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Canadian Atlantic Fisheries Scientific Advisory Committee

Comité scientifique consultatif des pêches canadiennes dans l'Atlantique

CAFSAC Research Document 90/68

CSCPCA Document de recherche 90/68

AN INVESTIGATION OF WHITE HAKE (*Urophycis tenuis*) POPULATION STRUCTURE IN THE SOUTHERN GULF OF ST. LAWRENCE NAFO DIVISION 4T USING MORPHOMETRIC AND MERISTIC CHARACTERS

by

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ABSTRACT

Previous analyses of the distribution of catches of white hake during annual (September) and seasonal surveys of NAFO Division 4T have identified two geographically separate concentrations of fish: an offshore "channel" group along the slope of the Laurentian Channel and an inshore "strait" group from the shallow, southern Gulf. To test the hypothesis that these groups represent discrete components ('stocks'), discriminant function analyses were performed on nineteen morphometric and nine meristic characters of white hake sampled from this division in 1986.

Two distinct components were identified consisting of:

(1) Fish from the southernmost, inshore areas (depths <= 200 m) of the Gulf, principally the Northumberland Strait area (the "strait" component) and

(2) Fish from along the slope of the Laurentian Channel in depths in excess of 200 m (the "channel" component).

Although meristic characters provided some evidence for stock separation, the best statistical separation was obtained with morphometric characters. Morphometric discriminant functions derived from "learning" samples were able to correctly classify "test" samples with accuracies of 78 % for females and 77 % for males (56 % of the females and 50 % of the males could have been correctly classified by chance alone).

The majority of the specimens (53 % of the females and 36 % of the males) that were misclassified by the morphometric discriminant function were located near the 200 m depth 'boundary'. These misclassified specimens represent 26 % of the fish from this boundary area.

A greater relative snout length in fish sampled from the Laurentian Channel compared with those from the southern Gulf was the primary character difference. Head length contributed to the multivariate discrimination for females and length of the upper jaw and preanal length contributed to the discrimination between male white hake.

The combined evidence from this study of morphological characters and previous tagging and distributional studies suggests that the populations from these two areas may represent seperate stocks, and if so, then the traditional management unit for white hake in NAFO Division 4T is no longer appropriate. However, additional evidence, preferably genetic, is required to confidently designate the two groups as discrete stocks.

RÉSUMÉ

Des analyses antérieures de la distribution des prises de merluche blanche durant les relevés annuels (septembre) et saisonniers dans la division 4T de l'OPANO ont révélé la présence de deux concentrations de poissons géographiquement séparées : un groupe "chenal", au large, qui suit la pente du chenal Laurentien et un groupe "détroit", près de la côte, qui vit dans les eaux peu profondes du sud du golfe. Pour vérifier l'hypothèse selon laquelle ces deux groupes représenteraient des éléments (stock) distincts, on a réalisé une analyse discriminante portant sur 19 caractéristiques morphométriques et 9 caractéristiques méristiques de merluches blanches prélevées dans cette division en 1986.

On a défini deux éléments distincts se caractérisant de la manière suivante :

1) les poissons des régions les plus méridionales du golfe, près de la côte, vivant à une profondeur égale ou inférieure à 200 m, principalement dans la région du détroit de Northumberland (l'élément "détroit") et
2) les poissons vivant le long du chenal Laurentien à des profondeurs excédant 200 m (l'élément "chenal").

Bien que les caractéristiques méristiques aient fourni certaines indications qu'il s'agissait de deux stocks séparés, la meilleure séparation statistique a été obtenue grâce aux caractéristiques morphométriques. Les fonctions discriminantes morphométriques dérivées des échantillons "d'apprentissage" ont permis de classer correctement les échantillons "tests" avec une exactitude de 78 % pour les femelles et de 77 % pour les mâles (le simple hasard aurait pu permettre de classer correctement 56 % des femelles et 50 % des mâles).

On a établi que la majorité des spécimens qui ont été mal classés par la fonction discriminante morphométrique (53 % des femelles et 36 % des mâles) ont été prélevés près de la "limite" de 200 m. Ces spécimens mal classés représentent 26 % des poissons provenant de cette zone limite.

Une plus grande longueur relative du museau chez les poissons provenant du chenal Laurentien comparativenment aux poissons du sud du golf a été la principale caractéristique distinctive. La longueur de la tête a contribué à l'analyse discriminante à variables multiples dans le cas des femelles, tandis que le longueur de la mâchoire supérieure et la longueur pré-anale en ont fait autant dans le cas des mâles.

Les résultats combinés de cette étude des caractéristiques morphologiques et des études antérieures par marquage-recapture (distribution) laissent entendre que les populations de ces deux régions pourraient représenter des stocks distincts, auquel cas l'unité de gestion traditionnelle de la merluche blanche dans la division 4T de l'OPANO ne conviendrait plus. Cependant, des indications additionnelles, préférablement d'ordre génétique, seraient nécessaires avant que l'on puisse affirmer avec plus de certitude que ces deux groupes constituent effectivement des stocks distincts.

INTRODUCTION

The white hake (Urophycis tenuis, Mitchill) is a demersal, continental shelf and upper continental slope fish species of the western Atlantic Ocean that occurs from southern Labrador and the Grand Banks southward to North Carolina. This species is exploited throughout its geographical range by directed seasonal fisheries with the majority of the catch taken in the southern Gulf of St. Lawrence, NAFO Division 4T.

Landings in this fishery have ranged from a low of 3,616 tonnes in 1974 to a high of 14,039 tonnes in 1981 (Table 1).

This fishery is carried out mainly by small inshore vessels (tonnage class 0 and 1) and it is strongly affected by weather and local market conditions. Winter ice conditions preclude inshore fishing from December through April of most years.

There are essentially four different types of fishing gear used in this fishery: gill nets, longlines, otter trawls and seines (Table 1). In one sector of the fishery, gillnets and longlines are used in the summer and, if the weather permits, longlines are used into the fall. In the other sector, composed of fishermen from southeastern New Brunswick, Nova Scotia (Gulf coast) and eastern Prince Edward Island, small (< 20 m long) otter trawlers and seiners are used.

In recent years, the majority of the fishery for white hake in NAFO Division 4T has been conducted in the Northumberland Strait, off the eastern and western ends of Prince Edward Island and off the northwestern coast of Cape Breton Island.

The fishery for white hake in NAFO Division 4T was not managed by a TAC (Total Allowable Catch) until the precautionary quota of 12,000 tonnes was imposed in 1981. The first analytical assessment was carried out on this management unit in 1985 (Clay et al. 1985) and the long term harvesting level recommended at that time was no higher than 8,000 to 9,000 tonnes annually. Subsequent assessments (Clay et al. 1986; Clay, 1987; Clay and Hurlbut, 1988, 1989) have recommended long term harvests in the range of 5,000 to 6,000 tonnes. The TAC for 1987 was reduced to 9,400 tonnes and that of 1988 and 1989 was reduced to 5,500 tonnes (Table 1).

Fisheries management in the northwest Atlantic and elsewhere, is founded on the "stock concept": the idea that fish can be arranged into more-or-less independent units or "stocks" which have unique biological attributes and are suitable groups for assessment and management purposes. However, despite the fundamental importance of this concept, the nature of a stock has been poorly understood (Kenchington, 1984).

In its simplest sense, the stock concept merely holds that a fish species is composed of a number of discrete groups, rather than being a single intermingling population.

In 1989, the CAFSAC Groundfish Subcommittee recommended an investigation of the stock structure of white hake in NAFO Division 4T in response to evidence presented by Clay and Hurlbut (1989) which indicated that the white hake population(s) in that management unit are probably composed of at least two geographically separate components (stocks): an offshore component along the slopes of the Laurentian Channel and an inshore component in areas around the Northumberland Strait. This evidence, resulted from an examination of the distribution of catches of white hake during annual and seasonal surveys of the southern Gulf, conducted from 1970 to 1988.

In this paper we investigate the structure of white hake populations in the southern Gulf of St. Lawrence by examining geographic variation in morphometric and meristic characters. This investigation is based in part on the results of an MSc. thesis by the senior author at Mount Allison University.

MATERIALS AND METHODS

Sample Collection

Samples of white hake were collected from bottom trawl catches on two consecutive cruises of the research vessel Lady Hammond (Cruise No's. H158 and H159). On both of these cruises the collection of white hake for this project was a supplementary activity and the cruise tracks were not modified for this purpose. These cruises were conducted between the following dates: 04/08/86 - 24/09/86. Seasonal groundfish surveys indicate that by this time of year most white hake have spawned and that they have reached the limits of their summer distribution in the southern Gulf of St. Lawrence (Clay, 1989).

On both cruises, the samples were captured during standardized trawl sets of thirty minutes duration (speed = 3.5 knots) using a 'Western II A' otter trawl with a 6 mm liner in the codend.

A preference for specimens between 35 - 50 cm (total length) was established to minimize the effects of allometric growth within the samples. However, fish that were larger or smaller than the preferred size range were frequently sampled in an effort to obtain the required minimum number per stratum. Several juveniles (< 10 cm total length) and adults (> 60 cm total length) were also sampled to provide information over the range of sizes attained by white hake. Cruise personnel were requested to collect white hake from every set until a minimum of 50 specimens were obtained from specific strata. The collected fish were bagged and packed in an undistorted condition in cardboard cartons and then were rapidly frozen.

White hake were sampled from twenty-eight different strata, however only five strata yielded the preferred minimum sample size of fifty fish (Table 2 and Figure 1). There were many strata in which white hake were not caught at all. The resulting collection had a preponderance of samples from the northern and southeastern extremes of NAFO Division 4T, although there were some from as far west as the mouth of the St. Lawrence River.

Although this collection cannot be described as a totally random sample, it includes samples from throughout the range of white hake in the southern Gulf of St. Lawrence and as such the data are probably not greatly different from those which a truly random sampling scheme would have produced.

The Gulf of St. Lawrence includes three divisions of the NAFO convention area (Divisions 4R, 4S and 4T). Along the edge of the Laurentian Channel, within NAFO Division 4T, two different but overlapping stratification schemes are recognized (Figure 2) depending on the principal area surveyed (ie. southern _versus_ northern Gulf). Because cruises H158 and H159 were surveys of the northern and southern Gulf respectively, both stratification schemes were used, and the overlap in these strata must be remembered.

All the samples were stored frozen for a period of several months up to a year. The variability in time before the fish were processed may have had some effect on the final morphometric measurements but data are not available to assess this.

Laboratory Methods

Previously, there has been a great deal of confusion regarding the species of _Urophycis_ that occurs in the Gulf of St. Lawrence. This confusion (see Table 1) carried over into the commercial fishery statistics (McCracken, 1966) and persisted until Musick (1967, 1969 and 1972) revised the taxonomic characters that permit distinction between U. _tenuis_ and U. _chuss_. Due to their small size, counts of the lateral line scales proved to be seldom repeatable and extremely time consuming. Therefore, in order to detect the occurrence of U. _chuss_ in this collection of samples, specimens were first identified on the basis of a count of rakers on the epibranchial of the first, left gill arch. If more than two rakers were encountered, then the following characters were examined:

1) the rakers on the epibranchial of the first, right gill arch were counted.
2) the scales along the lateral line were counted (counts were made three times for consistency).
3) the caudal fin rays (total) were counted.

Any specimens that could not be positively identified as white hake were forwarded to the Atlantic Reference Centre (St. Andrews, N.B.) for confirmation.

Musick (1969 and 1972) also described morphometric characters that varied regionally between white hake from the Gulf of St. Lawrence and those from the Nova Scotia shelf and New England waters. These characters as well as several additional ones were measured in order to identify regional differences among white hake from the areas sampled.

Morphometric Characters

Whenever possible, morphometric measurements were made on the left side of each specimen (Figure 3).

A description of each morphometric character is found in Appendix I (for convenience the acronyms for the morphometric characters will be used occasionally).

Most of the morphometric characters are standard measurements as described by Hubbs and Lagler (1958). Two of the characters measured were described by Musick (1972) specifically for morphometric comparisons of U. *tenuis* and U. *chuss*. These characters are differentiated from analogous characters described by Hubbs and Lagler (1958) by use of the extensions: -Musick or -Lagler in the character name.

Characters that were less than 30 cm long for all of the specimens (except for lengths of the sagittal otoliths: OTOLHSL and OTORHSL) were measured to the nearest 0.1 mm with vernier calipers. These characters were: snout length-Lagler (SNOUTLL), snout length-Musick (SNOUTLM), eye diameter (EYEDIAM), head length-Lagler (HEADLL), head length-Musick (HEADLM), head width (HEADWID), upper jaw length (UPJAWL), and pectoral fin length (PECTFL).

Characters that tended to be longer than 30 cm (except for total length (TOTALL) and standard length (STANDL)) were measured to the nearest millimeter with modified calipers constructed from a meter stick with sliding needle points. These characters were: second dorsal fin base (SDORFBAS), anal fin base (ANALFBAS), pre-anal length (PREANALL), post-first dorsal fin length (PFDORFL), post-second dorsal fin length (PSDORFL), post-pectoral fin length

(PPECTFL) and post-pelvic fin length (PPELVFL).

Total and standard lengths were measured on a measuring board to the nearest millimeter.

Pectoral body girth (PECTBGIR) was measured with a piece of nylon twine to the nearest millimeter.

Meristic Characters

Upon completion of the morphometric examination, all of the meristic characters were determined from radiographs taken on a Torrex 120D X-ray Inspection System with Gaevert D7 industrial x-ray film (sheet size 43 X 35 cm).

Specimens were eviscerated before they were x-rayed. Due to their relative thinness, the first gill arch and pectoral fin from the left side were removed and x-rayed separately. Fish that were too large to fit on a sheet of x-ray film were bisected between the first and second dorsal fins.

All of the meristic counts follow criteria established by Hubbs and Lagler (1958). A description of each meristic character is found in Appendix II (to save space these characters will occasionally be referred to by their acronyms throughout the remainder of the text).

Statistical Analysis

Inadequate sample sizes precluded comparison on a set-by-set basis. Thus, to investigate whether there are geographic heterogeneities in the morphology of white hake in the southern Gulf of St. Lawrence, several arbitrary groupings were imposed on the data.

A preliminary analysis revealed significant heterogeneities among the five strata that fulfilled the minimum sample requirement (n = 50). These five strata collectively represented just over half (n = 319) of the fish in the dataset, however an arbitrary grouping that included all of the fish from all of the areas was preferred (consequently the specimens were not grouped by strata). The first grouping (Scenario one - Figure 4) with six areas was created with the following objectives:

(1) distinction between deep *versus* shallow areas (<= 100 m *versus* > 100 m)
(2) maintenance of the geographic proximity between specimens and

(3) as much as possible for the areas to contain similar numbers of fish (**note**: area 3 was the only area which required a compromise in terms of these objectives, it includes sixty-two fish collected from depths of 123 - 128 m and nineteen fish from depths < 35 m).

The second and third arbitrary groupings explored the stock structure postulated by Clay (1989) and Clay and Hurlbut (1989). Scenario two contrasted fish from along the slope of the Laurentian Channel (depths > 100 m) with those from shallower (depths <= 100 m) areas of the southern Gulf, principally the Northumberland Strait area. Scenario three was an extension of scenario two and contrasted fish from along the slope of the Laurentian Channel (depths > 200 m) with those from depths shallower than 200 meters.

Morphometric characters being continuous variables tend to be normally distributed whereas meristic characters are discrete variables and frequently have skewed, leptokurtic distributions. Due to these distributional differences and because morphometrics are size-dependent whereas meristics are not (Sokal and Rohlf, 1969), the morphometric and meristic characters were analyzed separately throughout.

SAS (Statistical Analysis System) procedures (SAS Institute, 1985) were used to perform all statistical analyses.

1. Morphometric Characters

The morphometric measurements were transformed to common logarithms because multivariate normality is more closely approximated by logarithms than the original variables (Bliss, 1967; Pimental, 1979). Log transformed variables were used in all subsequent analyses.

Because sexual dimorphism can result in greater variations in morphology than may be attributable to geographic variation between populations, analysis of covariance (ANCOVA), with total length (TOTALL) as the covariate was used to test for differences between males and females from the six areas for each character.

Allometry, or variation in shape resulting from variation in size must be considered in the analysis of morphometric data (Gould, 1966). It is necessary to partition variation resulting from these size (length) differences so that patterns of morphometric variation can be determined from characters independent of size (Claytor and MacCrimmon, 1986; Thorpe, 1976).

The relationships of the morphometric variables to total length were determined by linear regression analysis and by plotting each character against total length (TOTALL).

Before the morphometric variables can be standardized for size it is necessary to determine whether there are differences in allometric relationships (ie. slopes) among fish from the six areas of scenario one. Two ANCOVA models were used to test this assumption for each sex (TOTALL was the covariate). In the first (the "reduced" model) the slope is held constant and the intercept is allowed to vary between the six areas. In the second (the "full" model) the slopes and intercepts are allowed to vary among the six areas (Sokal and Rohlf, 1981). The correlation coefficients for each of the models indicate how well each model fits the data. If the difference between the r^2 values is small (ie. $< 5\%$) it can be concluded that any differences in allometric relationships between the areas is negligible (Claytor, 1984).

Two types of regression analysis were used to adjust the morphometric characters for each sex to a common total length. The total overall regression slopes were derived irrespective of area of origin and the pooled within-group slopes were determined from the previous ANCOVA analysis for differences in allometry. Using the total overall and pooled within-group slopes, new variables, adjusted to the overall mean total length for each sex, were obtained using the formula:

ADJCHAR=ORGCHAR-[SLOPE X (TOTALL-MEANTOT)]

where ADJCHAR equals the value of the size standardized character, ORGCHAR is the original value of the character, SLOPE is the slope (total overall or pooled within-group) of the respective characters versus the size standard (TOTALL), TOTALL is the total length of each fish and MEANTOT is the overall mean total length for females or males respectively.

The effectiveness of the two different slopes for standardizing size was then tested by a regression of the proposed size-standardized characters against the size standard (TOTALL) (Claytor and MacCrimmon, 1986). The first two canonical variables for each set of standardized characters was determined by canonical discriminant function analysis. These canonical variables were then regressed against total length. Correlation coefficients were used as a relative measure of standardizing success. Size was considered to be standardized if all the regressions associated with a slope calculation were not significant ($p < 0.05$).

Correlations between the morphometric characters before and after size standardization were compared as an additional measure of the effectiveness of size standardization.

Analysis of variance (ANOVA) was used to test for significant differences between the six arbitrary areas for each sex for each of the size-standardized morphometric characters. If a significant difference ($p < 0.001$) between groups was indicated by the ANOVA, a pairwise comparison using the least squares means method was made to identify where significant differences between the groups occurred.

2. Meristic Characters

Sexual dimorphism may also be manifest in the expression of meristic characters. Therefore, ANOVA was used to test for differences between males and females for each character.

Analysis of variance was also used to test for significant meristic differences between the six arbitrary areas of scenario one (sexes separated). If a significant difference between groups was found, a pairwise comparison using the least squares means method was made to identify where significant differences between the groups occurred.

3. Discriminant Function Analyses

Discriminant function analysis is an objective method for identifying group membership and selecting important characters (Claytor and MacCrimmon, 1986). It has emerged as the preferred method for discriminating between stocks using morphometric and meristic characters (Saila and Flowers, 1969; Messieh, 1975; Ihssen et al., 1981; Bowering and Misra, 1982; Almeida, 1987; Davidson et al., 1985).

The informational content of a discriminant analysis does not necessarily increase in direct proportion to the number of intercorrelated morphometric characters (Cailliet, et al., 1986). In this investigation, several of the morphometric characters are likely to be redundant; that is they may be different measurements of the same thing or effect (ie. snout length-Lagler, snout length-Musick, head length-Lagler, head length-Musick, etc.).

