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Development of habitat inventory techniques for rapidly assessing impacts of forest management practices on deer

Mark D. Lowery

FINAL JOB COMPLETION REPORT

State: New York

Project No.: W-105-R

PROJECT TITLE: Wildlife Ecology, Behavior, and Habitat Improvement in New York.

STUDY NO. AND TITLE: XIII - Deer Management Research in Northern New York Ecosystems.

STUDY OBJECTIVE: To research selected aspects of the deer resource dynamics that have been identified as key components in the redefinition and/or implementation of deer management strategic plans and programs in northern New York.

JOB NO. AND TITLE: XIII-2 Development of habitat inventory techniques for rapidly assessing impacts of forest management practices on deer.

JOB OBJECTIVE: To develop a method for providing an inventory of current vegetation and land use status, and relating this to habitat suitability for white-tailed deer in northern New York.

PERIOD COVERED: April 1, 1978 to March 31, 1982.

Abstract: Two analyses were used to relate population levels of white tailed deer *(Odocoileus virginianus)* to habitat characteristics. Both analyses were based on multiple linear regression. Deer populations were indexed by county specific adult male harvest statistics. Estimates of the availability of forest types in each of the 14 Adirondack counties were obtained from the U.S. Forest Service Forest Surveys completed in 1967 and 1978. Agricultural data were obtained from the U.S. Bureau of Census, Census of Agriculture. In the first analysis, indices of deer populations in each of the 14 counties were used as the dependent variable. The values of the predictor variables were the percentages of the county in each of the recognized forest or land use types. A split-sample, cross-validation was used to analyze data from both survey periods. This analysis was an index to the change in deer populations in each county between the two survey periods. The values of the predictor variables were the changes in percentages of the county, in each forest or land use type, between the two time periods. This analysis yielded a model ($Y = B_0 + B_1 X_1 ... + B_K X_K + \ell$) which can serve to predict change in habitat quality, if changes in forest and land use conditions can be predicted. This regression model was modified to fit biological interpretations. Examples of the use of this modified model are provided for St. Lawrence County and for the Adirondack region. Means of predicting land use changes, as well as weaknesses and assumptions of the model are discussed and exemplified.

INTRODUCTION

The objective of this work was to develop a method of predictive trends in habitat quality for white-tailed deer in the Adirondacks. The method was intended to be rapid and easy to use. Projections of habitat quality change were to be based on projections of land management schedules and their likely effects on habitat quality. These objectives necessitated development of a model predictive of habitat quality change, given changes in land use and forest condition. Also needed was a means to gather the information necessary to drive the model, or identification of an existing data base which supplies the necessary information.

Past efforts at quantitative assessments have consisted of tallies of the total area in each township or county which could reasonably be expected to be used by deer. In these estimates, deer habitat consists of woodlands, pasture and idle lands. There has been no attempt to weigh the components of deer habitat according to their relative importance to deer. Nor has there been any attempt to ascribe habitat values to different conditions of habitat components (Severinghaus and Sauer 1964).

Other habitat assessments in New York have included identification of wintering areas as critical habitat. However, past research on wintering areas has concentrated on the relationship between winter mortality and winter severity, with little examination of differences in yard quality (Sauer 1976). Yearling antler beam diameter is used in New York as an index to the balance between herd size and habitat conditions.

Most research in northern areas has concentrated on winter habitat quality. The assumption has been that adequate provision for the most severe period of the year would ensure good herd conditions throughout the year. However, research has demonstrated the importance of non-winter habitat as well. Winter survivorship of deer is dependent not only upon the length and severity of winter but also upon the condition of the deer as winter begins (Verme and Ozaga 1971, Mautz 1978). Julander et al. (1961) related mule deer *(O. hemionus)* productivity to summer range conditions in the west. They found that not only did the lower quality and availability of forage on the poorer summer range produce smaller deer, it also led to lower reproduction. Mautz (1978) points out that deer in many northern areas cannot survive the winter if they do not store sufficient amounts of fat during the summer and fall. The present study has not focused on a particular aspect of habitat but has attempted to quantify population responses to change in a variety of habitat components.

METHODS

Multiple linear regression was used to develop a model to predict changes in deer harvest, given changes in forest condition and land use. A predictive equation of the form

$$Y = B_{\Theta} + B_1 X_1 + B_2 X_2 + B_K X_K + \ell$$

was developed. $\hat{B}_O - \hat{B}_K$ are estimates of the parameters $B_O - B_K$. The value of $\hat{Y}$ is both an estimate of the expected value of Y and, of greater interest, a particular value of Y for given values of the predictor variables $X_1 - X_K$. Values of the parameter estimates $\hat{B}_O - \hat{B}_K$ are chosen so as to minimize the sum of squares of deviations of the predicted values of Y and the true value of Y for each set of values of $X_1 - X_K$. Selection of parameter estimates according to this criteria is known as the least squares method of fitting a line. In the equation "e" is some error that is random and represents the variability of Y (Mendenhal 1968).

Two types of analysis were performed in this study. Both analyses utilized the estimated adult male harvest per mi^2 of deer habitat as calculated by Severinghaus and Sauer (1969) for each of the 14 Northern Zone counties[1]. Information on forest condition in each county was obtained from the forest survey of the U.S. Forest Service (Ferguson and Mayer 1970, Barnes[2] pers. comm.). Information on agricutural land use was obtained from the U.S. Census of Agriculture (Bureau of Census 1969, 1978).

Forest survey methods are described by Ferguson and Mayer (1970). Two independent inventories were used. The first inventory was based on remeasurement of survey plots established during the first survey in 1950 (Marquis 1954). These remeasurements were used to estimate current timber volume and forest area.

The second inventory was based on the most recent aerial photography of

[1] Clinton, Essex, Fulton, Hamilton, Herkimer, Jefferson, Lewis, Oneida, Oswego, St. Lawrence, Saratoga, Warren, Washington Counties.

[2] Robert Barnes, Research Wildlife Biologist, U.S.F.S. Northeast Forest Experiment Station.

the state. Photo plots were classified as forested or nonforested and forested plots were placed in volume classes. Subsamples of the photo plot volume classes were measured on the ground to provide estimates of the mean and variance of area and volume for the photo volume classes. This information was then expanded by photo volume class to yield estimates of forest area and timber volume. Final estimates of area and volume were obtained by combining the results of the two independent inventories. The contribution of each inventory was dependent on the variance obtained by that method. Forest surveys of New York were completed in 1967 and 1978.

The forest survey recognizes commercial forest land (CFL)[1], noncommercial forest land (NFL), unproductive forest land, and nonforest land. Forest Preserve lands are included in the noncommercial forest land category. Timber volume, and area of forest types and stand sizes are reported only for CFL. Use of forest survey data then implies that one of two assumptions is being made. (1) The condition of CFL is representative of the condition of other categories of forest land throughout the county. (2) CFL is the most dynamic of forest land categories and most likely to affect deer populations. The latter assumption does not appear to be unreasonable, especially within the Adirondack Park. Forest Preserve lands would be expected to reach maturity and undergo relatively little further change.

The Statistical Analysis System (SAS) procedure STEPWISE was used for these analyses (SAS Institute 1979). Stepwise regression is used to select a subset of predictor variables to yield a predictive equation with the fewest possible terms. Stepwise regression may be forward, backward of combinatorial.

[1] Appendix B provides a summary of mnemonics used in this report.

In forward regression the best single predictor variable is chosen to begin the model building. In the next step, the remaining predictor variables are examined and that predictor which will make the most improvement in the model's predictability is added to the model. Depending on the computer package in use, the user might specify the number of predictor variables to be included, the minimum level of significance of the regression coefficients of variables in the model, or the minimum amount of unexplained dependent variable variance that inclusion of the predictor variable would explain (i.e. minimum increase in r^2 (SAS Institute 1979, Nie et al. 1975).

Backward regression begins with a model which includes all of the predictor variables. The variables making the smallest contribution to the model, according to one of the criteria listed above, are successively dropped from the model, until all of the remaining variables contribute significantly to the model. Combinatorial methods use combinations of forward and backward stepwise regression. These methods use a variety of criteria to select combinations of predictor variables to be examined. For example, the SAS STEPWISE procedure - STEPWISE option is a modification of the forward regression technique. After each variable is addded to the model, any variable already in the model, which does not now meet the statistical criteria for remaining in the model, is deleted from the model (SAS Institute 1979).

The SAS combinatorial procedure STEPWISE with maximum r^2 improvement option (STEPWISE/MAXR) was used for these analyses. This technique is considered to be almost as good as regression on all possible subsets of predictor variables. STEPWISE/MAXR first finds the predictor variable which produces, by itself, the highest coefficient of determination (r^2). The best (i.e. highest r^2) variable model is then found. At this step, the variables in the model are compared to those not in the model. STEPWISE/MAXR determines if removing any variable or replacing it with another will increase r^2. This yields the best 2-variable model. The next variable is added to the model and the comparing and switching continues until the best 3-variable model is found. The process of adding variables and comparing, deleting and switching variables continues until no further improvement in r^2 is possible (SAS 1979).

Analysis I

In the first analysis the dependent variable was the mean number of adult male deer harvested per mi^2 of deer habitat in each of the 14 counties, for the five years bracketing the year in which the forest data were collected. That is, deer harvest data for 1965-1969 were used with the 1967 forest survey data, and 1976-1980 data were used with the 1978 forest survey data. Five year means were used to eliminate effects of other factors such as year-to-year differences in weather, hunting pressure or hunter success. The same estimates of deer habitat in each county were used in the two time periods because no updated estimates were available (Severinghaus and Sauer 1964). It is recognized that the amount of habitat certainly changed significantly from the time the estimates were first made (1959) to 1980. It was felt, however, that in the absence of later estimates, it was more reasonable to use these estimates of habitat for calculation of buck kill indices (BKI) than to use total county land area.

