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IMPACTS OF SMALL-SCALE HABITAT FRAGMENTATION ON ABUNDANCE
AND MOVEMENT OF
SIGMODON HISPIDUS AND *MICROTUS OCHROGASTER*

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Small mammals are impacted by habitat fragmentation resulting from habitat loss in a number of quantifiable ways. Remnant patches often become areas for breeding and resource acquisition for individuals that were members of the former continuous habitat. Vegetative cover is important for both hispid cotton rat (*Sigmodon hispidus*) and prairie vole (*Microtus ochrogaster*) population dynamics. I conducted field work at the John H. Nelson Environmental Study Area near Lawrence, Kansas, using a small mammal trapping grid (with 99 trapping stations) that had been in operation since 1973. I examined abundance of individuals in mowed areas (postM) after deliberate habitat removal (by mowing a checkerboard-like pattern) from a continuous landscape (and compared this to 27 years of pre-mowing data) to determine species responses to fragmentation. I examined abundance of individuals in unmowed (postU) areas and movement subsequent to fragmentation to determine if postU patch size was appropriate. I examined variance-to-mean ratios of distributions of movements to determine if individuals changed the proportion of short- or long-distance movements made post-fragmentation. I examined the responses by individuals to fragmentation for the following categories of both species: overall, sex, reproductive condition (reproductive and non-reproductive), and stage class (adult, sub-adult, and juvenile). Decreases in abundance occurred for all categories on the postM patches. Decreases in abundance occurred on postU patches together with decreases or no change in movement length between successive captures for the majority of the categories. Most individuals also moved a greater proportion of shorter distance movements within their distribution of movements post-mowing. Thus, patch size was appropriate for the individuals; however, there were fewer individuals traversing the grid subsequent to fragmentation. Thus, on a local scale, habitat fragmentation can alter abundance and movement patterns of individual small mammals.

Key Words: abundance, habitat fragmentation, *Microtus ochrogaster*, movement, patch, removal, *Sigmodon hispidus*

IMPACTS OF SMALL-SCALE HABITAT FRAGMENTATION ON ABUNDANCE AND MOVEMENT OF *SIGMODON HISPIDUS* AND *MICROTUS OCHROGASTER*

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PREFACE

This manuscript is formatted according to the guidelines set forth by the American Society of Mammalogists (ASM) for submission to the *Journal of Mammalogy*. Information for Contributors can be viewed at the ASM website: www.mammalogy.org.

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INTRODUCTION

Habitat fragmentation is any process by which continuous habitats are altered to create patches with a smaller total area, isolated from one another by a matrix distinctly different from the original (Wilcove et al. 1986). For fragmentation to become meaningful to an organism, it must elicit some response from the organism. There are several characteristics of fragmentation, which typically include habitat loss, increase in patch number, decrease in patch size, and increase in patch isolation (Fahrig 2003, Wiegand et al. 2005). Potential impacts also include alteration of ecosystem functioning, e.g., water and nutrient flux (Saunders et al. 1991, Kozakiewicz 1993) and modification of naturally existing landscape mosaics, e.g., loss of distinct character, increase in matrix habitat, and varying vegetation types among remnant patches (Saunders et al. 1991, Kozakiewicz 1993, Schweiger et al. 2000). Remnant biota that continue to use remaining patches for breeding and resource acquisition also can be affected by fragmentation (Fahrig and Merriam 1994). Comparing abundances of these individuals' post-fragmentation (versus pre-fragmentation) should provide an indication of which habitat type, i.e., either remnant or matrix, individuals use after fragmentation (Diffendorfer et al. 1995) and if that is different from areas used before fragmentation. For instance, Schmiegelow et al. (1997) found crowding among boreal birds on intact patches, and Davies and Margules (1998) reported population declines, due to overcrowding and isolation in carabid beetles on remaining patches in fragmented systems.

Increased vegetative cover typically provides greater protection from predators and better areas for resource foraging (Kotler et al. 1988). For species that are vulnerable to predators and constantly foraging, reduced vegetative cover could provide areas of less favorable habitat, and, subsequently, reduced abundances. Specifically, vegetative cover is an important component of both hispid cotton rat (*Sigmodon hispidus*) and prairie vole (*Microtus ochrogaster*) population dynamics (Kotler et al. 1988, Langley and Shure 1988) and, therefore, altering the habitat by removing cover should impact their abundance.

Depending on resource requirements, dispersal ability, and habitat availability, individuals also might leave remnant patches in search of more continuous habitat (Fahrig and Merriam 1994). Specifically, exploratory movement immediately post-fragmentation is common because individuals must find resources in areas other than those that no longer contain resources (Fahrig and Merriam 1994). Thus, examining post-fragmentation movement might provide an indication of how inhabitants of a former continuous landscape are using space to obtain resources.

To date, few researchers have deliberately manipulated a continuous landscape and compared abundance and movement of individuals before and after habitat fragmentation resulting from habitat removal (Wolff et al. 1997, Debinski and Holt 2000, Slade and Crain 2006). Moreover, there is no research in which long-term data sets have been used as a comparison for changes in abundance and space use after fragmentation.

The present investigation examined changes in abundance and movement patterns by *S. hispidus* and *M. ochrogaster* in response to mowing a continuous landscape (in a checkerboard-like pattern) in northeast Kansas. Twenty-seven years of data, collected from the same study area, were used as a baseline to compare abundance changes and movement patterns of the two species. Prior research has suggested that *S. hispidus* and *M. ochrogaster* rarely are found in areas with sparse vegetation, and densities for both have been shown to be positively associated with vegetation height (Kaufman and Fleharty 1974, Slade and Swihart 1983, Foster and Gaines 1991, Schweiger et al. 2000). Additionally, previous research suggests that individuals typically expand movement, i.e., increase distance moved, when the area of remaining patches in a fragmented habitat becomes less than the minimum space required by the individual (Fahrig and Merriam 1994, Andreassen et al. 1998). Therefore, I hypothesized that fragmentation resulting from habitat removal would affect abundance and movement of both species. Specifically, I predicted that the responses by both species to habitat fragmentation would be reduced abundances on mowed (postM) patches. For clarity purposes, prior to mowing, patches that would be mowed are denoted preM and patches that would be left unmowed are denoted preU. Post-mowing, mowed and unmowed patches are referred to as postM and postU, respectively.

If the species decrease abundance in the postM patches and there is an increase in abundance on the postU patches, an increase in movement length would indicate that postU patch size was too small and individuals increased the length of distance traveled in response to overcrowding. A decrease or no change in movement length would indicate that postU patch size was appropriate and individuals were either confined to postU patches or preU patches were not at capacity (Fig. 1).

If the species decrease abundance in the postM patches and there is a decrease in abundance on the postU patches, an increase in movement length would indicate that postU patch size was too small and individuals moved from patch to patch over unsuitable patches. A decrease or no change in movement length would indicate that postU patch size was appropriate but fewer individuals were traversing through these patches, likely causing the observed decrease in postU abundance (Fig. 1).

If the species decrease abundance in the postM patches and there is no change in abundance on the postU patches, an increase in movement length would indicate that postU patch size was too small and individuals used multiple postU patches and moved through the postM patches. A decrease or no change in movement length would indicate that postU patches were of appropriate size, but long-distance movements were restricted (Fig. 1).

I addressed the effects of fragmentation on space use by examining: (1) mean distances (m) moved between successive captures of individuals of each species pre- and post-mowing and (2) variance-to-mean ratios (VM ratios) (created by using the distances moved by individuals between successive captures) of distributions of movements of each species before and after habitat removal.

MATERIALS AND METHODS

Study area.—The 2.25-ha study site was located at the University of Kansas' John H. Nelson Environmental Study Area, 14.5 km northeast of Lawrence, Kansas (Fig. 2). A small mammal trapping grid was established at this site in 1973 to study small mammal community dynamics. The site consisted of a rectangular grid (180 m x 150 m) with 99 trapping stations spaced at 15 m intervals (Fig. 3). All trapping stations contained two Sherman live traps (8 x 9 x 23 cm) (H. B. Sherman Traps, Tallahassee, Florida) covered with a piece of plywood, which provided protection from precipitation and sunlight.

The study site was situated in an abandoned field, with the north edge bordered by brome grass (*Bromus inermis*), the south edge bordered by oak-hickory woodland, the southeast edge bordered by a 3 m wide road that also transected the north and south halves (not shown in Fig. 3), the northeast edge bordered by a pond and lawn, and the west edge bordered by a lawn on the north half (not shown in Fig. 3) and oak-hickory woodland on the south half. Quantitatively, the common plant species on the north half of the site were foxtail (*Setaria* spp.), milkweed (*Asclepias* spp.), and smartweed (*Polygonium* spp.); common plant species on the south half were *B. inermis* and asters (*Aster* spp.) and forbs such as goldenrods (*Solidago* spp.) and sunflowers (*Helianthus* spp.).

Design.—The trapping grid was mowed to create nine 900 m^2, two 450 m^2, one 2250 m^2, and one 1575 m^2 clear-cut plots (shaded white on Fig. 3) and ten 900 m^2 and one 450 m^2 intact plots (shaded gray on Fig. 3). Each 225 m^2 section of the grid contained one trapping station (Fig. 3).

I conducted 14 trapping sessions at weekly intervals from mid-June 2004 through the end of August 2004 and monthly intervals from September 2004 through November 2004. The grid was mowed three times from June to November 2004, only when the vegetation in the postM areas reached a mid-calf height, or approximately 30-40 cm. Post-mowing trapping sessions followed mowing sessions by ≥ 3 days to allow for recovery from the disturbance. During trapping sessions, all traps were baited with cracked corn and dry oats, checked and rebaited each day for 3 days, and locked open on the fourth day. Individual cotton rats and prairie voles were marked using numbered ear tags (National Band and Tag Company, Newport, Kentucky) and toe clips, respectively. Upon capture, the following data were recorded: trap station, species, newly or previously captured, sex, weight (mass) to the nearest gram, external reproductive condition (males: abdominal or scrotal testes) (females: closed, partially open, or wide open pubic symphysis; perforate or nonperforate vagina; and normal, prominent, or enlarged nipples), and any other pertinent observations such as missing tail, large wound, etc.

Because the age of cotton rats and prairie voles is difficult to estimate from their size (Cameron and Spencer 1981, Stalling 1990), stage classes were assigned using mass (g) (Table 1). Stage class assignments were kept consistent with those used in the previous 27 years. Incidental captures of birds and reptiles were released without marking (other species of small mammals were also counted as incidental captures). Traps were locked open and left on-site between trapping sessions. Trapping and marking protocols followed the American Society of Mammalogists guidelines and were approved by the Emporia State University Animal Care and Use Committee (ESU-ACUC-04-002). Research on the trapping grid was continued under permits previously issued to Norm Slade and the University of Kansas Field Station and Ecological Reserves.

The data I obtained from June through November 2004 were compared to data collected (primarily by Norm Slade and other researchers affiliated with the University of Kansas) from 1977 - 2003 (only during June – November of those years) using monthly trapping sessions on the same grid. The trapping protocol remained the same. However, for this study, the grid was not experimentally manipulated until June 2004.

Statistical analysis.—Initially, I examined space use by *S. hispidus* and *M. ochrogaster* in response to fragmentation resulting from habitat removal. Typically, space use is quantified using home range size: the area used by an individual during typical activities of acquiring food, mating, and nurturing young (Burt 1943), home range overlap, or intensity of use within a home range (Hayne 1949, Andreassen et al. 1998). I calculated home range using a method similar to the Harmonic Mean (HM) method (Dixon and Chapman 1980), which gives an indication of concentrated areas of use within a home range. I made the assumption that the 225 m^2 immediately surrounding any given trap station on the grid was used, in some fashion, by the individual that was captured in the trap. Thus, if an individual was captured only once, or multiple times at the same trap station, the estimated home range size was 225 m^2. However, if an individual was caught in more than one trap, or multiple times at several different trap stations, an average home range size was assigned to the individual based on the trap location and number of captures.

Several researchers have reported on the proper number of captures per individual to use when determining home range estimates. For instance, Slade and Russell (1998) reported $\geq$ 10 captures, Jenrich and Turner (1969) reported a minimum of 3 captures per individual, and Slade and Swihart (1983) reported $\geq$ 4 captures per individual. Using a cumulative performance curve, I plotted the cumulative mean home range size as a function of the number of captures for all individuals (both species calculated separately) captured exactly 10 times. I did this for two reasons: (1) research indicating the appropriate number of captures to calculate home range is inconsistent; (2) to establish a cutoff criterion for calculating home range based on the number of captures of a particular individual for my specific study. I found cumulative mean home range size as estimated by HM, for both *S. hispidus* and *M. ochrogaster*, increased (not tested for significance) as a function of the number of captures (Fig. 4); therefore, my sample size was inadequate to measure home range and, subsequently, space use.

I transitioned to analyzing movements by individuals because research shows that home ranges are comprised of day-to-day movements, which are representative of the distance that an individual travels within its home range (Stickel 1968). However, I examined abundance estimates by individuals to determine species responses to fragmentation.

Abundance.—I determined relative measures of abundance, separately for both *S. hispidus* and *M. ochrogaster*, by dividing the total number of unique individuals per trapping session by the total number of trap nights per session. All uniquely numbered individuals were included in the analysis only once per trapping session but could be included in subsequent trapping sessions to prevent 'trap-happy' individuals from skewing the abundance data. I calculated trap nights by multiplying the total number of traps on the grid by the number of nights each trapping session was run (198 traps x 3 nights/session = 594 trap nights/session). (There was no trap night correction for closed traps or incidental captures, which is consistent with how the previous data were collected.) During 1977 – 2003, there were six, 3-night trapping sessions/year within the June to November time frame.

I performed pairwise correlations using Pearson's product-moment correlation coefficient to examine the monthly abundance estimates for each species from 10 randomly selected pre-mowing years. I did this to determine if there was a relationship between abundances of a single species across the years, i.e., seasonality or lack thereof. I then tested the Pearson's correlation coefficients from the pairwise correlations for significance using single sample t-tests ($\alpha = 0.05$). Seasonality would be evidenced by a significantly positive or significantly negative correlation between the monthly abundances for the pairwise comparisons. Therefore, it would not be appropriate to pool the abundance data within each year because I would need to determine where the abundance changes were occurring and why, e.g., natural seasonal changes in abundance, etc. If there was not seasonality, the correlation for the pairwise comparison would not test significant, and it would be appropriate to pool the monthly abundance data within each year.

I performed 45 pairwise correlations (for each species) on the abundance data for the 10 randomly selected pre-mowing years (Tables 2 and 3). Monthly abundance estimates for *S. hispidus* and *M. ochrogaster* for the 10 randomly selected years are shown in Figs. 5 and 6, respectively (also shown in Figs. 5 and 6 are the post-mowing monthly abundance estimates, note: *S. hispidus* and *M. ochrogaster* were not captured in every month within every pre-mowing year). Using $\alpha = 0.05$, by chance alone, one in 20 times a correlation would appear significant. Therefore, a correlation was only considered significant if the P value from the single sample t-test was less than $0.05/45 = 0.0011$, i.e., $P < \alpha/\text{total number of correlations}$. Out of 45 correlations for each species, none were significant for either species (Tables 2 and 3). This indicated that, as a whole, abundances were not rising and/or falling in the same months each year for either species, i.e., there was a lack of seasonality. Thus, I determined that it would be appropriate to pool the abundance data within each year because there was no indication of seasonality in terms of monthly abundance estimates across years.

To test for abundance differences pre- and post-mowing, I used a relative measure of abundance of unique individuals for both *S. hispidus* and *M. ochrogaster* separately, using the same method for estimating abundance mentioned previously on preM, preU, postM, and postU patches. However, unlike the method above, if an individual was captured on a preM and preU patch (or postM and postU) within the same trapping session, that individual was counted twice, once as a preM individual and once as a preU individual, so as not to bias the abundance in one patch type. No individuals were marked as reproductive and non-reproductive within the same trapping session. I then took the number of unique individuals on the preM patches minus the number of unique individuals on the preU (and postM – postU) patches for each trapping session within each year. I averaged these numbers for each year, based on the number of trapping sessions in that year, i.e., six, to produce a yearly abundance difference estimate. I then used single sample t-tests ($\alpha = 0.01$) to compare the post-mowing (sample) average abundance difference estimate to pre-mowing (population) average abundance difference estimate. (I used a Type I error rate of 0.01 for my single sample t-tests because there were multiple comparisons within a single data set, and therefore, a lack of independence.) I did this for overall, sex, reproductive condition, and stage class for both species.

Movement.—I examined means and VM ratios of the pre- and post-mowing distances moved by individuals between successive captures for overall, sex, reproductive condition, and stage class for both species. I did this to examine differences in the shape of the distribution of movements between successive captures. I used single sample t-tests ($\alpha = 0.01$) to compare the post-mowing sample averages, i.e., mean distance and VM ratio, to the distributions of pre-mowing population averages. All statistical analyses were performed using SigmaStat 3.11 (Systat Software 2004).

RESULTS

In total, there were 96,228 trap nights pre-mowing (27 years x 594 trap nights/trap session x 6 trap sessions/year) and 8,316 trap nights post-mowing (594 trap nights/trap session x 14 trap sessions).

Abundance.—I pooled all monthly abundance difference estimates (preM – preU) to arrive at a yearly abundance difference estimate. I averaged these differences for all pre-mowing years and compared them to the post-mowing average abundance estimate differences (postM – postU) for all categories of both species. All categories for *S. hispidus* and *M. ochrogaster* (excluding *M. ochrogaster* sub-adults) had significantly lower post-mowing sample mean differences, in terms of the preM – preU versus the postM – postU abundance estimate data. These results, in conjunction with the raw abundance data, indicate that abundance decreased on both patch types, but decreased more on the postM patches (Table 4).

Movement by Sigmodon hispidus.—*(Overall)* The post-mowing sample mean distance moved by individuals in the overall category came from the distribution of pre-mowing mean distances moved (all mean distances were rounded to the nearest integer) (Table 5). The distribution of pre-mowing VM ratio averages ranged from 7 to 28 (Fig. 7) and the post-mowing sample VM ratio average came from the distribution of pre-mowing VM ratio averages (all VM ratios were rounded to the nearest integer) (Table 6).

