Fisheries and Oceans Science | Pêches et Océans Sciences

C S A S | **S C C S**

Canadian Science Advisory Secretariat | **Secrétariat canadien de consultation scientifique**

Research Document 2001/146 | **Document de recherche 2001/146**

Not to be cited without permission of the authors *

Ne pas citer sans autorisation des auteurs *

Preliminary Comparative Analysis of Herring Biosamples from an Alternative Harvest Method

Josie Osborne[1], Gayle Brown[2], and Don Hall[1]

[1] Nuu-chah-nulth Tribal Council
PO Box 1383
Port Alberni, BC V9Y 7M2

[2] Fisheries and Oceans Canada
Salmon Stock Assessment Division
Pacific Biological Station
3190 Hammond Bay Road
Nanaimo, BC V9T 6N7

ISSN 1480-4883
Ottawa, 2001

Abstract

Since the inception of roe herring fisheries in 1975, Fisheries and Oceans Canada (DFO) has conducted an extensive test fishing program using commercial seine boats to provide critical information for the management of Pacific herring stocks. To examine whether herring biosample data could also be collected by an alternative method to charter vessels, the Nuu-chah-nulth Tribal Council (NTC) initiated the "Alternative Herring Biosampling Program" in 1995 for the West Coast of Vancouver Island. We describe the three different sampling methods (pre-fishery, fishery, and hand purse seine) and compare the population characteristics of the herring sampled by each method. We conclude that data collected by the hand purse seine are no less variable than data collected by the other two methods, but that the hand purse seine captures more mature fish and more males due to the timing of its use during spawning. The hand purse seine is relatively inexpensive and simple to operate compared to commercial herring vessels, and can be used to collect herring biosample data; however, further refinement of the analyses is required to determine if this method has potential as supplemental sampling in appropriate circumstances (e.g., minor stock areas, major stock areas in years without commercial herring fisheries, or areas that test vessels have difficult operating in). We also found that differences exist between data collected far in advance of the fishery (prior to March 1st) and data collected near or during the fishery, which may have implications for post-season assessment that relies on data that is representative of catch. This should be further investigated.

Résumé

Depuis le début des pêches du hareng rogué en 1975, Pêches et Océans Canada (DFO) mène un vaste programme de pêche expérimentale effectuée par des senneurs commerciaux afin d'obtenir des données essentielles à la gestion des stocks de hareng du Pacifique. Pour déterminer si l'on peut obtenir des données sur des échantillons de hareng par une méthode autre que celle des bateaux affrétés, le conseil tribal Nuu-chah-nulth a entamé un programme d'échantillonnage alternatif du hareng en 1995, sur la côte ouest de l'île de Vancouver. Nous décrivons trois différentes méthodes d'échantillonnage (échantillonnages de pré-saison, durant la saison de pêche et par senne coulissante manuelle) et comparons les caractéristiques de population du hareng échantillonné par chaque méthode. Nous concluons que les données sur les prises capturées par senne coulissante manuelle ne sont pas moins variables que les données recueillies par les deux autres méthodes, mais que la senne coulissante manuelle capture davantage de poissons matures et de mâles en raison de son utilisation durant le frai. Comparé aux bateaux de pêche commerciale du hareng, l'engin manuel est peu coûteux et facile à utiliser, et il peut servir à recueillir des données sur des échantillons de hareng. Toutefois, les analyses doivent être perfectionnées pour déterminer si cette méthode présente du potentiel pour l'échantillonnage complémentaire dans certaines circonstances (p. ex. zones de stock secondaires, zones de stock importantes pour les années sans pêche commerciale ou zones où l'utilisation des bateaux de pêche expérimentale est difficile). Nous avons également trouvé des différences entre les données recueillies longtemps avant la saison de pêche (avant le 1er mars) et les données recueillies durant la saison de pêche ou peu de temps avant ou après, ce qui peut avoir des conséquences pour les évaluations post-saison fondées sur des données représentatives des prises. Il faut examiner davantage cet aspect.

Table of Contents

List of Tables

List of Figures

Introduction

Under the present management system for Pacific herring (*Clupea pallasi*) fisheries, Fisheries and Oceans Canada (DFO) has developed an extensive test fishing program that provides critical information for the management of Pacific herring stocks. The test fishing program for the herring fishery, which has been in existence since the roe herring fishery's inception in 1975, collects three general types of data:

- Abundance, location, fish size, and roe maturity to help fishery managers make in-season management decisions such as fishery openings and boundaries;

- Biological characteristics (e.g., fish size, sex, and age distribution) of herring populations in that year for use in post-season herring stock assessment; and

- Spawn data (e.g., spawn bed width and egg density), collected from SCUBA and surface spawn surveys and used in herring stock assessment.

This information is necessary to assess and manage herring fisheries under the present management system. Most of the assessment and monitoring work is conducted by contract vessels that are paid with a share of the herring resource, through a program administered by the Herring Research and Conservation Society.

To examine whether herring biosample data could also be collected by an alternative method to charter vessels, the Nuu-chah-nulth Tribal Council (NTC) initiated the "Alternative Herring Biosampling Program" in 1995 for the West Coast of Vancouver Island. After consideration of different gear types, NTC staff found that a small, hand-operated purse seine was well suited for collecting biosamples from actively spawning herring populations. Biosamples using this method were collected, mostly in Barkley Sound, from 1996 – 2000 (inclusive).

The purposes of this paper are to: (1) describe the different sampling methods (pre-fishery, fishery, and hand purse seine); (2) provide a preliminary comparison of the population characteristics of the herring sampled by the different methods to determine the degree of similarity between them; and (3) to make recommendations on the use of the hand purse seine in herring biosample data collection.

Methods

1.1 Biosample collection

Three types of biosamples were made: pre-fishery samples (PF), fishery samples (FSH), and hand-purse seine samples (HPS).

Pre-fishery samples were collected using a commercial seine vessel which made sets on larger schools of herring that skippers felt represented the fishable stocks in the area. To obtain a representative sample, the seine net is pursed until the captured herring "boil", presumably mixing all ages, sizes, sex, and maturity level of fish in the set. Hoop nets or dip nets were used to obtain samples from seine nets; the depth at which samples were taken was generally between 1 m and 20 m. Up to five samples were taken from different parts of the set and placed in buckets, and all the non-sampled fish were released (i.e., the seine net was not "dried up"). The five buckets were mixed to further increase the homogeneity of the samples.

Two types of biological sampling occur from each pre-fishery sample: one sample is frozen in a 20 l bucket (~120 herring) for subsequent length, age, and sex sampling, and an additional four or five buckets are processed on-board immediately for length frequency, sex ratio, and roe maturity. The total number of 20 l samples buckets collected in a year depends on the number of pre-fishery test sets in the area (generally with more samples taken in areas where a commercial opening is planned than in areas where no opening is planned) and on the number of sets made during a commercial opening.

Fishery samples are taken from catches at the fish processing plant, where catches, whose specific location, date, and vessel are known, are randomly sampled. Similar to pre-fishery samples, samples are frozen in a 20 l bucket (~120 herring) for subsequent length, age, and sex sampling. Pre-fishery and fishery samples were taken from 1975-2001.

Hand purse seine samples were collected using a 30 m long x 3 m deep hand purse seine from a small boat (e.g., 4.5 m rigid hull inflatable) at shallow spawning sites during spawning events. Biosamples were taken from the hand purse seine using a dip net, from about 1.5 m depth, placed in 20 l buckets, and frozen for subsequent length, age, and sex sampling. Hand purse seine samples were collected from various areas on the West Coast of Vancouver Island (see Tables 1-3) from 1995-2001.

1.2 Biological analysis

All frozen pre-fishery, fishery, and hand purse seine samples were processed by a DFO contractor, Tidewater Ltd. (Nanaimo, BC). Samples were thawed, and up to 100 fish were randomly sampled from each sample bucket for fork length and wet weight. Individual fish were then dissected to determine sex and to remove gonads for measurement of gonad wet weight (not all fish were sampled for gonad wet weight, see Table 1). Maturity was assessed by gonad texture and appearance according to a seven-stage maturity scale adapted from Bowers and Holliday (1961) and Parrish and Saville (1965).

Scale samples were taken, and DFO staff at the Pacific Biological Station's Ageing Lab conducted all ageing analyses. DFO herring staff collated and summarized all other biological data.

1.3 Data analysis

In all years, only pre-fishery data was collected before March 1st. Biological data from the pre-fishery sampling was separated into two categories for graphical presentation of the data and for discriminant function analysis: data from samples collected prior to Mar 1st (PF1), and data from samples collected on or after Mar. 1st (PF2). Sampling locations were assigned numerical values, with consecutive numbers roughly corresponding to locations along a coastline or within a certain area. Sampling dates were converted to Julian days.

Sexes were assigned a numerical value (1=male, 2=female). "Mean sex" of each sample was therefore a value between 1 and 2, with values less than 1.5 indicating a higher proportion of males. Gonosomatic index (GSI), a quantitative measure of maturity, was also calculated as percent wet body weight of gonads.

For each sample (e.g., by each method and in each year), mean and standard deviation of length, total weight, sex, age, maturity, gonad weight, and gonosomatic index (GSI) were determined using Systat 8.0 (SPSS 1998). Slope of the length-weight relationship was determined for each sampling method, in each year, for all herring, female herring, and male herring. Discriminant function analysis was applied to the four sampling methods (pre-fishery 1, pre-fishery 2, fishery, and hand purse seine) using Systat 8.0.

Results and Discussion

Summary information about herring sample dates, locations, and missing data points is provided in Table 1. Tables 2 and 3 show sample numbers at different locations and dates, respectively.

Six variables were used in this preliminary comparative analysis to examine whether sampling methods could be distinguished by sampling location, sample date, or sampling year: length, weight, age, sex, gonosomatic index, and state of maturity.

1.4 Effect of sampling location and date

1.4.1 Mean values of sample variables

Sample means of length, maturity, age, and sex vary considerably at locations where two or more methods were used, but do not appear to vary according to sample method (Fig. 1). Sample means of any one method varied considerably at any particular location, and did not differ obviously according to sample method. Differences in the range of sample mean values at different locations are likely due to the number of samples taken rather than a difference between locations (see Table 1). There are some indications of differences in the range of mean values among the years that samples were taken. For example, mean length of herring appears to decline from 1995 to 1997. A finer scale analysis may reveal more interesting patterns associated with sampling location.

More structure is apparent among the sample mean length, maturity, age, sex (Fig. 2) and mean weight and GSI (Fig. 4) when viewed by sampling day. Mean length and weight appear to decline in most years (1995-1998) from the earliest samples (always by the pre-fishery method) to the latest samples (always by the hand purse seine method). This observation led us to separate pre-fishery samples to those taken before March 1st (PF1) and those taken March 1st or later (PF2) (see Section 2.3 Data Analysis). Pre-fishery samples, always spanning the most days of the herring sampling season, show a consistent downward trend in mean length. This suggests that the trend is not due to sampling method only (e.g., mean length and weight may decline for hand purse seine samples because they are biased toward males, which are smaller than females, but other methods do not show the same sex composition bias). Mean sample age follows same trends as length and weight, which is not surprising as age and size are correlated.

Mean sample values of maturity state, with higher values indicating more mature fish, generally increase over the sampling season with hand purse seine samples showing the highest mean values (Fig. 2). This is expected, as hand purse seine sampling takes place during shallow spawning events while other sampling methods occur in deeper areas where herring have schooled in preparation for spawning. Similarly, in all years GSI values for the hand purse seine samples were considerably lower than mean GSI values of PF2 and fishery samples, and in most years mean GSI of the PF1 samples were somewhat lower than PF2 and fishery samples. This is not surprising, as GSI for female herring peaks immediately before spawning (Hay 1985), and the hand purse seine captured a significant portion of spawned out fish. Interestingly, the hand purse seine method consistently captured more males than females with the exception of a few samples, unlike the other methods, which gave roughly equal sex ratios on average (Fig. 2).

1.4.2 Variability in sample variables

Standard deviations (SD) of sample means for length, age, maturity, sex, weight, and GSI show considerable variation independent of sampling method (Fig. 3 and 4), although in almost every year (except 2000), SD of GSI increases throughout the season with the greatest variability in GSI occurring in hand purse seine samples. While there are apparent differences among years in the range of SD, there are no consistent trends with the exception of possible autocorrelation in variables such as length and age. In 1996, however, SDs were generally greater for each variable, and in 1997 the range of SD was the largest of six years of sampling for all variables except GSI. In general, SD of mean sample length, maturity, age, and GSI were higher for hand purse seine samples than the other two methods (with exceptions such as SDs of mean length in 1998). Standard deviations for mean sex were typically lower for hand purse seine samples, which is expected as these samples were biased towards males.

1.4.3 Skew and kurtosis in sample variables

It is useful to examine deviations from the normal distribution, as inferences about differences between methods may be made. Skew and kurtosis of sample length, maturity, age, and sex are shown in Figures 5 and 6, and of sample weight and GSI in Figure 7. Skew measures the symmetry of the distribution of sample values, while kurtosis measures the size of distribution tails. Positive kurtosis, or leptokurtic distributions, have too few values in the tails and are tall “spiky” distributions relative to the normal distribution. Negative kurtosis, or platykurtic distributions, indicate too many values in the tails and are short “squat” distributions.

Skew and kurtosis do not appear to differ between methods (i.e., all methods are sampling populations with similar distributions of variables), but differences are seen between sampling variables and between years. Absolute values of skew and kurtosis in mean length indicate that length is normally distributed, but interestingly, values of skew are mostly negative in 1995 (indicating few small fish), increasing to mostly positive in 1997 (indicating few large fish), then decreasing again to mostly negative in 1999 and 2000. A similar trend is also seen in sample weight (Fig. 7). These trends are not surprising, given that the average size of fish decreased from 1995 to 1997 then increased again.

Absolute values of skew and kurtosis of state of maturity are generally greater than values of other sampling methods, indicating that state of maturity may not be a normally distributed variable. Even so, no one method is distinguishable from others by these values, indicating that all methods are likely sampling the same population, regardless of the shape of its distribution of state of maturity. State of maturity is generally leptokurtic, having too few values in the tails of the distribution. This could result from herring all maturing at the same rate within a year, regardless of size or age.

Skew and kurtosis of age follows the same trend as length and weight (increasing from 1995 to 1997 then decreasing to 1999 and 2000), but skew values are always positive, indicating that there are always too few older fish in the distribution of sample values, with the least proportionate number in 1997. This indicates that either all methods are biased by selective sampling, perhaps due to avoidance behaviour by larger fish, or that this trend is the result of changing population structure, perhaps due to environmental conditions or fishing effects, or both.

The distribution of sex composition is almost always platykurtic (too many samples in the distribution tails) for all sampling methods, with the hand purse seine resulting in more case that are closer to mesokurtosis.

Although the mean values of several variables (most notably sex ratio and maturity) appear to be lower for hand purse seine samples than the other sample categories, the variability seen in all sample variables for all methods indicates that no individual sample could be used to distinguish itself according to sample method.

However, this comparative analysis is preliminary, therefore finer scale analyses (such as regression analysis) should be used.

1.5 Effect of method and year on mean of mean sample variables

Means of mean sample variables reveal more striking differences between sampling methods and sample years (Fig. 8 and 9) (data values in Appendices 1-6). For example, regardless of sampling method, mean length, weight, and age showed a common pattern: decline from 1995 to 1997, indicating herring populations comprised of younger, smaller fish, then a slight increase or levelling off toward 2000. Gonosomatic index (GSI) also generally shows this trend, whereas maturity and sex remain more constant over time. Decreasing values of mean GSI cannot be inferred from decreasing mean weights alone: it indicates fish with relatively smaller gonads. However, maturity state does remain relatively constant over time.

That these trends are detected by each sampling method indicates that sampling methods are similar (i.e., all methods are biased, or all methods are sampling to the same degree of representativeness). Maturity and sex composition are population characteristics more likely to remain constant over years; therefore it is not surprising that trends are not seen in the data. However, PF2 samples (conducted after March 1st) and commercial fishery samples resulted in more constant mean maturity and sex composition over time, with less variation in any one year, than PF1 samples (conducted before March 1st) and hand purse seine samples. This is likely due to the fact that PF2 and commercial fishery sampling each occur over the shortest time frame as the herring ripen to the optimal roe quality and the fishery is executed over a matter of hours or days. PF1 and hand purse seine sampling occur over longer periods of time and are more likely to sample fish that are at the tail ends of the distribution of maturity state, particularly if fish are maturing at the same rate, regardless of age or size.

