DETAILED EXAMINATION OF SAK INPUTS

The SAK method has a number of assumptions which must be true for the estimate to be accurate. These assumptions are: **(1)** that registered harvest is counted accurately, **(2)** that the aged sample of harvested deer represents the age structure of the herd, **(3)** that compliance with harvest registration can be estimated, **(4)** that the estimate of fawn production is accurate, **(5)** that nonharvest mortality can be estimated, **(6)** that the herd is age-stable and stationary, **(7)** that buck harvest rate is stable from year to year, and **(8)** that adult bucks can potentially be harvested (i.e., they are not completely protected by refuges). These assumptions are met to varying degrees in different units; never are all of them completely met.

There are 6 basic inputs to the SAK calculation. Some of these inputs are measured well in some areas of the state while values in some areas must be extrapolated from nearby similar units or derived intuitively.

Registered Buck Harvest

The first and most important SAK input is harvest. Registered kill (since 1953) is the one thing, more than any other, that puts Wisconsin out in front of most other states and provinces when it comes to population monitoring and harvest management precision.

The buck harvest used in the SAK calculation includes kill from all seasons (early bow, gun, muzzleloader, and late bow). For units in the ceded territory, off-reservation kill by tribal members is included. Bucks killed on damage permits are also included. Complete reporting of registered kill by registration stations and accurate sorting, counting, and entry of registration data is vital for accurate estimates of unit deer population size.

Yearling Buck Percent (YB%)

The YB% is the percent of bucks ($\geq$1.5 yrs) aged at deer hunting registration stations that were 1.5 years old. An important assumption of the SAK procedure, as currently implemented, is that percentage of yearlings in the harvest during the first 2 or 3 days of the firearms season is representative of the percentage of yearlings in the population. **This assumption could be violated if hunters selected against shooting yearlings or if yearlings were more vulnerable to harvest due to behavioral differences between yearlings and older bucks. Increasing interest in "quality deer management" is raising concern about the possibility of hunter selection against yearlings. Accurate interpretation of harvest age data would become more difficult if avoidance of shooting yearlings becomes widespread.**

The validity of this assumption has received considerable discussion. Maguire and Severinghaus (1954) noted a tendency for yearling bucks to be more vulnerable to harvest on opening day but age-related vulnerabilities rapidly equalized. They concluded that the age distribution of the entire harvest was representative of the prehunt population. Eberhardt (1960) found little evidence of higher vulnerability of yearlings in Michigan; instead, many yearlings in the Upper Peninsula had sub-legal antlers and were less vulnerable to harvest. In contrast, McCullough (1979) concluded that yearlings were more vulnerable to harvest than were older bucks on the George Reserve in Michigan. Burgoyne (1981) argued that the percentage of yearlings in the harvest sample should be reasonably representative of the population in Michigan. During a 17-day hunt on the Crab Orchard Refuge in southern Illinois, 1.5-year-old

bucks comprised 35% of the adult buck harvest during the first 3 days of the hunt compared to 32% of the adult buck harvest during the entire season (Roseberry and Klimstra 1974). During the total herd removal at Sandhill, the harvest age composition of adult bucks with 25% and 50% of the buck population removed did not differ significantly from the age composition of the entire buck population (DNR unpublished data). Therefore, we believe our sampling scheme is relatively free from vulnerability bias. However, further research on age structure of early archer kill should be considered.

As discussed in the conceptual framework, theYB% equals adult buck mortality rates. However, this is true only under the special condition that the buck population is age-stable and stationary. The special condition is illustrated by the following model:

The model *(Table 6.1)* starts with 1,000 bucks alive in the first year; 500 are yearlings and 500 are older bucks. The percentage of yearlings is 50%. In all years, the mortality rate for all bucks is 50%. In year 2, the 250 surviving yearlings become 2.5 year-olds, joining the 250 surviving 2.5+ year-olds. The 500 deaths is exactly replaced by the recruitment of 500 yearlings. This process is repeated in years 3, 4, and 5. In this example, the percentage of yearlings stays at 50% which exactly equals the buck mortality rate.

Table 6.1. **Illustration of buck age structure in an age-stable, stationary population. Buck mortality rate is a constant 50%.**

Population parameter	**Yr 1**	**Yr 2**	**Yr 3**	**Yr 4**	**Yr 5**
1.5 yr-old bucks alive prehunt	500	500	500	500	500
2.5+ yr-old bucks alive prehunt	500	500	500	500	500
Total bucks alive prehunt	1000	1000	1000	1000	1000
% 1.5 yr-old bucks in popul.	50%	50%	50%	50%	50%
1.5 yr-old bucks dying	250	250	250	250	250
2.5+ yr-old bucks dying	250	250	250	250	250
Total bucks dying	500	500	500	500	500
1.5 yr-old bucks surviving	250	250	250	250	250
2.5+ yr-old bucks surviving	250	250	250	250	250

In the real world, deer populations are rarely if ever age-stable and stationary. Therefore, the percentage of yearlings in the population is often a biased estimate of the true mortality rate. Changes in recruitment can result from severe winters causing an increase in fawn mortality or decrease in doe productivity. Changes in harvest rate can result from poor hunting conditions or high numbers of small-antlered and sub-legal spike bucks in the population. The following, unrealistic, example illustrates the effect of an extreme recruitment failure in one year on the percentage of yearlings:

In this example (*Table 6.2*), everything is the same as the previous model except there is a recruitment failure in year 2 when only 100 yearlings are recruited. The percentage of yearlings in the population drops from 50% to 17%, but the mortality rate on bucks remains at 50%. In year 3, recruitment returns to normal, but there are only 300 2.5+ year-olds so yearlings comprise 63% of the population. The percentage of yearlings moves back toward 50% in years 4 and 5 as the population recovers from the recruitment failure. The mortality rate in this example remains at 50% in all years, but the percentage of yearlings in the population is a very poor estimate of the buck mortality rate in years 2 and 3. However, the average percentage of yearlings over the 5-year period is 47% which is a reasonable approximation of the mortality rate.

Table 6.2. **Illustration of buck age structure changes caused by a recruitment failure in year 2. Buck mortality rate is a constant 50%.**

Population parameter	**Yr 1**	**Yr 2**	**Yr 3**	**Yr 4**	**Yr 5**
1.5 yr-old bucks alive prehunt	500	100	500	500	500
2.5+ yr-old bucks alive prehunt	500	500	300	400	450
Total bucks alive prehunt	1000	600	800	900	950
% 1.5 yr-old bucks in popul.	50%	17%	63%	56%	53%
1.5 yr-old bucks dying	250	50	250	250	250
2.5+ yr-old bucks dying	250	250	150	200	225
Total bucks dying	500	300	400	450	475
1.5 yr-old bucks surviving	250	50	250	250	250
2.5+ yr-old bucks surviving	250	250	150	200	225

We have been using a multi-year average of YB% (AYB%) to estimate buck mortality rates; thereby approximating the ideal situation of an age-stable, stationary population. Interpretation of observed changes in annual estimates of yearling percents has been facilitated by the fairly stable hunting season framework in Wisconsin which tends to minimize changes in hunter distribution and effort and, therefore, in mortality rates of bucks. Annual estimates of YB% have been fairly variable in northern Wisconsin, but this variation largely corresponds with changes in other indices of recruitment (fawn:doe ratios and yearling doe percents).

Figure 6.1 shows the number of bucks that have been aged by management unit during 1996-2000. Figure 6.2 shows geographic variation in estimates of AYB% statewide during 1996-2000. Estimates for units without adequate aging data are interpolated from surrounding units, taking into consideration habitat, hunting pressure, and season type. Mean YB%s ranged from 50%-80% during 1996-2000. Units with the lowest YB%s were mostly in the western portion of the Northern Forest. The majority of units with YB% $\geq$ 75 were in the Eastern and Western Farmland regions.

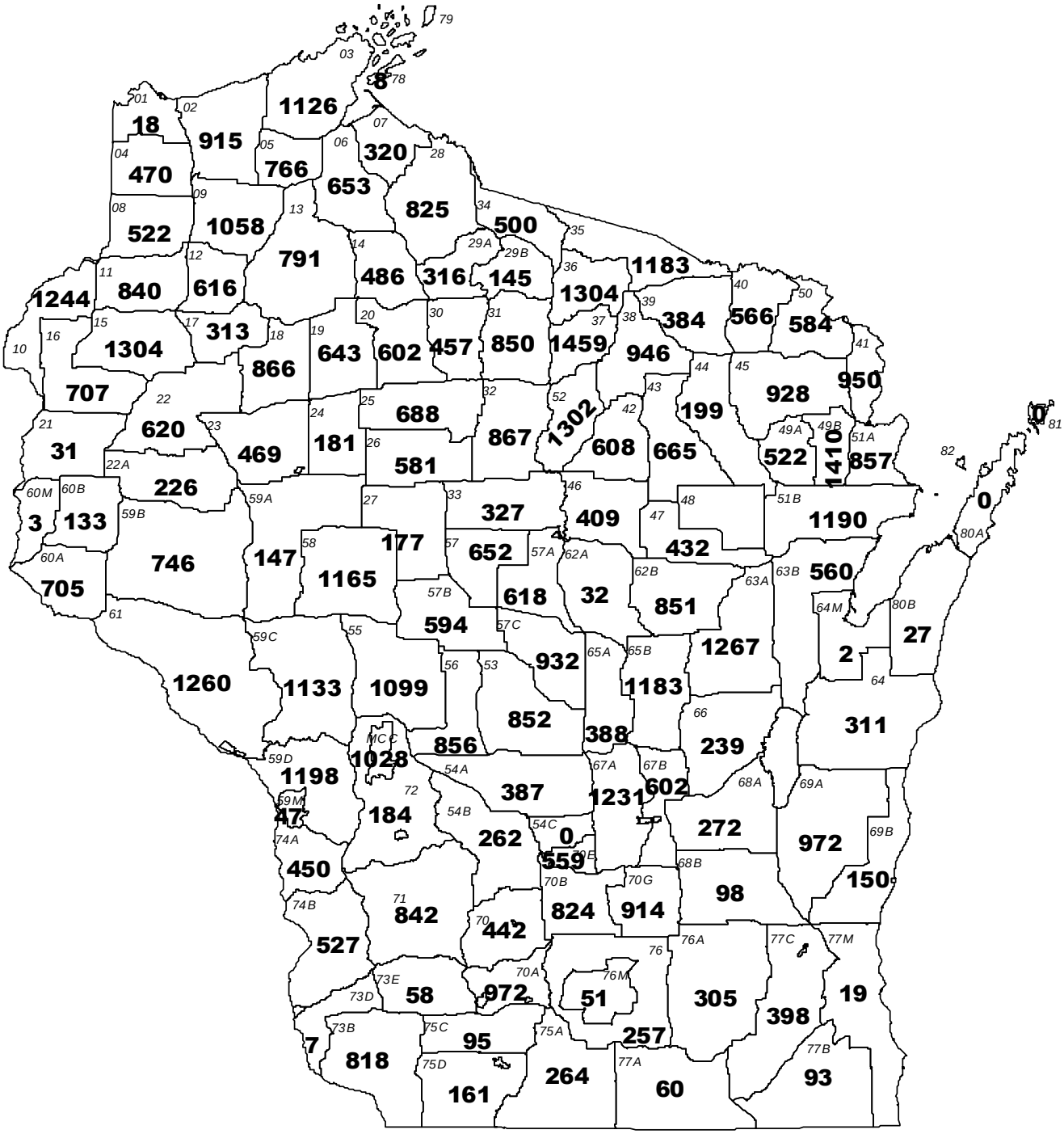


Figure 6.1. **Number of adult (≥ 1.5 year-old) bucks aged at Wisconsin deer registration stations, 1996-2000.**

