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Canadian Atlantic Fisheries Scientific Advisory Committee

Comité scientifique consultatif des pêches canadiennes dans l'Atlantique

CAFSAC Research Document 83/53

CSCPCA Document de recherche 83/53

Herring Gonadosomatic Index in Relation to Maturity Stage

by

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Les Documents de recherche sont publiés dans la langue officielle utilisée par les auteurs dans le manuscrit envoyé au secretariat.

Abstract

Gonad weight and gonadosomatic index of herring in NAFO Division 4T were examined in relation to gonad development and time of year. Frequency distributions by maturity stage were considered to assess the potential of using gonad weight to remove some of the subjectivity associated with assignment to maturity stage. A total of 48,000 fish collected from 1970 to 1982 were considered in the analysis and results suggest that assignment to maturity stage can be enhanced by use of the gonadosomatic index and transition points between stages were identified. A generalized pattern of gonad development in relation to spawning season is presented but it is recognized that histological studies are required to validate conclusions.

Résumé

Le poids des gonades et l'indice gonadosomatique du hareng dans la div. 4T de l'OPANO ont été examinés en relation avec le développement des gonades et le temps de l'année. La distribution des fréquences par stade de maturité a été analysée en vue d'évaluer la possibilité d'utiliser le poids des gonades et se débarasser ainsi d'une partie de la subjectivité associée à l'attribution à un stade de maturité. Un total de 48 000 poissons capturés entre 1970 et 1982 ont servi à l'analyse. Les résultats donnent à penser que l'utilisation de l'indice gonadosomatique pourrait amméliorer l'attribution à un stade de maturité particulier. Nous avons de plus défini des points de transition entre stades. Nous présentons un schéma généralisé de développement des gonades en relation avec la saison de ponte, mais nous admettons que des études histologiques sont nécessaires pour confirmer les conclusions.

Introduction

Herring from the southern Gulf of St. Lawrence (NAFO Division 4T) consist of two major spawning components, one which spawns in the spring and the other which spawns in late summer and fall and, to assess stock status, it is necessary to assign catches to one of the components based on biological samples of commercial fisheries. Various criteria have been used to accomplish this division but some inconsistency has been noted and the effect of incorrect classification may have substantial impact on estimates of stock abundance (Cleary et al, 1982).

Indirect evidence of spawning group, such as otolith morphometrics, may provide good results but statisitical analysis of measurements (Messieh, 1972) suggests considerable overlap in the distribution of single parameters. Discriminant function analysis may yield better results but has limited application for individual separation and requires a number of parameters and special sampling methods.

Direct evidence of spawning group can be derived from maturity stage and associated proximity to date of spawning but the eight levels used in the ICES scale (Parrish and Saville, 1965) are subject to interpretation and are not definitive at certain times of the year. Cleary et al (1982) reviewed and modified the descriptions for each stage and also identified the need to relate time and development between adjacent stages as a method of standardizing classification to spawning group. Histological analysis of gonads may refine and improve the assignment of maturity stage but a simpler and more direct method is required for routine application and use in the laboratory.

The eight maturity stages used have a general relation to changes in the relative size of the gonad as well as changes in appearance, colour and presence of ova and sperm. This study considers changes in weight of the gonads and attempts to develop a functional association between gonadosomatic index and maturity stage.

Materials and Methods

Total gonad weight of herring in Division 4T is measured as a routine parameter for all samples from commercial catches. Gonads are extracted from the body cavity, cleaned of extraneous material and weighed to the nearest 0.01gm on electronic balances. Total weight (0.1gm), total length (mm), sex, maturity stage and otolith age are also recorded for each specimen. Individual samples consist of 100 fish selected at random from the catch, identified by area of capture, date and gear type, and frozen for later examination in the laboratory.

Samples were available for the thirteen year period from 1970- 1982 and covered the entire fishing season from April to November. Standard sampling techniques were used for all samples and the same personnel were involved in the laboratory examination of specimens.

A gonadosomatic index (GI), defined as the percent ratio of gonad weight to total fish weight (gonads included), was calculated for each fish. Analysis was limited to maturity stages III-VIII, since immature fish cannot be assigned to a spawning group on the basis of gonad development.

Percent maturity stage composition of samples, combined by month over the available time series, was examined to follow the progression of stages throughout the fishing season. Frequencies were normalized to the major stage represented in each month to reduce the effect of differing sample sizes in each month and males and females considered separately.

A strong correlation between gonad weight and fish length was anticipated and this was examined by comparing the average gonad weight by fish length and maturity stage and also by comparing the mean gonad weight by stage and month within maturity stages. All length intervals were considered but analysis was limited to stages III-V and lengths 30-34cm for males and females for combined samples.

Maturity stages III and VIII were identified as the most difficult for separating spawning components since the first is a pre-spawning, developing stage and the second is a post-spawning, recovering stage. Criteria for separating these stages may not be definitive and the potential for misclassification is significant and can lead to incorrect assignment of spawning groups. Frequency distributions of gonad weight by stage over a 30-35cm length interval were examined for males and females and, to reduce the effect of length, similar analysis of maturity stage and the calculated gonadosomatic index were considered. Comparisons were made between stages III and IV, and between stages IV and V for both sexes.

The frequency distribution of the GI by month for stages III and VIII, combined, was examined in an attempt to identify possible incorrect classification of stages based on the assumption that component analysis of the frequency could be used to resolve contributing fractions. Similar analysis was considered for all maturity stages combined.

The mean monthly GI for males and females was calculated and plotted against month to relate gonad development to season and to show the anticipated bi-modal pattern associated with two spawning components.

Cleary et al (1982) had suggested a possible relationship between the GI and maturity stage and the potential use of this information to validate or assign stages. To examine this possibility, samples from all months were combined in pairs of stages VIII and III, III and IV, and IV and V and the ratio of stages at each interval determined. Ratios were normalized to 1 and plotted for each of the pairs of adjacent stages to provide a possible key to assist in identifying stages and to show the transition in GI between stages.

It was assumed that within stages the relation of fish length and GI should be constant and therefore mean GI at length by stage was calculated for males and females. Mean GI in bi-monthly intervals for stage IV for fish over the available length range was also examined.

