SOME METHODS OF WATERFOWL AND MARSH INVENTORIES

Thesis for the Degree of M. S.

MICHIGAN STATE UNIVERSITY

Carl L. Bennett, Jr.

1965

102 2 244
118P
1314 2 157
125-265
DEC 28 '76
334
121 324
V-299 SH-026
713 OCT 26 1994
50
342
OCT 2 '76 236

ABSTRACT

SOME METHODS OF WATERFOWL AND MARSH INVENTORIES

by Carl L. Bennett, Jr.

Because of the author's dissatisfaction with the more established techniques of marsh investigations, namely vegetation and duck inventories, an outline for quickly and accurately obtaining basic data of a more universal nature upon which marsh evaluation and/or further research can be built is herein presented. The proposed methods, as put forth, are for single marsh usage but can be adapted to marsh complexes and even large geographic areas.

Vegetation inventories of two types are presented, each serving a different function; plots placed at ecotones are used to determine rates of prisere encroachment while stratified random sampling is used for inventorying and for comparing subseres. Data are presented only to illustrate since rates of vegetation encroachment and change are undoubtedly marsh dependent.

Waterfowl inventory methods for nests, broods, and hunting season kill are presented. Kill and nest inventory methods are modifications of previous techniques while the brood inventory is a sampling procedure based on the assumption that as the number of different broods seen increases it becomes progressively more difficult to see a "new" brood; and the rate of this decline follows a logarithmic series curve. Data for the nest and kill inventories are again only for illustration but substantiating data for the brood inventory method are included.

Usage of these proposed methods allows the yearly collection of data in a relatively short period of time even by different observers with a minimal lack of continuity. Thus, statistical treatment of data to evaluate research findings and to predict the effects of management practices is possible.

SOME METHODS OF WATERFOWL

AND MARSH INVENTORIES

By

Carl L. Bennett, Jr.

A THESIS

Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree of

MASTER OF SCIENCE

Department of Fisheries and Wildlife

1965

ACKNOWLEDGMENTS

To all those people who contributed towards this manuscript but are not named, I humbly acknowledge your efforts.

I am deeply grateful to the Erie Shooting and Fishing Club for the area and the funds (granted to me by the Erie Research Committee through the Department of Fisheries and Wildlife of Michigan State University) to conduct research.

To C. E. Kincaid (then manager-Erie Club) and his assistant and to W. A. Matulis and D. J. Drumm a special note of thanks for aiding me in collecting data on the Erie Club marsh.

I am also grateful to the personnel, especially Dr. C. T. Black and Dr. J. A. Kadlec, of the Rose Lake Wildlife Research Center of the Michigan Department of Conservation's Research and Development Section for collecting data for my use and to Dr. P. J. Clark (until his untimely death) and L. A. Ryel for their help with the statistical aspects of the paper.

I wish to acknowledge the efforts of Dr. M. D. Pirnie, for whose guidance and counciling I am deeply indebted, who helped initiate and directed the project and who offered valuable editorial comments.

Special thanks go to Dr. D. W. Douglass for critically reviewing and to Beatrice Byerlay for her diligence in typing the manuscript.

Lastly, to my wife, Joanne, I am ever grateful for tolerating many inconveniences and for providing the needed impetus.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

Marsh investigational techniques, especially vegetation sampling, are many, diverse, and of varying degrees of accuracy. When investigators repeatedly and somewhat sporadically study different marshes, results often lack continuity. Even when the same techniques are employed, because of original design, data are still not quantitatively comparable.

A resumé of techniques now in use, with a short critique of each, is included under each section and will not be presented here. Each section is designed as a complete entity to save wear and tear on the reader's mind.

The proposed methods are based on studies conducted in Saginaw County, Michigan, at the Shiawassee Refuge of the U. S. Fish and Wildlife Service, where I worked as a Student Assistant; at the Erie Shooting and Fishing Club in Monroe County, Michigan, where I studied as a research waterfowl biologist under a grant from the Erie Research Committee; at the Conservation Department's Rose Lake Wildlife Research Center, Clinton and Shiawassee counties, Michigan; and at the Gratiot-Saginaw and Maple River state game areas. Studies at Rose Lake and on the game areas dealing with waterfowl and vegetation inventories were either conducted or supervised by me in my present capacity as biometrician for the Michigan Department of Conservation.

Before proceeding further, I wish to establish that these proposals have arisen from the negative rather than the positive point of view. While at both the Shiawassee Refuge and the Erie Club, I followed previously established techniques of inventorying vegetation, duck nesting, and duck broods. Many doubts arose in my mind as to the actual worth of the techniques. Most of the methods proposed have had only weak field testing at best and are suggested because of my dissatisfaction with the established techniques.

Some of the vegetation inventories herein discussed I instituted while at the Erie Club in 1961, with the assistance of Walter A. Matulis and Dennis Drumm. These inventories have been continued since that time. In 1964 two Conservation Department aides, under my direction, inventoried the vegetation on part of the Maple River State Game Area, the results of which are included to exemplify a particular use.

At an impoundment on the Rose Lake area, Center personnel and I have and still are testing my proposed method of estimating broods. The survey utilizes an observation point placement and sampling system devised by Robert Heath and John Kadlec.

I am not going to consider surveys of waterfowl during spring or fall migrations. Nor am I going to consider a "breeding pairs" survey, the validity of which I strongly question. Also, I am not including a method for making use estimates during the early fall shuffle. The reason for not considering these surveys is simple: I have no method to offer.

Some proposed methods for vegetation and waterfowl inventories are presented for consideration. Ways of estimating total waterfowl production on an area are somewhat archaic and a better method is badly needed. In an attempt to fill this gap I have devised a method that seems to work on one particular type of impoundment, and through modifications may work elsewhere. There are in existence good methods of estimating duck kill; these are included. Also I include a duck nest inventory method that is old in design but new in philosophy.

Proposing of these methods is in no way an attempt to create hard and fast guidelines. I assume investigators will continue to display individualism in type and scope of research projects, but by also incorporating these standardized methods time can be saved and continuity preserved.

Certain background data are necessary to form a good working base upon which to superimpose the methods. An outline of these data and their contributions is included in the appendix (Necessary background information).

Throughout the paper the word "technique" will be used when the work plan was someone else's idea. For my proposed work plan I will use the term "method" to save confusion. Also the terms "survey," "census," "inventory," and "sample" will occur many times. The best way to show their use and meaning is in the following sentence, "An inventory is the result of a survey accomplished by either sampling or censusing."

VEGETATION INVENTORY

SUMMARY OF EXISTING TECHNIQUES

Most techniques of vegetation inventory have been developed for timber and grasslands while marsh and aquatic habitats have been somewhat neglected (Loveless, 1957). To try to use the techniques employed in grasslands and in timber stands does not seem appropriate since developed techniques are based on growth habit and growth form of the plants (Brown, 1954; Hasel, 1954).

