

Canadian Atlantic Fisheries
Scientific Advisory Committee

Assessment of the 1980 4WX Herring Fishery

by

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Abstract

The definition of the portion of the total herring catch in 4WX which should be included in the assessment was reviewed. In contrast with previous assessments the 4X_b juvenile purse seine catches are included. The New Brunswick weir and shutoffs catches however were still excluded from the analysis. Finally the fixed gear catches in NAFO Subarea 463 were included.

The summer purse-seine landings were considered to underestimate the actual catch by approximately 40%. After correction the catches by the "adult fisheries" were estimated to have risen sharply to over 100,000 t after the historical low reported in 1979. The gillnet component exceeded 20,000 t, the highest recorded level. The juvenile fisheries in contrast experienced their worst year suggesting an extremely weak 1978 year-class. The catch from the adult fisheries was dominated by the large 1976 year-class. The poor juvenile fisheries were supported by the age 1 and 3 fish, the 1979 and 1977 year-classes respectively. Due to misreporting on the logs and market constraints the 1980 adult catch rates are interpreted as being unreliable. The 1980 juvenile catch rates indicate an exceptionally small 1978 year-class and an unexceptional 1977 year-class. The adult catch rates did not rise in relation to the qualitative industry information indicating an exceptional abundance of mature fish. The Bay of Fundy autumn larval survey data was analysed to provide an index of mature biomass. The time series was from 1972 to 1980.

Cohort analysis was "fine tuned" in relation to the best autumn larval survey index and juvenile catch rate indices (from N.B. weir data).

Two population options were presented, the only difference being the estimated sizes of the 1977 and 1979 year-classes. In the more optimistic option, which is considered the more realistic, the 1977 and 1979 year-classes are respectively 1.50 and 1.34 billion. The analysis indicates that the mature biomass (age 4+) has risen to approximately 350,000 t, the level estimated for the mid 70's. The resultant population estimates were used to estimate catchability (q) trends for the summer purse-seine fishery. After correction for the q changes, there was a good fit between the summer purse-seine catch rates (up to 1979) and fishable biomass. It is also noted that the 4+ biomass in 1978 and 1979 was below 100,000 t. Projections at $F_{0.1}$ indicate a yield 112,000 t in 1981 (using the more optimistic population estimate in 1980).

Résumé

Nous avons examiné comment avait été définie la portion des prises totales de hareng dans 4WX à être incluse dans l'évaluation. Contrairement aux évaluations antérieures, les prises de juvéniles à la senne coulissante dans 4X_b ont été incluses. Par ailleurs, les prises des parcs et des sennes-barrages du Nouveau-Brunswick ont encore été exclues de l'analyse. Enfin, les prises par engins fixes dans la sous-zone 463 de l'OPANO ont été incluses.

On est d'avis que les débarquements des senneurs en été ont sous-estimé d'environ 40 % les prises réelles. On a estimé que les prises dans les "pêcheries d'adultes", après correction, avaient augmenté abruptement à plus de 100 000 t après le creux historique signalé en 1979. Les prises des filets maillants dépassèrent 20 000 t, le plus haut niveau jamais enregistré. Par contre, les pêcheries de juvéniles connurent leur pire année, signe que la classe d'âge de 1978 serait extrêmement faible. Les prises dans les pêcheries d'adultes étaient dominées par l'importante classe d'âge de 1976. Celles des pêcheries de juvéniles, pauvres, étaient alimentées par des poissons d'âge 1 et 3, soit les classes d'âge de 1979 et 1977 respectivement. A cause de faux rapports de prises et de mauvaises conditions de marché, on a jugé que les taux de capture d'adultes n'étaient pas fiables. D'après les taux de capture des juvéniles en 1980, la classe d'âge de 1978 est exceptionnellement faible et celle de 1977 normale. Les taux de capture des adultes ne se montrèrent pas à la hauteur des rapports qualitatifs de l'industrie, à l'effet que les poissons matures étaient exceptionnellement abondants. Les données des relevés larvaires d'automne dans la baie de Fundy ont été analysées dans le but d'obtenir un indice de biomasse mature. La série couvre les années 1972-80.

On a fait un ajustement précis de l'analyse des cohortes en relation avec le meilleur indice du relevé larvaire d'automne et les indices des taux de capture des jeunes (à partir des données des parcs du N.-B.).

Deux états de population ont été présentés, différant seulement par l'importance estimée des classes d'âge de 1977 et 1979. Dans le cas le plus optimiste, et le plus réaliste à notre avis, les classes d'âge de 1977 et 1979 sont respectivement de 1,50 et 1,34 milliard de poissons. L'analyse indique que la biomasse des sujets matures (âge 4+) a augmenté à environ 350 000 t, le niveau estimé des années 1970. Les estimations de populations qui en résultent ont été utilisées pour calculer les tendances du potentiel de capture (q) des sennes coulissantes dans la pêche d'été. Après correction pour tenir compte des changements de q , on a observé un bon accord entre les taux de capture des sennes coulissantes en été (jusqu'en 1979) et la biomasse pêchable. On a noté également que la biomasse de 4+ en 1978 et 1979 était inférieure à 100 000 t. Les prévisions à $F_{0,1}$ indiquent un rendement de 112 000 t en 1981 (avec l'estimation de population la plus optimiste en 1980).

Problems with stock definition

There has continually been a problem in defining that proportion of the total catch in 4WX which should be included in the analytical assessments. It is assumed that to a large degree a unit stock, in the biological sense, is being assessed (i.e. the major stock with spawns off south-west Nova Scotia). It is nevertheless recognized that the smaller "local" stocks in the immediate area - e.g. the Scotts Bay and Grand Manan stocks - are subsumed in this management unit. Also, although there is thought to be some intermixing of the two other major stocks in NAFO SA 5 and 6 within the 4WX fishery (either in the juvenile nursery grounds or during summer feeding) the degree of mixing has not been estimated. To partially circumvent the mixing problem, a major portion of the juvenile catches in 4X(b) have not been included in past assessments (except for the 1972 and 1973 "Grand Manan" purse-seine catch). The details, and the justification, of the 4WX catch included in the management unit are given in Sinclair and Iles, 1980. The results of the population analyses in recent assessments, however, have been rather unsatisfactory; due both to the variation in the proportion of the juvenile catch included and to the strong temporal trend in the magnitude of the 4X(b) mobile gear juvenile fishery. For example, the 1970 year-class has been consistently estimated to be larger than the earlier, very strong year-classes (1963 and 1966) which were heavily fished as juveniles. Also the fine tuning of the cohort analyses using catch rate data from both the N.B. weirs and the purse-seines has been difficult. Clearly the year-class strength time series from the cohort analyses, given the trend in juvenile catch not included in the analyses, are highly suspect. In the previous two assessments an attempt has been made to generate a more realistic year-class strength time series by including a portion of the 4X(b) catches. The result could not be easily translated into quota advice because of the subsequent need for a N.B. weir allocation. In this assessment a different approach is taken. As in the "traditional" stock definition the N.B. weir and shutoffs are not included. The total 4X(b) purse-seine catch, predominantly by the "brit" fishery is, however included. The "brit" fishery prosecutes predominantly recently metamorphosed fish aggregated off St. John. There is good evidence to conclude that these fish come from the "S.W. Nova Scotia" larval population and thus should be included in the management unit. Their inclusion will be shown to result in a more satisfactory year-class strength time series (and a tighter relationship with historical weir and purse-seine catch rates) without causing problems in subsequent quota allocation to a new gear type. In addition the relatively large catch by gillnets in NAFO subarea 463 is included in this analysis. A high catch in this area has only occurred in 1980, and is in a contiguous area to the "traditional stock" area.

Catch Description

The seasonal timing of the various components of the overall 4WX herring fishery are shown in Figure 1, and their geographical location shown in Figure 2. Both juveniles and adults are being (or have been) fished during all seasons, and at each phase of the adults annual migration. The best estimates of landings by gear type for the 1980 fishery are given in Table 1. A consistently reported estimate of the degree of under reporting by the 4Xa purse-seine fishery is 40% (from fishermen, processors and port sampler interviews). The sociological reasons for the breakdown in the reporting scheme as well as the methods used are described by Kearney (1981). The catch by this gear component has been appropriately adjusted upwards. The gillnet catches reached their highest recorded level at close to 20,000 t. The allocations and quotas for gear components concentrating on adult fish were considerably exceeded. In contrast the catch of juveniles in the

weir and shutoffs reached an historical low suggesting an extremely weak 1978 year-class. There was again, for the third year, a lucrative trap fishery in Liverpool Bay which was arbitrarily shut down at close to 2,000 t. This fishery has prosecuted almost exclusively the large 1976 year-class, which supports the previous conclusion that the fishery has been supported by a presumably ephemeral expansion of geographical range. The historical catch trends are shown in Table 2 and Figures 3, 4 and 5. The total catch by the new stock definition for 1980 (column M in Table 2) has risen sharply after the historical low of 1979.

Biological sampling and catch recording

The 4WX herring catches by all gear components have again been well sampled. This is reflected in the catch-to-sample ratios for 1977 and 1980 in Table 3. The "area of catch" reporting system by the purse-seine fleet, which broke down during the 1979 summer fishery, seems to be functioning again. The above mentioned misreporting of landings however raises a more serious problem.

The length frequency samples were matched with catch-by-area generally on a monthly basis. The "areas" used for two gear components are shown in Figures 6a and 6b. Age length keys were done on a monthly basis where possible and again, if appropriate, on a gear component basis (e.g. separate age length keys for the N.B. weirs versus N.S. weirs). As good as the biological sampling has been, the accuracy of the generation of numbers-at-age has been seriously undermined by the misreporting of purse-seine landings. This problem deserves immediate consideration by the Atlantic Small Pelagics Management Committee.

Age composition

The overall age composition of the catch of the various components of the fishery are shown in Table 4 and Figure 7. The catches for the 1970 and 1971 year-classes have been adjusted in accordance with the criteria adopted by Stobo et al. 1978. The adjustment is deemed necessary due to an ageing problem for the 1970 year-class. The adult fisheries were dominated, as predicted, by the 1976 year-class (age 4 fish). The 1970 year-class (assuming the adjustment is valid) is still contributing to the fishery as age 10, about 9 million fish being taken. The 1978 year-class is almost non-existent (by far the lowest number of age two fish taken by the weirs of any previous year-class). In excess of a quarter of a billion one-year olds (1979 year-class) were taken in 4X(b) during 1980. This N.B. weir catch on one year olds was the second highest since the 1963 year-class, being exceeded only by the 1970 year-class in 1971. There are some interesting differences in age composition by area and month that are not reflected in the combined age compositions. The Scotts Bay purse-seine fishery on spawning aggregations, for example, had a markedly more balanced adult age structure. This further suggests the biological integrity of this spawning group. The overall percentage age composition for the stock and for the 4WX total are shown in Figure 8. The dominance of the 1976 year-class and the very low percentage of age 2 and age 5+ fish is striking.

Effort and catch rates

Associated with the misreporting of landings by the purse-seine fleet there was inaccurate recording of catch rates on the log records (in order to show consistent data with the landings on the purchase slips). This breakdown in the log

record accuracy must be considered in evaluating the 1980 catch rate data. The temporal trends in catch rates for various gear components are shown in Table 5. The juvenile gears catch rates declined markedly in 1980 paralleling the drop in catches. The purse-seine catch rates did not increase strongly in response to the 1976 year-class entering the adult fishery. The market influences and the misreporting practices (Kearney 1981) no doubt influenced the catch rates. The 1980 gillnet fishery catch rates which were also influenced by the market constraints did rise, but not to the level of 1977 (the first year of this short-time series). In sum, due to the specific complications of the 1980 fishery the adult fishery catch rate data are interpreted as being unreliable. The various catch rate time series up to 1979, however, still contain valuable information.

In the past two assessments (Sinclair et al. 1979b, Sinclair and Iles 1980) the question of changes in catchability in the purse-seine fishery due to stock size fluctuations, and increases in efficiency by the fleet, were considered in some detail. The importance of catchability changes by the purse-seine fleet are pursued further in this assessment. The winter and the summer purse-seine catch rate time series are compared in Figure 9. The 1972 and 1973 points appear to be outliers. This can be plausibly interpreted as a response to the effort directed to the exceptionally large 1970 year-class by the summer purse-seine fishery. At that time there was an unlimited market for juveniles in the meal fishery. In an attempt to construct a reasonably consistent time series on adult fish these two outliers were corrected by eye in relation to the relationship indicated in Figure 9. It is the longer summer purse-seine catch-rate time series (1967 to 1980) which is more useful to help key in the cohort analysis.

In sum the 1980 juvenile catch rates indicate an exceptionally small 1978 year-class and an unexceptional 1977 year-class (three year olds, if from a very large year-class, would have been able to sustain the weir fisheries). The adult fishery 1980 catch rates did not rise in relation to the qualitative industry information indicating an exceptional abundance of mature fish.

Autumn larval survey - "Relative spawning estimates"

A variety of estimates of larval abundance are shown in Table 6. A large proportion of the 1975 survey was not completed. Thus, for all but one method this year is interpolated. The station locations are shown in Figure 10. The details of the survey methodology are given in Sinclair et al. 1979a. There are good reasons for concluding that the survey covers the major part of the larval distribution for this management unit (one major and two minor biological stocks) to the exclusion of other contiguous spawning stocks (Gulf of Maine and Georges Bank), Figure 11. The geometric mean larval abundance has been shown to be the best estimation of spawning stock size (O'Boyle, pers. comm.) for this survey, and was chosen to help key in the cohort analysis.

Population Size

The catch matrix for the 4WX stock as well as the new additions are shown in Table 7. A partial recruitment vector is difficult to estimate for this fishery because of the constant state of flux in markets, combined with dramatic year-class strength variability (and associated changes in fish size). The historical averaging method is suspect because of the strong temporal trends, as well as the observed between year variability for the years 1973 to 1977. There are some guidelines however. There is good evidence for full recruitment by age five and some evidence for a reduction in availability of age 3 fish (not every year). The

following partial recruitment vector was somewhat arbitrarily selected to initiate the analysis.

| | AGE | | | | | | | | | |
|-----|------|------|------|------|---|---|---|---|---|----|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| PR. | 0.01 | 0.80 | 0.60 | 0.90 | 1 | 1 | 1 | 1 | 1 | 1 |

The partial recruitment of two and three year olds are higher than in previous assessments but the stock definition has been slightly changed with the inclusion of the 4Xb purse-seine catches. The terminal fishing mortalities were defined by iteration, averaging the age 4 to 7 fishing mortalities. The "not fishing complete" equation was used for the cohort analysis.

The fishing mortality-at-age for 1980 was defined initially in relation to the larval survey time series (1972 to 1980). A mature F of 0.32 (times the above PR vector) gave a reasonable fit between mature biomass and autumn larval abundance (Tables 8, 9 and Figure 12). A mature F value of 0.30 put the 1980 mature biomass considerably higher than indicated by the larval abundance. A higher starting F vector would give a marginally better fit to the larval data but results in an estimate of the 1976 year-class which is not consistent with independent estimates. The mature F 0.32 option, with the above PR vector, indicates the following recent year-class strengths.

| <u>Year-class</u> | <u>Abundance ($\times 10^{-9}$) at age 2</u> | <u>"N.B. weir" predicted abundances at age 2</u> |
|-------------------|---|--|
| 1976 | 3.98 | 4.92 |
| 1977 | 0.75 | 1.78 |
| 1978 | 0.47 | -0.90 |

In Figure 13 the relationship between estimated year-class strength at age 2 and N.B. weir catch rates is shown (1966 to 1975 year-classes). The N.B. weir catch rate index is the numbers of a year-class caught at age 2 by N.B. weirs divided by the number of active weirs in the appropriate year. The cumulative fishing mortalities shown in Table 9 indicate that the 1966 to 1975 year-class strengths-at-age 2 should be relatively insensitive to the initial starting conditions. The G.M. regression predicts higher year-class strengths than estimated from the cohort analysis with the above described starting condition. It was not felt justified however to use the precise "N.B. weir" predicted values, because of the mixing problems in this gear component (Gulf of Maine and S.W. Nova Scotia juveniles are both caught by these weirs). The Gulf of Maine 1977 year-class appears to be very strong in the U.S. fishery. It did not however show a parallel strength in 4WX fisheries. How much of the relative differences in inferred year-class strength between areas that may be explained by rapid expansion of juvenile effort in the USA is difficult to determine.

The 1979 year-class strength also looks promising, ranking second in numbers caught-at-age 1 in N.B. weirs. The relationship between cohort analysis estimates and catch rates is not, however, predictive (Figure 14).

In sum, there is evidence that the 1976 year-class is very large, that the 1977 year-class is of moderate size and that the 1978 year-class is the worst on record. The only evidence for the 1979 year-class is that it is of moderate strength.