For this reason, a forward, stepwise discriminant analysis was performed to select the characters that best distinguish between the areas (for each sex) in each scenario and evaluate the relative contribution of each character. At each step in the analysis, the variable is entered that contributes most to the discriminatory power of the model as measured by Wilk's lambda. When none of the unselected variables meet the entry criterion, the forward selection process stops (SAS Institute, 1985).

In cases where two analogous morphometrics (ie. snout length-Lagler and snout length-Musick) were selected, the character with the lowest Wilk's lambda was eliminated from the subsequent discriminant analysis.

To investigate patterns of morphometric variation in scenarios one, two and three, discriminant function analysis was conducted on the size standardized characters for each sex. The kappa (K) statistic was computed to determine the improvement over chance of the classifications derived from the discriminant functions (Titus et al. 1984).

The positions of specimens that were misclassified by the morphometric discriminant function which provided the best discrimination were plotted to assess whether there were any obvious patterns present.

The observed percentage of cases correctly classified by a discriminant function may be an inflated estimate of the functions true performance when the same cases are used to both derive the function and test it.

In order to obtain a better estimate of the true misclassification rate, the samples from the scenario that provided the best discrimination were randomly split into two datasets (even versus odd fish numbers). The first dataset was used to derive the discriminant function ("learning" sample) and the second to determine the accuracy of the function ("test" sample) (Pella and Robertson, 1979). The observed error rates in the test samples should better reflect the effectiveness of the functions. These analyses were conducted with the same characters (morphometric and meristic) that were used in the analysis of the scenario that provided the best discrimination.

A graphical representation of the relationships between the six areas of scenario one was obtained by constructing 75 % confidence ellipses for each area by the method described by Owen and Chmielewski (1985). The relationships between the areas for the scenario that provided the best discrimination were represented with plots of the mean first canonical variable scores.

Many of the readily available forms of discriminant function analysis are not well suited to discretely distributed data (Habbema and Hermans, 1977). However, such an analysis of the white hake meristics was desired for comparison with the analysis of the morphometric characters. Several alternative methods have been proposed for the discriminant analysis of such data. One approach is to use a mathematical transformation on the samples so that their distribution function is approximately normal, and then use the conventional linear or quadratic discriminant analysis procedures.

One transformation that applies to all distributions equally well is the rank transformation (Lachenbruch, 1975; Moore and Smith, 1975) in which each component of the multivariate samples is replaced by its rank, from rank 1 for the smallest to rank N for the largest of that component in all of the groups combined (Conover and Iman, 1980). Therefore, the meristic characters were transformed to their ranks.

A forward, stepwise discriminant analysis was used to identify the characters of greatest value in discriminating between the areas in each scenario.

The rank transformed meristic variables were used as input to a discriminant function analysis to explore patterns of meristic variation in the three scenarios. The classifications were corrected for chance using the kappa (K) statistic.

"Learning" and "test" samples were created to evaluate the effectiveness (ie. unbiased error rates) of the meristic discriminant functions for the scenario that provided the best discrimination.

From the results of the discriminant function analysis, seventy-five percent confidence ellipses were constructed for each of the areas of scenario one as in the analysis of the morphometric characters. Likewise, the relationships between the areas for the scenario that provided the best discrimination were represented by plots of the mean first canonical variable scores.

RESULTS and DISCUSSION

Morphometric Characters

Total length of the fish in this collection ranged from 7 to 70 cm. Although there was considerable overlap in the range of total length for the fish (both sexes) from the six areas of scenario one (Figure 5), it was still necessary to partition variation resulting from these size (length) differences.

The relationships of the morphometric characters (before standardization) to total length are shown in Table 3. For every character the correlations and slopes are significant (beyond $p = 0.001$). There is a simple linear relationship between each of the morphometric characters and total length and hence to each other (see scatter plots for SNOUTLM, HEADLL, UPJAWL, and PREANALL - Figure 6).

The results of the ANCOVA test for differences in morphometric characters between female and male white hake (Table 4), with terms for area and sex*area interaction revealed significant differences ($p < 0.001$) in ten of the nineteen morphometric characters (Sex*area interaction was not significant for any of the characters). Therefore, the analysis of morphometric characters was conducted with the sexes separated.

When Musick (1972) conducted a similar analysis, sexual dimorphism was not indicated, however Hunt (1982) and Clay (1987) have subsequently described dimorphic growth in white hake.

With regression analysis, three different slopes can be used to partition the effect of size from morphometric data: (1) separate within-group slopes (2) pooled within-group slopes and (3) total overall regression slopes. If there are no differences in allometric relationships among the groups or areas examined then the latter two slopes may be appropriate for size adjustment. Thorpe (1976) provides a detailed explanation of the differences between these slopes.

There were no significant differences between the two ANCOVA models ("reduced" and "full") in explaining character variation relative to total length (the difference between r^2 values for each model was less than five percent - Table 5). Because there were no differences among the slopes for each area (by sex), it was concluded that there were no allometric differences among the six areas examined for either sex. Total overall regression slopes and pooled within-group slopes were therefore appropriate to further investigate size partitioning.

When the effectiveness of the two slopes for partitioning size from the morphometric data was compared, the overall regression slopes were found to be superior because p-values were consistently high only with this slope (Table 6). In contrast, the p-value for the regression of the second canonical variable using the pooled within-group slopes for male white hake was significant ($p < 0.05$) and the highest r^2 values were obtained with this regression. The morphometric characters were therefore adjusted using the overall regression slopes for each sex.

Thorpe (1976) recommended that the pooled within-group slope be used exclusively when employing regression procedures to partition size from morphometric data because the pooled within-group slope may be different from the overall regression slope. When Claytor and MacCrimmon (1986) compared the effectiveness of five statistical procedures currently used to partition size from morphometric data, their results indicated that the overall regression slope was most consistent in partitioning size.

Character correlations were much lower after than before size standardization using the total overall regression slopes (Table 7 a and b). After size was standardized with the overall regression slopes, correlation coefficients averaged 0.017 and 0.196 for females and males respectively.

The results of the ANOVA test for area differences in the size standardized morphometric characters revealed significant differences ($p < 0.01$) between the six areas of scenario one for both sexes (Table 8 and Figure 7). Two of the morphometric characters were significantly different ($p < 0.001$) for both sexes (SNOUTLM and HEADWID).

Meristic Characters

The distributions of the meristic characters are skewed and in one case (EPIRAK) very strongly (Table 9). As well, kurtosis is evident in all of the distributions. These skews and kurtoses make these data unsuitable for many conventional multivariate analyses. They should only be used in analyses that are robust to such deviations from normality.

The ANOVA to test for differences in meristic characters between female and male white hake revealed a significant difference ($p < 0.01$) in one of the meristic characters (ABDVERT); therefore, the data were treated separately by sex (Table 10).

When ANOVA was used to test for differences between the six areas of scenario 1 , significant differences ($p < 0.001$) were found for two of the meristic characters (PECTFR for females and CERRAK for males) (Table 11 and Figure 8).

Discriminant Function Analyses

Scenario One

Forward, stepwise discriminant function analysis revealed that eleven of the nineteen morphometric characters contributed significantly to the multivariate discrimination between the six areas of scenario one for female white hake (Table 12 a). In contrast, fifteen of the nineteen morphometric characters contributed to the multivariate discrimination between the areas for male white hake in the same scenario. Redundant characters were selected (entered) in the stepwise discriminant analyses for both sexes. These characters were omitted from subsequent canonical discriminant analyses.

Morphometric evidence from discriminant function analysis of the six arbitrary areas of scenario one (Figure 9 a and b, Table 12 a) indicates a morphological dichotomy between white hake populations from areas 1, 2 and 3 (southern Gulf - depths < 100 m) and populations from areas 4, 5 and 6 (along the slope of the Laurentian Channel). The mean first canonical variable scores for areas 1, 2 and 3 are all greater than those from areas 4, 5 and 6. This pattern is consistent for both sexes. The observed percentage of correct classification (Table 12 a) for the six areas of this scenario is 49 % for females and 55 % for males. The kappa statistics indicate that these classifications are 37 % (females) and 46 % (males) better than would have occurred by chance. A greater relative snout length (SNOUTLM) with respect to total length (TOTALL) in the fish from areas 4, 5, and 6 compared with those from areas 1, 2, and 3 is the primary character difference for both sexes (Figure 9 a and b).

Stepwise discriminant analysis applied to the meristic data of scenario one resulted in four characters (PECTFR, ABDVERT, CAUDFR and CERRAK) contributing to the discriminant functions for females and only one character (CERRAK) for males (Table 12 b). (**note**: to construct 75 % confidence ellipses for the male white hake of this scenario it was necessary to include an additional meristic character (EPIRAK) in the discriminant function analysis because the number of canonical variables is the minimum of the number of variables (ie. 2 including EPIRAK) and the number of areas minus one (6-1=5)).

Meristic evidence from this scenario (Figure 9 c and d, Table 12 b) also indicates a discontinuity between white hake populations from the "strait" and "channel" areas. The mean first canonical variable scores for "channel" populations are all greater than those of "strait" origin, however there is considerably more overlap among the area centroids for these characters. As well, the observed percentages of correct classification are significantly lower (31 % for females and 19 % for males) and the chance corrected classifications are very low (17 % and 3 % better than chance for females and males respectively).

Greater numbers of pectoral fin rays (PECTFR) in the female white hake of "channel" origin compared with females from the "strait" area is the primary character difference (Figure 9 c). For male white hake, the number of rakers on the ceratobranch (CERRAK) is the primary character difference ("Channel" fish > "Strait" fish - Figure 9 d).

Scenarios Two and Three

The results of the discriminant function analyses of the morphometric and meristic data for scenarios two and three are similar (Tables 13a - 14b). The stepwise discriminant function analyses revealed that for each sex, many of the same characters (morphometric and meristic) contributed to the multivariate discrimination between the two areas of both scenarios. With one exception (morphometrics for female white hake), from one to four more characters contributed to the discriminant functions of scenario three than for scenario two.

Two to four morphometric variables dominated the discriminant functions of both scenarios for each sex, as indicated by the standardized coefficients of the first canonical variables. One to three meristic variables dominated the discriminant functions of both scenarios.

The observed percentages of correct classification for the morphometric and meristic datasets were considerably higher with scenario two relative to scenario one (Table 13 a and b). With one exception (meristics for female white hake), the kappa statistics reflect this improvement in correct classification. A posteriori classifications using discriminant functions derived from meristic data were considerably less successful than functions derived from morphometric data in their ability to correctly classify samples. The kappa statistics indicate that the classifications based on morphometric characters were significantly better than chance (41 % and 61 % for females and males respectively) unlike the classifications based on meristic characters (16 % and 10 % for females and males respectively).

The highest percentages of correct classification occurred for the discriminant function analyses of scenario three, indicating reliable separation between the two areas (samples from depths <= 200 m versus > 200 m - Tables 14 a and b and Figure 10 a and b). A posteriori classifications yielded 77 % correct classification for females and 83 % for males for morphometric characters. These classifications were 52 % (females) and 66 % (males) better than would have occurred by chance alone.

There was considerably more overlap in the distributions of first canonical variable scores with the meristic discriminant functions (Figure 10 c and d) than with the morphometric discriminant functions (Figure 10 a and b). This relatively high degree of overlap is reflected in the observed percentages of correct classification (66 % for females and 60 % for males) and low kappa statistics (these classifications were 31 % and 20 % better than would have occurred by chance alone - females and males respectively).

The majority of the specimens (53 % of the females and 36 % of the males) that were misclassified by the morphometric discriminant functions for this scenario (3) were located near the 200 m depth 'boundary' (Figures 11 a and b). These misclassified specimens represent 26 % of the fish (both sexes) from this boundary area.

Morphometric discriminant functions derived from "learning" samples for this scenario were able to correctly classify "test" samples with accuracies of 78 % for females and 77 % for males (these classifications were 51 % (females) and 54 % (males) better than would have occurred by chance alone - Tables 15).

The test samples could not be accurately classified with either of the meristic discriminant functions. The observed percentages of correct classification (64 % for females and 57 % for males) were only 28 % and 13 % better than would have been obtained by chance (Table 15).

The evidence from this investigation is consistent with the results of a limited tagging study conducted off eastern Prince Edward Island by Kohler (1971). His study indicated that white hake in the southern Gulf probably remain in the Gulf year round, with little mixture with white hake populations outside (the Gulf). No fish from the Laurentian Channel or outside the Gulf were tagged.

The combined evidence from this analysis of morphological characters, seasonal and annual distribution studies and a tagging study indicates that white hake in NAFO division 4T, are characterized by two distinct components composed of:

(1) fish from the shallow inshore southern Gulf (depths <= 200 m), principally the Northumberland Strait area (the "strait" component) and
(2) fish from along the Laurentian Channel in depths in excess of 200 m (the "channel" component).

Musick (1972) suggested that there may be a strong biological basis for morphometric differences between white hake from the southern Gulf of St. Lawrence and those from Nova Scotia and New England waters. The southern Gulf group gathers in large spawning aggregations from June to early August, whereas the Nova Scotia - New England group probably spawns in the fall. Thus the two groups may be reproductively isolated.

Markle et al. (1982) reviewed evidence from ichthyoplankton surveys which indicated that white hake from the deeper depths (200 - 400 m) of the Gulf may spawn in late winter - early spring and their larvae may be dispersed into the Atlantic.

Musick (1972) also investigated variability in meristic characters in white hake from the southern Gulf of St. Lawrence, the Nova Scotia shelf and from off New England. None of the meristic characters that he examined showed statistically significant differences among his samples from these three areas.

When discriminant analysis procedures are used to identify stocks of anadromous species, high percentages of correct classification are generally obtained (Almeida, 1987). For example, when Claytor and MacCrimmon (1988) examined morphometric variability among North American Atlantic salmon, the observed percentage of correct classification for their Newfoundland-Labrador versus Gaspe-Maritime stock designation exceeded 90 % and was 80 % (kappa) better than would have occurred by chance.

However, when the stock structure of non-anadromous marine fish species has been investigated successfully with discriminant analysis (ie. Atlantic herring (Parsons, 1972; Messieh,1975), capelin (Sharp et al. 1978) and summer flounder (Wilk et al. 1980), the percentages of correct classification have generally been lower than for anadromous species (Almeida,1987).

Using a morphometric discriminant function to classify spawning and post-spawning silver hake from the New England - Mid Atlantic area, Almeida (1987) obtained 76 % and 80 % correct classification for females and males respectively. In comparison, the morphometric discriminant function for scenario three of this investigation yielded 77 % and 83 % correct classification for females and males respectively (these classifications were 52 % and 66 % better than would have occurred by chance - Table 16).

When Sharp et al. (1978) used meristic discriminant functions to classify capelin from several northwest Atlantic populations, the classifications obtained were only 20 % and 27 % correct for females and males respectively. They concluded that meristic characters offer little potential for identification of capelin stocks in Canadian Atlantic waters.

In this study, the meristic discriminant function for scenario three correctly classified 66 % of the females and 60 % of the males (these classifications were 31 % and 20 % better than chance - Table 16). Thus, although meristic characters provide some evidence for stock separation of white hake, the best statistical separation is obtained with morphometric characters.

The implication of this study is that there is probably more than one component to the white hake currently being managed in NAFO division 4T.

CONCLUSIONS

The present study indicates that white hake inhabiting the southern Gulf of St. Lawrence, NAFO division 4T, are characterized by two distinct components:

(1) Fish from the southernmost, inshore areas (depths <= 200 m) of the Gulf, principally the Northumberland Strait area (the "strait" component) and
(2) Fish from along the slope of the Laurentian Channel in depths in excess of 200 m (the "channel" component).

The strongest evidence for this conclusion was obtained with the morphometric discriminant functions for scenarios two and three, which contrast "strait" and "channel" samples. Although meristic characters provide some evidence for stock separation of white hake, the best separation is obtained with morphometric characters.

White hake in NAFO division 4T have been assessed and managed as a "unit stock" for lack of evidence to the contrary. This study suggests that this management unit may no longer be appropriate.

ACKNOWLEDGEMENTS

We would like to thank Ghislain Chouinard, Doug Swain and Ross Tallman for many constructive comments on an earlier draft and Gerald Chaput and Ross Claytor for more recent reviews of this manuscript. We extend special thanks to Ross Claytor for his considerable assistance with many aspects of this analysis.

DISCLAIMER

The mention of any brand names or commercially available products does not imply endorsement by the authors or the Department of Fisheries and Oceans.

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Table 1. Nominal landings (t) of white hake from NAFO division 4T by gear, year and TAC (Total Allowable Catch). All data from 1986 to 1989 are provisional.

	YEAR	TRAWL	SEINE	LINE	GILLNET	OTHER	TOTAL	TAC
	1960						2015+	
	1961						5333+	
	1962						7244+	
	1963						6546+	
	1964						6205+	
	1965						4706"	
	1966						7024	
	1967						6550	
	1968						4260	
	1969						4208	

+ referred to as hake unspecified in NAFO statistical bulletins
" referred to as red hake in NAFO statistical bulletins

	YEAR	TRAWL	SEINE	LINE	GILLNET	OTHER	TOTAL	TAC
	1970	1463	382	385	2149	1289	5668	
	1971	1523	632	702	1622	1228	5707	
	1972	1140	863	1604	1190	960	5757	
	1973	2468	211	1045	1265	713	5702	
	1974	1454	305	345	1100	412	3616	
	1975	1576	306	324	1285	634	4125	
	1976	1429	398	183	1147	601	3758	
	1977	1227	408	231	1300	818	3984	
	1978	1303	729	456	1829	508	4825	
	1979	2826	912	479	3189	704	8110	
	1980	3430	1615	832	4831	1715	12423	
	1981	4733	1922	799	6174	411	14039	
	1982	2885	994	1027	4625	245	9776	12000
	1983	2141	906	753	2959	546	7305	12000
	1984	1614	592	674	3631	81	6592	12000
	1985	1639	1008	799	2480	88	6014	12000
*	1986	1316	676	1068	1884	4	4948	12000
*	1987	795	1339	1521	2292	275	6222	9400
*	1988	629	550	730	1938	14	3860	5500
*	1989	1120	1222	923	1838	25	5128	5500
	1990							5500

1970 to 1989

	TRAWL	SEINE	LINE	GILLNET	OTHER	TOTAL
AVERAGE	1836	799	744	2436	564	6378
PERCENT	29	13	12	38	9	
89 Percent	22	24	18	35	0	

*** - provisional statistics**

Table 2. Location and parameters associated with samples of white hake collected on two cruises of the *Lady Hammond* in 1986.