The predictor variables in Analysis I were variables related to agricultural land use and forest condition in the counties. Agricultural variables included total harvested cropland (HC), land in corn (CORN), land in harvested crops other than corn (OHC) and land in pasture (PAST). The values of these variables were the relative proportions of the estimated deer habitat in each county in each land use class. For example, deer habitat for a county may be estimated at 47,000 ha., with 3760 ha. in pasture. The value of the variable PAST for this county would be (3760 ha ÷ 47,000 ha) X 100 = 8%.

The forest survey recognizes 9 forest type groups in New York, each of which type groups consists of several forest types. Appendix A provides a list of the forest types included in each forest type group. In this study, the white and red pine, spruce-fir and loblolly-shortleaf pine forest type groups were combined to form the softwoods (SW) class. The oak-pine, oak-hickory, oak-gum-cypress, elm-ash-cottonwood, northern hardwoods and aspen-birch forest types comprised the hardwood (HW) class. Three size classes, seedling-sapling (SS), poletimber (PO) and sawtimber (ST) were recognized for both the HW and SW classes. For the purposes of this report, the classification entity defined by a specific size class of a specific timber class will be termed a habitat type (e.g. HWST). A seventh habitat type, nonstocked stands (NSTK) was also included.

Data from the 2 survey periods were analyzed separately in a split-sample, cross-validation design, the data from each survey period being equivalent to one half of the sample. Green (1978) provides an algorithm for this type of analysis. In the first step, a stepwise regression procedure is used to find the best predictive model for each of the subsamples. The two predictive models are compared. Variables which have significant (i.e. significantly different from 0) parameter estimates and whose parameter estimates maintain the same sign (±) in both models are identified. A predictive equation is again calculated for each subsample, using only these identified variables. The general applicability of the models is tested by cross-validation. The predictve model developed for the data in the first subsample is applied to the data in the second subsample, and vice versa. In addition, the two data sets are combined to form one set, and a predictive equation, including only the variables identified as significant and consistent in sign in both of the split-sample analyses, is calculated. The correlation coefficients between predicted and observed values of the dependent variable and values for the dependent variable, predicted by each of the three predictive equations are calculated. Similar values for these three correlation coefficients indicate the general applicability of the model. Lack of agreement may indicate a sample specific model which has limited predictability when applied to new data. Appendix B contains a list of mnemonics used in this report.

Analysis II

The second analysis was based on the same data as was the first analysis, and also involved stepwise regression. The first analysis was an attempt to relate differences in deer populations to differences in habitat characteristics among counties at the same "point" in time. The second analysis was an attempt to relate changes in deer populations to changes in habitat characteristics within each county between two "points" in time.

The dependent variable (CHNGBH) in Analysis II was the change, between the two 5-year periods, in the proportion (percentage) of the total Adirondack adult male harvest taken in each county. The predictor variables were the change in forest and land use variables in each county between the two time periods. Predictor variables used in Analysis II were the change in the proportion of the county's CFL (or total deer habitat for agricultural land use categories) in the three size classes of softwoods and hardwoods, nonstocked areas, pasture, and harvested crops. Squared transformation for each of these variables were also included in the analysis. As in Analysis I, SAS procedure STEPWISE/MAXR was used.

RESULTS

Appendix C provides the county deer harvest, forest and agricultural data used in these analyses.

Analysis I

The first analysis was an attempt to relate differences in deer populations, as indexed by harvest statistics, among counties to differences in forest condition and agriculture among these counties. As described above, data from the period 1965-1969 were first analyzed independently of those from 1976-1980. Stepwise regression of the earlier data yielded no model with an acceptable level of significance or coefficient of determination. Similar analysis of the later data provided the model presented in Table 1.

The model in Table 1 is highly significant and has a relatively high coefficient of determination. Although the stepwise procedure continued to add variables to the model to maximize r^2, the three variable model was selected as the best for several reasons. The three variable model had the highest level of significance, while r^2 increased by only small amounts in larger models. The three variable model was the largest model in which all parameter estimates were significant. Despite the high significance of this model, no satisfactory model could be derived from the 1965-1969 data. Thus further analysis following the split-sample, cross-validation procedure was impossible.

Analysis II

The second analysis was an attempt to relate changes in deer populations to changes in habitat across time, within counties. Stepwise regression on the set of nine main effect variables yielded the model presented in Table 2. Although r^2 increased in models with greater numbers of variables, this two variable model was selected as the best to be derived from the set of main effect variables as it is the largest one in which all parameter estimates are significant. This model also has the greatest overall level of significance.

Because the habitat data represents change, values could be positive or negative for each habitat type. The next step in Analysis II was stepwise regression on the set of main effect variables and their squared transformations so that differential response of CHNGBH to opposite trends of change in habitat types might be identified. The model in Table 3 was selected as the best model. Again, because it has the highest level of significance and no insignificant parameter estimates.

An examination of Table 3 indicates that the two main effect variables of Table 2 have been retained. The squared transformations of CHHWPO and CHSWPO have been added. The addition of these two transformations increased r^2 by 0.26. However, the presence of a square term without the associated main effect term is difficult to interpret because it defines a parabola symmetrical around $X = 0$. The SAS regression procedure General Linear Model (GLM) was used to define a model in which CHNGBH was related to the 4 variables in Table 3, as well as to the main effect terms CHHWPO and CHSWPO. This regression yielded the model of Table 4.

The addition of the two main effect terms increases r^2 by only 0.01, while decreasing the level of significance. The insignificance of the increase in predictability is due to the redundancy of information provided by the main effect and square transformation for CHHWPO and CHSWPO. The correlation coefficients (r) between main effect and square transformation are > 0.91 ($P < 0.001$) for both pairs.

Figures 1 and 2 demonstrates the response of CHNGBH to the main effect term and to the main effect term in combination with the square transformation, for CHHWPO and CHSWPO, respectively. As these figures indicate, the trend of response predicted by the two models is similar, for both habitat types. Thus, if these models were to be used to predict trends in deer habitat quality, it would probably make little difference which model were used, if the anticipated change in habitat type were within the range of change observed here.

If the anticipated change in type is beyond the observed range, special care should be taken in using the models to predict changes in habitat quality. The majority of observed values of CHHWPO and CHSWPO are positive. A model containing only the square term for CHHWPO or CHSWPO is less likely to be indicative of the true response of CHNGBH to change in the type, than is a model containing both the main effect and square terms. This is because the portion of the curve indicating response to a decrease of type HWPO or SWPO is actually the mirror image of the response to an increase in the type. The strong influence of the observations showing increases of the types overwhelms the influence of the few observations showing decreases, particularly because the decreases that are observed are small.

It would be supposed that the main effect term would allow the models to provide more accurate descriptions of the actual response of CHNGBH to decreases in these two types. It is interesting to note that, for both types, the predicted value of CHNGBH is more positive for the models containing the square term than for the model containing the square term and the main effect term. However, the sum of the residuals in observations in which CHHWPO or CHSWPO are negative are much smaller in the model containing only the square term for these two types (Table 5). This appears somewhat anamalous in that one would not expect the trend in response of CHNGBH to change direction at X = 0. This would lead to the expectation that the presumably more definitive model (i.e. main effect and square terms) would indicate, if not a negative response of CHNGBH when HWPO or SWPO declines, at least a less positive one.

It is probably most appropriate to state that the paucity of observations with declining HWPO or SWPO makes any estimate of prediction of the response of CHNGBH to decline in these two types suspect. It is the author's recommendation that the best linear approximation of the response to increases of these types be extrapolated to situations in which declines of HWPO or SWPO are observed.

Two main effect terms are present in each of the two models. These are CHHWSS and CHNSTK. All but two of the observed values of CHHWSS are negative. The trend indicated by the four-variable model, as indicated in Figure 3, is one of decreasing magnitude of negative CHNGBH with decreasing magnitude of HWSS decline. Extrapolation of this trend to cases of increasing HWSS does not appear unreasonable.

Figure 4 displays the predicted effect of CHNSTK on CHNGBH according to the four-variable model. All observations of CHNSTK are zero or negative. The slope of the line indicates that the value of CHNGBH increases with increasing losses of NSTK. Although little data is available on which to base predictions of the effect of increasing NSTK, extrapolation of the line in Figure 4 to indicate an increase in the magnitude of CHNGBH decline with increasing NSTK is probably reasonable.

DISCUSSION

Analysis I

The attempt to relate difference in deer populations among counties to differences in habitat among those counties (Analysis I) failed to yield a statistically significant model. It may be easier to understand this problem if the deer populations at the time of data collection are considered. In 1967 Adirondack deer populations reached what may have been their highest peak ever. The mean annual Adirondack buck harvest for the period 1965-1969 was 10,614. Populations crashed, however, as a result of three severe winters in 1968-1970. The herds had recovered somewhat by the late 1970's, but the mean annual Adirondack buck kill in the period 1976-1980 was 6,861, 65% as large as in the earlier period. This information may allow some conjecture as to the somewhat contradictory models produced by analysis of the data from the two different time periods.

During periods of high population densities, habitats with lower suitabilities are freqeuntly used. Assessments of habitat use generally ignore this. It is usually implicitly assumed that population densities are such that all suitable habitats are being used, but that no unfavorable habitats are being used. The large decline in deer populations after 1969 indicates that populations were too high, that the habitat was "oversaturated." Populations in the later period were probably closer to the true carrying capacity of the habitat. It would seem reasonable, on these grounds, to consider the model developed from the later period (Table 1) as the model more likely to reflect true population responses to habitat quality. It is logical that the overall ability of a model to predict a population response to habitat quality would decline during a period when less suitable habitats were being used. The differences between high quality and low quality habitats might be obscured, resulting in lower predictability of the model.

