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New Maturity Cycle Charts for the Herring Stocks along the West Coast of Newfoundland (NAFO Division 4R) and the North Shore of Quebec (NAFO Division 4S)

by

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ABSTRACT

A study was conducted to describe the annual evolution of the gonadal development of west coast of Newfoundland and Quebec north shore herring in order to add precision to the maturity cycle chart used to separate the spring and autumn spawners in these stocks. A separate maturity cycle chart was produced for both males and females in NAFO Divisions 4R and 4S which classified individual fish as a spring or autumn spawner from its maturity stage, calculated from the gonadosomatic index, and the month of capture. The results showed the annual maturity cycles of these stocks differed substantially from the chart presently used by CAFSAC. The new maturity cycle charts should enable more accurate spawning type determinations from the historical as well as from future sampling data.

RESUME

L'évolution annuelle du développement des gonades des harengs de la côte ouest de Terre-Neuve et de la Côte-Nord du Québec a été décrite afin d'ajouter des précisions au tableau de cycle de maturation des reproducteurs de printemps et d'automne de ces stocks. Un tableau de cycle de maturation a été produit pour les mâles et les femelles de chacune des Divisions 4R et 4S pour identifier chaque poisson individuellement comme reproducteur de printemps ou d'automne selon son stade de maturité, calculé à partir du rapport gonadosomatique, et le mois de capture. Les résultats ont montré que les cycles annuels de maturation de ces stocks sont considérablement différents de celui présentement utilisé par le CSCPCA. Les nouveaux tableaux de cycle de maturation devraient permettre des déterminations plus précises des groupes reproducteurs à partir des données historiques ainsi que des données futures.

INTRODUCTION

Herring (Clupea harengus harengus L.) population assessments have been conducted separately on the spring and autumn spawning stocks of the northeast Atlantic since the early 1970's (Winters and Hodder, 1975). However, in regions where both spawning types are found, the two groups often intermingle in feeding and overwintering areas and are caught in mixed commercial fisheries. The accuracy of the assessments have therefore been highly dependent upon the precision with which individual fish, sampled from the commercial catches, have been assigned to their respective spawning group.

For the past few decades, the macroscopic appearance of the gonads, in relation to the time of capture, has been used routinely for spawning group assignments of several northeast Atlantic herring stocks. The stage of sexual maturity of each fish was identified using the Hjort maturity stage key, modified by ICES and CAFSAC (Parrish and Saville, 1965; Cleary et al., 1982), and the most likely spawning group was determined from a maturity cycle chart given the assigned maturity stage (Cleary et al., 1982). This method has the advantage of determining the spawning type directly by estimating when a fish had or would have spawned, as opposed to indirect methods, such as otolith characteristics, which presumably identify the season in which the fish had hatched and infers that the spawning season would be the same. Although the maturity stage method can be relatively reliable for mature fish caught during the spawning season where the spawning type is obvious, the gonadal development cycles of the two groups have not been sufficiently documented for each of the various stock complexes in the Gulf of St. Lawrence (Figure 1) to reliably determine the spawning type at other times of the year. McQuinn (in preparation) has shown that using an inappropriate maturity cycle chart can lead to a significant number of spawning group misclassifications.

The maturity cycle chart presently used by CAFSAC (Cleary et al., 1982) was derived from the consensus view of the herring biologists from the various regions as a guide for the Canadian east coast herring populations in general and was not considered to be necessarily accurate for every stock. In addition, maturity stage identification using the Hjort classifications can be highly subjective, especially at the beginning of gametogenesis, and was designed for use on fresh specimens. Several criteria, such as gonad colour, are unreliable for use on frozen samples (Cleary et al., 1982). Because of these sources of error, a study was initiated to describe the annual progression of the gonadal development of west coast of Newfoundland (NAFO Division 4R) and Quebec north shore (NAFO Division 4S) herring from their gonadosomatic index (GSI) in order to add precision to the maturity cycle chart used to separate the spring and autumn spawners in these stocks.

METHODS AND MATERIALS

All the analyses for the present study were performed separately for males and females. Although the two sexes have often been treated together in maturity studies, the staging scheme and the physiological processes

occurring within the gonads are based on different criteria (Landry and McQuinn, 1987). Although the rates of maturation are more or less synchronized, as both sexes must attain maturity at the same time for successful reproduction, the timing of the maturation processes and the actual developmental events themselves are very different and must be treated as such.