Comparing sampling methods by trends in means of mean variables is facilitated by displaying them together (Fig. 10). The trend of decreasing mean length, weight, age, and GSI for all sampling methods is more obvious, and differences in the absolute values of means are more easily seen. Mean sample length and weight were typically highest in PF1 samples and lowest in hand purse seine samples, independent of year, whereas mean maturity state showed the opposite pattern among sampling methods. This pattern in maturity state is not surprising, given that PF1 samples always took place prior to March 1st as herring were moving inshore and just beginning to ripen, whereas hand purse seining took place during spawning events (i.e., most mature life stage possible) (see also Fig. 2). Recall that mean length of fish tended to decrease through the sampling season (particularly in 1995) (Fig. 2). This would result in the observed pattern.

Mean GSI was consistently greater in PF2 and commercial samples, although in 1995 and 1997, PF1 samples approached that of PF2 and commercial fishery samples, because these samples are taken close to or during the commercial fishery, which targets herring that are as mature as possible with very low proportions of spawned out individuals. GSI is likely lower in PF1 samples because they are taken earlier in the season before gonads are fully developed. GSI is lower in hand purse seine samples due to the proportion of spawned-out fish with therefore low GSI values. In addition, hand purse seine samples mean GSI values may be further decreased because they are biased to males, whose GSI peaks in late January/early February (Hay 1985) and is lower than that of females.

One of most striking difference between sampling methods is seen in sex composition: the hand purse seine reveals a consistent bias towards males. The general pattern of sex composition over time is similar among methods, with relatively constant composition from 1995 to 1997, an increase in the proportion of males in 1998 (when all methods sampled more males than females, and increase in the proportion of males in 1999 followed by another decrease in 2000 (when again all methods gave more males that females). This bias has an important implication for estimates of mean weight, because males are generally smaller at a given age or length than females.

The difference in hand purse seine samples indicates that either the hand purse seine is sampling a different population of herring than the other methods, which is unlikely, or the hand purse seine is selective to males. Herring are unlikely to detect and avoid the hand purse seine during spawning events due to the cloudy milt-filled water and we have not observed any change in herring behaviour due to the approach of a boat or the dispersal of the purse seine, therefore the bias towards males is probably not caused by avoidance behaviour.

Pacific herring do demonstrate sex related differences in migrating to spawning areas. Male herring tend to approach the spawning grounds before females (Hay 1985). Males may also linger, whereas females are may spawn then leave the spawning area. This behaviour pattern would explain the apparent bias toward males in the hand purse seine samples.

1.6 Effect of method and year on length-weight relationship.

The length-weight relationship is often used to characterize and compare populations. Mean slope of the linear relationships between weight and length of individual samples reveals a strong trend (Fig. 11 and 12) (data values in Appendices 7-9): decrease in mean slope from 1995 to 1998 followed by slight increase towards 2000. Mean slope decreased in 1998 even though mean length increased (Fig. 8) due to the decrease in mean weight (Fig. 8) (i.e., in 1998, fish were smaller at a given length than in 1997, even though the average herring was longer than in 1998). This trend is seen independent of sampling method or sex of fish, although hand purse seine samples do not show the same increase in mean slope in 1999 and 2000 as the other three methods. The hand purse seine may not be as effective in detecting small changes between years in population characteristics due to herring spawning behaviour (i.e., stratification by size and sex in time or space) whereas the change in population composition from 1995 to 1997 was likely large enough to be detected by all sampling methods.

The hand purse seine consistently gave lower mean slope values, regardless of sex, than the other methods. This bias is likely due to the fact that the hand purse seine captures more spawned-out herring than other methods, resulting in smaller mean weights of herring caught and decreased length-weight slope values. Pre-fishery and commercial fishery samples do not show any distinguishable patterns. For all methods and in all years (particularly 1999), mean slope values are greater for females than males which is expected as female fish are bigger at a given length than males.

1.7 Total body weight vs. somatic body weight

Both total herring weight and gonad weight were recorded for some herring samples. We compared mean of mean somatic weight values of herring (i.e., total weight minus gonad weight) to determine the influence of gonad development (Fig. 12). Compared to the mean weight panel in Figure 8, the difference among methods is reduced, but the hand purse seine remained lowest in three of the six years of sampling and PF1 samples are highest of all methods in all years but two. However, hand purse seine sample values should probably be even lower than shown in Figure 11 because many herring in the hand purse seine samples were spawned-out and therefore no gonad weight was recorded (i.e., for a proportion of fish in the sample, the gonad weight that was subtracted from total body weight was zero or negligible), whereas almost all fish had some gonad weight in pre-fishery and commercial fishery samples. Herring cease feeding prior to spawning, meaning that PF1 samples may be relatively higher in somatic weight than in other sampling methods, and the conversion of somatic tissue energy to developing gonads results in decreasing somatic weights prior to spawning.

1.8 Age and state of maturity frequency distributions

Examining the frequency distribution of some of the variables measured provides additional insight into any observed differences or trends of mean values of those variables between sampling methods or across years. Age frequencies of all herring sampled and aged (the distributions of the mean of sample means shown in Figure 9) reveal no differences between sampling methods in any year for all herring, female herring, and male herring (Fig. 14-16). However, changes in age frequency between years are visible: a strong recruitment of 3 yr olds is seen in 1997, and this cohort is seen in 1998 and 1999. This strong pulse of recruits causes the highly leptokurtic age distributions seen in Figure 6 (1997 and 1998 panels). By 2000, the age distribution of fish was more similar to those of 1995 and 1996.

The frequency distributions of states of maturity (the distributions of the mean of sample means shown in Figure 9) do reveal some differences between methods (Fig. 17-19). The hand purse seine shows a definite bias to more mature fish (state #6-8), indicating that most fish had begun or completed spawning. The majority of fish taken in other samples had not begun spawning.

Unlike age frequencies, state of maturity frequencies show differences between sexes. The PF2 and commercial fishery sample distributions for all fish are almost identical, as expected due to the short range of sampling time (see Section 3.2), and less variable that the PF1 and hand purse seine distributions. However, almost all female fish caught in the commercial fishery samples are at maturity state #5 (Fig. 18), whereas males show more variability in the commercial fishery samples (Fig. 19) and are on average more mature. Unlike the distributions of females from PF2 and commercial fishery samples, the distribution of males is not as similar between these two methods. These are not surprising results, as the commercial fishery is timed so that roe (from female fish only) is of the optimal quality for fishermen, and males tend to mature slightly earlier than females (Hay 1985).

Males caught in the hand purse seine are also more mature than females caught using the same method: this is expected as males tend to begin spawning earlier than females (Hay 1985). Like the commercial fishery samples, female PF2 samples also show very little variability and are comprised mostly of fish at maturity state #5. Interestingly, mature female and male fish were recorded in every sample, even though some samples were taken well in advance of observed spawning activity.

1.9 Discriminant function analysis

While numerous differences are indicated by individual variables among the sampling methods, as suggested in a number of the figures, statistical comparisons are hampered for a number of reasons. First, samples taken by different methods cannot be considered a random subset of all possible sampling locations or dates. Second, there was little correspondence among the sampling methods at sampling locations or on sampling dates in any given year (Tables 1-3). In addition, even when samples were taken at the same location by the different methods in a given year, these never occurred on the same date (and vice versa with date and location). Possible effects due to both sampling location and date need to be taken into account in statistical analyses but we are not aware of any statistical approaches that can accommodate such complex cross-correlations among samples.

Despite limitations in statistical approaches, we employed a quantitative approach that included all or at least a number of the available variables simultaneously to portray relative similarity (or difference) among samples collected by the three methods. We applied Discriminant Function Analysis (DFA) (Systat 1998) to accomplish this task. DFA is a classification technique that uses a supplied set of variables to derive a function by which each sample is assigned to one category of the classification factor. While DFA is typically used to generate a function by which to classify future samples, we use it here only as a means for quantitatively representing similarity or difference among the sampling methods.

All sample means (N=316) of the various sample variables (length, total weight, age, state of maturity, GSI, and sex) were submitted to the analysis using the four sampling categories (PF1, PF2, commercial fishery, and hand purse seine) as the factor for classification. An automatic ‘backward stepping’ variable selection procedure was also employed to determine the smallest set of variables necessary to produce the most accurate classification of the samples into sampling categories.

Since the number of samples was not balanced across categories (PF1=48, PF2=129, FSH=57, and HPS=82), we performed two separate analyses, one that included the proportion of samples in each sampling category out of the total as a weighting factor, and one that did not. Each reduced the list of included variables to the same subset (length, total weight, maturation index and GSI index), however, they resulted in slightly different classifications of the samples (Tables 4 and 5). A jackknife procedure, in which every sample was also classified using a separate function derived with it excluded, was performed in conjunction with each of the two analyses (Tables 4 and 5). This procedure is a form of cross-validation of the performance of DFA in classifying the samples. The DFA has performed relatively well if the classification of samples by the jackknife procedure differs little from that based on all samples.

Overall, both analyses correctly classified most of the samples (72% and 67% with and without the weighting factor included, respectively) and the close agreement of the companion jackknife procedures indicates the results were quite robust (Tables 4 and 5). Both analyses correctly classified most samples in the PF1, PF2 and HPS categories (with the weighting factor: 69%, 89% and 82%, see Table 4; without the weighting factor: 73%, 57% and 82%, see Table 5). Most of the misclassified PF1 and HPS samples were incorrectly classified as PF2s. Interestingly, most of the FSH samples were incorrectly classified with the weighting factor included (only 21% correct) and every misclassification was identified as a PF2 sample. Without the weighting factor, more FSH samples were correctly classified (65%) but again, all misclassifications were identified as PF2s. While 89% of PF2 samples were classified correctly with the weighting factor included, only 57% were without it and most misclassifications were confused as FSH samples. This relatively poor separation of the PF2 and FSH samples is evident in their high degree of overlap in scatterplots between each of the three canonical scores (Fig. 20) derived per sample from the DFA (number of scores always equals number of variables –1). Confusion between PF2 and FSH samples seems simply explained by the fact that these samples overlapped in timing of collection most years while the PF1s and HPSs overlapped with neither them nor each other (Table 3).

The most striking result of all is that out of both analyses and their companion jackknife procedures, only one PF1, PF2 or FSH sample was misclassified as a HPS sample. Likewise, few PF2, FSH or HPS samples were misclassified as PF1s (5 and 13 with and without the weighting factor, respectively). This indicates that for the most part, the HPS and PF1 samples were relatively distinct from the others and from each other. This is also evident in their greater separation in the scatterplots between the canonical scores (Fig. 20). Overall, the results of the DFA show detectable differences between the hand purse seine and the other sampling methods, which may be due to the differences between these methods in the maturity, sex, and GSI of the fish they capture. Figure 20 shows only the results from the DFA without the weighting factor included and the reason for this is that the results from the DFA with the weighting factor were highly similar visually to those without.

Conclusions

We have presented an overview and summary of the herring biosample data taken by the pre-fishery, fishery, and hand purse seine methods. The hand purse seine is a viable method for catching herring for biosample analysis, indicated by our success in consistently capturing herring with it. Because a robust analysis of the differences in the data collected by the pre-fishery, fishery, and hand purse seine methods is difficult to conduct due to the differences in timing and locations of sampling (e.g., is the difference in results between methods due to the methods, or the sampling date, or location, etc.?), we have presented a preliminary comparative analysis. Interpretation of this analysis is further complicated by the possibly confounding effects of environmental variation and fishing on herring population structure, maturation rates, and distribution in space and time. Nevertheless, we conclude the following:

1. The hand purse seine is a viable method for collecting herring biosample data.

2. The hand purse seine detects the same year-to-year trends detected by other sampling methods.

3. Due to the timing of its use during active spawning, the hand purse seine captures more mature fish (including spawned-out fish) and more males, which may bias sample weight and weight related variables (e.g., GSI and length/weight slope).

4. The variability seen in all sample variables for all methods indicates that no individual sample could be used to distinguish itself according to sample method. However, this comparative analysis is preliminary, therefore finer scale analyses (such as regression analysis) should be used.

5. The hand purse seine is relatively inexpensive and simple to operate compared to commercial herring vessels, and can be used to collect herring biosample data; however, further refinement of the analyses is required to determine if this method has potential as supplemental sampling in appropriate circumstances (e.g., minor stock areas, major stock areas in years without commercial herring fisheries, or areas that test vessels have difficult operating in).

6. Differences in sample variables do exist between years. Many of these differences (e.g., size-at-age) have been discussed elsewhere and are the subject of on-going research programs.

7. In addition to differences in some data collected by hand purse seine, our comparative analysis (including the discriminant function analysis) shows that some differences exist between data collected well in advance of the fishery (PF1) and data collected near or during the fishery (PF2 and FSH). This may have implications for post-season assessment that relies on data that is representative of catch and should be further investigated.

Acknowledgments

Field work and data collection was supported by the Nuu-chah-nulth Tribal Council. Data analysis and report writing was supported by the Herring Conservation and Research Society and the NTC. Jake Schweigert, Lorena Hamer, Laurie Gordon, Dennis Chalmers, and other DFO staff assisted the project with technical, logistic, and equipment support. Jim Lane (NTC), Roger Dunlop (NTC), and the Mowachaht/Muchalaht and Ahousaht Fisheries staffs collected most of the hand purse seine samples. The Ucluelet First Nation, via Ken Widsten and the crew of the FPV *Ganges*, provided meals and accommodation.

References

Bowers, A.B., and F.G.T. Holliday. 1961. Histological changes in the gonad associated with the reproductive cycle of the Pacific herring (*Clupea harengus* L.). Mar. Res. Soc. No. 5: 16 p.

Hay, D.E. 1985. Reproductive biology of Pacific herring (*Clupea harengus pallasi*). Can. J. Fish. Aquat. Sci. 42 (Suppl. 1):111-126.

Hay, D.E., Cooke, K.D., and Gissing, C.V. 1986. Experimental studies of Pacific herring gillnets. Fish. Res. 4:191-211.

Parrish, B.B., and A. Saville. 1965. The biology of the northeast Atlantic herring populations. Oceanogr. Mar. Biol. Ann. Rev. 3:323-373.

SPSS. 1998. SYSTAT 8.0 Statistics. SPSS Science Marketing, Chicago. 1086 pp.

Tanasichuk, R. 1997. The effect of sampling time on the age composition of herring test fishing samples. PSARC Working Paper H97-6.

Ware, D. and Tanasichuk, R. 1989. Biological basis of maturation and spawning waves in Pacific herring (*Clupea harengus pallasi*). Can. J. Fish. Aquat. Sci. 46:1776-1784.

Table 1 Summary information concerning all herring samples taken by three different methods, pre-fishery (PFS), fishery (FSH), and hand purse seine (HPS), in Statistical Area 23, 1995-2000.

	1995			**1996**			**1997**			**1998**			**1999**			**2000**		
	PFS	**FSH**	**HPS**	**PFS**	**FSH**	**HPS**	**PFS**	**FSH**	**HPS**	**PFS**	**FSH**	**HPS**	**PFS**	**FSH**	**HPS**	**PFS**	**FSH**	**HPS**
N Samples	31	13	15	40	4	11	34	10	27	27	11	17	28	11	1	17	8	11
Total Fish Sampled	3096	1300	1500	4000	400	1098	3400	1000	2700	2700	1100	1700	2800	1100	100	1700	800	1100
N Sampling Dates	18	2	2	22	2	3	15	1	5	16	1	3	19	2	1	13	2	1
Date of First Sample	2/20	3/3	3/16	2/18	3/14	3/13	2/20	3/4	3/11	2/19	3/9	3/7	2/21	3/10	3/31	2/24	3/8	3/23
Date of Last Sample	3/12	3/4	3/17	3/14	3/15	3/15	3/10	3/4	3/16	3/13	3/9	3/17	3/30	3/11	3/31	3/14	3/9	3/23
N Locations Sampled	13	4	6	12	2	4	11	3	8	12	8	6	9	4	1	5	2	4
Missing Lengths	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Missing Weights	5	0	1	2	0	0	1	0	1	0	0	1	0	0	0	0	0	2
Missing Sex	0	0	2	8	0	0	2	0	3	3	0	0	5	2	0	6	0	0
Missing Maturitys	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Missing Ages	163	161	82	186	88	36	116	125	73	103	120	59	135	101	3	78	89	56
N Dual-aged	56	21	21	88	6	19	57	17	41	34	13	30	43	22	1	16	11	12
Missing Gonad Lengths	25	39	368	54	13	258	28	17	34	64	68	721	64	46	29	50	72	486
Missing Gonan Weights	32	39	481	37	7	279	27	11	669	53	62	720	56	41	29	29	66	484

Table 2. Locations sampled in statistical area 23 during 1995-2000. Shown are the numbers of samples collected by the three sampling methods. ‘PFS’ indicates prefishery seine samples, ‘FSH’ indicates fishery seine samples and ‘HPS’ indicates hand purse seine samples. Multiple samples in any year at a given location indicate multiple sampling dates.