CRUISE	STRATUM	SET	LATITUDE (Deg-Min)	LONGITUDE (Deg-Min)	DEPTH (m)	DATE (Yr=86) (Day/Mon)	NUMBER OF WHITE HAKE MALES	FEMALES	COMBINED
H158	*1401	93	48-06	61-14	262	14/08	32	20	52
		97	47-44	60-34	227	15/08	10	8	18
	*1402	180	48-25	62-45	267	26/08	28	21	49
	*1403	163	49-19	65-35	252	23/08	1	2	3
		165	49-14	64-51	234	24/08	23	22	45
		167	48-57	64-05	267	24/08	11	7	18
	*1404	92	48-10	61-16	360	14/08	2	1	3
		95	47-50	60-37	318	15/08	5	5	10
	*1405	172	48-50	63-13	358	24/08	1	4	5
		179	48-28	62-49	326	26/08	10	7	17
		181	48-23	62-23	331	26/08	2	5	7
	*1406	166	49-11	64-30	329	24/08	1	5	6
	*1407	91	48-18	61-24	402	14/08	0	1	1
		98	47-34	60-15	485	15/08	1	3	4
	*1408	173	48-48	62-58	395	24/08	1	0	1
		178	48-34	62-37	421	25/08	2	1	3
		182	48-25	61-59	404	26/08	0	4	4
	*1410	155	49-18	66-49	311	23/08	1	1	2
		164	49-21	65-09	344	23/08	1	3	4
	*1803	4	47-58	60-06	485	06/08	1	0	1
		89	48-21	60-39	452	14/08	0	2	2
		118	48-39	61-54	417	19/08	0	2	2
	*1804	120	48-38	62-10	412	20/08	4	0	4
		125	48-48	62-32	397	20/08	3	2	5
		129	49-00	63-19	397	20/08	3	1	4
		133	49-04	63-39	391	21/08	3	2	5
	*1818	174	49-01	62-43	214	25/08	3	5	8
						Totals:	149	134	283
H159	401	78	46-49	63-49	32	10/09	6	2	8
	402	214	45-53	63-08	21	23/09	10	3	13
	415	1	48-48	63-17	312	18/09	1	8	9
		6	48-49	63-35	224	18/09	6	14	20
	416	5	48-29	63-40	147	19/09	3	1	4
		7	48-26	63-23	118	18/09	0	1	1
	418	14	48-03	64-35	37	20/09	3	0	3
		16	48-09	64-09	39	21/09	1	1	2
	419	17	47-51	65-20	60	20/09	1	0	1
		121	47-46	63-34	34	20/09	9	2	11
	420	116	46-60	64-32	27	16/09	1	1	2
		117	47-15	64-35	32	16/09	6	1	7
		118	47-42	64-23	34	17/09	2	0	2

Table 2 - Cont'd.

CRUISE	STRATUM	SET	LATITUDE	LONGITUDE	DEPTH	DATE (Yr=86)	NUMBER OF WHITE HAKE MALES	FEMALES	COMBINED
H159	421	24	46-58	64-16	30	16/09	3	2	5
		144	46-53	64-27	31	16/09	2	1	3
	422	27	47-17	64-25	42	16/09	3	0	3
		28	47-15	64-00	32	17/09	1	0	1
	429	47	46-36	63-13	39	11/09	2	0	2
	432	54	45-56	62-31	45	12/09	4	2	6
		254	45-56	62-31	44	15/09	4	16	20
		255	45-55	63-03	28	23/09	3	3	6
	433	143	46-02	62-08	36	12/09	14	7	21
		257	45-53	62-14	31	23/09	4	11	15
		356	45-59	62-11	39	23/09	13	7	20
		457	45-53	62-15	31	24/09	13	3	16
	435	62	47-08	61-51	31	10/09	10	2	12
		132	47-17	61-24	35	05/09	6	1	7
	436	65	47-20	60-27	68	04/09	3	3	6
	437	67	46-52	60-57	128	22/09	16	6	22
		68	46-57	60-46	123	04/09	24	16	40
	439	72	47-18	60-13	256	04/09	7	7	14
		137	47-31	60-24	308	05/09	6	8	14
						Totals:	187	129	316
						Grand Total: (H158+H159)	336	263	599

*** - These strata from NAFO Divisions 4R and 4S (Cruise H158 only) are prefixed with a "1" to distinguish them from strata in NAFO Division 4T that bear the same number (see Figure 2).**

Table 3. Relationships of morphometric characters (before size standardization) with total length (TOTALL), sexes combined.

Morphometric Character Acronym	r^2	Intercept (B)	Slope (A)	S.E. of Intercept	S.E. of Slope	n
STANDL	.9992	-3.0401	.8834	.4499	.001	613
SNOUTLL	.8904	.4804	.0528	.3275	.0007	612
SNOUTLM	.9161	4.1611	.0895	.4785	.0011	613
EYEDIAM	.8843	2.2899	.0321	.2077	.0005	597
HEADLL	.9793	-1.8951	.2241	.5763	.0013	612
HEADLM	.9768	-1.6646	.2129	.5793	.0013	613
HEADWID	.8997	-14.0309	.1597	.9436	.0022	610
UPJAWL	.9114	-.8228	.0979	.5409	.0012	611
PECTFL	.9723	-4.4752	.1709	.5094	.0012	613
SDORFBAS	.9902	5.8579	.4903	.8632	.0019	610
ANALFBAS	.9806	10.4738	.3654	.9094	.0021	610
PREANALL	.9861	-14.1187	.4476	.9399	.0022	611
PFDORFL	.9978	4.9645	.7439	.6189	.0014	613
PSDORFL	.9961	9.9785	.6513	.7244	.0017	613
PPECTFL	.9972	3.3565	.7826	.7339	.0017	613
PPELVFL	.9966	.8678	.8537	.8746	.002	613
PECTBGIR	.9383	-29.3942	.5543	2.5405	.0058	597
OTOLHSL	.9553	3.0788	.0355	.1511	.0003	510
OTORHSL	.9619	2.8428	.0359	.1322	.0003	570

Table 4. Results of analysis of covariance (ANCOVA) test for sexual dimorphism in morphometric characters with terms for area and sex*area interaction.
(1) Common logarithms of the morphometric characters were used instead their size-standardized values.
(2) Areas used were the six arbitrary areas of Scenario 1.

Morph. Character Acronym	Sex Effect F-Value	Sex Effect Signif.	Area Effect F-Value	Area Effect Signif.	Sex*Area F-Value	Sex*Area Signif.
STANDL	.06	N.S.	5.75	***	1.76	N.S.
SNOUTLL	11.79	***	7.95	***	.10	N.S.
SNOUTLM	.01	N.S.	36.13	***	.20	N.S.
EYEDIAM	20.86	***	4.46	***	.87	N.S.
HEADLL	24.75	***	5.98	***	.96	N.S.
HEADLM	24.42	***	6.52	***	.83	N.S.
HEADWID	.05	N.S.	16.02	***	.71	N.S.
UPJAWL	4.16	*	5.11	***	1.19	N.S.
PECTFL	.05	N.S.	2.76	*	.31	N.S.
SDORFBAS	21.41	***	1.19	N.S.	1.23	N.S.
ANALFBAS	10.22	**	2.77	*	1.23	N.S.
PREANALL	25.95	***	2.65	*	1.09	N.S.
PFDORFL	29.35	***	5.18	***	1.24	N.S.
PSDORFL	18.48	***	4.89	***	1.24	N.S.
PPECTFL	28.79	***	1.24	N.S.	1.70	N.S.
PPELVFL	14.82	***	2.03	N.S.	1.43	N.S.
PECTBGIR	.57	N.S.	7.53	***	.98	N.S.
OTOLHSL	2.14	N.S.	2.83	*	.62	N.S.
OTORHSL	1.75	N.S.	3.30	**	.96	N.S.

Significance Levels:
* - Level of Significance < 0.05
** - Level of Significance < 0.01
*** - Level of Significance < 0.001
N.S. - Level of Significance > 0.05

Table 5. The slopes determined from the analysis of covariance (ANCOVA) and regression procedures to partition size from the morphometric data. The differences (< 5 %) in the r^2 values from the full (F) and reduced (R) ANCOVA models indicates there are no differences in the slopes between areas (from Scenario 1) in any of the ANCOVA analyses.

Morph. Character Acronym	ANCOVA Pooled Within-Group Slopes MALES SLOPE	r^2(F)	r^2(R)	FEMALES SLOPE	r^2(F)	r^2(R)	REGRESSION Overall Regression Slopes MALES SLOPE	r^2	FEMALES SLOPE	r^2
STANDL	1.0015	.9994	.9994	1.0091	.9992	.9991	1.0032	.9993	1.0085	.9991
SNOUTLL	1.0033	.9222	.9206	1.0436	.9063	.9020	.9650	.9129	1.0270	.8959
SNOUTLM	.9170	.9509	.9499	.9120	.9301	.9285	.8962	.9286	.9209	.9098
EYEDIAM	.8953	.9173	.9117	.7992	.8786	.8754	.9069	.9072	.8072	.8716
HEADLL	1.0194	.9859	.9859	1.0594	.9827	.9818	1.0056	.9845	1.0586	.9812
HEADLM	1.0174	.9830	.9828	1.0492	.9809	.9804	1.0044	.9815	1.0494	.9793
HEADWID	1.2816	.9439	.9414	1.2907	.9049	.9026	1.2986	.9342	1.3073	.8858
UPJAWL	1.0258	.9279	.9271	1.0514	.9091	.9035	.9892	.9215	1.0433	.9011
PECTFL	1.0685	.9745	.9738	1.0873	.9717	.9709	1.0804	.9729	1.0919	.9702
SDORFBAS	.9654	.9926	.9925	.9628	.9894	.9890	.9716	.9923	.9599	.9888
ANALFBAS	.9519	.9889	.9882	.9192	.9781	.9777	.9515	.9879	.9146	.9769
PREANALL	1.0612	.9907	.9905	1.0994	.9877	.9873	1.0618	.9900	1.0945	.9869
PFDORFL	.9857	.9986	.9985	.9737	.9979	.9979	.9869	.9984	.9725	.9977
PSDORFL	.9693	.9976	.9976	.9565	.9956	.9955	.9687	.9975	.9535	.9953
PPECTFL	.9954	.9982	.9981	.9810	.9972	.9971	.9958	.9981	.9799	.9970
PPELVFL	1.0003	.9975	.9974	.9959	.9964	.9963	.9989	.9974	.9950	.9961
PECTBGIR	1.1243	.9556	.9521	1.1711	.9481	.9438	1.1292	.9477	1.1807	.9408
OTOLHSL	.8374	.9633	.9629	.8148	.9586	.9569	.8535	.9624	.8240	.9547
OTORHSL	.8559	.9709	.9706	.8194	.9641	.9627	.8369	.9698	.8152	.9603

Table 6. Values of r^2 and P for the test of size partitioning (Pooled Within-Group Slopes <u>versus</u> Overall Regression Slopes) by regression of the proposed size-free characters against total length (TOTALL) for each slope.

	Pooled Within-Group Slope CV1	CV2	Overall Regression Slope CV1	CV2
Males				
P-Value	.361900	.035700*	.963300	.945200
r^2	.002600	.013800	.000007	.000015
Females				
P-Value	.911900	.209000	.814300	.618500
r^2	.000054	.006900	.000240	.001080

CV - Canonical Variable

* - Significant Regression

Table 7 a and b. Correlation matrices for female (a) and male (b) white hake before (above diagonal) and after (below diagonal) size standardization using Overall Regression Slopes.

a

Morph. Character Acronym	TOTALL	STANDL	SNOUTLL	SNOUTLM	EYEDIAM	HEADLL	HEADLM	HEADWID	UPJAWL	PECTFL	SDORFBAS	ANALFBAS	PREANALL	PFDORFL	PSDORFL	PPECTFL	PPELVFL	PECTBGIR	OTOLHSL	OTORHSL
TOTALL	1.00000	.99950	.94019	.95061	.92559	.98970	.98880	.92919	.94567	.98452	.99352	.98573	.99248	.99867	.99723	.99824	.99775	.96689	.97282	.97538
STANDL	-.00012	1.00000	.93938	.94989	.92483	.98897	.98834	.93048	.94422	.98186	.99387	.98601	.99278	.99801	.99670	.99782	.99737	.96699	.97128	.97347
SNOUTLL	.00004	-.02949	1.00000	.97837	.88133	.96602	.96062	.86547	.92471	.92296	.92119	.92332	.94015	.93193	.93118	.93177	.93560	.91151	.91034	.91530
SNOUTLM	.00029	-.07091	.79575	1.00000	.96092	.97510	.97099	.86049	.92529	.93719	.93284	.92858	.94857	.94225	.94192	.94224	.94628	.91999	.92474	.92748
EYEDIAM	.00009	-.00340	.07586	.23981	1.00000	.92789	.92429	.87451	.88614	.92281	.91657	.89512	.92837	.92253	.92059	.92065	.91917	.91213	.89824	.91226
HEADLL	.00029	-.10182	.72759	.78540	.20016	1.00000	.99569	.91268	.95354	.98028	.97676	.97152	.98674	.98492	.98313	.98342	.98560	.96114	.96741	.96985
HEADLM	-.00020	-.03380	.60384	.68008	.15619	.79807	1.00000	.91156	.93783	.97743	.97415	.96996	.98732	.98283	.98168	.98282	.98555	.95535	.96462	.96756
HEADWID	-.00007	.12697	-.10439	-.23112	.07855	-.15866	-.17319	1.00000	.85326	.91823	.92491	.91245	.93175	.92953	.92828	.93305	.93070	.93687	.89817	.90254
UPJAWL	.00007	-.07094	.33929	.28626	.09553	.37046	.07686	-.19720	1.00000	.93643	.93939	.93161	.93367	.94520	.93936	.93789	.93664	.91871	.93078	.93062
PECTFL	-.00008	-.41016	-.05517	.04195	.11801	.22649	.16012	.04701	.05849	1.00000	.97422	.96462	.97955	.98282	.97986	.98073	.98130	.95966	.96214	.96551
SDORFBAS	.00086	.28762	-.31228	-.36052	-.10945	-.41968	-.48273	.13805	-.04243	-.23842	1.00000	.98231	.98393	.99550	.99632	.99354	.99149	.95987	.96431	.96689
ANALFBAS	-.00010	.16615	-.07128	-.21371	-.27022	-.19968	-.23681	-.02204	-.09350	-.19340	.20267	1.00000	.96773	.98496	.98515	.98529	.98491	.94570	.95792	.95961
PREANALL	.00038	.23210	.15877	.12720	.20250	.23484	.33111	.17853	-.10992	.06442	-.11968	-.47731	1.00000	.98964	.98771	.98990	.98990	.96899	.96678	.96975
PFDORFL	.00033	-.06024	-.41579	-.47988	-.12736	-.48759	-.61098	.11790	.04122	-.05273	.55094	.13581	-.29732	1.00000	.99857	.99844	.99714	.96449	.96996	.97300
PSDORFL	.00006	-.00866	-.26787	-.29593	-.12156	-.37366	-.39826	.08274	-.17085	-.13123	.65779	.22295	-.26428	.68106	1.00000	.99775	.99665	.96005	.96928	.97237
PPECTFL	.00119	.04498	-.38832	-.42165	-.15717	-.56013	-.50926	.22125	-.31852	-.17973	.29067	.19122	-.17498	.52718	.49051	1.00000	.99884	.96344	.96898	.97140
PPELVFL	.00024	.03950	-.13962	-.13406	-.14164	-.21956	-.12907	.10069	-.31881	-.07621	.05266	.15376	-.09369	.20168	.31857	.69623	1.00000	.96311	.96992	.97227
PECTBGIR	-.00005	.06088	.01275	.00778	.14951	.09287	-.05023	.40691	.01633	.09336	-.00114	-.12554	.29040	-.07375	-.18964	-.08380	-.11536	1.00000	.93789	.94011
OTOLHSL	-.04925	-.14554	.00480	.07921	.13196	.17641	.12871	.10644	.12281	.16984	-.12710	-.07681	.10043	-.14139	-.07778	-.14037	-.03061	.08047	1.00000	.99617
OTORHSL	.05248	-.18642	.03123	.08089	.13775	.19114	.13563	.06885	.12942	.17919	-.14873	-.12877	.12279	-.12407	-.07455	-.16298	-.03938	.06625	.92852	1.00000

b

Morph. Character Acronym	TOTALL	STANDL	SNOUTLL	SNOUTLM	EYEDIAM	HEADLL	HEADLM	HEADWID	UPJAWL	PECTFL	SDORFBAS	ANALFBAS	PREANALL	PFDORFL	PSDORFL	PPECTFL	PPELVFL	PECTBGIR	OTOLHSL	OTORHSL
TOTALL	1.00000	.99957	.94151	.95313	.94613	.99030	.98825	.95690	.95417	.98455	.99584	.99257	.99375	.99912	.99850	.99877	.99841	.96568	.97790	.98162
STANDL	-.00144	1.00000	.94074	.95203	.94458	.98951	.98769	.95701	.95379	.98205	.99604	.99257	.99405	.99883	.99789	.99836	.99802	.96512	.97646	.97999
SNOUTLL	.00010	-.02818	1.00000	.97327	.88583	.96588	.96532	.88689	.91977	.92015	.92644	.93025	.93996	.93509	.93637	.93475	.93881	.89344	.90658	.92185
SNOUTLM	-.00015	-.10126	.72343	1.00000	.93171	.97573	.97525	.88815	.92284	.93723	.93995	.93978	.95073	.94678	.94895	.94621	.94983	.91115	.93192	.94331
EYEDIAM	.00012	-.15331	-.02284	.32888	1.00000	.94452	.94418	.91179	.90300	.94563	.93974	.92967	.94571	.94327	.94395	.94399	.94384	.92790	.93163	.94759
HEADLL	-.00025	-.09577	.69396	.75324	.24207	1.00000	.99600	.94117	.95954	.97778	.98047	.97889	.98724	.98645	.98613	.98538	.98685	.95387	.97694	.98074
HEADLM	.00003	-.01713	.64618	.70700	.23507	.81733	1.00000	.93877	.94613	.97401	.97742	.97548	.98755	.98391	.98419	.98348	.98522	.94834	.97257	.97684
HEADWID	.00012	.03790	-.08619	-.21496	.07884	-.08779	-.07109	1.00000	.90242	.94630	.95342	.94834	.95507	.95603	.95438	.95962	.95638	.95251	.93074	.94022
UPJAWL	-.00016	.00883	.21207	.15334	.04178	.35241	.06818	-.15242	1.00000	.94284	.95159	.94530	.94445	.95457	.95006	.94787	.94799	.92376	.93104	.93914
PECTFL	-.00020	-.43479	-.07826	.05220	.24337	.17670	.10053	.03671	.03122	1.00000	.97684	.97295	.98024	.98228	.98156	.98275	.98134	.95668	.96569	.97200
SDORFBAS	-.00012	.23151	-.33520	-.34573	-.13219	-.45468	-.47905	-.07404	.05493	-.19596	1.00000	.99212	.98748	.99707	.99713	.99597	.99478	.96208	.96774	.97330
ANALFBAS	.00031	.11560	-.10215	-.20847	-.29301	-.27492	-.31434	-.03943	-.05838	-.20390	.29016	1.00000	.97798	.99290	.99300	.99271	.99199	.95405	.96451	.97073
PREANALL	.00000	.22748	.13292	.12531	.13255	.23778	.35506	.13571	-.09322	.04891	-.20051	-.58957	1.00000	.99165	.99063	.99161	.99193	.96515	.97295	.97656
PFDORFL	.00206	.09247	-.36124	-.41280	-.17168	-.46601	-.49506	-.10884	.14780	-.22395	.51085	.25058	-.29250	1.00000	.99886	.99863	.99782	.96482	.97347	.97809
PSDORFL	.00083	-.08076	-.21199	-.20349	-.09278	-.36008	-.30657	-.09320	-.11538	-.14936	.53309	.28283	-.27197	.58743	1.00000	.99839	.99762	.96137	.97324	.97778
PPECTFL	-.00016	.00808	-.31609	-.37517	-.10592	-.53847	-.45190	.22641	-.33448	-.09778	.25824	.24505	-.20092	.32893	.40609	1.00000	.99914	.96447	.97350	.97794
PPELVFL	.00060	.01617	-.03823	-.09304	-.06293	-.22266	-.15555	.05230	-.25791	-.13564	.05807	.18635	-.10021	.11092	.22471	.69215	1.00000	.96311	.97382	.97789
PECTBGIR	.00016	-.00510	-.13164	-.07501	.15766	-.02335	-.07897	.34801	.03814	.05934	-.03258	-.12341	.18212	-.03783	-.20777	-.03827	-.09972	1.00000	.93977	.95034
OTOLHSL	-.09935	-.14051	.02528	.18112	.38086	.34108	.26854	.09240	.09691	.19653	-.22256	-.19830	.14124	-.31889	-.24122	-.22637	-.14355	.05308	1.00000	.99635
OTORHSL	.10995	-.17843	.03687	.19136	.40655	.34669	.26585	.12069	.11833	.19856	-.22051	-.16619	.13210	-.28687	-.24168	-.24076	-.13815	.09939	.91219	1.00000

Table 8. Results of analysis of variance (ANOVA) test for area differences in the morphometric characters.
(1) Morphometric characters were standardized for size using Overall Regression Slopes.
(2) Areas used were the six arbitrary areas of Scenario 1.