Analysis II

The model from Analysis II relates changes in deer populations to changes in habitat conditions, within counties across time. This type of analysis appears superior to Analysis I for several reasons. Analysis II provides a model which is more desirable because it predicts changes in deer harvests over time. It is more reasonable to predict changes in harvests from individual counties than to predict outright the BKI for a county using a model based on data from 14 counties without regard to previous observed harvests in the county for which the prediction is being made.

The model from Analysis II is probably superior because hunting pressure and, especially important in the Adirondacks, hunter distribution are likely to be more constant from year to year within each county. Error is introduced in Analysis I because some counties are underhunted. This results in a BKI that indicates a lower population than actually existed. Hunting pressure and distribution differences are less likely to be significant across time within counties than across counties at a point in time.

CHNGBH is related to change in hardwood poletimber (CHHWPO). The slope of the line in Figure 1 indicates that HWPO has some positive value to deer, as CHNGBH increases with increasingly positive CHHWPO. Stands in which half or more of the stocking is in trees greater than 12.7 cm DBH, with stocking in trees 12.7 - 27.9 cm DBH exceeding that of trees greater than 27.9 cm DBH are HWPO. HWPO is generally thought to be of little value to deer. Its primary value is likely to be as nonwinter escape and hiding cover. The presence of poletimber stands may make adjacent areas of high forage production more valuable by providing escape cover. Even-aged stands are likely to be in this stage 21-70 years after an even-aged regeneration cut. Uneven-aged stands might also be in this stage, particularly after harvesting of large timber (e.g. by a heavy diameter limit cut).

Stands are classified as hardwood seedling-sapling (HWSS) if half of the total stocking is in trees 12.7 cm DBH. These stands result from intensive timber harvesting, natural stand destruction and reversion of cleared lands. The likely values of HWSS include browse, herbaceous forage and understory (soft) mast. Such stands may also be valuable as hiding and escape cover (Stocker and Gilbert 1977, Hassinger et al. 1975).

The model in Table 3 indicates that CHNGBH should be positive and increasing when CHSWPO is positive and increasing. Insufficient data are available to specify a trend for negative CHSWPO. SWPO stands are those in which over half of the stocking is in trees at least 12.7 cm DBH and in which stocking in trees

12.7 - 22.9 cm DBH exceeds that in trees greater than 22.9 cm DBH. Such stands provide nonwinter escape and hiding cover. Their primary value, however, is as winter thermal cover. The response of CHNGBH to CHSWPO is quadratic, yielding a response curve which indicates that CHNGBH should be positive and increasing for CHSWPO positive and increasing. Extrapolation of the quadratic effect for CHSWPO negative and increasing in magnitude would have indicated that CHSWPO would be positive and increasing as more SWPO is lost. It is difficult to make a biological interpretation of this result. It does not seem appropriate to specify a response for CHSWPO negative and increasing in magnitude because of the few observations which have negative CHSWPO and the small magnitudes observed in these cases. If counties are encountered in which large declines of SWPO are predicted, it would probably not be unreasonable to use the slope of the best linear approximation of the curve for positive CHSWPO, as the coefficient for negative CHSWPO.

Nonstocked areas are the only type that, according to the model of Table 3, have a significantly negative effect on deer populations. Nonstocked stands have less than 2.9 mi^2 of basal area per ha. While the forest survey recognizes softwood and hardwood nonstocked stands, this study combines the two because the trees of these types are likely to be so sparse that they are of little value to deer. Such areas are dominated by shrubs, grasses and forbs. These areas would, presumably, be valuable for forage, as well as for night bedding sites. It is not clear why deer populations should decrease as nonstocked areas increase.

One possible answer may be that deer populations are responding not to CHNSTK, but to changes in some other type, that is correlated with CHNSTK. Intercorrelation of predictor variables is a problem inherent to multiple regression. One method suggested to alleviate the problem is to identify pairwise correlations between predictor variables through examination of the matrix of correlation coefficients among all predictor variables. Any variable pair with a magnitude of $r > 0.7$ should be examined to ascertain if any biological interpretations might be affected. The critical value of 0.7 is suggested because correlation coefficients of this magnitude indicate that over one-half of the variance of one member of the pair is explained by the other member of the pair.

The matrix of correlation coefficients among the main effect variables used in Analysis II is presented in Table 6. As can be seen in the correlation matrix, all magnitudes of r are < 0.7. It is interesting to note, however, the significant negative correlation between CHNSTK and CHHWST. It is reasonable to expect that deer populations might increase with increases in HWST.

A regression analysis was performed in which the variable CHNSTK of the 4-variable model (Table 4) was replaced by CHHWST. The resultant model is presented in Table 7. This revised model is certainly not as statistically satisfying as is the 4-variable model of Table 4. The coefficient of determination is lower, as is the level of significance. This revised model is more easily explained biologically, however.

The area of nonstocked CFL decreased between the survey periods, while HWST area increased. Obviously this is indicative of the reversion of nonstocked areas to stocked CFL and maturation of pole stands to HWST. This trend is in agreement with trends noted by Ferguson and Mayer (1970) and Considine and Frieswyk (1982). primary question is: assuming that one of the two models is correct, are deer responding to increases in HWST or to decreases in NSTK?

Nonstocked areas would revert to seedling-sapling stages over the 10 year period. Yet there are no significant correlations between CHNSTK and any other variables, except CHHWST. This would indicate that counties exhibiting declines of NSTK are not exhibiting concommitant increases in seedling-sapling stands.

It is possible, however, that the statistical evidence of this assumed trend is obscured by reversion of seedling-sapling stands to poletimber.

It is difficult to decide which trend, decline of NSTK or increase of HWST would serve as a better predictor of changes in deer populations. It seems likely that reversion of NSTK to seedling-sapling stands would be more significant to deer populations than would increases of HWST, in this heavily forested region. Therefore, the 4-variable model including the variable CHNSTK will be used through the remainder of this report.

Inventory of Forest Management Schedules

Discussions with forest owners, managers and New York State foresters indicated that long-range forest management planning is almost nonexistent in the Adirondacks. One state forester indicated that he wrote management plans for only about 10% of the landowners holding 80 ha or more in the counties for which his office is responsible. Furthermore, he stated that only a very small fraction of this 10% followed the plans for very long. Management by large and small forest owners alike seems to respond to fluctuations in markets and, especially in the case of small landowners, occasional needs for cash.

It is impractical to attempt an inventory of forest management schedules when the harvest of timber is likely to be affected so much by market fluctuations. It would be more reasonable to project long-term trends in timber harvesting methods and acreages affected. However the data for even these projections are not available. The U.S. Forest Service estimates, by species, the volume of timber produced by each county and projects wood demands of primary users of Adirondack timber products. However, there would be no way of reasonably converting these volume estimates to acreages logged. The volume removed per ha would differ with the forest type, species composition, silvicultural systems employed and product marketability. It would be impossible to derive even rough estimates and predictions of areas of forest type annually harvested by each harvesting method.

This problem was summarized by the Joint Government-Industry Steering Committee on Intensive Timber Harvest in the Adirondack Park[1] (1981:36). "New York does not have good current regional and subregional characterizations of the growth, inventory and removal characteristics of Adirondack forests." The report of this committee does, however, include estimates of the areas of Adirondack forest annually affected by various harvest techniques (Table 8). These estimates are informal discussions and are not on a statistical sample. They are, however, the only estimates of annual cuts available. These estimates do not specify in which types the harvesting will take place or the distribution of the cutting among counties.

The most recent estimates of timber removal in New York are by Nevel et al. (1982). This report provides statistics on timber harvest and use at the state level, and for three regions within the state. The 11-county Northern Region includes the Adirondack Park area.

The Northern Region yielded an industrial harvest of 2,081,800 cu.m. in 1979 (Nevel et al. 1982). This area has 2,658,827 ha of CFL (Considine and Frieswyk 1982). If 2% of this area is cut, as assumed by the Steering Committee (1981:56), the harvested timber would have come from 53,177 ha. The mean volume removal would have been about 39.15 cu.m. per ha (559.50 cu ft per acre).[3]

1 Hereafter reffered to as the Steering Committee.

2 Clinton, Essex, Franklin, Fulton, Hamilton, Herkimer, Jefferson, Lewis, Oneida, St. Lawrence and Warren Counties.

3 Does not include firewood or removal not manufactured into industrial products.

The Steering Committee (1981) examined 20 logging operations and found average removals of 2964-9880 bd. ft./ha for sawlogs and 12.4 - 74.1 cds/ha for pulpwood. Although the Steering Committee's data presentation does not allow a single value for average removal per ha to be determined, it is possible to estimate a range of volumes removed in these operations. Conversion factors of 3.48 cu m/1000 bd. ft. and 2.41 cu m/cd were used (Considine and Frieswyk 1982). The range of volumes removed per ha for the 20 operations examined would be approximately 10.31-34.38 cu. m. for sawlogs and 12.05-72.3 cu. m./ha for pulpwood. The average removal required to meet the estimates of total removal (Nevel et al. 1982) and Steering Committee (1981) estimates of extent of cutting was 39.15 cu. m./ha. This estimate appears to be within the range of removals found by the Steering Committee (1981).

Obviously this apparent agreement does not prove that either the estimates of total removals or of extent of cutting are accurate. The fact that the calculated average removal is within the range observed by the Steering Committee (1981) should, however, indicate that these independent estimates are reasonable. These are the best data available for predicting forest management in the Adirondacks and will be used in the remainder of this report.