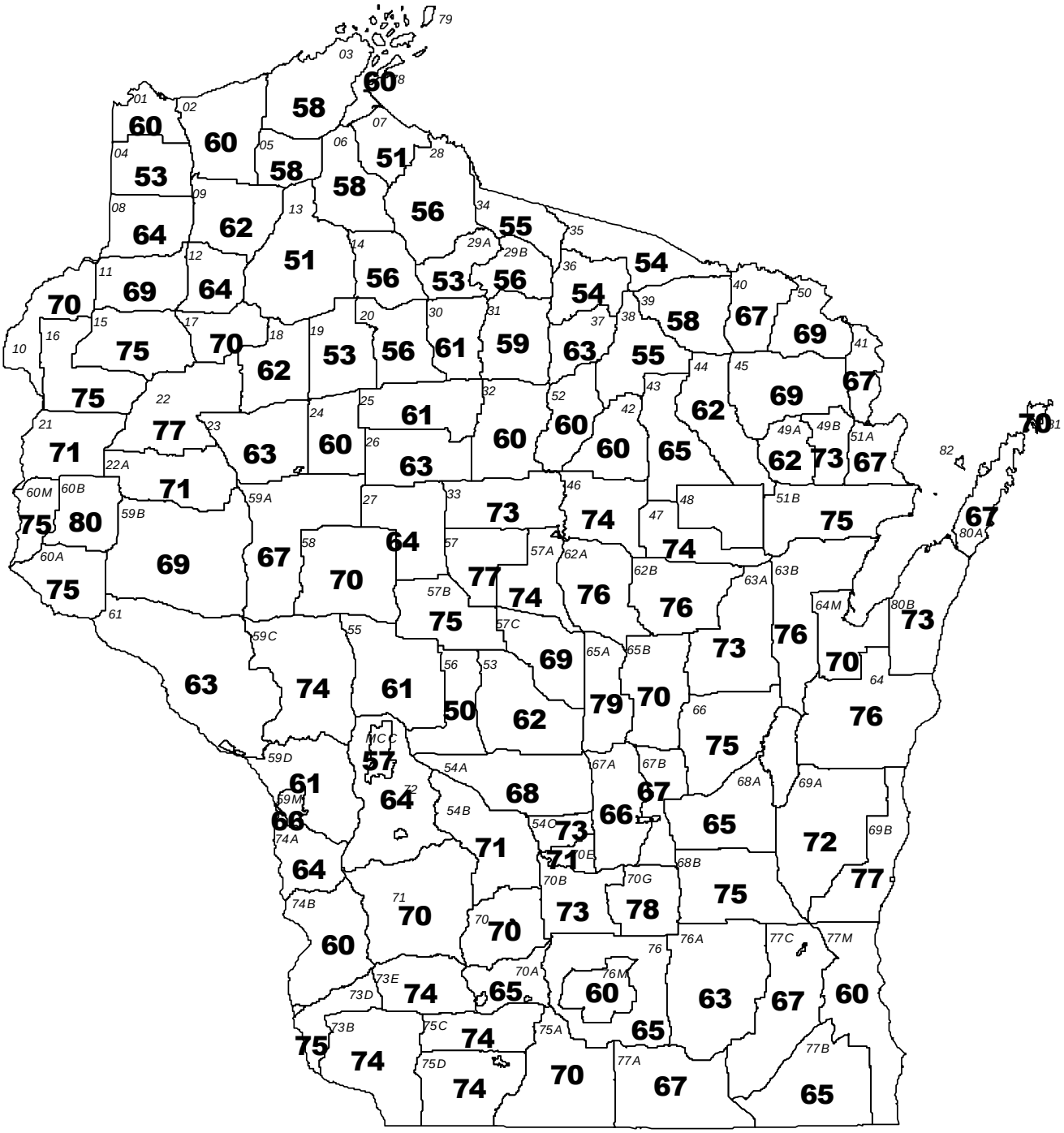


Figure 6.2. **Estimates of average percentage of yearlings among adult bucks during 1996-2000 used for 2000 SAK population densities.**

Temporal variation in YB% in the 5 deer management regions are shown in Figure 6.3. Annual variation has been greatest in the Northern Forest Region. Yearling buck percents in the Northern Forest varied greatly during the 1960s and early 1970s, were relatively stable during the mid 1970s and 1980s, and again exhibited substantial variation in the 1990s. Variation in yearling buck percents in this region largely reflects changes in recruitment associated with fluctuations in winter severity. The long-term trend in the Central Forest generally parallels the Northern Forest trend. Rising hunter pressure during the late 1970s and 1980s also played a role in the higher YB%s during this period in the forested regions. Statewide, the number of licensed gun hunters increased from fewer than 400,000 to over 600,000 during the 1960s and early 1970s, plateauing between 650,000 and 700,000 after 1985.

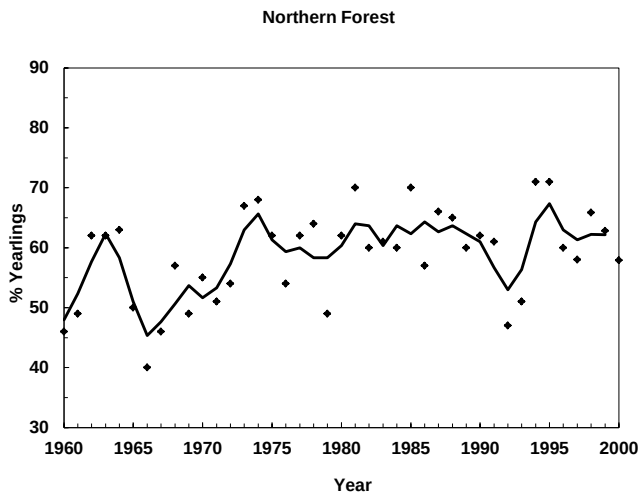
The farmland regions show less year-to-year variability than the forested regions, reflecting higher mortality and more stable recruitment. The increasing trend in the three farmland regions during the 1960s and early 1970s reflects increased hunter pressure. YB%s were high and fairly stable through the late 1980s but then declined in the farmland regions. Poor hunting conditions during the gun seasons of 1991 and 1992 likely depressed mortality rates (blizzard on the opening weekend of the 1991 season, flooded lowlands and unharvested corn in 1992). But the trend for lower yearling percents has continued in recent years. Although questions remain about the cause of these lower yearling percents, we suspect they are due in part to high antlerless quotas and reduced hunter access. Field personnel report less deer-driving and more still-hunting now than prior to 1990. The combination of residential sprawl, the migration of urban residents into rural areas, and interest in growing older bucks may be reducing access and mortality rates.

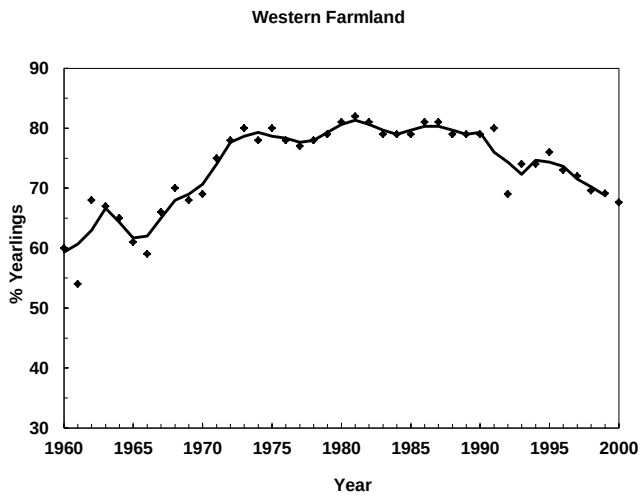
The temporal changes in yearling buck percents necessitate the periodic review and adjustment of this input in the SAK formula. Changes in buck mortality rates also require revising estimates of Buck Recovery Rate, as discussed below.

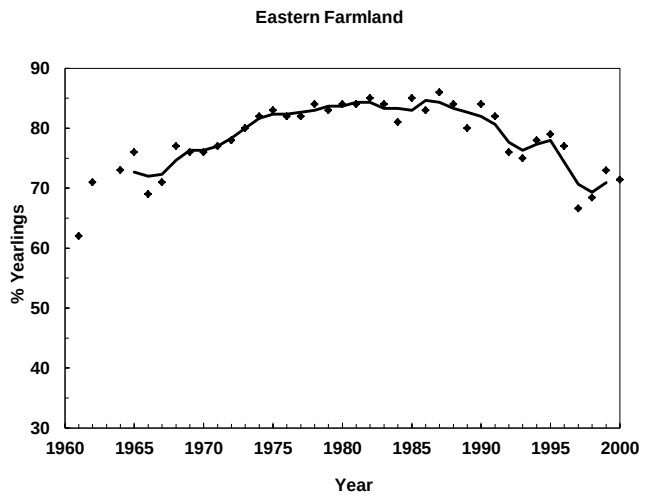
Buck Recovery Rate

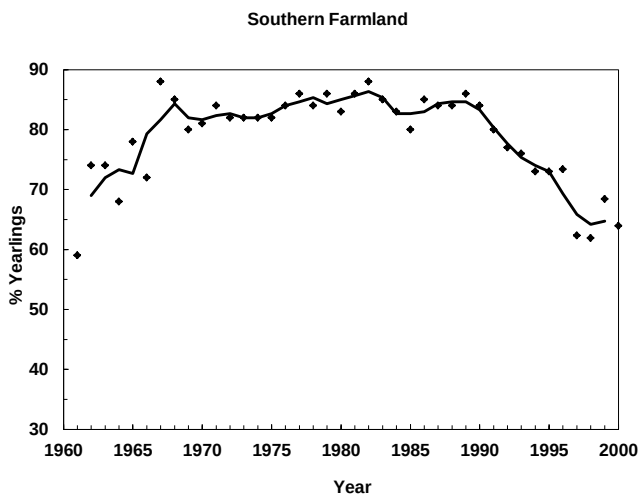
The Buck Recovery Rate (BRR) is the proportion of total adult ($\geq$1.5 yr) buck mortality that is caused by registered harvest and is used in the estimation of buck harvest rate. The proportion of buck mortality due to all other causes (non-harvest) is 1-BRR. For example, if BRR is 0.80 then 20% of all buck mortality would be due to causes other than registered harvest (e.g., out-of-season poaching, roadkill, non-compliance with registration, winter stress, unretrieved gun and archery kills, predation, etc.). BRR increases as hunting pressure and harvest rates increase and fewer bucks survive the hunting season to be exposed to non-harvest losses.