The gonadosomatic index, as described by McQuinn (in preparation), was calculated as:

$$GSI = \frac{W_G}{L_T^{\alpha}} \times 10^{13}$$

where W_G is the fresh gonad weight, L_T is the fresh total length and α is the empirically fitted regression coefficients of ln W_G versus ln L_T (all stages combined) equal to 5.37 for the males and 5.29 for the females. GSI distributions were plotted by month for each sex from all herring sampling data available from 4R (from Cape Ray to Cape Norman) between 1973 and 1985 (Figure 2) and likewise from 4S (from Baie Trinité to Blanc Sablon) between 1980 to 1985 (Figure 3). These data have been log-transformed for a more discernible representation of the distributions of each spawning group.

The divisions between the maturity stages (Figures 2 and 3) were defined by discriminant analysis, which delimited the GSI distributions of adjacent histologically determined stages (classification data set) from samples collected in the Chaleur Bay area (Division 4T) in 1984 (McQuinn, in preparation). The stage-specific discriminant functions produced by this analysis were then used to calculate a score for each maturity stage from the GSI for herring sampled in 4R and 4S. The highest score indicated the most probable maturity stage of the fish, relative to the classification data set. McQuinn (in preparation) showed that determining maturity stages from the GSI by discriminant analysis was both more objective than the Hjort maturity stage key and more precise, as several of the eight stages could be further subdivided for a more detailed assessment of sexual development.

The spawning types were then segregated by following the progression of the GSI distributions of each group throughout the year and identifying the maturity stages which encompassed the distributions of each spawning group. As spawning type cannot presently be determined from the gonads of immature fish (stages I and II), these individuals were excluded from these analyses. In addition, the GSI cannot be used to discern stage VI (spawning) or VII (spent) gonads, therefore the macroscopic maturity stage identification was used for these stages.

A separate maturity cycle chart was then produced for both male and female herring in 4R and 4S which classified individual fish as a spring or autumn spawner from its calculated maturity stage and the month of capture. In cases where the GSI distributions of both spawning groups were found within the same maturity stage, the second discriminant function was used to determine the spawning group. If, for example, the preceding maturity stage had the second highest discriminant score, indicating that the gonad was at the beginning of that stage of development, the fish would then be allocated to less advanced spawning group. This enables the further

subdivision if each maturity stage into an early or an advanced phase.

RESULTS

The Maturation Cycle and Assignment of Spawning Type:

In general, the monthly GSI distributions and the corresponding maturity stages of each spawning type are quite distinct (Figures 2a,b; 3a,b), facilitating the separation of the two spawning groups. In certain cases however, the GSI distributions of the two groups overlap, eg. in June and September. The overlap arises from the rapid gonadal growth of the non-spawning group during these months. For example, the autumn spawners, who have been in stage VIII and the beginning of stage III throughout the winter and early spring, begin rapid gonadal development in June, passing through stages VIII and III very quickly and reach stages III, IV and V by July. Because of this rapid development, the GSI distribution of this group is more elongated in June than in other months and may overlap the late spring spawners still in stage IV. The separation between spring and autumn spawners in June is therefore made between stages III and IV, as the stage IV and V fish are late spring spawners and will spawn before the end of the month. By convention, any fish which spawns after the first of July is considered to be an autumn spawner (Cleary et al., 1982), therefore stage IV and V fish in July are classified as autumn spawners. These areas of overlap would lead to a certain amount of spawning group misclassification, although the overall error would be minimal as only a few questionable stages and months were involved.

The Maturity Cycle Charts:

The maturation cycle of each sex and spawning group was summarized in a maturity cycle chart for each Division (Tables 1a,b; 2a,b). Both spawning types are indicated on the charts when the second discriminant function must be used to distinguish them. These annual maturity cycles for Divisions 4R and 4S differed substantially from the chart presently used by CAFSAC (Table 3a,b from Cleary et al., 1982). The differences (indicated on Table 3a,b) came not only from inaccuracies in the assumed timing of gonadal development of each spawning group, but also by assuming that the males and females developed from one stage to the next at the same rate.