The cohort analysis in Table 8 estimates the 1977 year-class at 0.75 billion

at age 2. If it is set at 1.5 billion at age two (which is below the N.B. weir catch rate prediction) the fishing mortality on the year-class at age 3 in 1980 was 0.072 and the partial recruitment 0.23. In the second option in Table 8 the 1977 year-class is set at this level and the 1979 year-class strength at age 1 (GM 1964 to 1975), 1.34 billion. This option agrees better with the weir catch rates but infers a very low fishing mortality at age 3 in 1980, but one that is similar to that estimated for the 1976 year-class in 1979 (age 3).

Even though the 1980 summer purse-seine catch rate estimate is inappropriate for keying in the 1980 fishing mortality the rest of the time series is useful. Prior to its use, temporal changes in catchability were evaluated. Fishing mortality (F) per unit of effort (E) was calculated using the catch equation. The purse-seine catch-at-age and the population matrix (Table 8), for the relevant years for which there are data available on CPUE for the fleet, provided the input data for the calculation of F-at-age. A mean fishing mortality (ages 4 to 10) weighted by population numbers was estimated for each year and divided by effort (catch by purse-seine fleet/CPUE). The derived estimates of FUE or q are shown in Table 10 and Figure 15. The analysis (as already indicated Sinclair et al. 1979b and Sinclair and Iles 1980) suggests marked changes in catchability with time.

The CPUE values, corrected for the q changes, are plotted in Figure 16 in relation to fishable biomass (50% of age 3 and 4+ numbers times mean weight-at-age). Except for the years when the very large year-classes are three years old (1969, 1973 and 1979) there is a tight relationship. The catch rates in 1969 and 1973 are higher than fishable biomass indicates, whereas in 1979 the catch rate is relatively depressed in relation to the estimated fishable biomass. The different directions of the outliers from the relationship are reasonable, given the recent changes in market demand for small fish.

When CPUE values are not corrected for q changes there is a clear downward trend in the absolute value of the catch rate standard (Figure 17). For example 40 t/set can represent from 600,000 t to 300,000 t depending on the time period. The good fit indicated in Figure 16 suggests that the input parameters affecting mature biomass for the cohort analysis are consistent with the temporal trends in catch rates. The poor relationship in Figure 17 underlines that caution is necessary when using a purse-seine catch-rate standard.

The 1+ and 4+ biomasses for options A and B are plotted in Figure 18. Both options indicate a healthy mature biomass in the summer of 1980. (The only difference being in the estimated sizes of the 1979 and 1977 year-classes.) A second point to note is the very low 4+ biomass in mid 1978 and 1979 (< 100,000 t). If the 1976, 1977 and 1979 year-classes are as strong as indicated by the N.B. weir catch rates Option B (which is still considered a conservative estimate) indicates that 1+ biomass has rebounded to the levels estimated during the mid 70's.

Yield per recruit

As requested during the recent CAFSAC meeting on assessment methodology the difference between "average" conditions and the "immediate" conditions on $F_{0.1}$ values was evaluated. Using the following PR vector

| | | | | | | | | | | |
|-----|-----|-----|-----|-----|---|---|---|---|---|----|
| AGE | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| PR | 0.0 | 0.8 | 0.6 | 0.9 | 1 | 1 | 1 | 1 | 1 | 1 |

and both the mean July weights (1969 to 1978) and the 1980 mean weights for the fishery (Table 12) generated values of respectively 0.24 and 0.25.

A change in the PR vector had a much more pronounced effect. The 1980 fishery weights-at-age and the following vector (which appears more representative of the most recent years 1978 to 1979) were run.

| | | | | | | | | | | |
|-----|-------|------|------|------|---|---|---|---|---|----|
| AGE | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| PR | 0.006 | 0.40 | 0.23 | 0.90 | 1 | 1 | 1 | 1 | 1 | 1 |

The partial recruitments for age 1 and 3 are consistent with the year-class strengths "fixed" in option B (1.5 billion for 1977 year-class at age 2 and 1.34 billion for the 1979 year-class at age 1). The partial recruitment value at age 2 is arbitrarily set slightly higher than that at age 3 (as frequently observed). These conditions provide a $F_{0.1}$ value of 0.293.

Projections

The following input parameters were used in the five year projections:

Option A

- (i) weight-at age (means from 1967 to 1979, July), Table 12
- (ii) partial recruitment which gave the lower $F_{0.1}$ values
- (iii) catch-at-age for 1980 as in Table 7
- (iv) population numbers-at-age (for January 1, 1980) for Option A, Table 8
- (v) recruitment equal to 1.34×10^9 (geometric mean for 1965 to 1980, option A population matrix)
- (vi) $F_{0.1}$ equal to 0.249

Option B

As above except for Option B population numbers-at-age and $F_{0.1}$ equal to 0.293.

The detailed five year projections are shown in Table 11 and Figure 19. The more optimistic population status and lower partial recruitment at age generates a 1981 catch of 112,000 t, the less optimistic 79,000 t. Given that the 1976 year-classes maximizes its biomass during the coming fishing season and that the recent year-class strengths (1976, 1977 and 1979) have been set at conservative levels even in option B, the higher $F_{0.1}$ yield is perceived as being the more realistic.

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Table 1. Provisional catch (t) during 1980 4WX herring fishery

| | NOV | DEC | JAN | FEB | MAR | APR | MAY | JUNE | JULY | AUG | SEPT | OCT | NOV | DEC | TOTAL |
|-----------------------------------|-----|-----|------|---------|------|------|-------|--------|---------|---------|--------|------|-----|-----|---------|
| <u>4W</u> | | | | | | | | | | | | | | | |
| Purse seine ("Chedabucto Bay") | 165 | 665 | 8128 | | | | | | | | | | | | 8958 |
| <u>4Xa</u> | | | | | | | | | | | | | | | |
| Purse seine (reported landings) | | | | | | | (327) | (7410) | (19289) | (15913) | (2015) | (32) | | | (44986) |
| (Landings adj. for misporting) | | | | | | | 545 | 12350 | 32148 | 26522 | 3358 | 53 | | | 74976 |
| Gillnet ("stock") | | | | 13 | 2 | 6 | 1079 | 996 | 7416 | 4945 | 795 | | | | 15252 |
| Gillnet (463) | | | | 8 | 54 | 17 | 2455 | 1339 | 448 | 218 | 4 | 9 | | | 4552 |
| Weir | | | | | | | 69 | 648 | 1271 | 395 | | | | | 2383 |
| Trap (Liverpool) | | | | ←2010→ | | | | | | | | | | | 2010 |
| <u>4WXa Total</u> | 165 | 665 | 8128 | | 1021 | 1066 | 637 | 16532 | 35754 | 34781 | 8521 | 852 | 9 | | 108131 |
| <u>4Xb</u> | | | | | | | | | | | | | | | |
| Purse seine | | | | ← 787 → | | | | | | | | 32 | 155 | 469 | 1443 |
| Weir and shut-offs | | | | | | | 37 | 119 | 1734 | 5622 | 2415 | 958 | 215 | | 11100 |
| Shut-offs | | | | | | | | | 116 | 818 | 469 | 670 | 352 | | 2425 |
| <u>4Xb Total</u> | | | | 787 | | | 37 | 119 | 1850 | 6440 | 2884 | 1660 | 722 | 469 | 14968 |

Table 2. Annual 4WX herring catch by different components of the fishery (tonnes)

| YEAR | 4W | | 4X _a | | | | | 4X _b | | | | 4WX Foreign Total | Stock Total ^c |
|------|--------------------------|-------------------------|------------------------|------------------------|--------------------|--------------------|-----------------------------------|----------------------|--------------------|---------------------|-----------------------|---------------------|---|
| | Purse Seine ^a | Fixed Gear ^b | Summer Purse Seine | Gill ¹⁴ Net | Weir | Liver-pool Trap | Fixed Gear Non-Stock ^b | Winter Purse Seine | | | Misc. & Shut-Offs | | |
| | | | | | | | | Grand Manan | Saint John | Weir | | | |
| 1963 | - | | 15093 ⁵ | 2955 ⁵ | 5345 ⁵ | - | | - | 6871 ⁵ | 28203 ⁵ | 1163 ⁵ | | |
| 1964 | - | | 24894 ⁵ | 4053 ⁵ | 12458 ⁵ | - | | - | 15991 ⁵ | 27337 ⁵ | 2095 ⁵ | | a. winter catch, Nov.-Apr. is put into latest calendar year |
| 1965 | - | | 54527 ⁵ | 4091 ⁵ | 12021 ⁵ | - | | - | 15755 ⁵ | 31684 ⁵ | 1662 ⁵ | | 86394 ¹⁶ |
| 1966 | - | | 112457 ⁵ | 4413 ⁵ | 7711 ⁵ | - | | - | 25645 ⁵ | 35601 ⁵ | 204 ⁵ | | 150226 |
| 1967 | - | 431 | 117382 ⁵ | 5398 ⁵ | 12475 ⁵ | - | | - | 20888 ⁵ | 29932 ⁵ | 100 ⁵ | 598 ⁹ | 156741 |
| 1968 | - | 375 | 133267 ⁵ | 5884 ⁵ | 12571 ⁵ | - | | - | 42223 ⁵ | 32114 ⁵ | 1031 ⁵ | 2417 ⁹ | 196362 |
| 1969 | 25112 ⁴ | 343 | 84525 ⁵ | 3474 ⁵ | 10744 ⁵ | - | | - | 13202 ⁵ | 25646 ⁵ | 893 ⁵ | 13405 ⁹ | 150462 |
| 1970 | 27107 ⁴ | 151 | 70849 ⁵ | 5019 ⁵ | 11706 ⁵ | - | | - | 14749 ⁵ | 15073 ⁵ | 767 ⁵ | 60952 ⁹ | 190382 |
| 1971 | 52535 ⁴ | 169 | 35071 ⁵ | 4607 ⁵ | 8081 ⁵ | - | | - | 4868 ⁵ | 12139 ⁵ | 521 ⁵ | 23939 ⁹ | 129101 |
| 1972 | 25656 ⁴ | 330 | 61158 ⁵ | 3789 ⁵ | 6766 ⁵ | - | | 32153 ^{5,8} | 21 ⁵ | 31995 ⁵ | 704 ⁵ | 23906 ¹⁰ | 153449 |
| 1973 | 7921 ⁴ | | 36618 ⁵ | 5205 ⁵ | 12492 ⁵ | - | | 25155 ^{5,8} | 2167 ⁵ | 19088 ⁵ | 847 ⁵ | 32702 ¹⁰ | 122260 |
| 1974 | 27107 ⁴ | | 76859 ⁵ | 4285 ⁵ | 6436 ⁵ | - | | - | 10131 ⁵ | 19028 ⁵ | 1574 ⁵ | 24483 ¹⁰ | 149301 |
| 1975 | 27030 ⁴ | | 79605 ⁶ | 4995 ⁶ | 7404 ⁶ | - | | - | 1152 ⁶ | 30819 ⁶ | ? | 23711 ¹⁰ | 143897 |
| 1976 | 37196 ³ | | 58396 ³ | 8322 ³ | 5959 ³ | - | | 94 ⁶ | 746 ⁶ | 29206 ⁶ | ? | 4133 ³ | 114846 |
| 1977 | 23251 ¹ | 1138 | 68538 ¹ | 18523 ¹ | 5213 ¹ | - | | - | 1236 ¹ | 30697 ¹ | 2790 ¹ | 410 ¹ | 117171 |
| 1978 | 17274 ¹ | | 57973 ¹³ | 6059 ¹³ | 8057 ¹³ | - | | 3832 ¹³ | 2687 ¹³ | 33570 ¹³ | 5272 ^{13,11} | - | 95682 |
| 1979 | 14073 ¹³ | | 25265 ⁷ | 4363 ⁷ | 9307 ⁷ | 2174 ¹⁵ | | 2973 ⁷ | 220 ² | 32477 ⁷ | 5351 ^{7,11} | - | 58375 |
| 1980 | 8958 ² | | 74976 ^{17,18} | 19804 ^{17,19} | 2383 ¹⁷ | 2010 ¹⁵ | | 656 ¹⁵ | 787 ¹⁵ | 11100 ¹⁷ | 2425 ^{17,11} | - | 109574 |
| 1981 | 16422 ² | | | | | | | | | | | | |
| | A | B | C | D | E | F | G | H | I | J | K | L | M |

¹Stobo et al. CAFSAC Res. Doc. 78/25

²"Best estimate", provisional

³Miller & Stobo, CAFSAC Res. Doc. 77/11

⁴Stobo, ICNAF Res. Doc. Dec. 75/39

⁵Miller & Iles, FRB Tech. Rep. 594

⁶"Catch at age" printouts

⁷St. Andrews provisional catch statistics, March 1980

⁸Grand Manan catch incorporated into previous assessments catch-at-age matrix

⁹Miller, ICNAF Res. Doc. 73/95

¹⁰ICNAF Stat. Bull.

¹¹Shut-offs only

¹³Sinclair et al. CAFSAC Res. Doc. 79/19

¹⁴Gillnet catches in Stat. districts 32-44

¹⁵Statistics Branch

¹⁶Catch matrix starts in 1965

¹⁷St. Andrews provisional catch statistics, March 1981

¹⁸Adjusted upwards assuming 40% misreporting

¹⁹Includes area 463 catch

(columns A+C+D+E+F+H+I+L)

Table 3. Temporal distribution of catch to sample ratio for 4WX herring fishery (1977 to 1980).

| | JAN. | FEB. | MAR. | APR. | MAY | JUNE | JULY | AUG. | SEPT. | OCT. | NOV. | DEC. |
|-----------------------------------|---------|------|------|------|---------|------|------|------|-------|--------|------|------|
| <u>Purse Seine</u> | | | | | | | | | | | | |
| 4X 1977 | - | - | - | - | 382 | 72 | 184 | 112 | 109 | 160 | 130 | 107 |
| 4X 1978 | - | - | - | - | 139 | 598 | 498 | 157 | 294 | 164 | - | - |
| 4X 1979 | 217 | 123 | - | - | 4 | 222 | 140 | 182 | 396 | 389 | 40 | - |
| 4X 1980 | ← 394 → | - | - | - | ← 209 → | - | 316 | 455 | 682 | ← 94 → | - | 235 |
| 4Wa 78/79 | 220 | - | - | - | - | - | - | - | - | - | - | 226 |
| 4Wa 79/80 | 220 | - | - | - | - | - | - | - | - | - | - | 118 |
| <u>Gillnet</u> | | | | | | | | | | | | |
| 1977 | - | - | - | - | 348 | 271 | 1118 | 462 | 945 | - | - | - |
| 1978 | - | - | - | - | 21 | 116 | 114 | 305 | 219 | - | - | - |
| 1979 | - | - | - | - | ← 481 → | - | - | 188 | 378 | → | - | - |
| 1980 | - | - | ← | - | 519 | 778 | 492 | 663 | → | - | - | - |
| <u>N.S. Weirs</u> | | | | | | | | | | | | |
| 1977 | - | - | - | - | 366 | 127 | 1021 | 1144 | 50 | 15 | - | - |
| 1978 | - | - | - | - | 176 | 200 | 212 | 95 | 22 | 51 | 239 | 28 |
| 1979 | - | - | - | - | 64 | 126 | 127 | 73 | - | 111 | 15 | - |
| 1980 | - | - | - | - | ← 120 → | - | 212 | 99 | - | - | - | - |
| <u>Liverpool Fishery</u> | | | | | | | | | | | | |
| 1978 | - | - | 171 | - | - | - | - | - | - | - | - | - |
| 1979 | - | - | 50 | - | - | - | - | - | - | - | - | - |
| 1980 | - | - | 155 | - | - | - | - | - | - | - | - | - |
| <u>N.B. Weirs & Shut-offs</u> | | | | | | | | | | | | |
| 1977 | - | - | - | - | - | 42 | 136 | 93 | 110 | 169 | 123 | 107 |
| 1978 | - | - | - | - | 17 | 43 | 148 | 114 | 236 | 270 | - | 132 |
| 1979 | 286 | 52 | - | - | 14 | 51 | 97 | 228 | 155 | 132 | 142 | 37 |
| 1980 | - | - | - | - | 37 | 40 | 103 | 124 | 288 | 326 | 283 | - |

Table 4. Catch-at-age ($\times 10^{-3}$) by gear for the 1980 4WX herring fishery

| | AGE | | | | | | | | | | | TOTAL NUMBERS | TONNES |
|-------------------|--------|-------|-------|--------|-------|------|------|------|---------|---------|------|------------------|--------|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11+ | | |
| <u>4Wa</u> | | | | | | | | | | | | | |
| Purse-seine | 0 | 51 | 18493 | 33266 | 1257 | 603 | 1458 | 2739 | 3696 | 2399 | 1303 | 65265 | 8958 |
| <u>4Xa</u> | | | | | | | | | | | | | |
| Purse-seine | 978 | 335 | 30995 | 357030 | 19976 | 1920 | 1960 | 1393 | 1930 | 758 | 428 | 417703 | 74976 |
| Liverpool | 0 | 8 | 1706 | 18583 | 393 | 27 | 30 | 0 | 33 | 39 | 0 | 20819 | 2010 |
| Gillnet "stock" | 0 | 0 | 233 | 66015 | 5786 | 957 | 380 | 574 | 558 | 299 | 141 | 74943 | 15252 |
| 463 | 0 | 0 | 49 | 12451 | 2323 | 836 | 382 | 754 | 970 | 358 | 233 | 18356 | 4552 |
| Weir | 31 | 3031 | 14218 | 7752 | 186 | 8 | 81 | 48 | 81 | 4 | 0 | 25440 | 2383 |
| <u>4WXa Total</u> | 1009 | 3425 | 65694 | 495097 | 29921 | 4351 | 4291 | 5508 | 7268 | 3857 | 2105 | 622526 | 108131 |
| | | | | | | | | | (2248)* | (8877)* | | | |
| <u>4Xb</u> | | | | | | | | | | | | | |
| Purse-seine | 1005 | 6275 | 7263 | 7199 | 27 | 0 | 0 | 0 | 0 | 0 | 0 | 21769 | 1443 |
| Weir and | 208920 | 3320 | 48245 | 18762 | 833 | 89 | 106 | 54 | 17 | 10 | 0 | 280356 | 11101 |
| Shut-offs | 49075 | 2005 | 13842 | 2853 | 91 | 36 | 18 | 13 | 40 | 53 | 0 | 68026 | 2425 |
| <u>4Xb Total</u> | 259000 | 11600 | 69350 | 28814 | 951 | 125 | 124 | 67 | 57 | 63 | 0 | 370151 | 14969 |

* adjustments made in the relative proportions of the 1970 and 1971 year classes (see text for justifications).