Results

A total of 22384 males and 23187 females in maturity stages III-VIII from April-November were available for the analysis. An initial examination of the data indicated little variation in monthly distribution between years and it was felt justified in combining years to improve the number of observation at each length interval and maturity stage. The normalized frequency distribution of maturity stages by month is shown in Figure 1. As expected, the relative contribution by stage is very similar for males and females and in two distinct patterns, showing that spring spawning can be identified by stages V and VI fish in April and May and the fall component by stages V and VI fish in August and September. Some progression in maturity stage between months can also be noted but is more apparent for fall spawning fish. Stages III and IV in June-July appear as stages V and VI in August-September and as stages VIII and III in October-November. The large numbers of stages V and VI fish evident in April-May appear not to be represented in subsequent months but may be part of the stages III and IV fish in October-November. This would imply that the spring spawning fish move or disperse from the area and are not represented in samples (or catches) until later in the year. Most herring fisheries in Div. 4T are directed at pre-spawning aggregations of the stock and may not catch (or sample) the post-spawning fish.

The relationship between mean gonad weight and fish length is shown in Figures 2(b) and 3(b) for males and females. The effect of length on gonad weight is most apparent for stages IV-VI but is less significant for stages III,VII and VIII. Within stage variation in mean weight by month was also considered and results for the 32cm length interval are presented in Figures 2(a) and 3(a) for males and females at stages III-V. Peaks in the mean weight can be noticed which correspond with spawning season, particularily for stages III and V which implies a general increase in weight as spawning approaches. Stage III fish would be the opposite spawning group to stage V but could be in phase with any increase in weight. Stage IV fish appear to have more variation and are less consistent in relation to spawning season. Males show an unexpected decrease in August and this could indicate mixing of two spawning groups or a bias in assigning large stage III fish to the stage IV group. Females at stage IV have a more consistent pattern of change in mean weight and follow the trend of stage V to increase at the peak of spawning.

The frequency distribution of stages III and VIII for males and females is shown in Figures 4 and 5 for 30-35cm length intervals. Considerable overlap in the two distributions is apparent as is the progression in mean weight with increasing length. No obvious misclassification of the two stages is apparent, as might be suggested by a bi-modal distribution, and separation based on gonad weight seems unlikely. Similar frequency distributions are shown in Figures 6 and 7 but the calculated GI has been used instead of gonad weight. The GI ranged from 0.5-6.0% and the degree of overlap is similar to that observed for weight and no separation of stages by modal value is suggested. By comparison, the frequency distribution for stages IV and V (Fig. 8 and 9) indicates good separation of the two stages. As further test of possible bi-modality, the frequency distribution for stages III and VIII were combined and replotted but, as shown in Figure 10, no separation is possible and the modal analysis technique of Hunt (1980) failed to resolve modes. The GI frequency distribution for all stages combined for females is presented in Figure 11 by month,and as expected two patterns of increasing percentage are evident which correspond to peak spring and fall spawning. The mean monthly GI for females (Figure 12) also confirms the bi-modal pattern in GI with peaks in May and August.

A further test of the relationship between maturity stage and GI was accomplished by calculating the ratio of stages at each GI interval, normalizing to 1 and plotting against the GI. For example, the frequency distributions of stage III and IV were combined and the number at each interval of the GI expressed as a ratio of stage III to stage IV. These calculations yielded a probability curve over the GI range for stages III and IV . Results of combinations of stage VIII vs III, stage III vs IV and stage IV vs V, by sex are shown in Figures 13-15 and approximate a sin-curve relationship. Approximate 50% transition points between stages appears to be consistent for males and females for each of the comparisons and occurs at a GI of about 2.25% for stage VIII to III, 5.25% for stage III to IV and 20.0% for stage IV to V based on freehand curves. This relationship implies that confidence limits could be assigned to each maturity stage based on the GI and values outside of a defined range for GI checked for validity, but such a test would require a constant association between maturity stage, GI and fish length over the entire range of lengths. Analysis of this relation is shown in Figure 16 for stages III-VI for 26-37cm fish and some inconsistencies can be seen. For both males and females, stage V appears to increase with length while stage IV decreases at a reciprocal rate which may indicate incorrect stage assignment or may be the effect of time and season when samples for each stage were collected. The latter possibility was considered by checking the number of fish sampled over the 30-36cm length groups but sampling appeared adequate and did not account for the variation between stages IV and V. To examine the effect of seasonal distribution of samples, mean bi-monthly GI values for stage IV females were calculated and are shown in Figure 17. The decline in mean GI appears to be confined to the two peak spawning periods (April/May and August/September) which suggests possible mis-classification of maturity stage and potential bias by personnel in assigning stage IV. A discussion with sampling technicians indicated there may be a tendency to over-estimate the incidence of stage IV in larger fish and that some proportion of these fish should in fact be classed as stage III (rather than stage V, which is more distinct). The effect of this error would tend to lower the mean GI for stage IV and, if corrected, would increase the mean for both stage IV and stage III for larger fish and result in a positive correlation between stage, GI and fish length. This potential error cannot be quantified but its effect should be of limited significance when experienced personnel are used.

Evidence on the duration of stages may be derived from Figure 17, if it is assumed that stage IV fish in April/May and stage IV fish in October/November belong to the same spawning group. This would imply that the cycle from a large stage IV to a small stage IV requires about six months (April to October) and that this stage may be an over-wintering "resting" interval. There appears to be good correlation between the upper values of GI shown in Figure 14 and the mean GI for stage IV in Figure 17 and the point at which the mean GI becomes discontinuous (approximately 20%) also agrees with the 50% transition between stage IV and V shown in Figure 15. Allowing a period of about one month for progression from stage IV through stages V, VI and VII, a residual time of about five months remains for development from stage III to IV to complete the annual cycle. Using the approximate 50% transition points of Figures 13-15 suggests that progression from a GI of 2% (stage VIII) to 5% (stage III) requires about five months, from 5% (stage VI) to 20% (stage V) about six months with the balance of one month required for pre-spawning development, spawning and recovery. This proposed cycle is illustrated in Figure 18 for a 24 month period and has been applied to peak spawning at May 1 and September 1. Areas of overlap between the two cycles which could lead to incorrect assignment to spawning group occur in September and October when "early" and "late" stage III fish could be expected and to a lesser degree in March when the two extremes of stage IV are present.

The cycle proposed above is very subjective and may have both internal and seasonal variation which limit its application. However, it may be of some use for improving the use of maturity stage as an indicator of probable spawning season. An exponential curve was fit to the pre-spawning part of the cycle, plotted against time in months and the boundaries of each stage marked as shown in Figure 19.

Summary

The relative composition of herring maturity stages in commercial catches from Div. 4T over the April-November season were shown to follow two distinct patterns of development which correspond to spring and fall spawning. Some discontinuity in the progression of stages was noted but this may reflect selective fishing patterns and the apparent absence of immediate post-spawning fish in samples.