Nevertheless, some investigators cognizant of the drawbacks have tried to census marsh vegetation by applying techniques developed for grasslands. For example, point sampling (Brown, 1954; Subcommittee on Range Research Methods, 1962; Greig-Smith, 1957; Coupland, 1950) which is of questionable accuracy even in grasslands (Brown, 1954; Greig-Smith, 1957; Blackman, 1935; Goodall, 1952) has been tried as a technique to inventory marsh border (Sincock and Powell, 1957; Berg, 1956) and aquatic vegetation (Uhler and McGilvrey, 1965).

Other investigators, who appeared aware of the necessity of a survey technique unique to marsh vegetation and flexible enough to circumvent differences in growth form between marsh border and aquatic plants, devised new techniques of varying degrees of accuracy. Generosoff (1934) first mapped the area, then traversed it estimating plant abundance and graded the density per species on a decimal system within marsh sections. By knowing the areas involved and percentage composition of their vegetation, he calculated the approximate acreage of stands of any plant species or group of species. He also made stem counts on "selected" one-meter quadrats to determine "medium" density for each species; those biased counts were used as standards for the density ratings.

Siegler (1941) walked segments or total shorelines listing the number of times a particular species occurred alongside of his right (or left) foot. He needed a list of species present before starting and could census only two species per trip. He also felt that quadrats may be necessary to help analyze and correct the total picture.

Stoudt (1944) used basically the same system as Generosoff (1934) with one important exception. After having type-mapped the vegetation, he checked seed production of the various waterfowl food plants occurring along the marsh border and computed the percent frequencies of the purely aquatic food plants.

The bulk of the techniques for inventorying marsh vegetation have utilized some variation of the transect method which Dorothy Brown (1954) stated was best for vegetation which traversed a land gradient. Transects have also been used in timber (Pielou, 1962) and grasslands (Rice, 1952).

True transects (Penfound and Hathaway, 1938), line transects (Siegler, 1941; Beard, 1953), line transects with systematically placed plots (Anderson, 1950; Jessen and Lound, 1962; Keith, 1961), line transects with randomly located plots (Loveless, 1957), line transects of variable direction (Swindale and Jahn, 1956) and randomized line transects (Uhler and McGilvrey, 1965; Berg, 1956) are illustrations of a few of the variations that have been tried. Excluding the transect work of Penfound and Hathaway (1938), the investigators used line transects, usually with quadrats along them. Basically the use of this technique stems from a desire for quantitative data but an unwillingness to spend considerable time collecting it.

Some of the waterfowl refuges under the jurisdiction of the U. S. Fish and Wildlife Service have had repeated vegetation inventories from staked plots placed at ecotones* along line transects (Bennett, 1960; Robert Meeks, student assistant, Seney Refuge, 1960, personal communication).

Subjective inventories based on relative frequencies are biased and not suitable for yearly comparisons; actual measurements of both expanse and composition of plant communities are needed. Therefore, cover maps should be the result and not the agent of marsh inventories.

Penfound (1945) presents evidence suggesting that frequency is the most artificial and least important manner of inventorying vegetation compared to cover (measurements on the amount of ground area shaded by each species) and density (stem counts). Also the relation of density did not change with quadrat size, number of species present, or the total plant cover, which suggests that density is a true quantitative condition and hence more reliable than frequency or cover.

The use of permanent transects with systematically placed plots has three possible drawbacks: first, the validity of calculated confidence limits is questionable; second, the accuracy of the sample varies inversely with the number of vegetative communities within the marsh; and third, the transects are usually not randomly picked. This means that the accuracy of such a vegetation inventory is neither

*As used by Clarke, 1954.

calculable nor independent of the marsh. However, a systematic sample can serve a useful function when used as a subsampling technique within a particular vegetative community (where the assumption can be met that the variability between samples is greater than the variability within subsamples which allows pooling data collected from subsamples (Cochran, 1953) and treating them as a single sample).

Even the use of randomly located transects, regardless of how the quadrats are placed on them, does not seem highly efficient to me. The sampling unit is still the transect; the quadrats are subsampling units. Thus variability measurements are between transects and not between quadrats over all transects.

Establishment of permanent transect lines with staked plots at ecotones has two possible drawbacks: The first is merely mechanical--stakes are hard to keep placed and hard to find; the second is statistical--plots are not representative of the marsh because they are not randomly selected and sample only transition zones. "Ecotone Transects" (as I choose to call them) can serve a useful function but will not stand alone as an adequate marsh vegetation inventory.

THEORY

When I attempted to devise an adequate sampling scheme calling for minimum effort expenditure, it came to mind that two greatly different situations are likely to occur in any given marsh--prisere* (primary succession) and subsere** (secondary succession) areas.

*As used by Clarke, 1954.

**As defined by Hanson, 1962.

The rate of change in plant composition within and the rate of edge movement outward for a prisere area is markedly different (usually) slower in vegetative change and faster in edge movement) from those same rates in a subsere. Therefore, maybe priseres should be studied with emphasis on rate of encroachment while subseres should have the emphasis upon vegetative changes, albeit much of the rate of change with respect to time depends upon the amount and duration of inundation.

I think an "Ecotone Transect" technique will yield enough desirable information to compensate for the hardships encountered when utilizing permanently located stakes.

Two different uses are, I believe, possible. When the transition zone is extremely narrow (emergent vegetation and open water as an extreme example), measurements from stake to edge for several years should yield data that can be used to calculate the rate of edge migration with respect to time and corrected for differential water depths by using a multiple regression. The second use stems from the occurrence of wider and more complex ecotones. Possibly by sampling within the transition zones the changes in species composition over several years will provide data which can also be used to determine rates of encroachment through either inverse relations projected with regressions or through ratios projected by an appropriate mathematical series to the zero point.

A side benefit of using "Ecotone Transects," assuming they are laid out with transit and tape, is that measurements across homogeneous vegetative types are available for scaling air photos.

It has been my observation that most subsere areas (most experimental plots are in this category) change rapidly in vegetative composition, with reciprocating encroachment that is of little consequence in determining the time of reversion back to the vegetation present before disturbance. This being the case, I feel the most important aspect to be considered is the rate of change in plant composition. A form of stratified random sampling (Cochran, 1953) then becomes the most logical tool to use. The sampling plan can be devised for determining the change in the gross number of species, for an inventory of the major species, for an inventory of total duck food available, and/or for determining a rate change of primary species to secondary species over time.

The latter possibility can be used for evaluating a management technique in terms of money spent to length of time it is useful. The duck food production inventory, I think, is useful when one wishes to compare two different subsere areas (test areas primarily), if differences in species composition *per se* cause no hardship in making the contrast.

FIELD USE

I think a combination of both "Ecotone Transects" and stratified random sampling should be employed in a marsh subjected to frequent study, especially if research continuity over time is desired. When only single or sporadic vegetation censuses are needed, the usefulness of the "Ecotone Transect" is lost and is not worth the time and effort.