Table 5. CPUE trends for various components of the 4WX herring fishery

| | <u>Purse Seine</u> | | <u>Fixed Gear</u> | | |
|------|------------------------|------------------------|-----------------------------|-------------------------------|-------------------------------|
| | <u>4Xa¹</u> | <u>4Wa¹</u> | <u>Gillnets⁶</u> | <u>N.S. Weirs⁷</u> | <u>N.B. Weirs⁷</u> |
| 1965 | - | - | | 481 | 162 |
| 1966 | - | - | | 308 | 183 |
| 1967 | 55.5 ⁵ | - | | 499 | 153 |
| 1968 | 52.8 ⁵ | - | | 503 | 165 |
| 1969 | 41.7 ⁵ | - | | 430 | 132 |
| 1970 | 39.0 ⁵ | - | | 468 | 77 |
| 1971 | 32.6 ⁵ | - | | 323 | 62 |
| 1972 | 45.0 ⁵ | 74.5 ³ | | 271 | 164 |
| 1973 | 49.1 ⁵ | 73.6 ³ | | 500 | 98 |
| 1974 | 45.2 ² | 144.1 ² | | 257 | 98 |
| 1975 | 50.9 ² | 146.3 ² | | 296 | 158 |
| 1976 | 44.6 ² | 127.4 ² | | 238 | 150 |
| 1977 | 37.4 ² | 100.3 ² | 4.2 | 209 | 157 |
| 1978 | 39.5 ² | 85.7 ⁴ | 1.6 | 269 | 150 |
| 1979 | 31.7 ² | 71.0 ² | 2.1 | 332 | 142 |
| 1980 | 28.5* ² | 68.2* ² | 3.0 | 85 | 48 |
| 1981 | | 76.1* ² | | | |

¹Catch per successful night

²Re-analysis of logs

³Stobo, ICNAF Res Doc 75/39

⁴Interpolated (see text for rationale)

⁵Stobo et al, CAFSAC Res Doc 78/25

⁶t/purchase slip (areas 32 to 37)

⁷t/year

*Misreporting and/or avoidance of large sets

Table 6. 4WX larval herring abundance indices

| | <u>Mean Weighted on area (82 Stations)</u> | <u>Mean Weighted on area (115 Stations)</u> | <u>Arithmetic mean</u> | <u>Geometric mean</u> |
|------|--|---|----------------------------|---------------------------|
| 1972 | 8.36 | 8.31 | 7.24 | 2.64 |
| 1973 | 4.99 | 5.59 | 5.27 | 2.30 |
| 1974 | 30.85 | 43.30 | 37.49 | 7.60 |
| 1975 | 10.93 | 27.71* | 24.56* | 6.02* |
| 1976 | 11.95 | 12.12 | 11.62 | 4.44 |
| 1977 | 4.92 | 5.01 | 4.57 | 1.83 |
| 1978 | 1.91 | 4.39 | 3.51 | 1.24 |
| 1979 | 3.92 | 6.61 | 6.32 | 2.18 |
| 1980 | 21.06 | 20.52 | 19.48 | 4.61 |

* interpolated

Table 7. New catch matrix for the 4WX herring stock (and the difference from the traditional stock matrix)

| | | Catch Matrix | | | | | | | | | | | | | | | |
|----|---------|--------------|--------|---------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|------|
| | | 65 | 66 | 67 | 68 | 69 | 70 | 71 | 72 | 73 | 74 | 75 | 76 | 77 | 78 | 79 | 80 |
| 1 | CAT | 270378 | 154323 | 722208 | 164703 | 108875 | 699720 | 87570 | 0 | 754 | 14151 | 0 | 0 | 0 | 0 | 311 | 2014 |
| 2 | 1084719 | 914093 | 613970 | 2389061 | 290329 | 576896 | 404224 | 649254 | 126421 | 596153 | 264491 | 48470 | 140494 | 346719 | 170523 | 9700 | |
| 3 | 34835 | 448940 | 153626 | 224956 | 531812 | 76532 | 183896 | 71984 | 595992 | 72381 | 180898 | 176226 | 28659 | 36177 | 226442 | 72957 | |
| 4 | 234383 | 73382 | 266454 | 83109 | 132319 | 286278 | 106630 | 148516 | 109530 | 616622 | 92487 | 130598 | 192958 | 11338 | 47200 | 502296 | |
| 5 | 49925 | 321857 | 110051 | 290285 | 162439 | 201215 | 113566 | 77207 | 34422 | 53199 | 383650 | 72334 | 106061 | 107627 | 4639 | 29948 | |
| 6 | 10592 | 45916 | 159203 | 73087 | 112631 | 120280 | 75593 | 75384 | 25562 | 15254 | 50599 | 219788 | 55066 | 60431 | 19695 | 4351 | |
| 7 | 1693 | 13970 | 57948 | 90617 | 62506 | 111937 | 93620 | 49065 | 19361 | 8120 | 9357 | 18960 | 150588 | 27286 | 15521 | 4291 | |
| 8 | 561 | 7722 | 4497 | 31977 | 22595 | 41257 | 50022 | 48700 | 17604 | 5313 | 3238 | 4967 | 12466 | 96741 | 9981 | 5508 | |
| 9 | 54 | 1690 | 409 | 15441 | 6345 | 21271 | 36618 | 26055 | 19836 | 10964 | 3481 | 3556 | 2873 | 9838 | 35386 | 2248 | |
| 10 | 37 | 215 | 296 | 5668 | 2693 | 7039 | 7536 | 13792 | 9661 | 5787 | 2842 | 1835 | 1253 | 2169 | 3834 | 8877 | |

Changes from Previous Matrix

| | | CATADD | | | | | | | | | | | | | | | |
|----|--------|--------|--------|---------|--------|--------|--------|----|-------|--------|-------|-------|-------|--------|-------|----|----|
| | | 65 | 66 | 67 | 68 | 69 | 70 | 71 | 72 | 73 | 74 | 75 | 76 | 77 | 78 | 79 | 80 |
| 1 | 270378 | 154323 | 722208 | 164703 | 108875 | 699720 | 87570 | 0 | 754 | 14151 | 0 | 0 | 0 | 0 | 157 | 0 | |
| 2 | 873923 | 870463 | 566022 | 1637355 | 219793 | 469980 | 260057 | 0 | 96765 | 477852 | 28901 | 28548 | 84860 | 232550 | 65273 | 0 | |
| 3 | 8385 | 178872 | 85196 | 145023 | 147345 | 18366 | 10234 | 0 | 33376 | 26781 | 21957 | 14589 | 9191 | 14132 | 43493 | 0 | |
| 4 | 2236 | 14791 | 28060 | 18002 | 13359 | 917 | 460 | 0 | 0 | 416 | 131 | 1 | 135 | 697 | 1444 | 0 | |
| 5 | 173 | 13082 | 237 | 15767 | 1716 | 118 | 5 | 0 | 0 | 0 | 4 | 0 | 0 | 97 | 22 | 0 | |
| 6 | 0 | 437 | 0 | 260 | 1779 | 57 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 7 | 0 | 0 | 0 | 0 | 0 | 26 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 9 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 10 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |

MEAN WEIGHT OF INDIVIDUALS IN CATCH

18/ 3/81

| 1 | 65 | 66 | 67 | 68 | 69 | 70 | 71 | 72 | 73 | 74 | 75 | 76 | 77 | 78 | 79 | 80 |
|---|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|
| | 0.06 | 0.10 | 0.08 | 0.08 | 0.13 | 0.10 | 0.14 | 0.12 | 0.13 | 0.12 | 0.15 | 0.18 | 0.19 | 0.15 | 0.13 | 0.17 |

MEAN AGE OF INDIVIDUALS IN CATCH

18/ 3/81

| 1 | 65 | 66 | 67 | 68 | 69 | 70 | 71 | 72 | 73 | 74 | 75 | 76 | 77 | 78 | 79 | 80 |
|---|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|
| | 2.26 | 2.87 | 2.60 | 2.65 | 3.49 | 2.96 | 3.76 | 3.49 | 3.50 | 3.22 | 3.85 | 4.51 | 4.62 | 4.04 | 3.55 | 4.06 |

Table 8. Estimated population numbers-at-age for 4WX herring

OPTION A
POPULATION NUMBERS

| | 65 | 66 | 67 | 68 | 69 | 70 | 71 | 72 | 73 | 74 | 75 | 76 |
|----|----------|---------|----------|---------|---------|----------------|---------|---------|---------|---------|---------|---------|
| 1 | 3510358 | 2735609 | 6135384 | 1263588 | 1728879 | 2182739 | 6196472 | 1009047 | 1955676 | 1432764 | 194319 | 611451 |
| 2 | 3871007 | 2629390 | 2100090 | 4369747 | 885509 | 1316972 | 1153942 | 4994005 | 826138 | 1600490 | 1160243 | 159095 |
| 3 | 989355 | 2187818 | 1325657 | 1163865 | 1415935 | 462293 | 556249 | 579011 | 3501276 | 561994 | 770949 | 710605 |
| 4 | 1325750 | 778495 | 1385016 | 946349 | 749344 | 678066 | 309244 | 289022 | 408920 | 2327327 | 394629 | 467516 |
| 5 | 342492 | 873354 | 570979 | 892858 | 699605 | 493783 | 296118 | 156705 | 102248 | 235689 | 1347511 | 239409 |
| 6 | 95011 | 235235 | 423813 | 367900 | 468349 | 425807 | 222209 | 139682 | 58439 | 52568 | 144829 | 756108 |
| 7 | 49684 | 68204 | 151048 | 202936 | 235079 | 281539 | 239788 | 113530 | 46152 | 24717 | 29236 | 72792 |
| 8 | 4395 | 39146 | 43200 | 71234 | 84157 | 135909 | 129220 | 111611 | 48555 | 20267 | 12889 | 15470 |
| 9 | 1229 | 3091 | 25063 | 31300 | 29387 | 48457 | 73942 | 60535 | 47314 | 23824 | 11786 | 7623 |
| 10 | 310 | 957 | 1001 | 20150 | 11655 | 18319 | 20426 | 27405 | 25986 | 20789 | 9585 | 6500 |
| 1+ | 10189591 | 9551299 | 12161252 | 9329927 | 6307899 | 6043884 | 9197610 | 7480553 | 7020705 | 6300428 | 4075977 | 3046570 |
| 2+ | 6679233 | 6815690 | 6025868 | 8066340 | 4579020 | 3861146 | 3001138 | 6471506 | 5065029 | 4867664 | 3881658 | 2435119 |
| 3+ | 2808226 | 4186301 | 3925778 | 3696593 | 3693511 | 2544173 | 1847196 | 1477501 | 4238891 | 3267175 | 2721415 | 2276024 |
| 4+ | 1818872 | 1998482 | 2600121 | 2532727 | 2277576 | 2081881 | 1290947 | 898490 | 737614 | 2705180 | 1950466 | 1565419 |
| | 77 | 78 | 79 | 80 | 81 | 78 OPTION 79 B | | | 80 | 81 | | |
| 1 | 4857521 | 915399 | 57974 | 695484 | 1337475 | 1 | 1832104 | 57974 | 1337082 | 1337475 | | |
| 2 | 500613 | 3977002 | 749465 | 47184 | 567595 | 2 | 3977002 | 1500000 | 47184 | 1092891 | | |
| 3 | 86399 | 282743 | 2942369 | 459315 | 29906 | 3 | 282743 | 2942369 | 1162252 | 29906 | | |
| 4 | 422339 | 44805 | 198756 | 2204115 | 310361 | 4 | 44805 | 198756 | 2204115 | 885746 | | |
| 5 | 264600 | 171186 | 26425 | 120020 | 1353002 | 5 | 171186 | 26425 | 120020 | 1353002 | | |
| 6 | 130561 | 120668 | 42770 | 17437 | 71354 | 6 | 120668 | 42770 | 17437 | 71354 | | |
| 7 | 420177 | 57069 | 44114 | 17197 | 10367 | 7 | 57069 | 44114 | 17197 | 10367 | | |
| 8 | 42442 | 207754 | 22034 | 22074 | 10224 | 8 | 207754 | 22034 | 22074 | 10224 | | |
| 9 | 8171 | 23469 | 82660 | 9009 | 13123 | 9 | 23469 | 82560 | 9009 | 13123 | | |
| 10 | 3023 | 4091 | 10313 | 35575 | 5356 | 10 | 4091 | 10313 | 35575 | 5356 | | |
| 1+ | 6735846 | 5804185 | 4176781 | 3627409 | | | | | | | | |
| 2+ | 1878325 | 4888786 | 4118807 | 2931925 | | | | | | | | |
| 3+ | 1377711 | 911785 | 3369342 | 2884741 | | | | | | | | |
| 4+ | 1291313 | 629041 | 426972 | 2425427 | | | | | | | | |

Table 9. Estimated fishing mortalities-at-age and the cumulative fishing mortality for individual cohorts for 4WX herring (1965 to 1980).