(Sex and Reproductive Condition) The post-mowing sample mean distance moved by males came from the distribution of pre-mowing mean distances while the post-mowing sample means for reproductive males (left, indicates the position of the post-mowing sample mean on the x-axis, relative to the distribution of pre-mowing means) and non-

reproductive males (right) did not (Table 5). The distribution of pre-mowing VM ratios ranged from 5 to 32 for males, 9 to 31 for reproductive males, and 5 to 36 for non-reproductive males (Figs. 8, 9, and 10, respectively). The post-mowing sample VM ratio means came from the distributions of pre-mowing VM ratio means for males and reproductive males; however, the post-mowing sample VM ratio for non-reproductive males (right) did not come from the pre-mowing distribution (Table 6). The post-mowing sample mean distance moved by females (right) did not come from the distribution of pre-mowing mean distances; however, the post-mowing sample mean distances moved by reproductive females and non-reproductive females came from their respective distributions of pre-mowing mean distances (Table 5). The distribution of pre-mowing VM ratios ranged from 5 to 25 for females, 7 to 28 for reproductive females, and 1 to 31 for non-reproductive females (Figs. 11, 12, and 13, respectively). The post-mowing sample VM ratio came from the pre-mowing distribution of VM ratios for females and reproductive females; however, the post-mowing sample VM ratio (right) did not come from the pre-mowing distribution of VM ratios for non-reproductive females (Table 6).

(*Stage Class*) The post-mowing sample mean distances moved by adults, sub-adults, and juveniles came from their respective distributions of pre-mowing mean distances (Table 5). The distribution of pre-mowing VM ratios ranged from 15 to 32 for adults, 9 to 47 for sub-adults, and 6 to 29 for juveniles (Figs. 14, 15, and 16, respectively). The post-mowing sample VM ratio average came from the distribution of pre-mowing VM ratio averages for adults; however, the post-mowing sample VM ratio average did not come from the pre-mowing distributions of VM ratio averages for sub-adults (right) or juveniles (left) (Table 6).

Movement by Microtus ochrogaster.—*(Overall)* The post-mowing sample mean distance moved came from the distribution of pre-mowing mean distances (Table 5). The distribution of pre-mowing VM ratio averages ranged from 7 to 32 (Fig. 17), and the post-mowing sample VM ratio (right) did not come from the distribution of pre-mowing averages (Table 6).

(Sex and Reproductive Condition) The post-mowing sample mean distances moved by male, reproductive male, and non-reproductive male *M. ochrogaster* came from their respective distribution of pre-mowing means (Table 5). The distribution of pre-mowing VM ratios ranged from 9 to 46 for males, 9 to 35 for reproductive males, and 9 to 63 for non-reproductive males (Figs. 18, 19, and 20, respectively). The post-mowing sample VM ratio average did not come from the distribution of pre-mowing VM ratio averages for males (right) and non-reproductive males (right); however, the post-mowing sample VM ratio average came from the distribution of pre-mowing VM ratio averages for reproductive males (Table 6).

The post-mowing sample mean distance moved by females came from the distribution of pre-mowing mean distances moved while the post-mowing sample means for reproductive females (right) and non-reproductive females (left) did not (Table 5). The distribution of pre-mowing VM ratios ranged from 5 to 45 for females, 1 to 69 for reproductive females, and 9 to 43 for non-reproductive females (Figs. 21, 22, and 23, respectively). The post-mowing sample VM ratio average did not come from the distribution of pre-mowing VM ratio averages for females (right), reproductive females (right), or non-reproductive females (left) (Table 6).

(*Stage Class*) The post-mowing sample mean distance moved by adults came from the distribution of pre-mowing mean distances moved; however, the post-mowing sample mean distance moved by sub-adults (left) and juveniles (left) did not (Table 5). The distribution of pre-mowing VM ratios ranged from 7 to 32 for adults, 3 to 41 for sub-adults, and 8 to 15 for juveniles (Figs. 24, 25, and 26, respectively). The post-mowing sample VM ratio average did not come from the distribution of pre-mowing VM ratio averages for adults (right). The post-mowing VM ratios for sub-adult and juvenile *M. ochrogaster* were undefined because individuals were either captured only once or were captured multiple times at the same trap station, making the mean distance moved equal to zero meters (Table 6).

DISCUSSION

The goal of the present investigation was to quantify changes in abundance and space use by *S. hispidus* and *M. ochrogaster* after habitat fragmentation resulting from habitat removal.

Abundance.—Abundance estimates quantify pre- and post-mowing occupancy of habitat patches and, thus, establish if organisms responded to the fragmentation. Abundance estimate differences (preM abundance estimate – preU abundance estimate) were pooled within each year and then averaged among all of the pre-mowing years for each category. I anticipated that the overall pre-mowing abundance estimate difference for each category would be very close to zero, suggesting that grid use was uniform by both species prior to mowing. What I found was that for both species in all categories, individuals used the preM patches slightly more than the preU patches, evidenced by a lack of negative pre-mowing (population) mean differences (Table 4). These results are surprising, in that I arbitrarily chose the pattern that was mowed on the field. The postU patches were used more than the postM patches, evidenced by a lack of positive post-mowing (sample) mean differences (Table 4). However, based on my observation alone, there were few individuals using either patch type post-mowing. The decrease in abundance on the postM patches, however, did indicate that individuals found the postM patches unsuitable (excluding sub-adult prairie voles). The sub-adult prairie vole P value of 0.036 was approaching significance ($\alpha = 0.01$), and it may be reasonable to infer that this category of individuals is of no more interest, in terms of the abundance differences on the pre- and post-mowing patch types, than any of the other categories (Table 4).

Similar results, i.e., abundance decreases by *S. hispidus* and *M. ochrogaster* in mowed areas, have been documented on the same grid; however, in that study, the grid was mowed into 15 m strips and the impacts of mowing may not have been as substantial due to strip-mowing creating a more continuous landscape pattern (Slade and Crain 2006). The results from my study are not surprising in that both species prefer vegetative cover over bare ground and are typically not found in areas with sparse cover (Slade and Swihart 1983, Foster and Gaines 1991, Schweiger et al. 2000). The following section provides discussion on how the various categories of individuals responded, in terms of movement, to fragmentation.

Movement.—Several of the categories of both *S. hispidus* and *M. ochrogaster* had either a post-mowing mean distance that came from the pre-mowing distribution of mean distances or a significantly smaller mean distance that did not come from the pre-mowing distribution (Table 5). Thus, although postU patch size appeared to be appropriate for these categories of individuals, the abundance decreases on the postU patches were likely a result of fewer individuals traversing through these patches. There also were categories of individuals where the post-mowing sample VM ratio average did not come from the distribution of pre-mowing VM ratio averages, which provides evidence that there were changes in the proportion of short- or long-distance movements made by individuals in response to fragmentation.

To calculate a VM ratio for any category (overall, sex, reproductive condition, or stage class), at least one individual within that category had to have moved the distance between two trap stations, i.e., 15 m. Unfortunately, these types of biased distances, i.e., predetermined distances between trap stations, are encountered when using trapping grids (Slade and Russell 1998), and, based on the grid layout, there existed a finite amount of estimatable distances that an individual could have potentially moved between sequential captures. These distances occurred within all *S. hispidus* categories and all but two categories of *M. ochrogaster* (sub-adults and juveniles).

PostU patch size was appropriate for both the overall category of *S. hispidus* and the overall category of *M. ochrogaster*, but fewer individuals in both categories were moving through the postU patches. (Refer to Fig. 1 for the possible abundance and movement scenarios post-fragmentation, indicative of postU patch size appropriateness for all categories of both species). Of the movements by *S. hispidus* overall, there was no evidence of an increase or decrease in the proportion of short- or long-distance movements and, therefore, the distribution of movements did not become more or less skewed. Conversely, although postU patch size was not a factor, in terms of size, for the overall category of *M. ochrogaster*, they did show aggregation around, or an increased tendency towards, shorter distance movements within the distribution of movements in response to habitat fragmentation. Additionally, the individuals in the overall category of prairie voles cut off long distance movements within their distribution of movements.

Male *S. hispidus* and male *M. ochrogaster* demonstrated results like those of their respective overall categories. Thus, postU patch size for both categories was appropriate, but there were significantly fewer individuals moving throughout the entire grid. The overall shape of the distribution of movements for male cotton rats remained the same, and there were no more or less short- or long-distance movements made by these individuals post-mowing. The mean length of the movements within the distribution of movements for the male prairie voles did not change; however, they did increase the proportion of short-distance movements made post-mowing.

PostU patch size was also appropriate for both reproductive male cotton rats and reproductive male prairie voles; therefore, the observed abundance decreases on the postU patches were likely caused by fewer of these individuals wandering through the patches. And, the shapes of the movement distributions for both categories did not change post-mowing. Thus, the proportion of long- and short-distance movements making up their respective distributions of movements did not change in response to fragmentation. Post-mowing, reproductive male *S. hispidus* moved significantly shorter distances within their distribution of movements. Reproductive male cotton rats were presumably the largest, oldest, and most territorial individuals on the grid (Beeman 1947, Christian 1970, Gosling et al. 2000). Therefore, it might be reasonable to assume that, in addition to postU patch size being appropriate, these individuals decreased the overall length of their movement to occupy the remaining postU patches. Further, mammals generally occupy the habitat for which they are best adapted and, typically, the best areas within the habitat are occupied by the most territorial individuals (Christian 1970). Also, more territorial individuals have greater success at occupying habitat patches than those individuals that are less territorial (Spencer and Cameron 1983).

Non-reproductive male cotton rat results suggested that patch size was too small for these individuals and they were likely moving from postU patch to postU patch, over unsuitable postM patches, to acquire resources. On the other hand, postU patch size for non-reproductive male *M. ochrogaster* was suitable. Additionally, there was an increase in the proportion of shorter distance movements for both non-reproductive male *S. hispidus* and non-reproductive male prairie voles post-mowing. Thus, it could be that instead of postU patch size being too small, non-reproductive male cotton rats were moving from patch to patch to find areas not saturated with territorial individuals, in particular, reproductive male *S. hispidus* (Christian 1970). Additionally, assuming that non-reproductive males were moving to different areas to avoid the reproductive males, the habitats sought by these individuals likely were marginal compared to those occupied by reproductive males (Goertz 1964). PostU patch size was appropriate for non-reproductive male prairie voles, but this category of individuals ceased making the long-distance movements that were made prior to mowing.

Female cotton rats showed a similar response as the non-reproductive male cotton rats in terms of an increase in the overall length of movement within the distribution of movements, suggesting that postU patch size was too small and individuals were likely using multiple postU patches. However, the overall shape of the distribution of movements did not change for female cotton rats post-mowing. Patch size for *M. ochrogaster* females was appropriate, but there was post-mowing aggregation around the shorter-distance movements within their distribution of movements.

Reproductive female cotton rats demonstrated the same results as the overall category of *S. hispidus*. Therefore, postU patch size was appropriate and there was no more or less movement aggregation post-mowing. On the contrary, reproductive female prairie voles showed aggregation around the shorter-distance movements and an overall increase in movement length within their distribution, suggesting that postU patch size was too small. Results from reproductive female prairie voles are not surprising, in that studies have shown that habitats sought by female rodents, in particular reproductive females, are based on food quality/quantity due to the high cost of lactation associated with reproduction (Kincaid and Cameron 1985, Ostfeld 1985, Cameron and Spencer 1985, Ims 1987, Jones 1990, Slade et al. 1997). Thus, it may be that these individuals were moving from postU patch to postU patch to find adequate resources, but perhaps not finding sufficient resources in any given postU patch.

PostU patch size for both non-reproductive female cotton rats and non-reproductive female prairie voles was adequate. Movements by non-reproductive female cotton rats clustered around the shorter-distance end of their distribution of movements, while movements by non-reproductive female *M. ochrogaster* aggregated around the longer-distance end of their distribution of movements.

In terms of the actual pre- and post-mowing distances moved between successive captures, both sexes demonstrated movement tendencies consistent with observations of several other researchers who have suggested that longer-distance movements made by males are typical within not only *S. hispidus* and *M. ochrogaster*, but within several other small mammal species (Fleharty and Mares 1973, Cameron et al. 1979, Slade et al. 1997, Andreassen et al. 1998, Solomon and Jacquot 2002). This was true for both species, both pre- and post-mowing (Table 5). Therefore, it appears as though habitat fragmentation did not alter this documented species characteristic.

Adult *S. hispidus* showed the same response as the overall category of cotton rats and, therefore, postU patch size was appropriate and there were no more or less short- or long-distance movements made in response to habitat fragmentation. Adult prairie voles also showed the same response as their overall category in terms of postU patch size being appropriate and individuals within the category moving a greater proportion of shorter-distance movements within the distribution of post-mowing movements. The results from the adult categories for either species are not surprising in that, based on my observation alone, the majority of the individuals captured both pre- and post-mowing were adults, and subsequently, the bulk of their respective overall categories.

PostU patch size for sub-adult cotton rats was sufficient. Additionally, these individuals made a greater proportion of short-distance movements post-mowing and did not increase or decrease the overall length of movement within their distribution of movements. However, the extremely long-distance travels within the distribution of movements were ceased by these individuals in response to fragmentation. The sub-adult prairie voles that were captured were only captured once or multiple times at the same trapping station, making the post-mowing VM ratio average undefined. Even though this category decreased the length of their overall movement, there were very few of these individuals captured post-mowing, i.e., seven, and, therefore, results might be attributable to the small sample size, which could provide further evidence that this category of individuals (and the juvenile category of *M. ochrogaster*) is more sensitive to the impacts of fragmentation.

Juvenile cotton rats clumped their movements around the longer-distance movements within the distribution of movements. These individuals also ceased making the short distance movements within the distribution of movements, but the overall length of the movements within the movement distribution did not change in response to habitat fragmentation. Juvenile prairie voles, like sub-adult prairie voles, had an undefined post-mowing VM ratio average as well as a shorter post-mowing average distance moved. As few individuals were captured post-mowing, i.e., two, inferences regarding movement might be questionable as a result of the small sample size.

Overall conclusions.—There was no evidence that fragmentation at this scale resulted in crowding of postU patches and subsequent long-distance movements to compensate for over-populated patches for either *S. hispidus* or *M. ochrogaster*. Nor was there evidence that individuals from either species were confined to postU patches or that postU patches were not at capacity prior to mowing. Additionally, there was no instance where abundance on the postU patches or movement by individuals suggested that home range size was within postU patch size and long-distance movements were ceased. However, it did appear as though the generalized response by the individuals to the habitat fragmentation was simply relocation to somewhere other than the trapping grid. Granted, it is possible that some individuals may have been killed by the mower and/or the individuals moving through the grid were wanderers as opposed to members of the pre-mowing population. But, individuals were still moving through the grid and using the postU patches to some extent, indicating that the cover and resources provided by these patches was enough to promote at least minimal use by some individuals. And, in response to the fragmentation, most categories of individuals were moving a greater proportion of shorter-distance movements within their distribution of movements.

Future research might examine these individuals on the same fragmented trapping grid using radio-collars, such that the exact whereabouts of an individual could be tracked once it left the grid. Additionally, examination of the responses by other species caught on the trapping grid might provide insight concerning possible inter-specific interactions.

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TABLE 1. Stage class assignments according to mass (g) for *S. hispidus* and *M. ochrogaster*.

Species	Stage Class Assignment/Mass (g)		
	Juveniles	Sub-adults	Adults
S. hispidus	0-59	60-99	100+
M. ochrogaster	0-15	16-29	30+

TABLE 2. Pairwise correlation results ($\alpha = 0.05$) for *S. hispidus* – I performed the analysis on monthly abundance estimates from 10 randomly selected pre-mowing years to determine if there was a relationship between abundances across the years. Cell contents (top to bottom): Pearson's correlation coefficient, P value from single sample t-test, and number of samples. If the P value was less than $0.05/45 = 0.0011$, i.e., $P < \alpha$/total number of correlations, then it was considered significant. There were no significant correlations for *S. hispidus*. Note: *S. hispidus* was not caught in all six trapping sessions every year.

Year	1983	1984	1985	1986	1991	1993	1996	1997	2001
1980	-0.964 0.0357 4	0.981 0.0192 4	0.997 0.00318 4	0.968 0.0317 4	0.376 0.624 4	0.660 0.340 4	-0.288 0.712 4	1.000 -- 2	.0975 0.0247 4
1983		-0.755 0.140 5	-0.767 0.130 5	-0.765 0.132 5	-0.600 0.208 6	-0.746 0.0885 6	0.411 0.418 6	-1.000 -- 2	-0.857 0.0293 6
1984			0.984 0.00243 5	0.989 0.00132 5	0.123 0.843 5	0.628 0.257 5	0.114 0.855 5	1.000 -- 2	0.944 0.0159 5
1985				0.976 0.00432 5	0.0702 0.911 5	0.634 0.250 5	-0.0433 0.945 5	1.000 -- 2	0.963 0.00865 5
1986					0.0798 0.899 5	0.539 0.349 5	0.0599 0.924 5	1.000 -- 2	0.909 0.0326 5
1991						0.673 0.143 6	-0.0722 0.892 6	1.000 -- 2	0.303 0.559 6
1993							-0.118 0.824 6	1.000 -- 2	0.815 0.0481 6
1996								-1.000 -- 2	-0.205 0.697 6
1997									1.000 -- 2

TABLE 3. Pairwise correlation results ($\alpha = 0.05$) for *M. ochrogaster* – I performed the analysis on monthly abundance estimates from 10 randomly selected pre-mowing years to determine if there was a relationship between abundances across the years. Cell contents (top to bottom): Pearson's correlation coefficient, P value from single sample t-test, and number of samples. If the P value was less than $0.05/45 = 0.0011$, i.e., $P < \alpha$/total number of correlations, then it was considered significant. *The correlation between 1980 and 1985 was the only significant correlation (shown in bold). Note: *M. ochrogaster* was not caught in all six trapping sessions every year.