The estimates of extent of timber harvesting in the Adirondack Park, provided by the Steering Committee (1981) do not specify the counties in which the harvesting takes place, nor the forest types that will be harvested. In some cases, however, it is possible to assume which types are most likely to be affected because of the nature of the harvesting method. The use of these predictions for areas outside the Park may be problematical because Adirondack Park Agency (APA) regulations alter timber harvesting practices.

At the outset of this project, it had been hoped that a means of inventorying forest management schedules in individual Deer Management Units (DMU's) could be found so that DMU specific projections of habitat quality changes might be made. Unfortunately, it does not appear that a system to do this with reasonable accuracy and costs can be developed at this time. However, if certain assumptions can be reasonably made, some county specific projections of habitat change may be made using the 4-variable model of Table 3, forest survey data and Steering Committee (1981) estimates of extent of cutting. An example of how the model might be applied to available data is presented below. The necessary assumptions are discussed with the example. First, however, it is necessary to discuss the effects of each harvesting method, as predicted by the model.

Predicted Effects of Timber Harvesting

Intermediate cuttings are generally performed when stands are 30-60 years old (Smith 1962). They are most likely to be performed in poletimber stands. They may be applied in hardwood and softwood types. Thinnings have been shown to be beneficial to deer but only for 3-5 years (Behrend and Patric 1969, Jordan 1967, Cook 1939). Thinnings are beneficial in that they allow regeneration and some development of seedlings. The effect of an intermediate cut may be considered to be the conversion of at least part of the poletimber stand to seedlings and saplings. Thinning intensities typically reported are removal of 25-30% of the basal area. It may be reasonable to assume that thinning of pole stands will increase the seedling/sapling component by 25%. There would be a corresponding decline in the poletimber component. When applying the model, the values for decline of HWPO or SWPO and for increase of HWSS or SWSS would equal 25% of the total proportion of the CFL undergoing intermediate cutting. The net result would be a predicted increase in CHNGBH of ((0.3934) (0.25) (proportion CFL thinned)) - ((0.20) (0.25) (proportion CFL thinned)) = 0.25 (proportion CFL thinned) for hardwoods.

The model predicts that CHNGBH will not be affected significantly by changes in the SWSS type, but that it will be affected by the decrease in SWPO. Thus, if regeneration following thinning of SWPO is primarily softwoods, the net effect on CHNGBH would equal - ((0.25) (0.45) (proportion CFL thinned). If regeneration is primarily hardwoods the net effect on CHNGBH would equal ((0.25) (0.3934) (proportion CFL thinned)) - ((0.25) (0.45) (proportion CFL thinned)). The range of effect of thinning SWPO is then (-0.01) (proportion CFL thinned) to (-0.11) (proportion CFL thinned).

It is difficult to assess the effects of selection cutting, diameter limit cutting and high grading because the intensity of their application is highly variable and dependent on forest, site, and probably most importantly, market conditions. All of these methods should be expected to increase the seedling/ sapling component of hardwood stands. At the same time, the value of deciduous overhead cover for summer thermal protection would be diminished. For the purposes of this model, it will be assumed that selective cutting, diameter limit cutting or high grading of HWST stands will result in a decline of HWST and an increase in HWSS, each equal to 1/3 the proportion of CFL affected. The predicted CHNGBH will increase by (0.3934) (0.33) (proportion CFL affected) = 0.13 (proportion CFL affected).

These harvesting methods may regenerate hardwoods or softwoods when applied to SWST stands. The model specifies no change in CHNGBH as a result of loss of SWST or HWST, or as a result of increase in SWSS. If regeneration results in HWSS, predicted CHNGBH will increase by (0.3934) (0.33) (proportion CFL affected) = 0.13 (proportion CFL thinned). If regeneration is primarily softwoods, there would be no change in CHNGBH. The range of change is thus 0 to 0.13 (proportion CFL affected).

It is much easier to predict the effects of even-aged regeneration cuts on stand structure. Both clearcutting and shelterwood cutting reduce sawtimber stands to seedling/sapling stands. Both may be applied in softwoods or hardwoods. It is likely that in the softwood types in which shelterwood cutting is applied, the regeneration will be dominated by softwoods. Shelterwood cutting in hardwoods will usually regenerate hardwoods. Clearcutting is likely to regenerate hardwoods except, perhaps in spruce-fir types.

Shelterwood cutting or clearcutting of HWST will result in a loss of HWST and a concommitant increase in HWSS. The main effect on CHNGBH will be 0.3934 (proportion CFL affected). Shelterwood cutting of softwoods will result in a gain of SWSS to replace the loss of SWST. The model predicts no effect on CHNGBH. Clearcutting of SWST could result in a gain of HWSS or SWSS. If regeneration is hardwood dominated the effect on CHNGBH equals 0.3934 (proportion CFL affected). If softwoods regenerate the effect equals 0.

Whole tree utilization is being used primarily in spruce-fir types of relatively small size. For the purposes of the model, whole tree utilization will be considered to result in the conversion of SWPO to SWSS. The effect on CHNGBH will equal 0.0293 (proportion CFL affected).

The predicted effects on CHNGBH of the various harvesting methods are summarized in Table 9. These results are very close to what might have been expected. In hardwood types the heavier cutting results in greater benefits to deer, presumably because of greater forage production. The same trend is apparent in softwood types, although differences among methods are not as clear, due to uncertainty about the species composition of regeneration. According to these results the greatest positive impact on deer populations would result from conversion of SWST to HWSS by clearcutting, or of HWST to HWSS by shelterwood cutting or clearcutting.

Nonstocked areas in the Adirondacks are primarily abandoned farmlands which have not yet gained sufficient tree cover to be considered stocked. These non-stocked areas are most likely to revert to white pine (SWSS) or aspen-birch (HWSS) types. If regeneration is primarily hardwoods, the effect on predicted CHNGBH would be (0.31) (proportion CFL reverting) + (0.39) (proportion CFL reverting) = 0.70 (proportion CFL reverting). For softwood regeneration the effect equals 0.31 (proportion CFL reverting).

It is also necessary to consider the growth of forest stands from one size class to another. To accurately assess the effects of forest growth, it would be necessary to have an accurate assessment of age class distribution in the forest and of the rate of tree growth. Unfortunately, this information is not available. It is necessary to make some assumptions about existing age distribution and rate of growth. The age at which trees reach each of the three size classes recognized here is dependent upon a large number of factors. In general, however, trees less than 20 years old are considered to be in the seedling/sapling stage. The poletimber stange includes trees 21-70 years old and sawtimber, trees > 70 years old. It will be assumed that age distribution of stands is balanced, although this is almost certainly not true. These assumptions indicate that 5% of the area in the seedling/sapling stand would enter the poletimber stage annually and 2% of the area in poletimber would mature to sawtimber annually.

Example: St. Lawrence County

The purpose of this section is to demonstrate how the information provided above may be used to predict changes in habitat quality. Data from St. Lawrence County will be used for this analysis. The prediction of change in the buck harvest will be made over a period of ten years, that is, the BKI in 1988 will be predicted. CFL in this county had the following composition in 1978: HWST 28%,

HWPO 25%, HWSS 25%, SWST 7%, SWPO 6%, SWSS 5%, and NSTK 4%. The mean number of adult male deer killed per mi^2 of habitat in the years 1976-1980 was 0.60.

It will be assumed that harvest methods applicable in more than one forest type will be applied in proportion to the relative abundance of those types within the county. This assumption could be modified if additional information allowed the user of the model to predict the forest types most likely to be affected by each method in each locality. The proportion of CFL thought to be annually subjected to each harvesting method within the Park (Steering Committee 1981) will be assumed to represent the proportion affected by each method throughout St. Lawrence County. These proportions are as follows: intermediate cut 0.07%, selection cut 0.68%, high grading 1.08%, diameter limit cut 0.10%, shelterwood cut 0.02%, clearcut 0.13%, and whole tree utilization 0.01%.

Use of the model must begin with consideration of the effects of predicted forest management and succession on the forest type composition of the county. The following example proceeds step by step, describing the predicted extent of cutting by each harvesting method in each size class and the distribution of the cut between hardwoods and softwoods. The annual change in each of the affected types is noted[1].

The predicted effect of each impact on each forest class over the decade is provided in Table 10.

1) Sawtimber stands may be subjected to diameter limit cutting, selection cutting and high grading. It is assumed that these methods decrease the ST component by 0.33 and increase the SS component by a like amount. It is predicted that 1.86% of the CFL will be affected annually. Thirty-five percent

[1] In cases in which the type of regeneration is uncertain, the minimum and maximum possible change for HWSS and SWSS are used to establish a range of possible response.

of CFL is in ST stands, 28% HWST and 7% SWST.

(28% HWST/35% ST) X 1.86% X 0.33 = 0.49

annual loss HWST, annual gain HWSS

(7% SWST/35% ST) X 1.86% X 0.33 = 0.12

annual loss SWST, annual gain HWSS or SWSS

2) Sawtimber stands may also be subjected to shelterwood cuts. Gain in the SS component is equal to the loss of ST. It is estimated that 0.02% of CFL will be shelterwood cut.

(28% HWST/35% ST) X 0.02% = 0.016% loss HWST, gain HWSS

(7% SWST/35% HWST) X 0.02% = 0.004% loss SWST, gain SWSS or HWSS

3) About 0.13% of ST will be clearcut annually.