| | FISHING MORTALITY | | | | | | | | | | | | | | | | |
|----|-------------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| | 1 | 65 | 66 | 67 | 68 | 69 | 70 | 71 | 72 | 73 | 74 | 75 | 76 | 77 | 78 | 79 | 80 |
| 1 | 0.089 | 0.064 | 0.139 | 0.156 | 0.072 | 0.437 | 0.016 | 0.000 | 0.000 | 0.011 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.006 | 0.003 |
| 2 | 0.371 | 0.485 | 0.390 | 0.927 | 0.450 | 0.662 | 0.490 | 0.155 | 0.185 | 0.530 | 0.290 | 0.411 | 0.371 | 0.101 | 0.290 | 0.256 | |
| 3 | 0.040 | 0.257 | 0.137 | 0.240 | 0.536 | 0.202 | 0.455 | 0.148 | 0.208 | 0.154 | 0.300 | 0.320 | 0.457 | 0.152 | 0.089 | 0.192 | |
| 4 | 0.217 | 0.110 | 0.239 | 0.102 | 0.217 | 0.628 | 0.480 | 0.839 | 0.351 | 0.346 | 0.300 | 0.369 | 0.703 | 0.328 | 0.304 | 0.288 | |
| 5 | 0.176 | 0.523 | 0.240 | 0.445 | 0.297 | 0.598 | 0.551 | 0.786 | 0.465 | 0.287 | 0.378 | 0.406 | 0.585 | 1.187 | 0.216 | 0.320 | |
| 6 | 0.131 | 0.243 | 0.536 | 0.248 | 0.309 | 0.374 | 0.472 | 0.907 | 0.661 | 0.387 | 0.488 | 0.388 | 0.628 | 0.806 | 0.711 | 0.320 | |
| 7 | 0.038 | 0.257 | 0.552 | 0.680 | 0.348 | 0.579 | 0.565 | 0.649 | 0.623 | 0.451 | 0.437 | 0.339 | 0.504 | 0.752 | 0.492 | 0.320 | |
| 8 | 0.152 | 0.246 | 0.122 | 0.685 | 0.352 | 0.409 | 0.558 | 0.658 | 0.512 | 0.342 | 0.325 | 0.438 | 0.392 | 0.724 | 0.694 | 0.320 | |
| 9 | 0.050 | 0.927 | 0.018 | 0.788 | 0.273 | 0.664 | 0.793 | 0.646 | 0.622 | 0.711 | 0.395 | 0.725 | 0.492 | 0.622 | 0.642 | 0.320 | |
| 10 | 0.141 | 0.283 | 0.392 | 0.369 | 0.293 | 0.545 | 0.517 | 0.794 | 0.522 | 0.364 | 0.393 | 0.370 | 0.603 | 0.860 | 0.522 | 0.320 | |
| 5+ | 0.153 | 0.446 | 0.373 | 0.446 | 0.311 | 0.510 | 0.555 | 0.752 | 0.556 | 0.345 | 0.389 | 0.391 | 0.542 | 0.876 | 0.576 | 0.320 | |

| AGE | 1965 FCUM FISHMORT | | | | | | | | | | 1975 | | | | | | |
|-----|--------------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| | 1 | 3.693 | 4.247 | 5.420 | 4.838 | 5.107 | 4.077 | 3.680 | 3.439 | 3.404 | 3.543 | 1.731 | 1.148 | 0.478 | 0.482 | 0.262 | 0.003 |
| 2 | 3.926 | 3.604 | 4.183 | 5.281 | 4.683 | 5.034 | 3.640 | 3.664 | 3.439 | 3.404 | 3.532 | 1.731 | 1.148 | 0.478 | 0.482 | 0.256 | |
| 3 | 2.981 | 3.555 | 3.120 | 3.792 | 4.354 | 4.233 | 4.373 | 3.150 | 3.509 | 3.253 | 2.873 | 3.241 | 1.320 | 0.777 | 0.377 | 0.192 | |
| 4 | 3.490 | 2.941 | 3.298 | 2.982 | 3.552 | 3.818 | 4.031 | 3.918 | 3.002 | 3.301 | 3.100 | 2.573 | 2.921 | 0.864 | 0.624 | 0.288 | |
| 5 | 2.473 | 3.272 | 2.831 | 3.059 | 2.880 | 3.335 | 3.189 | 3.551 | 3.079 | 2.651 | 2.954 | 2.800 | 2.204 | 2.218 | 0.536 | 0.320 | |
| 6 | 1.591 | 2.298 | 2.749 | 2.591 | 2.614 | 2.584 | 2.736 | 2.638 | 2.764 | 2.613 | 2.364 | 2.577 | 2.394 | 1.619 | 1.031 | 0.320 | |
| 7 | 0.671 | 1.459 | 2.055 | 2.213 | 2.343 | 2.305 | 2.210 | 2.265 | 1.731 | 2.104 | 2.227 | 1.876 | 2.189 | 1.766 | 0.812 | 0.320 | |
| 8 | 1.471 | 0.633 | 1.203 | 1.503 | 1.533 | 1.995 | 1.726 | 1.645 | 1.616 | 1.108 | 1.653 | 1.790 | 1.537 | 1.685 | 1.014 | 0.320 | |
| 9 | 0.333 | 1.319 | 0.387 | 1.081 | 0.818 | 1.181 | 1.587 | 1.168 | 0.987 | 1.104 | 0.766 | 1.328 | 1.352 | 1.144 | 0.962 | 0.320 | |
| 10 | 0.141 | 0.283 | 0.392 | 0.369 | 0.293 | 0.545 | 0.517 | 0.794 | 0.522 | 0.364 | 0.393 | 0.370 | 0.603 | 0.860 | 0.522 | 0.320 | |

Table 10. Distribution of CPUE, EFFORT and catchability (q) for the 4Xa purse-seine fishery during 1967 to 1979

| Year | CPUE (4Xa) ⁽¹⁾ | CATCH (4Xa) | EFFORT | Catchability (q) ⁽⁵⁾ | Normalized Catchability ⁽²⁾ | Adjusted EFFORT ⁽³⁾ | Adjusted CPUE ⁽⁴⁾ |
|------|---------------------------|-------------|--------|---------------------------------|--|--------------------------------|------------------------------|
| 1967 | 55.5 | 117382 | 2115 | 12.4 | 0.909 | 1959 | 61.1 |
| 1968 | 52.8 | 133267 | 2524 | 11.0 | 0.806 | 2034 | 65.5 |
| 1969 | 41.7 | 84525 | 2027 | 7.0 | 0.513 | 1040 | 81.3 |
| 1970 | 39.0 | 70849 | 1817 | 10.3 | 0.755 | 1372 | 51.7 |
| 1971 | 32.6 | 35071 | 1076 | 10.7 | 0.784 | 844 | 41.6 |
| 1972 | 34.0 | 61158 | 1799 | 13.8 | 0.011 | 1819 | 33.6 |
| 1973 | 33.0 | 36618 | 1110 | 7.9 | 0.579 | 643 | 57.0 |
| 1974 | 45.2 | 76859 | 1700 | 10.5 | 0.769 | 1307 | 58.7 |
| 1975 | 50.9 | 79605 | 1564 | 12.5 | 0.916 | 1433 | 55.6 |
| 1976 | 44.6 | 58396 | 1309 | 13.2 | 0.967 | 1266 | 46.1 |
| 1977 | 37.4 | 68538 | 1833 | 16.0 | 1.172 | 2148 | 31.9 |
| 1978 | 39.5 | 57973 | 1468 | 27.7 | 2.030 | 2980 | 19.5 |
| 1979 | 31.7 | 25265 | 797 | 24.4 | 1.788 | 1425 | 17.7 |

(1) Catch per successful night fishing

(2) Normalized by the mean

(3) Effort x normalized catchability

(4) Catch ÷ adjusted effort

(5) Fishing mortality per unit of effort ($\times 10^5$) for the 4Xa purse-seine fishery.

Table 11.

Five year projections of catch at $F_{0.1}$ for 4WX herring using various assumptions concerning the input parameters (see text for details).

OPTION A

| POPULATION BIOMASS | | | | | | | 20/ 3/81 |
|--------------------|-----------|-----------|-----------|-----------|-----------|-----------|----------|
| | 80 | 81 | 82 | 83 | 84 | 85 | |
| 1 | 6954.84 | 13374.83 | 13374.83 | 13374.83 | 13374.83 | 13374.83 | |
| 2 | 1934.54 | 23271.38 | 44784.92 | 44784.92 | 44784.92 | 44784.92 | |
| 3 | 51443.25 | 3349.46 | 42646.75 | 82072.12 | 82072.12 | 82072.12 | |
| 4 | 379107.78 | 53382.07 | 3626.96 | 46179.99 | 88871.71 | 88871.71 | |
| 5 | 26164.28 | 294954.50 | 44273.02 | 3008.06 | 38299.90 | 73706.76 | |
| 6 | 4429.02 | 18123.95 | 219348.18 | 32924.42 | 2237.00 | 28482.40 | |
| 7 | 4918.23 | 2964.88 | 13025.28 | 157640.62 | 23662.04 | 1607.68 | |
| 8 | 7129.86 | 3302.27 | 2137.20 | 9389.13 | 113633.50 | 17056.52 | |
| 9 | 3189.22 | 4645.67 | 2310.02 | 1495.02 | 6567.92 | 79489.34 | |
| 10 | 13838.86 | 2083.52 | 3258.34 | 1620.18 | 1048.57 | 4606.55 | |
| | 499109.87 | 419452.52 | 388785.49 | 392489.28 | 414552.50 | 434052.84 | |

OPTION B

| POPULATION BIOMASS | | | | | | | 20/ 3/81 |
|--------------------|-----------|-----------|-----------|-----------|-----------|-----------|----------|
| | 80 | 81 | 82 | 83 | 84 | 85 | |
| 1 | 13370.82 | 13374.83 | 13374.83 | 13374.83 | 13374.83 | 13374.83 | |
| 2 | 1934.54 | 44808.53 | 44817.72 | 44817.72 | 44817.72 | 44817.72 | |
| 3 | 130172.22 | 3349.46 | 89132.61 | 89150.89 | 89150.89 | 89150.89 | |
| 4 | 379107.78 | 152348.27 | 3936.94 | 104766.16 | 104787.65 | 104787.65 | |
| 5 | 26164.36 | 294954.51 | 121446.00 | 3138.37 | 83515.43 | 83532.56 | |
| 6 | 4429.00 | 18124.03 | 209906.11 | 86427.76 | 2233.44 | 59434.25 | |
| 7 | 4918.34 | 2964.86 | 12464.64 | 144361.11 | 59439.94 | 1536.03 | |
| 8 | 7129.90 | 3302.37 | 2045.19 | 8598.23 | 99581.70 | 41002.25 | |
| 9 | 3189.19 | 4645.71 | 2210.65 | 1369.07 | 5755.76 | 66661.19 | |
| 10 | 13838.67 | 2083.49 | 3118.11 | 1483.74 | 918.90 | 3863.15 | |
| | 584254.83 | 539956.04 | 502452.79 | 497487.89 | 503576.26 | 508160.52 | |

CATCH BIOMASS

| | 80 | 81 | 82 | 83 | 84 | 85 | 20/ 3/81 |
|----|--------|-------|-------|-------|-------|-------|----------|
| 1 | 20 | 30 | 30 | 30 | 30 | 30 | |
| 2 | 398 | 3822 | 7356 | 7356 | 7356 | 7356 | |
| 3 | 8171 | 422 | 5377 | 10349 | 10349 | 10349 | |
| 4 | 86395 | 9750 | 662 | 8434 | 16232 | 16232 | |
| 5 | 6529 | 59169 | 8881 | 603 | 7683 | 14786 | |
| 6 | 1105 | 3636 | 44002 | 6605 | 449 | 5714 | |
| 7 | 1227 | 595 | 2613 | 31624 | 4747 | 323 | |
| 8 | 1779 | 662 | 429 | 1884 | 22795 | 3422 | |
| 9 | 796 | 932 | 463 | 300 | 1318 | 15946 | |
| 10 | 3453 | 418 | 654 | 325 | 210 | 924 | |
| | 109873 | 79437 | 70468 | 67509 | 71168 | 75080 | |

CATCH BIOMASS

| | 80 | 81 | 82 | 83 | 84 | 85 | 20/ 3/81 |
|----|--------|--------|-------|-------|-------|-------|----------|
| 1 | 20 | 21 | 21 | 21 | 21 | 21 | |
| 2 | 398 | 4500 | 4501 | 4501 | 4501 | 4501 | |
| 3 | 8171 | 198 | 5271 | 5272 | 5272 | 5272 | |
| 4 | 86395 | 32147 | 831 | 22107 | 22111 | 22111 | |
| 5 | 6529 | 68227 | 28092 | 726 | 19318 | 19322 | |
| 6 | 1105 | 4192 | 48554 | 19972 | 517 | 13748 | |
| 7 | 1227 | 686 | 2883 | 33393 | 13749 | 355 | |
| 8 | 1779 | 764 | 473 | 1989 | 23035 | 9484 | |
| 9 | 796 | 1075 | 511 | 317 | 1331 | 15420 | |
| 10 | 3453 | 482 | 721 | 343 | 213 | 894 | |
| | 109873 | 112292 | 91859 | 88660 | 90068 | 91129 | |

Table 12. 1980 mean weight-at-age for the overall fishery as defined by the present stock definition.

| <u>Age</u> | <u>1980 Fishery wt(kg)</u> | <u>Mean July 1969 to 1978 wt(kg)</u> |
|------------|--------------------------------|--|
| 1 | 0.0095 | 0.010 |
| 2 | 0.0355 | 0.041 |
| 3 | 0.0869 | 0.112 |
| 4 | 0.1734 | 0.172 |
| 5 | 0.2207 | 0.218 |
| 6 | 0.2583 | 0.254 |
| 7 | 0.3053 | 0.286 |
| 8 | 0.3330 | 0.323 |
| 9 | 0.3592 | 0.354 |
| 10 | 0.3697 | 0.389 |
| 11+ | 0.4046 | |

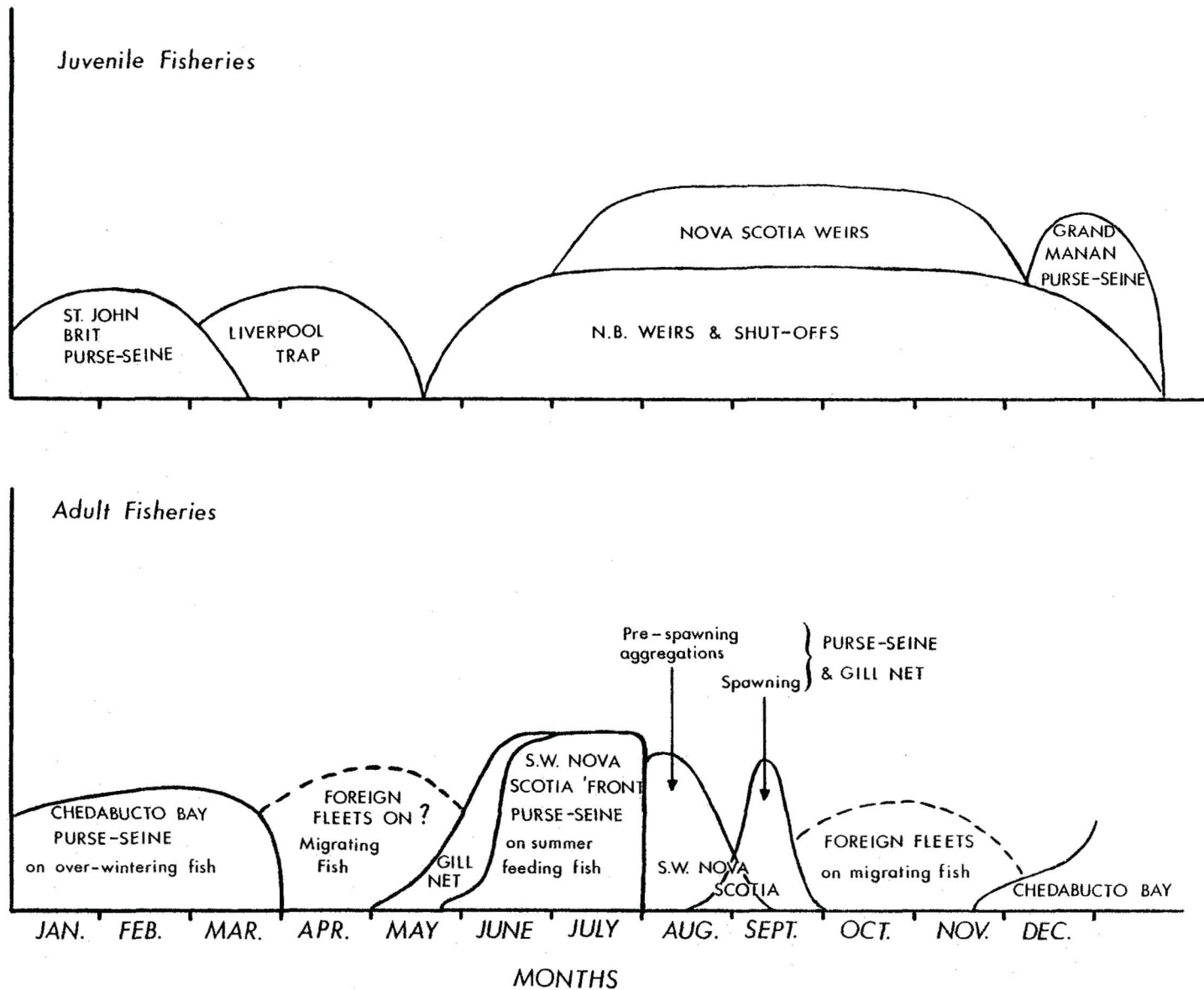


Figure 1. Schematic representation of approximate seasonal distribution of the various components of the juvenile and adult 4WX herring fishery.