Mean gonad weight was shown to be positively correlated with fish length and increased from about 50gm to about 80gm for stage V fish at 30 and 34cm, respectively. Some seasonal variation was also noted in mean gonad weight by stage within length intervals. The frequency distribution of gonad weight for stages III and VIII, by length intervals, indicated considerable overlap between these stages and separation by modal components was not possible. Simliar results were noted when the gonadosomatic index was used in place of weight.

The transition between stages, in terms of the GI, was examined by calculating the ratio of each stage and then assigning a probability to each stage. Sigmoid curves were found to best fit the data and it was possible to estimate the 50% transistion point between stage VIII and III, between III and IV and between stage IV and V as 2%, 5% and 20% of total body weight, respectively.

Between stage variation in mean GI by length was examined and found to be significant with stage V being positively correlated and stage IV negatively correlated. This could not be explained but it was suggested that misclassification of stages III and IV could be a factor. Within stage variation in mean GI by length was also considered and similar trends noted and the

effect of length was most pronounced for large fish (>32cm)

A proposed cycle of annual changes in GI in relation to spawning season was presented and the interface between adjacent stages calculated. However, practical application of this cycle cannot be accepted until verified by histological or other studies which are currently in progress.

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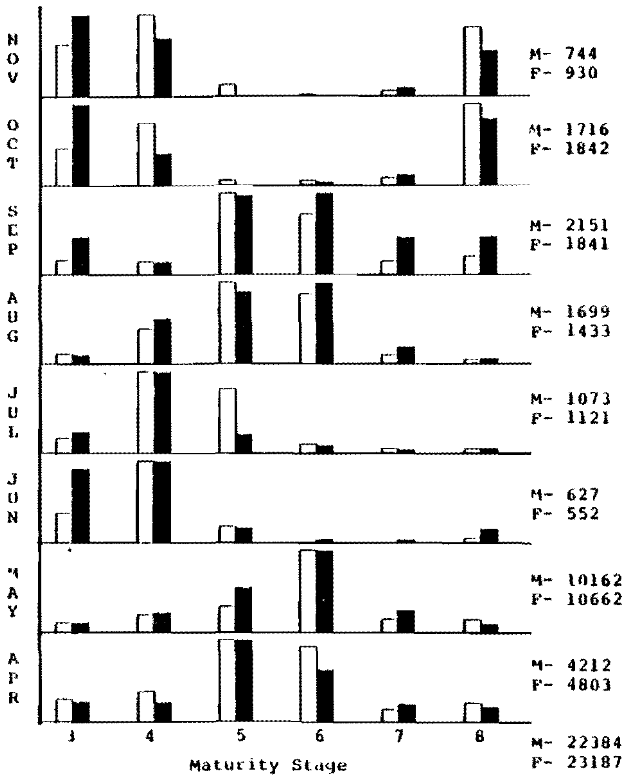

Figure 1. Relative proportion of maturity stages by month for males (open bar) and females (solid bar). 1970-82. Normalized to one.

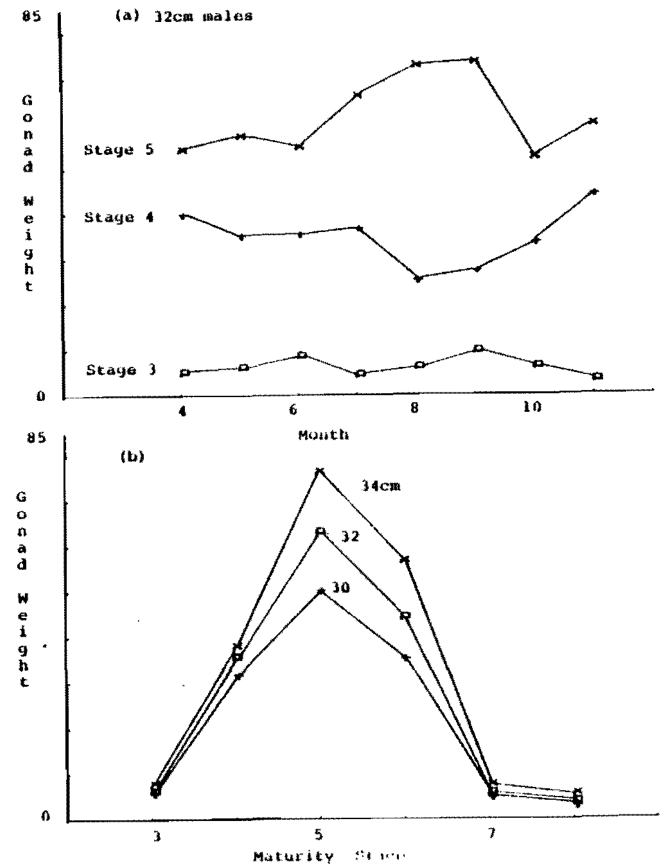

Figure 2. (a) Male gonad weight by stage and month for 32 cm fish.
(b) Mean gonad weight by length and stage fir males.

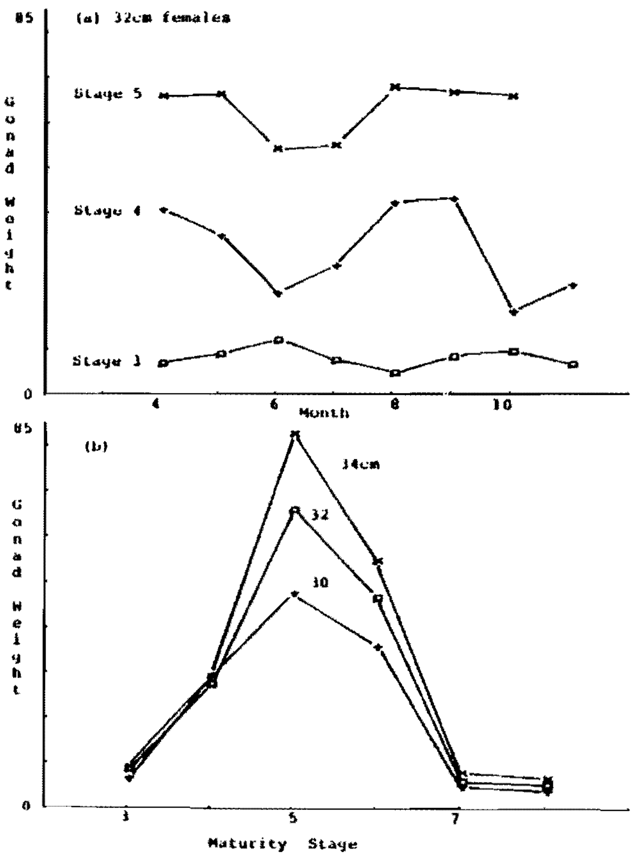

Figure 3. (a) Female gonad weight by dtage and month for 32 cm fish
(b) Mean gonad weight by length and stage for females.