(28% HWST/35% ST) X 0.13% = 0.10% loss HWST, gain HWSS

(7% SWST/35% ST) X 0.13% = 0.03 loss SWST, gain SWSS or HWSS

4) Poletimber stands are most likely to undergo intermediate cuts. It is estimated that intermediate cuts affect 0.07% of CFL. Loss of the PO component and gain of the SS component are assumed to equal 1/4 of the area cut.

(25% HWPO/31% PO) X 0.07% X 0.25 = 0.015% loss HWPO, gain HWSS

(6% SWPO/31% PO) X 0.07% X 0.25 = 0.003% loss SWPO, gain SWSS or HWSS

5) Softwood poletimber may be harvested by whole tree utilization over 0.01% of CFL. Loss of SWPO results in gain of equal amounts of SWSS.

0.01% loss SWPO. gain SWSS

6) It will be assumed that all NSTK areas (4% of CFL) will revert to SS over the decade.

4% loss NSTK, gain HWSS or SWSS

7) The folowing age and size class relationships are assumed: SS 0-21 years, PO 21-70 years, ST > 70 years. Within each size class, age distribution is

assumed to be balanced such that a constant proportion of the area in each size class matures to the next size class annually.

25% HWSS X 1/20 = 1.25% annual loss HWSS, gain HWPO

5% SWSS X 1/20 = 0.25% loss SWSS, gain SWPO

25% HWPO X 1/50 = 0.50% loss HWPO, gain HWST

6% SWPO X 1/50 = 0.12% loss SWPO, gain SWST

As can be seen in Table 11, the model predicts that over the decade 1978 - 1988, the proportion of the Adirondack buck harvest taken in St. Lawrence County will change by -0.42 to 1.16% (midrange = 0.37%). If the total Adirondack buck harvest remains constant over the decade, this would correspond to range of change from a decline of 24 bucks (-0.42% X 5678) to an increase of 66 bucks (1.16% X 5678) harvested, or a change in BKI of -0.11 to 0.31. It would be, of course, up to the user of the model to decide if a predicted decline in habitat quality of this magnitude is significant. Other factors such as weather and antlerless deer harvests could have even greater effects on buck harvest. In actuality, the model is not designed to predict BKI for each county, but predicted changes in BKI can be used as indications of predicted changes in habitat quality.

Example: Adirondack Park Counties

Folowing is another example of the application of the model (Table 12). The data in this example are from the 11 counties which are at least partially included in the Adirondack Park. All assumptions of the previous example will be retained. The forest type composition of the CFL in these 11 counties is as follows: HWST 33%, HWPO 24%, HWSS 20%, SWST 9%, SWPO 6%, SWSS 4%, and NSTK 3%.

Proportion of ST in HWST: 33% HWST/42% ST = 0.79
Proportion of ST in SWST: 9% SWST/42% ST = 0.21
Proportion of PO in HWPO: 24% HWPO/30% PO = 0.80
Proportion of PO in SWPO: 6% SWPO/30% PO = 0.20

1) 1.86% CFL uneven-aged harvested annually.

0.79 X 1.86% X 0.33 = 0.48 loss HWST, gain HWSS.

0.21 X 1.86% X 0.33 = 0.13% loss SWST, gain HWSS or SWSS.

2) 0.02% CFL shelterwood cut annually.

0.79 X 0.02% = 0.02 loss HWST, gain HWSS.

0.21 X 0.02% = 0.00 loss SWST, gain HWSS or SWSS.

3) 0.13% CFL clearcut annually.

0.79 X 0.13% = 0.10% loss HWST, gain HWSS.

0.21 X 0.13% = 0.03 loss HWST, gain HWSS or SWSS.

4) 0.07% CFL intermediate cut annually.

0.80% X 0.07% X 0.25 = 0.01% loss HWPO, gain HWSS.

0.20% X 0.07% X 0.25 = 0.00 loss SWPO, gain HWSS or SWSS.

5) 0.01% CFL whole tree utilization annaully.

0.01% loss SWPO, gain SWSS

6) Reversion of NSTK to SS.

3.00% loss NSTK, gain HWSS or SWSS.

7) Successional effects.

20% HWSS X 0.05 = 1.0% loss HWSS, gain HWPO.

4% SWSS X 0.05 = 0.2% loss SWSS, gain SWPO.

24% HWPO X 0.02 = 0.05% loss HWPO, gain HWST.

6% SWPO X 0.02 = 0.1% loss SWPO, gain SWST.

The anlaysis in this example predicts a range of values of -0.70 to 1.11 for CHNGBH from 1978-1988. Of course, it is not possible to apply the strict definition of CHNGBH (the change in the proportion of the total Adirondack buck harvest to be taken in a specific county) in this example. However, one might imagine that this analysis had been performed for a single Adirondack county, with the same forest characteristics. If such were the case, the results in Table 13 would indicate that habitat quality is not likely to change significantly by 1988. The reason for this predicted lack of improvement is the apparent failure of timber management to create HWSS at a rate faster than HWSS reverts to HWPO.

An important question to be considered is whether current land management practices are likely to significantly influence Adirondack deer populations. It is fair to say that most wildlife biologists would expect greater benefits to deer from even-aged regeneration cuts than from other harvesting methods. It is doubtful that selection cuts, diameter limit cuts and high grading provide long term benefits, because of rapid canopy closure and the tendency of the methods to regenerate nonpalatable beech. Intermediate cuts also have only short term effects (Kelty and Nyland 1981, Cooperrider and Behrend 1980, Drolet 1978, Krefting and Phillips 1970, Behrend et al. 1970, Curtis and Rushmore 1958, Westell 1954, Cook 1946, and Clepper 1936).

The Steering Committee (1981) estimates that 1908 ha (0.16%) of the over 1.2 million ha of CFL in the Adirondack Park is clearcut or shelterwood cut annually. Most forest types in the Adirondacks reach merchantable size in 70-120 years. If the forest were balanced in age class distribution, approximately 1% of the CFL could be clearcut or shelterwood cut annually to provide maximum benefit to deer and to maintain a balance of forest age classes. The Steering Committee (1981:49) indicates that the Adirondack forest is dominated by the 60-80 year old class and "in economic terms, ripe for liquidation harvest." It would seem that it is also ripe for harvest to regenerate deer browse.

Current APA regulations effectively limit the size of even-aged regeneration cuts to 10 ha or less. Cuts of this size often fail to regenerate properly because of overbrowsing by deer and are thus usually not silviculturally acceptable. APA regulations seem to encourage uneven-aged management. While such management has its merits, its benefits to deer are limited. It is recognized that many landowners practice such silviculturally unacceptable techniques as high grading for short term economic benefits. Regulations to limit this type of activity, coupled with relaxation of limits on even-aged regeneration cuts, may encourage the logging industry to undertake logging activities that will replace the important early succession stages that are currently maturing into less valuable stages. Unless logging practices change, it seems likely that the effects of forest management will be localized and relatively insignificant, in comparison with the effects of forest growth in the Adirondacks.

SUMMARY

The objective of this project was to develop techniques for inventorying vegetation and land use status and forest management schedules, and for predicting the effects of land use on habitat quality for white-tailed deer. Perhaps the most significant finding, in that regard, was that forest management schedules are virtually nonexistent in the Adirondack region. Timber harvest seems to respond primarily to short term market fluctuations and needs for cash. Any forest management inventory to determine the extent of timber harvesting by each method in each forest type, in a specific locality, would most certainly not yield reliable information.

It is more expedient to use existing data bases than to develop new ones, so the U.S. Forest Service forest type and size class composition of the commercial forest land was used. This information is reported at the county level. It would be possible to digitize the sample plot information to obtain information at the D.M.U. level. Forest survey data and estimates of extent of cutting may be applied by the techniques described to allow predictions of the trends of habitat quality change in each county.

A model was developed through multiple linear regression, which relates changes in deer populations to predicted changes in habitat condition. The model may be used to predict changes in habitat quality that are likely to result from predicted forest management and successional effects. Perhaps the greatest weakness of these methods is the inability to specify more precisely the extent and type of forest management that is likely to take place in each specific county. No methods currently exist for doing this and it is questionable whether the undertaking of an inventory of ongoing timber management activities is justified.

The justification for intensive inventories is even more suspect when the probability of real effects of timber harvesting on deer populations is considered. Current regulatory and market conditions appear to preclude the large scale heavy harvesting that is most likely to cause dramatic increases in deer populations.

Rather, it seems more likely that continued light cutting which removes less than the annual volume increment (Ferguson and Mayer 1970) will lead to a maturing forest and gradually declining habitat quality for deer. The influences of timber harvesting are likely to be localized and changes in habitat quality in response to specific operations are not likely to be identified by any inventory system currently available or feasible. It seems at this time, possible only to make general predictions of habitat quality change and to decide if the predicted change is likely to be significant in comparison with other factors affecting Adirondack deer populations.

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Table 1. Multiple linear regression model relating number of adult male deer harvested per mi^2 of deer habitat to proportions of county commercial forest land in various habitat types, 1976-1980 data.

Habitat Type	$\hat{B}$	F	Prob. > F
Intercept	0.6539		
HWSS	- 1.7719	17.33	0.0019
SWSS	- 3.8238	13.24	0.0045
PAST	6.7547	38.39	0.0001

Analysis of Variance

Source	df	SS	MS	F	Prob. > F	r^2
Regression	3	0.7022	0.2341	17.10	0.0003	0.84
Error	10	0.1369	0.0137			
Total	13	0.8319				

Table 2. Multiple linear regression model relating change in proportion of total Adirondack buck harvest taken in each county to change in proportion of each county in various habitat types - main effect predictor variables only.