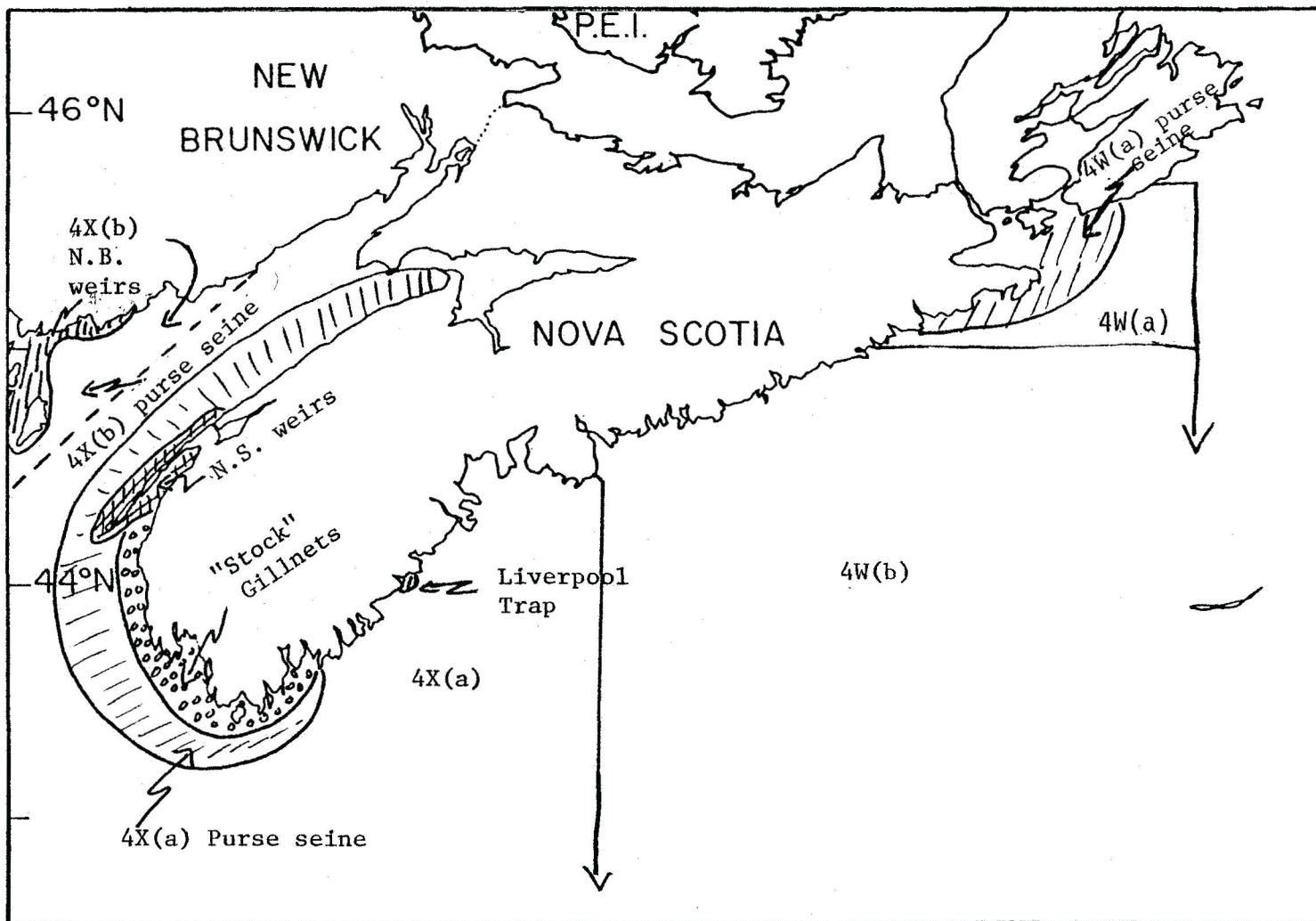


Figure 2. Geographical location of various components of the 4WX herring fishery.

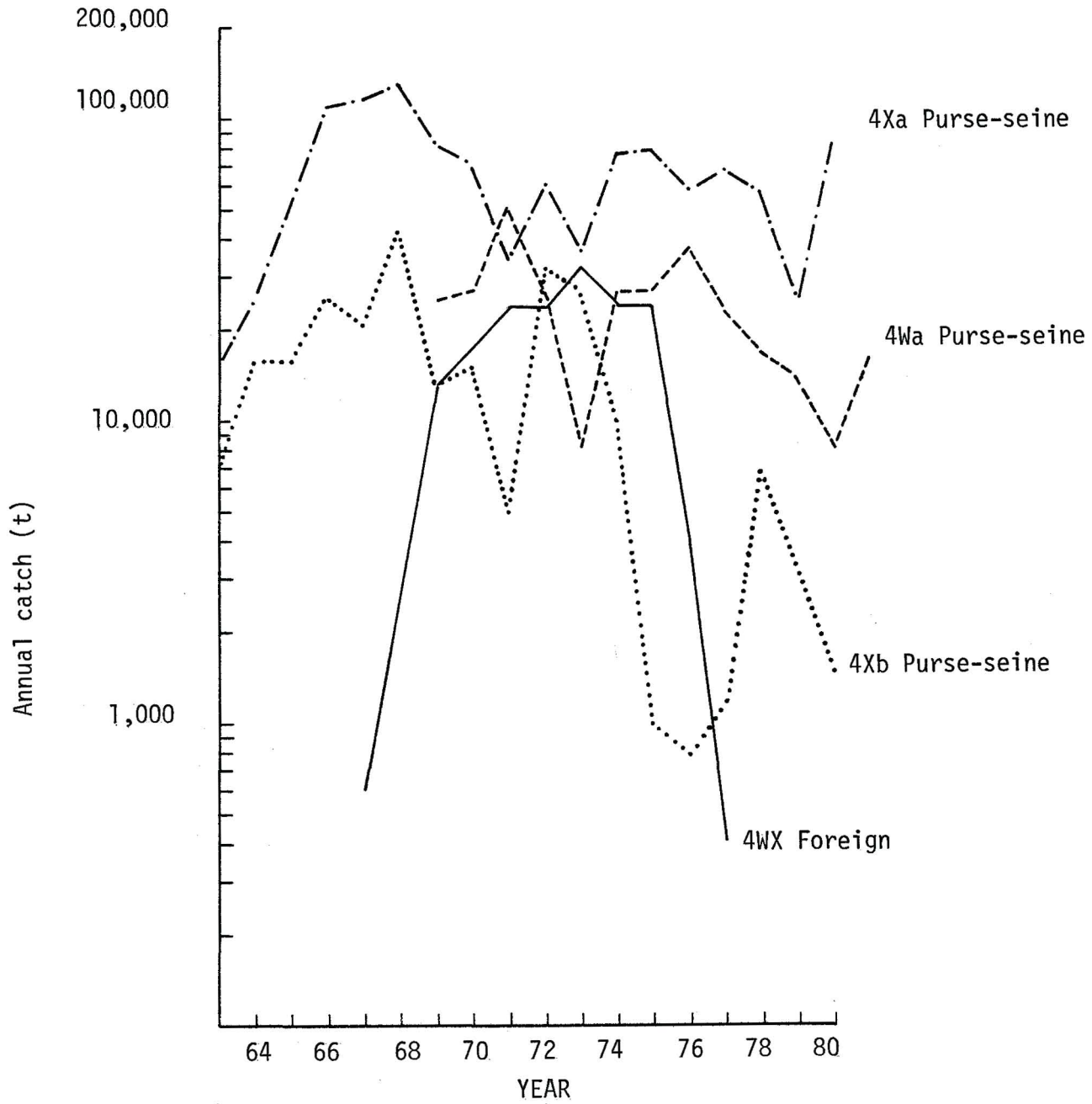


Figure 3. 4WX Mobile Gear Herring Catch (1963 to 1981).

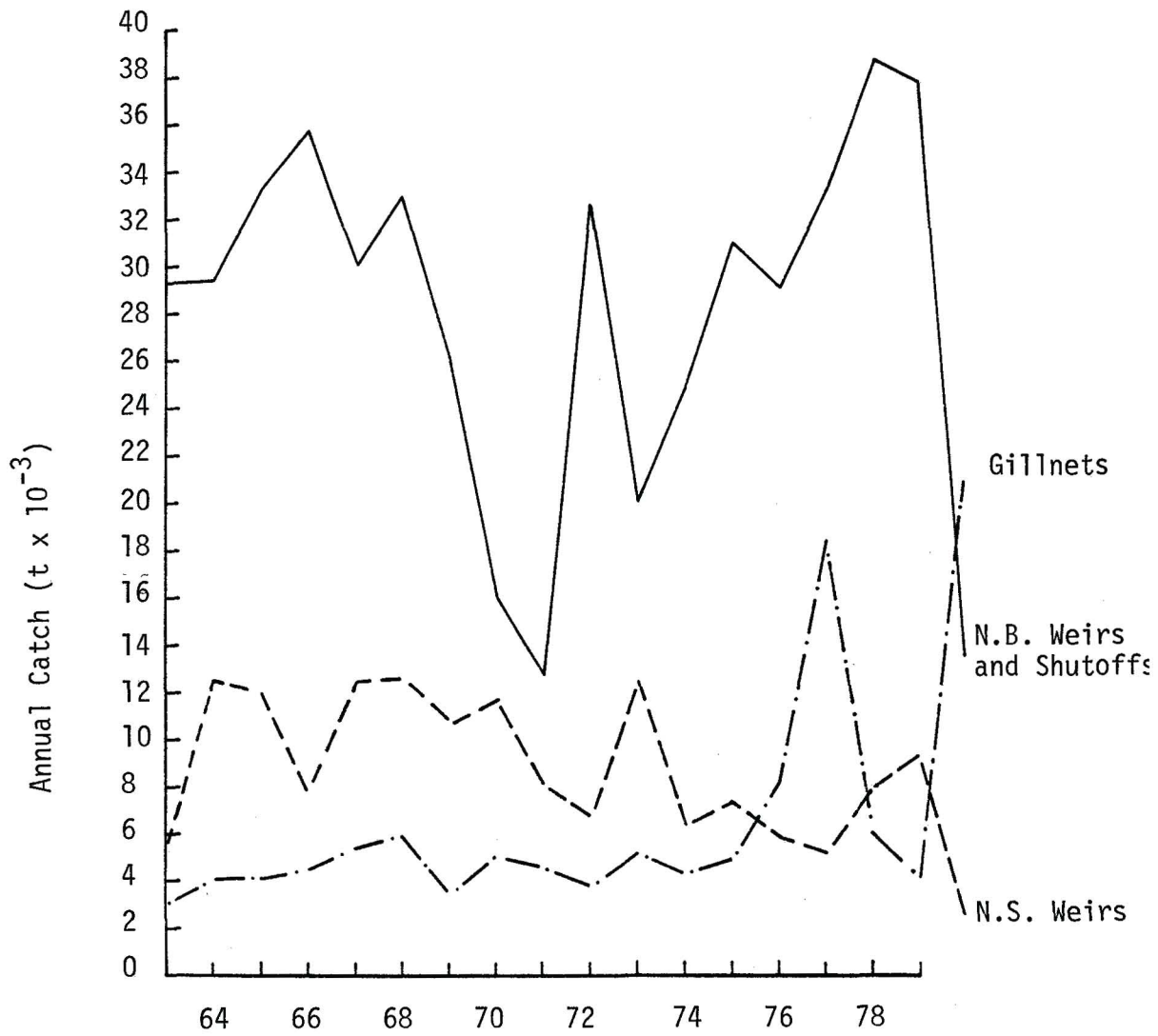


Figure 4. 4X Fixed Gear Herring Catch (1963 to 1980)

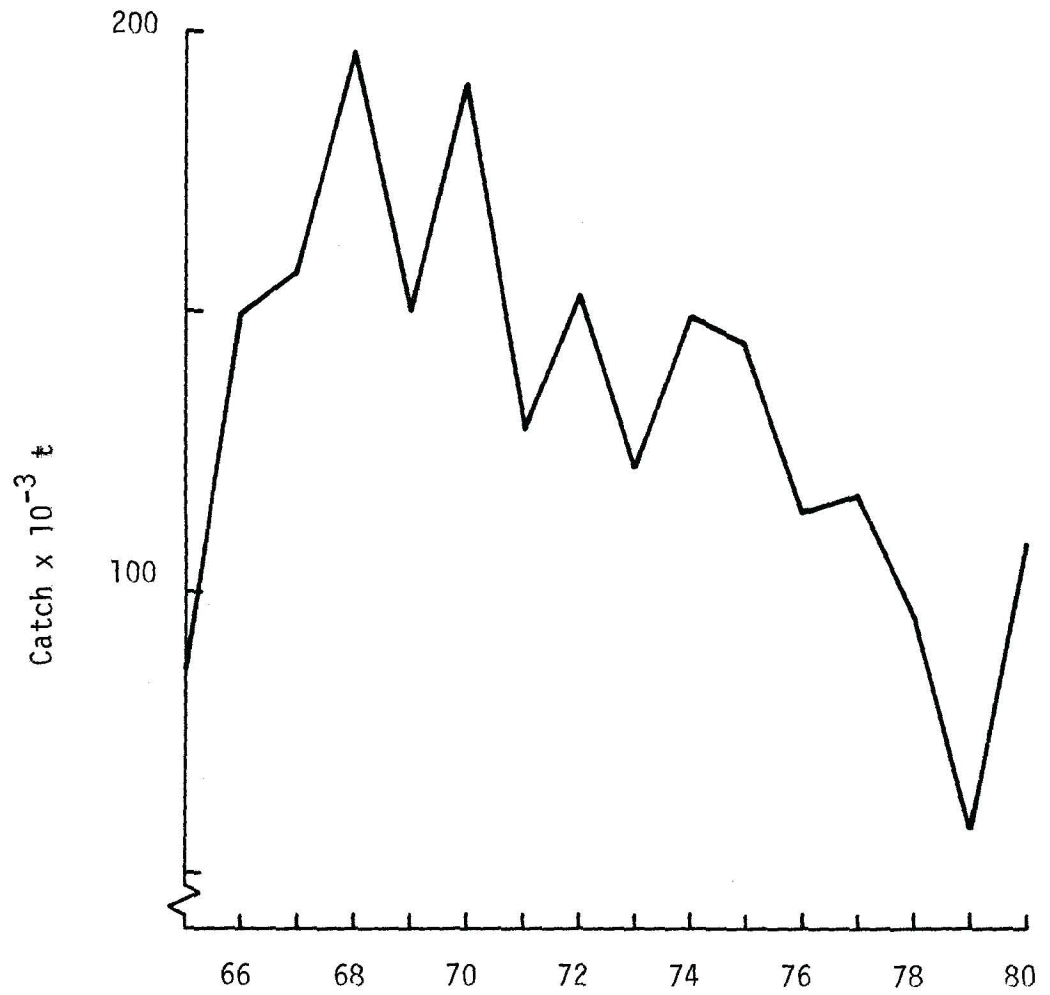


Figure 5. 4WX "Stock" Annual Catch (1965-1980)

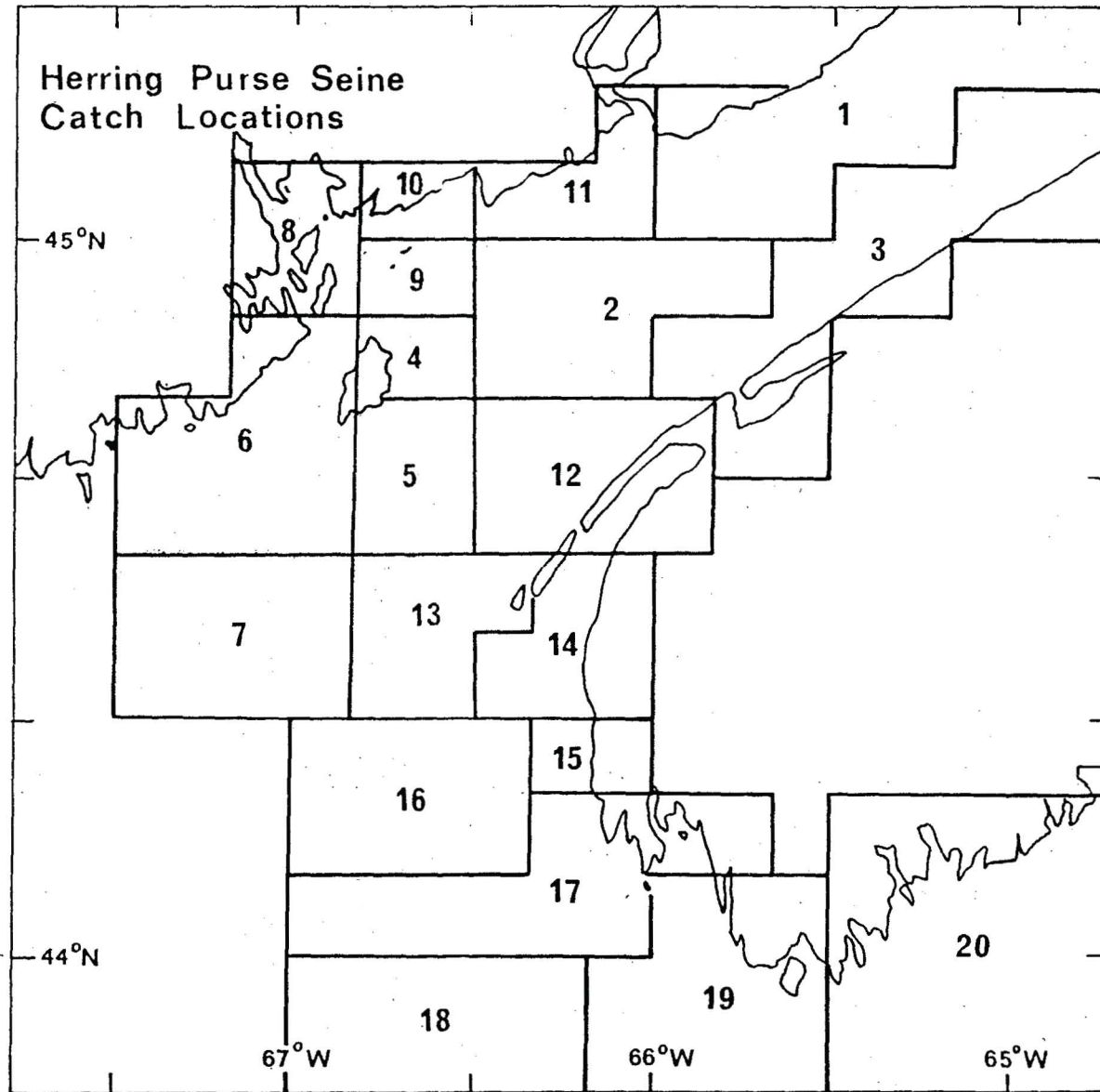


Figure 6a. Herring purse-seine catch locations that are used for the matching of catch and samples for the generation of numbers-at-age.