Year	1983	1984	1985	1986	1991	1993	1996	1997	2001
1980	-0.756 0.454 3	0.996 0.0579 3	-1.000 ***1.18x10^{-7}** 3	1.000 -- 2	-0.0524 0.967 3	0.804 0.405 3	0.857 0.345 3	0.943 0.216 3	0.954 0.194 3
1983		-0.862 0.0602 5	0.467 0.351 6	-0.780 0.120 5	0.852 0.0312 6	-0.630 0.180 6	-0.590 0.218 6	-0.250 0.633 6	-0.810 0.0505 6
1984			-0.746 0.148 5	0.989 0.0110 4	-0.457 0.440 5	0.813 0.0942 5	0.928 0.0231 5	0.668 0.218 5	0.816 0.0612 5
1985				-0.659 0.226 5	0.0689 0.897 6	-0.390 0.445 6	-0.794 0.0595 6	-0.046 0.931 6	-0.345 0.503 6
1986					-0.505 0.386 5	0.839 0.0757 5	0.712 0.178 5	0.820 0.0893 5	0.858 0.0631 5
1991						-0.247 0.637 6	-0.0944 0.859 6	0.0956 0.857 6	-0.631 0.179 6
1993							0.855 0.0302 6	0.848 0.0330 6	0.766 0.0759 6
1996								0.599 0.209 6	0.592 0.216 6
1997									0.550 0.258 6

TABLE 4. Single sample t-test ($\alpha = 0.01$) results for *S. hispidus* and *M. ochrogaster*– Pre- and post-mowing abundance estimate differences (preM – preU or postM – postU). Significant values are bold.

Species	Category	Pre-mowing (population) mean difference	Post-mowing (sample) mean difference	P value	df
S. hispidus	Overall	0.010	-0.026	**<0.001**	26
	Males	0.006	-0.013	**<0.001**	25
	Reproductive (m)	0.002	-0.008	**<0.001**	26
	Non-reproductive (m)	0.004	-0.007	**<0.001**	26
	Females	0.005	-0.013	**<0.001**	25
	Reproductive (f)	0.001	-0.002	**<0.001**	26
	Non-reproductive (f)	0.003	-0.010	**<0.001**	26
	Adults	0.004	-0.016	**<0.001**	25
	Sub-adults	0.003	-0.006	**<0.001**	25
	Juveniles	0.004	-0.004	**<0.001**	25
M. ochrogaster	Overall	0.017	-0.006	**<0.001**	26
	Males	0.007	-0.003	**<0.001**	26
	Reproductive (m)	0.006	-0.002	**<0.001**	26
	Non-reproductive (m)	0.002	-0.002	**<0.001**	26
	Females	0.009	-0.003	**<0.001**	26
	Reproductive (f)	0.002	-0.001	**<0.001**	26
	Non-reproductive (f)	0.004	-0.001	**<0.001**	26
	Adults	0.014	-0.006	**<0.001**	26
	Sub-adults	0.002	$4.81\text{x}10^{-4}$	0.036	26
	Juveniles	0.001	$-2.41\text{x}10^{-4}$	**<0.001**	26

TABLE 5. Single sample t-test ($\alpha = 0.01$) results for *S. hispidus* and *M. ochrogaster* – Pre- and post-mowing mean distances moved between successive captures. Mean distances are rounded to the nearest integer. Significant values are bold. The post-mowing *M. ochrogaster* sub-adults and juveniles that were captured were only captured once or multiple times at the same trap station making the mean distance moved 0 meters.

Species	Variable	Pre-mowing (population) mean (meters)	Post-mowing (sample) mean (meters)	P value	df
S. hispidus	Overall	24	27	0.031	24
	Males	29	30	0.472	24
	Reproductive (m)	40	28	**<0.001**	20
	Non-reproductive (m)	24	31	**<0.001**	24
	Females	20	25	**0.001**	22
	Reproductive (f)	19	24	0.078	18
	Non-reproductive (f)	23	24	0.382	19
	Adults	28	29	0.816	22
	Sub-adults	23	24	0.603	24
	Juveniles	23	25	0.532	22
M. ochrogaster	Overall	11	11	0.904	24
	Males	13	14	0.637	24
	Reproductive (m)	14	13	0.697	23
	Non-reproductive (m)	12	13	0.269	22
	Females	10	8	0.067	24
	Reproductive (f)	10	15	**<0.001**	24
	Non-reproductive (f)	9	3	**<0.001**	23
	Adults	11	12	0.237	24
	Sub-adults	12	0	**<0.001**	22
	Juveniles	5	0	**<0.001**	13

TABLE 6. Single sample t-test ($\alpha = 0.01$) results for *S. hispidus* and *M. ochrogaster* – Pre- and post-mowing average VM ratios. VM ratios are rounded to the nearest integer. Significant values are bold. The post-mowing *M. ochrogaster* sub-adults and juveniles that were captured were only captured once or multiple times at the same trap station making for a mean distance moved of 0 meters and, therefore, an undefined VM ratio (represented by Ø).

Species	Category	Pre-mowing (population) mean	Post-mowing (sample) mean	P value	df
S. hispidus	Overall	21	21	0.815	22
	Males	21	23	0.377	23
	Reproductive (m)	20	19	0.633	20
	Non-reproductive (m)	20	26	**0.007**	23
	Females	17	19	0.075	22
	Reproductive (f)	13	12	0.303	15
	Non-reproductive (f)	14	22	**<0.001**	19
	Adults	22	21	0.541	22
	Sub-adults	20	27	**0.006**	23
	Juveniles	14	7	**<0.001**	22
M. ochrogaster	Overall	17	46	**<0.001**	25
	Males	17	46	**<0.001**	24
	Reproductive (m)	15	15	0.909	23
	Non-reproductive (m)	20	98	**<0.001**	21
	Females	16	46	**<0.001**	24
	Reproductive (f)	17	50	**<0.001**	24
	Non-reproductive (f)	20	13	**0.001**	21
	Adults	17	46	**<0.001**	24
	Sub-adults	17	Ø	-	-
	Juveniles	8	Ø	-	-

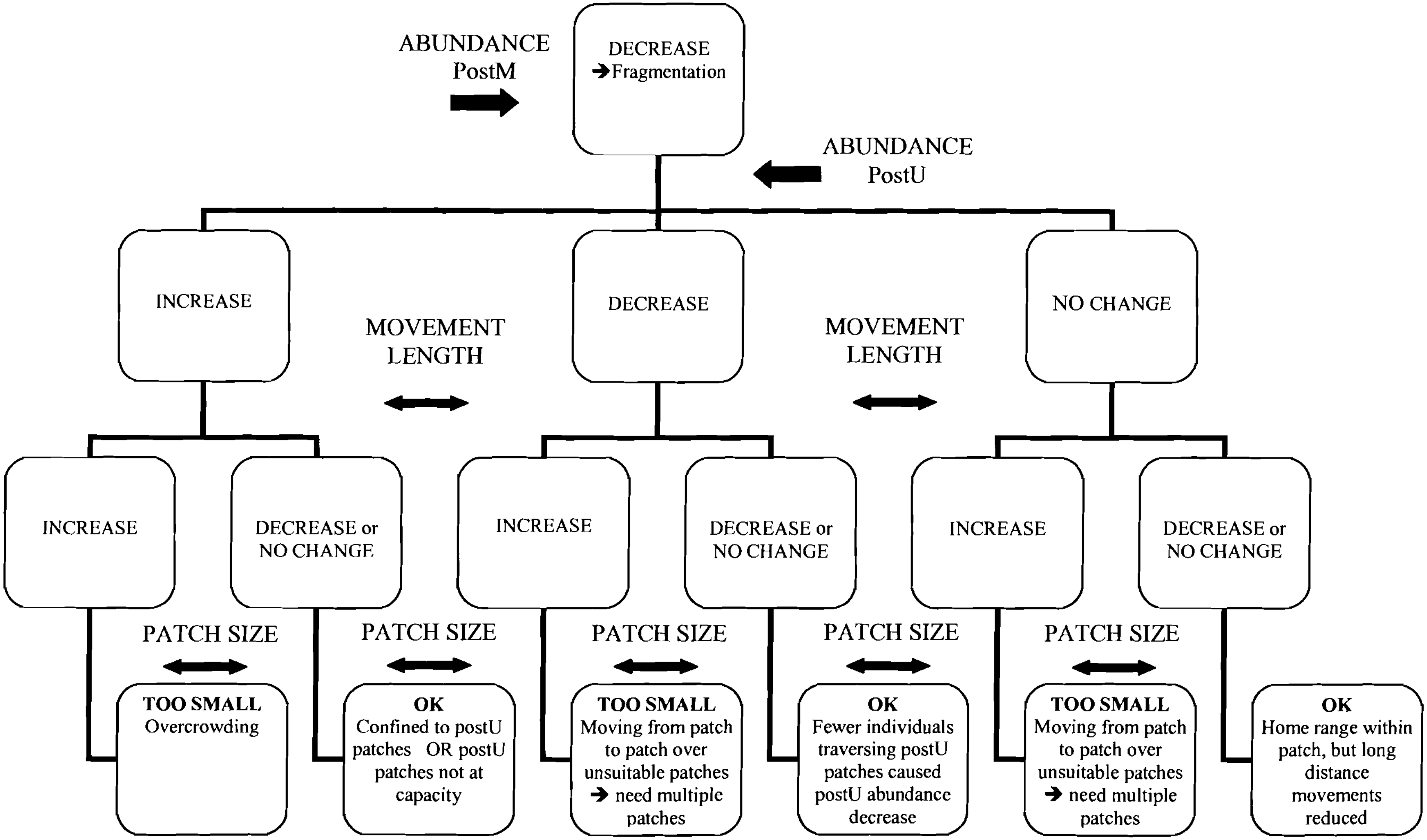

FIG. 1.—Flow chart of possible abundance scenarios on postU patches (following abundance decrease on postM patches) together with possible movement length scenarios post-fragmentation, indicative of postU patch size appropriateness and movement change (space use) post-fragmentation for *S. hispidus* and *M. ochrogaster*.

FIG. 2.—Aerial photograph of the University of Kansas' John H. Nelson Environmental Study Area, 14.5 km northeast of Lawrence, Kansas. The trapping grid is located in the upper right corner of the photograph and is outlined in red.

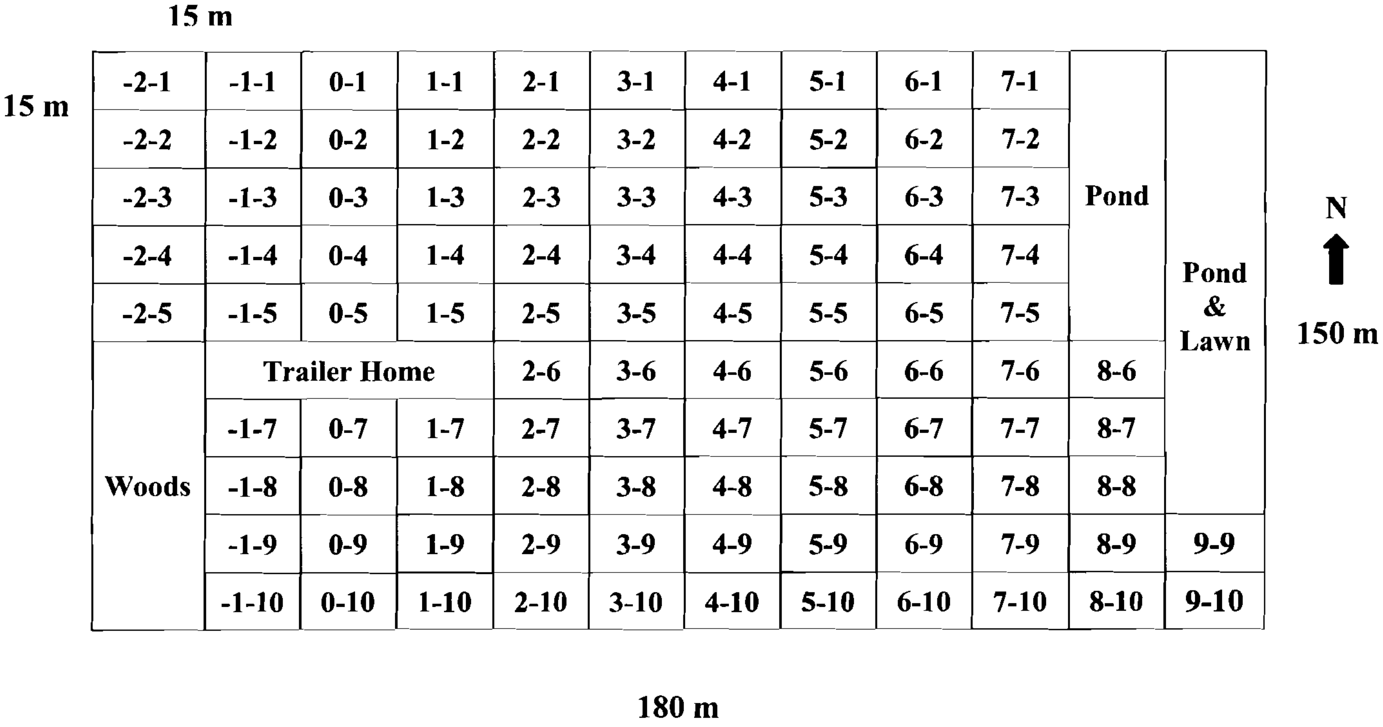

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FIG. 3.—Layout of small mammal trapping grid at the University of Kansas' John H. Nelson Environmental Study Area, 14.5km northeast of Lawrence, Kansas. Each numbered box represents a trapping station (spaced 15 m from neighboring trapping stations in the four cardinal directions) and consisted of two Sherman live traps (8 x 9 x 23 cm). Each numbered box consisted of a 225 m^2 area. A 3 m wide road transected the _-5's and the _-6's and wrapped around the southeast side of the grid. Post-mowing: shaded boxes represent areas left intact and white boxes represent mowed areas. Pre-mowing: the grid would have been entirely shaded representing a continuous unmowed field.

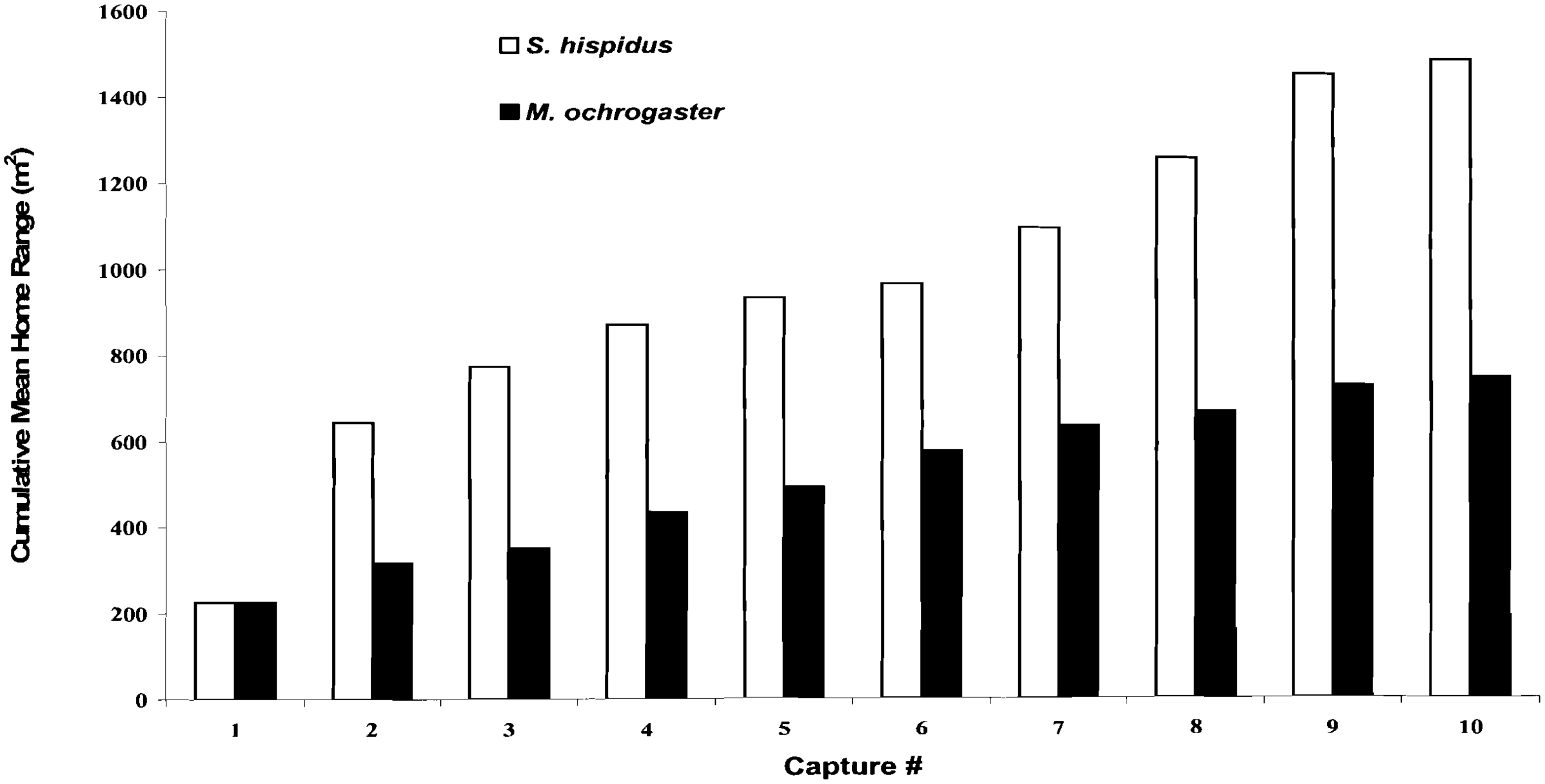

FIG. 4.—Cumulative mean home range (m^2) per capture for pre-mowing individuals captured exactly 10 times (N = 27 for *M. ochrogaster*; N = 7 for *S. hispidus*).