The best way to determine the proportion of deaths due to harvest would be to radio-tag large numbers of young bucks and document the causes of mortality. However, the costs of doing this have been estimated to exceed $100,000 per replicate. Several to many replicates would be necessary throughout Wisconsin because of varying hunting conditions and hunter pressures. In view of the high cost, it appears that modeling and indirect means, as discussed below, will continue to be the basis for estimates of BRR for the foreseeable future.


Northern Forest
% Yearlings
Year
90
80
70
60
50
40
30
1960
1965
1970
1975
1980
1985
1990
1995
2000


Western Farmland
% Yearlings
Year
90
80
70
60
50
40
30
1960
1965
1970
1975
1980
1985
1990
1995
2000


Eastern Farmland
% Yearlings
Year
90
80
70
60
50
40
30
1960
1965
1970
1975
1980
1985
1990
1995
2000


Southern Farmland
% Yearlings
Year
90
80
70
60
50
40
30
1960
1965
1970
1975
1980
1985
1990
1995
2000

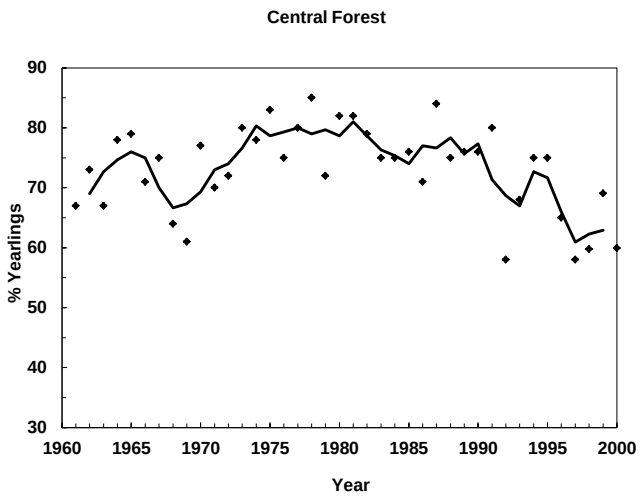


Figure 6.3. **Trends in the percentage of yearlings among adult bucks in Wisconsin deer management regions, 1960-2000. Dots are annual estimates and lines are 3-year running averages.**

Prior to 1985, we calculated SAK estimates using gun season harvests only and assumed that 80% of total mortality was due to gun season harvest (20% non gun-season mortality). We further assumed that BRR was constant both geographically and temporally. In 1986, we changed the SAK formula to include archery harvest and derived unit-specific estimates of BRR.

Geographic Variation in Buck Recovery Rates

Starting in 1986, we estimated BRR for individual deer management units. Estimates for Northern Forest units were based on a buck mortality model, the step-by-step derivation of which is described in the following narrative.

The first step was to plot average yearling buck percent (AYB%) over hunting pressure (*Figure 6.4*). The points here represented means for pressure classes for 2 periods of history. The solid line approximated the relationship described by the data. The broken line is an arbitrary extension to a base level of mortality on the Y-axis approximating mortality of an unhunted herd (i.e., the normal recruitment level). The combined curve represents estimates of total mortality on adult bucks relative to opening day hunting pressure.

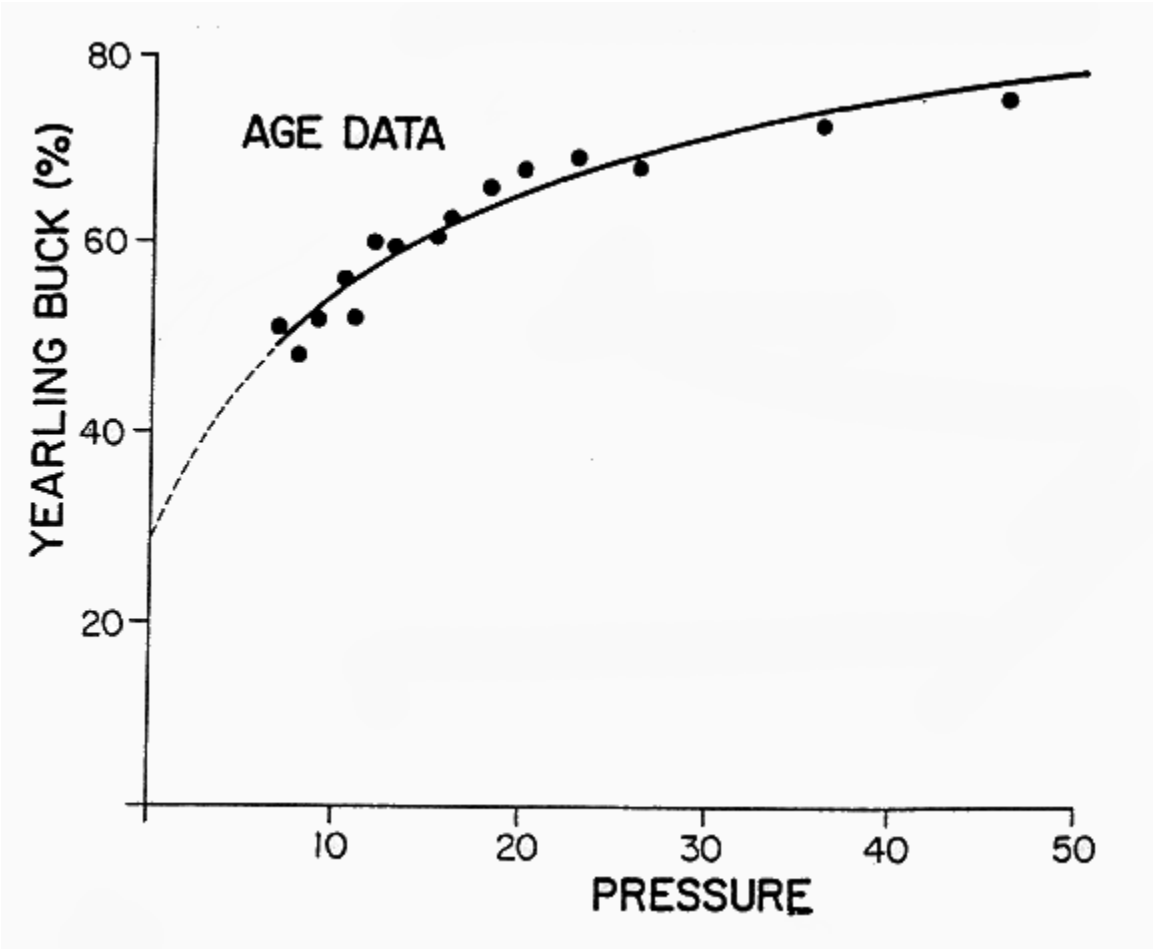


Figure 6.4. **Relation of observed percentage of yearlings among adult bucks to hunting pressure (hunters/mi^2 opening day) in the Northern Forest. The line is handfitted through points representing means for pressure classes.**

A minimum level of non-recovery (mostly unretrieved wounding mortality) of about 10% of total mortality was assumed to occur at the heaviest rate of exploitation in the North. This point was connected to the base mortality level on the Y-axis (*Figure 6.5*). The actual shape of the lower line was unknown but was curved to mirror the arch on the upper curve. This lower line became a preliminary estimate of nonharvest mortality for this range of hunting pressures.

A minor adjustment was proposed for flattening the upper curve. The AYB% in lightly hunted units is believed to be biased high for at least 2 reasons: (1) age samples in these units come disproportionately from the hunted portions which would have higher mortality rates than the unit as a whole, (2) age samples are more likely to be obtained in these units during periods of higher population and herd growth when YB%s are inflated. Hence, the AYB% curve might be flattened by the proposed curve to more nearly approximate a total mortality curve. The distance (on the Y-axis) between the modified upper and lower curves is the estimate of harvest mortality. While harvest mortality can be read directly from this model, the SAK formula calls for a BRR to calculate harvest mortality. The ratio of harvest mortality to AYB% is the BRR.

This model was corroborated using the historic relationship between buck harvests and population estimates from pellet group counts. To see this analysis, consult the 1989 edition of this Workbook or contact Integrated Science Services.

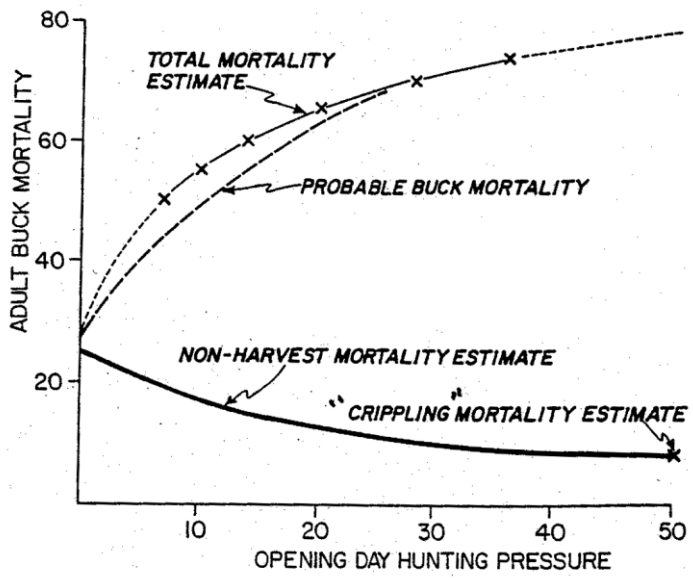


Figure 6.5. **Buck mortality model showing estimates of total adult buck mortality and nonharvest mortality relative to hunting pressure.**

Two approaches have been used to estimate BRR for northern units from the model. (1) For those units with age data, it was possible to work off of the Y-axis and assume the distance between the modified upper and lower curves at the AYB% to be buck harvest mortality. An estimate of BRR was determined by dividing this buck harvest mortality by the AYB%. (2) For units without age data, it was possible to work off of the X-axis at the measured hunting pressure, and again assume that the modified upper curve estimates total mortality at that pressure and that the distance between curves was buck harvest mortality. This buck harvest

mortality estimate divided by the corresponding value from the upper AYB% curve provides an estimate of BRR.

Estimates of nonharvest loss in the farmland and Central Forest regions were in large part intuitive and supported by some modeling exercises. Postseason dead-deer searches on the Sandhill Wildlife Area and in eastern Jackson County estimated unretrieved wounding mortality by firearm was equal to 7% of the counted gun harvest. With several other significant mortalities other than registered harvest (e.g., poaching, roadkill, non-compliance with registration, winter stress, unretrieved archery kills, predation, etc.), it seemed reasonable that harvest recovery of bucks might have been about 85% in Central Forest Units during the 1980s when buck mortality rates averaged 78%.