Morph. Character Acronym	**Males D.F.**	**S.S.**	**F-Value**	**Signif.**	**Females D.F.**	**S.S.**	**F-Value**	**Signif.**
STANDL	5	0.00032	8.34	***	5	0.00013	3.45	**
SNOUTLL	5	0.02666	5.43	***	5	0.01578	3.06	*
SNOUTLM	**5**	**0.07132**	**27.36**	*******	**5**	**0.03982**	**13.37**	*******
EYEDIAM	5	0.01552	3.20	**	5	0.00622	1.50	N.S.
HEADLL	5	0.00490	5.61	***	5	0.00170	1.84	N.S.
HEADLM	5	0.00511	4.82	***	5	0.00267	2.72	*
HEADWID	**5**	**0.04998**	**7.87**	*******	**5**	**0.07311**	**8.75**	*******
UPJAWL	5	0.01935	4.12	**	5	0.00653	1.26	N.S.
PECTFL	5	0.00379	2.01	N.S.	5	0.00202	1.27	N.S.
SDORFBAS	5	0.00064	1.49	N.S.	5	0.00044	0.98	N.S.
ANALFBAS	5	0.00100	1.56	N.S.	5	0.00151	1.77	N.S.
PREANALL	5	0.00196	3.03	*	5	0.00099	1.44	N.S.
PFDORFL	5	0.00020	2.40	*	5	0.00031	3.47	**
PSDORFL	5	0.00042	3.18	**	5	0.00040	2.22	N.S.
PPECTFL	5	0.00003	0.27	N.S.	5	0.00014	1.15	N.S.
PPELVFL	5	0.00019	1.29	N.S.	5	0.00027	1.63	N.S.
PECTBGIR	5	0.02302	5.94	***	5	0.01009	2.66	*
OTOLHSL	5	0.00108	0.93	N.S.	5	0.00275	2.21	N.S.
OTORHSL	5	0.00207	1.69	N.S.	5	0.00350	3.05	*

Significance Levels: * - Level of Significance < 0.05
** - Level of Significance < 0.01
*** - Level of Significance < 0.001
N.S. - Level of Significance > 0.05

Table 9. Summary of the distribution of the meristic characters (non-ranked).

Meristic Character Acronym	**Mean**	**Variance**	**Minimum**	**Maximum**	**Skewness**	**Kurtosis**	**n**
FDORFR	9.41	.55	8	11	.19	-.23	600
SDORFR	54.24	3.73	49	60	.02	-.26	607
CAUDFR	35.10	1.16	33	38	.15	-.21	597
ANALFR	47.75	3.20	43	52	.04	-.31	607
PECTFR	16.35	.56	15	18	-.12	-.48	605
TOTVERT	48.73	.40	47	50	-.24	.11	611
ABDVERT	15.93	.22	14	17	-.33	1.89	597
EPIRAK	2.10	.09	2	3	2.74	5.53	612
CERRAK	13.15	.78	11	15	.06	-.37	610

Table 10. Results of analysis of variance (ANOVA) test for sexual dimorphism in meristic characters with terms for area and sex*area interaction. The areas represent the six arbitrary areas of Scenario 1.

Meristic Character Acronym	Sex Effect F-Value	Sex Effect Signif.	Area Effect F-Value	Area Effect Signif.	Sex*Area Interaction F-Value	Sex*Area Interaction Signif.
FDORFR	1.06	N.S.	0.78	N.S.	0.31	N.S.
SDORFR	0.13	N.S.	1.64	N.S.	0.93	N.S.
CAUDFR	2.42	N.S.	0.88	N.S.	1.60	N.S.
ANALFR	1.62	N.S.	2.52	*	0.30	N.S.
PECTFR	2.31	N.S.	5.67	***	3.04	*
TOTVERT	0.31	N.S.	0.57	N.S.	0.77	N.S.
ABDVERT	**9.73**	**	**4.53**	***	**0.88**	**N.S.**
CERRAK	0.00	N.S.	7.66	***	0.87	N.S.
EPIRAK	0.18	N.S.	1.17	N.S.	0.74	N.S.

Significance Levels * - Level of Significance < 0.05
**** - Level of Significance < 0.01**
***** - Level of Significance < 0.001**
N.S. - Level of Significance > 0.05

Table 11. Results of analysis of variance (ANOVA) test for area differences in the meristic characters. Areas used refer to the six arbitrary areas of Scenario 1.

Morph. Character Acronym	Males D.F.	Males S.S.	Males F-Value	Males Signif.	Females D.F.	Females S.S.	Females F-Value	Females Signif.
FDORFR	5	0.546	0.20	N.S.	5	2.407	0.89	N.S.
SDORFR	5	24.405	1.37	N.S.	5	24.235	1.25	N.S.
CAUDFR	5	4.390	0.77	N.S.	5	11.008	1.86	N.S.
ANALFR	5	20.874	1.30	N.S.	5	21.502	1.48	N.S.
PECTFR	**5**	**3.183**	**1.17**	**N.S.**	**5**	**16.492**	**6.54**	***
TOTVERT	5	0.208	0.10	N.S.	5	2.291	1.16	N.S.
ABDVERT	5	1.569	1.61	N.S.	5	3.953	3.52	**
CERRAK	**5**	**15.152**	**4.62**	***	**5**	**14.893**	**3.52**	**
EPIRAK	5	0.289	0.71	N.S.	5	0.429	0.89	N.S.

Significance Levels: * - Level of Significance < 0.05
**** - Level of Significance < 0.01**
***** - Level of Significance < 0.001**
N.S. - Level of Significance > 0.05

Table 12 a. Discriminant Function Analysis (sexes separated) for the six areas of Scenario 1 - Morphometrics.

Morphometrics - Scenario 1

Females

Morph. Character Acronym	Initial F	Degrees of Freedom
SNOUTLL	1.855	5, 190
SNOUTLM	7.219	
EYEDIAM	1.329	
HEADLL	1.333	
HEADLM	1.409	
HEADWID	7.853	
UPJAWL	1.785	
PECTFL	.536	
SDORFBAS	.138	
ANALFBAS	1.563	
PREANALL	.418	
PFDORFL	2.147	
PSDORFL	2.371	
PPECTFL	1.669	
PPELVFL	1.618	
PECTBGIR	3.557	
OTOLHSL	1.960	
OTORHSL	2.165	

"Step" in Forward Discriminant Analysis	Character Entered	F Statistic	Wilks' Lambda	Degrees of Freedom
1	HEADWID	7.853	.8287	5, 190
2	SNOUTLM	6.547	.7064	5, 189
3	SNOUTLL *	15.288	.5022	5, 188
4	PPECTFL	3.786	.4560	5, 187
5	PFDORFL	2.711	.4251	5, 186
6	PSDORFL	3.242	.3908	5, 185
7	UPJAWL	2.680	.3643	5, 184
8	SDORFBAS	2.202	.3436	5, 183
9	PREANALL	2.276	.3234	5, 182
10	ANALFBAS	3.254	.2967	5, 181
11	OTORHSL	1.804	.2826	5, 180

* - Character redundant and omitted from subsequent discriminant analysis

Classification Matrix

Actual Group	Assigned Group 1	2	3	4	5	6
1	22	6	6	1	3	4
2	2	6	2	0	0	0
3	5	3	13	0	1	3
4	7	3	6	25	7	5
5	2	1	4	11	24	6
6	3	3	10	10	9	26

TOTAL= 239

Average Percent Correctly Classified: 48.54
Kappa Statistic: 37.28
95% Conf.Interval for Kappa: 29.39 - 45.16

Morph. Character Acronym	Standardized Coefficients of First Canonical Variable
SNOUTLM	-1.1853
HEADWID	0.2134
UPJAWL	0.6602
SDORFBAS	0.4982
ANALFBAS	0.4929
PREANALL	0.5856
PFDORFL	0.1165
PSDORFL	0.4771
PPECTFL	-0.5113
OTORHSL	-0.0318

Morphometrics - Scenario 1

Males

Morph. Character Acronym	Initial F	Degrees of Freedom
SNOUTLL	5.483	5, 247
SNOUTLM	17.868	
EYEDIAM	1.337	
HEADLL	4.418	
HEADLM	2.504	
HEADWID	7.713	
UPJAWL	3.131	
PECTFL	1.808	
SDORFBAS	2.101	
ANALFBAS	.709	
PREANALL	2.645	
PFDORFL	2.605	
PSDORFL	1.906	
PPECTFL	.407	
PPELVFL	2.361	
PECTBGIR	5.738	
OTOLHSL	1.726	
OTORHSL	1.021	

"Step" in Forward Discriminant Analysis	Character Entered	F Statistic	Wilks' Lambda	Degrees of Freedom
1	SNOUTLM	17.688	.7344	5, 247
2	SNOUTLL *	13.829	.5732	5, 246
3	HEADLL	6.479	.5063	5, 245
4	PECTBGIR	6.271	.4486	5, 244
5	PREANALL	5.501	.4030	5, 243
6	HEADWID	4.979	.3654	5, 242
7	UPJAWL	4.087	.3369	5, 241
8	PPELVFL	3.179	.3159	5, 240
9	EYEDIAM	2.941	.2976	5, 239
10	ANALFBAS	2.542	.2825	5, 238
11	SDORFBAS	2.831	.2666	5, 237
12	PSDORFL	3.411	.2487	5, 236
13	HEADLM *	2.213	.2375	5, 235
14	PFDORFL	2.209	.2268	5, 234
15	PECTFL	2.255	.2163	5, 233

* - Character redundant and omitted from subsequent discriminant analysis

Classification Matrix

Actual Group	Assigned Group 1	2	3	4	5	6
1	36	13	7	4	0	3
2	6	19	1	5	0	2
3	7	5	29	3	2	4
4	6	3	5	32	13	3
5	3	1	0	12	30	10
6	1	2	2	6	11	24

TOTAL= 310

Average Percent Correctly Classified: 54.84
Kappa Statistic: 45.52
95% Conf.Interval for Kappa: 38.71 - 52.34

Morph. Character Acronym	Standardized Coefficients of First Canonical Variable
SNOUTLM	-1.4586
HEADLL	0.3082
HEADWID	0.0549
UPJAWL	0.5610
PECTFL	0.0344
SDORFBAS	-0.4087
ANALFBAS	0.5045
PREANALL	0.8210
PFDORFL	-0.0226
PSDORFL	0.2739
PPELVFL	-0.1278
PECTBGIR	-0.2198
EYEDIAM	0.0353

Table 12 b. Discriminant Function Analysis (sexes separated) for the six areas of Scenario 1 - Meristics.

Meristics - Scenario 1

Females

Meristic Character Acronym	Initial F	Degrees of Freedom	"Step" in Forward Discriminant Analysis	Character Entered	F Statistic	Wilks' Lambda	Degrees of Freedom
FDORFR	.466	5, 228	1	PECTFR	5.475	.8928	5, 228
SDORFR	.778		2	ABDVERT	2.475	.8467	5, 227
CAUDFR	2.516		3	CAUDFR	2.193	.8075	5, 226
ANALFR	1.211		4	CERRAK	1.876	.7752	5, 225
PECTFR	5.475						
TOTVERT	1.219						
ABDVERT	2.831						
CERRAK	3.344						
EPIRAK	.719						

Classification Matrix

Actual Group	Assigned Group 1	2	3	4	5	6
1	17	7	8	8	1	4
2	1	4	2	1	0	1
3	3	5	12	1	0	4
4	8	12	3	18	1	13
5	7	8	7	12	7	8
6	10	4	10	12	5	17

TOTAL= 241

Average Percent Correctly Classified: 31.12
Kappa Statistic: 17.22
95% Confid. Interval for Kappa: 10.05 - 24.39

Meristic Character Acronym	Standardized Coefficients of First Canonical Variable
CERRAK	0.3780
PECTFR	0.7389
ABDVERT	0.3195
CAUDFR	0.2415

Meristics - Scenario 1

Males

Meristic Character Acronym	Initial F	Degrees of Freedom	"Step" in Forward Discriminant Analysis	Character Entered	F Statistic	Wilks' Lambda	Degrees of Freedom
FDORFR	.453	5, 309	1	CERRAK	3.677	.9439	5, 309
SDORFR	1.786						
CAUDFR	.968						
ANALFR	1.572						
PECTFR	1.284						
TOTVERT	.206						
ABDVERT	1.557						
CERRAK	3.672						
EPIRAK	.829						

Classification Matrix

Actual Group	Assigned Group 1	2	3	4	5	6
1	27	0	19	0	0	19
2	18	0	13	0	0	9
3	31	0	18	0	0	7
4	34	0	11	0	0	22
5	25	0	11	0	0	24
6	23	0	5	0	0	20

TOTAL= 336

Average Percent Correctly Classified: 19.35
Kappa Statistic: 2.58
95% Conf.Interval for Kappa: -2.627 - 7.784

Morph. Character Acronym	Standardized Coefficients of First Canonical Variable
CERRAK	1.0247

Table 13 a. Discriminant Function Analysis (sexes separated) for the two areas of Scenario 2 - Morphometrics.

Morphometrics - Scenario 2

Females

Morph. Character Acronym	Initial F	Degrees of Freedom
SNOUTLL	.111	1, 194
SNOUTLM	18.279	
EYEDIAM	3.156	
HEADLL	1.619	
HEADLM	2.668	
HEADWID	2.277	
UPJAWL	4.957	
PECTFL	.189	
SDORFBAS	.001	
ANALFBAS	2.869	
PREANALL	.579	
PFDORFL	2.564	
PSDORFL	1.252	
PPECTFL	.913	
PPELVFL	1.941	
PECTBGIR	5.404	
OTOLHSL	.042	
OTORHSL	.034	

"Step" in Forward Discriminant Analysis	Character Entered	F Statistic	Wilks' Lambda	Degrees of Freedom
1	SNOUTLM	18.279	.9139	1, 194
2	SNOUTLL *	37.796	.7642	1, 193
3	HEADWID	16.304	.7044	1, 192
4	PREANALL	6.813	.6802	1, 191
5	UPJAWL	5.843	.6599	1, 190
6	PECTBGIR	3.491	.6479	1, 189
7	ANALFBAS	3.405	.6364	1, 188

* - Character redundant and omitted from subsequent discriminant analysis

Classification Matrix

Actual Group	Assigned Group 1	Assigned Group 2
1	49	17
2	50	137

TOTAL= 253

Average Percent Correctly Classified: 73.52
Kappa Statistic: 40.89
95% Conf. Interval for Kappa: 28.51 - 53.27

Morph. Character Acronym	Standardized Coefficients of First Canonical Variable
SNOUTLM	-1.0256
PECTBGIR	-0.2252
PREANALL	0.7585
ANALFBAS	0.5526
UPJAWL	0.6173
HEADWID	0.1805

Morphometrics - Scenario 2

Males

Morph. Character Acronym	Initial F	Degrees of Freedom
SNOUTLL	5.113	1, 251
SNOUTLM	55.106	
EYEDIAM	4.444	
HEADLL	4.993	
HEADLM	6.634	
HEADWID	.510	
UPJAWL	14.528	
PECTFL	.435	
SDORFBAS	.007	
ANALFBAS	.135	
PREANALL	9.117	
PFDORFL	3.654	
PSDORFL	.805	
PPECTFL	.085	
PPELVFL	.012	
PECTBGIR	.423	
OTOLHSL	.985	
OTORHSL	.469	

"Step" in Forward Discriminant Analysis	Character Entered	F Statistic	Wilks' Lambda	Degrees of Freedom
1	SNOUTLM	55.106	.8199	1, 251
2	UPJAWL	28.640	.7357	1, 250
3	PREANALL	31.381	.6534	1, 249
4	SNOUTLL *	11.937	.6233	1, 248
5	ANALFBAS	7.070	.6060	1, 247
6	SDORFBAS	10.734	.5807	1, 246
7	PECTBGIR	7.529	.5634	1, 245
8	PPELVFL	2.671	.5573	1, 244

* - Character redundant and omitted from subsequent discriminant analysis

Classification Matrix

Actual Group	Assigned Group 1	Assigned Group 2
1	96	21
2	39	165

TOTAL= 321

Average Percent Correctly Classified: 81.31
Kappa Statistic: 60.94
95% Conf. Interval for Kappa: 51.84 - 70.03

Morph. Character Acronym	Standardized Coefficients of First Canonical Variable
SNOUTLM	1.1181
UPJAWL	-0.6581
SDORFBAS	0.2257
ANALFBAS	-0.5743
PREANALL	-0.9416
PPELVFL	-0.0480
PECTBGIR	0.2742

Table 13 b. Discriminant Function Analysis (sexes separated) for the two areas of Scenario 2 - Meristics.

Meristics - Scenario 2

Females

Meristic Character Acronym	Initial F	Degrees of Freedom	"Step" in Forward Discriminant Analysis	Character Entered	F Statistic	Wilks' Lambda	Degrees of Freedom
FDORFR	.948	1, 232	1	PECTFR	5.632	.9763	1, 232
SDORFR	.231		2	ABDVERT	4.198	.9589	1, 231
CAUDFR	3.776		3	CAUDFR	2.779	.9474	1, 230
ANALFR	.201						
PECTFR	5.632						
TOTVERT	.298						
ABDVERT	5.157						
CERRAK	3.925						
EPIRAK	1.611						

Classification Matrix

Actual Group	Assigned Group 1	Assigned Group 2
1	32	28
2	63	118

TOTAL= 241

Average Percent Correctly Classified: 62.24
Kappa Statistic: 15.50
95% Conf. Interval for Kappa: 1.53 - 29.48

Meristic Character Acronym	Standardized Coefficients of First Canonical Variable
PECTFR	0.6125
ABDVERT	0.5482
CAUDFR	0.4722

Meristics - Scenario 2

Males

Meristic Character Acronym	Initial F	Degrees of Freedom	"Step" in Forward Discriminant Analysis	Character Entered	F Statistic	Wilks' Lambda	Degrees of Freedom
FDORFR	.330	1, 313	1	CERRAK	4.100	.9871	1, 313
SDORFR	.731		2	EPIRAK	3.510	.9761	1, 312
CAUDFR	.940						
ANALFR	.068						
PECTFR	.042						
TOTVERT	.126						
ABDVERT	.609						
CERRAK	4.100						
EPIRAK	3.962						

Classification Matrix

Actual Group	Assigned Group 1	Assigned Group 2
1	88	36
2	127	85

TOTAL= 336

Average Percent Correctly Classified: 51.49
Kappa Statistic: 9.60
95% Conf. Interval for Kappa: -0.56 - 19.76

Morph. Character Acronym	Standardized Coefficients of First Canonical Variable
CERRAK	0.7110
EPIRAK	0.6769

Table 14 a. Discriminant Function Analysis (sexes separated) for the two areas of Scenario 3 - Morphometrics.