CONCLUSIONS

The use of the gonadosomatic index can be a powerful tool for determining the gonadal development of individual fish and, in the case of herring, for the assignment of the spawning group. McQuinn (in preparation) has shown that the spawning group of herring in Chaleur Bay can be correctly assigned with over 98% accuracy when determining the maturity stages by discriminant analysis and using the appropriate maturity cycle chart, when compared to assignments made from histologically determined maturity stages. The results of this study have shown that the gonadal development cycles of the spring and autumn spawning populations in the northern Gulf of St. Lawrence, as described by their monthly GSI

distributions, are also sufficiently distinct to reliably identify individuals of the two spawning components. The new maturity cycle charts should enable more accurate spawning type determinations from the historical as well as from future sampling data.

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Table 1. Assignment of herring spawning group from maturity stages as determined from the GSI for (a) males and (b) females in NAFO division 4R.

A) MALES

Mat.	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
III	S	S	S	-S/A-	-A/S-	A	A	-A/S-	S	S	S	S
IV	S	S	S	S	S	S	A	A	-S/A-	S	S	S
V	S	S	S	S	S	S	A	A	A	S	S	S
VI	S	S	S	S	S	S	A	A	A	A	A	A
VII	A	S	S	S	S	S	S	A	A	A	A	A
VIIIa	A	A	A	A	S	S	S	A	A	A	A	A
VIIIb	-A/S-	A	A	A	A	-S/A-	S	S	-A/S-	-A/S-	-A/S-	-A/S-

B) FEMALES

Mat.	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
IIIa	S	S	A	A	A	A	A	S	S	S	S	S
IIIb	S	S	S	-S/A-	-S/A-	A	A	A	-A/S-	S	S	S
IV	S	S	S	S	S	S	A	A	A	-S/A-	S	S
V	S	S	S	S	S	S	A	A	A	A	S	S
VI	S	S	S	S	S	S	A	A	A	A	A	A
VII	A	S	S	S	S	S	S	A	A	A	A	A
VIIIa	A	A	A	A	S	S	S	S	A	A	A	A
VIIIb	A	A	A	A	A	-A/S-	S	S	-S/A-	A	A	A
VIIIc	A	A	A	A	A	A	S	S	S	S	S	S

Table 2. Assignment of herring spawning group from maturity stages as determined from the GSI for (a) males and (b) females in NAFO division 4S.

A) MALES

Mat.	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
III	S	S	S	S	-A/S-	A	A	-S/A-	S	S	S	S
IV	S	S	S	S	S	S	A	A	-S/A-	S	S	S
V	S	S	S	S	S	S	A	A	A	S	S	S
VI	S	S	S	S	S	S	-A/S-	A	A	A	A	A
VII	A	S	S	S	S	S	S	A	A	A	A	A
VIIIa	A	A	A	A	S	S	S	A	A	A	A	A
VIIIb	A	A	A	A	A	-S/A-	S	S	-A/S-	-A/S-	-A/S-	-A/S-

B) FEMALES

Mat.	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
IIIa	S	S	S	A	A	A	A	S	S	S	S	S
IIIb	S	S	S	S	-S/A-	A	A	A	-S/A-	S	S	S
IV	S	S	S	S	S	S	A	A	A	S	S	S
V	S	S	S	S	S	S	A	A	A	A	S	S
VI	S	S	S	S	S	S	-A/S-	A	A	A	A	A
VII	A	S	S	S	S	S	S	A	A	A	A	A
VIIIa	A	A	A	A	S	S	S	S	A	A	A	A
VIIIb	A	A	A	A	A	S	S	S	-A/S-	A	A	A
VIIIc	A	A	A	A	A	-A/S-	S	S	S	S	S	S

Table 3. Assignment of herring spawning group from macroscopic maturity stages (CAFSAC Res. Doc. 82/41) for (a) males and (b) females (Assignments which differ from the GSI method have been circled).

