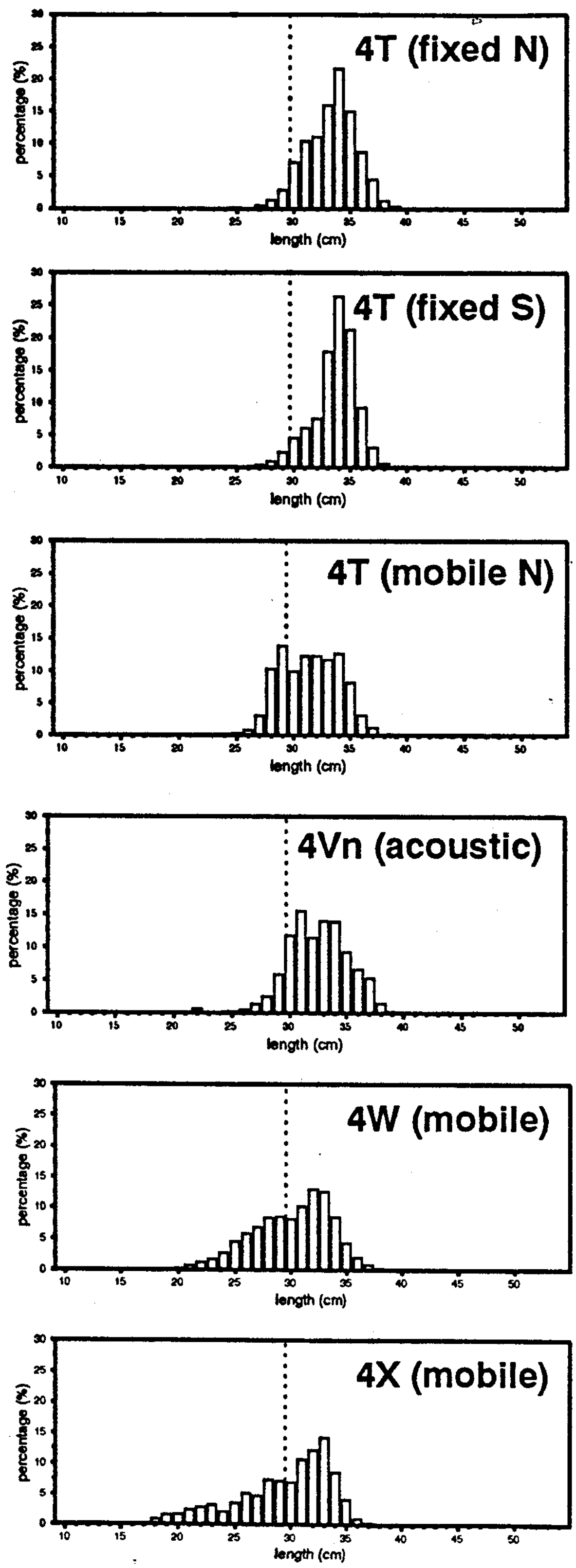

Figure 13 Histogram of herring length according to division and gear - 1990

1991 herring proportional length frequencies

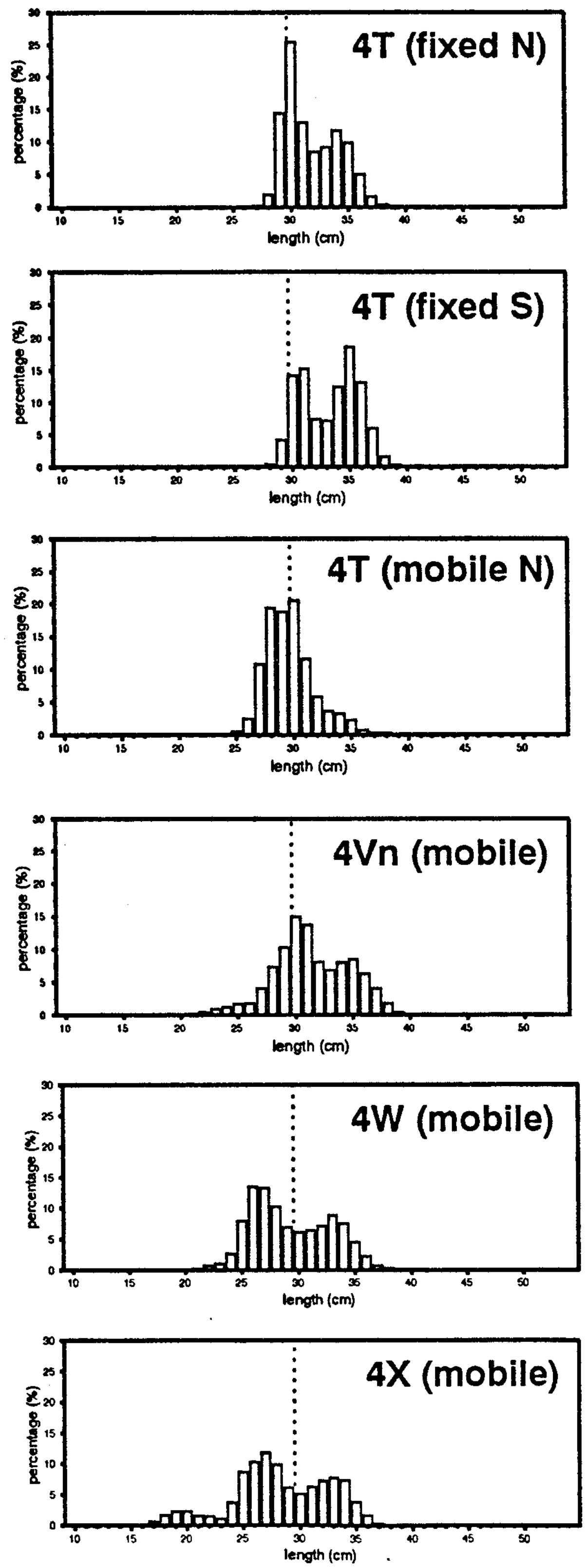

Figure 14 Histogram of herring length according to division and gear - 1991