Plot size for emergent and marsh border vegetation should be 1/4 milacre. Milacre quadrats would mean fewer plots and less "edge effect," but because of the tendencies of clumping and dispersion, a greater number of plots of smaller areas, I believe, are more suited to my purpose. Cochran (1953) believes that large sample units are nearly always cheaper but often less precise.

For sampling submerged vegetation a larger quadrat seems appropriate (Curtis and McIntosh, 1950). I have used I milacre quadrats for this purpose.

Several attempts at obtaining quantitative data from submerged sampling units are described in the literature (Swindale and Jahn, 1956; Swindale and Curtis, 1957; Tryon, 1954; Jessen and Lound, 1962; Anderson, 1950; Keith, 1961; Loveless, 1957) but seem to fall into two categories of deficiency: too time-consuming or too inefficient for good quantitative data. I have no tested technique to submit; only one to suggest. Possibly density calculated from frequency using the Poisson distribution as outlined by Blackman (1935) is not altogether erroneous for areas having haphazard water fluctuations or in newly created areas. I suspect from my field experience that the distribution of plants immediately following a major habitat disturbance is closer to being random than in established communities.

The question as to how many plots should be taken will need answering each time a survey is to be conducted. The burden of such a decision rests solely with the investigator. The ideal situation is to have time and money to run a "thumb-nail" investigation (take a few samples to determine amount of variability), the data from which can be used to roughly estimate desired sample sizes (Cochran, 1953). If this is not possible, either use data from elsewhere if available as a basis for selecting the number of plots, or use your own knowledge of the area.

Cain (1937) suggested a method for determining the break (point where a 10 percent sample gives a 10 percent increase in species) in the species-area curve. Penfound (1945) suggested that a sample at least ten times the number of quadrats obtained from the break in the species-area curve is necessary for a proper quantitative sample in plant community analysis.

The locations of randomly picked plots can be determined by compass and pacing at time of survey. Jolly (in Brown, 1954) and Greig-Smith (1957) both state that randomly picked plots need not be accurately located and that pacing is quite adequate.

Data collected at each 1/4 milacre quadrat should include the density, height, and seed production for each species and possibly the percent of cover per layer. Sampling just percent cover per layer of each species has too many possible year-to-year discrepancies regardless of consistency among observers. These stem from differences in temperatures, solar radiation reaching the ground, time and duration of inundation, etc., from one year to the next. Also the usefulness of purely cover percentages is quite limited even when the aforementioned inconsistencies are non-existent.

Suggested outline for "Ecotone Transect" sampling

Ecotone Transects are picked; not random. The idea is to place the transect so that both beginning and ending stakes are easily found and are not likely to be lost due to ice or some other factor, and so that the line crosses several major ecotones. The number of transects varies with the marsh but relatively few are necessary. At the Erie Shooting and Fishing Club, I established ten transects (five of which were extremely short and measured a single vegetation-open water ecotone in which I had a greater interest) which contained a total of 54 quadrat stakes (Appendix, Figure I and Table 7).

Each transect should be laid out by a transit and tape to aid in subsequent locating of stakes. Each quadrat stake should be placed at an ecotone in a systematic manner, i.e., at the point where each ecotone is first encountered, then the quadrat itself should be positioned in a predetermined relation to stake and transect line.

The data obtained from the quadrat inventory can then be used to determine edge migration through the use of regressions on the inverse relationship between the two adjacent vegetative communities. The slower the rate of edge migration the more useful this technique.

When edge migration is fairly rapid, then measurements from stake to edge for successive years is probably the most useful for rate (either positive or negative) determination through regression analysis. It is theoretically possible to determine the rate of closing of shallow open water areas with these data plus water depths and inundation data using a multiple regression.

As noted previously, these transects seem to fit prisere areas better because the rate of change in vegetation composition is rather slow and often one community is pushed out by another. Water levels that differ from year to year in depth, period of inundation, and time of inundation increase the complexity of the analysis but do not rule out the possibility of rate determinations. Rates are then predictable under particular sets of conditions. When data of this nature are available, results of management techniques based on water control are predictable in terms of edge migration.

I am well aware of several situations that can and do arise to confound transect results. As an example, muskrats may over-utilize the vegetation at times of high water preceded by low water that produced lush growth; but in this case muskrats are one of the factors of a particular management technique that can be accounted for in predicting the rate of edge migration.

Rates of edge migration undoubtedly follow curves other than linear and are probably governed by conditions in the particular marsh. Hence, the particular curve for such rates in each marsh must be determined using data from that marsh.

Stratified random sampling should be used to determine the actual abundance of species. Results can then be used for several different analyses.

Suggested outline for random sampling

Stratify the area in question into a series of fairly homogeneous vegetative types. Indirect stratifications may be done according to

elevations and/or water levels, soil series, or from air photos.

Determine the number of plots necessary for prisere areas. The number necessary and the uses of the data are few. Usually these areas are fairly homogeneous within a particular community with relatively few species. Therefore, only a very small number of plots are necessary and the only use is strictly as an inventory. For subsere areas, succession is much more rapid and some stages may either be skipped or present simultaneously. This means the number of different species is extremely large at any given time and the composition changes tremendously with respect to time. Therefore, a greater number of plots are needed than for a prisere.

Pick a series of random samples for each stratum, the plot size and the data collected to be as previously described. Use a reference point for each stratum (post, tree, etc.) so that stratum boundaries and sample plots can be determined by compass and pacing.

Three uses for these data besides inventory come to mind, and all point towards obtaining a measurement of usefulness for two purposes--for management to balance against cost and for research to compare with other subseres.

First, it might be possible to form a ratio of the primary succession plants to the secondary ones and to project this over time until the ratio is zero.

The second suggestion is a variation of the first. Instead of using succession stages as criteria, use a ratio of useful to unuseful plants over years where usefulness of a species is gauged by its value as a duck food.

The third suggestion is to use these data for comparisons between subseres or yearly changes in single areas. Hence, some method for comparing totally different species and communities must be devised. I think the following method has some merit:

Each duck food producing species found within a sample plot is to be rated on average seed production as to excellent, good, fair, poor, or none. These indices then get an arbitrary scaling from 5 to 1 respectively. A plant may produce seed in, say, "excellent" quantities for its species, but it is not directly comparable in seed production with another species of "excellent" rating. This can be corrected by choosing as a base a plant such as Polygonum lapathifolium. Now each species can be compared to the chosen base, i.e., the "excellent" for species A may be equal in total seed production to a "fair" P. lapathifolium. Thereby the ultimate rating for species A is 3 and not 5. Summation of the products of this ultimate rating times plot density for all duck food producing species within the plot, then extending this procedure over all plots, yields comparable seed production figures for all plots within and between strata.

The plot index figures have ordinal scaling which will allow testing within stratum segments, between strata, or conceivably between marshes with the Mann-Whitney "U" test (Siegel, 1956). To test adjacent experimental plots, the Friedman 2-way analysis of variance (Siegel, 1956), also a non-parametric test, could be used but requires related samples. It also needs at least ordinal scaling.