A) MALES

Mat.	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
III				(A)	(A)	(A/S)	(A/S)	(S)	S	(A/S)	(A/S)	(A/S)
IV				S	S	(A/S)	A	A	(A)	(A/S)	S	S
V				S	S	S	A	A	A	(A)	(A)	S
VI				S	S	S	A	A	A	A	A	A
VII				S	S	S	(A/S)	A	A	A	A	A
VIII				(A/S)	(S)	(S)	S	-A/S-	(A)	(A)	(A)	(A)

B) FEMALES

Mat.	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
III				(A)	(A)	(A/S)	(A/S)	(S)	(S)	(A/S)	(A/S)	(A/S)
IV				S	S	(A/S)	A	A	A	-A/S-	S	S
V				S	S	S	A	A	A	A	(A)	S
VI				S	S	S	A	A	A	A	A	A
VII				S	S	S	(A/S)	A	A	A	A	A
VIII				(A/S)	(S)	(S)	S	(A/S)	(A)	(A)	(A)	(A)

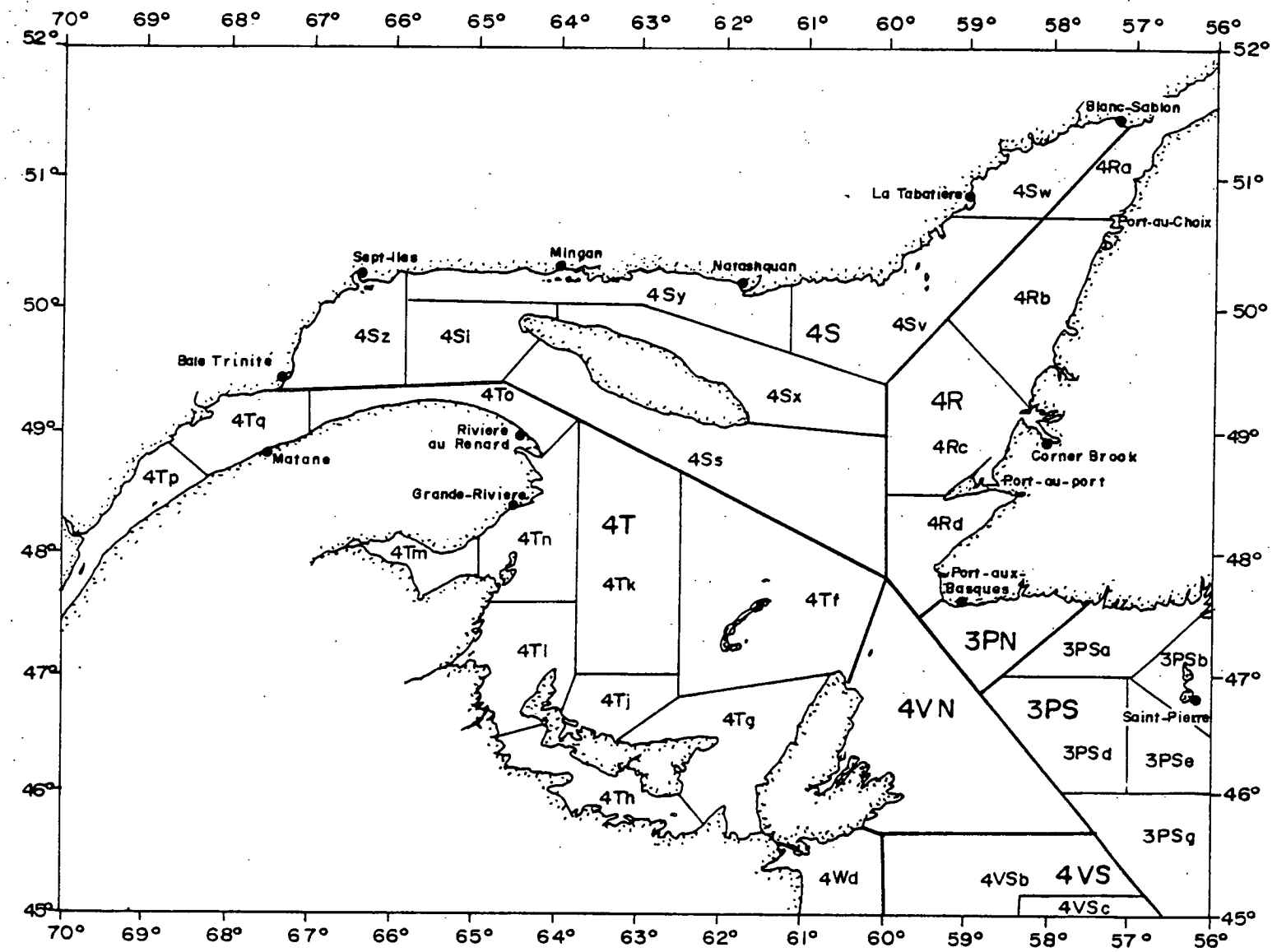

Figure 1. NAFO divisions in the Gulf of St. Lawrence.