Habitat variable	$\hat{B}$	F	Prob. > F
Intercept	0.9165		
CHHWSS	0.2240	5.83	0.0343
CHNSTK	- 0.1931	3.56	0.0857

Analysis of Variance

Source	df	SS	MS	F	Prob. > F	r^2
Regression	2	45.2929	22.6465	3.99	0.0498	0.42
Error	11	62.4214	5.6747			
Total	13	107.7143				

Table 3. Multiple linear regression model relating change in proportion of total Adirondack buck harvest taken in each county to change in proportion of each county in various habitat types - main effect predictor variables and square transformations.

Habitat Variable	$\hat{B}$	F	Prob. > F
Intercept	- 0.3105		
CHHWSS	0.3934	15.23	0.0036
CHNSTK	- 0.3086	10.62	0.0099
$CHHWPO^2$	0.0081	5.95	0.0375
$CHSWPO^2$	0.0293	5.24	0.0478

Analysis of Variance

Source	df	SS	MS	F	Prob. > F	r^2
Regression	4	73.2535	18.3134	4.78	0.0241	0.68
Error	9	34.4608	3.8290			
Total	13	107.7143				

Table 4. Multiple linear regression model relating change in proportion of total Adirondack buck harvest taken in each county to change in proportion of each county in various habitat types - variables of Table 3 plus associated main effect terms.

Habitat variable	$\hat{B}$	F	Prob. > F
Intercept	0.2614		
CHHWSS	0.3416	5.01	0.0603
CHNSTK	- 0.2935	6.92	0.0339
CHHWPO	- 0.1106	0.16	0.7021
$CHHWPO^2$	0.0106	1.37	0.2807
CHSWPO	- 0.2081	0.21	0.6626
$CHSWPO^2$	0.0354	2.02	0.1987

Analysis of Variance

Source	df	SS	MS	F	Prob. > F	r^2
Regression	6	74.4441	12.4074	2.61	0.1176	0.69
Error	7	33.2702	4.7529			
Total	13	107.7143				

Table 5. Comparison of observed change in buck harvest and that predicted by two regression models.

County	Observed CHNGBH	Predicted CHNGBH 4-variable Model	Residual	Predicted CHNGBH 6-variable Model	Residual
Clinton	0	0.9	-0.9	1.1	-1.1
Essex	-1	0.0	-1.0	0.4	-1.4
Franklin	-5	-5.3	-0.3	-5.2	0.2
Fulton	0	0.6	-0.6	0.1	-0.1
Hamilton	-4	-2.0	-2.0	-2.5	-1.5
Herkimer	-2	-0.9	-1.1	-0.7	-1.3
Jefferson	2	2.2	-0.2	2.6	-0.6
Lewis	1	-2.5	1.5	-2.2	3.2
Oneida	4	4.5	-0.5	4.5	-0.5
Oswego	2	0.4	1.6	-0.0	2.0
St. Lawrence	-4	-1.7	-2.3	-1.8	-2.2
Saratoga	2	1.3	0.7	1.0	1.0
Warren	-1	-1.1	0.1	-1.1	0.1
Washington	4	1.5	2.5	1.7	2.3

Correlation Coefficients
r/prob. >/r/

CHNGBH	Observed	Predicted 4-variable model	Predicted 6-variable model
Observed	1.0000 / 0.0000	0.8247 / 0.0003	0.8313 / 0.0002
Predicted 4-variable model		1.0000 / 0.0000	0.9920 / 0.0001

Table 7. Multiple linear regression model relating change in proportion of total Adirondack buck harvest taken in each county to CHHWSS, $CHHWPO^2$, $CWSWPO^2$, and CHHWST.

Habitat variable	$\hat{B}$	F	Prob. > F
Intercept	0.2038		
CHHWSS	0.3985	8.85	0.0156
CHHWST	0.1918	3.92	0.0791
$CHHWPO^2$	0.0103	4.41	0.0652
$CHSWPO^2$	0.0314	3.22	0.1065

Analysis of Variance

Source	df	SS	MS	F	Prob. > F	r^2
Regression	4	55.3765	13.8441	2.38	0.1287	0.51
Error	9	52.3377	5.8153			
Total	13	107.7143				

Table 8. Extent of timber harvesting on 3 million acres of private land in the Adirondack Park (Steering Committee 1981:56).

Harvesting Method	Areas affected (ac.) Industrial	Non-industrial	Total
Intermediate cut	500	1,500	2,000
Selection cut	12,250	8,000	20,250
High grading	1,500	31,000	32,500
Shelterwood	500	0	500
Clearcut	1,000	3,000	4,000
Whole tree utilization	250	0	250
			59,500

Table 9. Effect of timber harvesting methods on change in proportion of total Adirondack buck harvest taken in each county as predicted by 4-variable model.

	Effect X (proportion of CFL affected)	
Harvesting Method	Softwood	Hardwoods
Intermediate cutting	-0.11 - (-0.01)	0.05
Selection, diameter limit cutting, high grading	0-0.1	0.13
Shelterwood cutting	0.0	0.39
Clearcutting	0.00 - 0.39	0.39
Whole tree utilization	0.03 X (proportion CFL affected)^2	-

Table 10. Prediction of extent of change in habitat classes (% age of CFL) used in modified model of habitat quality change. St. Lawrence County 1978 - 1988.

Impact	predicted 10 year change in HWST	HWPO	HWSS	SWST	SWPO	SWSS	NSTK	HC
Diameter limit, selection cutting, high grading	-5.00	-	5.00-6.20	-1.20	-	0-1.20	-	-
Shelterwood cutting	-0.16	-	0.16-0.20	-0.40	-	0-0.04	-	-
Clearcutting	-1.00	-	1.00-1.30	-0.30	-	0-0.30	-	-
Intermediate cutting	-	-0.15	0.15-0.18	-	-0.04	0-0.03	-	-
Whole tree utilization	-	-	-	-	-0.10	0.10	-	-
Reversion of nonstocked	-	-	0-4.00	-	-	0-4.00	-4.00	-
Change in harvested crops	-	-	-	-	-	-	-	0
Succession	5.00	7.50	-12.50	1.20	1.30	-2.50	-	-
Net Change	-1.16	7.35	- 6.19 -(-0.62)	-0.07	1.17	-2.40 -(3.17)	-4.00	0

Table 11. Use of 4-variable model and predictions of forest change to predict change in buck harvest, St. Lawrence County, 1978-1988.

Forest Type	Predicted Change	Effect
HWSS	-6.19- -0.62	(0.3934) (-6.19) = -2.44- (0.3934) (-0.62) = -0.24
NSTK	-4.00	(-0.3086) (-4.00) = 1.23
HWPO	7.35	$(0.0081)\ (7.35)^2 = 0.44$
SWPO	1.17	$(0.0293)\ (1.17)^2 = 0.44$
		-0.73 -1.47
Intercept		-0.3105
Predicted CHNGBH		-0.42 - 1.16

Table 12. Prediction of extent of change in habitat classes used in modified model of habitat quality change. Adirondack Park Counties 1978 - 1988.

	predicted 10 year change in							
Impact	HWST	HWPO	HWSS	SWST	SWPO	SWSS	NSTK	HC
Diameter limit, selection cutting, high grading	-4.80	-	4.8-6.1	-1.30	-	0-1.30	-	-
Shelterwood cutting	-0.20	-	0.20	0	-	-	-	-
Clearcutting	-1.00	-	1.00-1.30	-0.30	-	0-0.30	-	-
Intermediate cutting	-	-0.10	0.10	-	0	0	-	-
Whole tree utilization	-	-	-	-	-0.10	0.10	-	-
Reversion of nonstocked	-	-	0-3.00	-	-	0-3.00	-3.00	-
Change in harvested crops	-	-	-	-	-	-	-	-1
Succession	5.00	5.00	-10.00	1.00	1.00	-2.00	-	-
Net Change	-1.00	4.90	- 3.90 - 0.70	-0.60	0.90	-1.90 -2.70	-3.00	-1

Table 13. Use of 4-variable model and predictions of forest change to predict change in habitat quality, Adirondack Park Counties, 1978-1988.

Forest Type	Predicted Change	Effect
HWSS	-3.90	(0.3934) (-3.90) = -1.53-
	0.70	(0.3934) (0.70) = 0.28
NSTK	-3.00	(-0.3086) (-3.00 = 0.93
HWPO	4.90	(0.0081) $(4.90)^2$ = 0.19
SWPO	0.90	(0.0293) $(0.90)^2$ = 0.02
		-0.39 -1.42
Intercept		-0.3105
Predicted CHNGBH		-0.70 -1.11