		1995			**1996**			**1997**			**1998**			**1999**			**2000**		
Location	**PFS**	**FSH**	**HPS**	**PFS**	**FSH**	**HPS**	**PFS**	**FSH**	**HPS**	**PFS**	**FSH**	**HPS**	**PFS**	**FSH**	**HPS**	**PFS**	**FSH**	**HPS**	**Total**
1116	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2
1131	-	-	-	-	-	-	-	-	2	-	-	2	-	-	-	-	-	-	4
1132	-	-	1	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	2
1133	2	2	-	-	-	-	4	-	-	-	-	-	-	-	-	-	-	-	8
1135	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2
1137	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	1
1138	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	1
1141	-	1	-	1	-	-	-	-	2	-	-	-	-	-	-	-	-	-	4
1142	2	8	1	1	-	-	11	-	14	3	3	-	-	-	-	1	-	-	44
1143	1	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	2
1144	5	-	5	-	-	5	6	-	2	-	1	4	-	-	-	-	-	-	28
1145	9	-	-	8	-	-	2	5	-	2	1	2	6	1	-	7	7	-	50
1146	2	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	3
1150	2	-	-	-	-	2	1	2	1	1	1	-	7	5	1	-	-	3	26
1152	-	-	-	1	-	-	-	-	-	-	-	-	3	1	-	-	-	-	5
1153	-	-	2	1	-	2	-	-	-	-	-	2	-	-	-	-	-	-	7
1154	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
1155	-	-	2	-	-	-	3	-	2	3	-	-	1	-	-	1	-	2	14
1156	1	-	-	-	-	-	-	-	-	-	1	-	1	-	-	-	-	-	3
1157	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	2
1158	1	-	-	3	-	-	-	-	2	-	-	-	-	-	-	-	-	-	6
1159	-	-	4	1	-	-	-	-	2	2	2	4	2	4	-	-	-	4	25
1413	-	-	-	11	-	-	1	3	-	2	-	-	-	-	-	-	1	-	18
1471	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	2	3
1542	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	2
1549	3	-	-	4	2	-	3	-	-	7	-	-	6	-	-	6	-	-	31
1551	1	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	2
1659	1	-	-	6	-	-	1	-	-	-	-	-	-	-	-	-	-	-	8
1755	-	-	-	-	2	2	-	-	-	1	-	-	-	-	-	-	-	-	5
1832	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	1
1869	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
1957	-	-	-	-	-	-	-	-	-	2	-	3	-	-	-	-	-	-	5
Total	31	13	15	40	4	11	34	10	27	27	11	17	28	11	1	17	8	11	316
N Locations	13	4	6	12	2	4	11	3	8	12	8	6	9	4	1	5	2	4	

Table 3. Dates sampled in 1995-2000 by the three sampling methods. Shown are the numbers of samples collected by the three sampling methods. 'PFS' indicates prefishery seine samples, 'FSH' indicates fishery seine samples and 'HPS' indicates hand purse seine samples. Multiple samples in any year on a given sampling date indicate multiple sampling locations.

			1995			**1996**			**1997**			**1998**			**1999**			**2000**	
Month	**Day**	**PFS**	**FSH**	**HPS**	**PFS**	**FSH**	**HPS**	**PFS**	**FSH**	**HPS**	**PFS**	**FSH**	**HPS**	**PFS**	**FSH**	**HPS**	**PFS**	**FSH**	**HPS**
2	18	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	19	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-
	20	1	-	-	2	-	-	2	-	-	-	-	-	-	-	-	-	-	-
	21	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-
	22	1	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-
	23	1	-	-	3	-	-	2	-	-	-	-	-	1	-	-	-	-	-
	24	-	-	-	1	-	-	1	-	-	1	-	-	-	-	-	1	-	-
	25	1	-	-	1	-	-	3	-	-	-	-	-	1	-	-	-	-	-
	26	1	-	-	-	-	-	1	-	-	1	-	-	-	-	-	2	-	-
	27	4	-	-	1	-	-	2	-	-	1	-	-	-	-	-	-	-	-
	28	3	-	-	1	-	-	1	-	-	-	-	-	1	-	-	-	-	-
	29	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	2	-	-
3	1	2	-	-	2	-	-	5	-	-	1	-	-	1	-	-	1	-	-
	2	3	-	-	1	-	-	2	-	-	3	-	-	-	-	-	1	-	-
	3	2	12	-	1	-	-	5	-	-	2	-	-	-	-	-	1	-	-
	4	4	1	-	1	-	-	3	2	-	2	-	-	2	-	-	2	-	-
	5	2	-	-	2	-	-	4	-	-	1	-	-	1	-	-	2	-	-
	6	1	-	-	1	-	-	1	-	-	2	-	-	1	-	-	1	-	-
	7	1	-	-	2	-	-	1	-	-	-	-	2	1	-	-	1	-	-
	8	-	-	-	3	-	-	-	-	-	2	-	-	1	-	-	1	5	-
	9	1	-	-	2	-	-	-	-	-	2	11	-	2	-	-	-	3	-
	10	1	-	-	2	-	-	1	-	-	-	-	-	4	3	-	-	-	-
	11	1	-	-	3	-	-	-	-	4	5	-	-	1	8	-	-	-	-
	12	1	-	-	3	-	-	-	-	4	1	-	-	1	-	-	1	-	-
	13	-	-	-	2	-	1	-	-	-	1	-	-	3	-	-	-	-	-
	14	-	-	-	3	3	3	-	-	6	-	-	-	-	-	-	1	-	-
	15	-	-	-	-	1	7	-	-	10	-	-	-	1	-	-	-	-	-
	16	-	-	2	-	-	-	-	-	3	-	-	6	1	-	-	-	-	-
	17	-	-	13	-	-	-	-	-	-	-	-	9	-	-	-	-	-	-
	18	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-
	23	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	11
	30	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-
	31	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-
Total Samples		31	13	15	40	4	11	34	2	27	27	11	17	28	11	1	17	8	11
N Sample Dates		18	2	2	22	2	3	15	1	5	16	1	3	19	2	1	13	2	1

Table 4. Discriminant function classification of all herring samples (N=316) collected from 1995-2000 in the different sampling categories. Samples in the row categories are classified into columns. The left half of the table shows the actual results of the analysis, whereas the right half shows the additional results of a jackknife procedure. These analyses included a weighting factor that equalled the proportion of samples that each sampling category made up out of the total number.

	Classification Matrix					Jackknifed Classification Matrix				
	PF1	**PF2**	**FSH**	**HPS**	**% correct**	**PF1**	**PF2**	**FSH**	**HPS**	**% correct**
PF1	33	15	0	0	69	32	16	0	0	67
PF2	4	115	10	0	89	4	114	11	0	88
FSH	0	45	12	0	21	0	45	12	0	21
HPS	1	13	1	67	82	1	13	1	67	82
Total	38	188	23	67	72	37	188	24	67	71

Table 5. Discriminant function classification of all herring samples (N=316) collected from 1995-2000 in the different sampling categories. Samples in the row categories are classified into columns. The left half of the table shows the actual results of the analysis, whereas the right half shows the additional results of a jackknife procedure. These analyses did not include the weighting factor**.**

	Classification Matrix					Jackknifed Classification Matrix				
	PF1	**PF2**	**FSH**	**HPS**	**% correct**	**PF1**	**PF2**	**FSH**	**HPS**	**% correct**
PF1	35	11	2	0	73	35	10	3	0	73
PF2	12	73	43	1	57	12	72	44	1	56
FSH	0	20	37	0	65	0	24	33	0	58
HPS	1	11	3	67	82	1	11	3	67	82
Total	48	115	85	68	67	48	117	83	68	66

Table 6. Distribution of misclassifications (i.e. errors) produced by the two discriminant function analyses by sampling category and year. Columns labelled with 'T' indicate the total number of samples available for classification in the category. 'W' indicates the number of misclassifications in the analysis with the weighting factor and 'NW' indicates the number without the weighting factor**.**

	PF1			PF2			FSH			HPS		
Year	**T**	**W**	**NW**	**T**	**W**	**NW**	**T**	**W**	**NW**	**T**	**W**	**NW**
1995	12	3	3	19	7	0	13	3	11	15	1	0
1996	12	0	0	28	7	2	4	2	4	11	2	2
1997	12	8	10	22	3	0	10	8	10	27	8	9
1998	5	0	0	22	15	4	11	1	5	17	2	2
1999	4	0	0	24	19	7	11	0	7	1	0	0
2000	3	2	2	14	5	1	8	6	8	11	2	2
Total	48	13	15	129	56	14	57	20	45	82	15	15

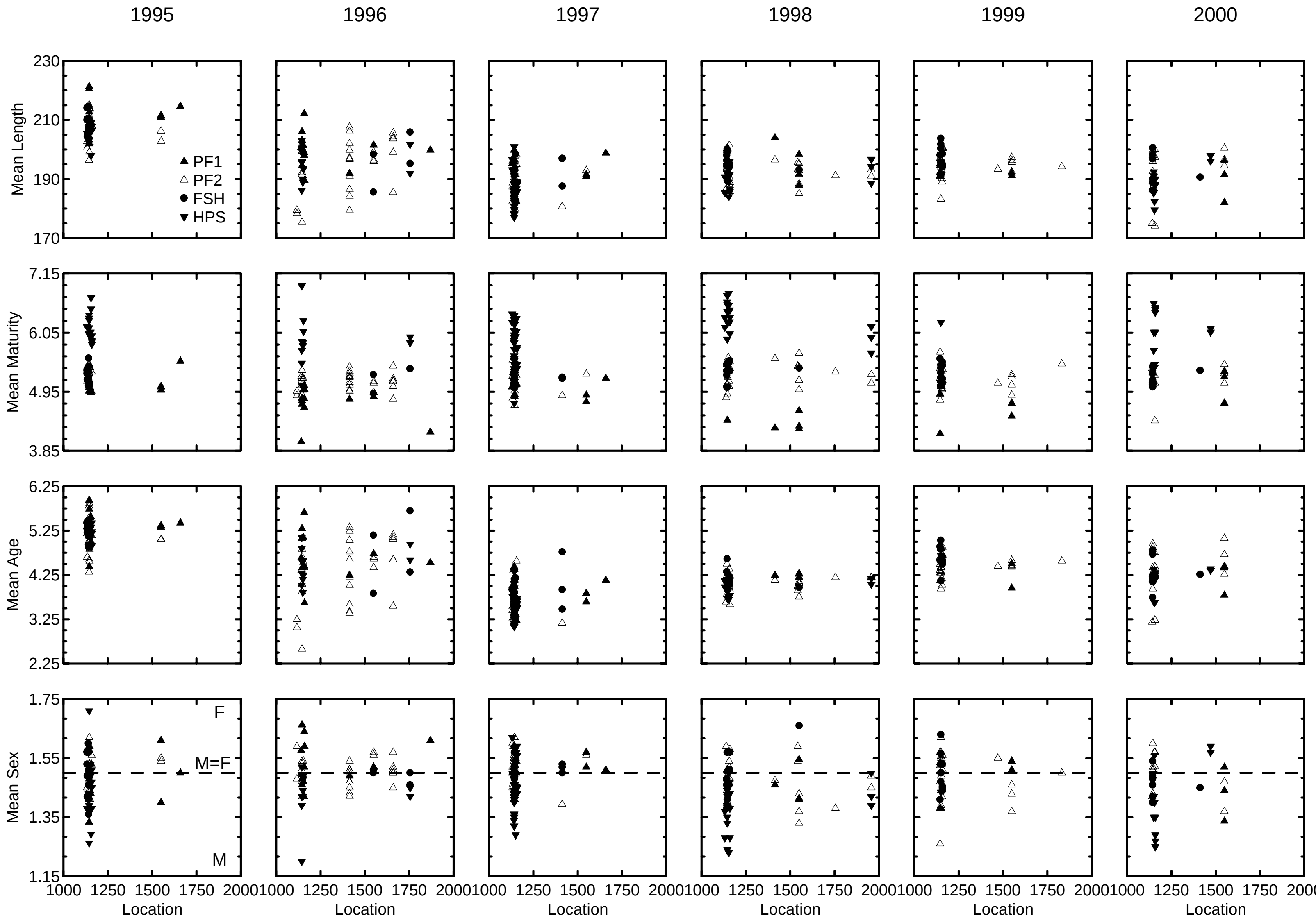

Figure 1. Mean length, maturity, age, and sex of pre-fishery herring samples (separated into those sampled prior to March 1st ▲ and those sampled March 1st or later △), fishery samples (○), and hand purse seine samples (▼) by location for 1995-2000.

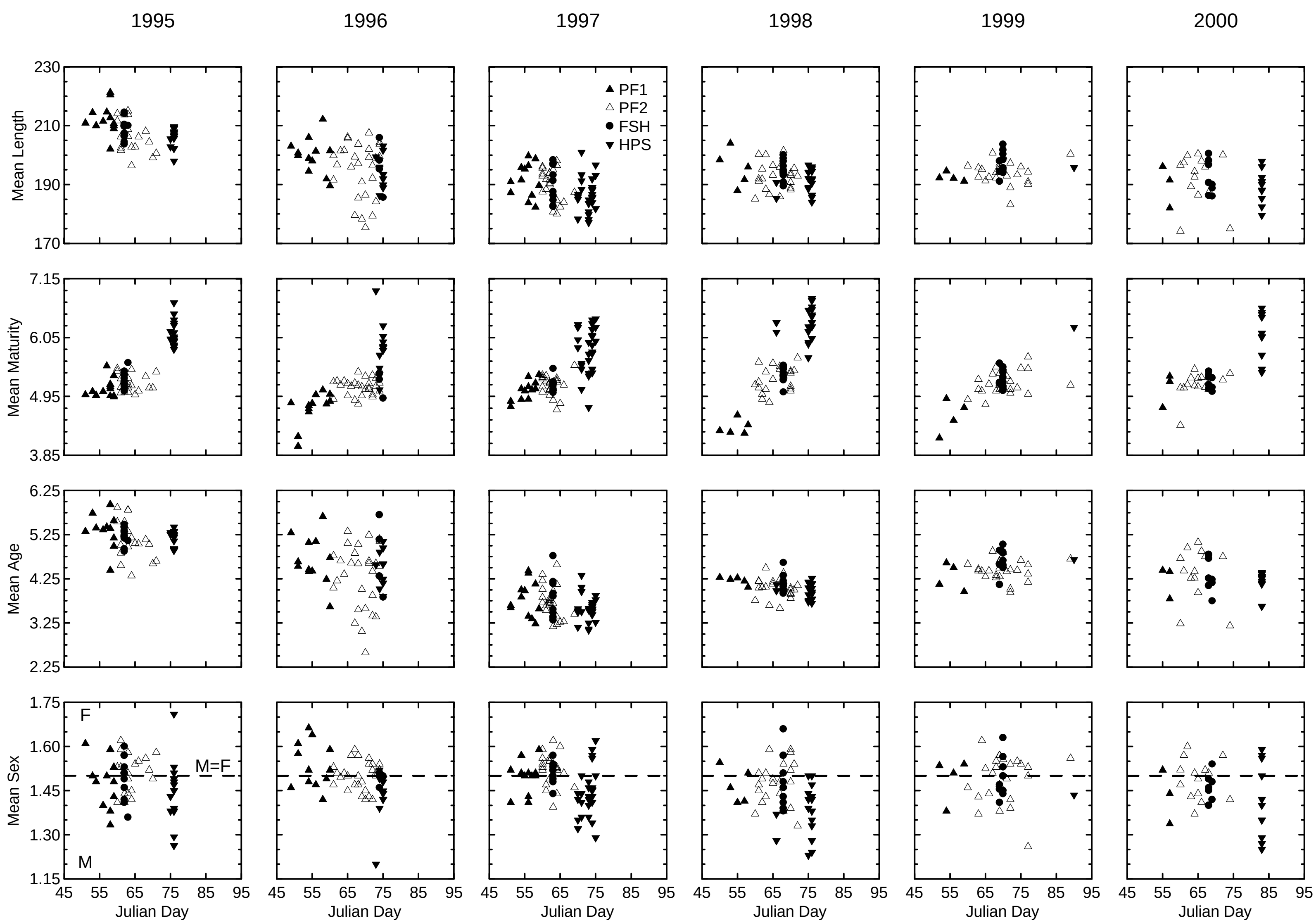

Figure 2. Mean length, maturity, age, and sex of pre-fishery herring samples (separated into those sampled prior to March 1st ▲ and those sampled March 1st or later △), fishery samples (○), and hand purse seine samples (▼) by Julian day for 1995-2000.