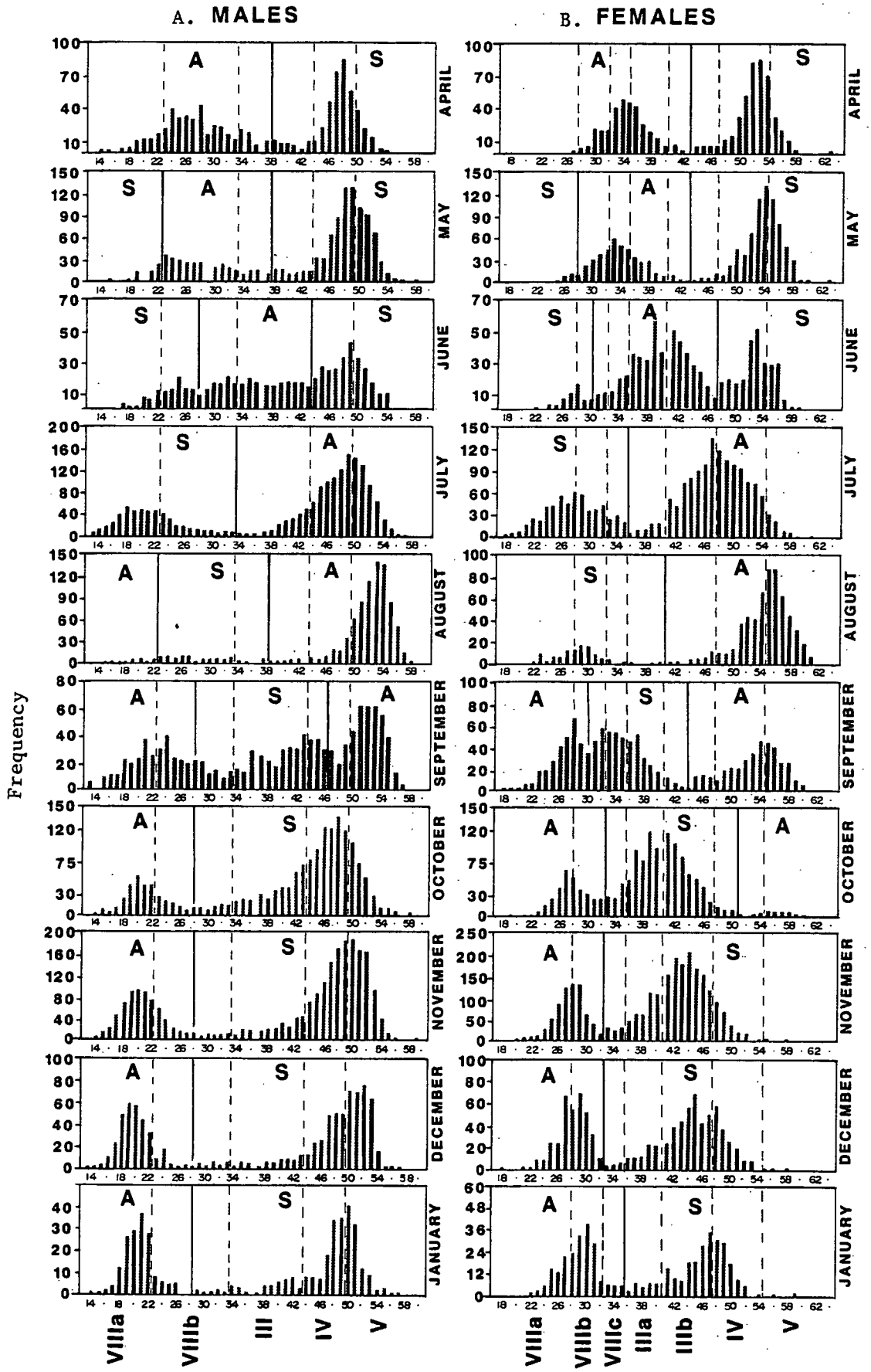

Figure 2. GSI distributions (ln GSI) of spring and autumn spawning herring by month for (a) males and (b) females, in NAFO division 4R from samples collected between 1973 and 1985. Hashed lines indicate separations between maturity stages VIIIa to V and solid lines indicate separations between spawning groups.