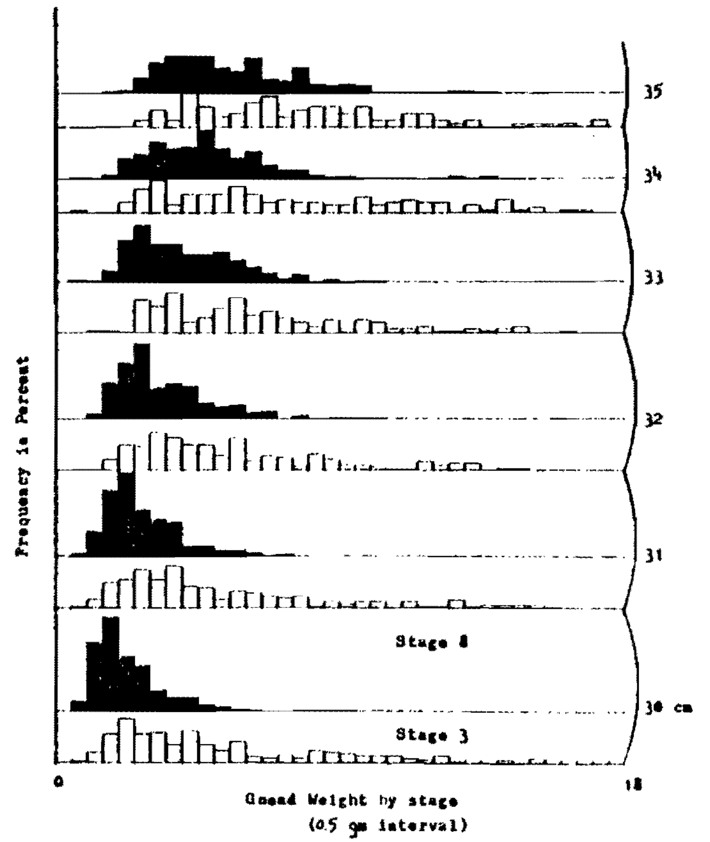

Figure 4. Frequency distribution of gonad weight for males by length and maturity stage. Years combined.

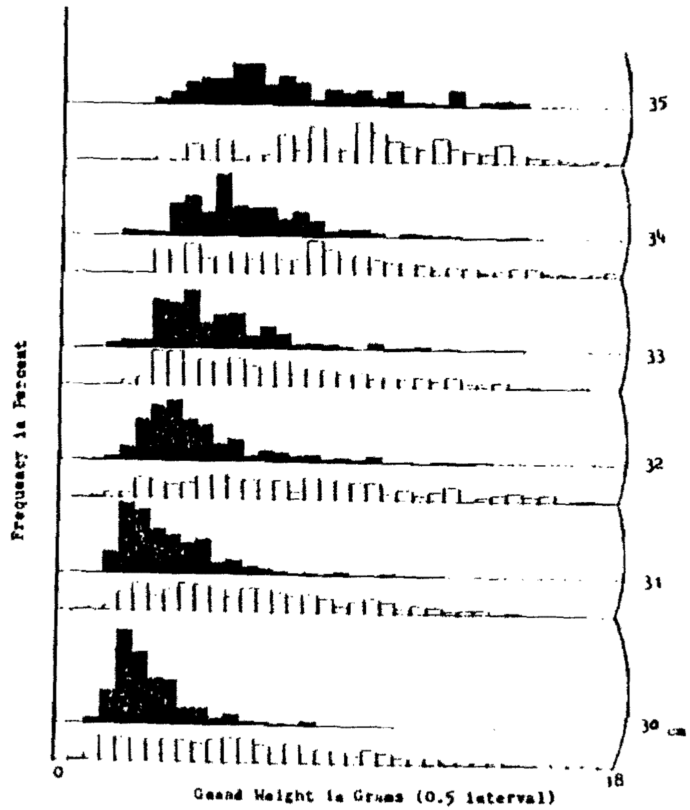

Figure 5. Frequency distribution of gonad weight for females by length and maturity stage. Years combined.

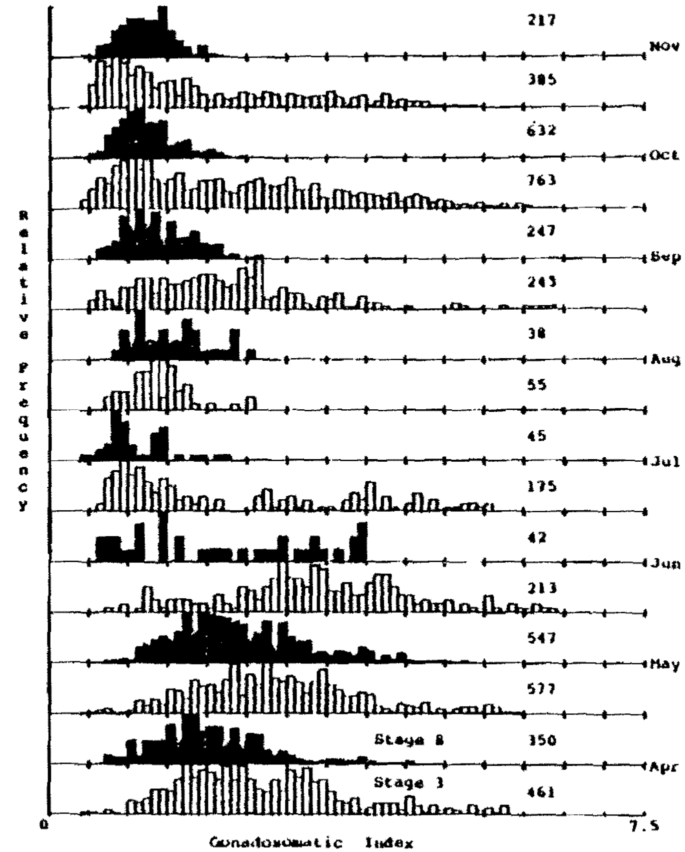

Figure 6. Comparison of frequency distribution for maturity stages 3 and 8. Females.