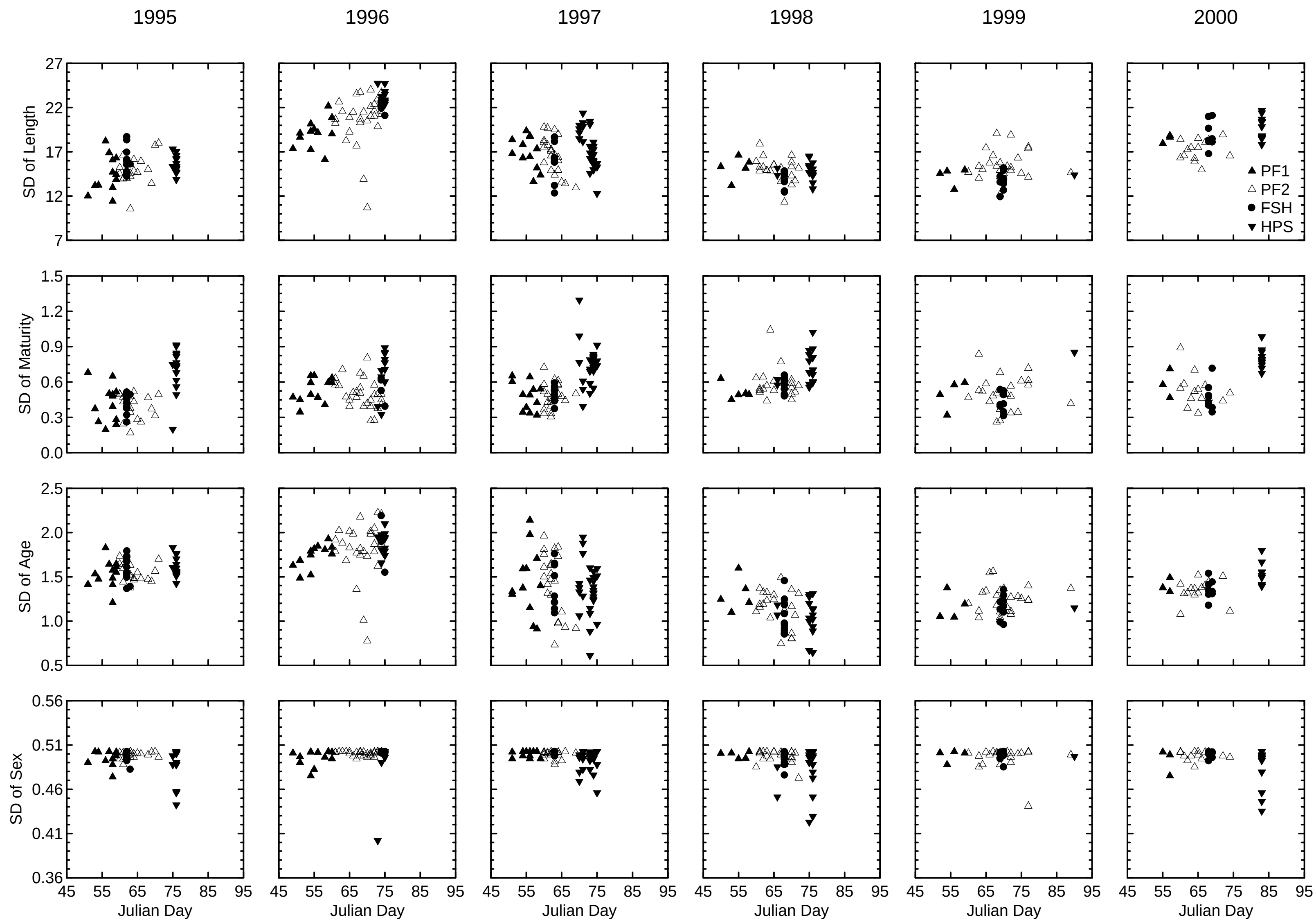

Figure 3. Standard deviation of mean length, maturity, age, and sex of pre-fishery herring samples (separated into those sampled prior to March 1st ▲ and those sampled March 1st or later △), fishery samples (○), and hand purse seine samples (▼) by Julian day for 1995-2000.

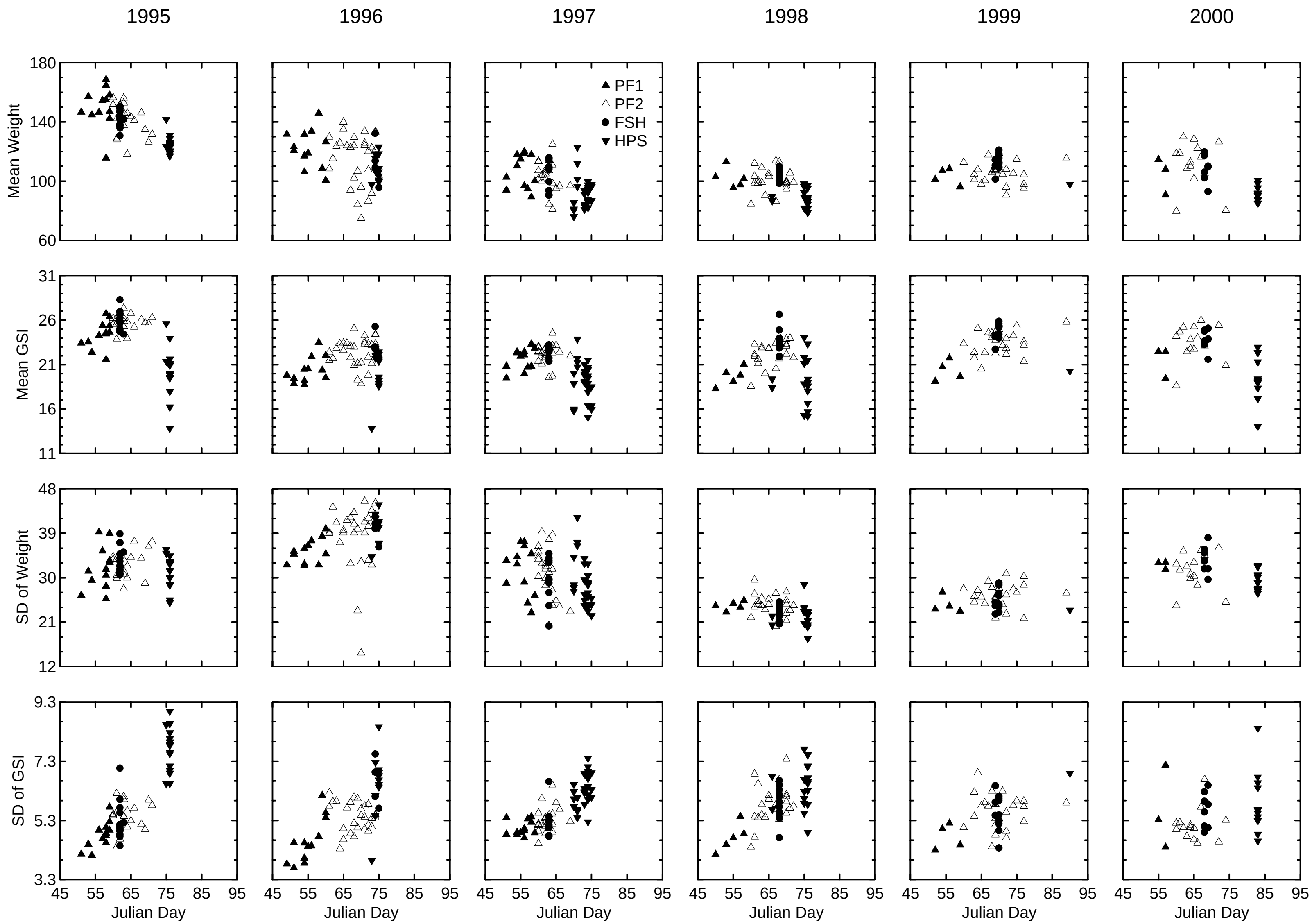

Figure 4. Mean and standard deviation of weight and GSI of pre-fishery herring samples (separated into those sampled prior to March 1st ▲ and those sampled March 1st or later △), fishery samples (○), and hand purse seine samples (▼) by Julian day for 1995-2000.

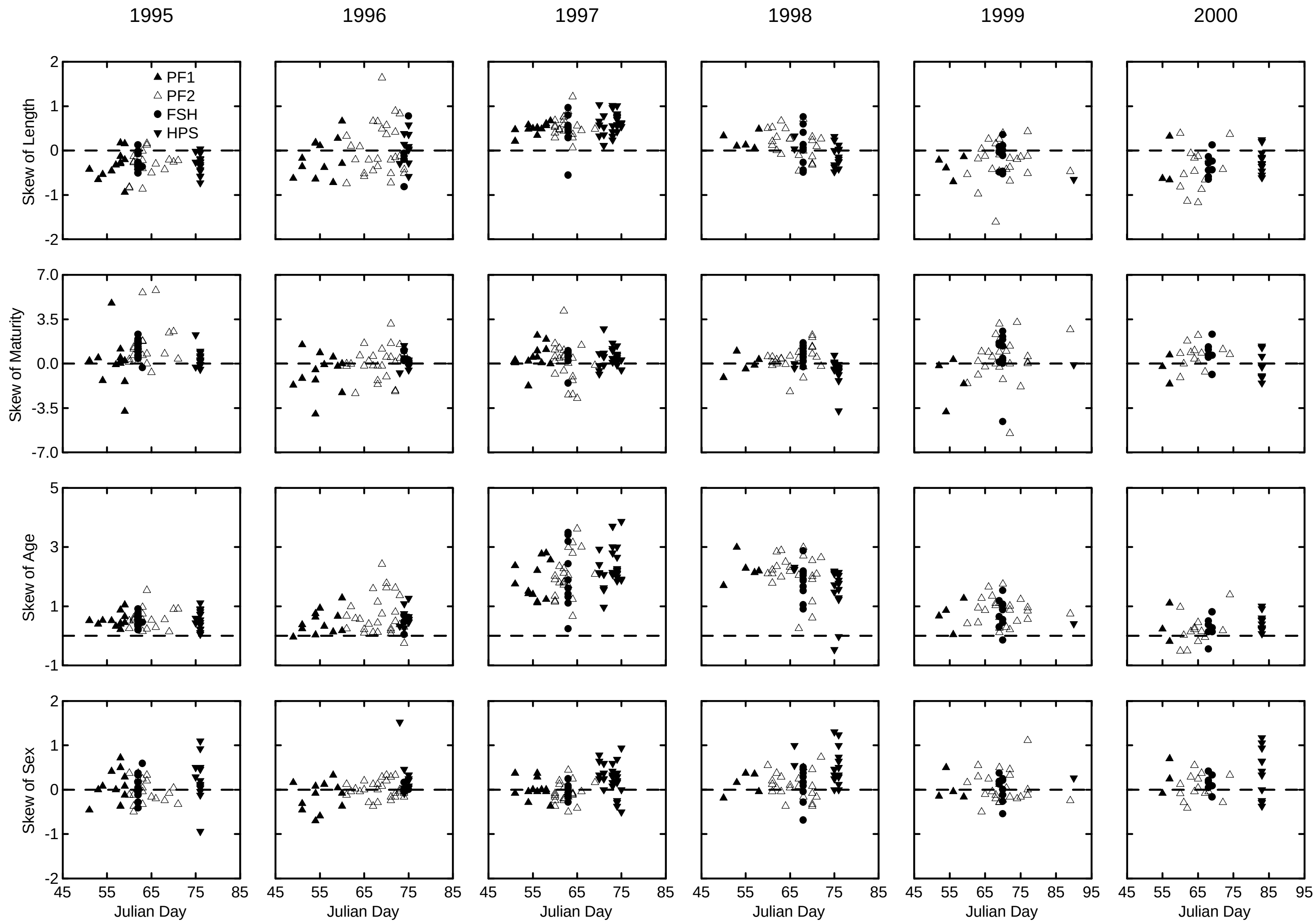

Figure 5. Skew of mean length, maturity, age, and sex of pre-fishery herring samples (separated into those sampled prior to March 1st ▲ and those sampled March 1st or later △), fishery samples (○), and hand purse seine samples (▼) by Julian day for 1995-2000.

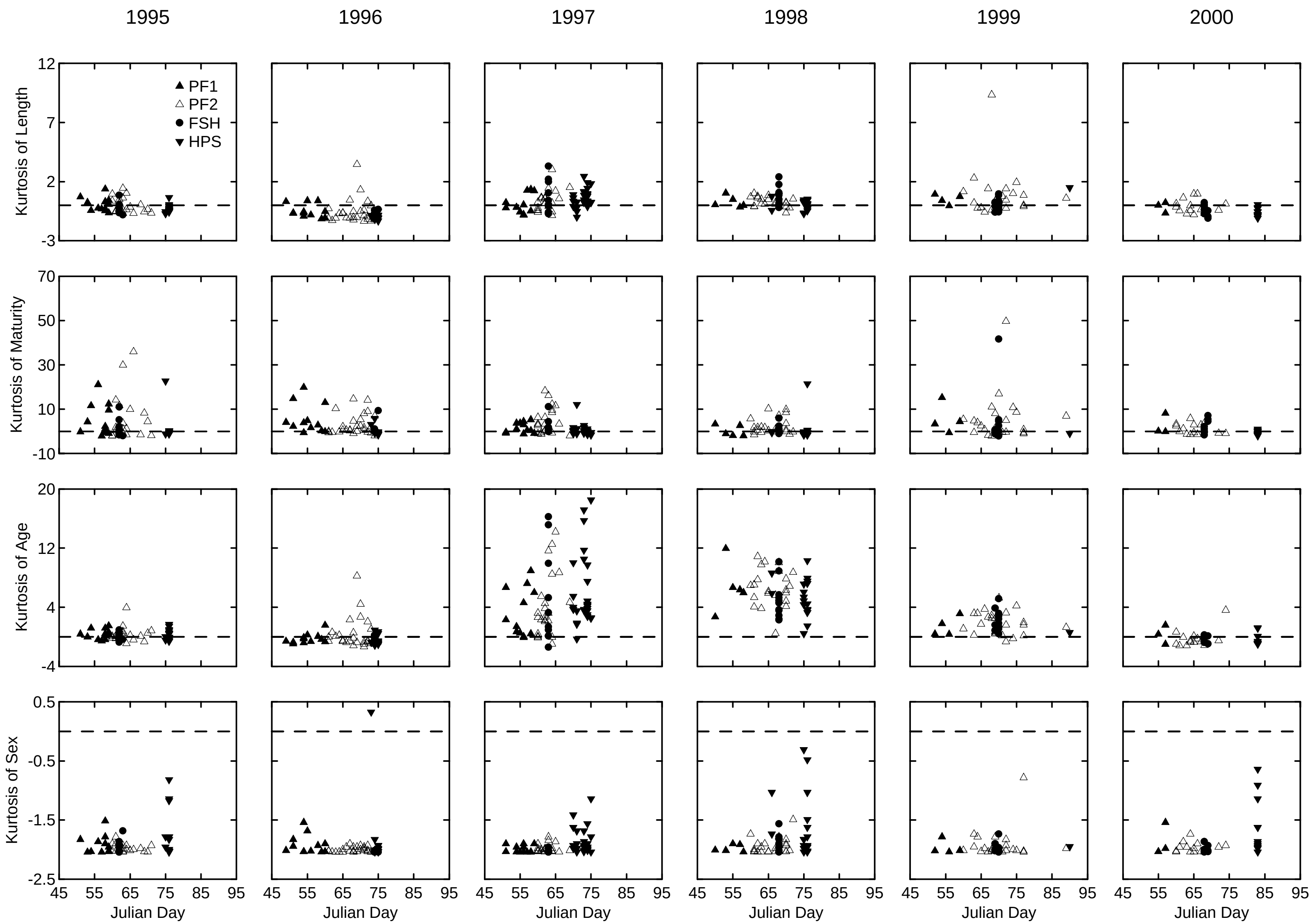

Figure 6. Kurtosis of mean length, maturity, age, and sex of pre-fishery herring samples (separated into those sampled prior to March 1st ▲ and those sampled March 1st or later △), fishery samples (○), and hand purse seine samples (▼) by Julian day for 1995-2000.