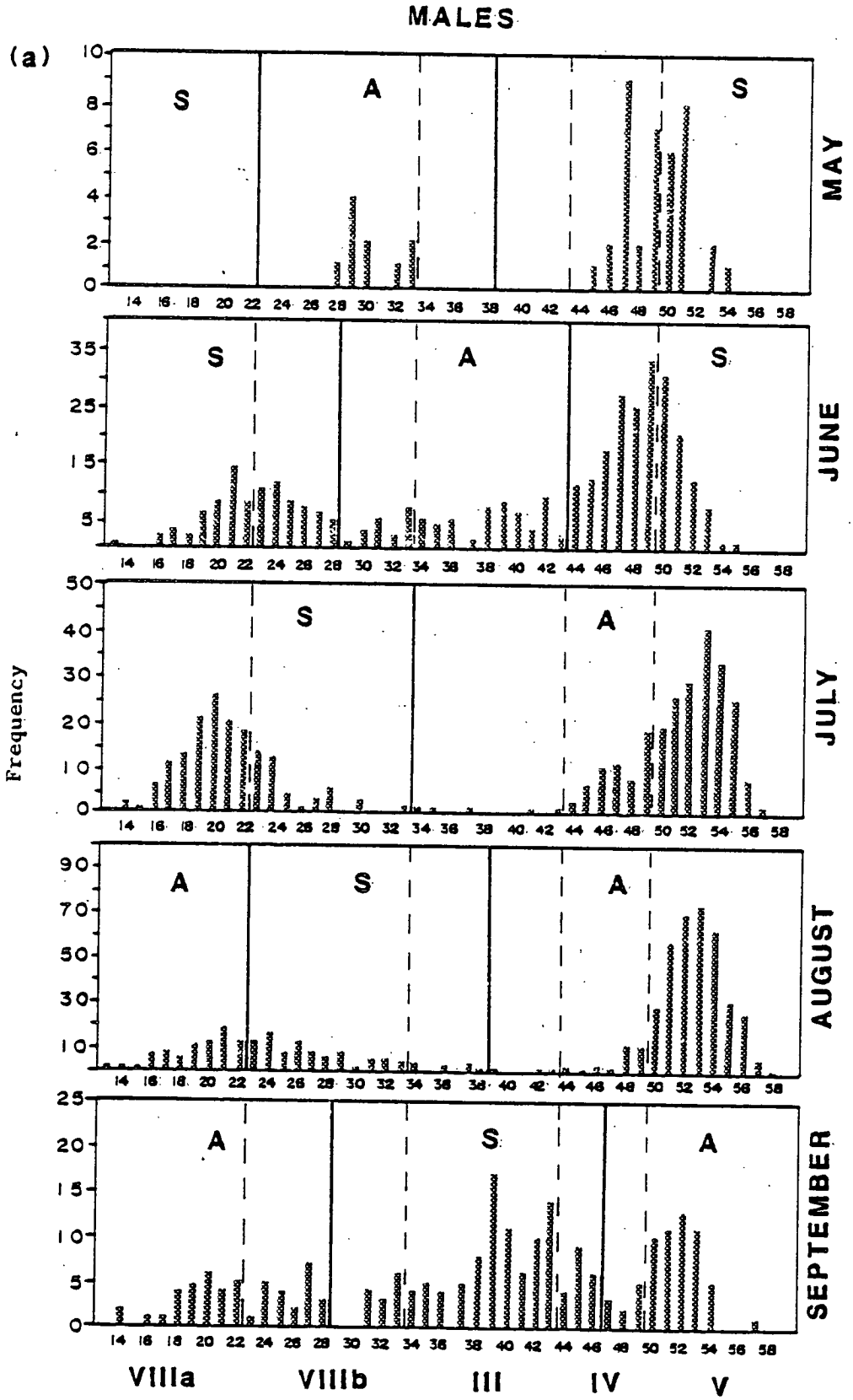

Figure 3. GSI distributions (ln GSI) of spring and autumn spawning herring by month for (a) males and (b) females, in NAFO division 4S from samples collected between 1980 and 1985. Hashed lines indicate separations between maturity stages VIIIa to V and solid lines indicate separations between spawning groups.