In the most heavily exploited farmland zones, we assumed that harvest recovery may be as high as 90%. Other losses in order of importance in farmland may be unretrieved wounding mortality (5%), roadkill (2%), non-registration (2%), and other (e.g., out-of-season poaching, predation, dog kills, etc. 1%). With annual mortality rates of 80% or higher in many farmland units during the 1980s, most yearling bucks died during their first year as an adult and had little opportunity to die from anything other than hunting. In farmland units where AYB% was 78% or less (similar to the AYB% in the Central Forest), we reduced our estimate of BRR to 85%.

These analyses yielded estimates of BRR for all units in the state during the late 1980s. All BRR estimates were rounded to the nearest 5%, and 60% was the lowest BRR used. The estimates of nonharvest mortality rates for the Central Forest and farmland regions were believed to be minimal estimates. If nonharvest mortality rates were greater than we assumed, then our estimates of buck recovery rate and buck harvest rate would have been biased high. Overestimation of buck harvest rate results in underestimation of population size. **Therefore, the SAK estimates for these regions were likely conservative estimates.**

Recent Update of Unit-Specific Buck Recovery Rates

Unit-specific estimates of BRR have been revised when AYB%s were updated *(Figure 6.6*). Throughout much of the farmland, yearling buck percents (mortality rates) were notably lower during the 1990s than during the 1980s. Lower YB%s were also evident in the Central Forest region, while AYB%s in the Northern Forest were similar to those in the 1980s.

We believe that the decline in annual mortality rates in the farmland and central forest regions was due to a decline in buck harvest rates and not reduced nonharvest mortality rates. If harvest rates decline and nonharvest mortality rates remain constant then the proportion of buck deaths due to harvests (BRR) would decline (*Table 6.3*). When buck harvest rates decline, more bucks are alive after the hunt and are exposed to nonharvest risks and the proportion of all deaths accounted in the registered harvest is lower.

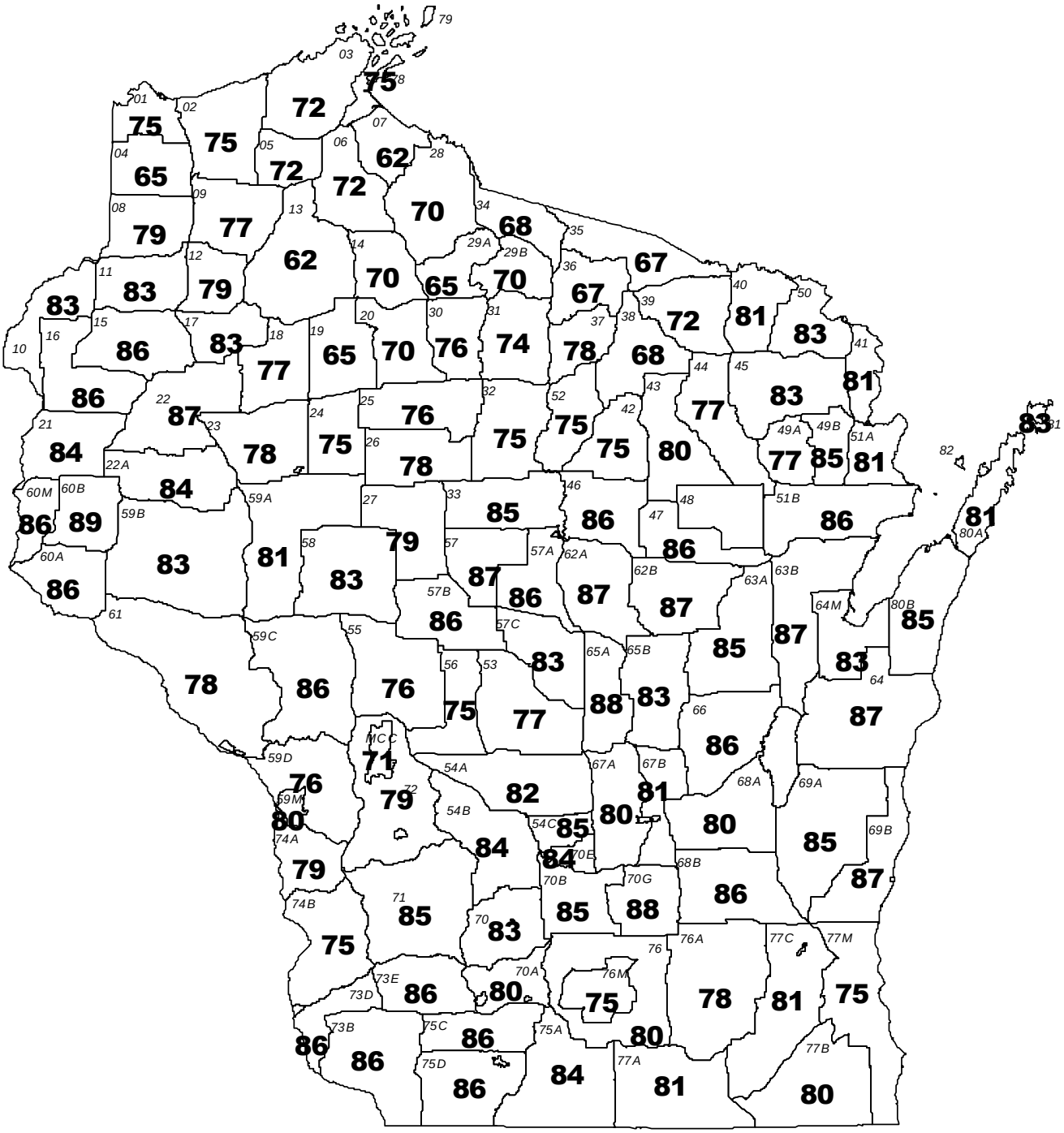


Figure 6.6. **Buck recovery rate used in calculating 2000 SAK deer population estimates.**

Table 6.3. **Illustration of changes in buck recovery rate with changing buck harvest rates, assuming a constant nonharvest mortality rate of 15%, and 1,000 bucks alive prehunt.**

Buck Harvest Rate	Bucks harvested	7% "crippled" or not reported	Bucks alive posthunt	Nonharv. buck deaths (15%)	Total buck deaths	Annual buck mortality rate	% deaths due to harvest BRR
80	800	56	144	22	878	88	91
70	700	49	251	38	787	79	89
60	600	42	358	54	696	70	86
50	500	35	465	70	605	60	83

Based on the buck mortality model (*Figure 6.5*) and modeling excercises similar to the illustration in Table 6.3, we proposed a relationship between total buck mortality and BRR (*Figure 6.7*). This hypothetical relationship was used in 1999 and 2000 to update estimates of BRR.

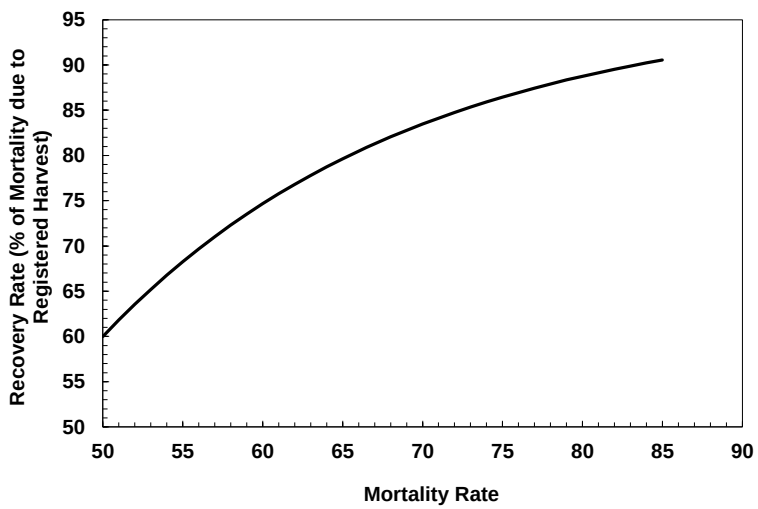


Figure 6.7. **Hypothetical relationship between buck mortality and recovery rates.**

Temporal Variation in Buck Recovery Rates

Incorporation of temporal variation in BRR into SAK estimates has been more difficult than including spatial variation. If we assume that buck harvest rates (product of AYB% and BRR) are constant, then the SAK procedure produces estimates of the prehunt buck population that are proportional to the buck kill. However, adverse conditions during the hunting season (especially precipitation, but also soft roads, unfrozen or flooded wetlands, standing corn, deep snow, snow on branches, or no snow) may suppress harvest rates and SAK estimates would be biased low. This was believed to occur in 1983 when rain fell every day of the 9-day gun season. If hunting conditions are markedly above average (1-4 inches of snowcover, no precipitation during days, frozen roads and marshes, corn harvested, early opening date, etc.) as in 1989, population estimates can be inflated. In the North, the extremes in opening date (17-23 November) may affect the harvest result by 10-15% as the date moves toward or away from the peak of the rut (normally about mid-November).

Harvest rates can also be affected by several other factors. In the Central Forest, the prevalence of sub-legal spikes (≤3") in some years may reduce buck kills by as much as 15% (as perhaps happened in 1985). In the farmland regions, huge numbers of antlerless-only permits in 1984 seemingly reduced buck kills by about 15%. The 1996 earn-a-buck provision in selected farmland units reduced buck harvests in these units by about 40%. These factors are not easily accommodated in the SAK procedure.

In some years we have attempted to refine SAK estimates by adjusting the BRR based on subjective assessments of hunting conditions/weather. In 1986, hunting conditions were recognized as being so good that District Wildlife Supervisors adjusted the SAK postharvest estimates downward for northern units. Again in 1987 and 1989, estimates were adjusted downward by using a model of the relationship of hunting conditions and BRRs (*Figure 6.8*).