I have neglected to put any calendar dates or time limits on the vegetation inventories. These have been conscious omissions. Survey dates are dependent upon geographical location of the marsh, climate, inundation period, length of growing season, and most important--what the investigator wishes to learn from the inventory. For some studies, several inventories in one year would be desirable or even necessary.

DISCUSSION

The primary purpose of the method outlined is to save field time without sacrificing accuracy. A negative correlation undoubtedly exists between the amount of time spent outlining the data collection procedure and the resulting field time required, whereas a positive correlation exists between the amount of planning time and the degree of precision that will be gained. The situation can be likened to the overworked but often unheeded proverb about an ounce of prevention being worth a pound of cure. A copy of the instructions I composed for inventorying a section (see Appendix, Figure 2, for picture of area) of the Maple River State Game Area is appended (Vegetation sampling instructions for Maple River West). The high and low vegetation strata were purely for inventory while the rest of the outlined procedures had at least a dual purpose.

The establishment of ecotone transects takes time and personnel, but once established they can be traversed and samples taken in a relatively short period. The measurements and quadrat data (Appendix, Tables 8 and 9) in addition to applications discussed under "Theory," can be used to delineate sample spaces for the stratified random sampling and, supplemented with air photos and personal observations, to make detailed cover maps (Appendix, Figure 3) of the areas (Bennett, et al., 1961).

In a good day, I figure on locating and sampling 40 to 50 1/4 milacre quadrats in rank growth. From data collected at the Maple River State Game Area two inexperienced aides working as a team (one of the aides had not studied aquatic plants prior to this assignment) located and censused 98 plots in four days in rank growth (high and low vegetation strata, Table 1), and collected other information. Utilizing information from the first table (Table 1), the second table (Table 2) presents the inventory results and calculated confidence limits (according to Cochran, 1953) for the plant groupings in which I was interested.

The estimates derived from the high and low vegetation strata (Table 3) show a remarkable stratification done entirely from air photos using a stereoscope to separate the strata. There was absolutely no ground reconnaissance beforehand in relation to vegetation distribution. The point I wish to stress is that 98 1/4 milacre plots more than adequately censused 83.5 acres of heterogeneous marsh vegetation!

Table I. Vegetation inventory - Maple River West, stratum results

Stratum	Notation	Cattail	River Bulrush	Smart-weeds	Duck Potato	Grasses	Broad-Leaved Misc.	Narrow-Leaved Misc.
Bank Area	ΣX_j	204	1,570	796	370	4,130	169	341
	ΣX_j^2	3,718	82,804	29,382	13,650	1042,390	10,927	25,443
	n	74	74	74	74	74	74	74
	s_j^2	43.2277	678.0074	285.2003	161.6438	11121.7993	144.3978	327.0087
	$\bar{X}_j$	2.7568	21.2162	10.7568	5.0000	55.8108	2.2838	4.6081
Mound Area	ΣX_j	181	795	2,386	459	6,768	179	500
	ΣX_j^2	2,247	39,047	205,472	40,245	1060,820	2,773	55,848
	n	114	114	114	114	114	114	114
	s_j^2	17.3418	296.4860	1376.4021	339.7958	2831.9870	22.0526	474.8232
	$\bar{X}_j$	1.5877	6.9737	20.9298	4.0263	59.3684	1.5702	4.3860
High Veg.	ΣX_j	409	1,844	893	272	1,010	203	154
	ΣX_j^2	5,987	94,144	27,653	4,820	105,138	24,169	5,876
	n	62	62	62	62	62	62	62
	s_j^2	53.9167	644.2602	242.4741	59.4543	1453.8488	385.3170	90.0571
	$\bar{X}_j$	6.5968	29.7419	14.4032	4.3871	16.2903	3.2742	2.4839
Low Veg.	ΣX_j	27	77*	387	76	4,377	000	368
	ΣX_j^2	285	4,657	30,069	1,776	740,891	000	18,404
	n	36	36	36	36	36	36	36
	s_j^2	7.5643	128.3516*	740.2500	46.1587	5963.4500	000	418.3492
	$\bar{X}_j$	.7500	2.1389	10.7500	2.1111	121.5833	000	10.2222

*One plot had 68 of the 77 stems and were 6' high. Obviously this plot was in the wrong stratum. The large variance and high mean value are a result of this plot.
Data collected September, 1964.

Table 2. Vegetation inventory - Maple River West, plant inventory estimates

	Stratum	Area in ¼ milacre	Prop. w_j	Mean $\bar{X}_j$	Plots n_j	w_j^2	Variance s_j^2	$\frac{w_j^2 s_j^2}{n_j}$
Cattail	Bank area	27,290	.0696	2.7568	74	.0048	43.2277	.0028
	Mound area	27,290	.0696	1.5877	114	.0048	17.3418	.0007
	High Veg.	209,620	.5347	6.5968	62	.2859	53.0471	.2446
	Low Veg.	124,656	.3180	.7500	36	.1011	7.5643	.0212
	Trees	3,148	.0081		0	.0001		.0000
	Total	392,004	1.0000		286			.2693
	$\bar{X}_{st}$ = 4.0682	S.E. = .5189	2 S.E. as % = 25.51%			Total stems = 1,594,471 ±25.51%		
River Bulrush	Bank area	27,290	.0696	21.2162	74	.0048	678.0074	.0440
	Mound area	27,290	.0696	6.9737	114	.0048	296.4860	.0125
	High Veg.	209,620	.5347	29.7419	62	.2859	644.2602	2.9709
	Low Veg.	124,656	.3180	2.1389	36	.1011	128.3516	.3605
	Trees	3,148	.0081		0	.0001		.0000
	Total	392,004	1.0000		286			3.3879
	$\bar{X}_{st}$ = 18.5452	S.E. = 1.8406	2 S.E. as % = 19.85%			Total stems = 7,269,793 ±19.85%		
Smart-weeds	Bank area	27,290	.0696	10.7568	74	.0048	285.2003	.0185
	Mound area	27,290	.0696	20.9298	114	.0048	1376.4021	.0580
	High Veg.	209,620	.5347	14.4032	62	.2859	242.4741	1.1181
	Low Veg.	124,656	.3180	10.7500	36	.1011	740.2500	2.0789
	Trees	3,148	.0081		0	.0001		.0000
	Total	392,004	1.0000		286			3.2735
	$\bar{X}_{st}$ = 13.3253	S.E. = 1.8093	2 S.E. as % = 27.16%			Total stems = 5,223,571 ±27.16%		

Table 2 (continued)