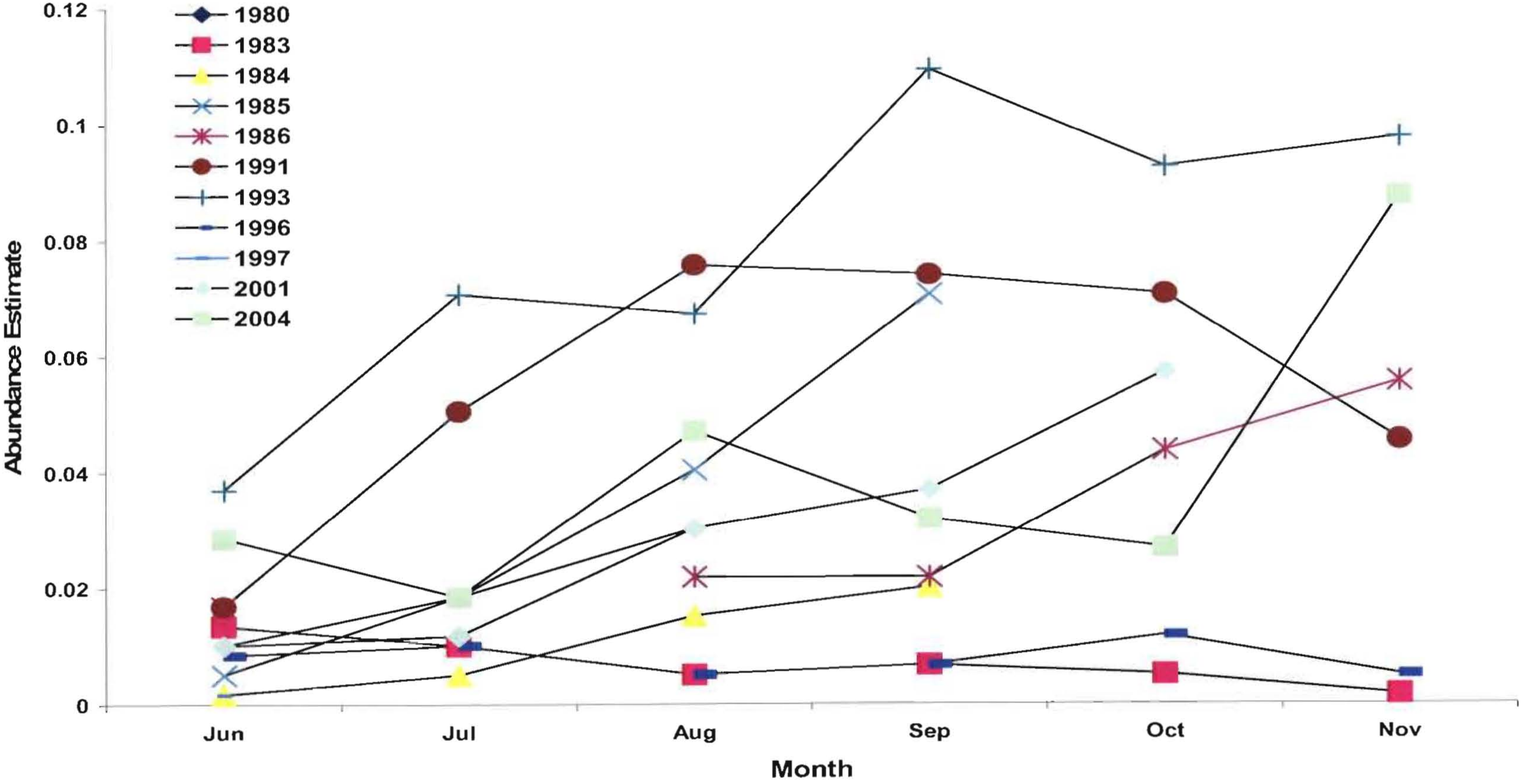

FIG. 5.—Monthly abundance estimates for *S. hispidus* for 10 randomly selected pre-mowing years, plus the post-mowing monthly abundance estimates. The line connecting the monthly abundance estimates is not continuous for each year as *S. hispidus* was not captured every month within every year.

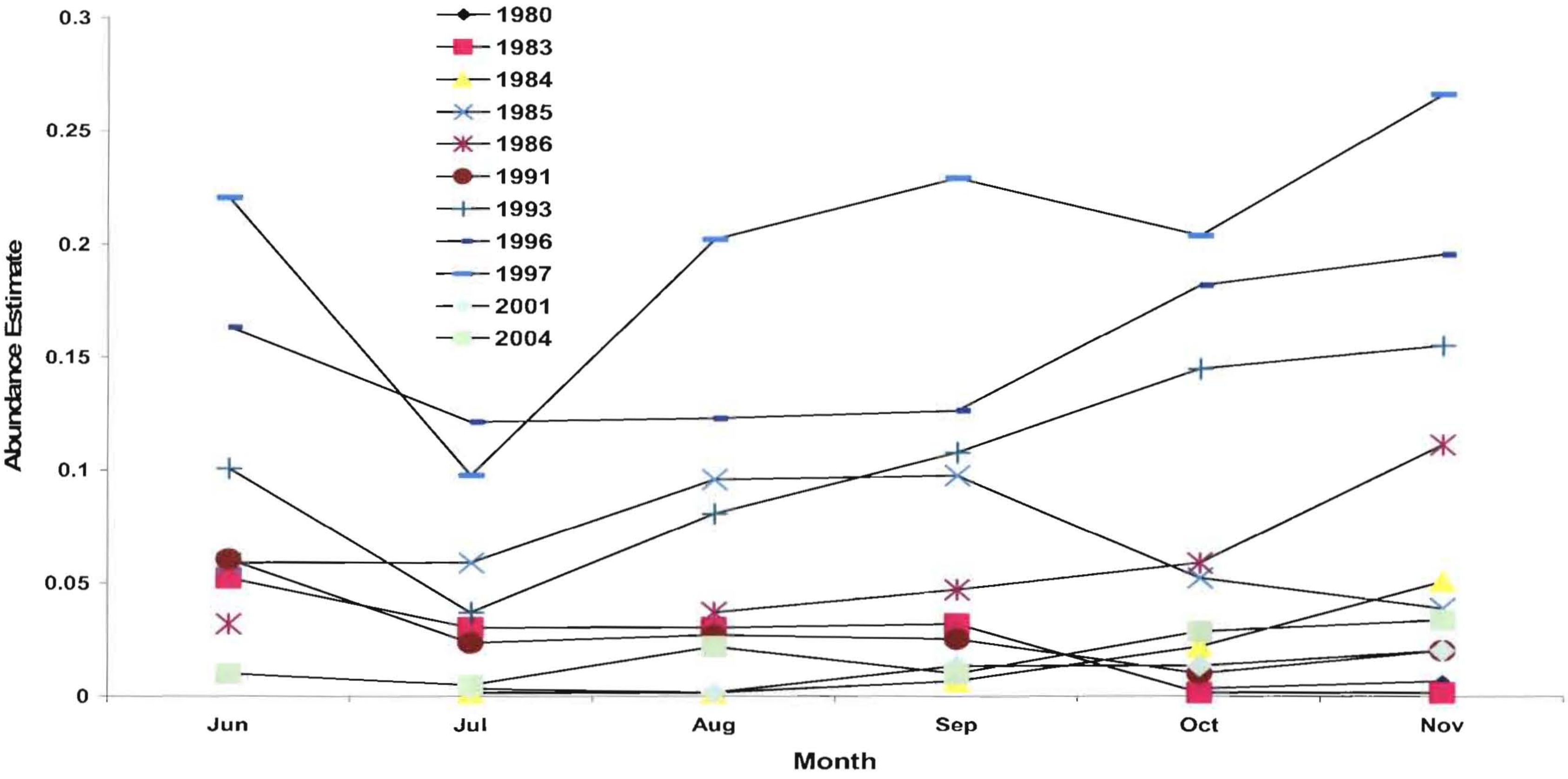

FIG. 6.—Monthly abundance estimates for *M. ochrogaster* for 10 randomly selected pre-mowing years, plus the post-mowing monthly abundance estimates. The line connecting the monthly abundance estimates is not continuous for each year as *M. ochrogaster* was not captured every month within every year.

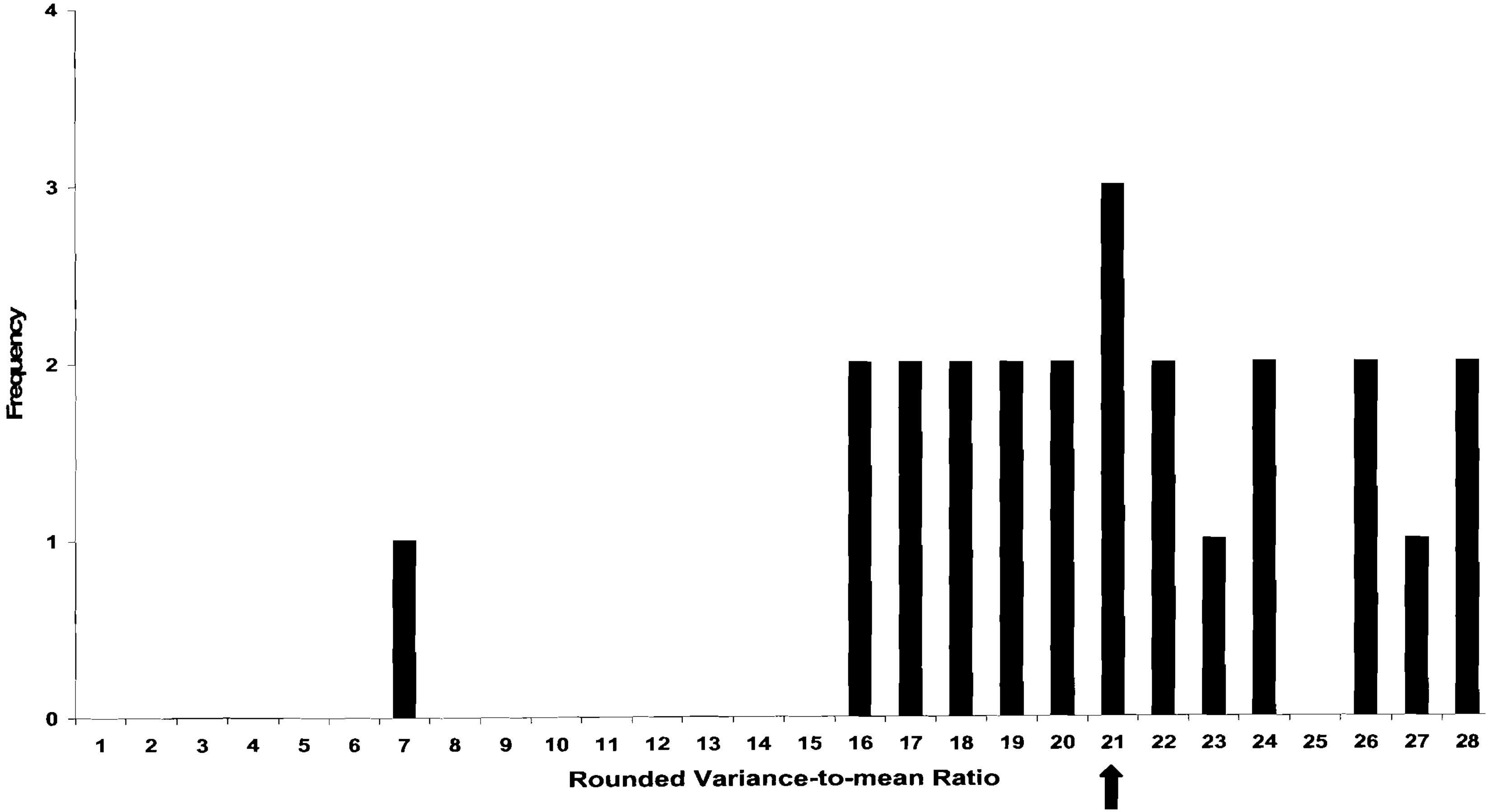

FIG. 7.—Frequency distribution of pre-mowing (1977 – 2003) VM ratio averages for overall *S. hispidus*. Positioning of the post-mowing (2004) VM ratio on the X-axis is denoted (21) with an arrow. VM ratios are rounded to the nearest integer.

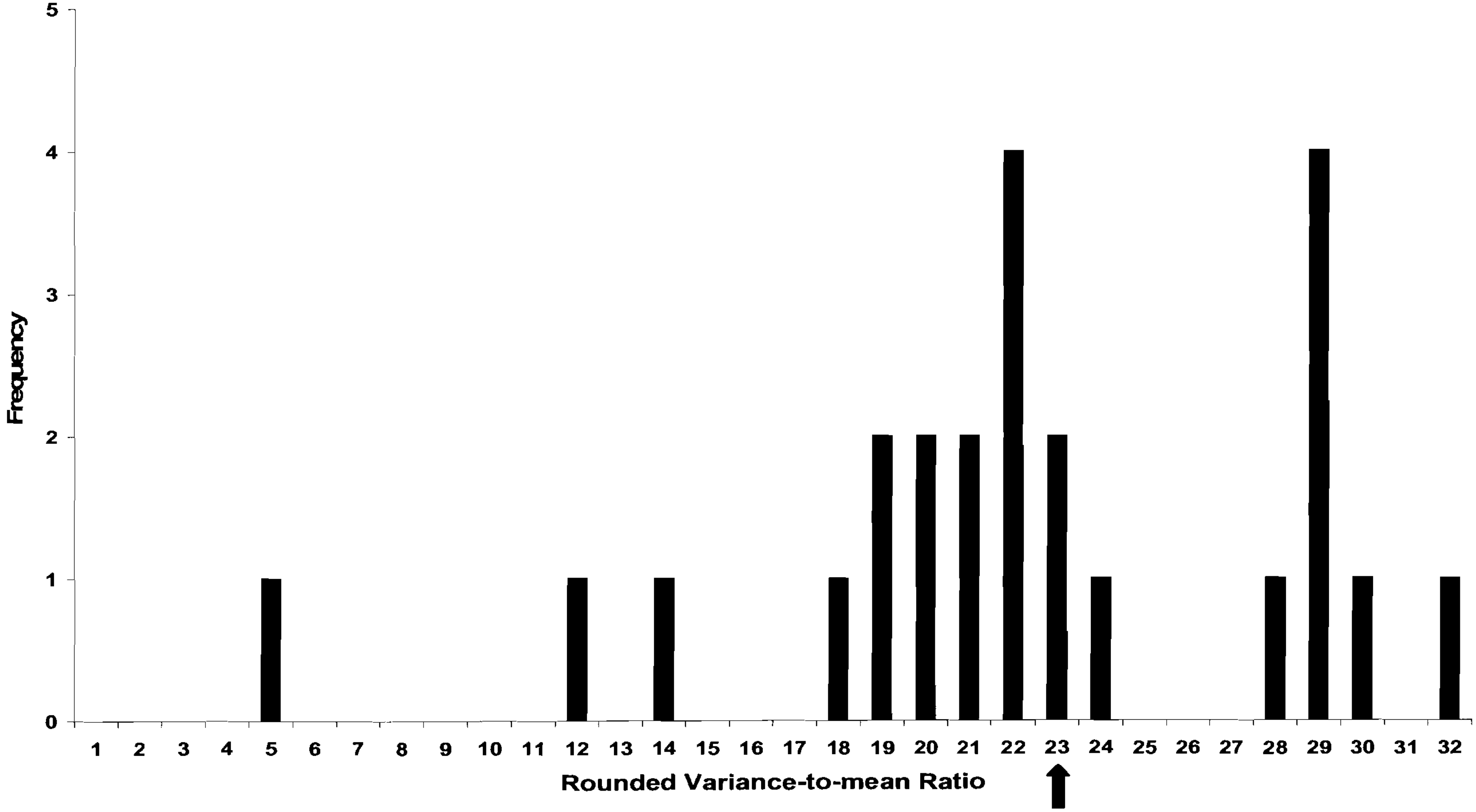

FIG. 8.—Frequency distribution of pre-mowing (1977 – 2003) VM ratio averages for male *S. hispidus*. Positioning of the post-mowing (2004) VM ratio on the X-axis is denoted (23) with an arrow. VM ratios are rounded to the nearest integer.