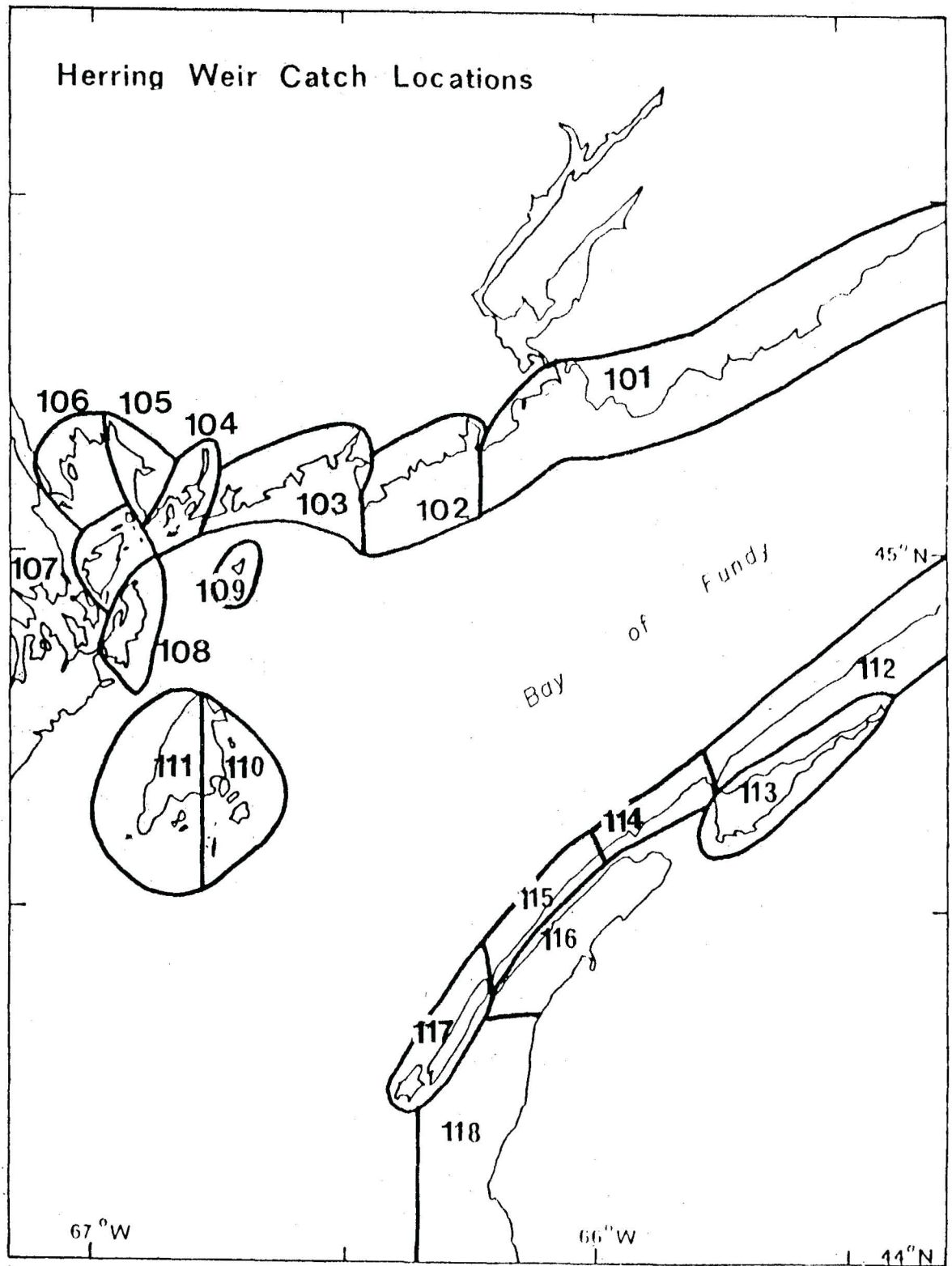


Figure 6b. Herring weir locations that are used for the matching of catch and samples for the generation of numbers-at-age.

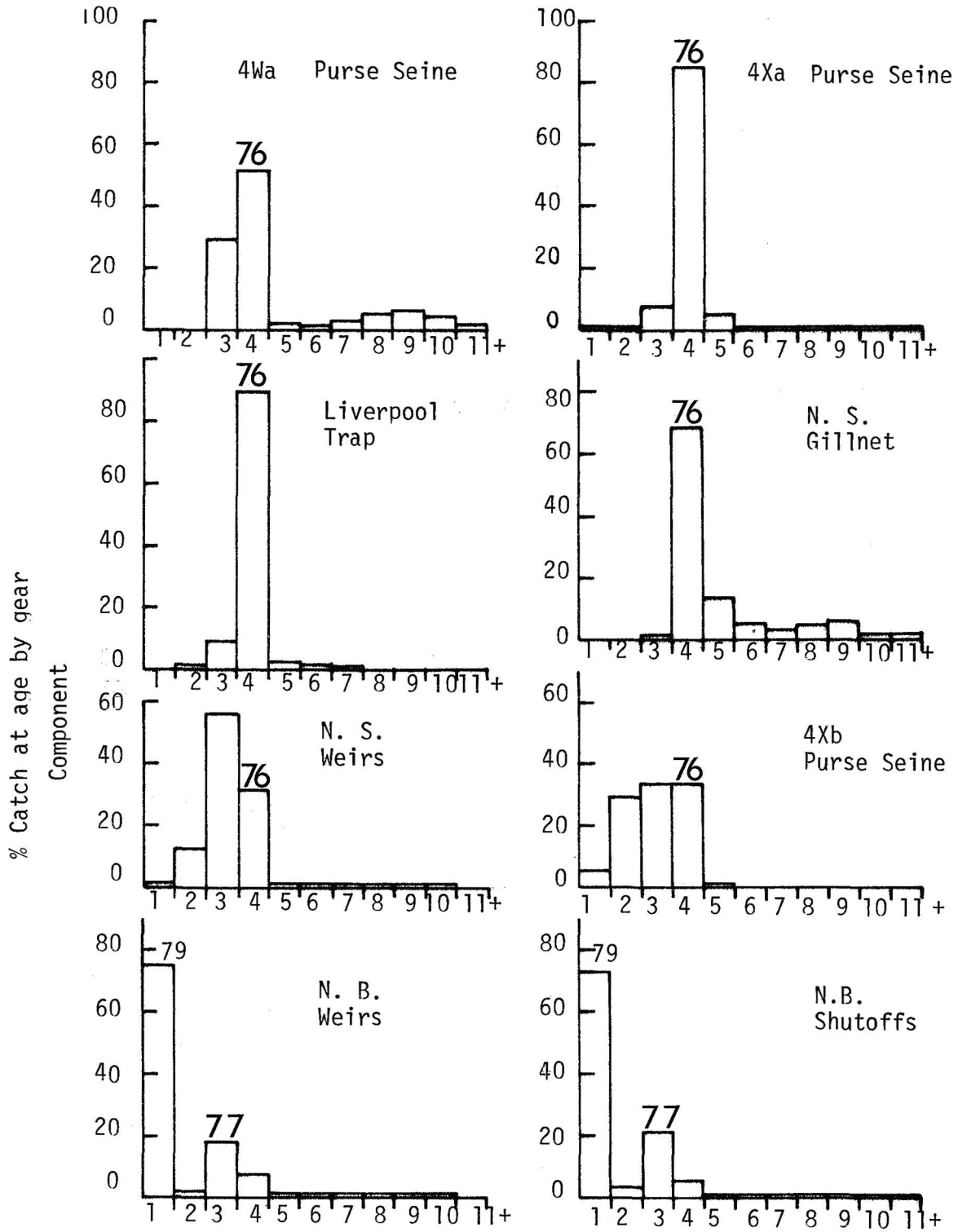


Figure 7. Age composition (%) of various components of the 4WX herring fishery during 1980.

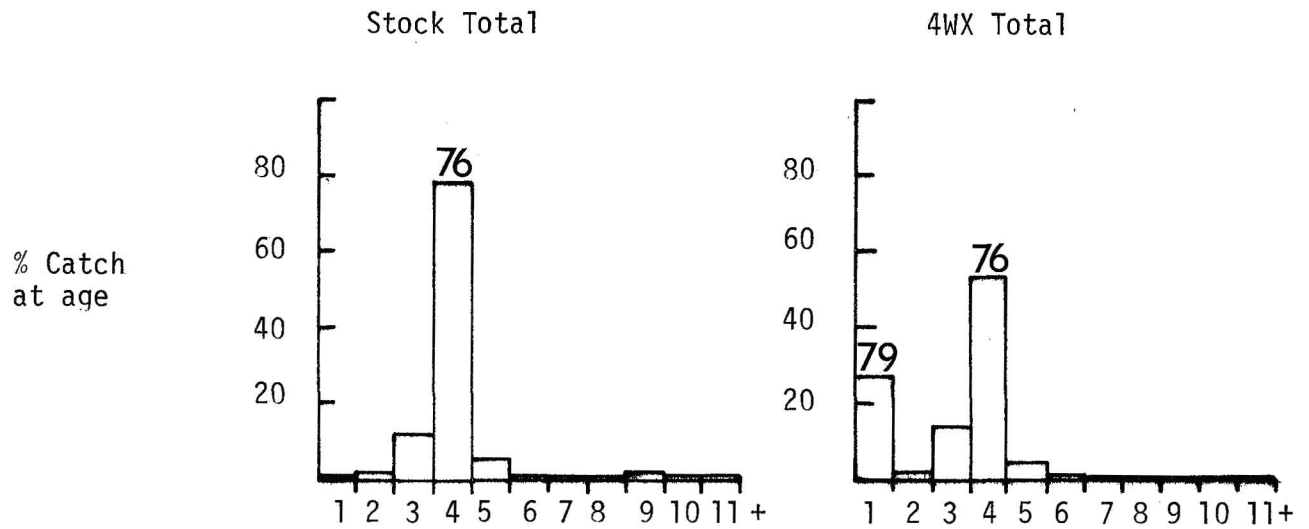


Figure 8. Age composition (%) of the overall 4WX herring fishery during 1980.

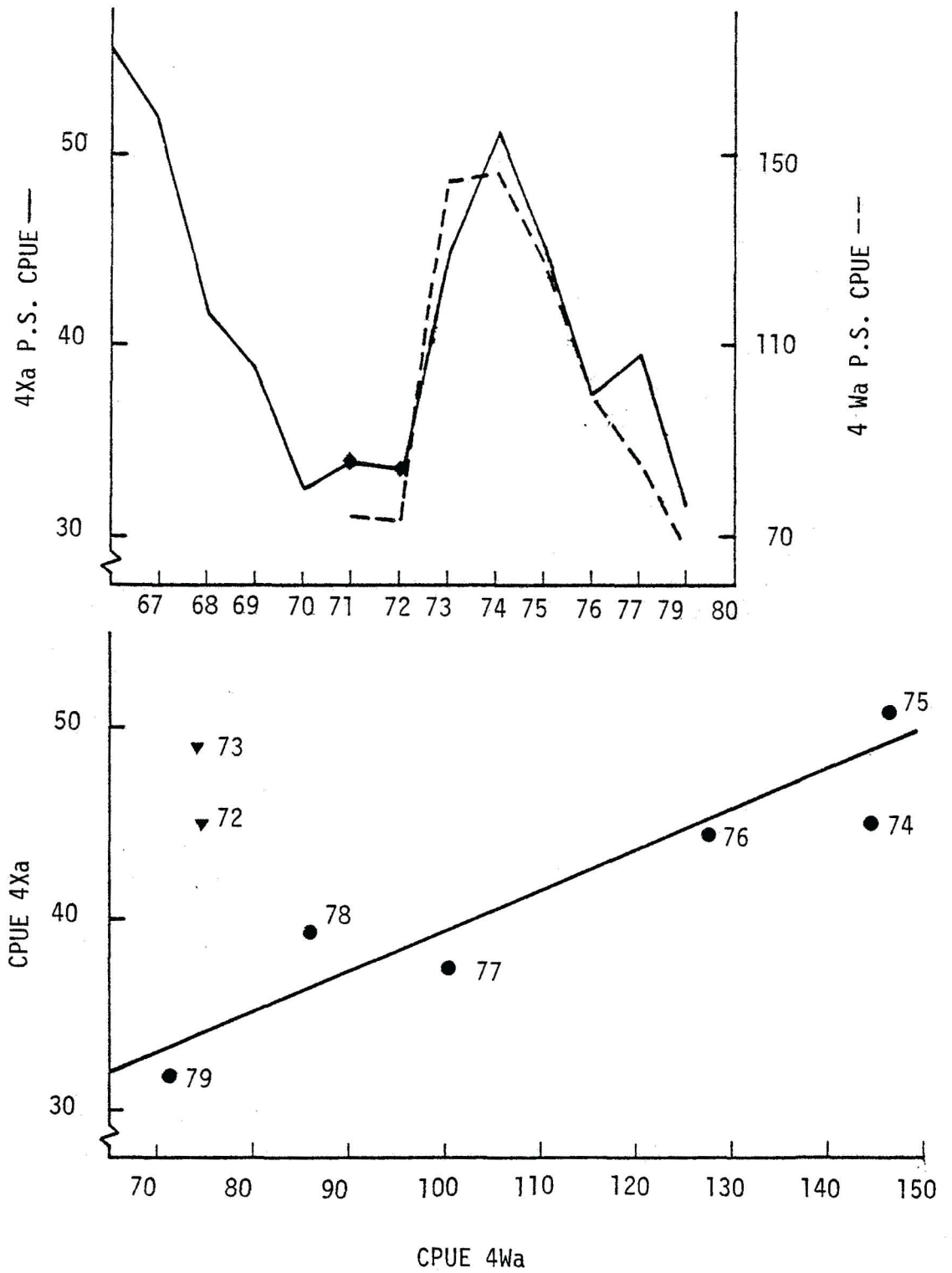


Figure 9. Purse-seine catch rate trends (upper graph), and the relationship between the summer and winter fisheries.

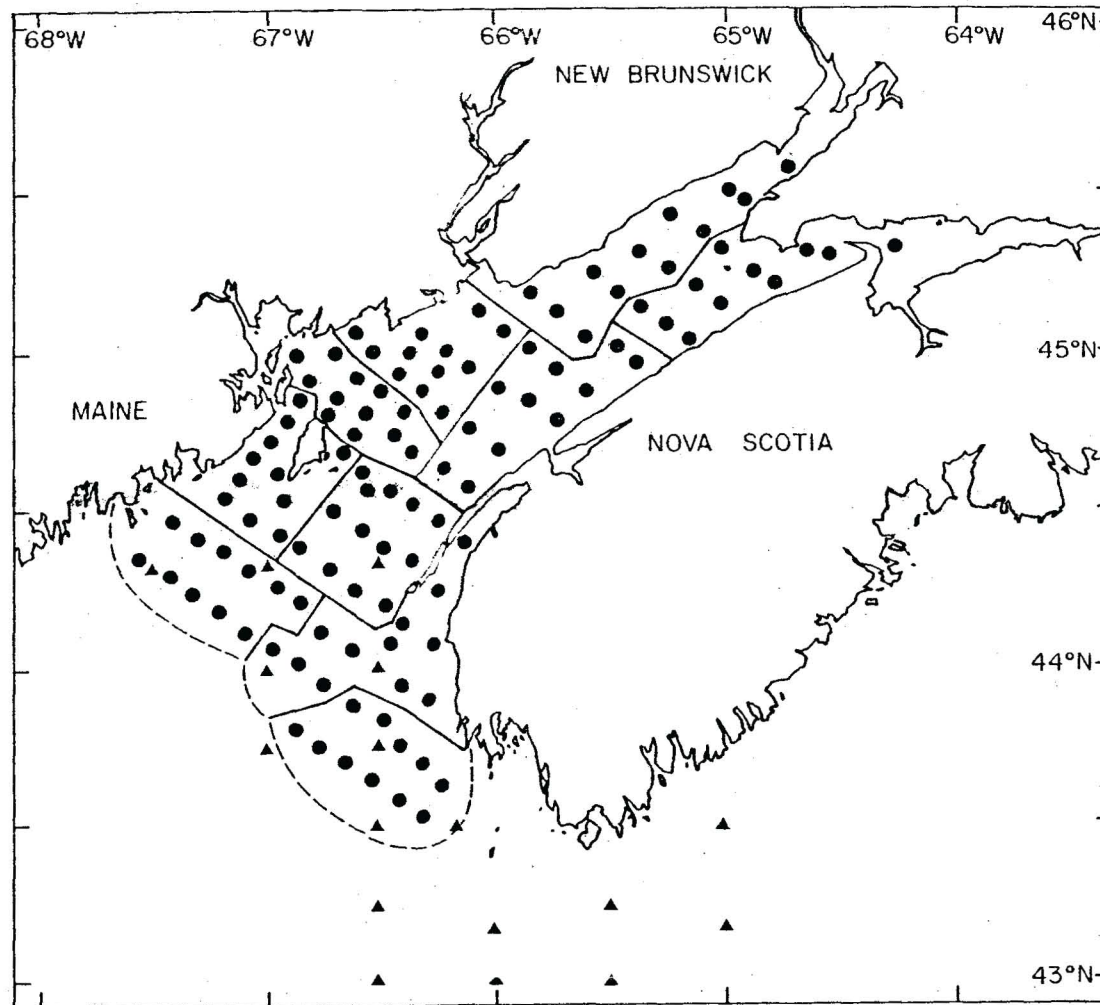


Figure 10. Location of standard sampling stations (circles) for the Bay of Fundy larval survey (triangles represent the ICNAF station locations).