	Stratum	Area in ¼ milacre	Prop. w_j	Mean $\bar{X}_j$	Plots n_j	w_j^2	Variance s_j^2	$\frac{w_j^2 s_j^2}{n_j}$
Duck Potato	Bank area	27,290	.0696	5.0000	74	.0048	161.6438	.0105
	Mound area	27,290	.0696	4.0263	114	.0048	339.7958	.0143
	High Veg.	209,620	.5347	4.3871	62	.2859	59.4543	.2742
	Low Veg.	124,656	.3180	2.1111	36	.1011	46.1587	.1296
	Trees	3,148	.0081		0	.0001		.0000
	Total	392,004	1.0000		286			.4286
	$\bar{X}_{st}$ = 3.6453	S.E. = .6547	2 S.E. as % = 35.92%			Total stems = 1,428,972 ±35.92%		
Grasses	Bank area	27,290	.0696	55.8108	74	.0048	11121.7993	.7214
	Mound area	27,290	.0696	59.3684	114	.0048	5831.9870	.2456
	High Veg.	209,620	.5347	16.2903	62	.2859	1453.8488	6.7041
	Low Veg.	124,656	.3180	121.5833	36	.1011	5963.4500	16.7474
	Trees	3,148	.0081		0	.0001		.0000
	Total	392,004	1.0000		286			24.4185
	$\bar{X}_{st}$ = 55.3904	S.E. = 4.9415	2 S.E. as % = 17.84%			Total stems = 21,713,258 ±17.84%		
Broad-leaved misc.	Bank area	27,290	.0696	2.2838	74	.0048	144.3978	.0094
	Mound area	27,290	.0696	1.5702	114	.0048	22.0526	.0009
	High Veg.	209,620	.5347	3.2742	62	.2859	385.3170	1.7768
	Low Veg.	124,656	.3180	.0000	36	.1011	.0000	.0000
	Trees	3,148	.0081		0	.0001		.0000
	Total	392,004	1.0000		286			1.7871
	$\bar{X}_{st}$ = 2.0190	S.E. = 1.3368	2 S.E. as % =132.42%			Total stems = 791,456 ±132.42%		
Narrow-leaved misc.	Bank area	27,290	.0696	4.6081	74	.0048	327.0087	.0212
	Mound area	27,290	.0696	4.3860	114	.0048	474.8232	.0200
	High Veg.	209,620	.5347	2.4839	62	.2859	90.0571	.4153
	Low Veg.	124,656	.3180	10.2222	36	.1011	418.3492	1.1749
	Trees	3,148	.0081		0	.0001		.0000
	Total	392,004	1.0000		286			1.6314
	$\bar{X}_{st}$ = 5.2048	S.E. = 1.2773	2 S.E. as % = 49.08%			Total stems = 2,040,302 ±49.08%		

Data collected September, 1964.

Table 3. Vegetation Inventory - Maple River West, stratum comparisons

	Cattail	Bulrush	Smartweeds	Potato	Grasses	Broadleaved Misc.	Narrowleaved Misc.
				MEANS			
High Veg.	6.5968	29.7419	14.4032	4.3871	16.2903	3.2742	2.4839
Low Veg.	.7500	2.1389*	10.7500	2.1111	121.5833	.0000	10.2222
				VARIANCE			
High Veg.	53.0471	644.2602	242.4741	59.4543	1453.8488	385.3170	90.0571
Low Veg.	7.5643	128.3516*	740.2500	46.1587	5963.4500	.0000	418.3492

*These values were strongly influenced by a single plot erroneously included in the low stratum (see Table 1).

Data collected September, 1964.

DUCK NESTING INVENTORY

SUMMARY OF EXISTING TECHNIQUES

Most techniques for estimating duck or goose nest abundance (Geis, 1956) follow the pattern used by L. J. Bennett (1938). He attempted in several ways to find all nests (complete census) in an area. Even with a pointing dog, only 75 percent of the nests were found. He concluded that probably the best way was for two individuals to drag a rope across sample strips if trained dogs were not available. But dragging a rope, with or without tin cans or chains attached to flush hens, is restricted to open grassy areas of fairly level terrain.

Other investigators (Glover, 1956; Burgess et al., 1965, for example) restricted the size of the search area, making no attempt at a complete census and used located nests as indexes (with pair and brood counts) to calculate total production and mortality of young.

Steel et al. (1956), along with a systematic search of dry areas, also attempted a sampling technique using boat and motor for estimating marsh nest production. It seemed to work best for divers and is an intriguing technique that should be explored further.

Most duck nests have been located close to the water's edge (Burgess, 1956; Bennett, 1938; Steel et al., 1956; Rogers, 1964) but some nests have been found two miles from water and others two miles from land (Wright, 1948).

Because of species differences in nest site preference, general adaptability, and willingness to travel long distances over land from nest to water, any possible duck nesting inventory technique will be taxed to furnish useful and reliable quantitative data. Hammond and Forward (1956) present data illustrating the fact that nesting studies usually provide unreliable information on production because of differential predation on located nests. They feel the greatest value of a nesting study is to learn details of nest density, distribution, and cover.

THEORY

I still think a nest inventory can be useful but with emphasis placed on the lack of nests as a measure of habitat rather than on nest density as a factor in calculating total production. The brood census will give an estimate of total broods in the marsh; what is needed is an evaluation to determine whether more broods could be produced in the marsh area through improved nesting sites. Hence, my proposed method is pointed towards the present day outlook which dictates we must strive for maximum utilization of nesting grounds (Griffith, 1948). When attempts are made to improve an area for nesting, a species restriction on the potential brood increase will undoubtedly be imposed. For example, species like the Ring-necked Duck (*Aythya collaris*) and the Blue-winged Teal (*Anas discors*) would probably benefit most if the altered area is next to water though other species also might nest in the improved area (I have found several Mallard (*Anas platyrhynchos*) and Black Duck (*Anas rubripes*) nests on small man-made islands).

A basic assumption for this method when used for estimating total nests is that all hens will be on the nest at the time of the inventory. This assumption probably is not true, but I think (given a fairly large sample) it is safe to assume that a fairly constant proportion will be on nests, therefore, yearly differences of fair magnitude with no overlapping confidence limits will demonstrate real differences at the chosen risk level.

My proposed method does not utilize a dog, but a strip census technique similar to that used for grouse (King, 1937) could be adopted if dogs are available.

FIELD USE

Two factors should be considered before starting a nest survey. My proposed method, though more versatile than the rope-dragging technique, is restricted as to where it can be applied. Also, since nesting is strung out over a long period because of late-nesting species and because of renesting attempts, more than one survey may be needed in an area, with times picked accordingly.

Suggested outline for nest inventory

Stratify the entire area subjectively into general categories of expected nests; "none," "few," "several," and "many," for example. "None" would be totally open water areas, "few" would be areas of dense cattail or open mud flats, etc. Then divide each stratum into longitudinal strips of predetermined width. Choose strips to be inventoried at random according to laws of optimum allocation, i.e., based on area and variability (which reflect estimated nest density).

Several of the ways of nest censusing in strips probably are satisfactory but I will cover only the one I used while at the Erie Club.

This method called for three men to walk abreast at 10-foot intervals, each man carrying a staff and swinging it through the vegetation at a height of approximately $1\frac{1}{2}$ feet above the ground. In this manner each man surveyed a 10-foot strip (five feet either side of the line of travel) giving a total strip width of 30 feet. More people can be used if available, thereby increasing the strip width and decreasing the number of samples needed.