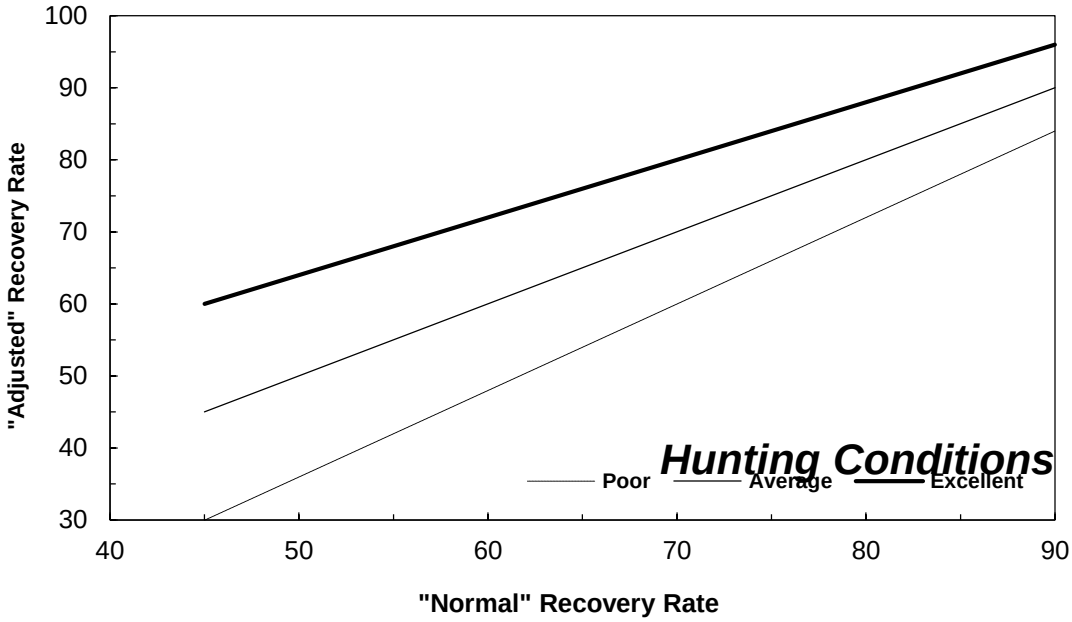


Figure 6.8. **Model of the relationship of hunting conditions and buck recovery rates in the Northern and Central Forest regions.**

This model assumed that units with a high average BRR would be less affected by hunting conditions than units with a low BRR. Thus, units with an average BRR of 80% might be increased by only 10% (to 88%) under "ideal" hunting conditions whereas a unit with an average BRR of 50% might be increased by as much as 30% (to 65%). These adjustments have been applied when experienced northern managers have rated the hunting season conditions 8 or above on an arbitrary scale of 1 to 10, with 10 being excellent (1989 was ranked a 12!).

An intermediate upward adjustment of BRRs was applied at the request of the Wildlife Management Bureau office in 1994 because of good hunting conditions and very high population estimates and a full adjustment was made in 1995.

The model also makes provision for downward adjustments of BRR (increasing SAK estimates) when buck harvests are seriously impaired by poor hunting conditions (e.g., 1970,

1976, 1978, 1982, 1983, 1991, 1992), although these adjustments have never been applied. The sequence of blizzards (October 31 and opening weekend of the firearm season) in 1991 seriously confounded the interpretation of buck harvests. As a result, SAK estimates were not used for planning the 1992 season. Until, a quantitative means of measuring hunting conditions is developed to aid in applying future BRR adjustments, adjustments are likely to be applied only in those years when hunting conditions markedly depart from average.

Yearling Doe Percent

The yearling doe percent (YD%) is the percent of does ($\geq$1.5 yrs) aged at registration stations that are 1.5 years old. YD% is a function of the productivity of the does bearing fawns the previous year and the subsequent survival to age 1.5. YD% will be high in productive herds and lower in less productive herds and will fluctuate for a given herd if there are major changes in either production or fawn survival.

In most cases, YD% does not change with increased adult doe mortality (unless production also increases) nor does it decrease proportionately with reduced adult doe mortality. Unlike bucks, the adult doe population could be gradually shot to extinction without showing major changes in YD% so long as does were shot proportionally across all age classes. As you shoot adult does you also preclude their future progeny, hence the ratio of yearling does to older does remains relatively unchanged.

As with YB%, the female segment of the population must be age-stable and stationary for YD% to also be an unbiased estimate of annual mortality rate. Under these conditions, YD% is also an estimate of recruitment, if recruitment is defined to take place at age 1.5 years.

Average YD% (AYD%) also indicates the approximate total annual mortality rate that the female segment of the population is capable of sustaining. For example, a unit with a YD% consistently running 34% can withstand mortality of about 34% of does, not all of which can be harvest mortality.

Figure 6.9 shows the number of does aged in each deer management unit during 1996-2000. Unit-specific sample sizes range from 0-1,079. Estimates of average YD%s used as SAK model inputs for 2000 are shown for each unit in Figure 6.10. Values for units with insufficient number of does aged were estimated by interpolation from surrounding units taking into consideration information on recruitment rates from fawn:doe ratios.

During the past 40 years, YD%s have averaged 26% in the Northern Forest, 34% in the Central Forest, 37% in the Eastern Farmland, 41% in the Western Farmland, and 41% in the Southern Farmland (*Figure 6.11*). Temporal variation in YD%s tends to mirror changes in YB%s in the Northern Forest, reflecting variation in recruitment associated with winter severity. YD%s in the Central Forest were depressed in late 1960's through early 1970's and in 1979 due to poor fawn survival resulting from severe winters. Peaks in Central Forest YD%s in 1977 and 1981 were associated with good production years. YD%s have tended to be fairly stable in the Eastern Farmland. Declining trends in YD%s during 1980's and again in the mid 1990's are suggested in the Western Farmland Region. A gradual decline in YD%s during the past 10 years is suggested in the Southern Farmland, perhaps due to a density-dependent decline in recruitment.

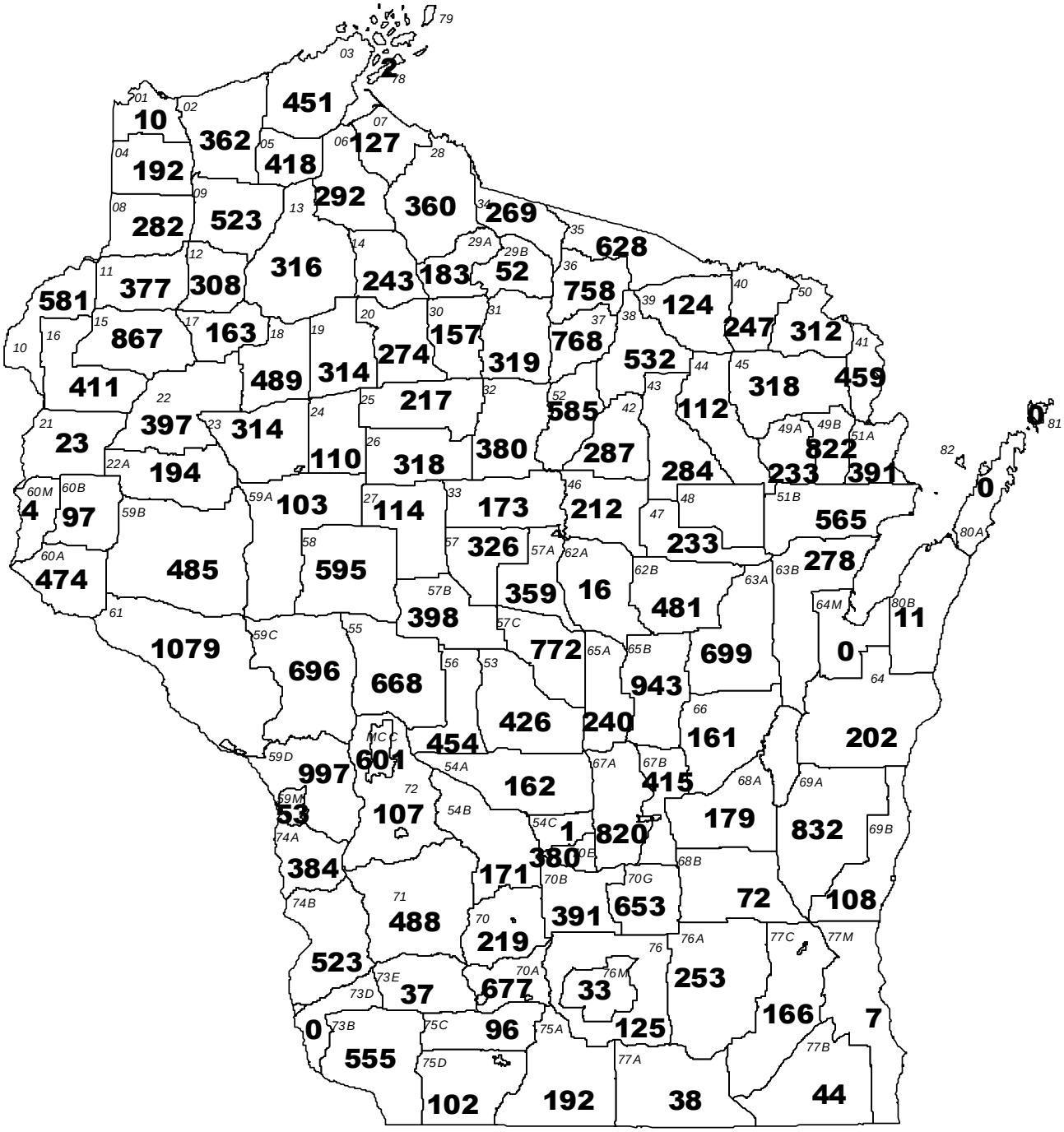


Figure 6.9. **Number of adult (≥ 1.5 year-old) does aged at Wisconsin deer registration stations, 1996-2000.**