Morphometrics - Scenario 3

Females

Morph. Character Acronym	Initial F	Degrees of Freedom	"Step" in Forward Discriminant Analysis	Character Entered	F Statistic	Wilks' Lambda	Degrees of Freedom
SNOUTLL	1.947	1, 194	1	SNOUTLM	3.508	.8565	1, 194
SNOUTLM	32.508		2	SNOUTLL *	38.540	.7139	1, 193
EYEDIAM	3.079		3	OTORHSL	9.204	.6813	1, 192
HEADLL	3.235		4	PECTBGIR	8.479	.6523	1, 191
HEADLM	5.083		5	HEADLL	7.497	.6275	1, 190
HEADWID	.804		6	PPELVFL	3.173	.6172	1, 189
UPJAWL	1.669						
PECTFL	.832						
SDORFBAS	.006						
PREANALL	.004						
PFDORFL	2.509						
PSDORFL	1.958						
PPECTFL	.219						
PPELVFL	1.871						
PECTBGIR	6.609						
OTOLHSL	1.995						
OTORHSL	4.422						

* - Character redundant and omitted from subsequent discriminant analysis

Classification Matrix

Actual Group	Assigned Group 1	Assigned Group 2
1	62	17
2	36	117

TOTAL= 232

Average Percent Correctly Classified: 77.16
Kappa Statistic: 51.93
95% Conf. Interval for Kappa: 40.33 - 63.53

Morph. Character Acronym	Standardized Coefficients of First Canonical Variable
SNOUTLM	1.7401
HEADLL	-0.9898
PECTBGIR	0.3730
PPELVFL	0.3147
OTORHSL	-0.1783

Morphometrics - Scenario 3

Males

Morph. Character Acronym	Initial F	Degrees of Freedom	"Step" in Forward Discriminant Analysis	Character Entered	F Statistic	Wilks' Lambda	Degrees of Freedom
SNOUTLL	5.175	1, 251	1	SNOUTLM	80.685	.7567	1, 251
SNOUTLM	80.685		2	SNOUTLL *	36.846	.6595	1, 250
EYEDIAM	2.221		3	PREANALL	17.996	.6151	1, 249
HEADLL	5.995		4	UPJAWL	15.380	.5792	1, 248
HEADLM	7.257		5	PECTFL	9.160	.5585	1, 247
HEADWID	12.653		6	EYEDIAM	6.891	.5432	1, 246
UPJAWL	5.712		7	ANALFBAS	8.674	.5247	1, 245
PECTFL	3.986		8	SDORFBAS	5.353	.5134	1, 244
SDORFBAS	0.000		9	PSDORFL	7.673	.4977	1, 243
ANALFBAS	.225		10	PPELVFL	5.031	.4876	1, 242
PREANALL	5.605		11	PECTBGIR	4.156	.4793	1, 241
PFDORFL	2.615		12	HEADWID	3.268	.4728	1, 240
PSDORFL	.399						
PPECTFL	.203						
PPELVFL	3.947						
PECTBGIR	.074						
OTOLHSL	.275						
OTORHSL	.001						

* - Character redundant and omitted from subsequent discriminant analysis

Classification Matrix

Actual Group	Assigned Group 1	Assigned Group 2
1	126	25
2	27	132

TOTAL= 310

Average Percent Correctly Classified: 83.23
Kappa Statistic: 66.44
95% Conf. Interval for Kappa: 57.49 - 74.93

Morph. Character Acronym	Standardized Coefficients of First Canonical Variable
SNOUTLM	-1.2130
HEADWID	0.2181
UPJAWL	0.5554
PECTFL	0.1540
SDORFBAS	-0.4863
ANALFBAS	0.4976
PREANALL	0.7962
PSDORFL	0.3515
PPELVFL	-0.2273
PECTBGIR	-0.2528
EYEDIAM	0.0498

Table 14 b. Discriminant Function Analysis (sexes separated) for the two areas of Scenario 3 - Meristics.

Meristics - Scenario 3

Females

Meristic Character Acronym	Initial F	Degrees of Freedom	"Step" in Forward Discriminant Analysis	Character Entered	F Statistic	Wilks' Lambda	Degrees of Freedom
FDORFR	1.424	1, 232	1	PECTFR	19.079	.9240	1, 232
SDORFR	2.002		2	ABDVERT	6.004	.9006	1, 231
CAUDFR	5.507		3	CAUDFR	3.893	.8856	1, 230
ANALFR	1.014		4	CERRAK	3.037	.8740	1, 229
PECTFR	19.079						
TOTVERT	.775						
ABDVERT	7.869						
CERRAK	10.213						
EPIRAK	.009						

Classification Matrix

Actual Group	Assigned Group 1	Assigned Group 2
1	59	25
2	58	99

TOTAL= 241

Average Percent Correctly Classified: 65.56
Kappa Statistic: 30.51
95% Conf. Interval for Kappa: 18.16 - 42.86

Meristic Character Acronym	Standardized Coefficients of First Canonical Variable
CERRAK	0.3490
PECTFR	0.6629
ABDVERT	0.4137
CAUDFR	0.3285

Meristics - Scenario 3

Males

Meristic Character Acronym	Initial F	Degrees of Freedom	"Step" in Forward Discriminant Analysis	Character Entered	F Statistic	Wilks' Lambda	Degrees of Freedom
FDORFR	.181	1, 313	1	CERRAK	18.312	.9447	1, 313
SDORFR	.167		2	EPIRAK	3.641	.9338	1, 312
CAUDFR	.012		3	ABDVERT	2.713	.9258	1, 311
ANALFR	.145						
PECTFR	.819						
TOTVERT	.566						
ABDVERT	4.342						
CERRAK	18.312						
EPIRAK	4.506						

Classification Matrix

Actual Group	Assigned Group 1	Assigned Group 2
1	117	47
2	87	81

TOTAL= 332

Average Percent Correctly Classified: 59.64
Kappa Statistic: 19.50
95% Conf. Interval for Kappa: 8.76 - 30.24

Meristic Character Acronym	Standardized Coefficients of First Canonical Variable
CERRAK	0.8459
EPIRAK	0.3813
ABDVERT	0.3446

Table 15. Results of the classification of "test" samples using discriminant rules derived from "learning" samples for scenario 3.

Classification Matrix for "Test Samples" - Morphometrics

Female White Hake

Actual Group	Assigned Group 1	Assigned Group 2
1	25	10
2	15	65
	TOTAL=	115

Male White Hake

Actual Group	Assigned Group 1	Assigned Group 2
1	66	14
2	22	54
	TOTAL=	156

	Female White Hake	Male White Hake
Average Percent Correctly Classified:	78.26	76.92
Kappa Statistic :	50.64	53.69
95 % Confidence Interval for Kappa :	33.18 to 68.11	40.16 to 67.23

Classification Matrix for "Test Samples" - Meristics

Female White Hake

Actual Group	Assigned Group 1	Assigned Group 2
1	29	11
2	32	47
	TOTAL=	119

Male White Hake

Actual Group	Assigned Group 1	Assigned Group 2
1	62	26
2	47	34
	TOTAL=	169

	Female White Hake	Male White Hake
Average Percent Correctly Classified:	63.87	56.81
Kappa Statistic :	28.32	12.56
95 % Confidence Interval for Kappa :	10.85 to 45.79	-2.87 to 27.99

**Table 16. Summary of the discriminant function analyses for the three scenarios.
Confidence intervals (95 %) for chance-corrected classifications (Kappa) and observed percentage correct classification for three stock designations suggested by morphometric and meristic discriminant function analysis.**

	Morphometric Character Set			Meristic Character Set		
Stock Desig.	Kappa	95% C.I. for Kappa	Observ. % Corr. Class.	Kappa	95% C.I. for Kappa	Observ. % Corr. Class.
SCENARIO ONE (Six Areas: <=100m versus >100m)						
Females	37.3	29.4 - 45.2	48.5	17.2	10.0 - 24.4	31.1
Males	45.5	38.7 - 52.3	54.8	2.6	-2.6 - 7.8	19.4
SCENARIO TWO (Two Areas: <=100m versus >100m)						
Females	40.9	28.5 - 53.3	73.5	15.5	1.5 - 29.5	62.2
Males	60.9	51.8 - 70.0	81.3	9.6	-0.6 - 19.8	51.5
SCENARIO THREE (Two Areas: <=200m versus >200m)						
Females	51.9	40.3 - 63.5	77.2	30.5	18.2 - 42.9	65.6
Males	66.4	57.5 - 74.9	83.2	19.5	8.8 - 30.2	59.6

Figure 1. Map showing locations where white hake samples were obtained during the two *Lady Hammond* cruises of 1986. (Numbers indicate the number of individual white hake sampled at that location).

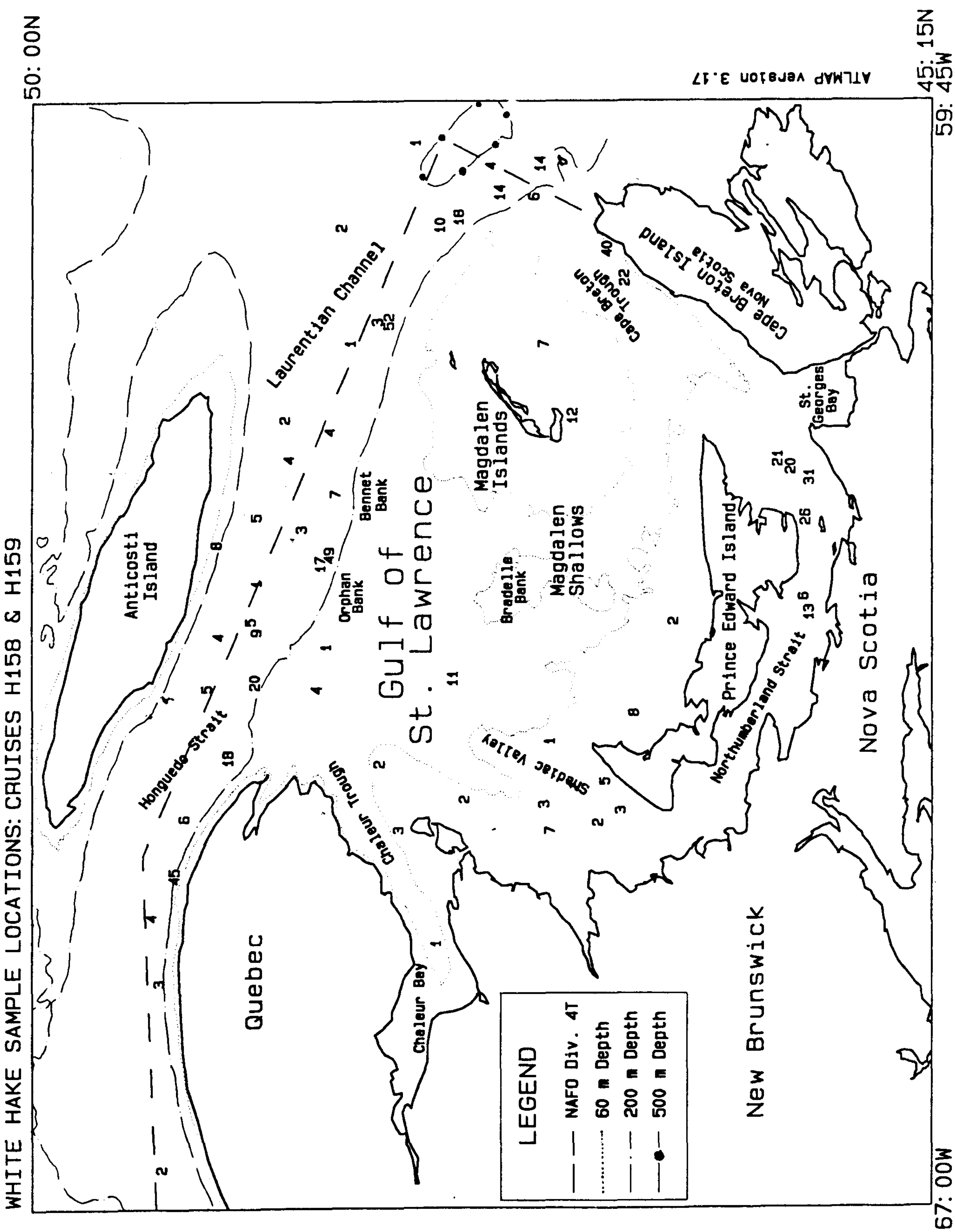
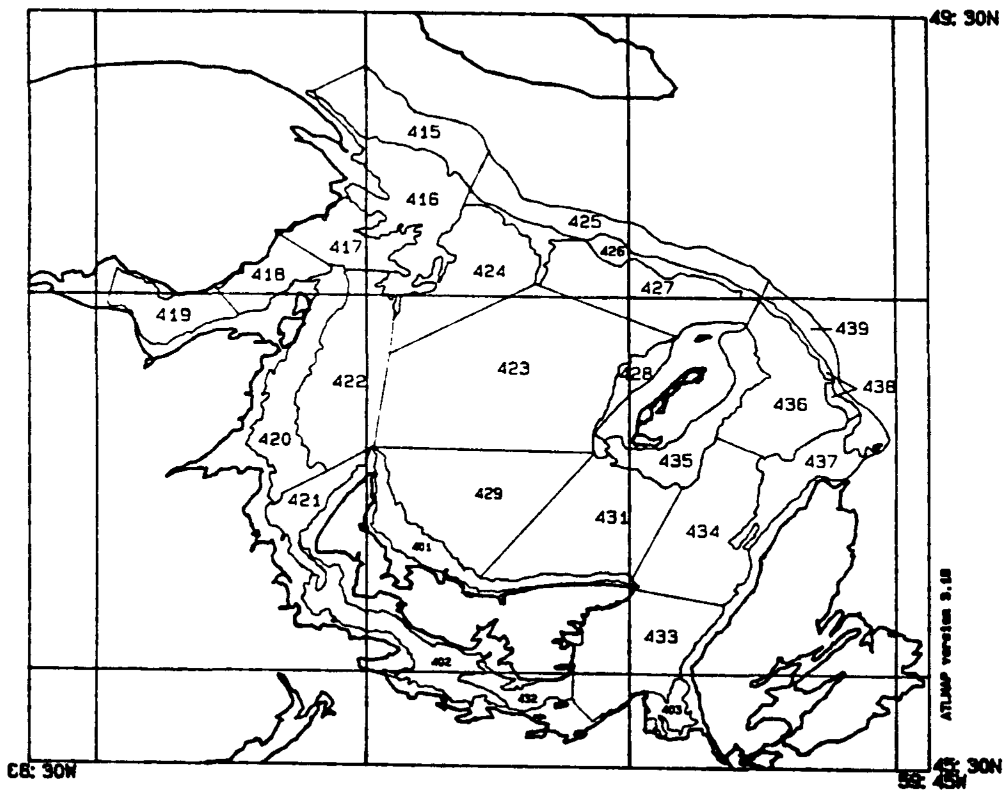


Figure 2. Map showing the stratification schemes in use for the southern (NAFO Div. 4T) and northern (NAFO Div's. 4R and 4S) Gulf of St. Lawrence. Note the overlap of strata along the slope of the Laurentian Channel (these strata are generally based on depth).



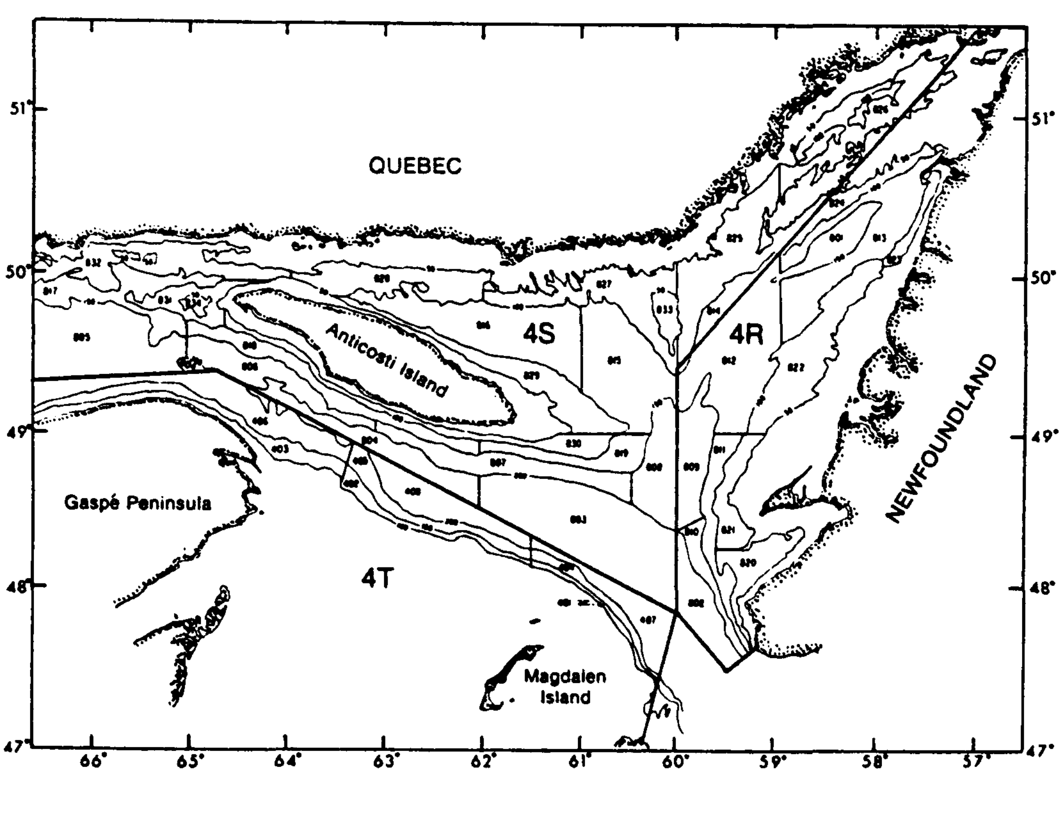


Figure 3. Morphometric measurements used for white hake in this investigation.
See Appendix I for a description of each morphometric measurement.

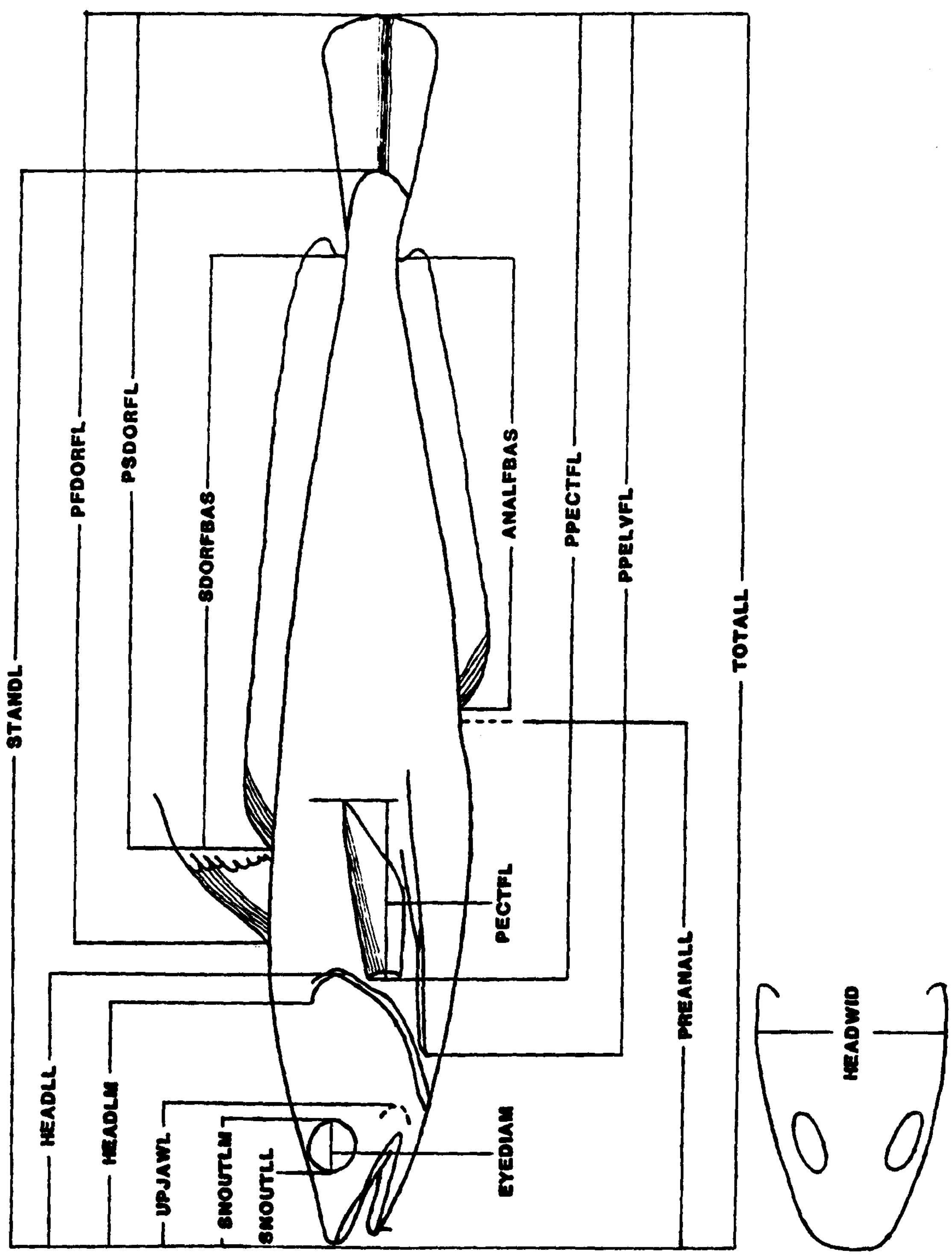


Figure 4. Map showing the six arbitrary areas of Scenario 1.