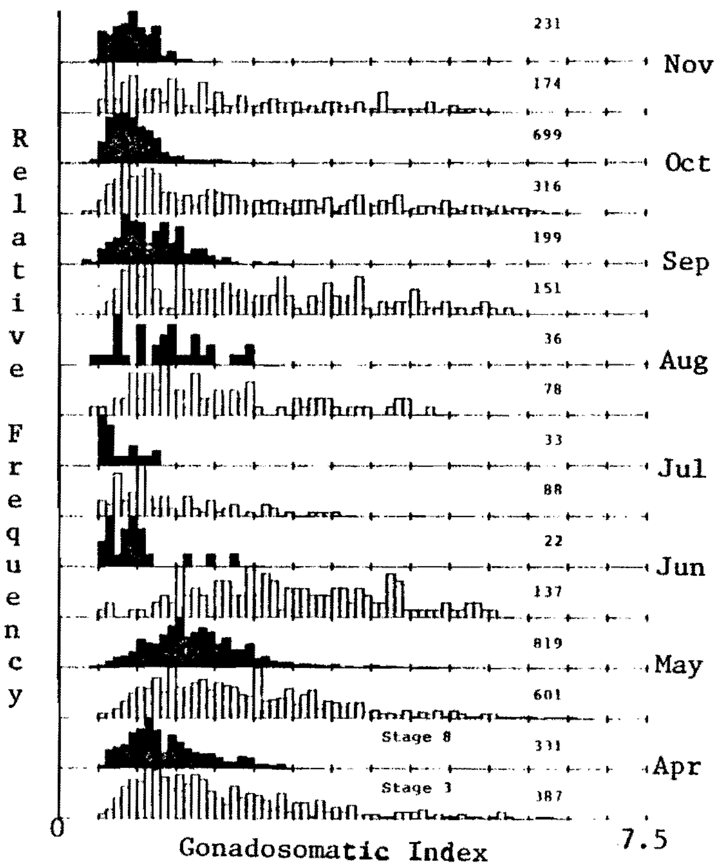

Figure 7. Comparison of frequency distribution for maturity stages 3 and 8. Males.

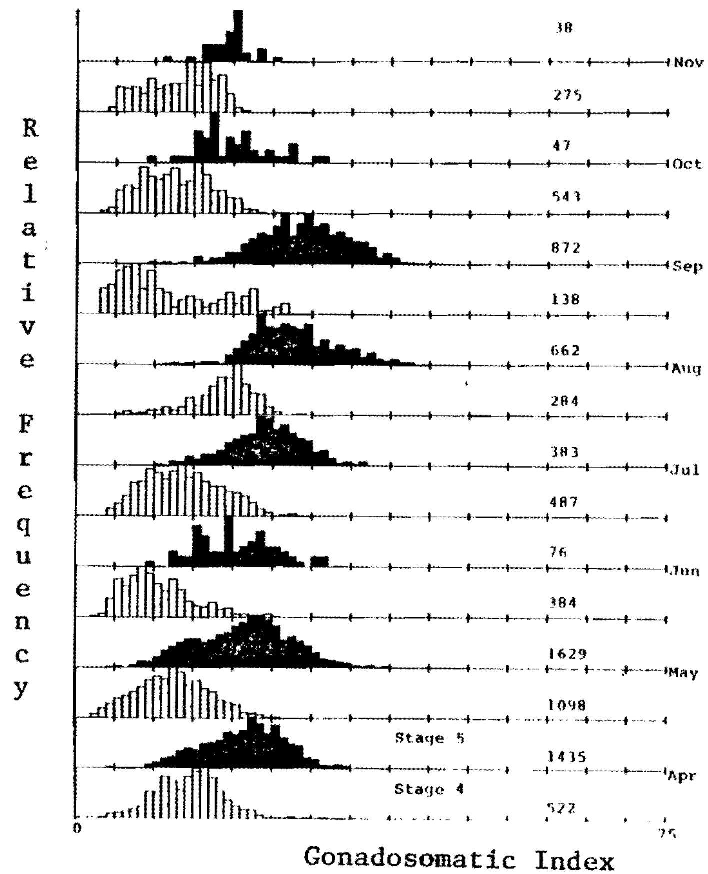

Figure 8. Comparison of frequency distribution for maturity stages 4 and 5. Males.

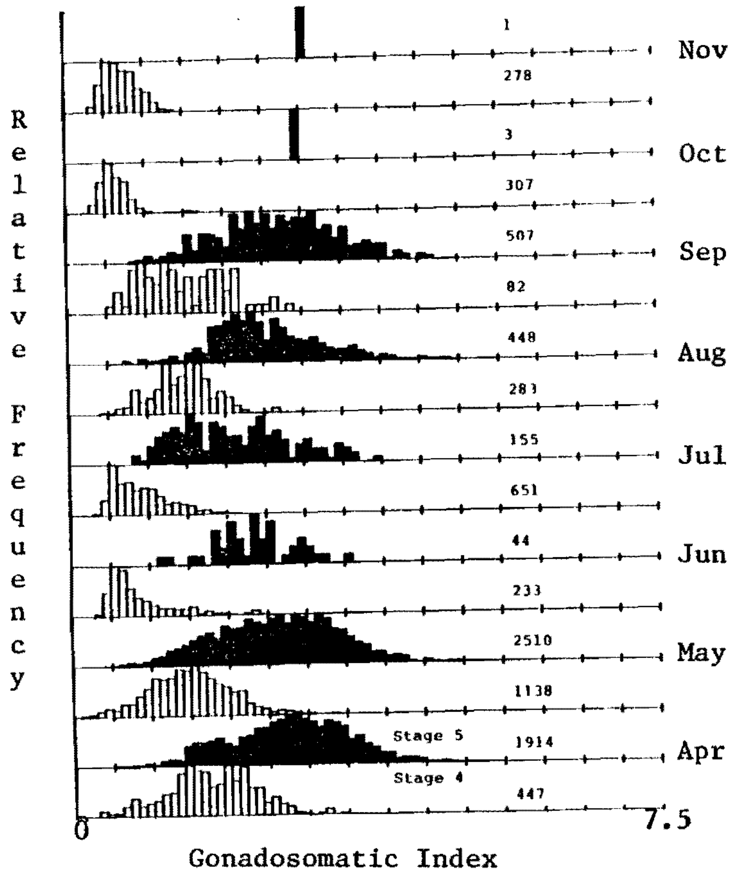

Figure 9. Comparison of frequency distribution for maturity stages 4 and 5. Females