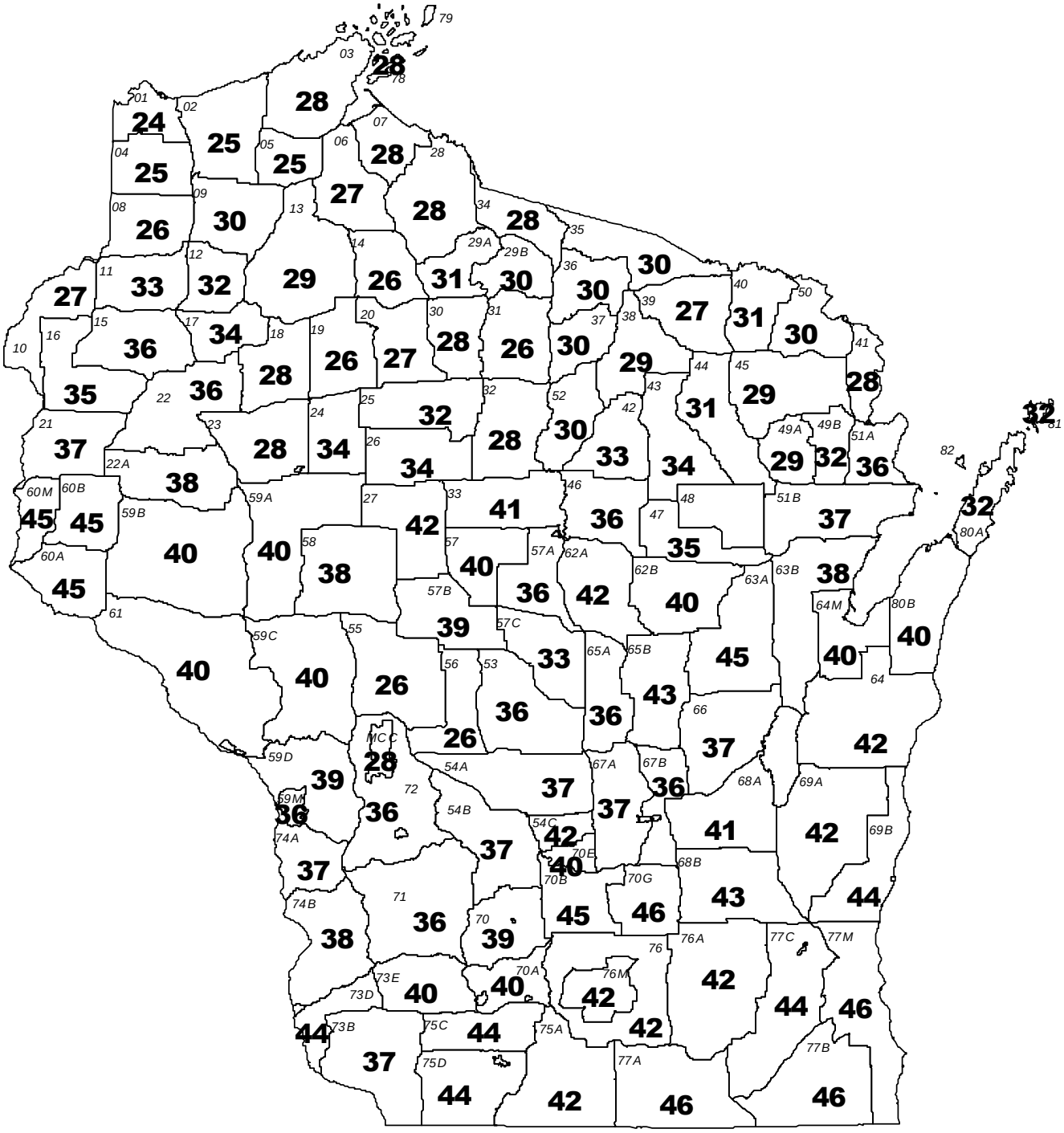


Figure 6.10. **Estimates of average percentage of yearlings among adult does during 1996-2000 used for 2000 SAK population estimates.**

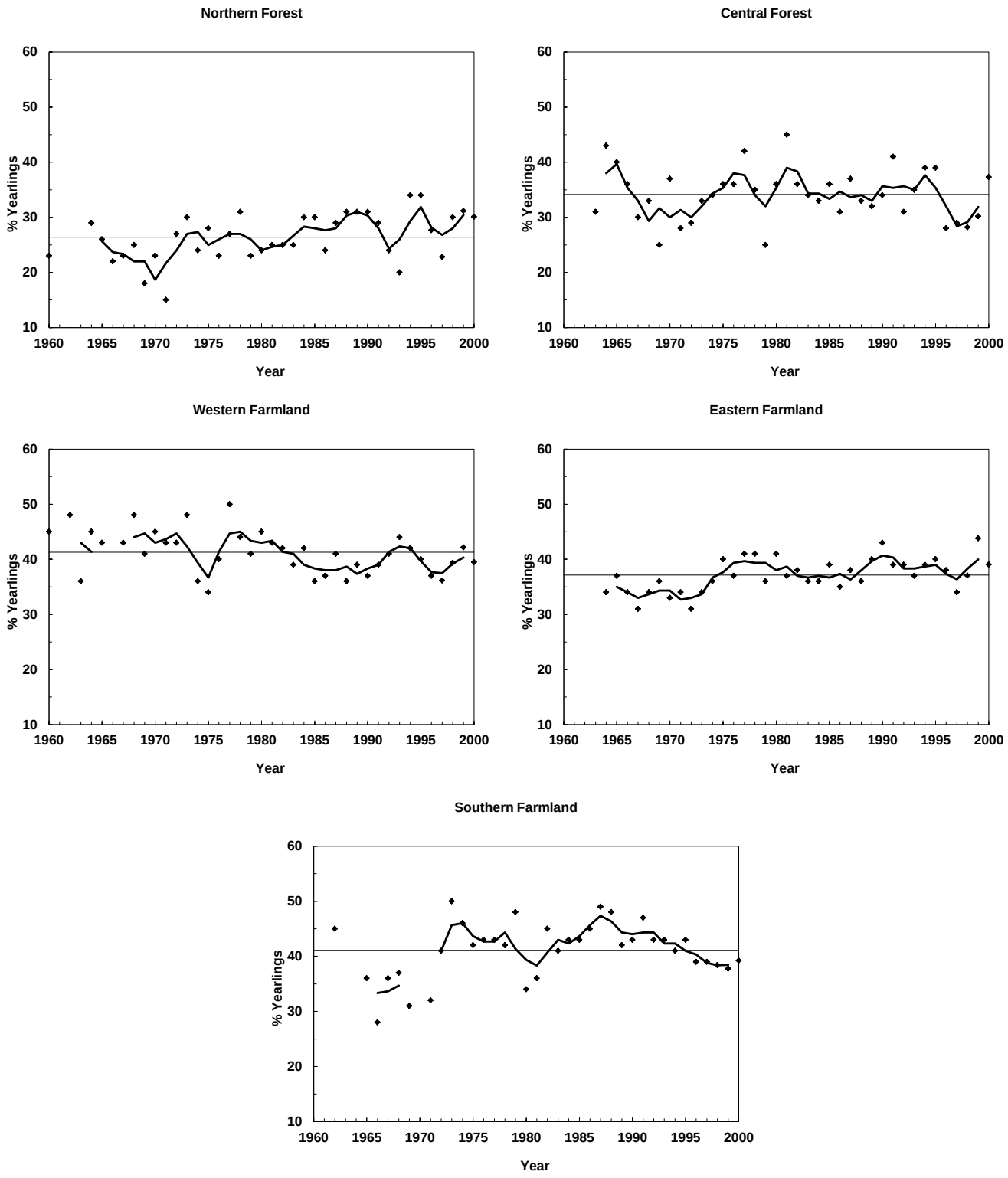


Figure 6.11. **Trends in the percentage of yearlings among adult does in Wisconsin deer management regions, 1960-2000. Dots are annual estimates, bold lines are 3-year running averages, and horizontal lines are long-term averages.**

Adult Sex Ratio

The percentages of yearling bucks and does are estimates of the mortality rates of the adult males and females. Thus, we can estimate adult sex ratio (ASR) by dividing the YB% by YD%. That is, if bucks are dying twice as fast as does and they are born into the population in approximately equal numbers, the ASR must be about 2 does to 1 buck. This method for estimating ASR was first described by Severinghaus and Maguire (1955) and has been used in several other deer population models (Lang and Wood 1976, Moen et al. 1986).

Heretofore, we have used long-term yearling percents to estimate long-term average sex ratios in each unit. However, ongoing analyses suggest that we might get better estimates of annual sex ratios by using annual observed YB% and YD%. Unlike estimates of mortality rates, estimates of ASR are not biased by fluctuations in recruitment or increasing or decreasing population trends because these changes affect the recruitment of both sexes equally. The main difficulty, if we were to use annual age samples, is getting samples of adequate size for both sexes in individual management units.

Figure 6.12 shows trends in adult sex ratios for the 5 regions of Wisconsin during 1960-2000. Sex ratios in the forested regions and the Eastern Farmland Region over the long term have averaged approximately 2 does/buck. The long-term average of sex ratios in the Western Farmland Region was 1.66 does/buck, compared to 1.79 does/buck in the Southern Farmland Region. Some of the variation in annual estimates of adult sex ratios may be due to small samples of aged deer, especially in the Northern Forest during the early 1970s. Changes in the 3-year average ASR likely reflect real changes in the sex structure of regional populations.

Merely dividing YB% by YD% will provide an approximation of ASR. However, like boys and girls, bucks and does are not born in exactly equal numbers in a deer herd. Therefore, the ratio of the yearling percentages is corrected slightly by multiplying by the fetal sex ratio.

Fetal Sex Ratio

The fetal sex ratio (FSR) is the proportion of male to female fawns at birth. Male mammals tend to be born in somewhat greater numbers than females. In utero examination of 1,803 fetuses during 1982-87 found 109 males/100 females in Wisconsin deer (McCaffery et. al. 1998). Fetal sex ratios did not vary among the 5 regions of Wisconsin. Minnesota showed a similar ratio of 107/100 for over 1,600 fetuses (Bill Berg, MN DNR, pers. comm.). With the exception of their Northeast food shortage area, Michigan's fetal sex ratios are near 110/100 irrespective of range type and latitude (Paul Friedrich, MI DNR, pers. comm.). Historically, in SAK calculations we used sex ratios of aged fawns in regional harvests for FSR. Since 1986, we have assumed that a statewide FSR of 110/100 is reasonable for Wisconsin and that this ratio does not vary among years. We further assume that this ratio carries over to the yearling age class. That is to say, we assume that fawn mortality rates do not differ among sexes. Future research may find that sex

ratios as yearlings may be closer to parity.

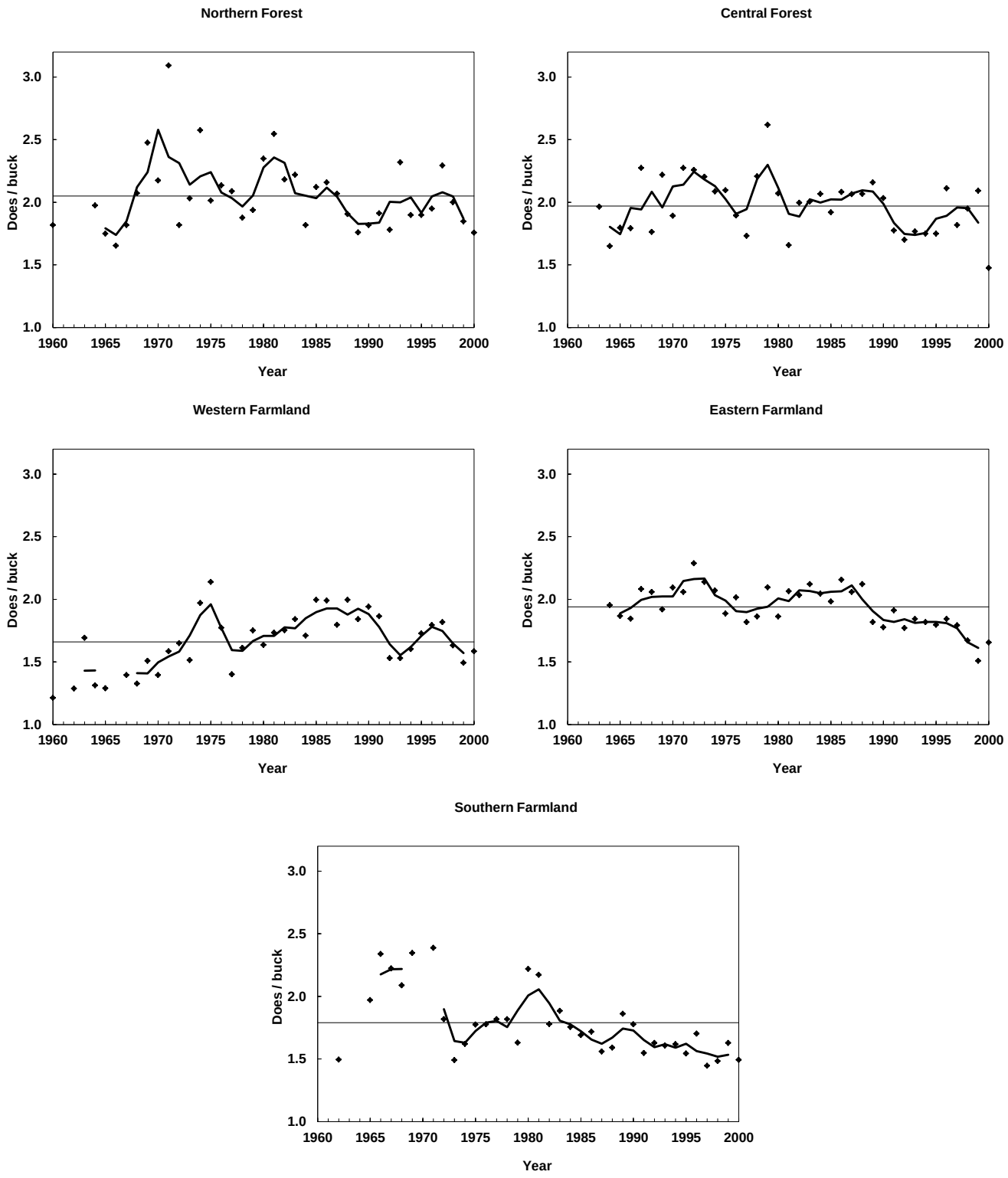


Figure 6.12. **Trends in the adult sex ratio in Wisconsin deer management regions, 1960-2000. Dots are annual estimates, bold lines are 3-year running averages, and horizontal lines are long-term averages.**