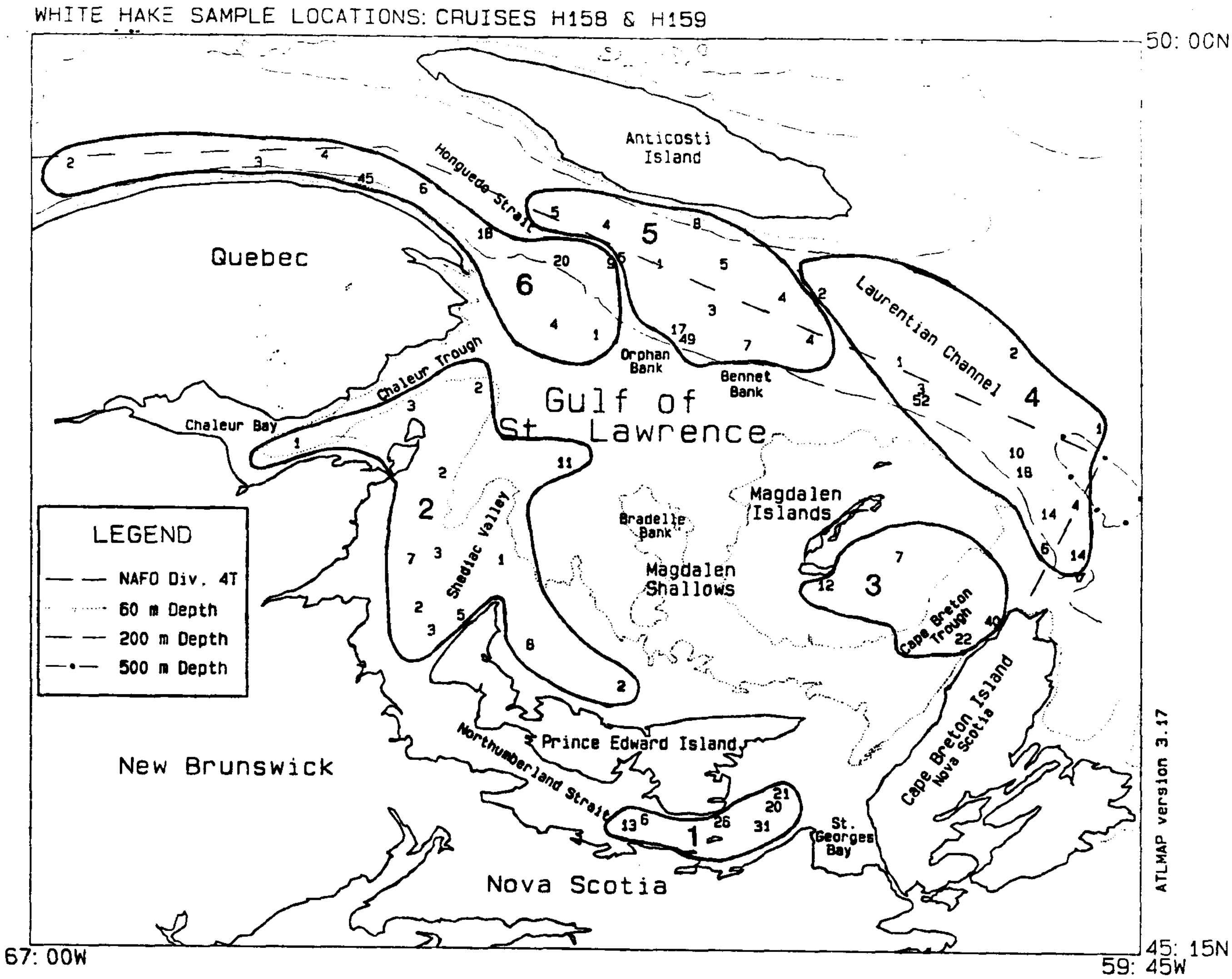
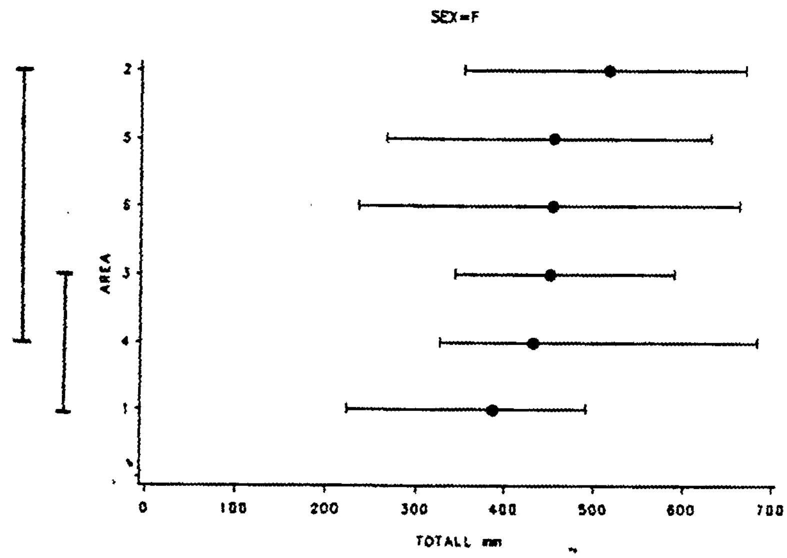


Figure 5. The ranges, means, and significant differences ($p < 0.001$) of total length (TOTALL) for white hake (sexes separated) examined in the morphometric analysis.
(1) The areas represent the six arbitrary areas of scenario 1.
(2) Range is indicated by a horizontal bar, the mean by a circle, and significant differences by a vertical line. Areas connected by a vertical line are not significantly different from each other.



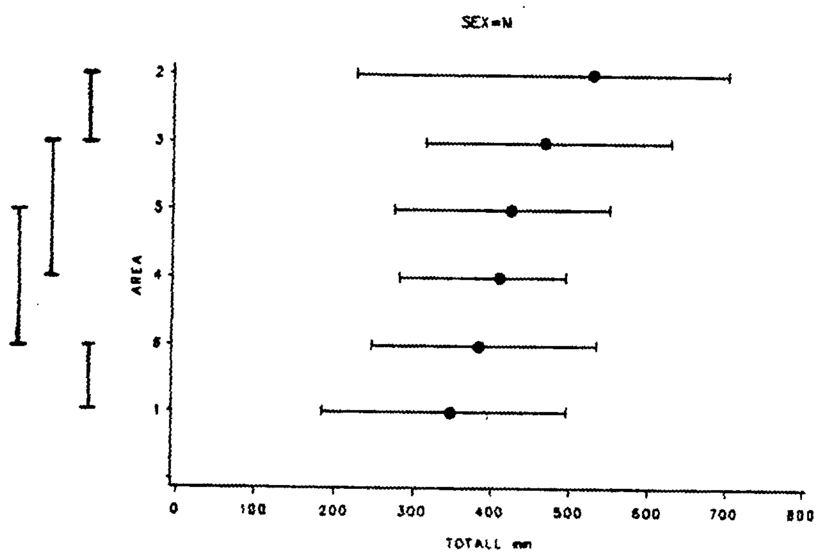


Figure 6. Scatter plots of four of the 'best' morphometric characters (scenario 3) versus total length (TOTALL), sexes combined. (See Table 3 for the number of specimens in each plot).

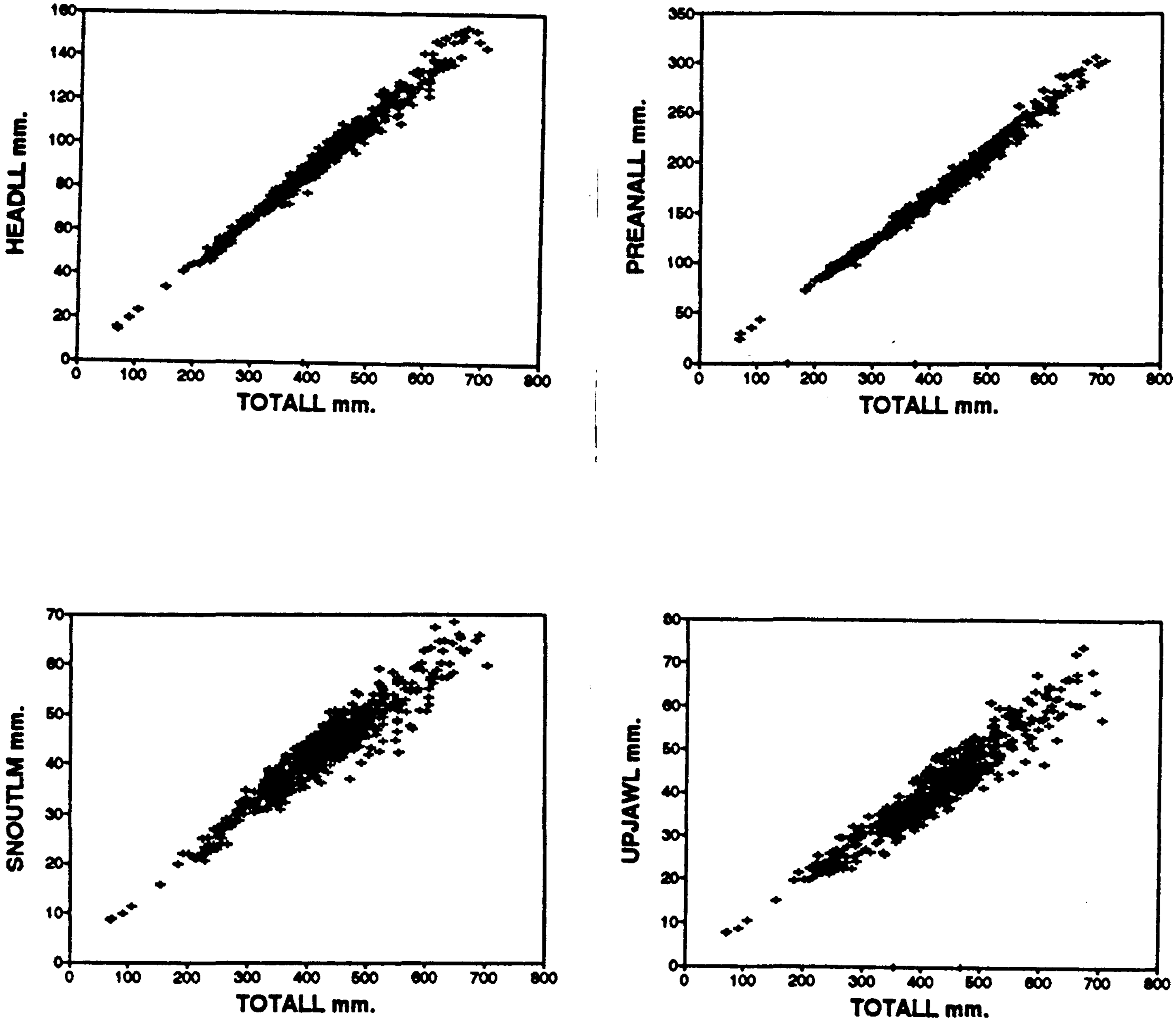


Figure 7. The ranges, means, and significant differences ($p < 0.001$) for the four 'best' morphometric characters (sexes separated) using the Least Squares Means (L.S.M.) procedure.

(1) The areas represent the six arbitrary areas of scenario 1.

(2) Range is indicated by a horizontal bar, the mean by a circle, and significant differences by a vertical line. Areas connected by a vertical line are not significantly different from each other.

(Note: A significant difference ($p < 0.001$) was indicated by the L.S.M. procedure for UPJAWL for male white hake. A significant difference ($p < 0.01$) was indicated by ANOVA (Table 8).

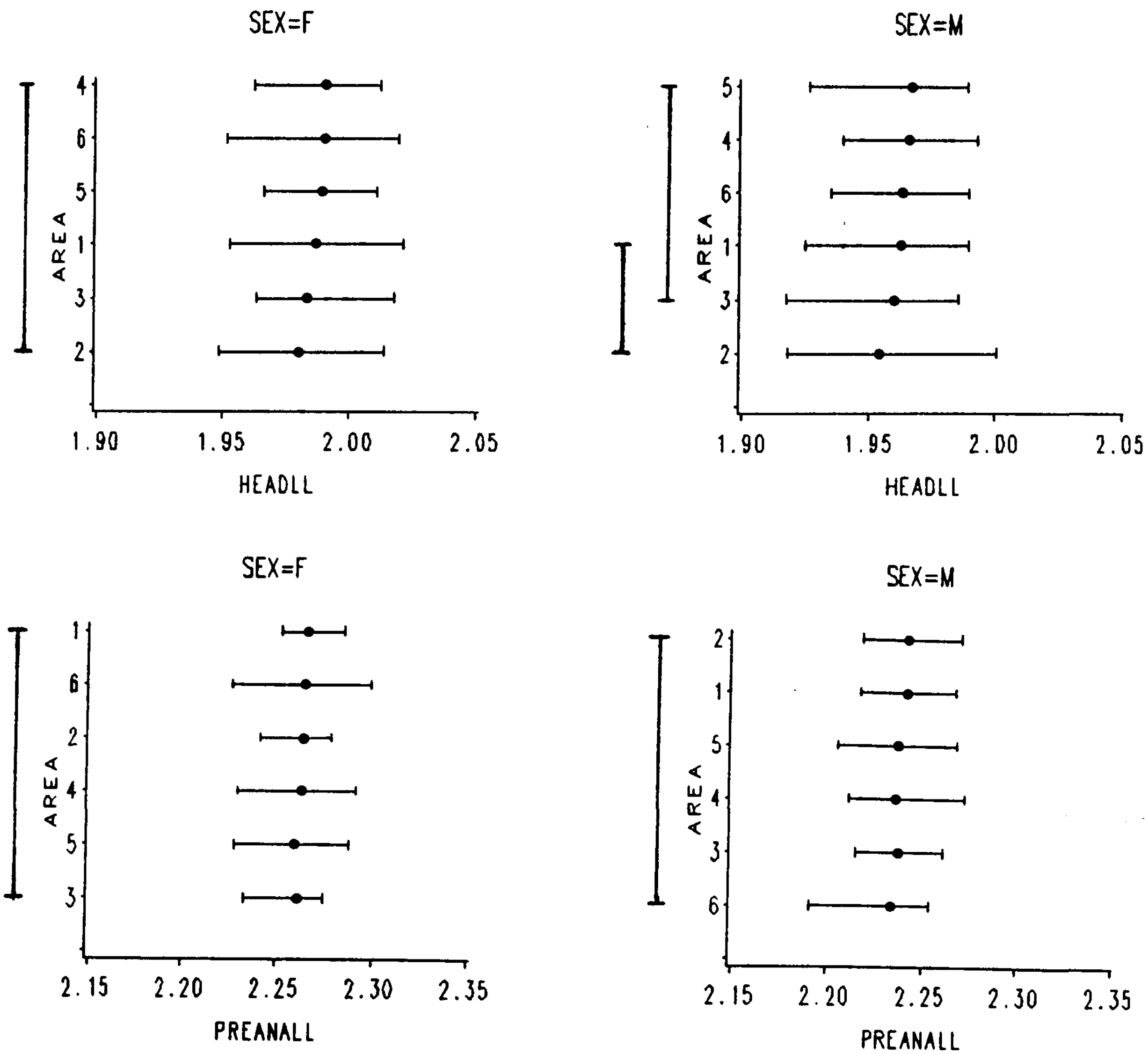


Figure 7. Cont'd.

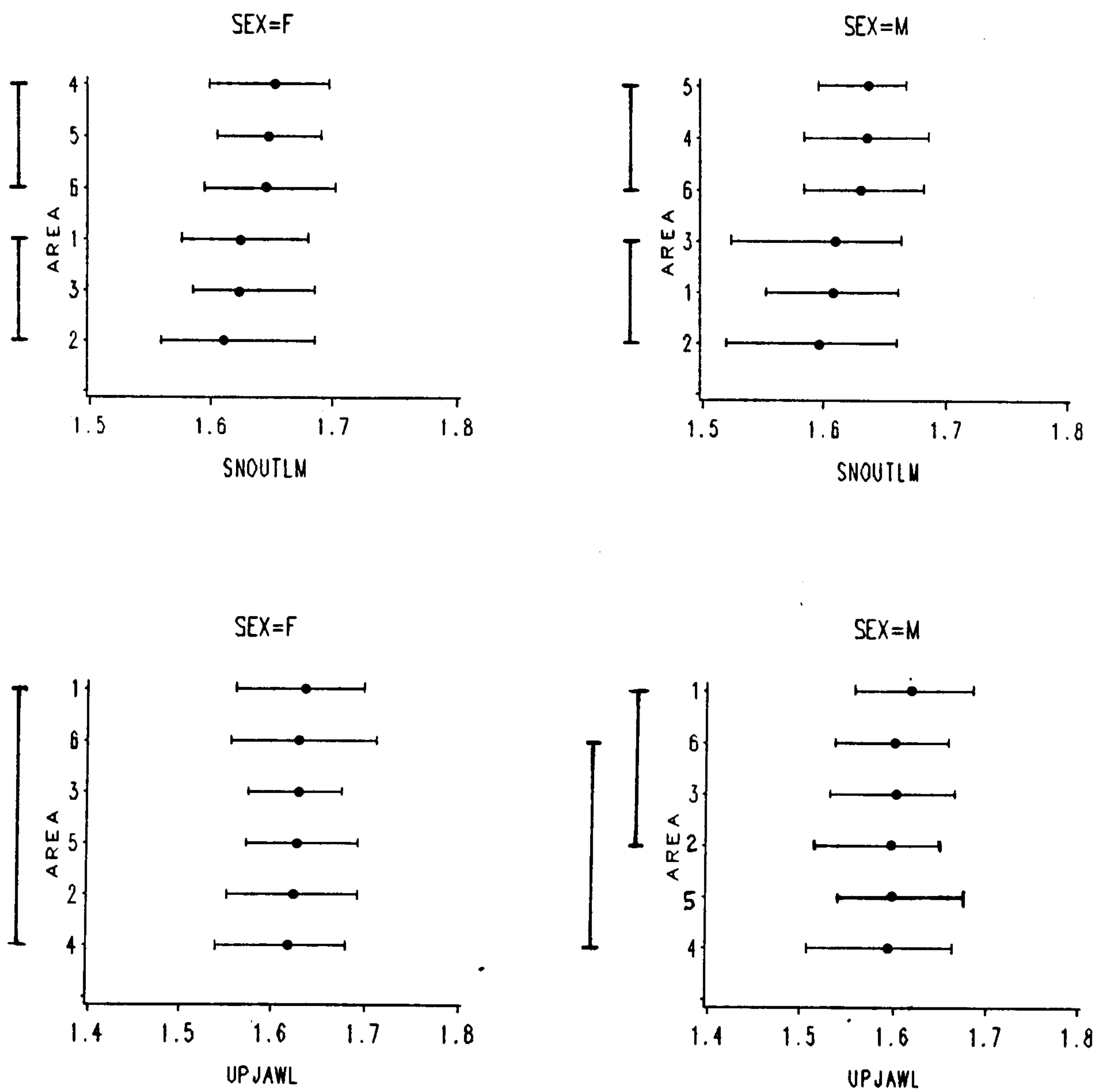


Figure 8. The ranges, means, and significant differences ($p < 0.001$) of two of the meristic characters examined (sexes separated) using the Least Squares Means (L.S.M.) procedure. (1) The areas represent the six arbitrary areas of scenario 1. (2) Range is indicated by a horizontal bar, the mean by a circle, and significant differences by a vertical line. Areas connected by a vertical line are not significantly different from each other.