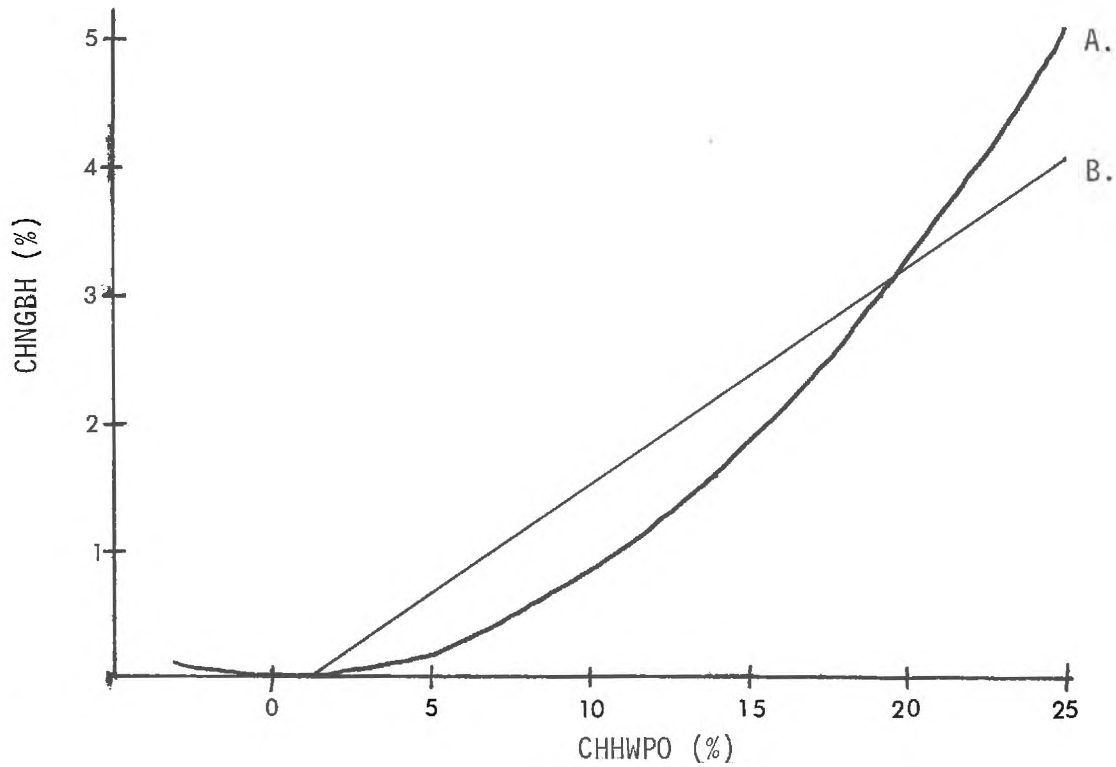

Figure 1. Response of change in buck harvest to change in proportion of commercial forest land in hardwood poletimber stands as predicted by 4-variable model. $Y = (0.0081)\ (CHHWPO)^2$
B. Linear approximation of curve A. $Y = 0.18\ (CHHWPO) - 0.5124$.

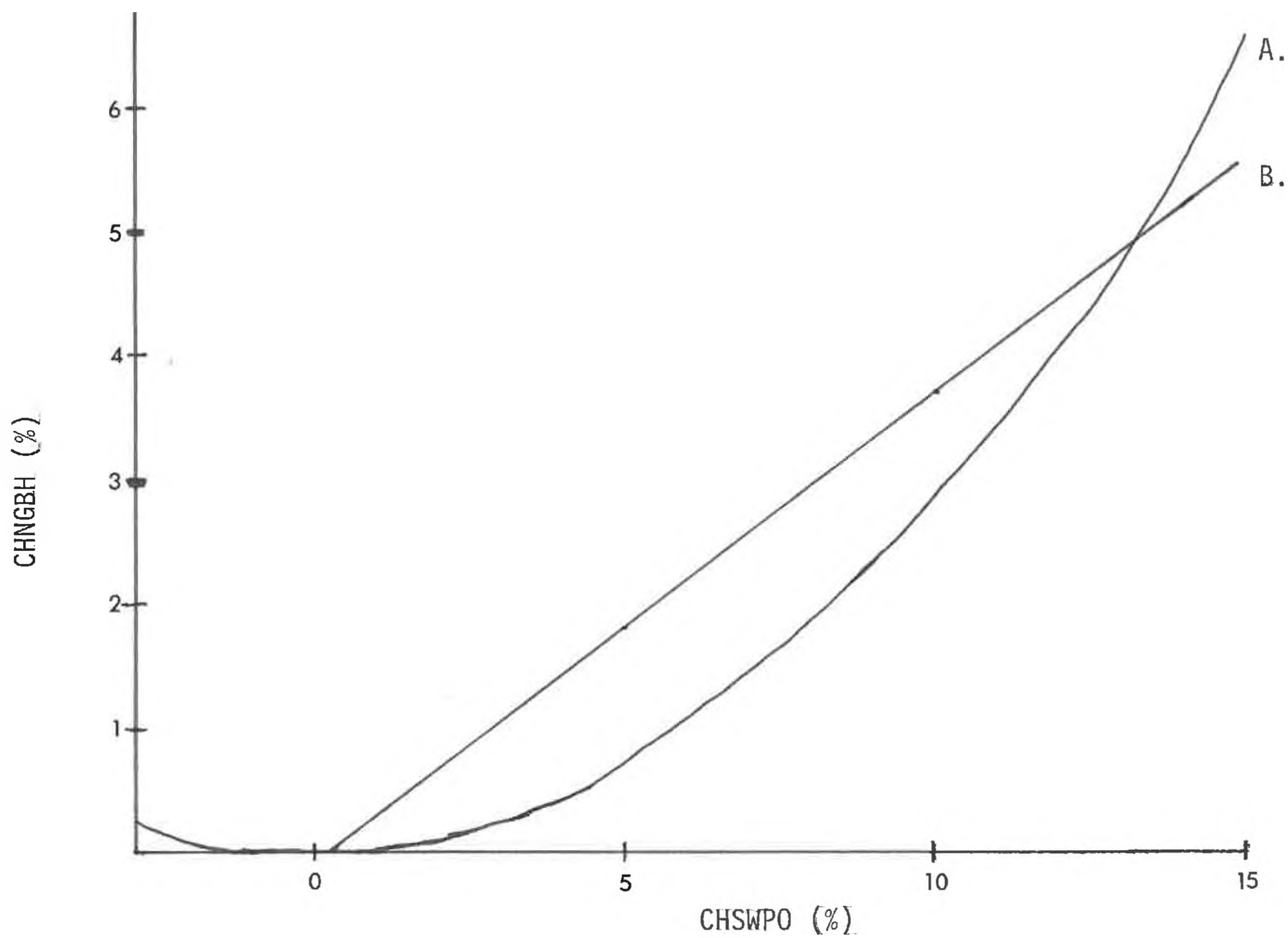

Figure 2. A response of change in buck harvest to change in proportion of commercial forest land in softwood poletimber stands as predicted by 4-variable model. $Y = (0.0293)\ (CHSWPO)^2$

B. Linear approximation of curve A. $Y = 0.38\ (CHSWPO) - 0.04$.

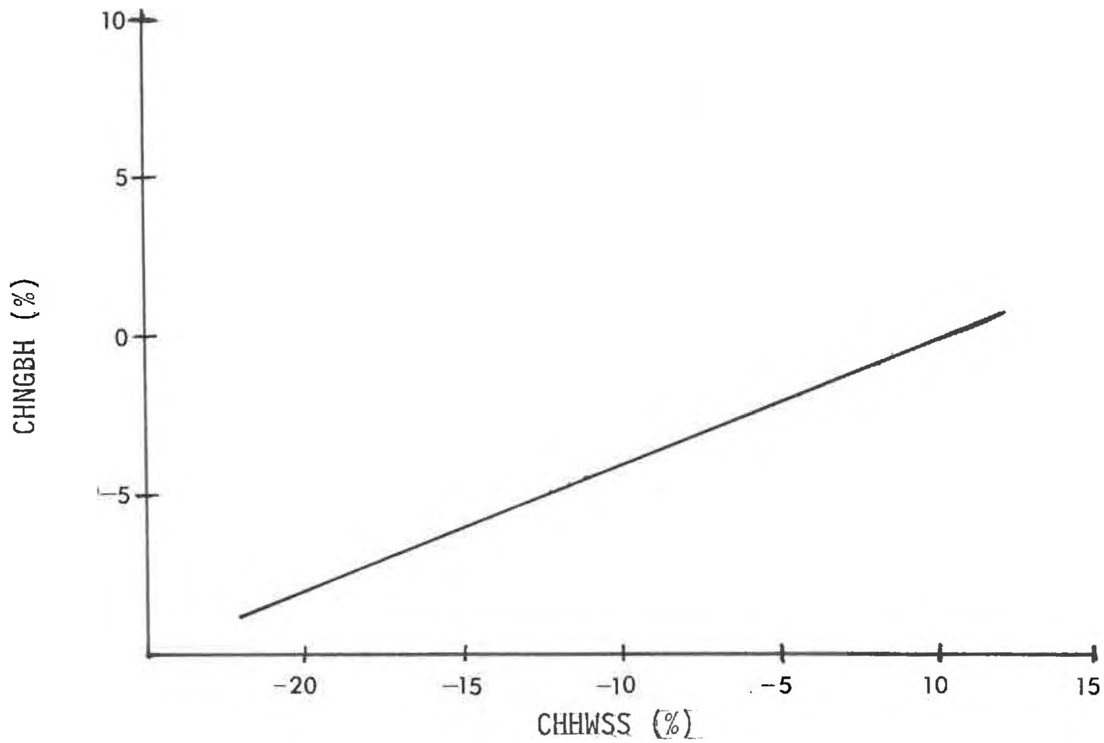

Figure 3. Response of change in buck harvest to change in proportion of commercial forest land in hardwood seedling/sapling stands as predicted by 4-variable model. Y = 0.3934 (CHHWSS).