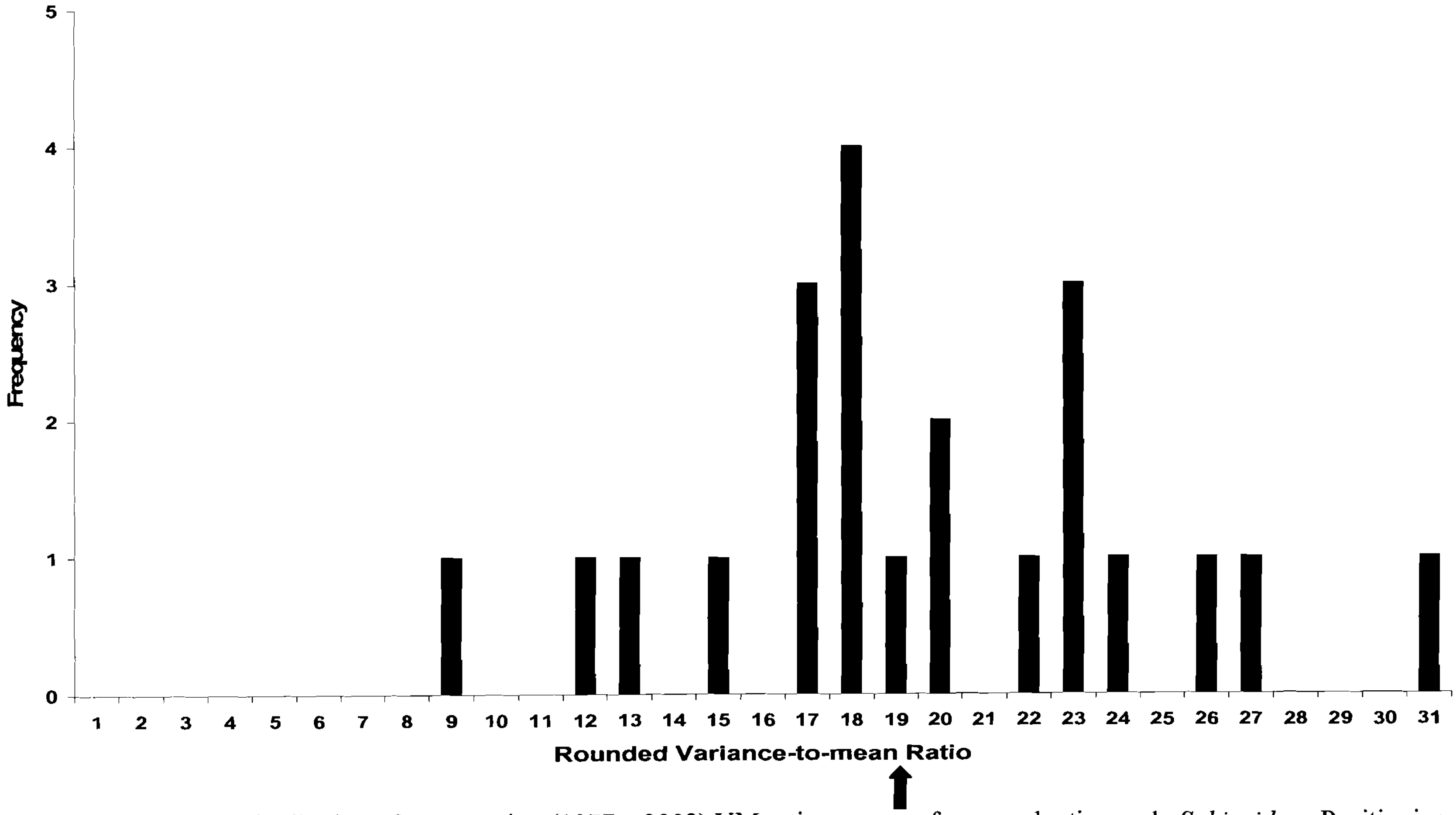

FIG. 9.—Frequency distribution of pre-mowing (1977 – 2003) VM ratio averages for reproductive male *S. hispidus*. Positioning of the post-mowing (2004) VM ratio on the X-axis is denoted (19) with an arrow. VM ratios are rounded to the nearest integer.

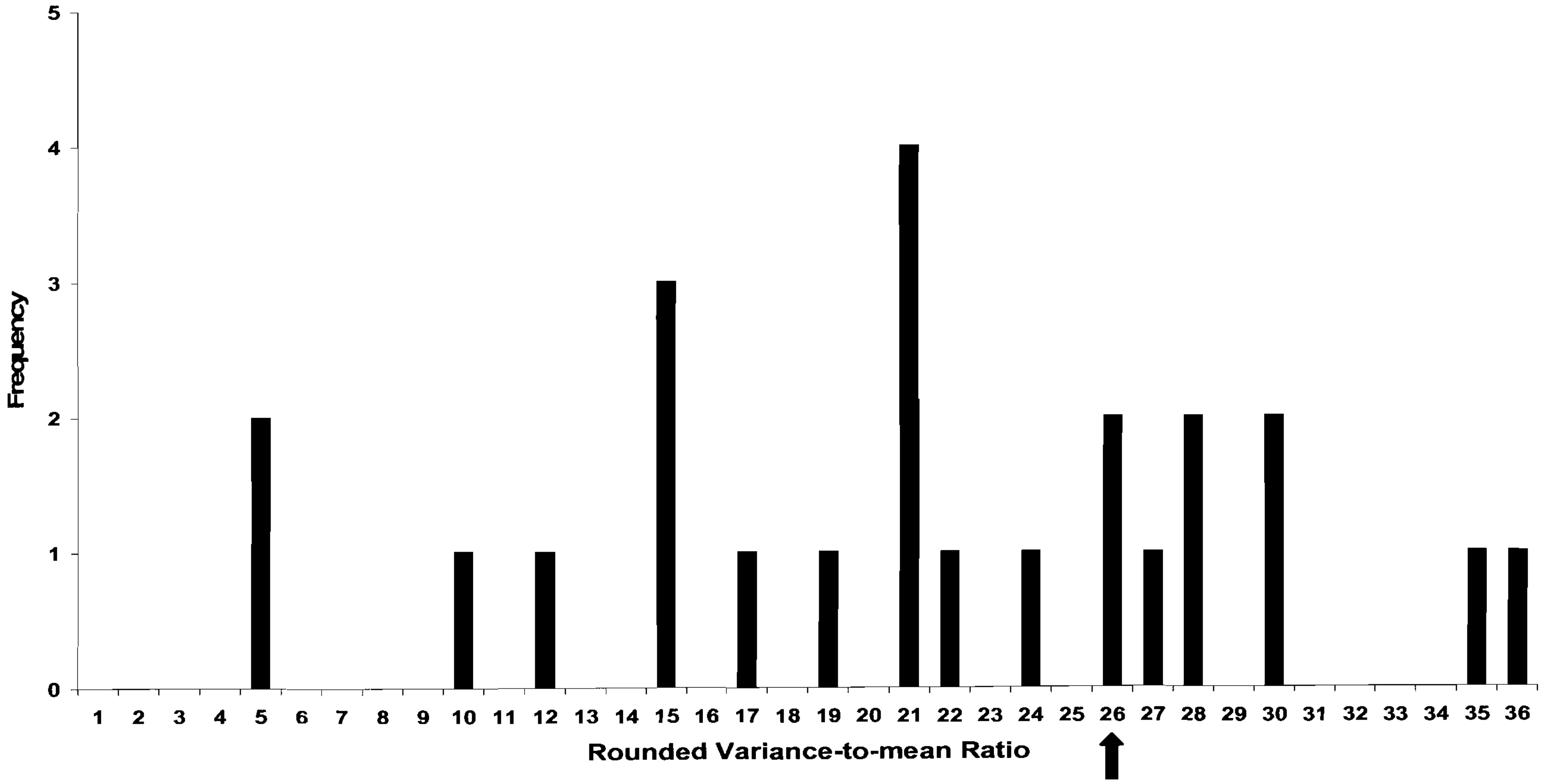

FIG. 10.—Frequency distribution of pre-mowing (1977 – 2003) VM ratio averages for non-reproductive male *S. hispidus*. Positioning of the post-mowing (2004) VM ratio on the X-axis is denoted (26) with an arrow. VM ratios are rounded to the nearest integer.

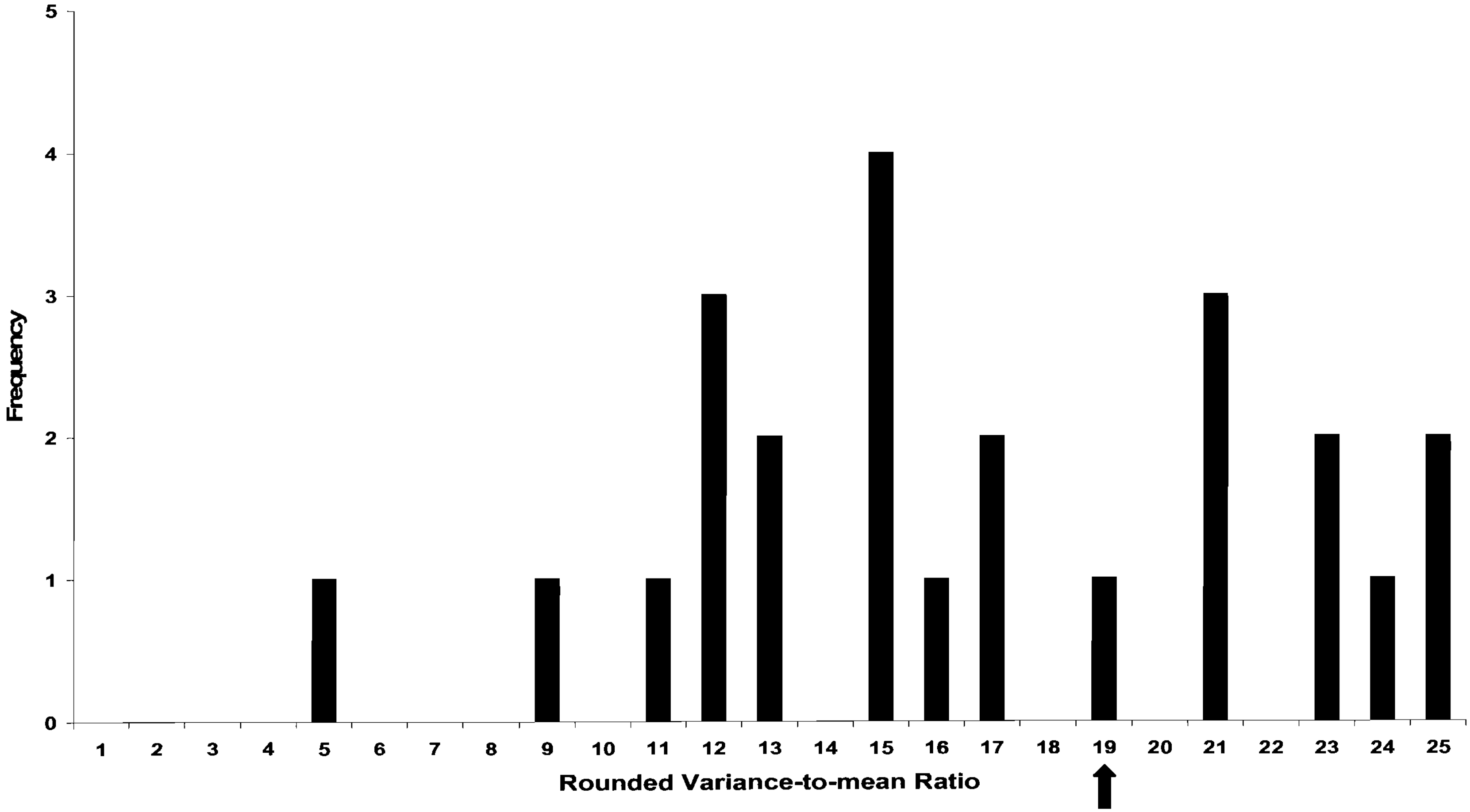

FIG. 11.—Frequency distribution of pre-mowing (1977 – 2003) VM ratio averages for female *S. hispidus*. Positioning of the post-mowing (2004) VM ratio on the X-axis is denoted (19) with an arrow. VM ratios are rounded to the nearest integer.

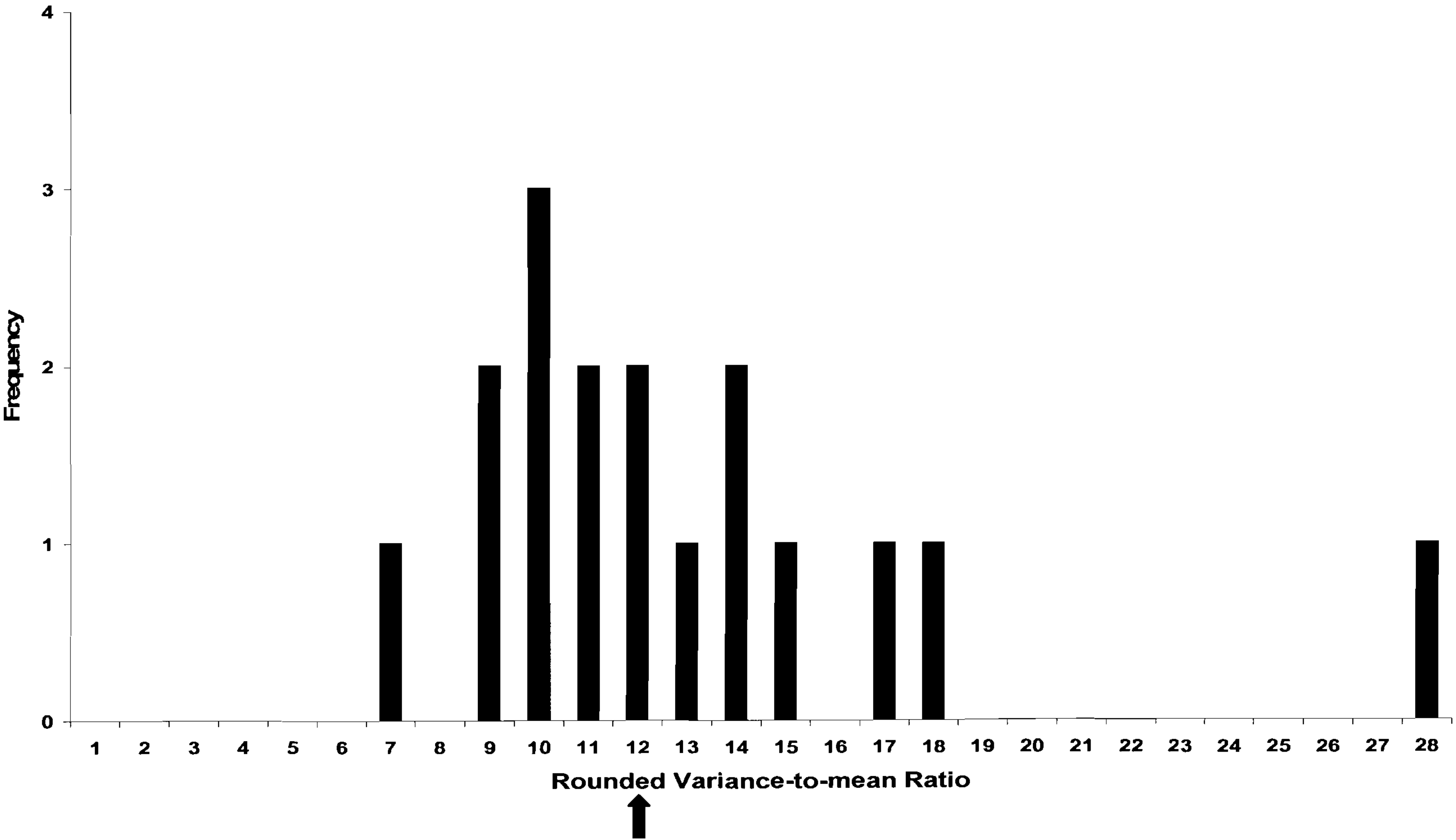

FIG. 12.—Frequency distribution of pre-mowing (1977 – 2003) VM ratio averages for reproductive female *S. hispidus*. Positioning of the post-mowing (2004) VM ratio on the X-axis is denoted (12) with an arrow. VM ratios are rounded to the nearest integer.

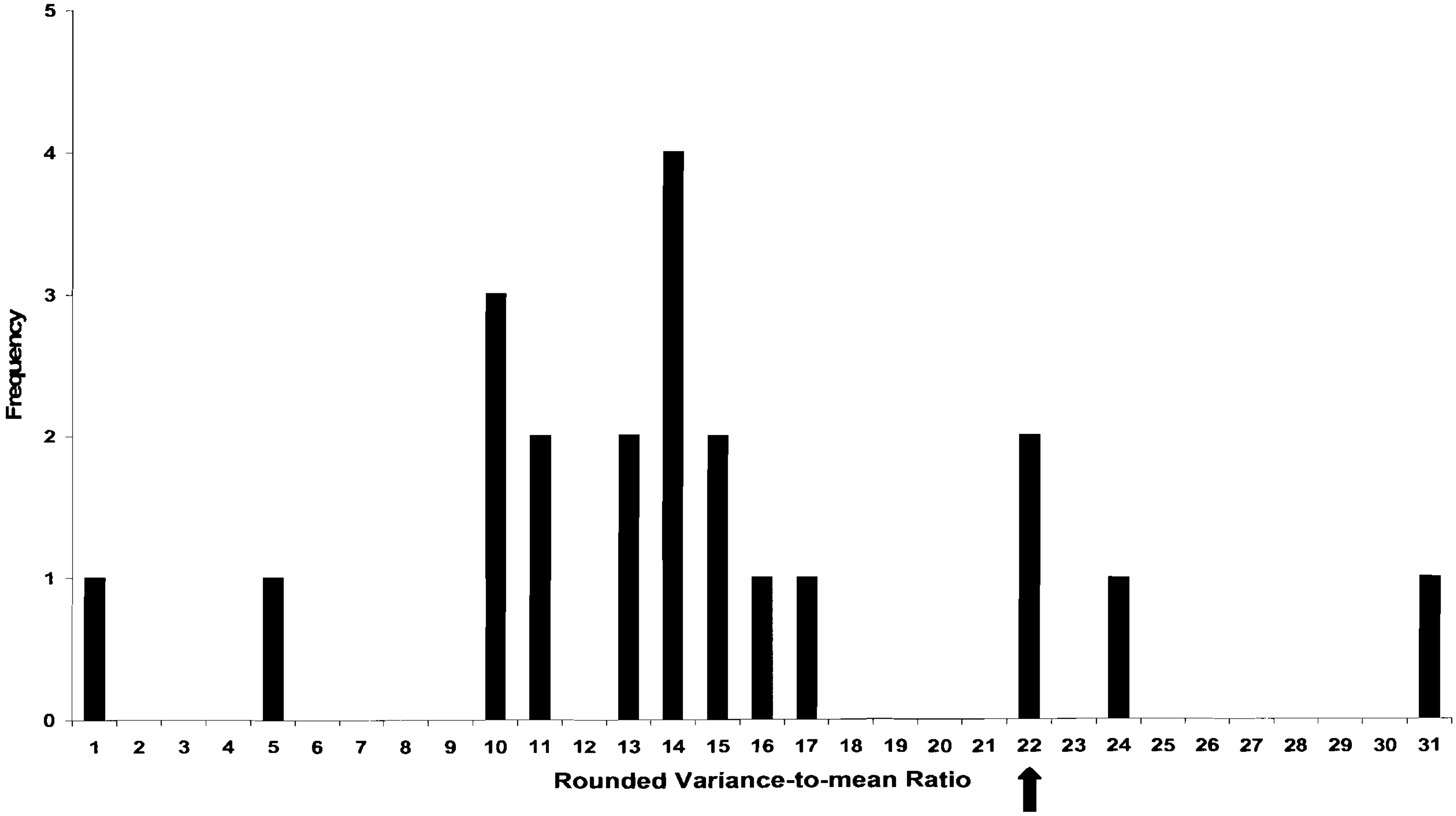

FIG. 13.—Frequency distribution of pre-mowing (1977 – 2003) VM ratio averages for non-reproductive female *S. hispidus*. Positioning of the post-mowing (2004) VM ratio on the X-axis is denoted (22) with an arrow. VM ratios are rounded to the nearest integer.