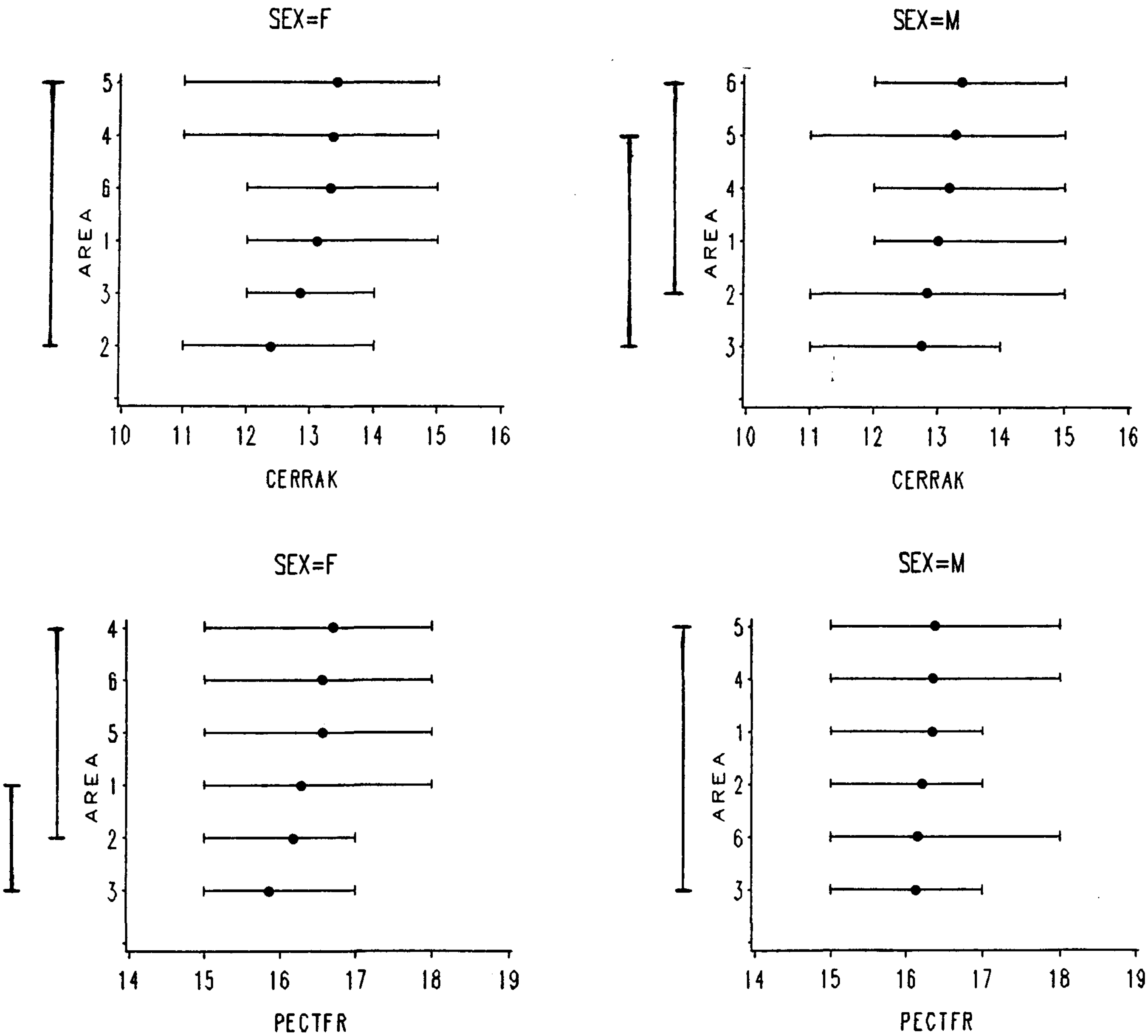


Figure 9 a.
Mean first and second canonical variable scores for the morphometric analysis (female white hake) of Scenario 1. Borders define the 75% confidence ellipses of individual specimens for each population within the "strait" and "channel" regional stocks. Shaded portion denotes the area of overlap between the regional stocks. Character vectors represent addition of the coefficients of the most differentiated characters. Numbers in parentheses indicate percent variance explained by each canonical variable. See Appendix I for a description of each morphometric character.

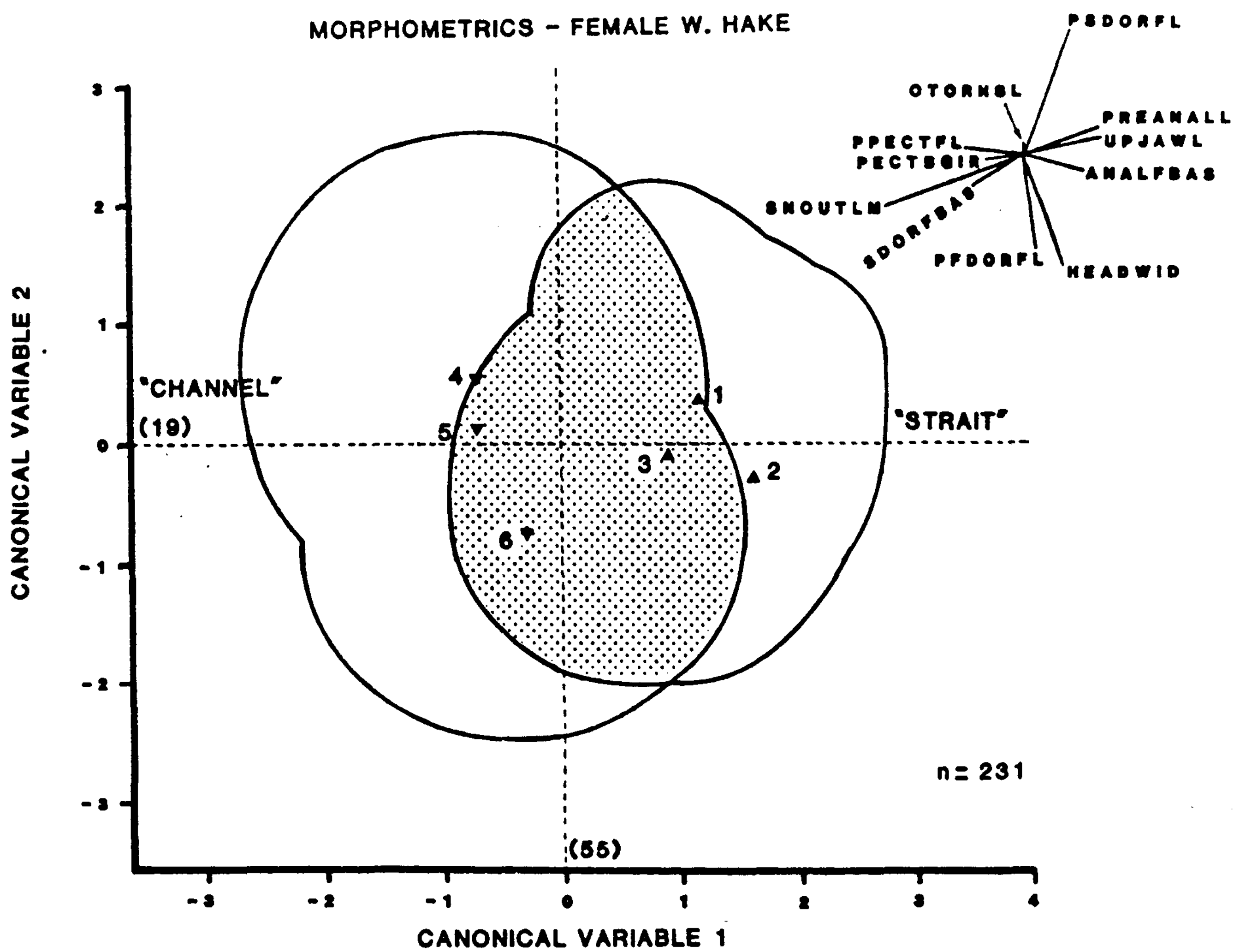


Figure 9 b.
Mean first and second canonical variable scores for the morphometric analysis (male white hake) of Scenario 1. Borders define the 75% confidence ellipses of individual specimens for each population within the "strait" and "channel" regional stocks. Shaded portion denotes the area of overlap between the regional stocks. Character vectors represent addition of the coefficients of the most differentiated characters. Numbers in parentheses indicate percent variance explained by each canonical variable. See Appendix I for a description of each morphometric character.

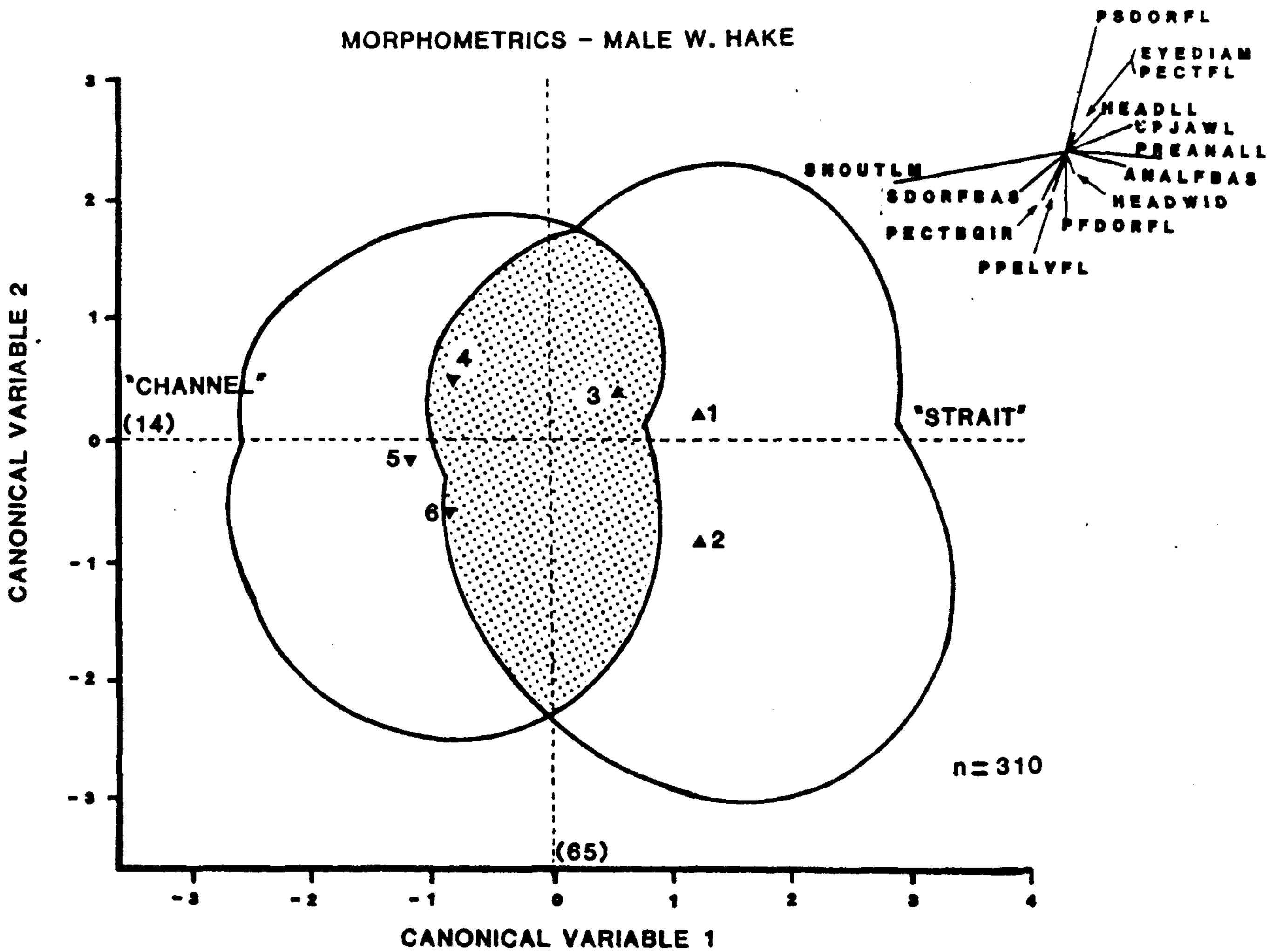


Figure 9 c.
Mean first and second canonical variable scores for the meristic analysis (female white hake) of Scenario 1. Borders define the 75% confidence ellipses of individual specimens for each population within the "strait" and "channel" regional stocks. Shaded portion denotes the area of overlap between the regional stocks. Character vectors represent addition of the coefficients of the most differentiated characters. Numbers in parentheses indicate percent variance explained by each canonical variable. See Appendix II for a description of each meristic character.

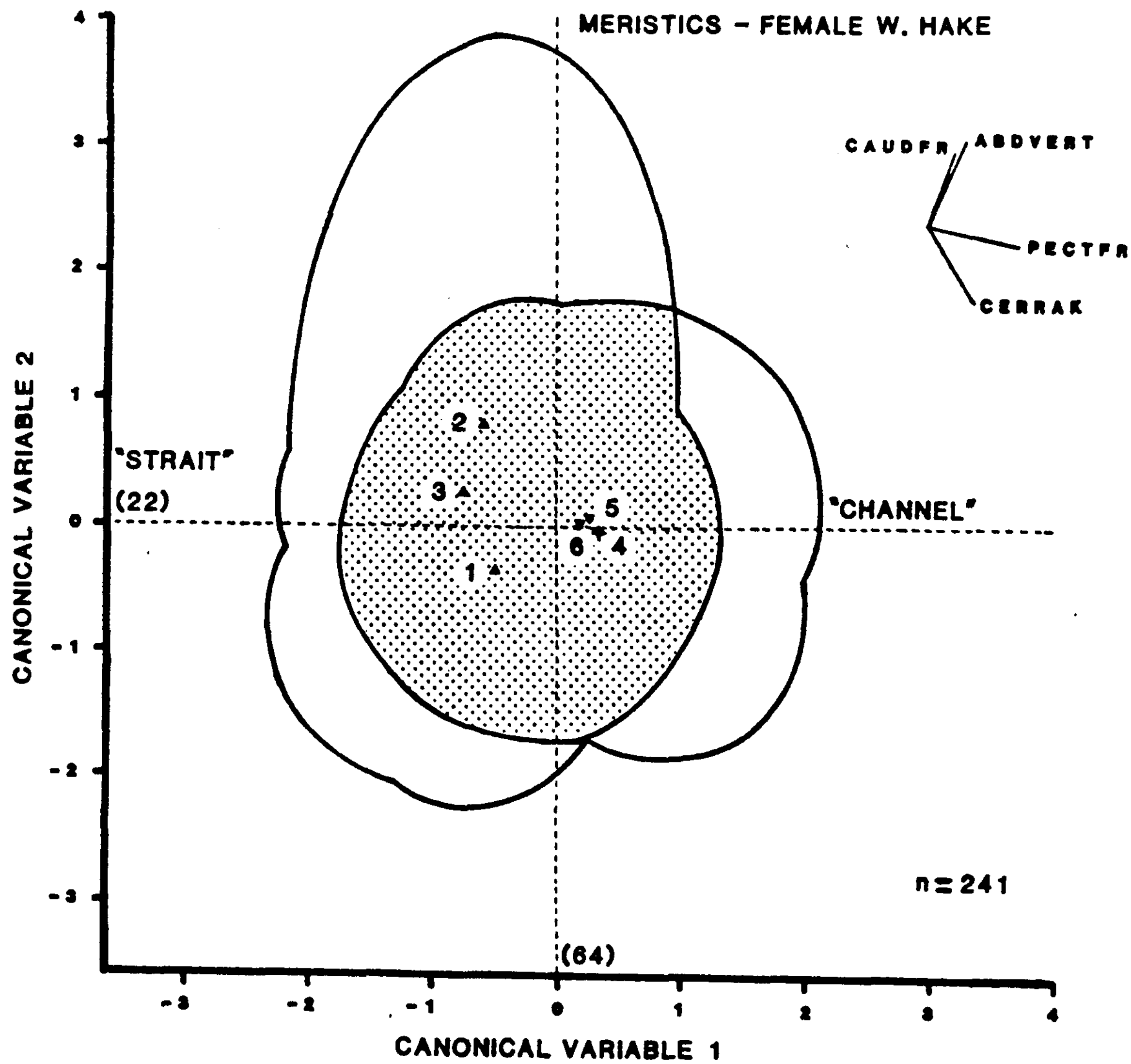


Figure 9 d.
Mean first and second canonical variable scores for the meristic analysis (male white hake) of Scenario 1. Borders define the 75% confidence ellipses of individual specimens for each population within the "strait" and "channel" regional stocks. Shaded portion denotes the area of overlap between the regional stocks. Character vectors represent addition of the coefficients of the most differentiated characters. Numbers in parentheses indicate percent variance explained by each canonical variable.
See Appendix II for a description of each meristic character.