Fawn:Doe Ratio

In SAK population estimates, we have been using annual estimates of fawn:doe ratios (FDR) from the Summer Deer Observation Survey for the Northern and Central Forest regions. The FDR's we have been using in SAK estimates for the forested regions have been calculated for Unit Groups, not individual deer management units. Unit-specific sample sizes tend to be small and unit-specific estimates of FDR are considered unreliable.

Annual variation in FDRs in the Northern Forest Region since 1960 has been significantly correlated with 2 other indices of recruitment, percentage of yearling bucks with forked antlers and YD% (*Figure 6.13*). Rasmussen (1985) concluded that antler development in yearling males is one of the most sensitive indices of physical condition of white-tailed deer. Annual changes in FDRs in the Northern Forest have also been negatively correlated with the Winter Severity Index (WSI, r[1] = -0.52, $P = 0.001$). In the Central Forest Region, FDRs were correlated with percentage of yearlings with forked antlers (r = 0.62, $P < 0.001$) but not with YD%s. The negative correlation between FDRs from the Central Forest and WSI has been weaker (r = -0.40, $P = 0.02$) than the Northern Forest relationship, but still significant.

Interpreting annual changes in FDRs from the farmland regions has been more difficult than from the forested regions. Correlation between annual estimates of FDRs since 1960 and the percentage of yearling bucks with forked antlers was significant in the Eastern Farmland Region (r = 0.44, $P = 0.008$), but not in the Western (r = 0.04, $P = 0.81$) nor Southern (r = 0.25, $P = 0.14$) Farmland regions. Likewise, the correlation between FDRs and the percentage of yearlings among does in the subsequent harvest was significant in the Eastern Farmland Region (r = 0.37, $P = 0.03$) but not significant in the other 2 farmland regions (Western, r = -0.22, $P = 0.22$; Southern, r = 0.12, $P = 0.51$). Although annual variation in 2 of the 3 farmland regions was poorly correlated with other recruitment indices, the statewide, geographic pattern of long-term average (1981-97) FDRs was significantly correlated with geographic variation in the percentage of yearlings with forked antlers (r = 0.54, $P < 0.001$) and the YD% (r = 0.56, $P < 0.001$).

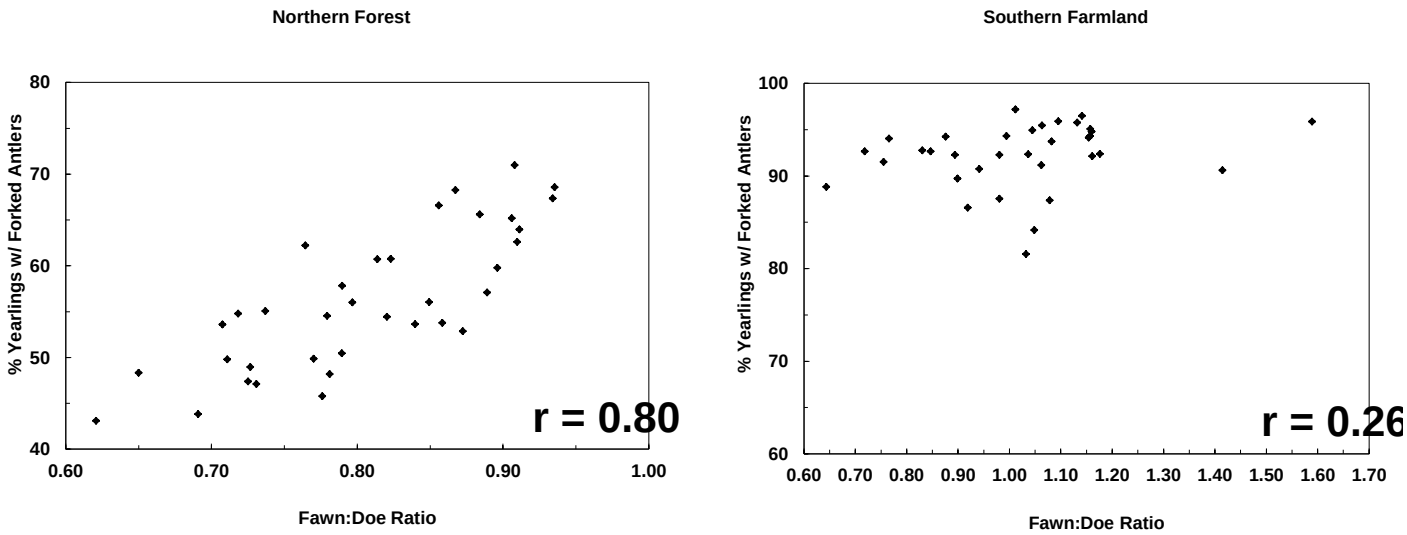
We do not fully understand the reasons for poor relationships between the FDRs from the Summer Deer Observation Survey and the other indices of recruitment. Sample sizes in the Southern Farmland Region have varied widely during 1960-2000, from 41 to 812 does reported. Variation in the proportion of observations reported during the 3 months of the survey may affect the annual estimates. For example, in the Southern Farmland during 1988-95, 48% of the observations reported were from July, but in 1996 70% of the observations were made in July. July observations consistently yield a lower FDR than observation in August and September because fawns are not yet consistently traveling with does in July. The high proportion of observations from July in 1996 appears to be largely responsible for the low FDR observed that year. In addition to the difficulty in interpreting changes to the annual estimates from the farmland regions, we suspect the long-term mean FDRs from these regions are biased low (*Figure 6.14*).

---

[1] r is the Pearson correlation coefficient. It can range from –1 to +1, –1 represents a perfect negative association between to variables, +1 a perfect positive association, and 0 no association.

The long-term mean ratios range from 0.92 in the Eastern Farmland to 1.01 in the Western Farmland. Estimates of regional in utero productivity, based on age-specific fetal counts of

Fawn:doe Ratio versus % Yearling Bucks with Forked Antlers



Fawn:doe Ratio versus % Yearling Does

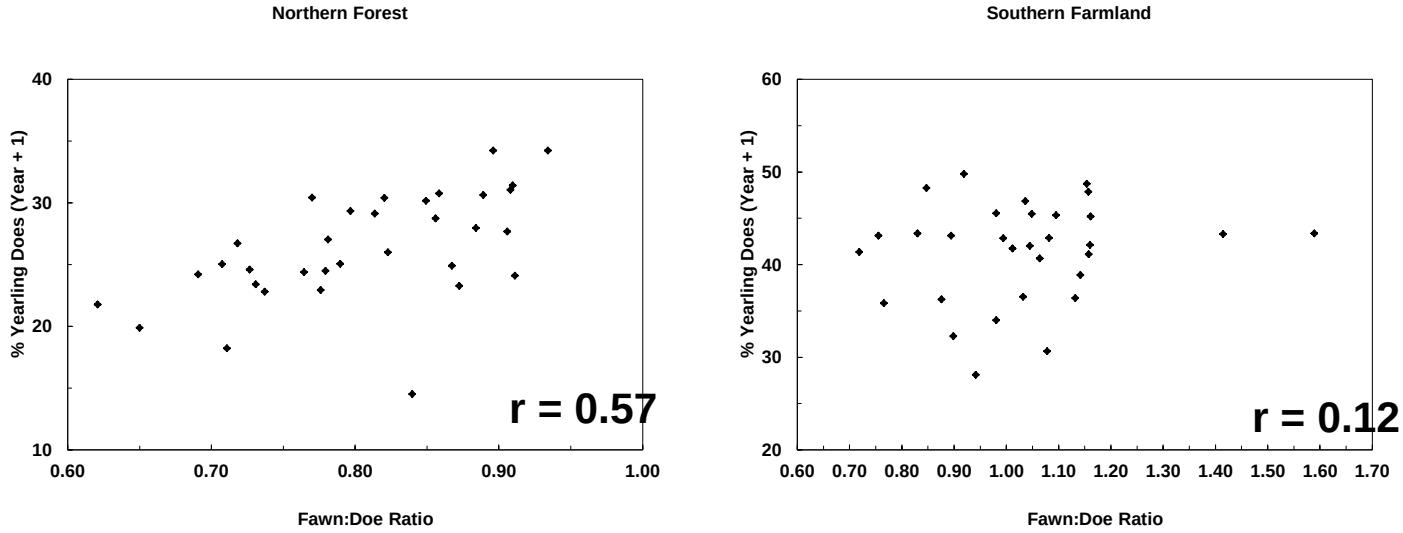


Figure 6.13. **Relationship between fawn:doe ratios and other indices of recruitment (percentage of yearling bucks with forked antlers and percentage of yearlings among adult does the following year) in the Northern Forest and Southern Farmland regions of Wisconsin, 1960-95.**