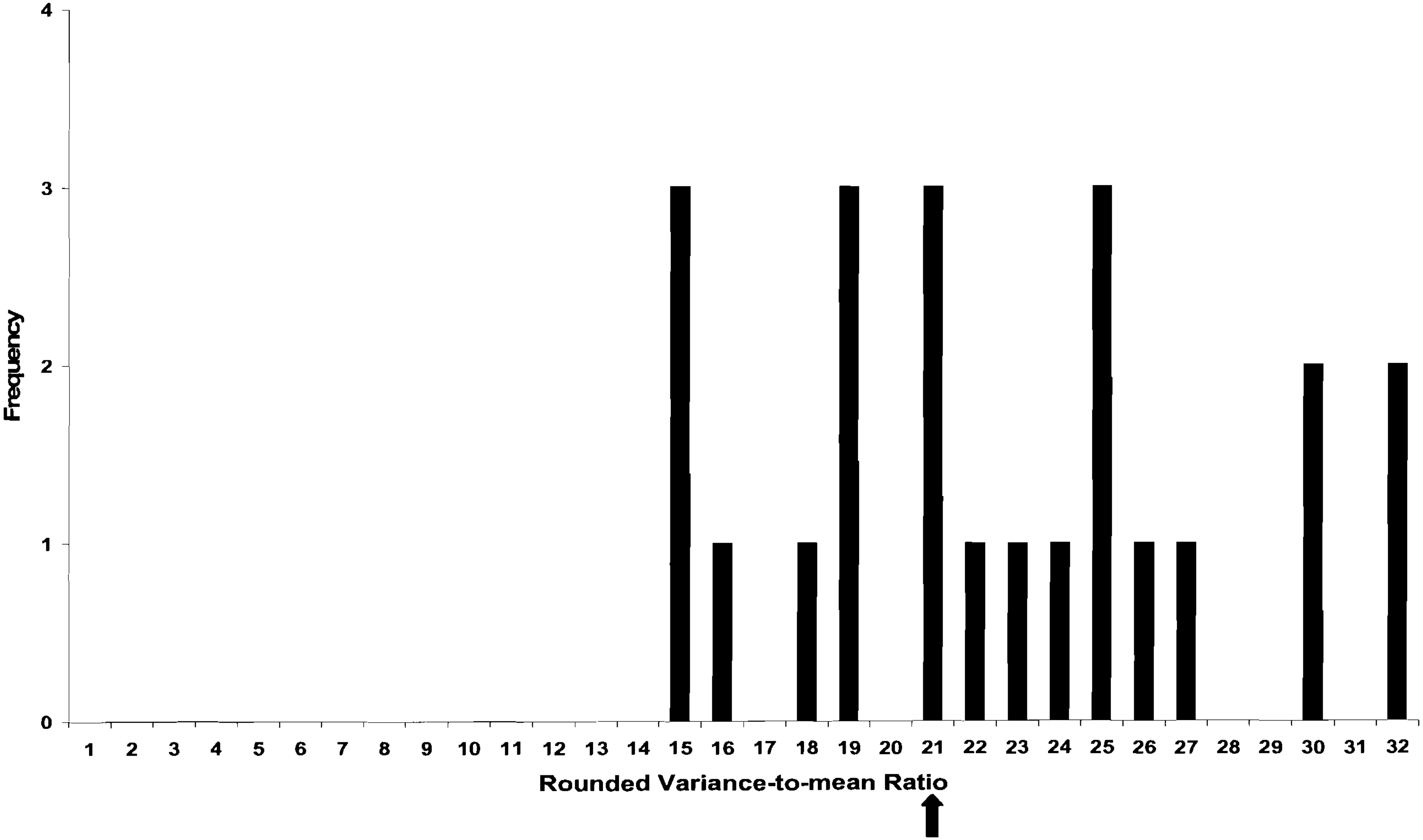

FIG. 14.—Frequency distribution of pre-mowing (1977 – 2003) VM ratio averages for adult *S. hispidus*. Positioning of the post-mowing (2004) VM ratio on the X-axis is denoted (21) with an arrow. VM ratios are rounded to the nearest integer.

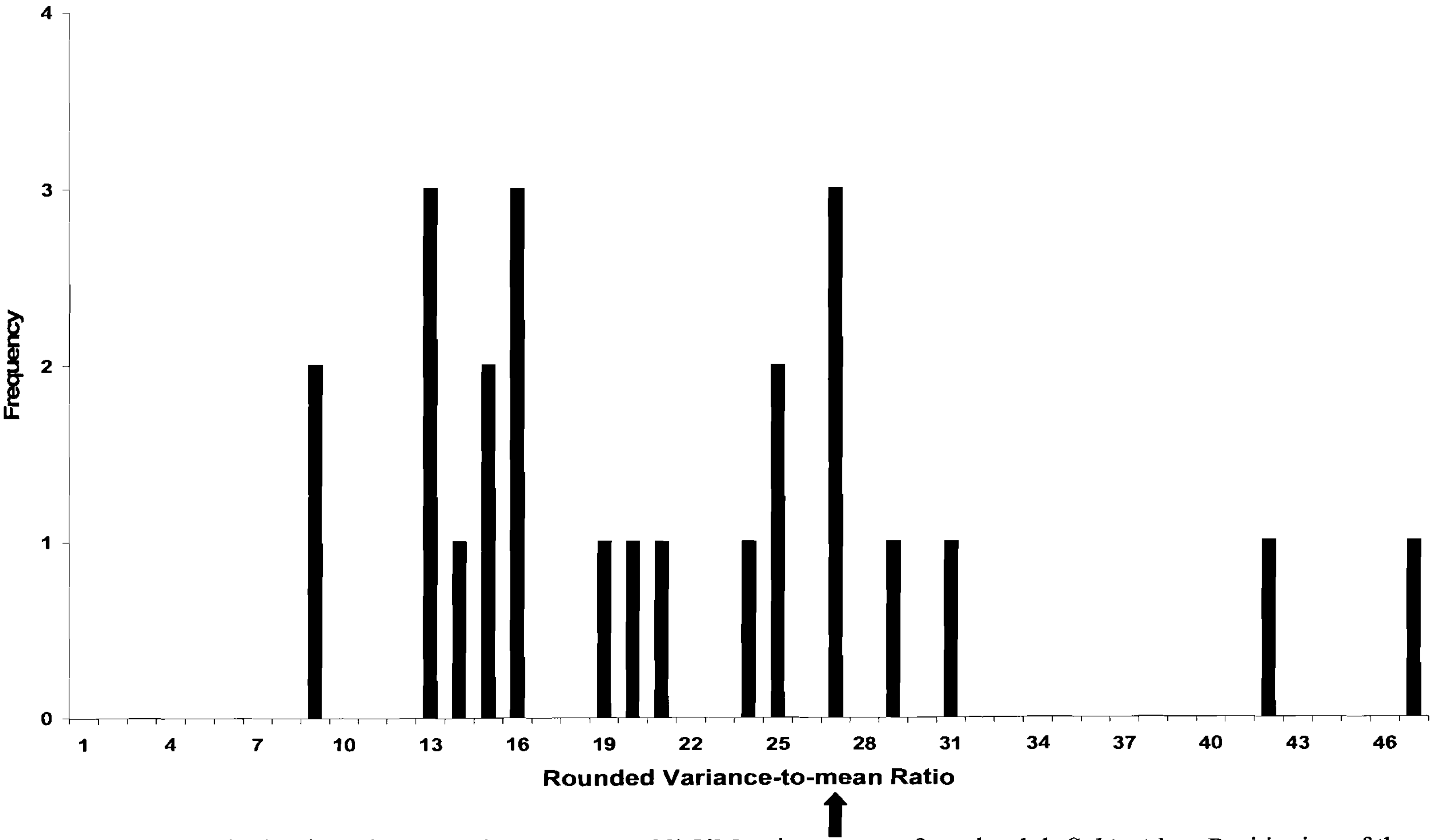

FIG. 15.—Frequency distribution of pre-mowing (1977 – 2003) VM ratio averages for sub-adult *S. hispidus*. Positioning of the post-mowing (2004) VM ratio on the X-axis is denoted (27) with an arrow. VM ratios are rounded to the nearest integer.

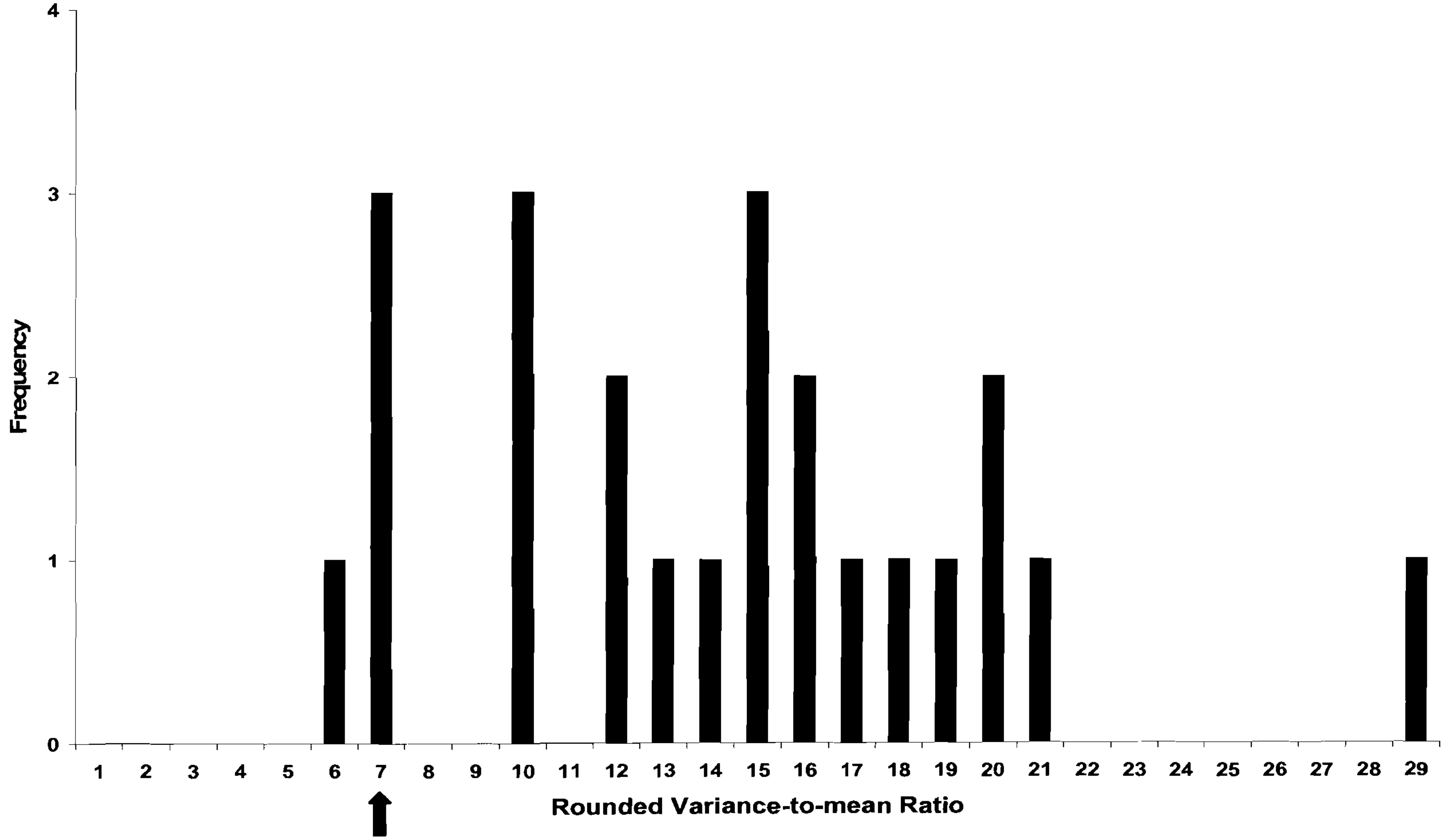

FIG. 16.—Frequency distribution of pre-mowing (1977 – 2003) VM ratio averages for juvenile *S. hispidus*. Positioning of the post-mowing (2004) VM ratio on the X-axis is denoted (7) with an arrow. VM ratios are rounded to the nearest integer.

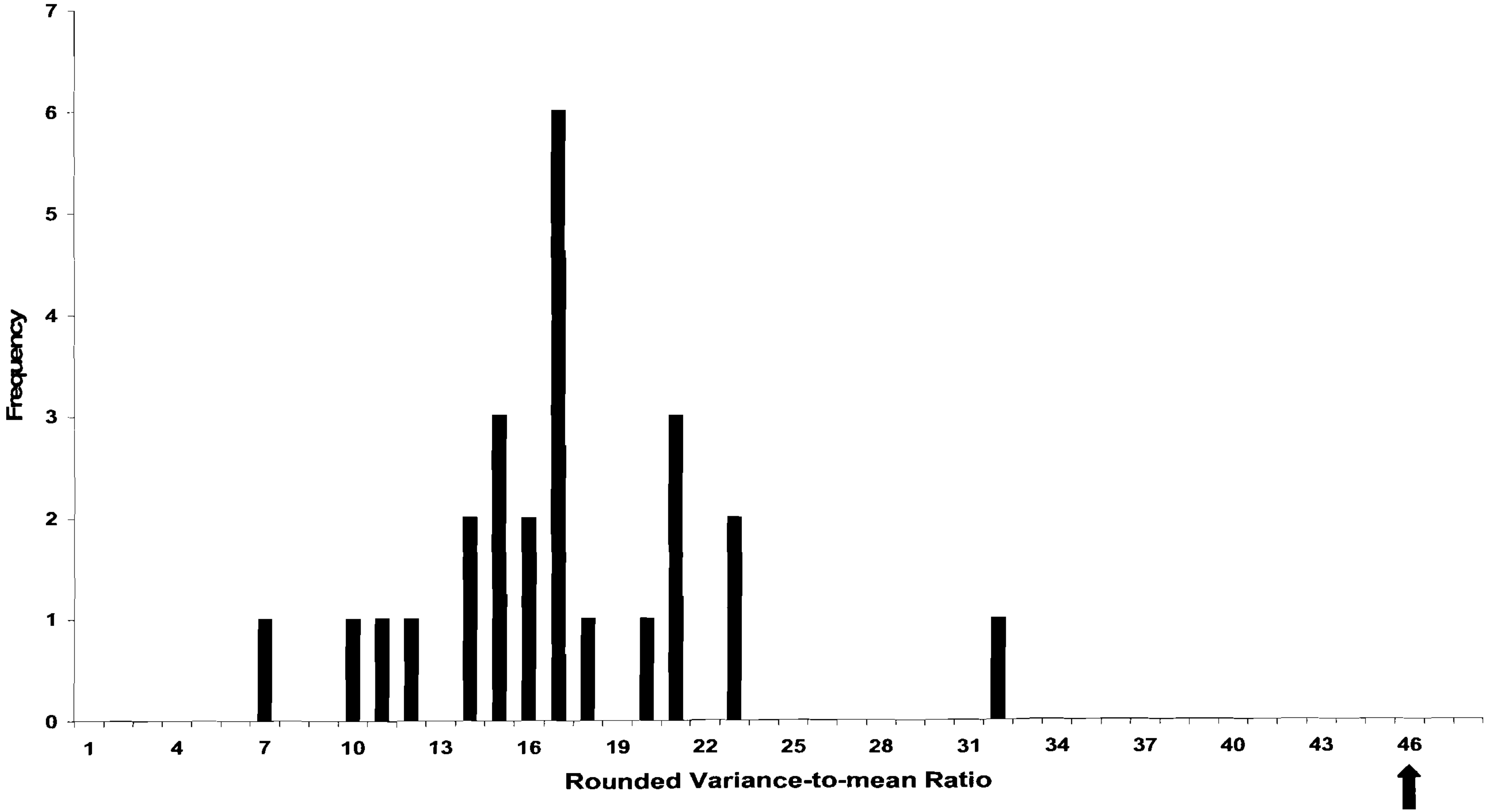

FIG. 17.—Frequency distribution of pre-mowing (1977 – 2003) VM ratio averages for overall *M. ochrogaster*. Positioning of the post-mowing (2004) VM ratio on the X-axis is denoted (46) with an arrow. VM ratios are rounded to the nearest integer.