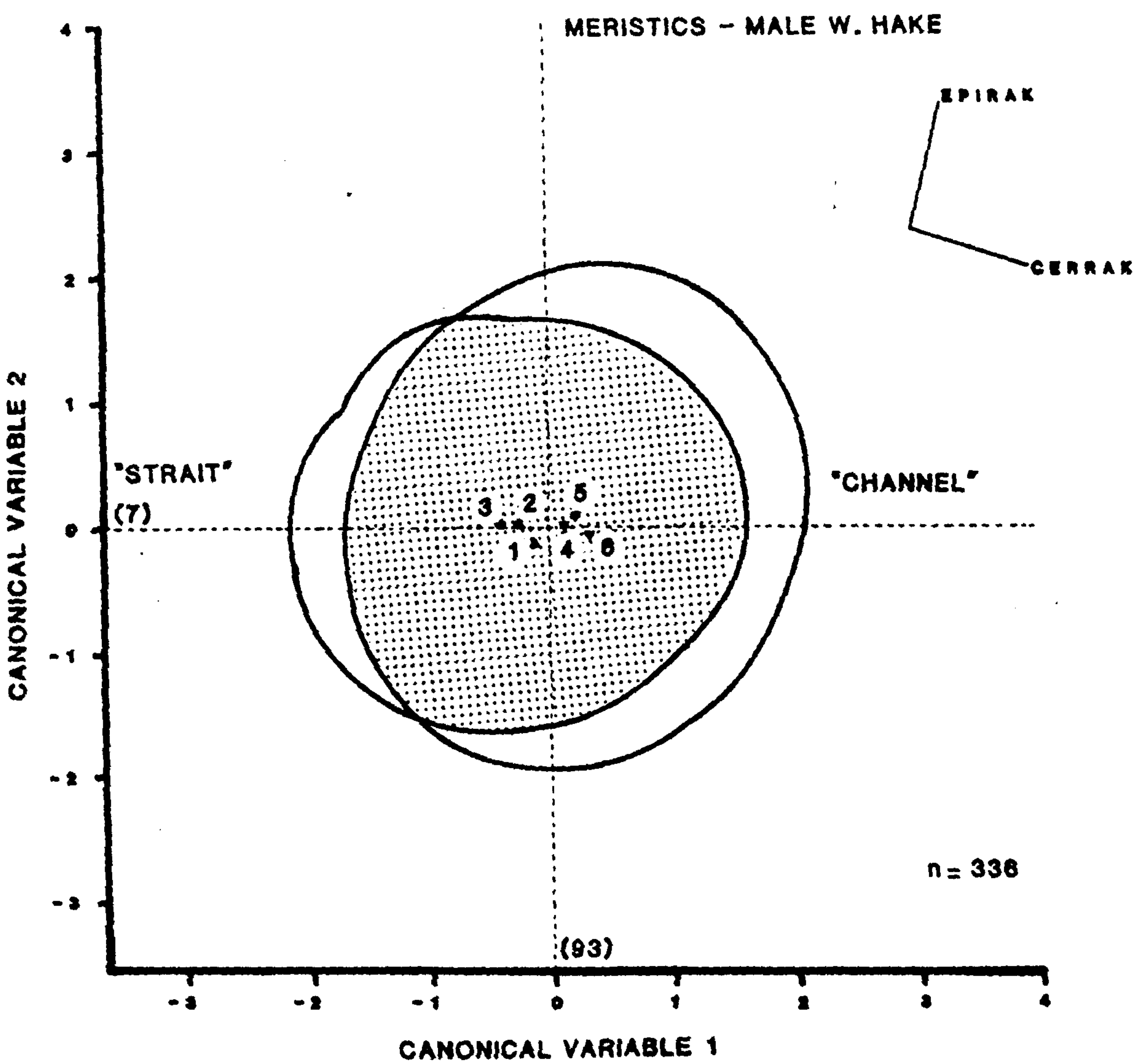


Figure 10 a and b.
Mean first canonical variable scores for the morphometric analyses of female and male white hake of scenario 3.

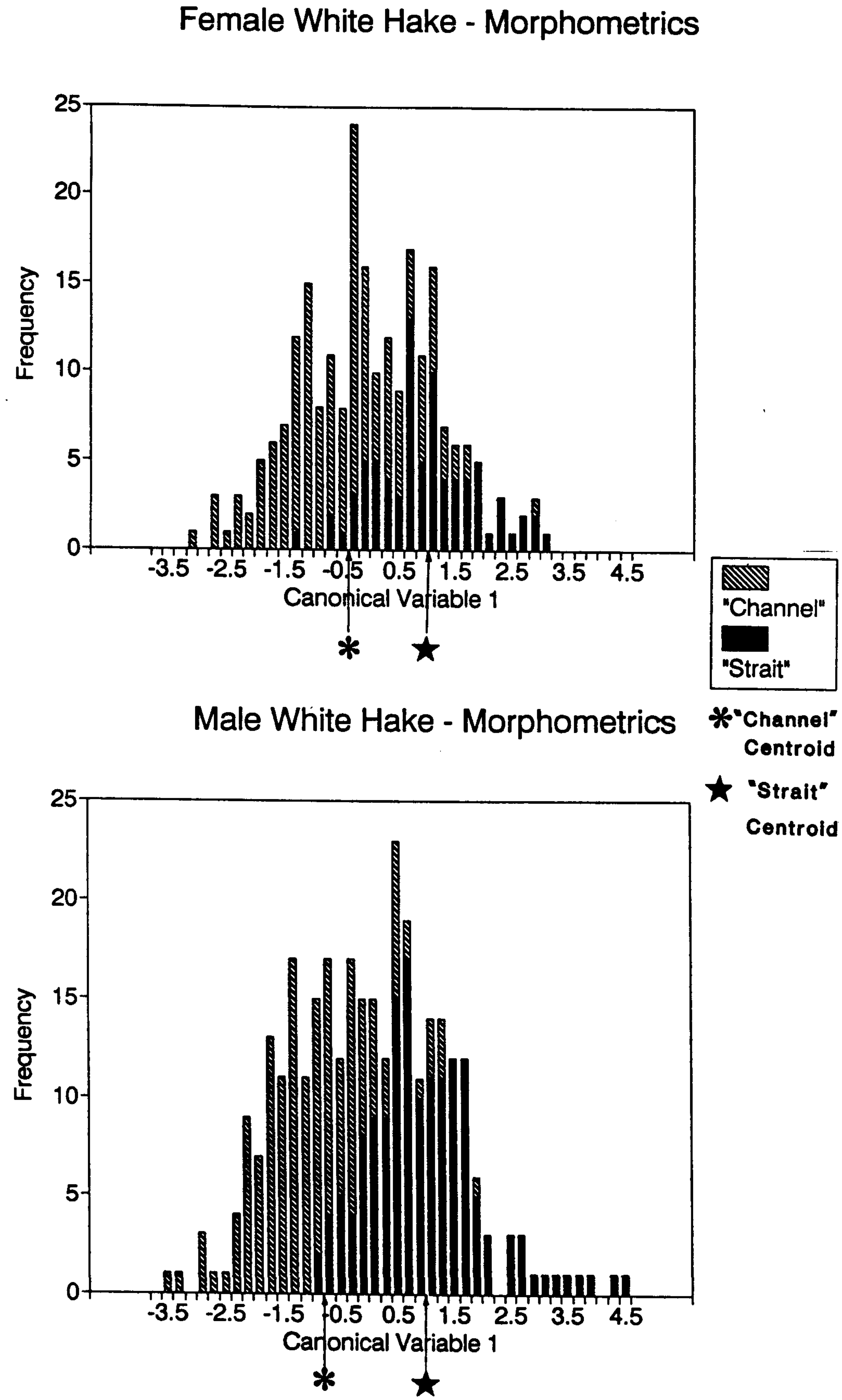


Figure 10 c and d.
Mean first canonical variable scores for the meristic analyses of female and male white hake of scenario 3.

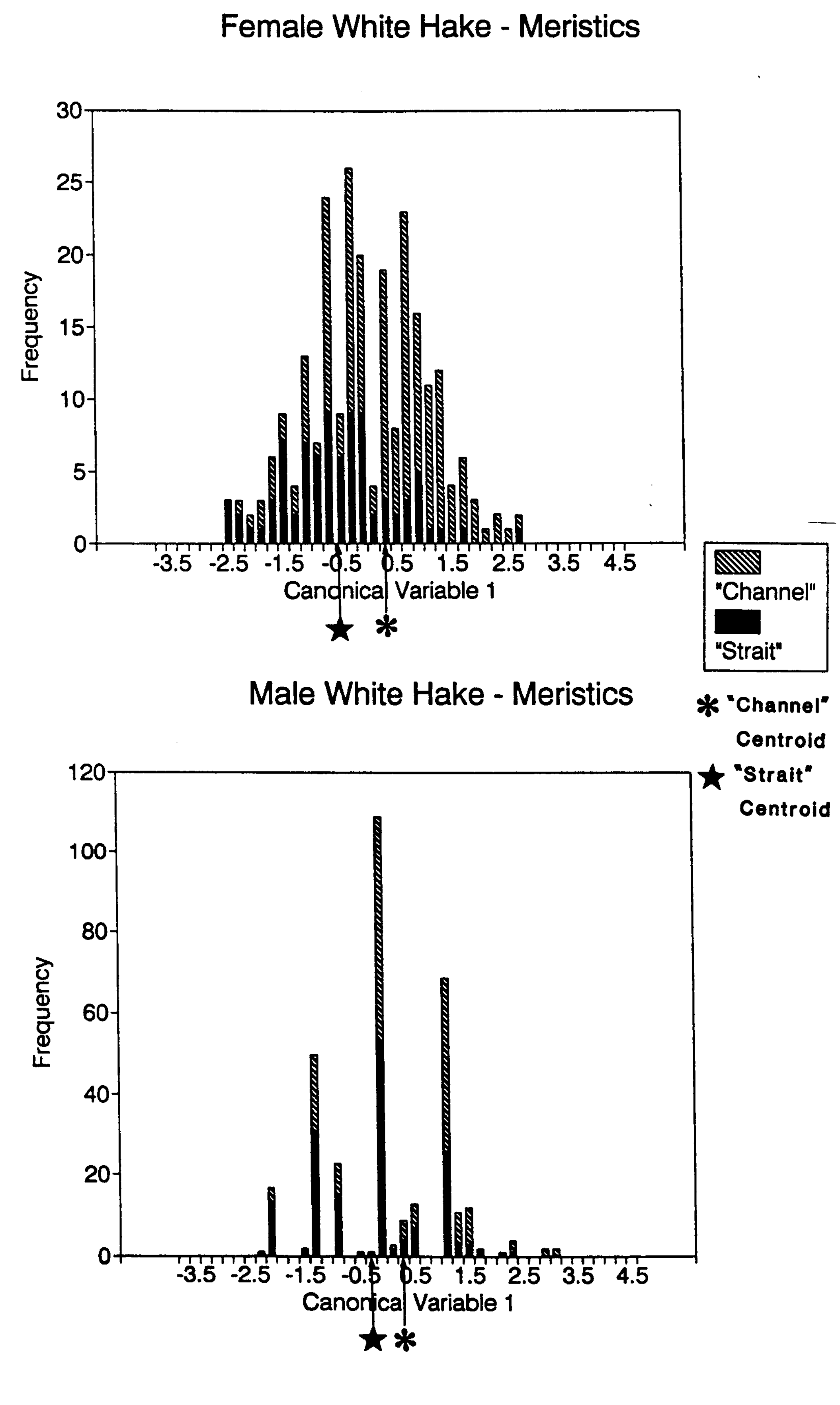
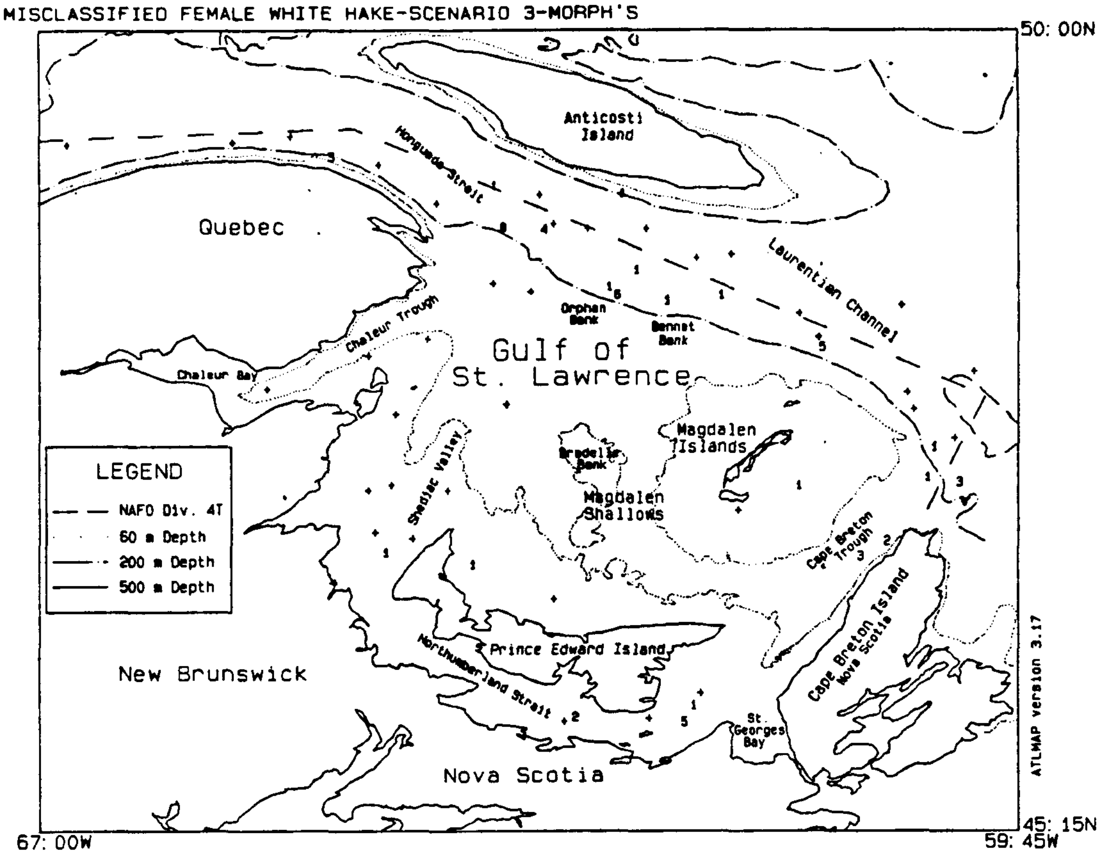
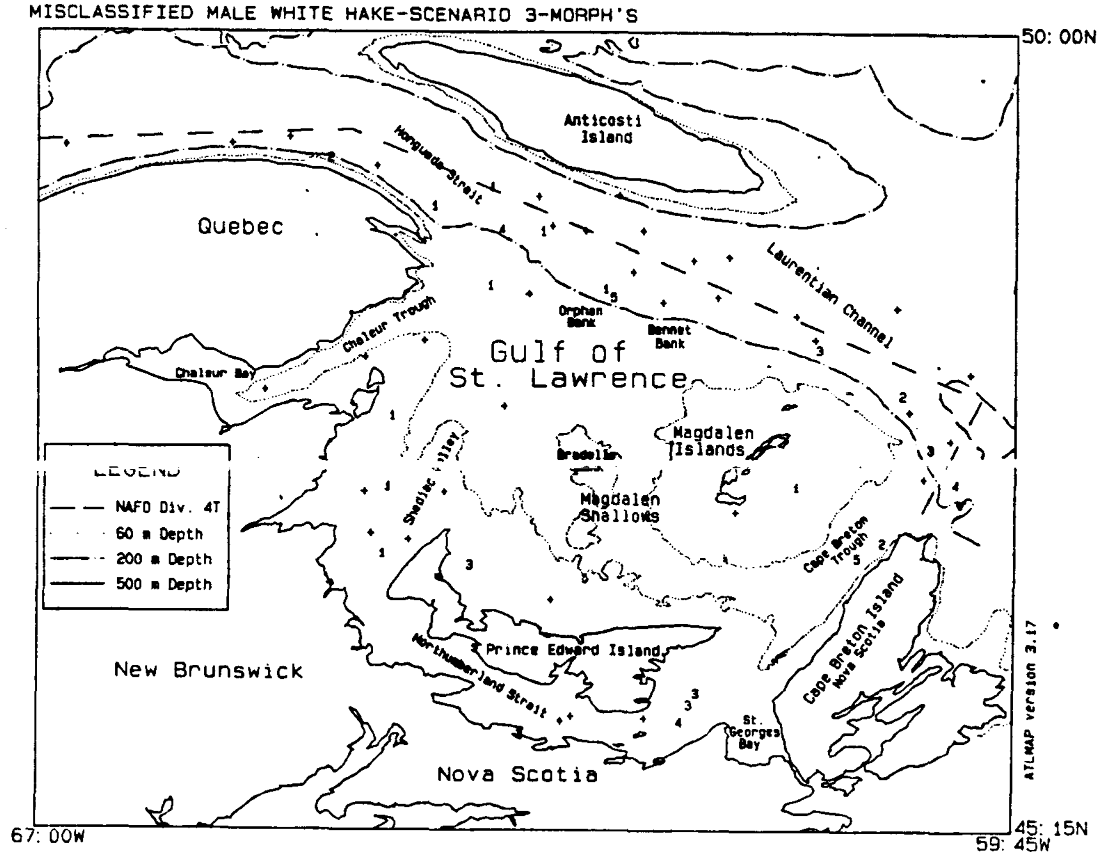


Figure 11 a and b.
Locations of specimens (female (a) and male (b)) that were misclassified by the morphometric discriminant function of scenario 3.

a MISCLASSIFIED FEMALE WHITE HAKE-SCENARIO 3-MORPH'S



b MISCLASSIFIED MALE WHITE HAKE-SCENARIO 3-MORPH'S



Appendix I

Description of the morphometric characters and their acronyms.

Total Length (TOTALL):
From tip of snout with mouth closed to tip of the longest caudal fin ray.

Standard Length (STANDL):
From tip of snout with mouth closed to end of the vertebral column (estimated by flexure of caudal fin and by position of most posterior scales).

Snout Length-Lagler (SNOUTLL):
From tip of snout with mouth closed to anterior bony margin of the orbit of the eye.

Snout Length-Musick (SNOUTLM):
From tip of snout with mouth closed to posterior bony margin of the orbit of the eye.

Eye Diameter (EYEDIAM):
Greatest distance measured across the cornea between the cartilaginous margins of the eyeball.

Head Length-Lagler (HEADLL):
From tip of snout with mouth closed to posterior bony tip of the operculum.

Head Length-Musick (HEADLM):
From tip of snout with mouth closed to the upper inner angle of the opercular opening.

Head Width (HEADWID):
Greatest dimension measured across the head when the operculae are in a reasonably "normal" position.

Upper Jaw Length (UPJAWL):
From the tip of snout with mouth closed to the posterior margin of the maxillary bone (revealed by slicing back the "cheek" to expose the maxillary).

Pectoral Fin Length (PECTFL):
From the extreme base of the anteriormost ray to the posteriormost tip of the pectoral fin.

Second Dorsal Fin Base Length (SDORFBAS):
Greatest overall basal length extending from the structural base of the first ray to the point where the membrane behind the last ray of the second dorsal fin contacts the body.

Anal Fin Base Length (ANALFBAS):
Greatest overall basal length extending from the structural base of the first ray to the point where the membrane behind the last ray of the anal fin contacts the body.

Pre-anal Length (PREANALL):
From tip of snout with mouth closed to anteriormost origin of the anus.

Post-First Dorsal Fin Length (PFDORFL):
From the structural base of the first ray of the first dorsal fin to the tip of the longest caudal fin ray.

Post-Second Dorsal Fin Length (PSDORFL):
From the structural base of the first ray of the second dorsal fin to the tip of the longest caudal fin ray.

Post-Pectoral Fin Length (PPECTFL):
From the extreme base of the anteriormost ray of the pectoral fin to the tip of the longest caudal fin ray

Post-Pelvic Fin Length (PPELVFL):
From the extreme base of the anteriormost ray of the pelvic fin to the tip of the longest caudal fin ray.

Pectoral Body Girth (PECTBGIR):
Circumferential distance measured immediately posterior to the base of the pectoral fins, perpendicular to the total length (Measured by extending a loop of nylon twine around the girth just behind the base of the pectoral fins -the loop was then drawn snug so that it conformed to the girth of the fish without distorting it).

Appendix II

Description of the meristic characters and their acronyms.

First Dorsal Fin Rays (FDORFR):
For the median dorsal and anal fins, the last ray consists of two elements that are separated at the very base of the fin. Therefore, the count is the total number of separable rays less one.

Second Dorsal Fin Rays (SDORFR):
Total number of separable rays less one.

Anal Fin Rays (ANALFR):
Total number of separable rays less one.

Pectoral Fin Rays (PECTFR):
Total number of separable rays including the smallest one at the inner end of the fin base.

Caudal Fin Rays (CAUDFR):
Total number of principal and procurrent rays.

Total Vertebrae (TOTVERT):
Total number of vertebrae excluding the urostylar half vertebrae.

Abdominal Vertebrae (ABDVERT):
Total number of anterior vertebrae without hemal spines.

Gill Rakers on the Epibranch (EPIRAK):
Total number of rakers on the epibranch of the first gill arch on the left side, including rudimentary rakers. If a raker "straddles" the angle between the epibranch and the ceratobranch, it is included in the count of the ceratobranch.

Gill Rakers on the Ceratobranch (CERRAK):
Total number of rakers on the ceratobranch of the first gill arch of the left side, including rudimentary rakers.