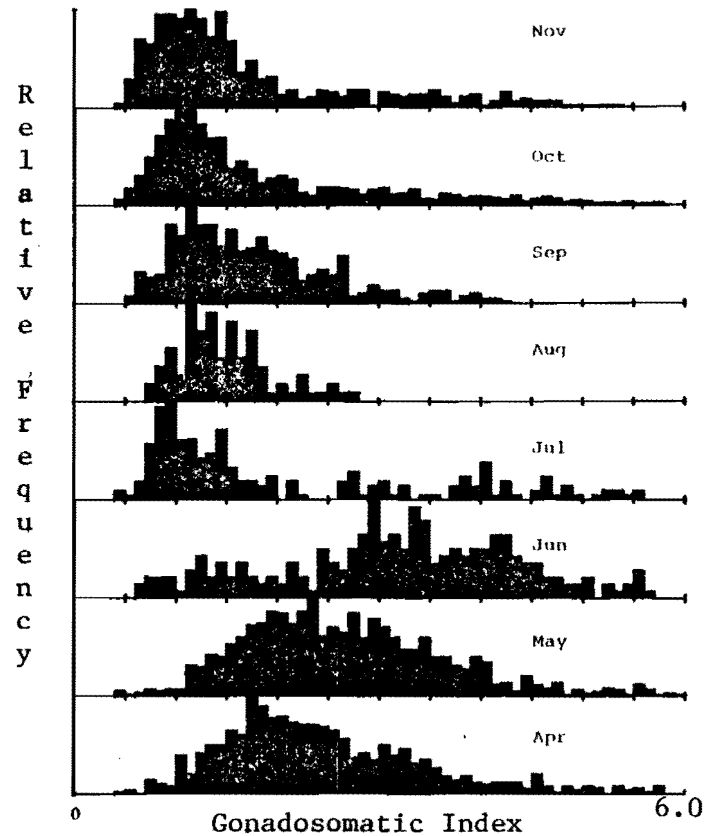

Figure 10. Frequency distribution of GI for females. Maturity stages 3 and 8 combined.

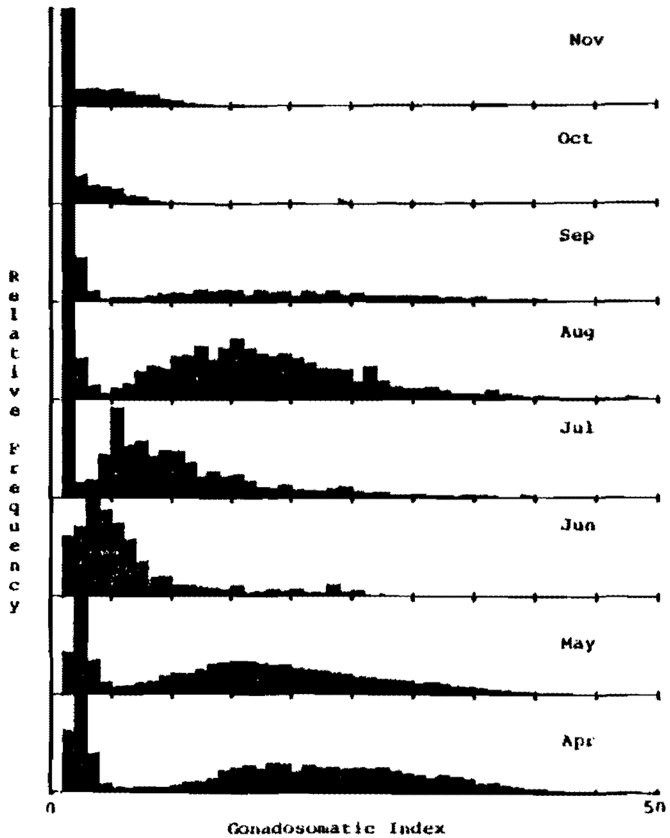

Figure 11. Frequency distribution of GI for females. Maturity stages 3 - 8 combined.

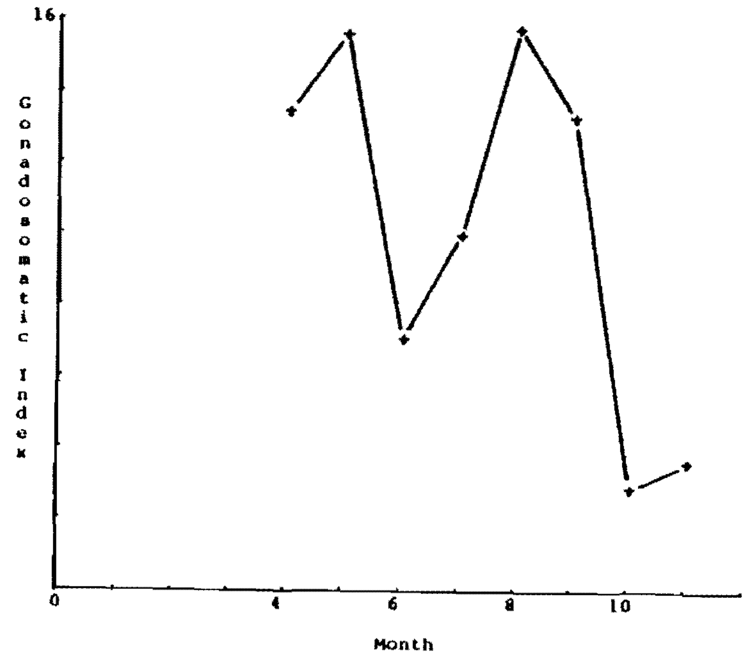

Figure 12. Mean gonadosomatic index by month for females.