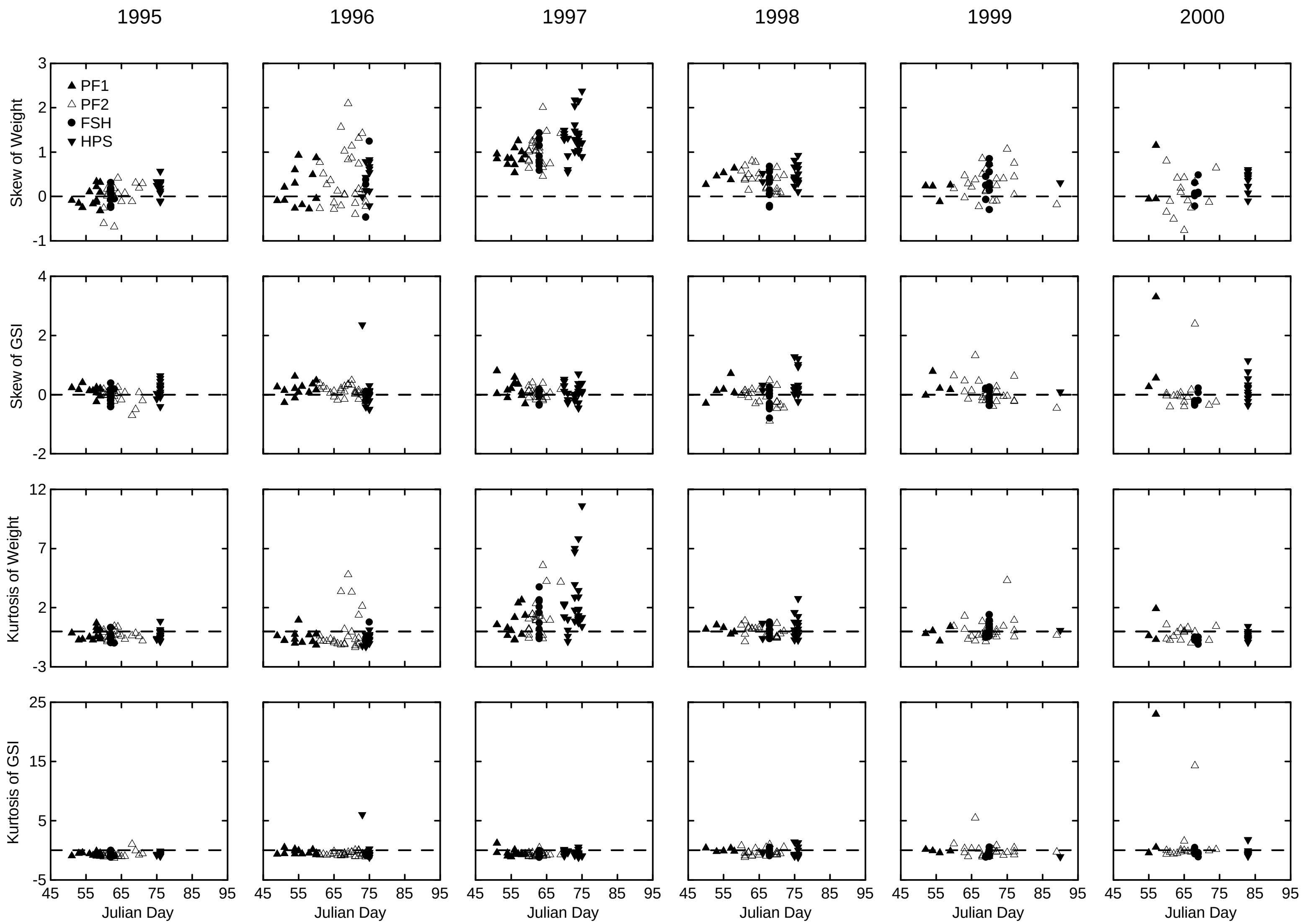

Figure 7. Skew and kurtosis of mean length, maturity, age, and sex of pre-fishery herring samples (separated into those sampled prior to March 1st ▲ and those sampled March 1st or later △), fishery samples (○), and hand purse seine samples (▼) by Julian day for 1995-2000

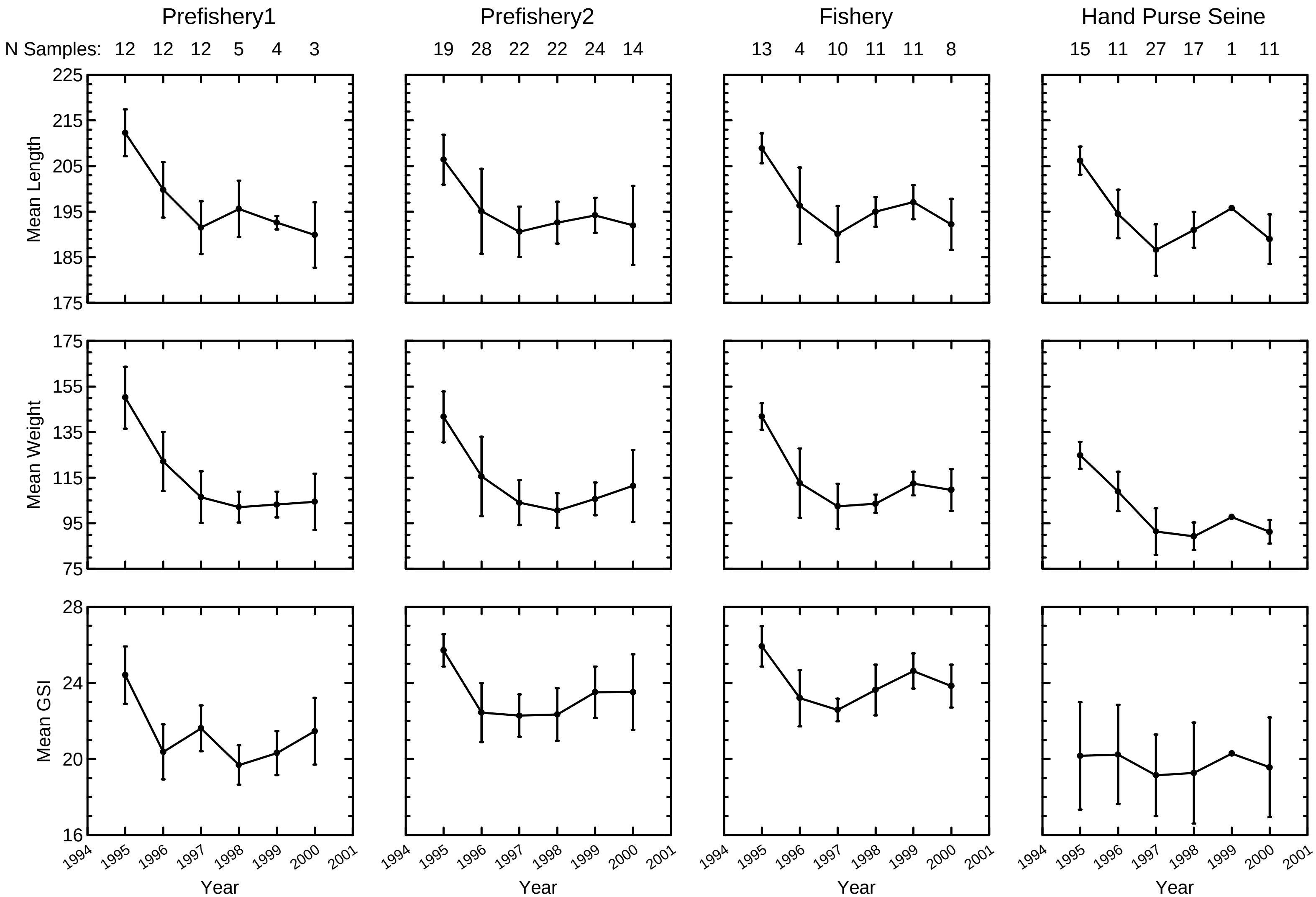

Figure 8. Mean of sample means of length, weight (total body mass including gonads), and gonosomatic index (GSI) (see text for details) for pre-fishery 1 (samples taken prior to Mar. 1st), pre-fishery 2 (samples taken Mar 1st or later), fishery, and hand purse seine samples. Error bars are standard error of sample means. Number (N) of samples means for each year and sample method noted above first row of graphs.

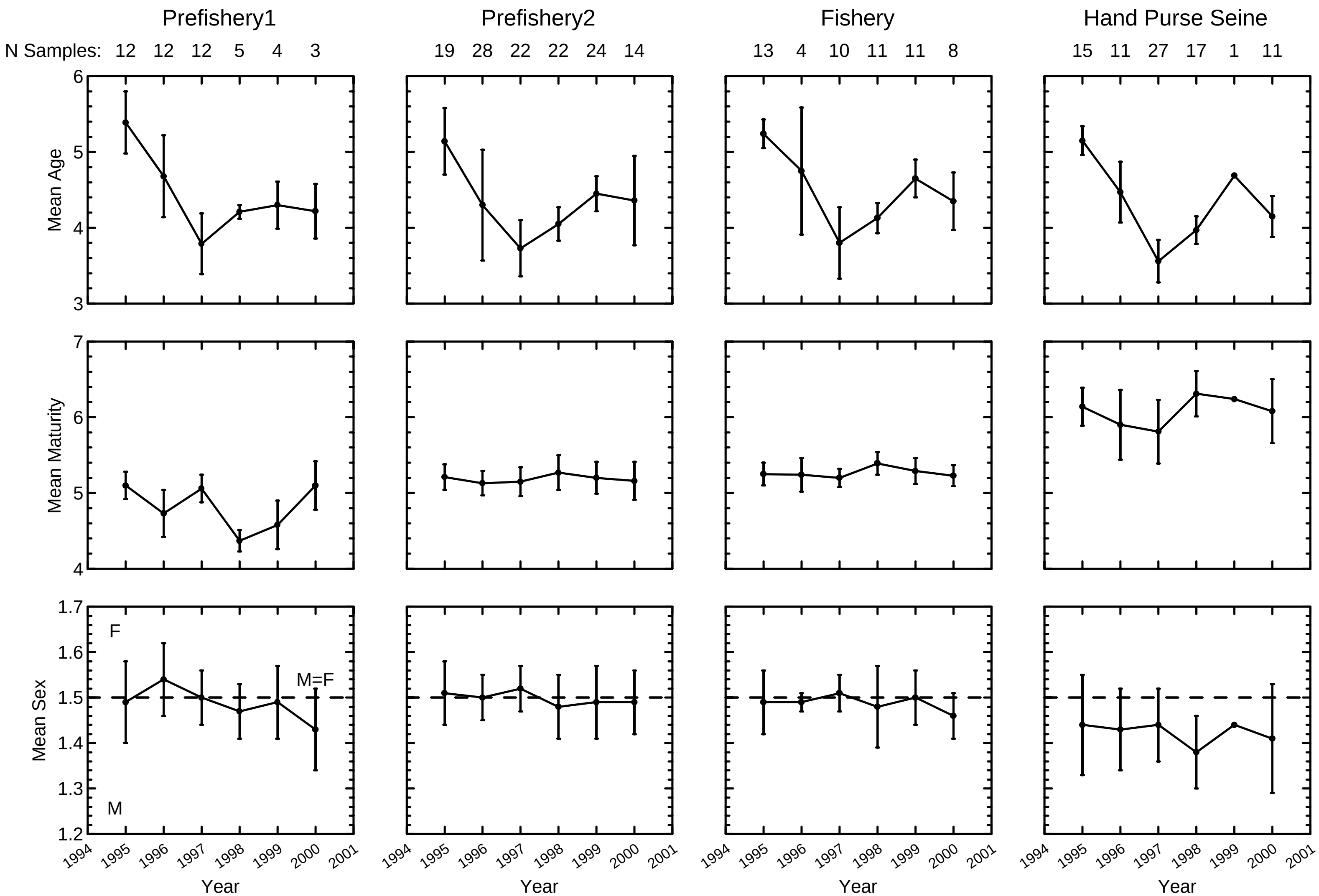

Figure 9. Mean of sample means of age, maturity, and sex ratio for pre-fishery 1 (samples taken prior to Mar. 1st), pre-fishery 2 (samples taken Mar 1st or later), fishery, and hand purse seine samples. Error bars are standard error of sample means. Number (N) of samples means for each year and sample method noted above first row of graphs.

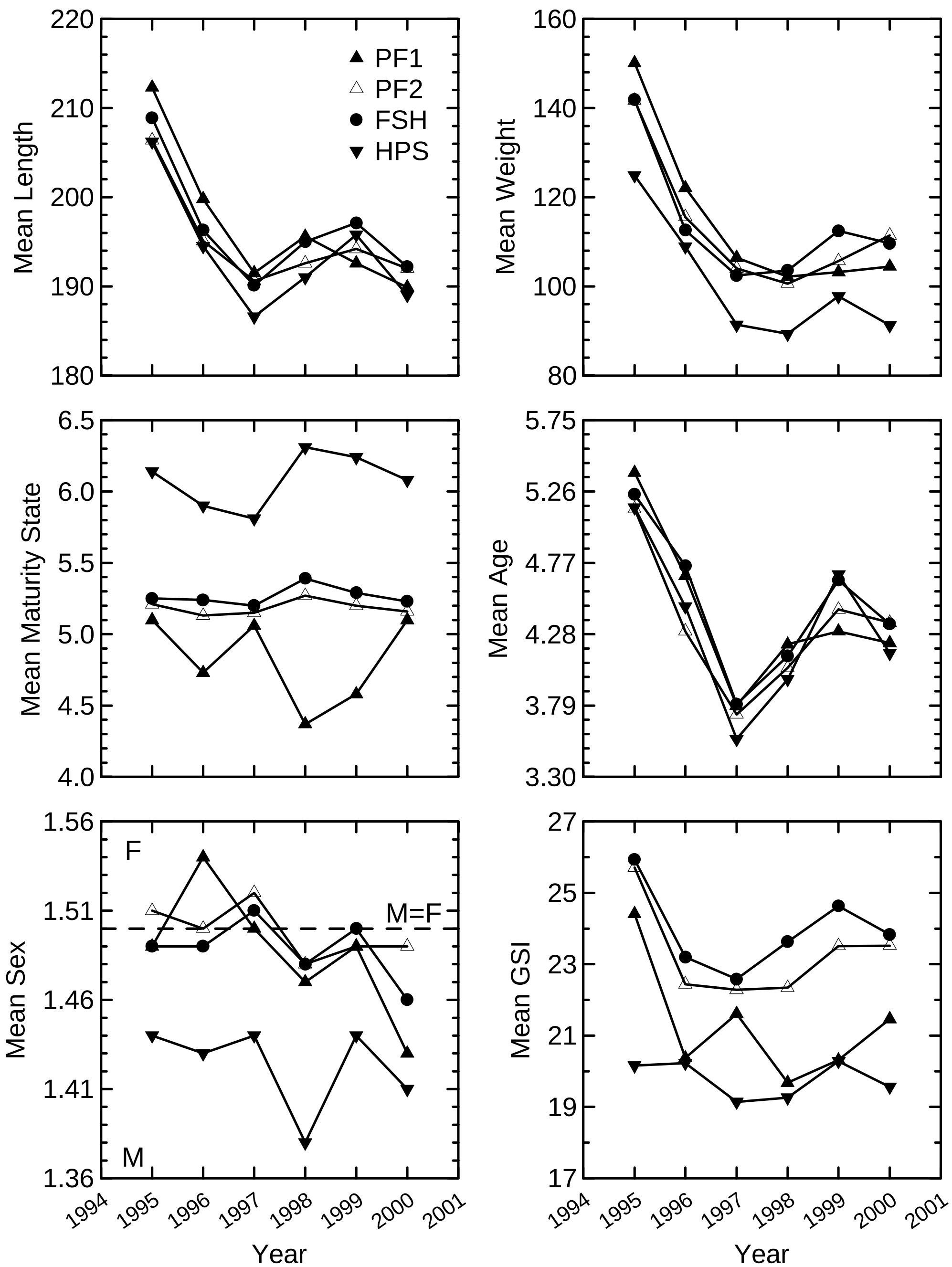

Figure 10. Mean of mean sample length, maturity, sex, weight, age, and gonosomatic index (GSI) for each sample type from 1995-2000 (same data as Fig. 6 and 7).