Data collected from such a sampling method can then be used to obtain an estimate of the total nests within the sampled area and to compute confidence limits on the estimates.

If small nesting islands occur in the marsh being studied, stratify them using the same criterion, choose a random sample of islands, and inventory the picked islands completely. Then the total nests, with confidence limits, can be computed for all islands.

DISCUSSION

A desirable side-effect of randomly choosing strips to census and running a strip only once is the possibility of reducing the chance of predators learning to locate nests more easily by following the human spoor.

The results of the survey I conducted on the Erie Club marsh (Table 4) demonstrated that there was no dearth of nesting sites, just that sites on dikes were too accessible to predators. The desertion of nests on islands probably resulted from harassment by muskrats which clipped all grass nesting cover to within about two inches of ground level. Probably the best way to raise brood production on that marsh would be to increase the number of nesting islands and provide better muskrat control. Since trapping of muskrats probably will not suffice, control can be aided by planting unpalatable woody species such as bitter nightshade (Solanum Dulcamara) on the islands along with grass (nests in the shade of woody shrubs were neither exposed by the muskrats nor subsequently abandoned).

This method should yield useful information with much less time and effort than any attempt at a total nest census. Data from a nesting study need not be complete for determining production, since the brood inventory method described in the next section, I hope, estimates the total number of broods on the area at the time of survey.

Table 4. Duck nesting

Species	No. of Eggs	Area	Date
Mallard	10*	Island No. 1, nest abandoned	6/16/61
Mallard	7	Island No. 10, starting incubation. Hatched 7/12/61	6/16/61
? Bl./Ma.	1*	Island No. 10, nest abandoned	6/16/61
Black	7	Island No. 10, starting incubation. Abandoned	7/12/61
B.W. Teal	12	30 yds. east of wier on so. side of dike, 10 yds. so. of road. Later broken up	6/16/61
Mallard	1	Island 12	6/17/61
Mallard	2	Island 14	6/17/61
Mallard	9	Island 15	6/17/61
Mallard	5	Island 17	6/17/61
Mallard	3*	Blind on Island 19, abandoned	6/17/61
B.W. Teal	1	So. side of Sulfur Springs, on dike. Increased to two eggs and both broken by 7/4/61	
B.W. Teal	8	So. main dike, directly so. of Is. 17, 5' from road. June 30, only 4 eggs left, no sign of breakage. July 2, four previously remaining eggs gone, no sign of breakage.	6/24/61
Mallard	8	15' SE of last stake on first transect N of Sand Island. Later broken up	7/5/61

*Rotten

(From Bennett et al., 1961)

DUCK BROOD INVENTORY

SUMMARY OF EXISTING TECHNIQUES

Present brood inventory techniques are basically of two types; large-scale surveys used to form yearly indexes of total waterfowl production and intensive studies on single marshes or small areas to determine actual production or use. Data from duck brood inventories on small areas have often been used as an adjustment factor to correct results of other studies.

L. J. Bennett (1938) outlines an extremely time-consuming technique for estimating duck production that entails determining total nests in the area, percent of nests successful, and number of young (reaching flying age) per female. Hammond and Forward (1956) present data to illustrate that duck nesting studies usually provide unreliable production information. Many other investigators, for example, Glover (1956), Steel et al. (1956), and Burgess et al. (1965), used estimated breeding pairs as being equal to the total number of nests started, thereby eliminating an intensive nest survey by adding a breeding pair survey.

Still other observers (Berg, 1956; Geis, 1956; Wright, 1948; Rogers, 1964) felt that through intensive field work they were able to locate all broods in their study areas. Hence, their production estimates were absolute counts. Stewart (1958) attempted in several different ways to get actual counts of wood duck production through observations. He concluded "that brood surveys are not sufficiently sensitive to indicate true trends in wood duck populations." The technique outlined by Blankenship et al. (1953) for locating broods by flushing can be extremely accurate depending on effort but puts such a tremendous demand on time and personnel that it is usually not feasible for areas other than of small pothole size.

Hochbaum (1948) stated that "There are conflicting reports of the numerical total for the waterfowl population. Different groups give out different figures obtained by different methods in different ranges at different times of the year." If a large-scale brood survey designed to estimate total production was attempted using the previously described techniques, these shaky population estimates would probably have to serve as a base.

In 1935 the More Game Birds in America Foundation conducted the first wide-scale ground and aerial survey of the Canadian wetlands (Cartwright, 1944). They believed the results of this survey estimated total production. The same survey (Cartwright, 1948) was later conducted by Ducks Unlimited. Quite often, in the first attempts at a complex survey by a sportsman-oriented group, the zeal with which the work is conducted is greater than the accuracy of the estimate; this survey was no exception.

Because of the apparent difficulties in estimating total production with present techniques, a system based on transects has been devised for determining yearly indexes of production (Smith and Hawkins, 1948; Day, 1949; Miller, 1949). It is still in use (Crissey, 1960) as the only large-scale survey. This technique has several difficulties (Smith and Hawkins, 1948) that need eliminating, and undoubtedly it will never be the panacea which all waterfowlers are striving for.

I feel there is a definite need for a method of estimating actual production that is not so time-consuming as to be impractical (Pirnie, 1935). In the hope of stimulating a different mode of brood-estimating procedure, I submit a method based on sampling which has been tested with some success at an impoundment of approximately 70 acres of recently flooded timber and brushy lowlands on the area of the Rose Lake Wildlife Research Center (Kadlec, 1964).

As implied by the title of this section, my proposed method is devised to obtain a quantitative measurement and will not furnish a qualitative measure for particular habitat types except indirectly through preponderances of sight records from proximal observation points. Established techniques of beating out a section (Blankenship et al., 1953) and of using dogs (Pirnie, personal communication) for locating broods for observation still seems the best for measuring the quality of a particular marsh section at a given time of day. For example, from my observations used for broods estimates, no real evaluation of escape cover is possible. Because counts were made only when broods exhibit the greatest movement with the observer concealed and motionless, broods were not stimulated to seek or use escape cover.

As with any method, both advantages and disadvantages are inherent. The field time involved can be minimal but precise brood identification and accurate aging of young (Gallop et al., 1954) are "musts."

THEORY

The theory behind the experimental model is that as the number of different broods seen increases, it becomes progressively more difficult to see a "new" brood. The rate of this decline when compared to the ratio of different broods seen to total brood sightings (including repeats) follows a logarithmic series curve. The formula which I propose for estimating total broods was originally designed to estimate the number of plant species in an area of known size (Evans et al., 1955).

The method, when used in impoundment evaluation to compare with another impoundment or with itself, estimates the total brood use. The existence of brood movement in or out is immaterial (and apparently self-compensating) except for its impact on the method itself when the survey period is too long.