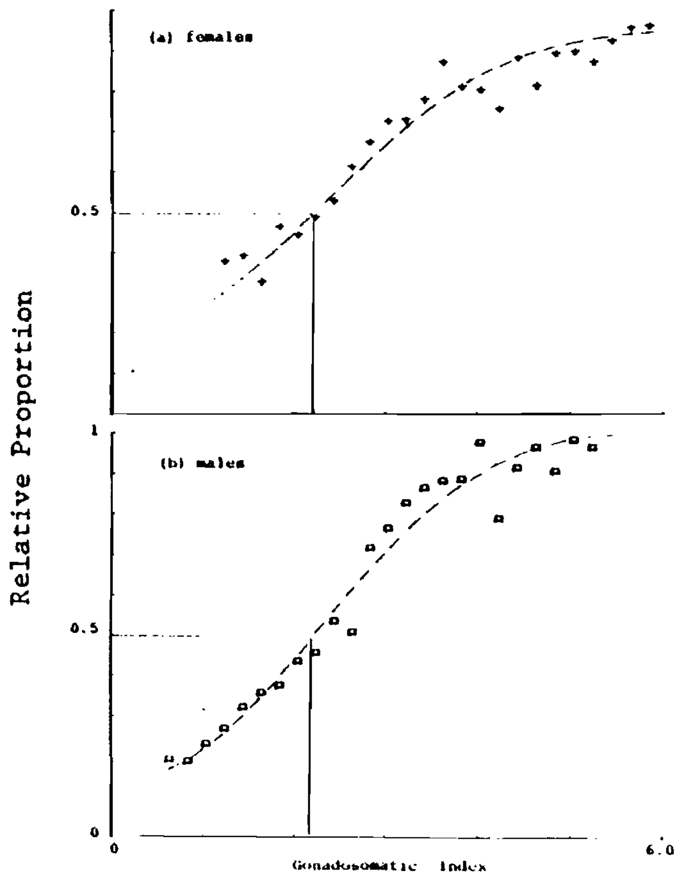

Figure 13. Relative proportion at stage 3 and 8 by GI for (a) females and (b) males.

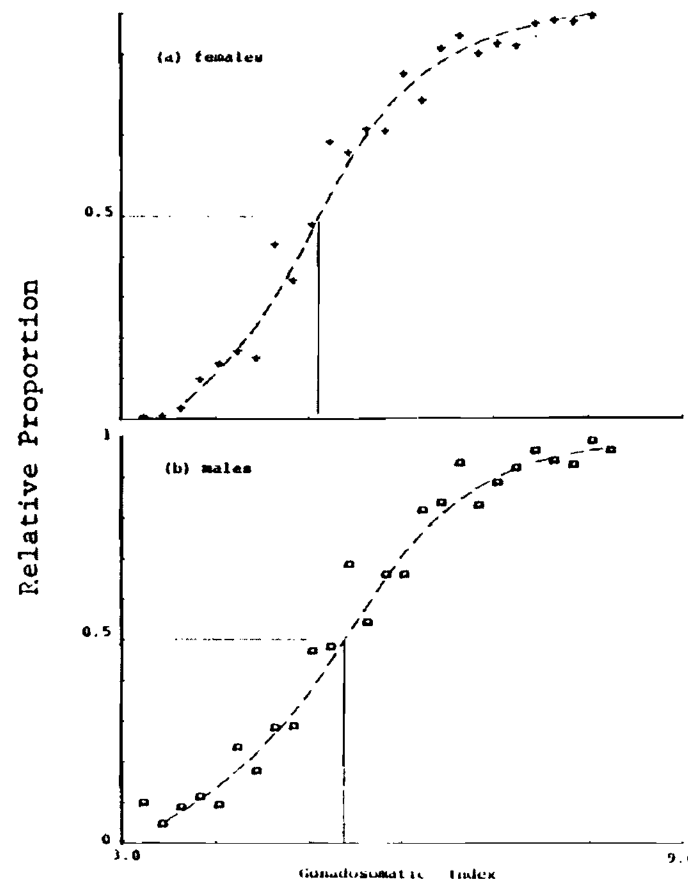

Figure 14. Relative proportion at stage 3 and 4 by GI for (a) females and (b) males.

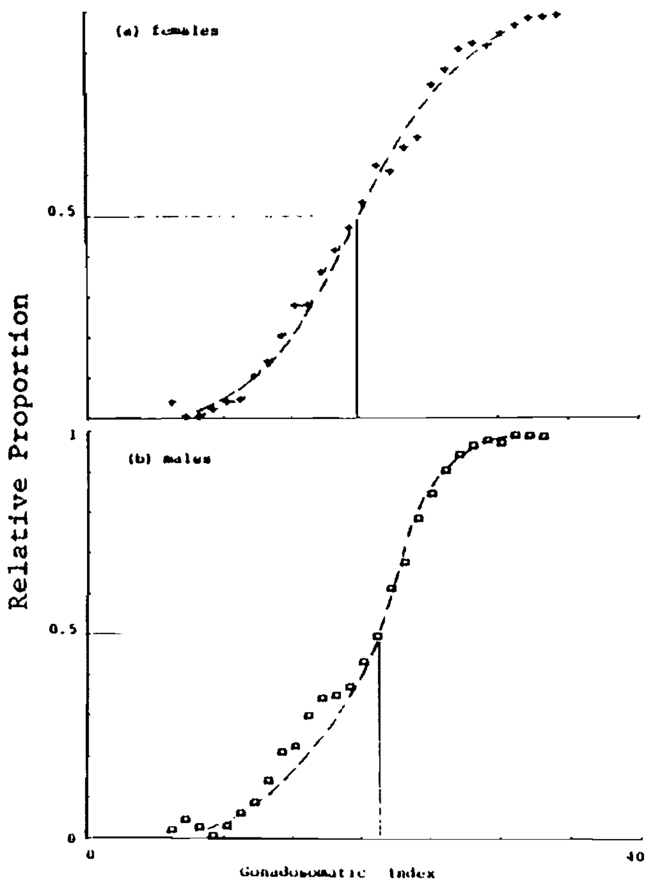

Figure 15. Relative proportion at stage 4 and 5 by GI for (a) females and (b) males.

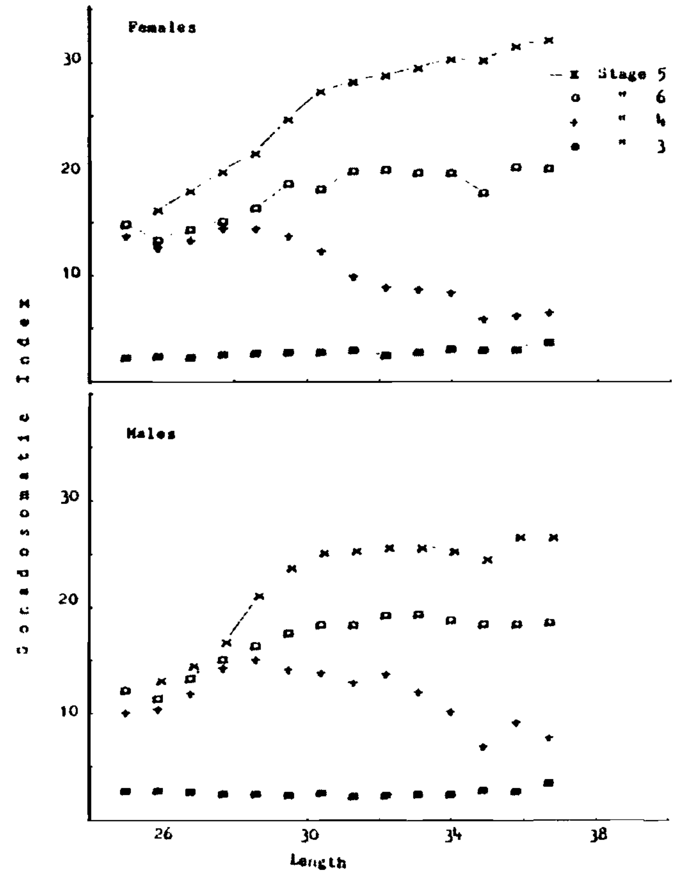

Figure 16. Relationship between mean annual GI and length by maturity stage.