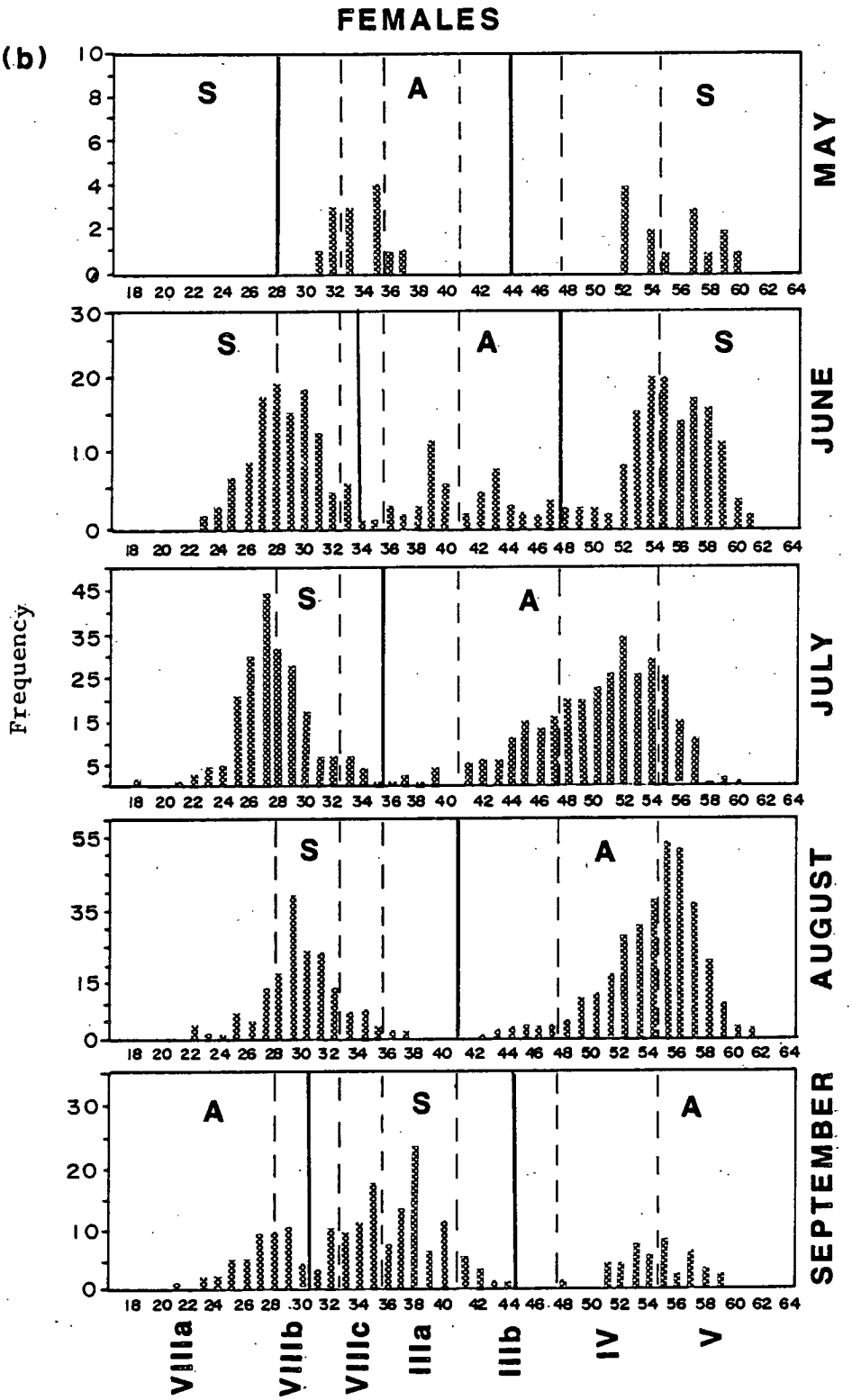

Figure 3. (con't.)