The basic formula, with the symbol identification I used, is as follows:

$$B = \frac{b}{\log_{10}(n + 1)} \log_{10}(N + 1)$$

where B = estimated total broods

b = number of different broods seen

n = total brood sightings

N = theoretical estimated total brood sightings necessary to see all the broods

N is an unrealistic value but logical appearances of the number is immaterial. That it is equal to the theoretical number of total brood sightings necessary to see all broods can be easily demonstrated:

$$B = \frac{b}{\log_{10}(n + 1)} \log_{10}(N + 1)$$

when all broods have been seen, B = b

therefore: N = n

The formula contains two unknowns, B and N. The N values must be assumed; I submit they fall around the point on the logarithmic curve where the tangent slope is .008. So to calculate N determine its value at the point where the tangent to the curve is .008.

Following is the derivation of the slope formula:

$$B = \frac{b}{\log_{10}(n + 1)} \log_{10}(N + 1)$$

for any particular problem $\frac{b}{\log_{10}(n + 1)}$ = a constant, X

$N + 1 \cong N$ when N is large

$$B = X \log_{10} N$$

$$dB/dN = \frac{X}{N} \log_{10} e$$

$$dB/dN = \frac{b/\log_{10}(n + 1)}{N} \log_{10} e$$

Then by transposing the equation into the following form it can be used to calculate N.

$$N = \frac{\frac{b}{\log_{10}(n + 1)} \log_{10} e}{dB/dN}$$

The slope value of .008 was empirically derived and subsequently judged to be reliable. This is not the procedure for calculating N I first devised. The original scheme called for arbitrarily picking different values for N and computing B values from the estimating formula until $B = B^{I}$ where $B^{I} = \frac{N}{b}$.

Why the new N?

A table of comparisons between the tangent and the $B = B^I$ procedures of determining N is attached (Table 5); counts listed in Table 5 were made by personnel of the Michigan Department of Conservation assigned to the Rose Lake Wildlife Research Center and by myself. The error values (differences between brood estimates computed from the two procedures) form a straight line, and have an inverse relation with estimated broods. It is readily apparent that this must arise purely from the differences in N values since the brood estimation formula remains unchanged. I believe the better of the two N estimating procedures can be determined by looking at the table showing the results of the time study (Table 6). The greatest difference in B between the two procedures is in the 15-minute period which is also the time of fewest observations. The final N value is fairly large and comparable in all cases. When the probabilities (see probabilities section) of the next brood seen being a "new" brood are calculated for all time categories, little change is observed for the slope procedure while a larger change appears in the $B = B^I$ scheme.

With N being large and the probability being extremely small for final values, then the smaller changes should be from better approximations of N. Therefore, I contend the slope procedure for determining N values is more universally applicable.

Probabilities

Calculations of the probabilities under each time category for both estimating procedures over all years were made for two reasons:

to observe the continuity over time periods for each scheme, and to shed light on which is the better of the two estimating procedures.

Probabilities were calculated from the formula (Feller, 1950):

$$q_k = \frac{\binom{n_1}{k}\binom{n-n_1}{r-k}}{\binom{n}{r}} \quad \text{let } r = k = 1$$

which becomes:

$$q_k = \frac{B - b}{N - n}$$

for the next event using my estimating formula symbols. Since the formula uses the unrealistic value N, the resultant probability is also unrealistic and is only to be considered as a pure number contrastable in magnitude alone.

FIELD USE

The method calls for making observations from predetermined points and tabulating all observed broods (not flying) seen according to species, age, and number. Observation periods are the first 2 hours of daylight (starting approximately ½ hour before sunrise) and the 1 hour before dark (starting approximately 15 minutes before sunset).

If the observer keeps still, broods will move about freely, and the differences in wariness between species should thereby be minimized, albeit some broods are more readily seen then others and are more likely to repeat. A random sample of broods and of species is theoretically possible as long as the observer is trained to look both in edges of vegetation and in open areas. Kadlec (1964) presents data supporting this assumption.

Established observation points, preferably lookouts hidden in trees to reduce disturbance (Beard, 1964), should be used. These are to be situated so that a fairly large area of the marsh is under surveillance from each point, but when the area seen from all points is compared to the total area, it can be extremely minimal. The only criterion possible to use for placement and number of observation points is the number of broods and the estimated degree of brood mobility for the individual area where the method is to be employed. Every brood should have the chance of being seen, i.e., each brood should pass within sight of an observation point sometime between hatching and the flying age.

An extremely large sample area can be further stratified or subdivided to reduce counts necessary for sample estimates based on brood mobility.

Approximately 3 counts per station are necessary, but total observations can conceivably run from 2 to 6. The adding of more counting stations on a sample plot reduces the number of observation times needed per station.

Suggested outline for conducting brood inventory

Randomize the stations and the observation periods per station by using a Latin square: It may become necessary to throw out cells from the square when the number of counts and the number of stations are not equal.

The counting time per observation period was originally set at 45 minutes. This meant only 3 counts per day were possible if the counting period limits are observed. By recording the time of each brood observation, several time categories can be devised and the estimated number of broods calculated. Table 6 has the results of the categories I felt worthy of testing. Thirty minutes, it appears, is ample counting time.

Ideally counts should be made after all renesting attempts have hatched and before any early hatched broods have started flying. For southern Michigan late June and early July seem nearly optimum. The formula is designed to give an instantaneous estimate of broods present at time of count. This means that the necessary counts for a reliable estimate have to be conducted in a fairly short period of time. If the area to be inventoried is large, it can be broken into blocks and each block treated as a separate impoundment. I think all counts for a single impoundment of relatively small size should be completed in the space of one week. Counts should be made only on days having no rain and little or no fog during counting periods.

<u>Suggested method for calculating estimates</u>

For calculating brood estimates the algebraic manipulations can be lessened by first calculating the $b/\log_{10}(n + 1)$ value. Then N can be calculated by multiplying the value by .43429/.008. The logarithm of N is then multiplied by the first division and calculates the total number of broods.

In mathematical terms:

$$\text{let } X = \frac{b}{\log_{10}(n + 1)}$$

$$N = \frac{X\log_{10}e}{dB/dN}$$

$$N = \frac{.43429X}{.008}$$

and then:

$$\text{Total Broods (B)} = X\log_{10}N$$

DISCUSSION

Table 13 from Kadlec (1964) is appended (Table 10). It contains the results of the brood inventory and a comparison of the known broods present (a minimum figure) by species for 2 years. The "shore circuit" counts, or "circuit" counts as I chose to call them, were also tried as a possible future technique.

Kadlec was able to spend considerable time trying to determine the actual number of broods using the area, but he left prior to the 1963 inventory. Since then nobody has been able to devote the necessary time to obtain the known broods present figure with which to compare the estimate from the proposed method.

As a result, I have recommended continuation of the circuit counts as a partial check on the observation point counts (Table 5). I fully realize that the circuit counts are subject to personal bias (which can be easily demonstrated), but this bias is somewhat predictable from knowing the personnel. The more familiar they are with brood behavior and the survey area, the greater the inflation due to personal bias.