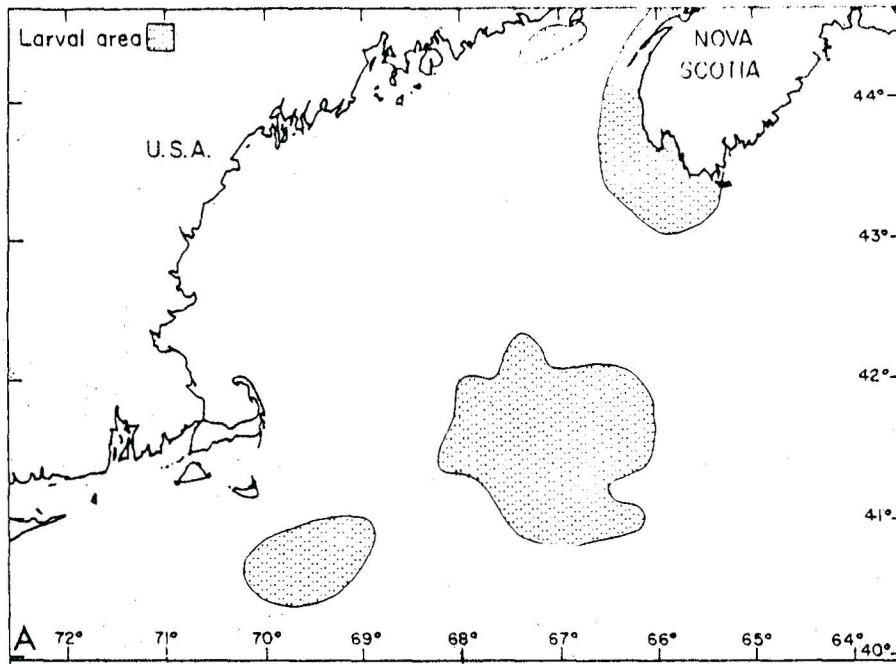


Figure 11. Representative autumn larval distributions for several of the stocks in the Gulf of Maine area.

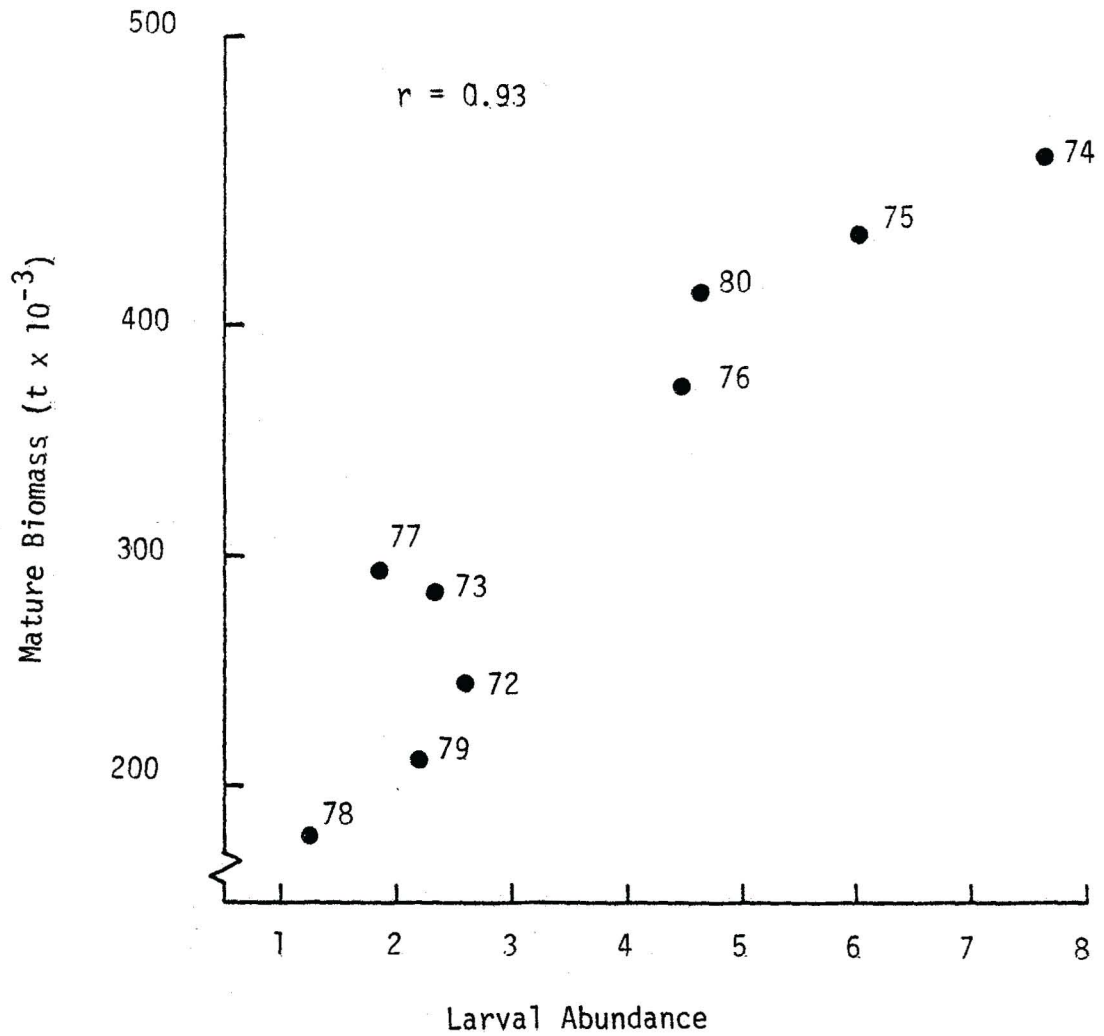


Figure 12. Relationship between mature biomass of 4WX herring and Bay of Fundy autumn larval abundance.

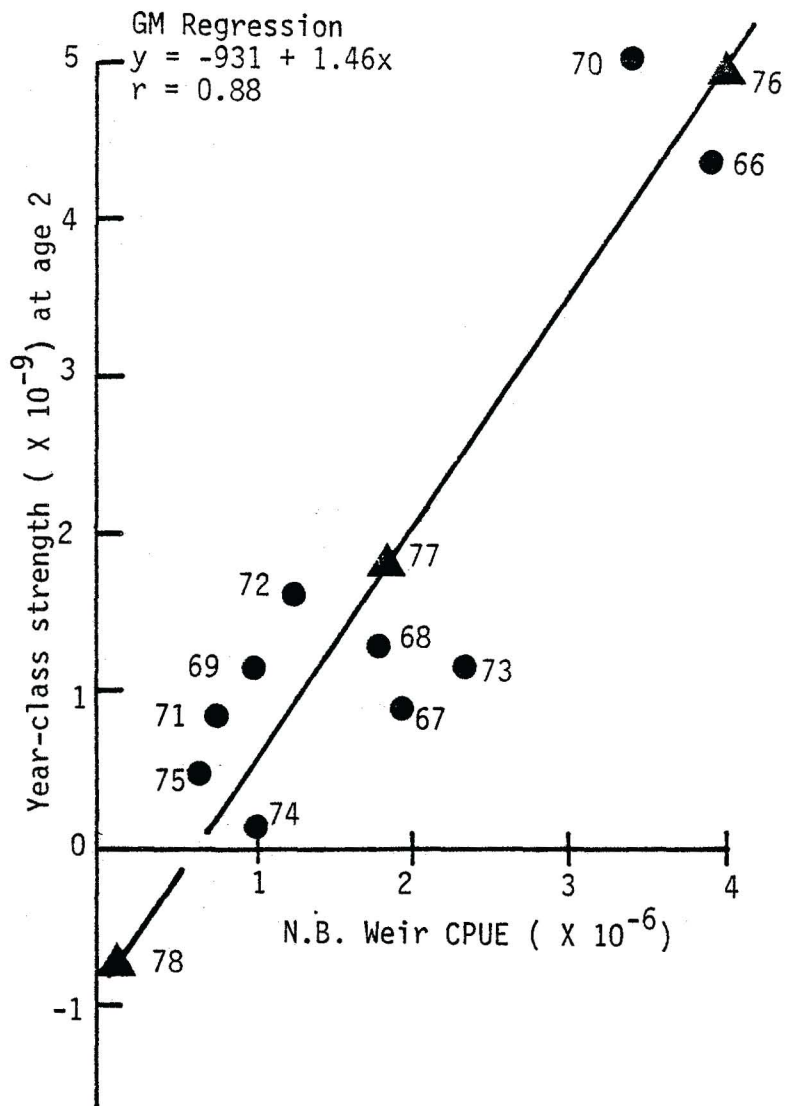


Figure 13. Relationship between 4WX herring year-class strength at age 2 and N.B. weir CPUE.

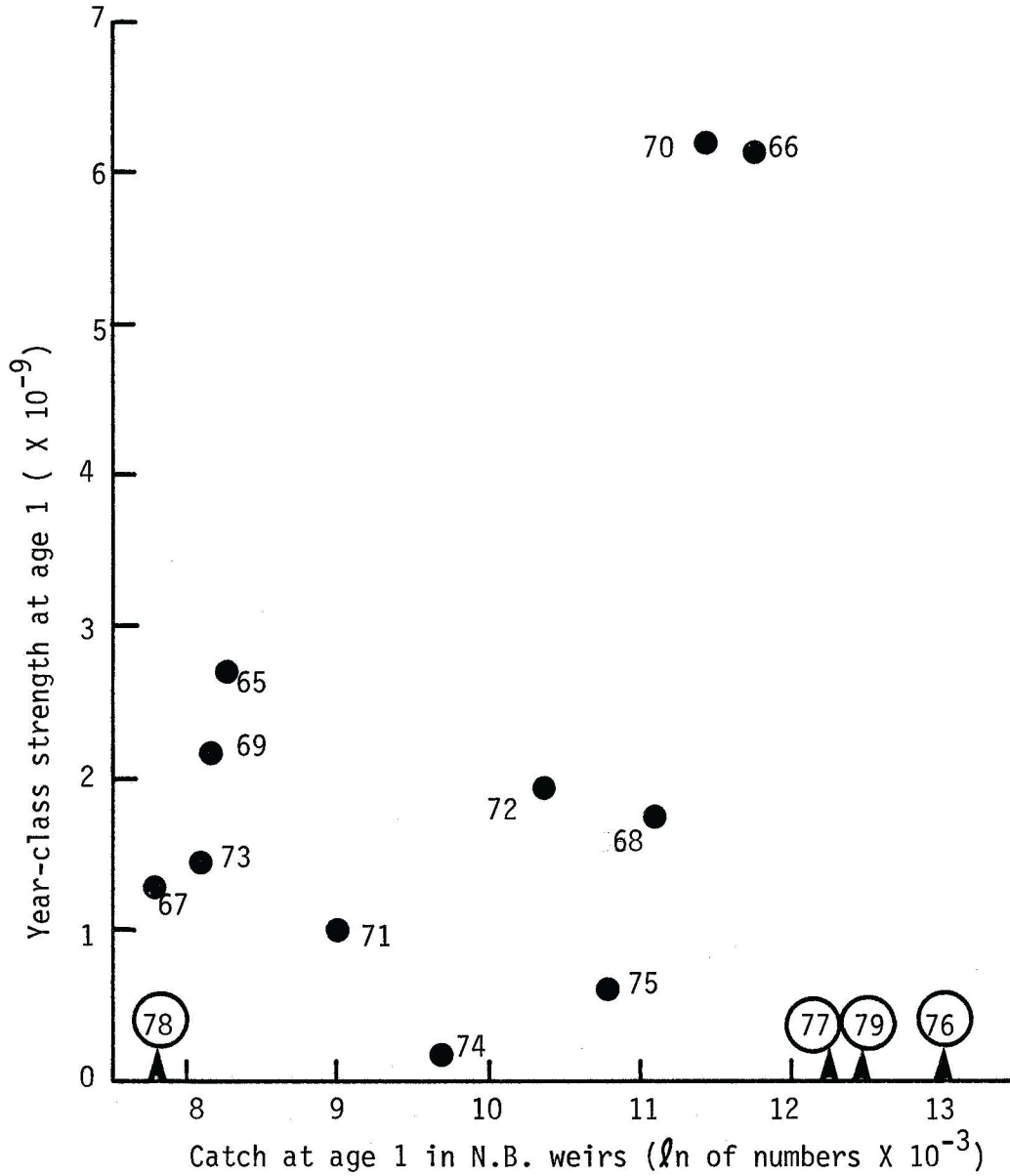


Figure 14. Relationship between 4WX herring year-class strength at age 1 and catch of age 1 fish in N.B. weirs.

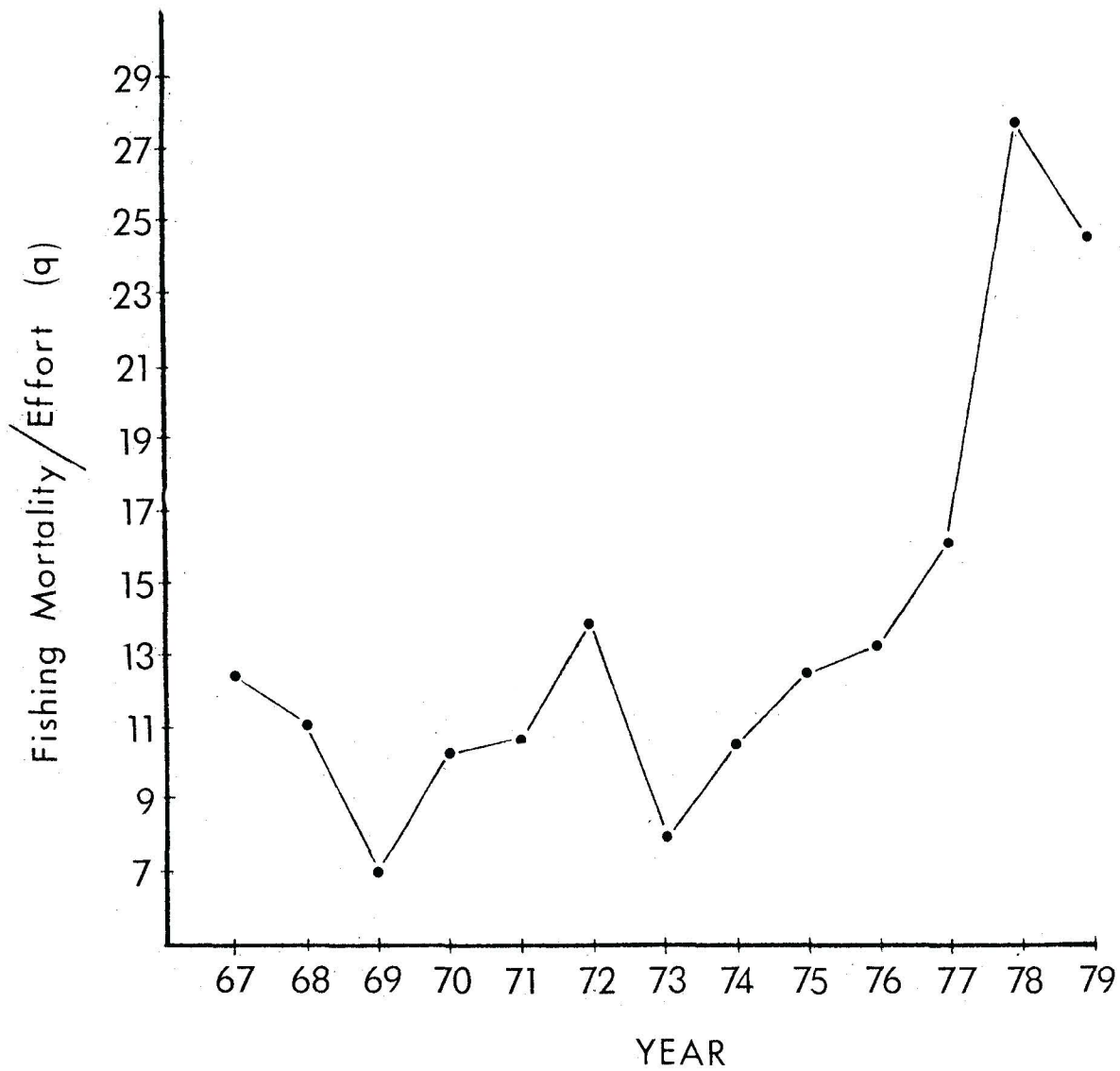


Figure 15. Trends in "q" for the summer purse-seine fishery.