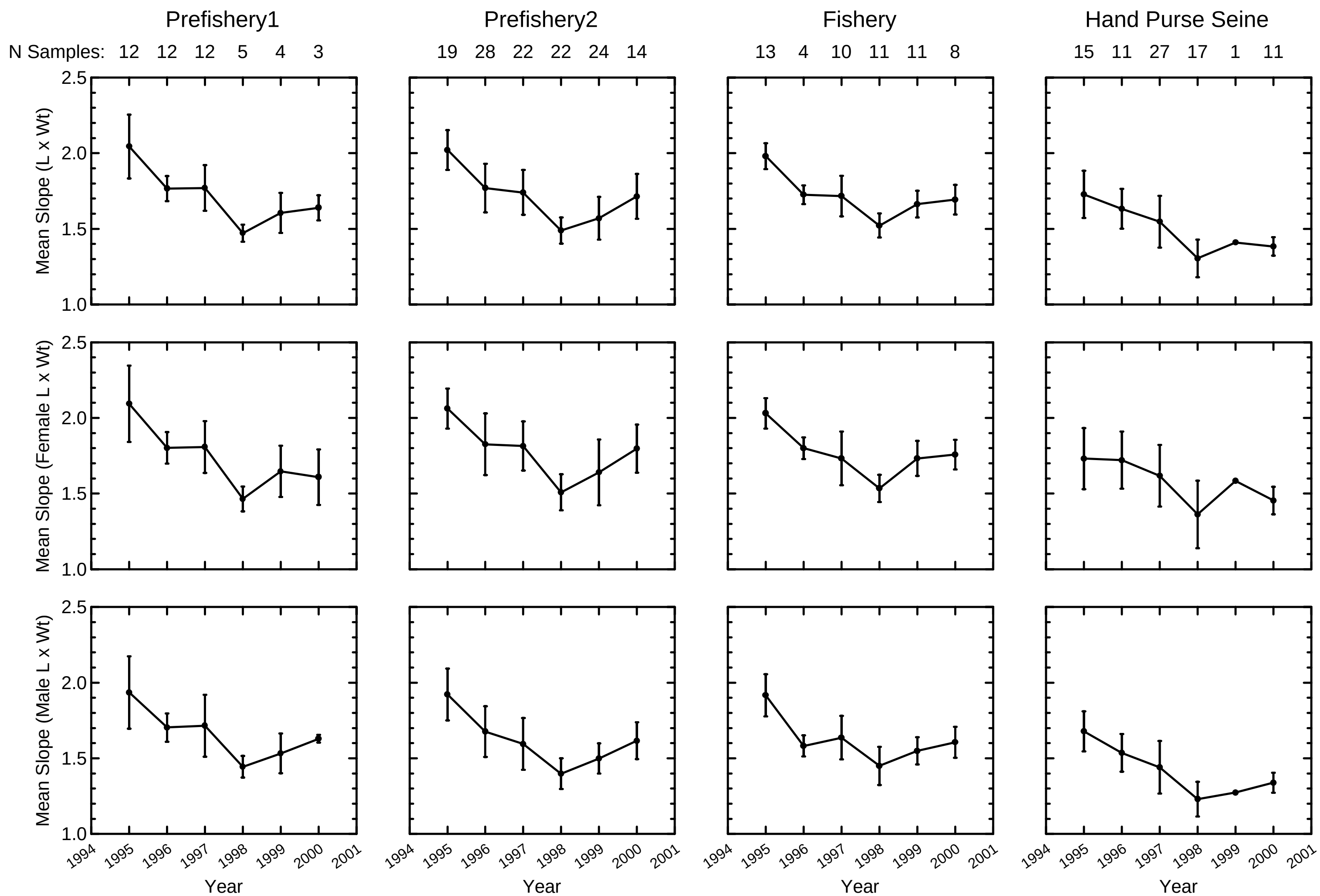

Figure 11. Mean slope of the linear length – weight relationships for 1995-2000 for each sample type (see text for details). Error bars are standard error of sample means (note only one hand purse seine sample was taken in 1999 therefore no SE is shown). Number (N) of samples means for each year and sample method noted above first row of graphs.

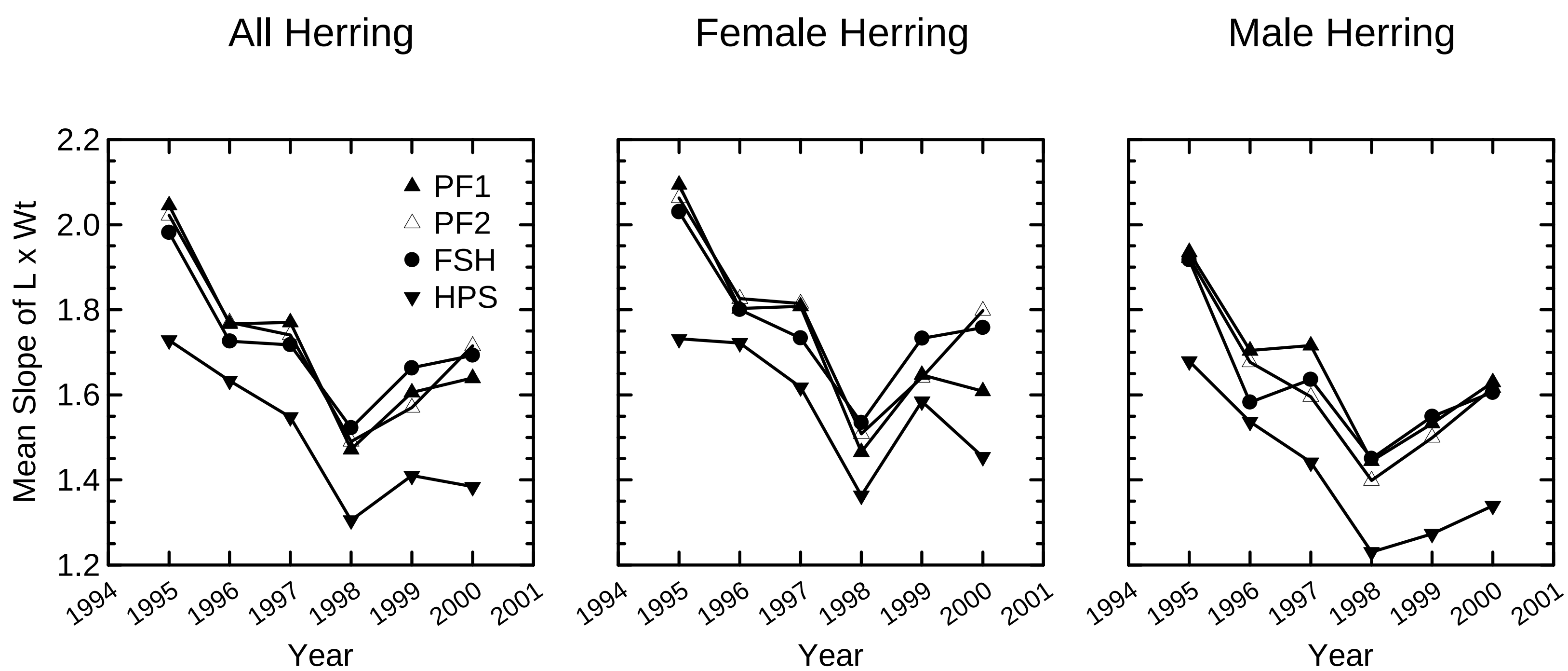

Figure 12. Mean slope values of length-weight relationships for each sample method from 1995-2000.

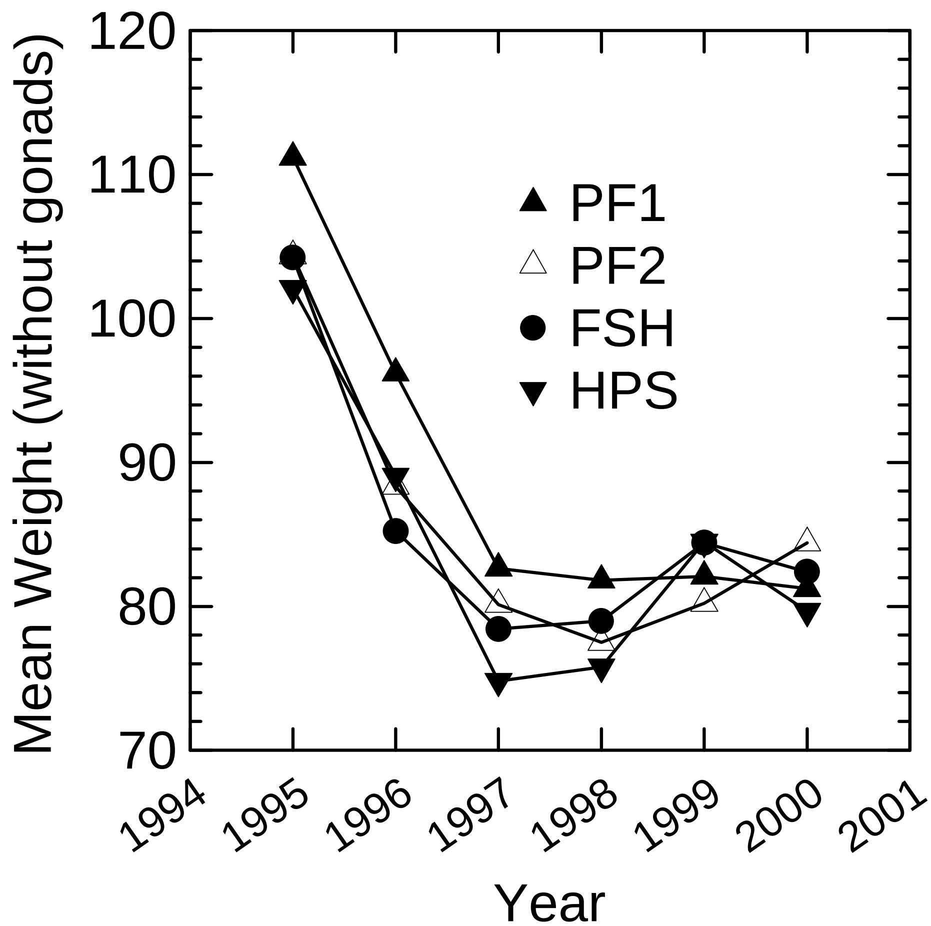

Figure 13. Mean sample weight (excluding gonads) of all herring sampled by each method (pre-fishery 1 (PF1), pre-fishery 2 (PF2), fishery (FSH), and hand purse seine (HPS)) from 1995-2000.

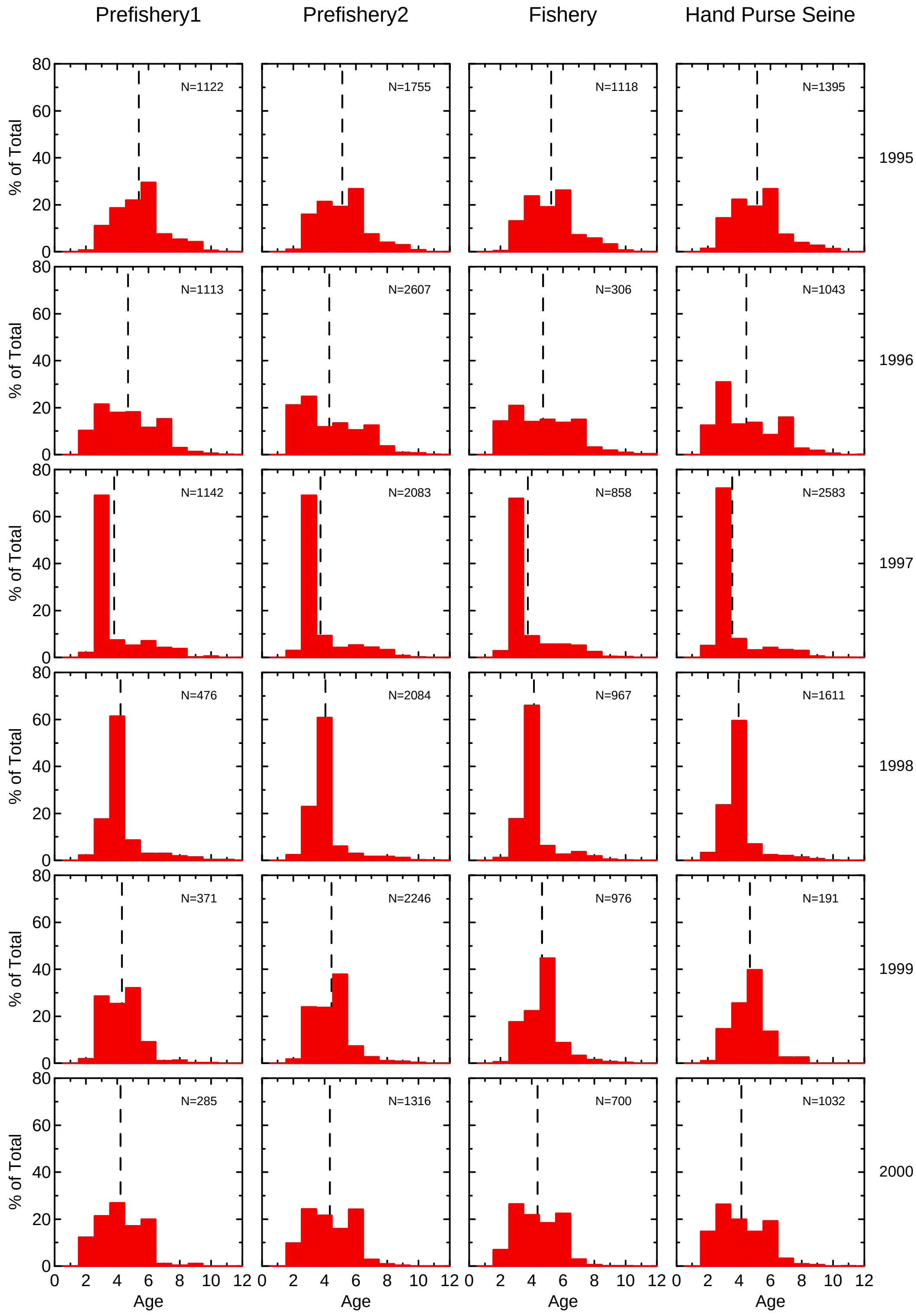

Figure 14. Age frequency distribution of all herring taken in samples between 1995 – 2000 in each sampling category: pre-fishery 1 (PF1), pre-fishery 2 (PF2), fishery (FSH), and hand purse seine (HPS). Number of fish in each distribution is shown in each panel. Vertical line denotes mean of distribution.