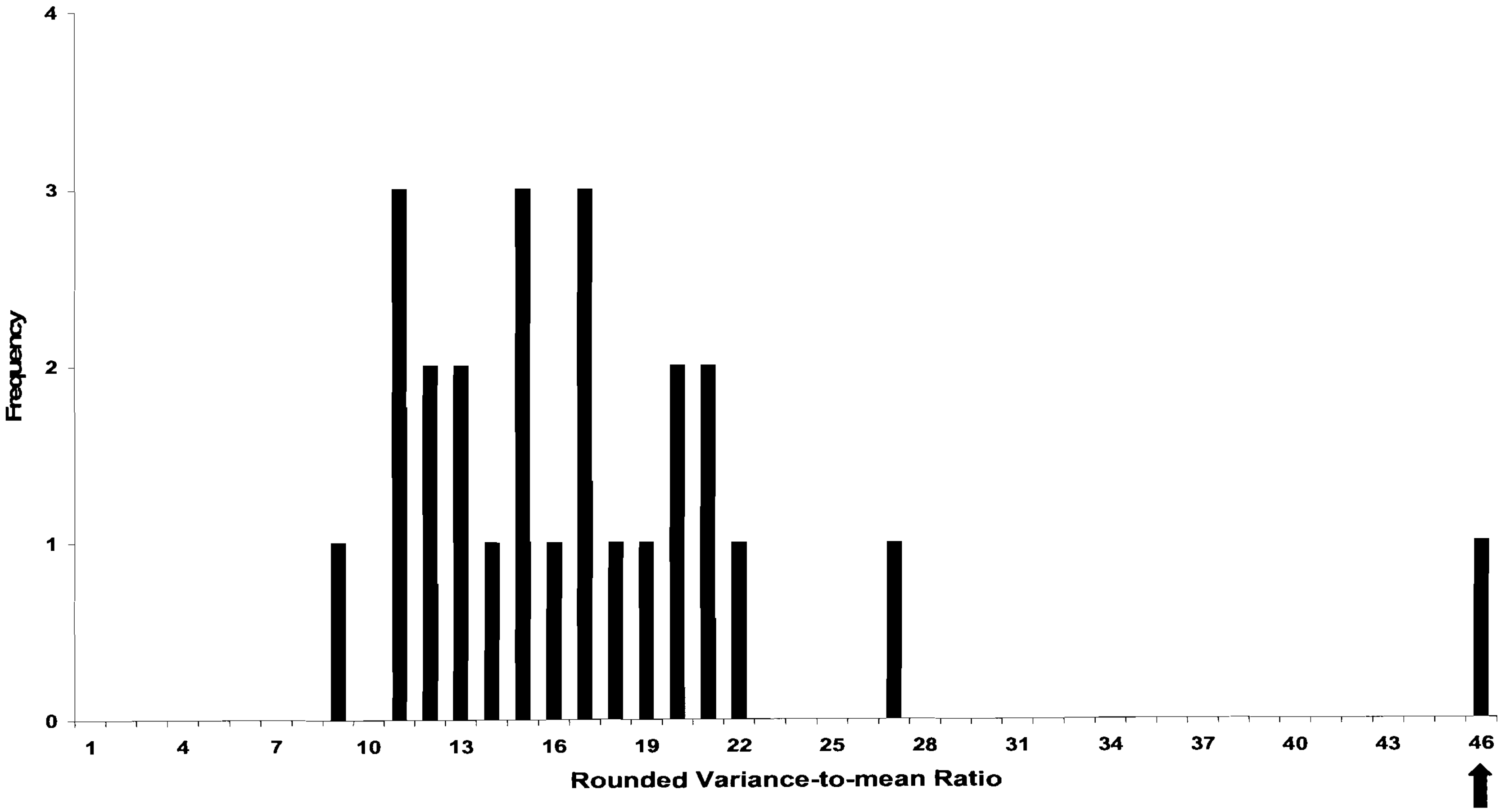

FIG. 18.—Frequency distribution of pre-mowing (1977 – 2003) VM ratio averages for male *M. ochrogaster*. Positioning of the post-mowing (2004) VM ratio on the X-axis is denoted (46) with an arrow. VM ratios are rounded to the nearest integer.

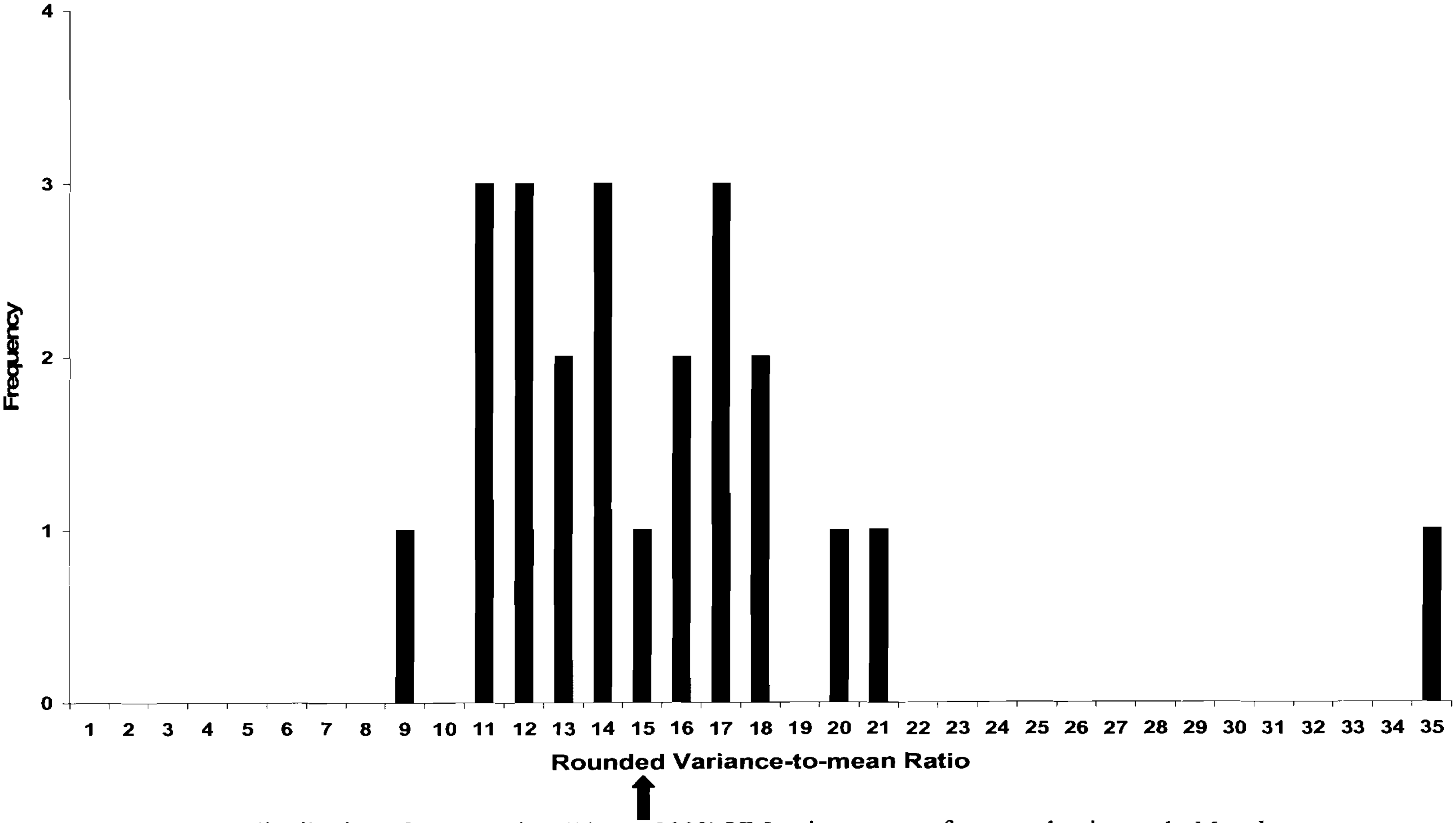

FIG. 19.—Frequency distribution of pre-mowing (1977 – 2003) VM ratio averages for reproductive male *M. ochrogaster*. Positioning of the post-mowing (2004) VM ratio on the X-axis is denoted (15) with an arrow. VM ratios are rounded to the nearest integer.

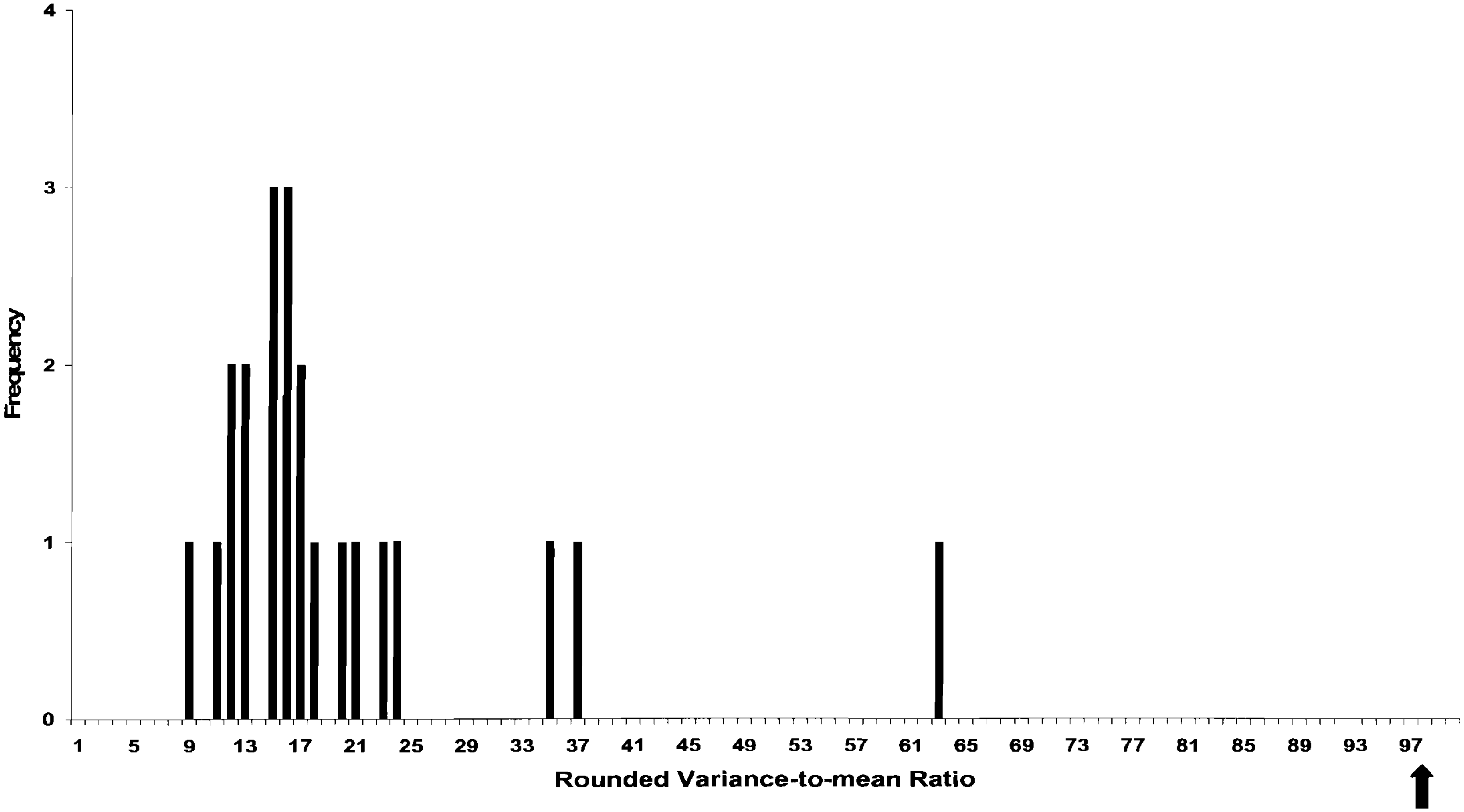

FIG. 20.—Frequency distribution of pre-mowing (1977 – 2003) VM ratio averages for non-reproductive male *M. ochrogaster*. Positioning of the post-mowing (2004) VM ratio on the X-axis is denoted (98) with an arrow. VM ratios are rounded to the nearest integer.

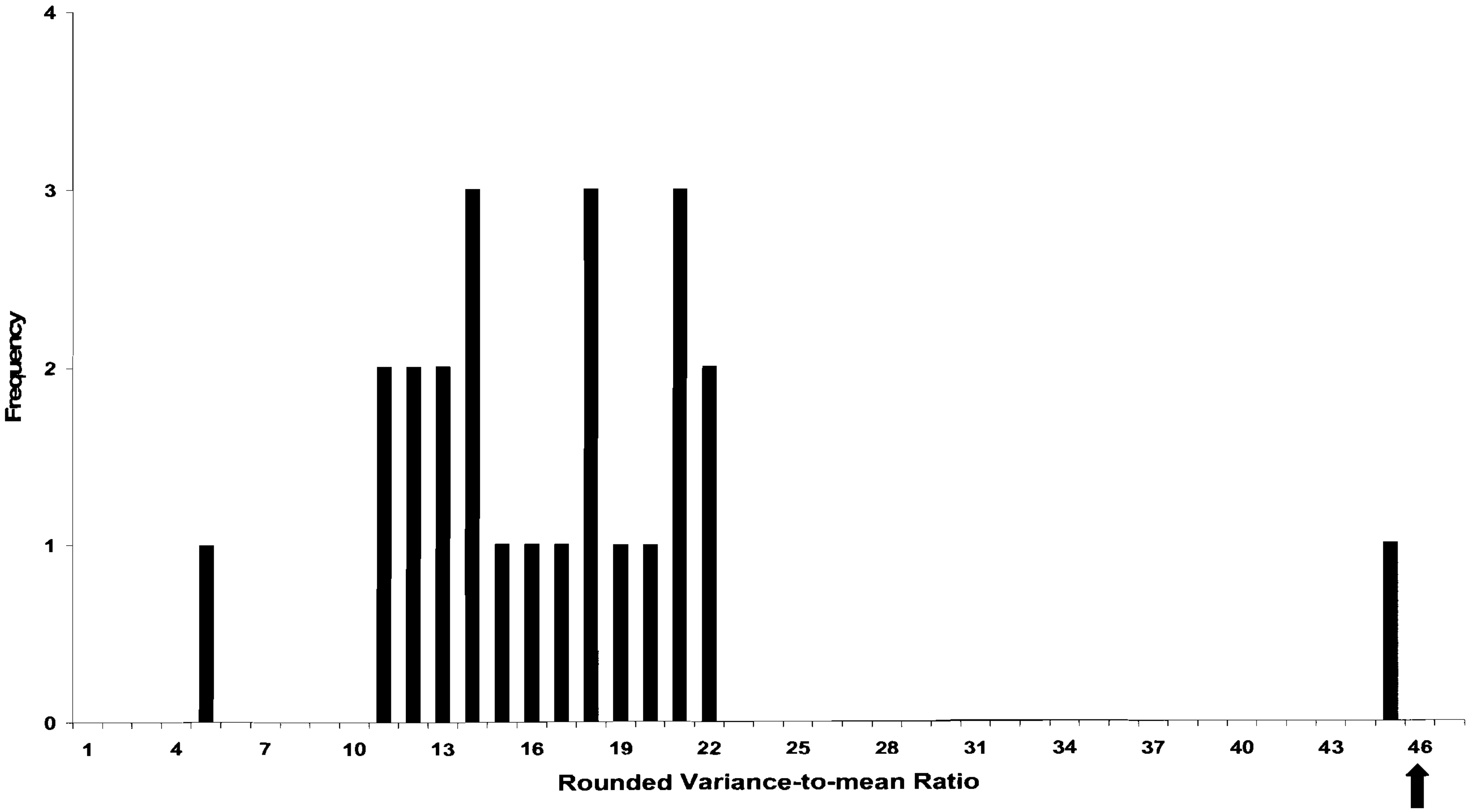

FIG. 21.—Frequency distribution of pre-mowing (1977 – 2003) VM ratio averages for female *M. ochrogaster*. Positioning of the post-mowing (2004) VM ratio on the X-axis is denoted (46) with an arrow. VM ratios are rounded to the nearest integer.

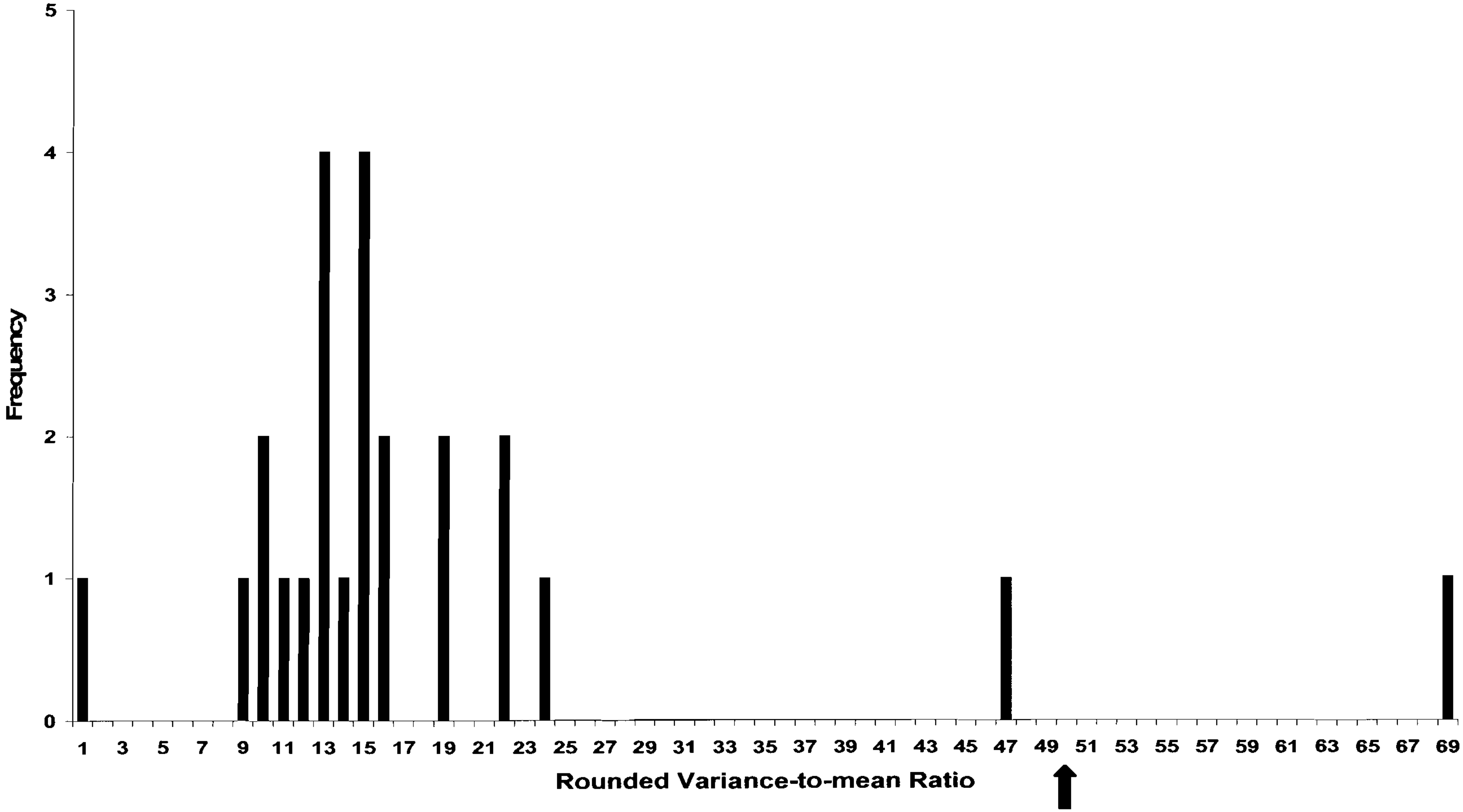

FIG. 22.—Frequency distribution of pre-mowing (1977 – 2003) VM ratio averages for reproductive female *M. ochrogaster*. Positioning of the post-mowing (2004) VM ratio on the X-axis is denoted (50) with an arrow. VM ratios are rounded to the nearest integer.