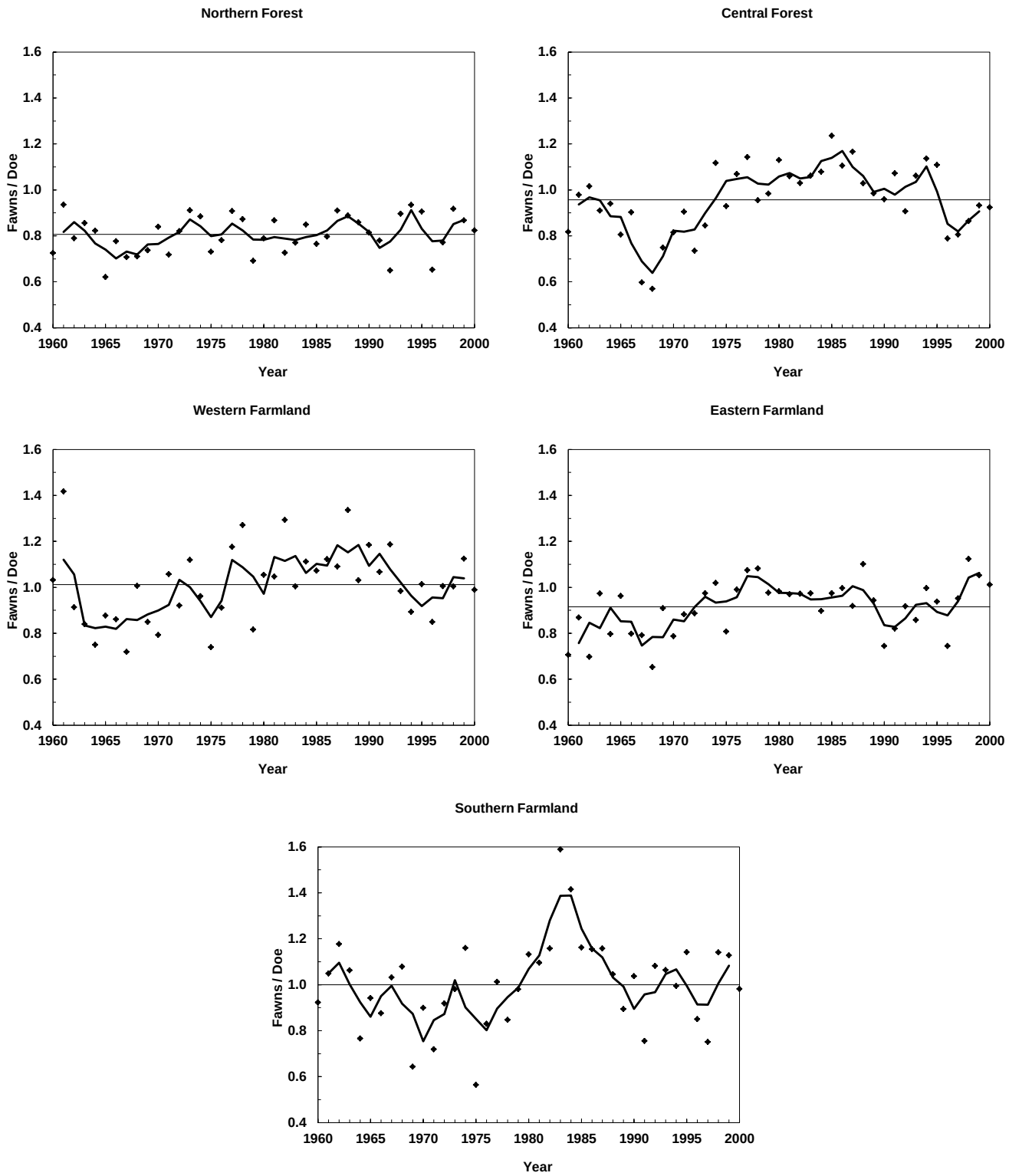


Figure 6.14. **Trends in the fawn:doe ratio in Wisconsin deer management regions, 1960-2000. Dots are annual estimates, bold lines are 3-year running averages, and horizontal lines are long-term averages**.

vehicle-killed does and population age structure, during 1982-87, ranged from 1.20 fawns/doe in the Western Region to 1.26 fawns/doe in the Southern Region. A possible reason that the Summer Deer Observation Survey may underestimate fall recruitment is the inclusion of observations from July. McCullough (1982) concluded that fawn/doe ratios from spotlight counts on the George Reserve in Michigan were severely biased low during July. Downing et al. (1977) documented unequal observability of does and fawns during July-September in daytime
roadside observations in Virginia and Texas. This bias was believed to be due to differences in feeding and bedding times. In Wisconsin, regional mean FDRs during 1988-95 calculated from the 3-month sample were 13-16% lower than ratios calculated from August and September observations only (*Figure 6.15*).

Because annual variation in FDRs from farmland regions has not been consistent with other indices of recruitment and concerns about potential bias of the ratio, we have been using long-term constant estimates of FDRs in the SAK calculations. We have used average yearling doe percents as a basis for assigning these constants to management units within the farmland regions. We have assumed a FDR of 1.0 where the AYD% is 32-34%, 1.1 if AYD% is 35-39%, and 1.2 if the AYD% $\geq$ 40% (*Figure 6.16*). Additional research may improve our ability to assess changes in fall recruitment.

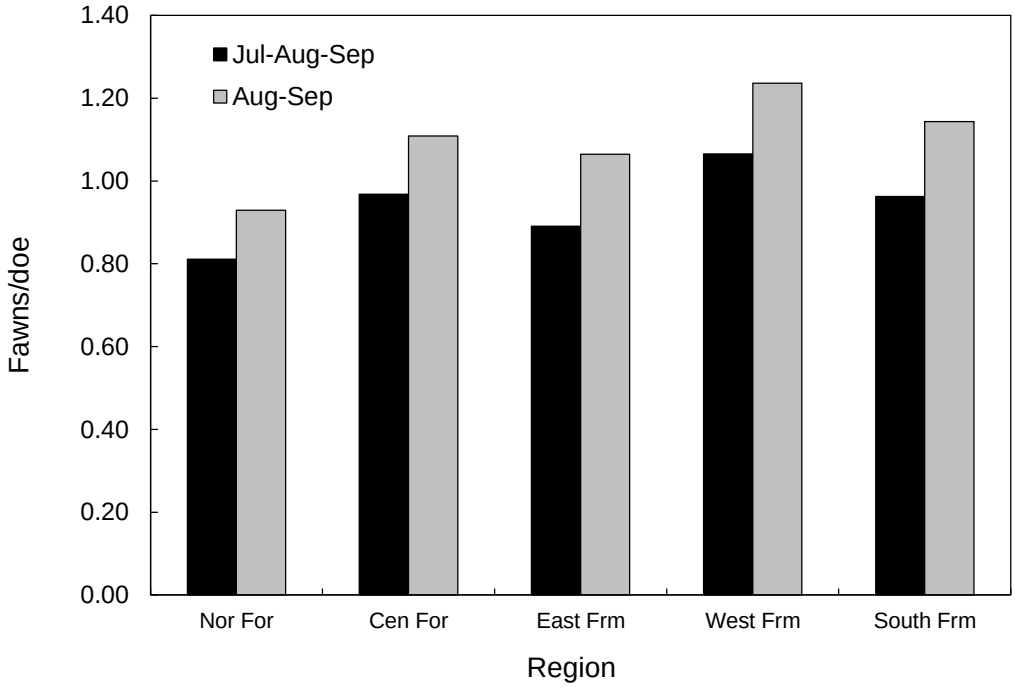
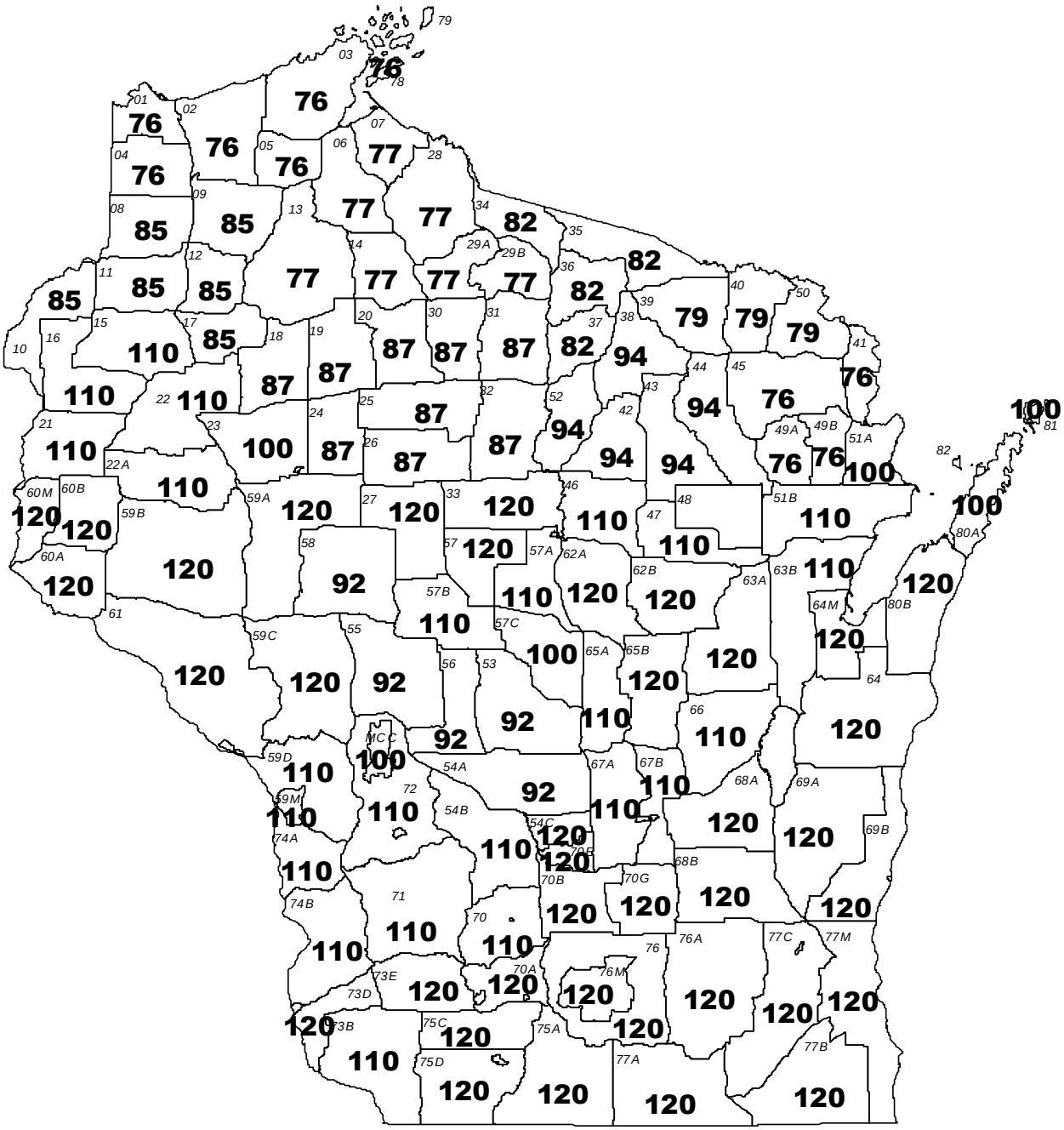


Figure. 6.15. **Effect of month on estimates of fawn:doe ratio in Wisconsin deer management regions, 1988-95**.


76
76
76
76
76
77
77
77
77
77
77
77
85
85
85
85
85
82
82
82
82
79
79
79
110
110
110
110
87
87
87
87
87
87
87
87
94
94
94
94
94
76
76
76
76
100
100
100
120
120
120