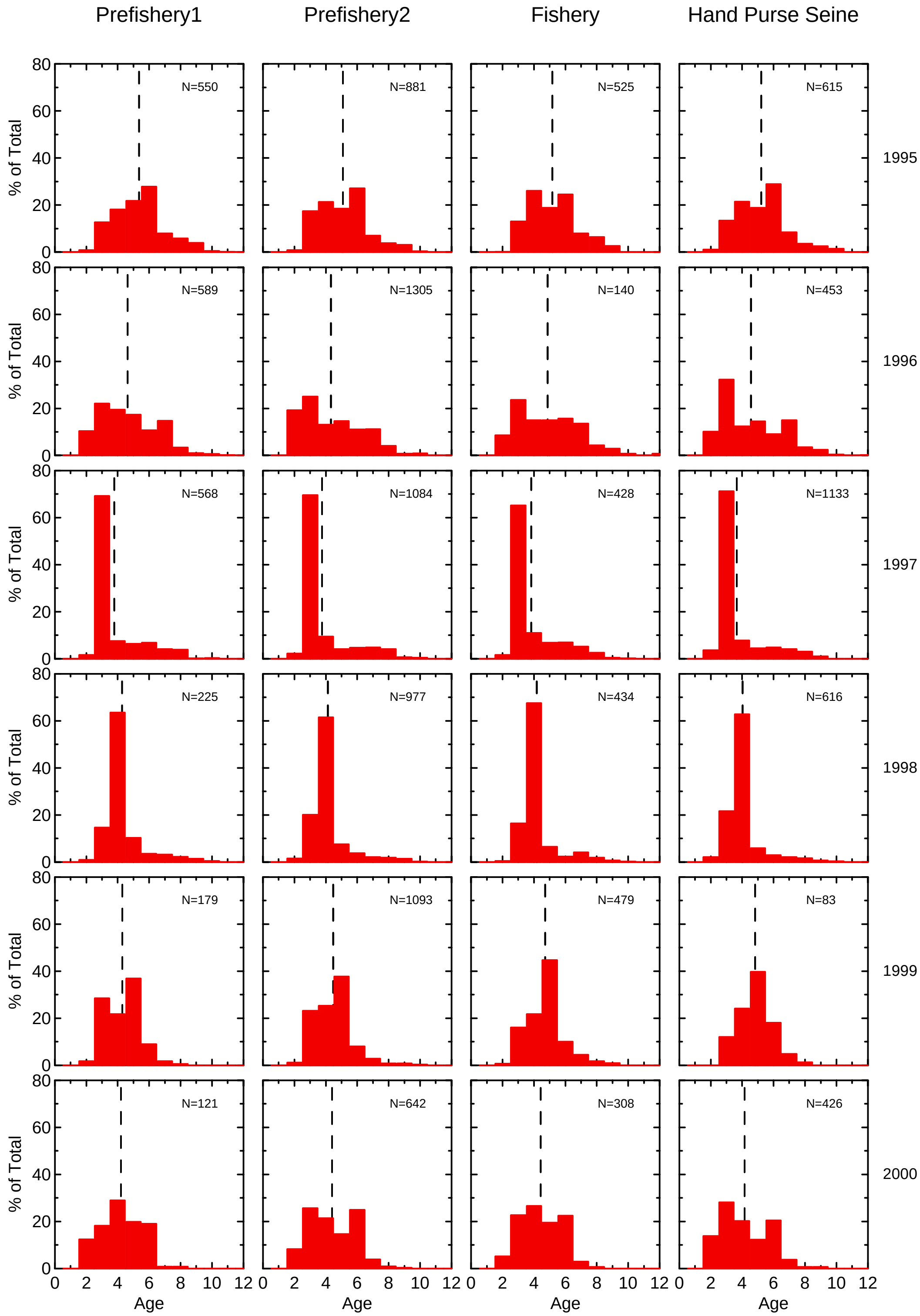

Figure 15. Age frequency distribution of all female herring taken in samples between 1995 – 2000 in each sampling category: pre-fishery 1 (PF1), pre-fishery 2 (PF2), fishery (FSH), and hand purse seine (HPS). Number of fish in each distribution is shown in each panel. Vertical line denotes mean of distribution.

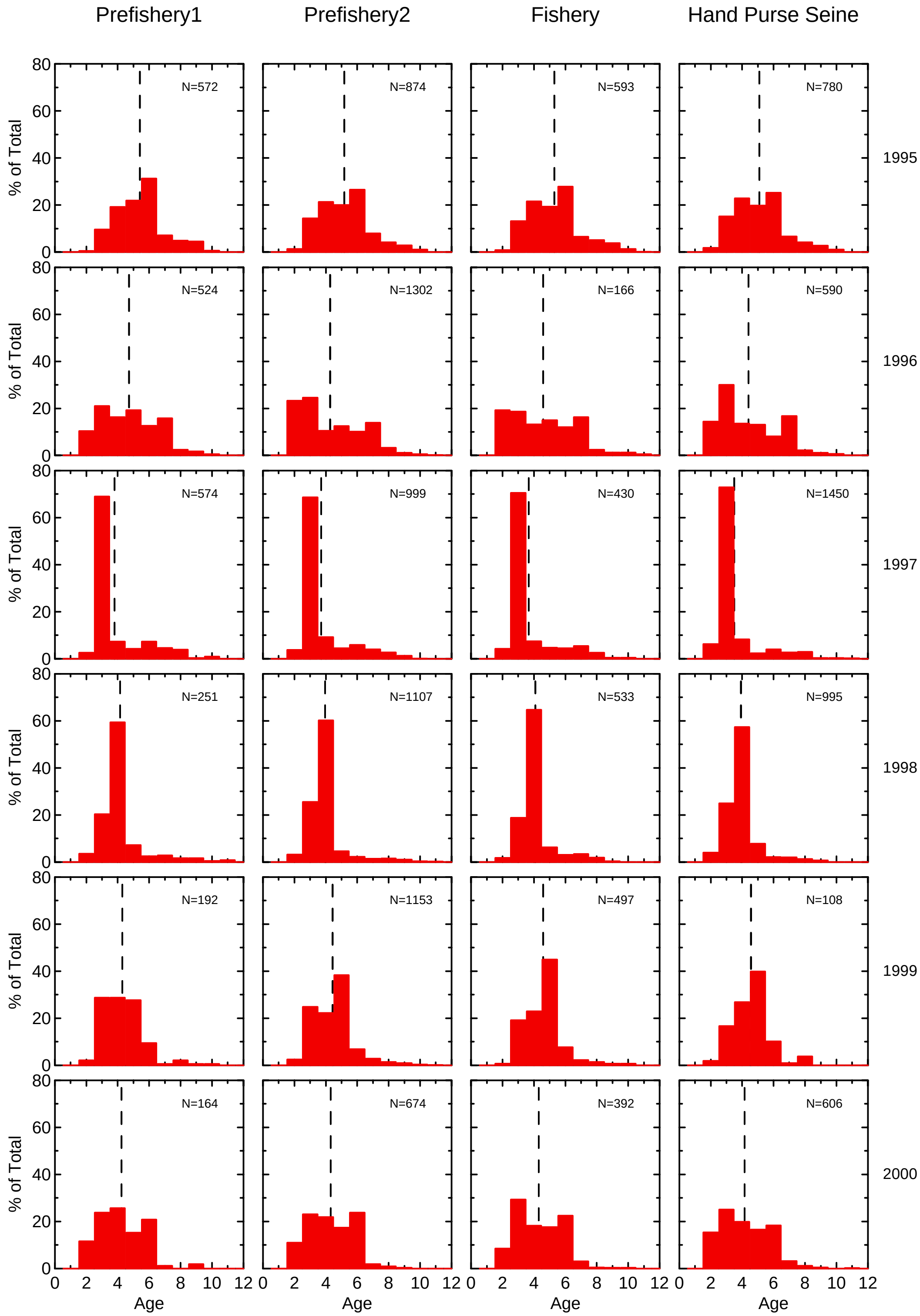

Figure 16. Age frequency distribution of all male herring taken in samples between 1995 – 2000 in each sampling category: pre-fishery 1 (PF1), pre-fishery 2 (PF2), fishery (FSH), and hand purse seine (HPS). Number of fish in each distribution is shown in each panel. Vertical line denotes mean of distribution.

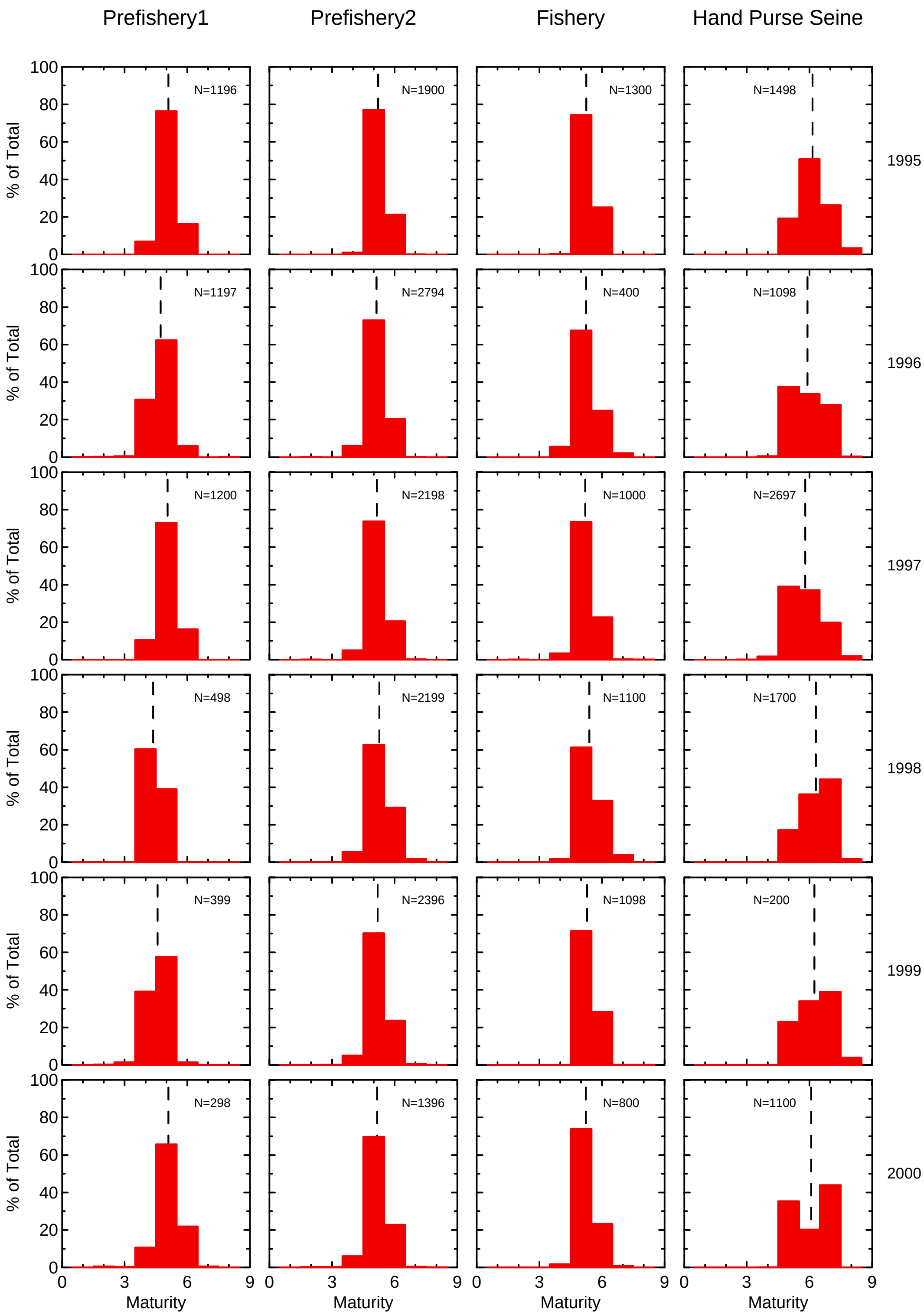

Figure 17. Maturity state distribution of all herring taken in samples between 1995 – 2000 in each sampling category: pre-fishery 1 (PF1), pre-fishery 2 (PF2), fishery (FSH), and hand purse seine (HPS). Number of fish in each distribution is shown in each panel. Vertical line denotes mean of distribution.

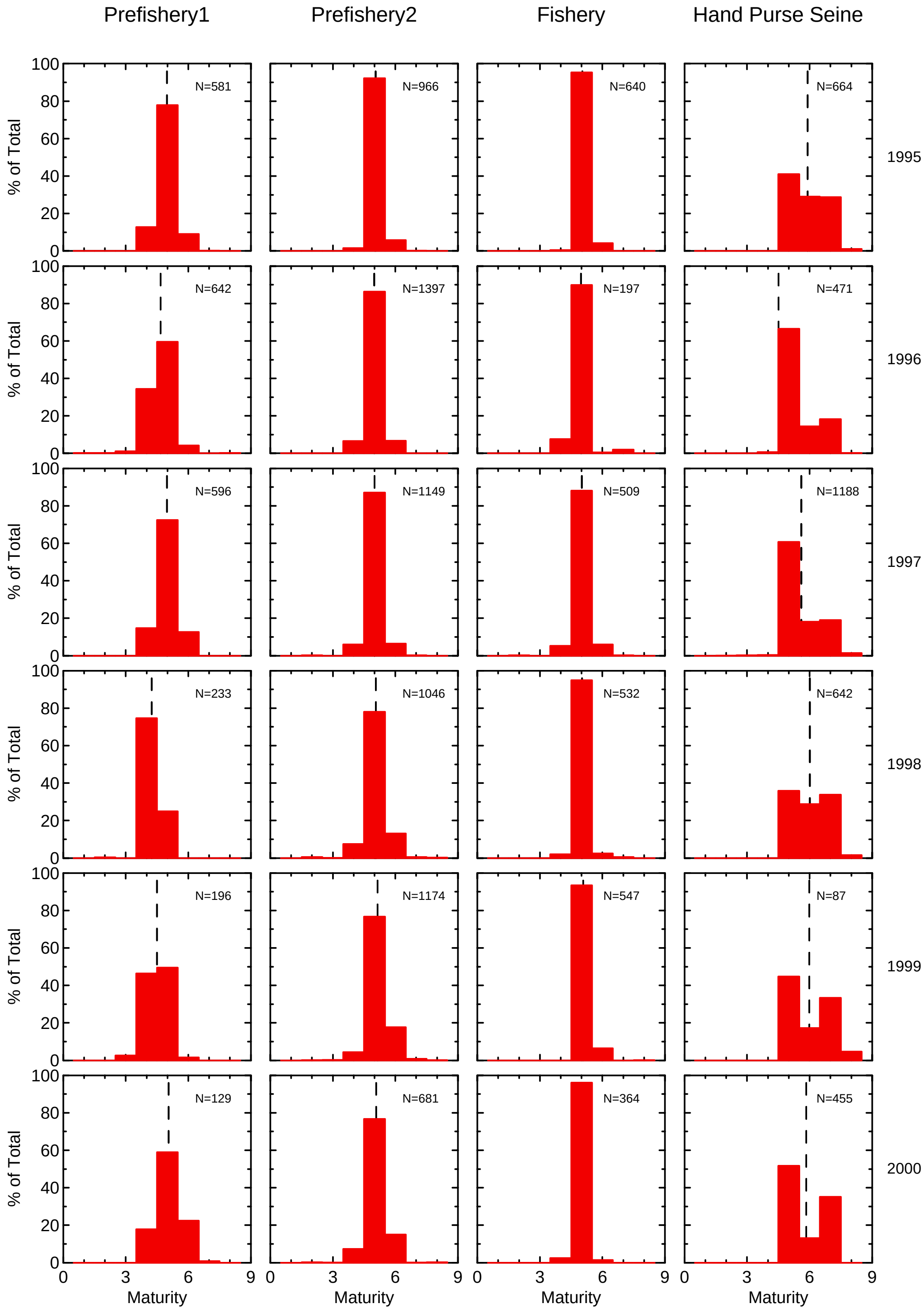

Figure 18. Maturity state distribution of all female herring taken in samples between 1995 – 2000 in each sampling category: pre-fishery 1 (PF1), pre-fishery 2 (PF2), fishery (FSH), and hand purse seine (HPS). Number of fish in each distribution is shown in each panel. Vertical line denotes mean of distribution.