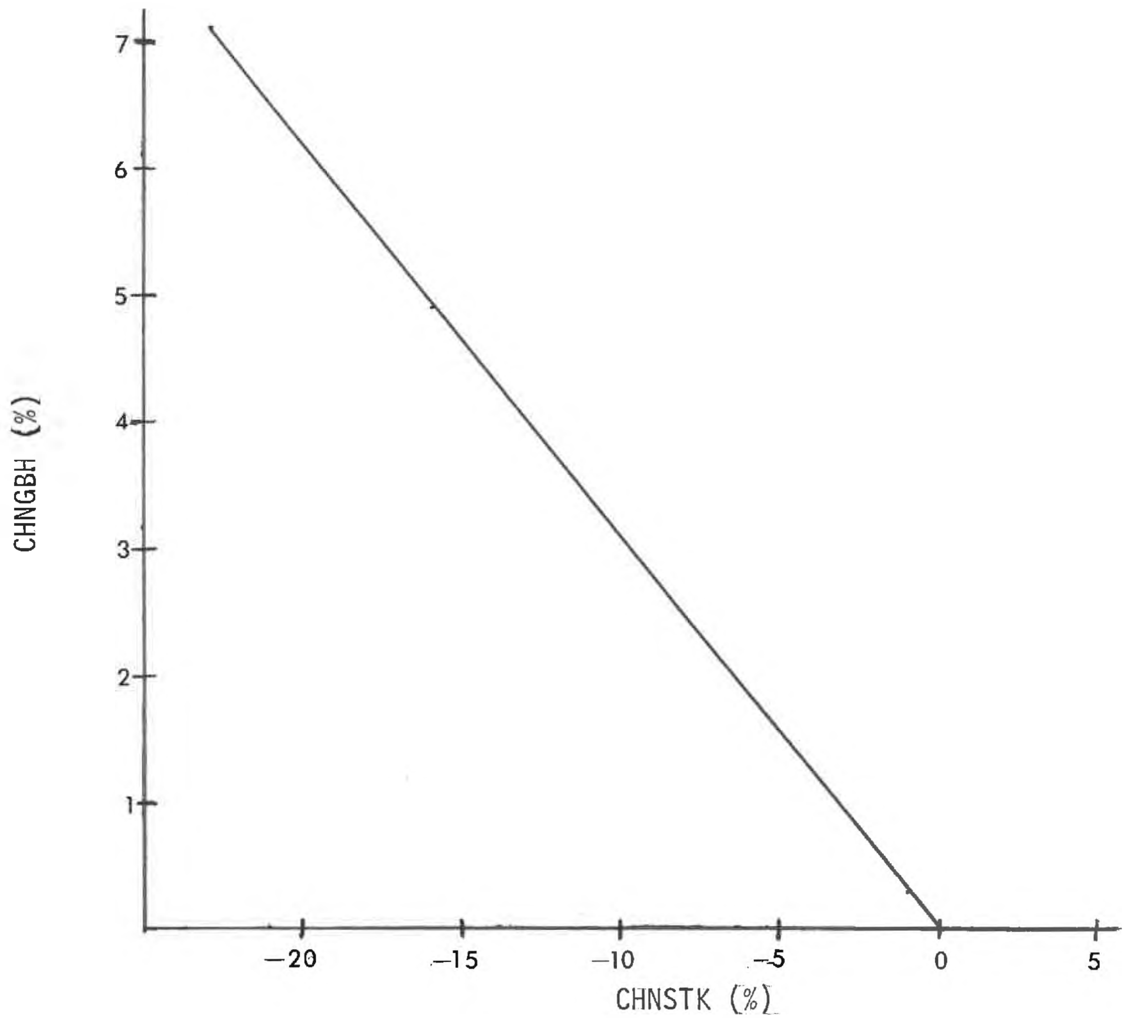

Figure 4. Response of change in buck harvest to change in proportion of commercial forest land in nonstocked stands as predicted by 4-variable model. Y = (-0.3086) (CHNSTK).

Appendix A. Forest types and type groups recognized by the Forest Survey in New York.

Softwoods

White/red pine group

Jack pine
Red pine
White pine
Scotch pine
White/hemlock
Hemlock

Loblolly/shortleaf pine group

Eastern red cedar
Pitch pine

Spruce/fir group

Balsam fir
Black spruce
Red spruce/balsam fir
Northern white cedar
Tamarack
Larch plantation
White spruce
Norway spruce

Hardwoods

Oak/pine group

White pine/northern red oak/white ash

Eastern red cedar/hardwood
Other oak/pine

Aspen/birch group

Aspen
Paper birch
Gray birch

Elm/ash/cottonwood group

Black ash/American elm/red maple

Cottonwood
Willow

Northern hardwoods group

Sugar maple/beech/yellow birch

Black cherry
Red maple/northern hardwoods
Pin cherry/reverting field
Mixed northern hardwoods

Appendix A. (cont.)

<u>Oak/hickory group</u>

- Chestnut oak
- White oak
- Northern red oak
- Scarlet oak
- White oak/red oak/hickory
- Yellow poplar/white oak/ northern red oak
- Yellow poplar
- Black locust
- Black willow
- Red maple/central hardwoods
- Mixed central hardwoods

Appendix B. Summary of mnemonics used in this paper.

BKI	Five year mean of adult male deer harvested per mi^2 of deer habitat.
CHNGBH	Change in the proportion of the total Adirondack adult male harvest in each county.
CFL	Commercial forest land.
NFL	Noncommercial forest land.
HC	Proportion of deer habitat planted in harvested crops.
OHC	Proportion of deer habitat planted in harvested crops other than corn.
CORN	Proportion of deer habitat planted in corn.
PAST	Proportion of deer habitat in pasture.
HWST	Proportion of CFL in hardwood sawtimber.
HWPO	Proportion of CFL in hardwood pole timber.
HWSS	Proportion of CFL in hardwood seedling/saplings.
SWST	Proportion of CFL in softwood sawtimber.
SWPO	Proportion of CFL in softwood poletimber.
SWSS	Proportion of CFL in softwood seedling/saplings.
NSTK	Proportion of CFL in nonstocked stands.

Appendix C. Deer harvest, forest and agricultural data used in Analysis I and II.

Obs.	Yr.	County	BKI	HWST	HWPO	HWSS	SWST	SWPO	SWSS	NSTK	HC	OHC	CORN	PAST
1	67	Clinton	0.23	20	14	35	06	05	11	08	14	13	00	09
	78		0.21	17	37	21	10	04	09	00	14	10	04	06
2	67	Essex	0.59	34	12	21	20	04	07	06	02	02	00	01
	78		0.37	42	20	13	09	10	04	03	02	02	00	01
3	67	Franklin	0.91	24	15	32	05	05	10	08	07	06	01	04
	78		0.39	42	20	13	09	10	09	03	07	06	02	03
4	67	Fulton	0.40	25	11	33	07	04	05	15	07	06	01	04
	78		0.30	27	23	20	19	07	03	00	08	06	02	02
5	67	Hamilton	0.96	36	11	20	21	04	06	00	00	00	00	00
	78		0.45	39	33	05	10	07	07	00	00	00	00	00
6	67	Herkimer	0.86	24	11	33	06	03	05	18	10	08	02	05
	78		0.49	38	25	15	10	03	03	02	17	14	03	05
7	67	Jefferson	0.21	14	09	41	07	04	13	15	33	28	04	16
	78		0.24	23	06	43	04	06	07	10	38	29	08	10
8	67	Lewis	0.75	23	10	35	08	04	06	14	11	10	01	06
	78		0.51	39	21	20	06	04	06	05	13	10	03	05

Appendix C. (cont.)

Obs.	Yr.	County	BKI	HWST	HWPO	HWSS	SWST	SWPO	SWSS	NSTK	HC	OHC	CORN	PAST
9	67	Oneida	0.51	16	07	37	05	03	06	25	25	20	05	13
	78		0.72	43	17	29	08	02	00	02	28	19	08	10
10	67	Oswego	0.31	23	13	46	03	02	04	09	11	09	02	05
	78		0.42	27	27	33	05	03	00	03	12	09	03	05
11	67	St. Lawrence	1.14	20	14	35	05	05	11	09	13	12	01	08
	78		0.60	28	25	25	07	06	05	04	13	11	03	06
12	67	Saratoga	0.36	30	12	25	18	05	09	01	00	00	00	00
	78		0.44	32	20	27	16	05	00	00	11	07	04	03
13	67	Warren	0.63	25	13	33	15	04	06	04	09	07	02	05
	78		0.36	26	12	09	34	19	00	00	00	00	00	00
14	67	Washington	1.00	20	14	35	13	04	08	06	29	21	07	14
	78		1.23	24	39	22	13	03	00	00	35	23	12	13

Appendix C. (cont.)

County	CHHWST	CHHWPO	CHHWSS	CHSWST	CHSWOP	CHSWSS	CHNSTK	CHHC	CHPAST	CHNGBH
Clinton	-03	23	-14	04	-01	-02	-08	00	-03	00
Essex	-10	16	-05	10	-03	-06	00	00	00	-01
Franklin	18	05	-19	04	05	-06	-05	00	-01	-05
Fulton	02	12	-13	11	03	-02	-15	01	-02	00
Hamilton	03	22	-15	-11	03	01	00	00	00	-04
Herkimer	14	14	-18	04	00	-02	-16	07	00	-02
Jefferson	09	-03	02	-03	02	-06	-05	05	-06	02
Lewis	16	11	-15	-02	00	00	-09	02	-01	01
Oneida	27	10	-08	03	-01	-06	-23	03	-03	04
Oswego	04	14	-07	02	01	-04	-06	01	00	02
St. Lawrence	08	11	-10	02	01	-06	-05	00	-02	-04
Saratoga	02	08	02	-02	00	-09	-01	11	03	02
Warren	01	-01	-22	19	15	-06	-04	-09	-05	-01
Washington	04	25	-13	00	-01	-08	-06	06	-01	04

Prepared by: Mark D. Lowery — Graduate Assistant
Mark D. Lowery — Title

Principal Investigator: Mark D. Lowery — Graduate Assistant
Mark D. Lowery — Title

Date

Approved by: William F. Porter
William F. Porter
Project Leader — Date

Approved by:
Eugene Parks, Leader
Game Species Section — Date

Approved by:
Stuart Free, Chief
Bureau of Wildlife — Date