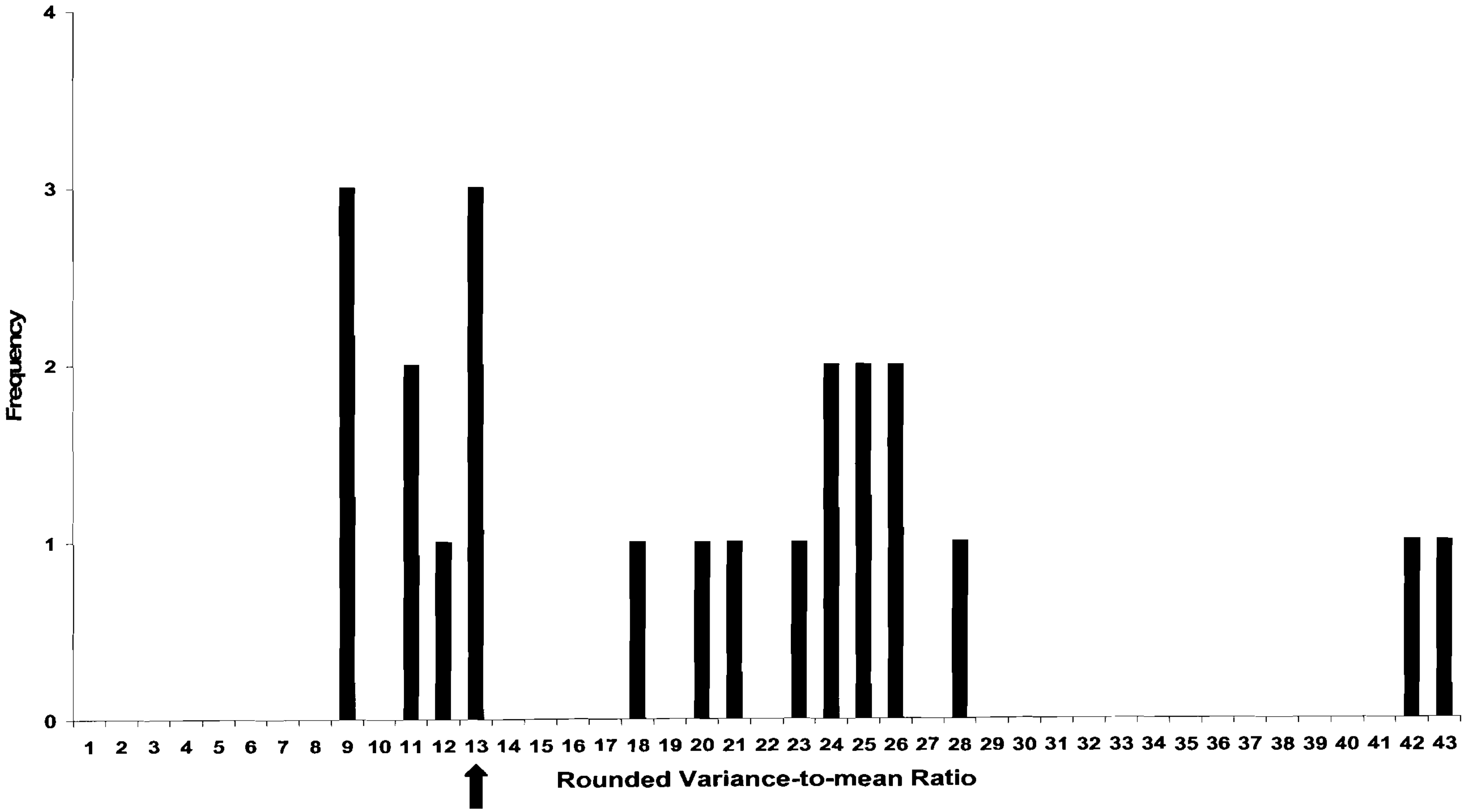

FIG. 23.—Frequency distribution of pre-mowing (1977 – 2003) VM ratio averages for non-reproductive female *M. ochrogaster*. Positioning of the post-mowing (2004) VM ratio on the X-axis is denoted (13) with an arrow. VM ratios are rounded to the nearest integer.

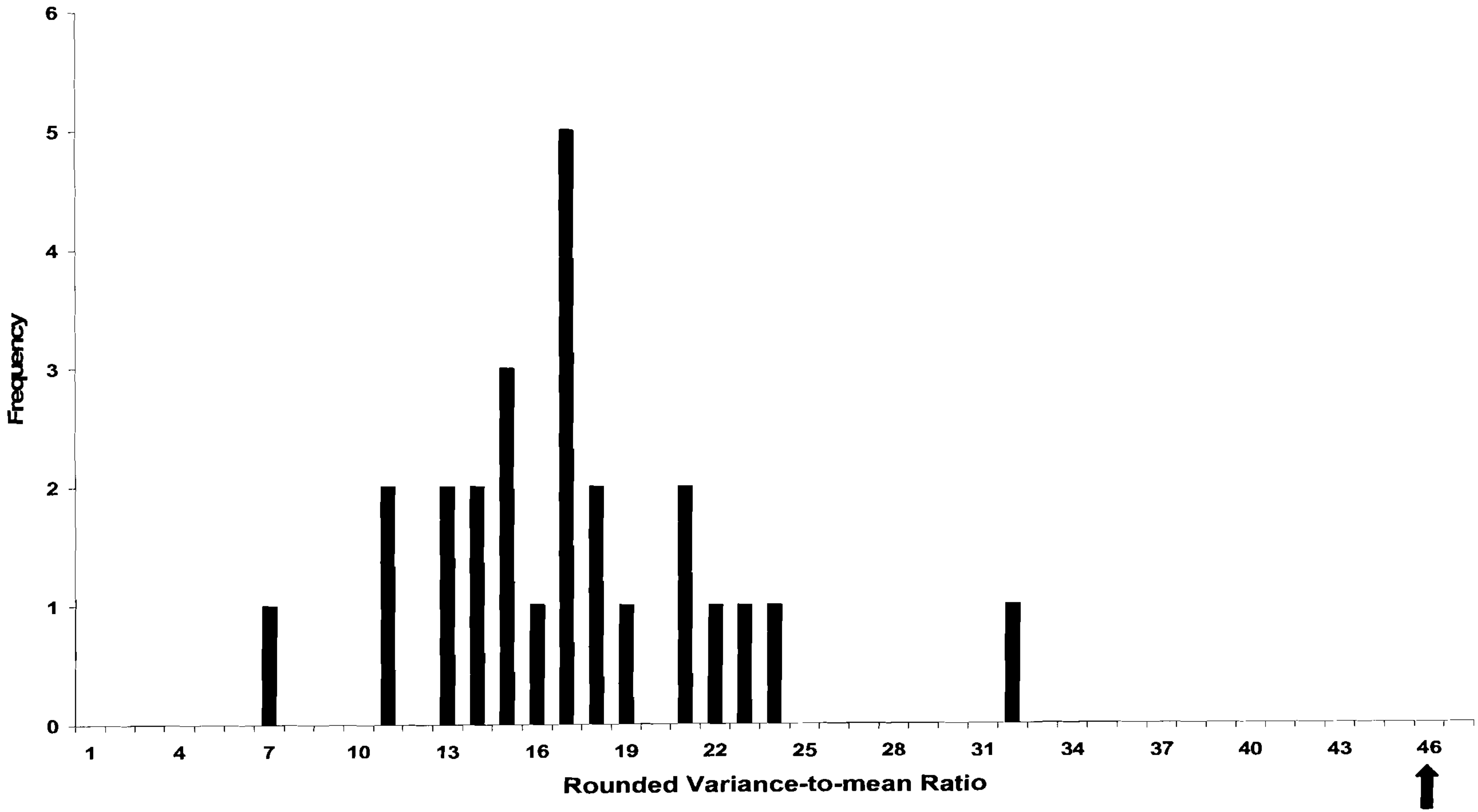

FIG. 24.—Frequency distribution of pre-mowing (1977 – 2003) VM ratio averages for adult *M. ochrogaster*. Positioning of the post-mowing (2004) VM ratio on the X-axis is denoted (46) with an arrow. VM ratios are rounded to the nearest integer.

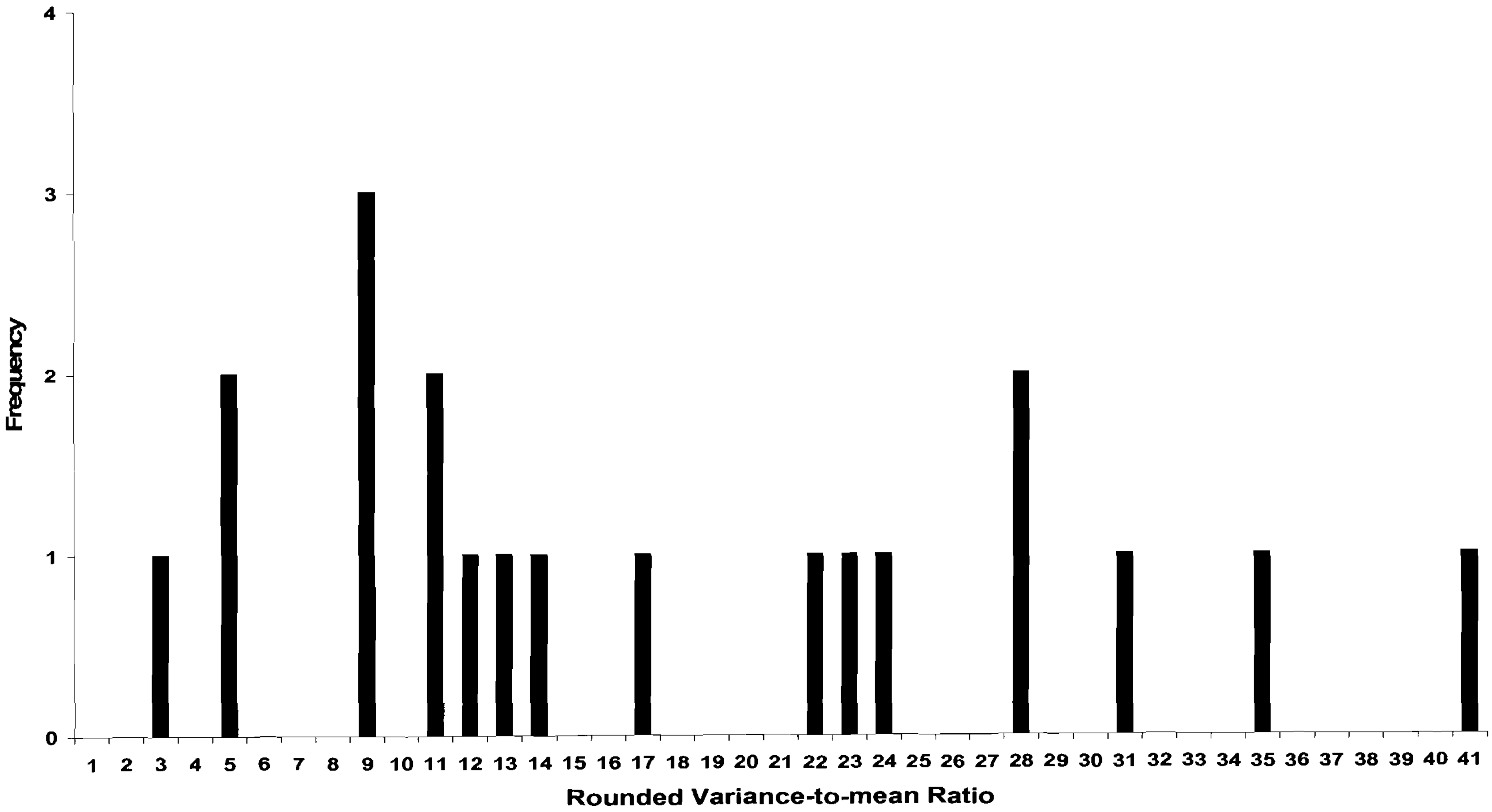

FIG. 25.—Frequency distribution of pre-mowing (1977 – 2003) VM ratio averages for sub-adult *M. ochrogaster*. Post-mowing- the *M. ochrogaster* sub-adults captured were only captured once or multiple times at the same trap station making for a mean distance moved of 0 meters and an undefined VM ratio. VM ratios are rounded to the nearest integer.

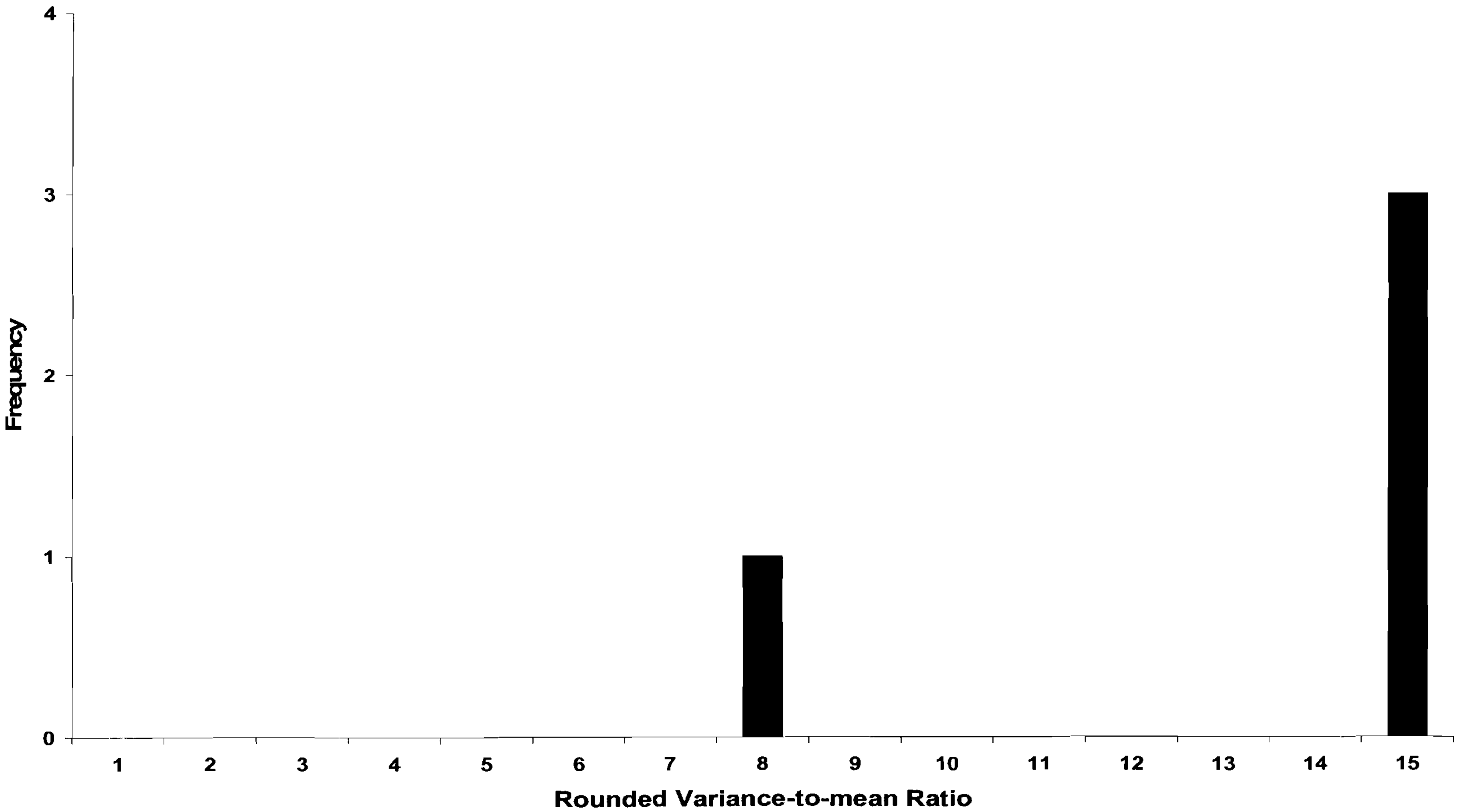

FIG. 26.—Frequency distribution of pre-mowing (1977 – 2003) VM ratio averages for juvenile *M. ochrogaster*. Post-mowing- the *M. ochrogaster* juveniles captured were only captured once or multiple times at the same trap station making for a mean distance moved of 0 meters and an undefined VM ratio. VM ratios are rounded to the nearest integer.

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Molly Humphries
Signature of Author

August 18, 2006
Date

Impacts of Small-Scale Habitat Fragmentation on Abundance
and Movement of *Sigmodon hispidus* and *Microtus ochrogaster*
Title of Thesis

Dora Cooper
Signature of Graduate Office Staff

8-23-06
Date Received