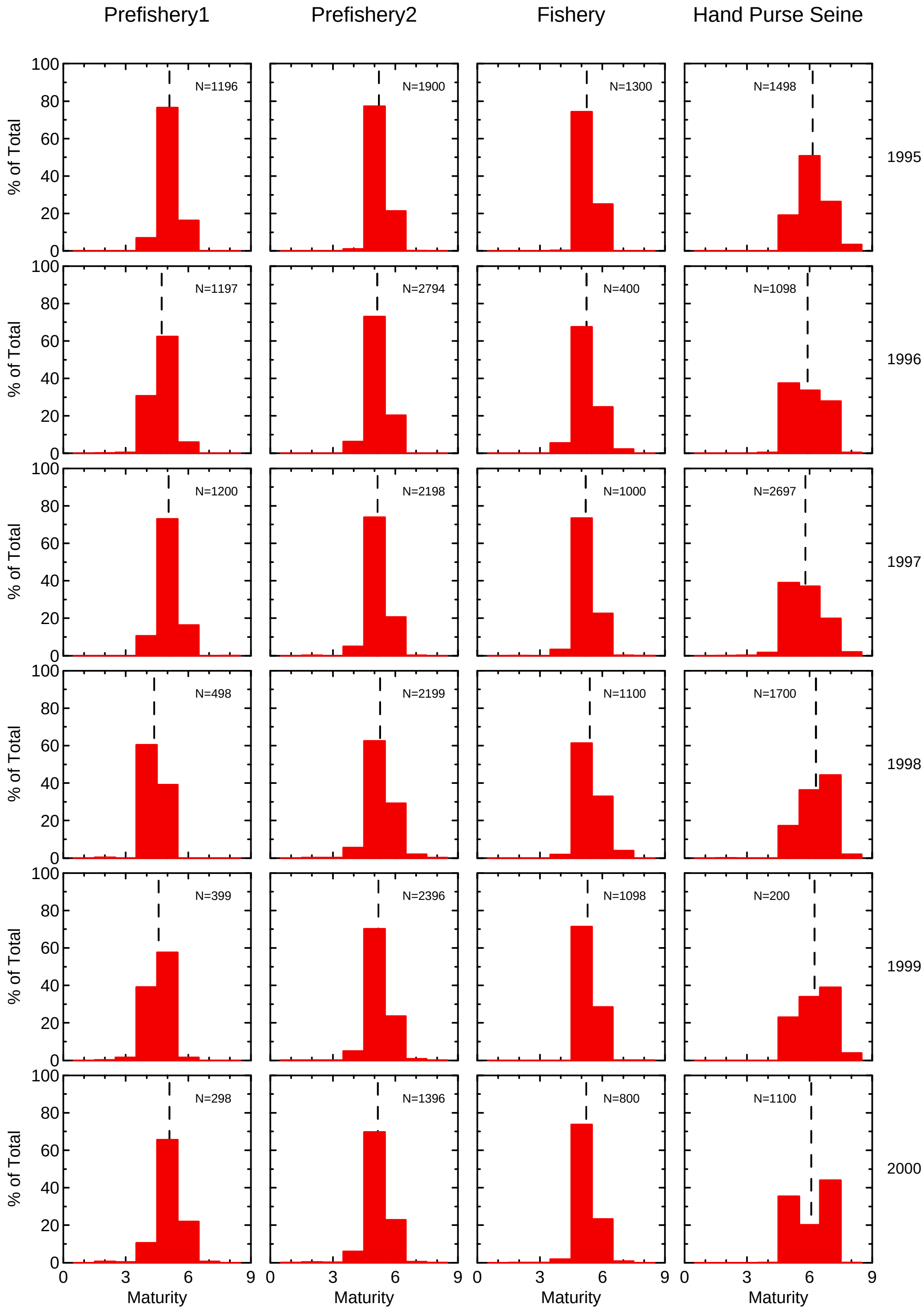

Figure 19. Maturity state distribution of all male herring taken in samples between 1995 – 2000 in each sampling category: pre-fishery 1 (PF1), pre-fishery 2 (PF2), fishery (FSH), and hand purse seine (HPS). Number of fish in each distribution is shown in each panel. Vertical line denotes mean of distribution.

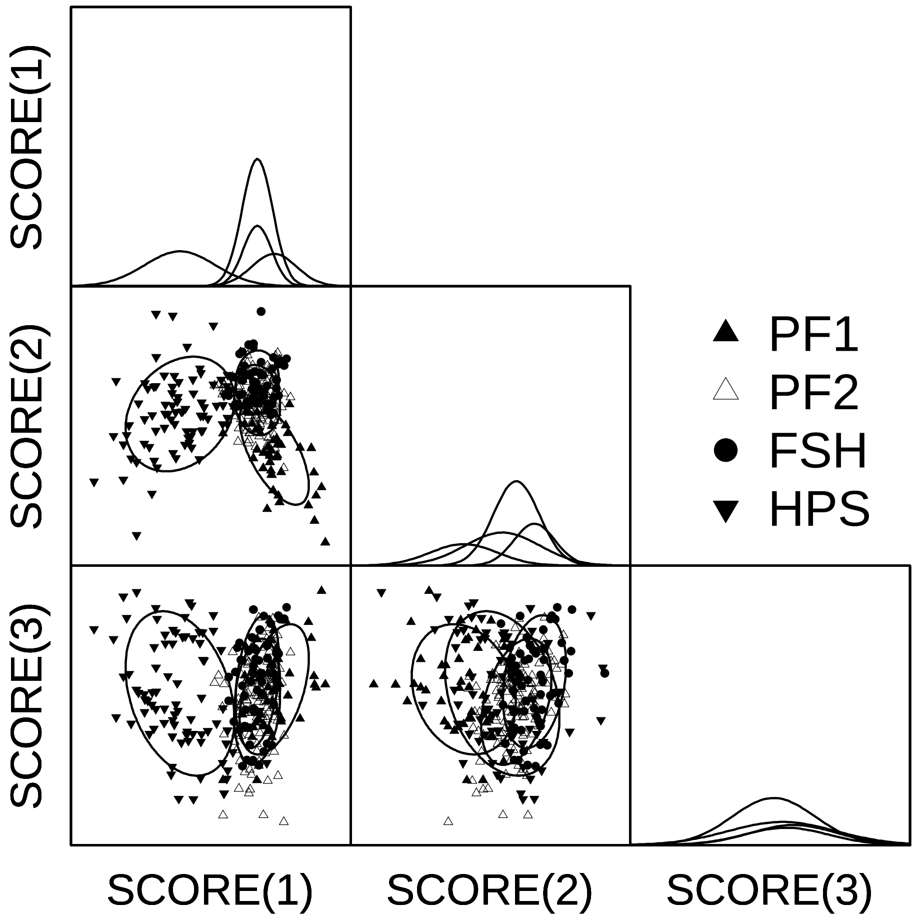

Figure 20. Scatterplot matrix of three canonical scores derived per herring sample from discriminant function analysis in the four sampling categories. Only scores with no weighting factors included are shown (see text for explanation). Ellipses are Gaussian bivariate confidence intervals centred on mean x- and y-axis values for each sampling category, representing one standard deviation from the mean. Line graphs are normal density curves for each canonical score by sampling category. Position of each curve aling its x-axis indicates identity with a sampling category.

Appendices

Appendix 1. Mean length (mm), standard error of the sample means, and sample sizes by sampling method and year. Column labels 'PF1' and 'PF2' indicate prefishery seine samples taken before and after Mar. 1 each year, 'FSH' indicates samples taken by commercial seine, and 'HPS', samples taken by hand purse seine. These same column labels are also used in Appendices 2-6. Sample sizes given are repeated but are the same in every table.

	Mean Length Among Samples (mm)				SE of Sample Means				N Samples			
Year	**PF1**	**PF2**	**FSH**	**HPS**	**PF1**	**PF2**	**FSH**	**HPS**	**PF1**	**PF2**	**FSH**	**HPS4**
1995	212.3	206.4	208.9	206.2	5.13	5.45	3.26	3.10	12	19	13	15
1996	199.8	195.1	196.3	194.5	6.09	9.31	8.41	5.31	12	28	4	11
1997	191.5	190.6	190.1	186.6	5.80	5.52	6.10	5.64	12	22	10	27
1998	195.6	192.6	195.0	191.0	6.19	4.56	3.26	3.96	5	22	11	17
1999	192.6	194.2	197.1	195.8	1.49	3.85	3.75	-	4	24	11	1
2000	189.9	192.0	192.2	189.0	7.18	8.65	5.60	5.44	3	14	8	11

Appendix 2. Mean weight (g), standard error of the sample means, and sample sizes by sampling method and year. This weight includes gonad weight.

	Mean Weight Among Samples (g)				SE of Sample Means				N Samples			
Year	**PF1**	**PF2**	**FSH**	**HPS**	**PF1**	**PF2**	**FSH**	**HPS4**	**PF1**	**PF2**	**FSH**	**HPS4**
1995	150.1	141.7	141.9	124.9	13.57	11.13	5.82	5.94	12	19	13	15
1996	122.1	115.6	112.6	108.9	12.95	17.46	15.17	8.65	12	28	4	11
1997	106.5	104.0	102.4	91.4	11.34	9.86	9.87	10.19	12	22	10	27
1998	102.2	100.6	103.6	89.3	6.80	7.63	3.96	6.02	5	22	11	17
1999	103.2	105.7	112.4	97.8	5.65	7.19	5.22	-	4	24	11	1
2000	104.5	111.4	109.6	91.2	12.33	15.78	9.20	5.14	3	14	8	11

Appendix 3. Mean gonosomatic (GSI) index (%), standard error of the sample means and sample sizes by sampling method and year. GSI is derived as the gonad weight divided by the total body weight multiplied by 100. Total body weight includes the gonad weight.

	Mean GSI Among Samples				SE of Sample Means				N Samples			
Year	**PF1**	**PF2**	**FSH**	**HPS**	**PF1**	**PF2**	**FSH**	**HPS**	**PF1**	**PF2**	**FSH**	**HPS**
1995	24.4	25.7	25.9	20.2	1.51	0.85	1.06	2.83	12	19	13	15
1996	20.4	22.4	23.2	20.2	1.45	1.55	1.48	2.61	12	28	4	11
1997	21.6	22.3	22.6	19.1	1.20	1.11	0.59	2.14	12	22	10	27
1998	19.7	22.3	23.6	19.3	1.04	1.38	1.34	2.66	5	22	11	17
1999	20.3	23.5	24.6	20.3	1.16	1.35	0.92	-	4	24	11	1
2000	21.5	23.5	23.8	19.6	1.76	1.99	1.13	2.62	3	14	8	11

Appendix 4. Mean age (yr), standard error of the sample means, and sample sizes by sampling method and year. Ages within individual samples could be as low as l and as high as 12, respectively.

	Mean Age Among Samples (yr)				SE of Sample Means				N Samples			
Year	**PF1**	**PF2**	**FSH**	**HPS**	**PF1**	**PF2**	**FSH**	**HPS**	**PF1**	**PF2**	**FSH**	**HPS**
1995	5.39	5.14	5.24	5.15	0.411	0.444	0.189	0.190	12	19	13	15
1996	4.68	4.30	4.75	4.47	0.540	0.726	0.836	0.396	12	28	4	11
1997	3.79	3.73	3.80	3.56	0.397	0.370	0.469	0.284	12	22	10	27
1998	4.21	4.05	4.13	3.97	0.089	0.219	0.196	0.178	5	22	11	17
1999	4.30	4.45	4.65	4.69	0.310	0.227	0.249	-	4	24	11	1
2000	4.22	4.36	4.35	4.15	0.364	0.586	0.381	0.274	3	14	8	11

Appendix 5. Mean maturation index, standard error of the sample means and sample sizes by sampling method and year. Mean values for individual samples were derived by averaging index values ranging from 0 to 8.

	Mean Maturation Index Among Samples				SE of Sample Means				N Samples			
Year	**PF1**	**PF2**	**FSH**	**HPS**	**PF1**	**PF2**	**FSH**	**HPS**	**PF1**	**PF2**	**FSH**	**HPS**
1995	5.10	5.21	5.25	6.14	0.016	0.011	0.007	0.018	12	19	13	15
1996	4.73	5.13	5.24	5.90	0.010	0.012	0.011	0.018	12	28	4	11
1997	5.06	5.15	5.20	5.81	0.012	0.011	0.007	0.017	12	22	10	27
1998	4.37	5.27	5.39	6.31	0.007	0.012	0.006	0.013	5	22	11	17
1999	4.58	5.20	5.29	6.24	0.013	0.014	0.008	-	4	24	11	1
2000	5.10	5.16	5.23	6.08	0.012	0.014	0.012	0.008	3	14	8	11

Appendix 6. Mean sex, standard error of the sample means and sample sizes by sampling method and year. Mean values for individual samples were derived by averaging categorical values of 1 for males and 2 for females.

	Mean Sex Among Samples				SE of Sample Means				N Samples			
Year	**PF1**	**PF2**	**FSH**	**HPS**	**PF1**	**PF2**	**FSH**	**HPS4**	**PF1**	**PF2**	**FSH**	**HPS4**
1995	1.49	1.51	1.49	1.44	0.088	0.065	0.069	0.107	12	19	13	15
1996	1.54	1.50	1.49	1.43	0.078	0.047	0.022	0.085	12	28	4	11
1997	1.50	1.52	1.51	1.44	0.056	0.054	0.036	0.080	12	22	10	27
1998	1.47	1.48	1.48	1.38	0.059	0.071	0.087	0.084	5	22	11	17
1999	1.49	1.49	1.50	1.44	0.075	0.083	0.063	-	4	24	11	1
2000	1.43	1.49	1.46	1.41	0.092	0.068	0.048	0.125	3	14	8	11

Appendix 7. Mean slope of length-weight relationships among samples, standard errors of sample means, and sample sizes by sampling category and year. Slope values for individual samples were derived through linear regression of length versus weight of all herring within samples. Mean slopes resulted from averaging the slopes derived from individual samples.

	Mean Slope (all) Among Samples				SE of Sample Means				N Samples			
Year	**PF1**	**PF2**	**FSH**	**HPS**	**PF1**	**PF2**	**FSH**	**HPS**	**PF1**	**PF2**	**FSH**	**HPS**
1995	2.05	2.02	1.98	1.73	0.211	0.131	0.086	0.156	12	19	13	15
1996	1.77	1.77	1.73	1.63	0.083	0.161	0.062	0.131	12	28	4	11
1997	1.77	1.74	1.72	1.55	0.151	0.148	0.134	0.172	12	22	10	27
1998	1.47	1.49	1.52	1.30	0.056	0.086	0.079	0.125	5	22	11	17
1999	1.61	1.57	1.66	1.41	0.132	0.141	0.089	-	4	24	11	1
2000	1.64	1.71	1.69	1.38	0.083	0.148	0.097	0.061	3	14	8	11

Appendix 8. Mean slope of female herring length x weight relationships among samples, standard errors of sample means, and sample sizes by sampling category and year.

	Mean Slope (females) Among Samples				SE of Sample Means				N Samples			
Year	**PF1**	**PF2**	**FSH**	**HPS4**	**PF1**	**PF2**	**FSH**	**HPS4**	**PF1**	**PF2**	**FSH**	**HPS4**
1995	2.09	2.06	2.03	1.73	0.252	0.132	0.101	0.201	12	19	13	15
1996	1.80	1.83	1.80	1.72	0.104	0.204	0.072	0.189	12	28	4	11
1997	1.81	1.81	1.73	1.62	0.172	0.163	0.177	0.204	12	22	10	27
1998	1.47	1.51	1.53	1.36	0.082	0.119	0.091	0.223	5	22	11	17
1999	1.65	1.64	1.73	1.58	0.170	0.217	0.116	-	4	24	11	1
2000	1.61	1.80	1.76	1.45	0.184	0.159	0.098	0.090	3	14	8	11

Appendix 9. Mean slope of male herring length-weight relationships among samples, standard errors of sample means, and sample sizes by sampling category and year.

	Mean Slope (males) Among Samples				SE of Sample Means				N Samples			
Year	**PF1**	**PF2**	**FSH**	**HPS**	**PF1**	**PF2**	**FSH**	**HPS4**	**PF1**	**PF2**	**FSH**	**HPS4**
1995	1.94	1.92	1.92	1.68	0.239	0.172	0.139	0.132	12	19	13	15
1996	1.70	1.68	1.58	1.54	0.093	0.168	0.070	0.125	12	28	4	11
1997	1.72	1.60	1.64	1.44	0.204	0.171	0.144	0.174	12	22	10	27
1998	1.44	1.40	1.45	1.23	0.072	0.101	0.126	0.115	5	22	11	17
1999	1.53	1.50	1.55	1.27	0.131	0.100	0.090	-	4	24	11	1
2000	1.63	1.62	1.61	1.34	0.025	0.122	0.102	0.067	3	14	8	11