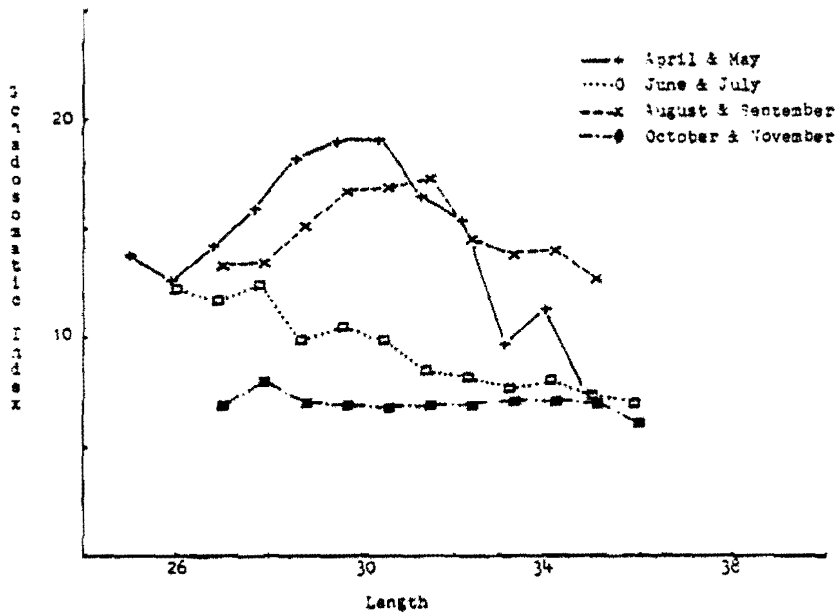

Figure 17. Comparison of mean GI for females at stage 4 by length and month.

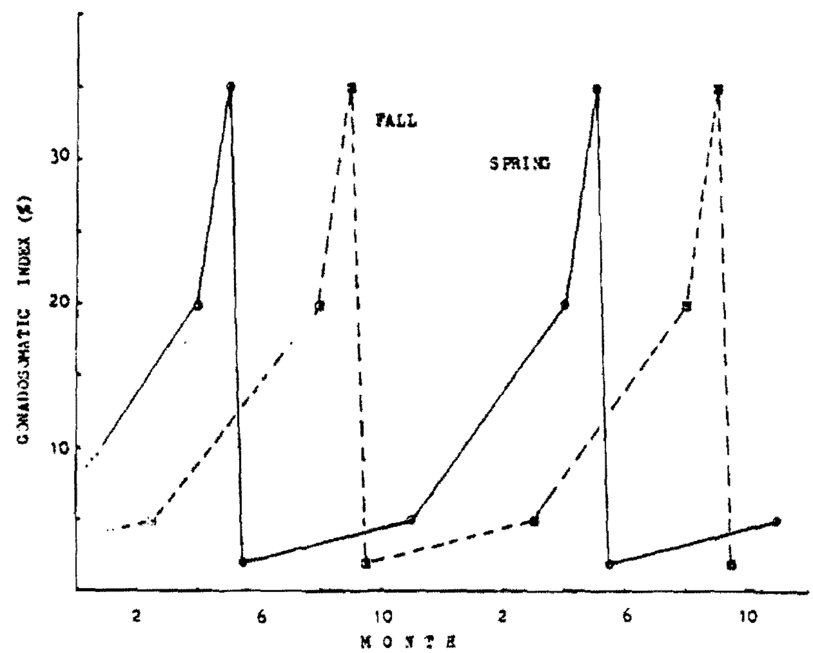

Figure 18. Proposed annual cycle of gonadosomatic index progression using 50% between stage transition points.

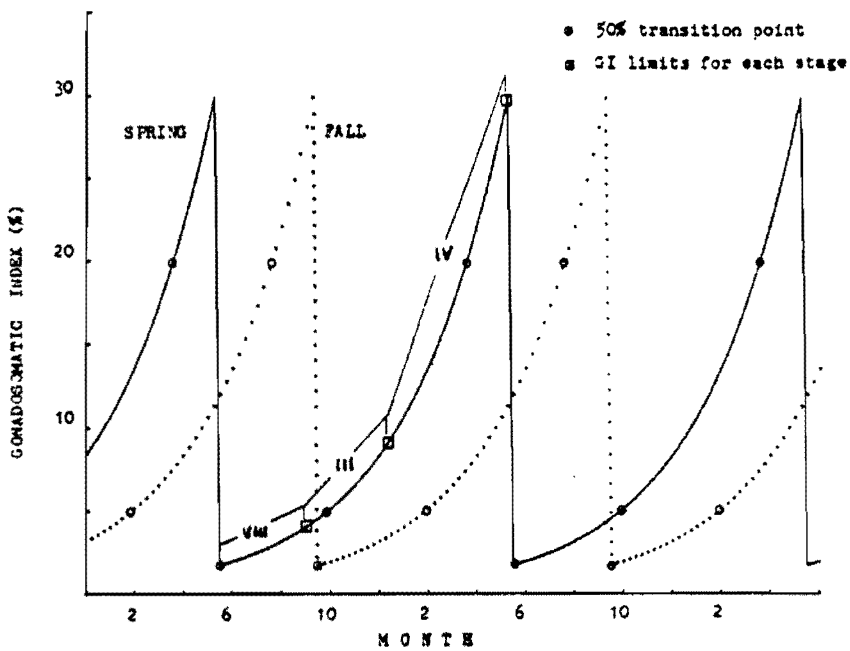

Figure 19. Calculated exponential relationship between GI and month. Range limits and 50% transition points are shown for each stage.