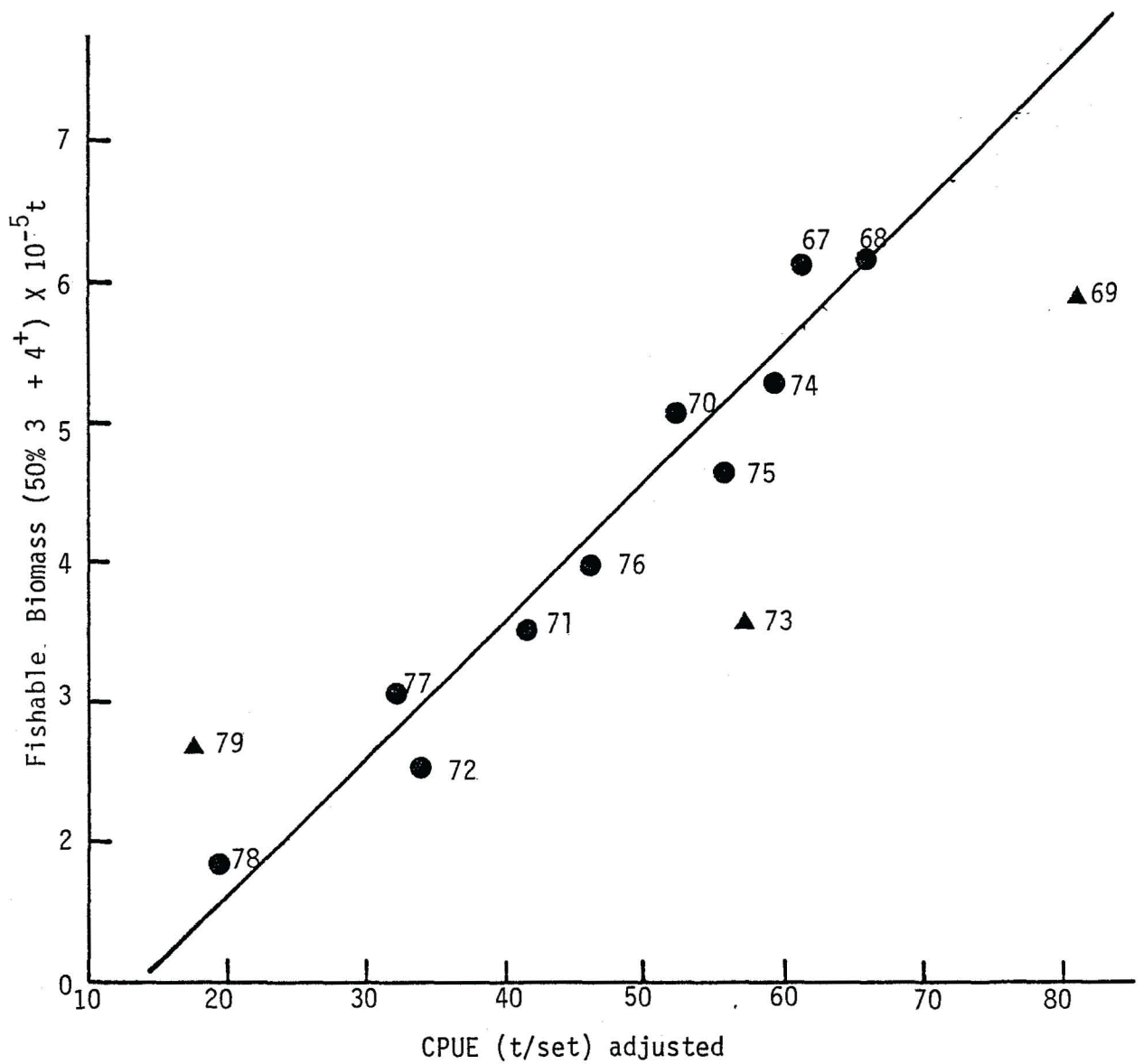
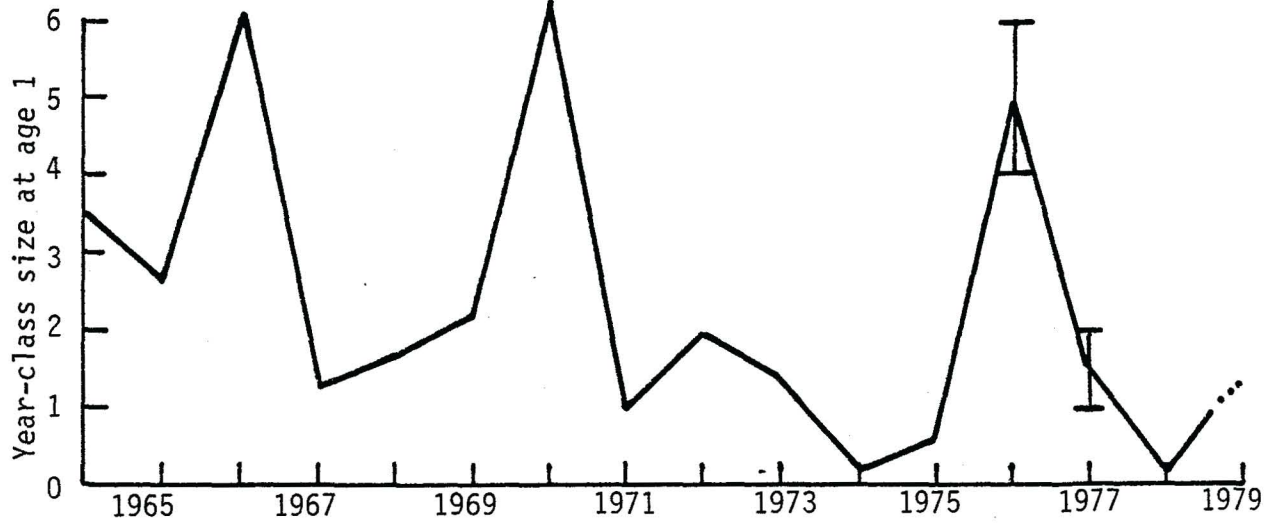


Figure 16. Relationship between 4WX herring fishable biomass and adjusted CPUE (summer purse-seine fishery).

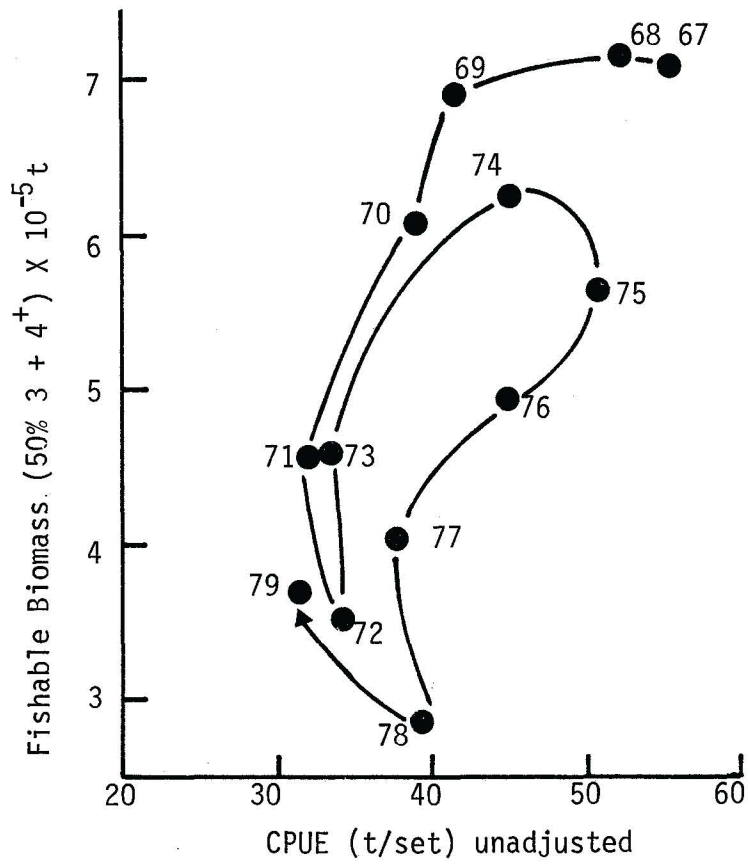


Figure 17. Relationship between 4WX herring fishable biomass and unadjusted CPUE (summer purse-seine fishery).

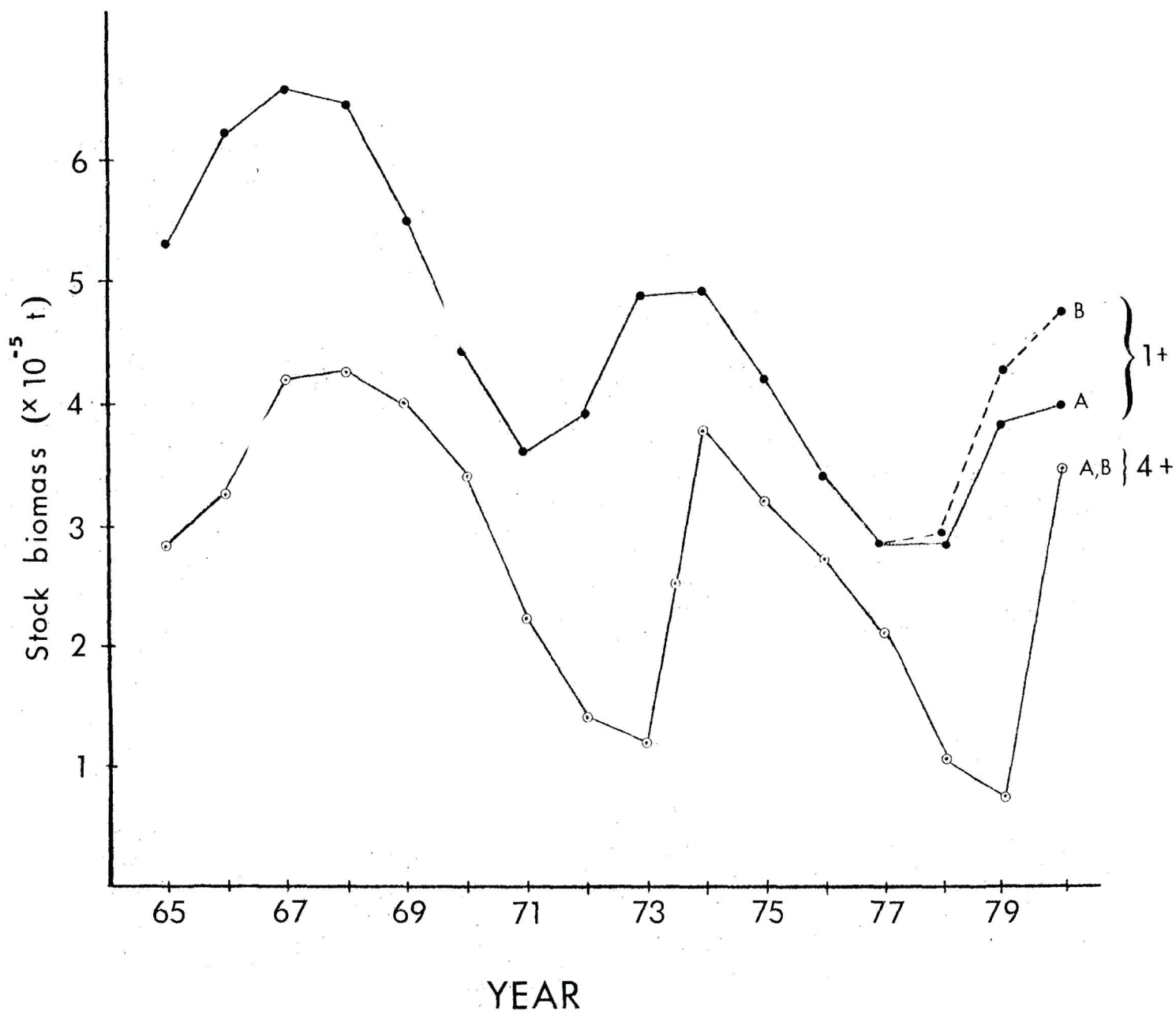


Figure 18. Trends in 4WX herring stock biomass.

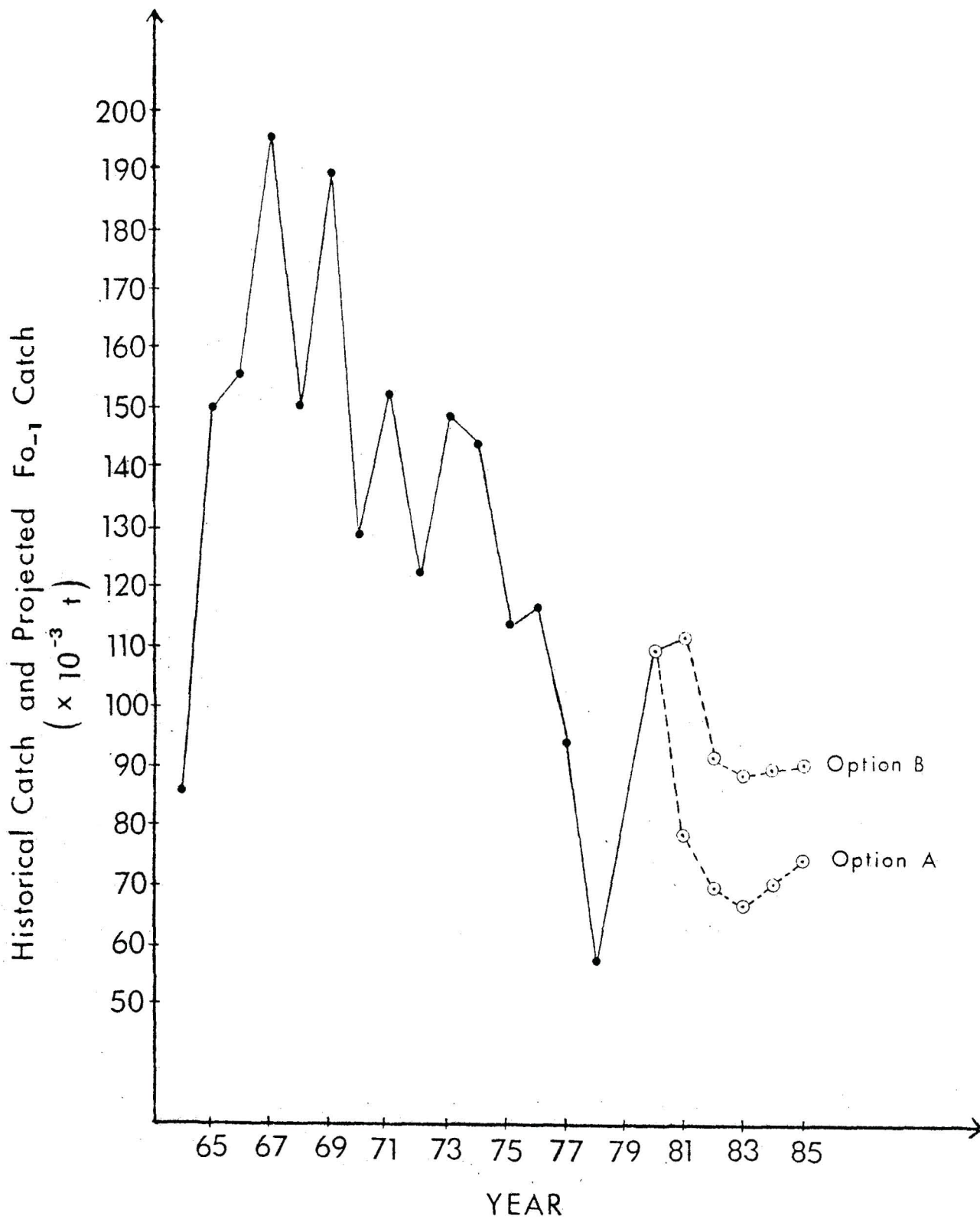


Figure 19. Historical trends in 4WX herring catch and projections (at $F_{0.1}$) to 1985.