I am fairly satisfied that the inventory method I have proposed gives better estimates of total brood use on a single impoundment for the time expended than any others with which I am familiar. In areas having both early and late nesting species it will probably be necessary to run the survey twice and have it species-oriented.

In 1964 the opportunity arose to attempt using the method on a series of small impoundments in close proximity to each other and somewhat similar to the Rose Lake impoundment in habitat and expected waterfowl species. I divided the area into three separate sections and assumed no brood interchanges between sections (not an altogether valid assumption but of little consequence when movement is slight). Within each section I assumed there would be free interchange between the impoundments, so I treated each section as a large single impoundment with one observation point per small impoundment (two had two points because of large size) within it, i.e., seven small impoundments in a section would have seven observation points.

The counting times were again randomized with a Latin square design by section. Final estimates were to be calculated also by section.

To speculate a bit further, I believe the method can be adapted to inventorying waterfowl production at least on the small interior marshes of a state. To accomplish such a survey would entail stratifying all areas into expected number of broods categories, picking a random sample, making counts and estimating totals on those picked, and applying those results to the appropriate stratum. Eberhardt (1963) explains better than I the reasoning for this method.

> "When mobile populations are involved, any probability sampling scheme is likely to be essentially 'two-stage' or 'cluster' sampling. That is, stratification by areas may be quite

feasible, and random samples of areas within strata can be drawn, but rarely will it be possible to enumerate actually all individuals on the selected sample areas. Some kind of subsampling thus becomes involved, often with selection probabilities quite thoroughly unknown. While the question of central importance concerns the bias of these subsampling estimates, a mildly comforting general principle is that estimates of over-all variability may be based on the totals or means for the subareas, without dealing directly with the variability of subsampling (although such variability is, of course, an integral part of the whole)."

The biggest drawback, I believe, for setting up such a large-scale survey is neither the mathematics nor statistics that would be necessary, but the inability of observers without prior training and experience to be able to identify and age broods accurately.

Table 5. Brood estimates

The error column shows the difference between B values determined from using N values computed from the tangent of .008 and from the formula $B = B^{I}$ where $B^{I} = \frac{N}{b}$.

	.008 tangent slope	
	"B" estimate	Error
1961		
Circuit count*	21	+3
Observation count*	21	+2
Kadlec and student aide**		
1962		
Circuit count	40	-2
Observation count	30	+1
Kadlec**		
1963		
Circuit count	36	0
Observation count	40	-1
Bennett and student aide**		
1964		
Circuit count	34	0
Observation count	30	+1
Bennett and Duvendeck**		

*These data are from two different types of counts made on the impoundment of the Rose Lake Wildlife Research Center.

**Observations made by:

Data collected late June and early July each year.

Table 6. Observation time study, using data from observation point counts on the impoundment of the Rose Lake Wildlife Research Center.

	15 minutes	30 minutes	35 minutes	40 minutes	45 minutes
1961					
Different broods	6	9	9	10	11
Total sightings	9	16	18	20	22
B from slope form.	15	19	18	20	21
Probability**	.0284	.0262	.0247	.0256	.0240
B from B = B' form.	11	16	15	17	19
Probability	.0893	.0556	.0513	.0473	.0435
1962					
Different broods	11	15	17	17	17
Total sightings	16	25	31	32	35
B from slope form.	24	29	31	31	30
Probability	.0277	.0255	.0241	.0243	.0233
B from B = B' form.	21	28	31	30	29
Probability	.0461	.0332	.0285	.0269	.0268
1963					
Different broods	13	20	20	20	22
Total sightings	15	33	36	39	42
B from slope form.	30	37	38	37	41*
Probability	.0298	.0251	.0217	.0208	.0222
B from B = B' form.	28	38	39	38	42*
Probability	.0436	.0566	.0230	.0224	.0205
1964					
Different broods	12	16	16	17	17
Total sightings	20	30	32	37	37
B from slope form.	24	30	29	30	30
Probability	.0254	.0254	.0241	.0238	.0238
B from B = B' form.	22	29	28	29	29
Probability	.0370	.0304	.0289	.0263	.0263

*Brood observation times were missing for 2 counts so four brood sightings are not included but immaterial to this observation.

**See text explaining value's magnitude.

DUCK KILL INVENTORY

SUMMARY OF EXISTING TECHNIQUES

Probably the first survey of a systematic nature for determining total kill over a large area utilized basically a technique I choose to call "The hunter report card system" (Lee, 1964; Sondrini, 1950; Hayne and Eberhardt, 1954). Such a technique has since been scrutinized and deemed unsuitable for acquiring useful data (Sondrini, 1950; Hayne and Eberhardt, 1954; Eberhardt, 1955).

Elder (1950) proposed the idea of using an x-ray to determine the proportion of the duck population by species carrying lead shot (other than ingested). He hypothesized that,

> "The amount of lead shot fired at waterfowl in any particular year, or at any one species in that year, should be proportionate to the number of ducks killed or the number killed of that species; and also it should be proportionate to the number of ducks that are crippled and die, and the number that survive their wounds and carry lead shot in their flesh ..... An accurate measure of any one of these four factors should give us an index to all others."

If the amount of lead shot fired is constantly proportionate to the total population, then the four factors are also population dependent and probably fairly constant in their relationship to both the total population and each other. Therefore, without a reliable estimated total of at least one of the defined populations, no estimate of total kill is possible. Also, since these factors would differ between

regions, considerable effort would necessarily be expended gathering data during a busy time of the year for biologists (spring) besides being a difficult time to get around and a difficult time to trap birds.

The U. S. Fish and Wildlife Service attempted a telephone survey one year to determine total kill (Day, 1949) but seemingly failed to secure adequate data. Recently they have used a wide-scale mail survey system (Heath and Rosasco, 1963) to estimate total kill, and also a wing collection survey (Carney and Godin, 1963) to obtain species composition of the kill. Many states, including Michigan (Hawn, 1964), now use mail surveys to estimate kill of several game species.

Even though mail surveys are widely employed, the data should not be used in blind faith; checks need to be periodically employed. Atwood (1956) illustrates types and magnitudes of biases he found in a survey of waterfowl hunters. Indeed, it appears that any form of interview, direct or indirect, is vulnerable to bias (response errors) regardless of the subject when answers must be based on memory--especially if some measure of competence is involved (Stoke and Lehman, 1930; Proctor, 1964).

For large-scale mail surveys, the population being sampled is all those who bought duck stamps. When a smaller population is to be sampled, e.g., that using a special area, it must be defined. Two techniques of estimating kill are designed to define the population and, in essence, gather kill and effort data simultaneously. Wandell (1946) and Palmer (1963) both used a system of placing cards on cars asking the drivers to fill in the desired data. Cards were then collected by technicians (Wandell, 1946) or mailed to the investigator (Palmer, 1963).

The second technique uses personal interviews to gather the data with an actual check of each individual's take. An early season index of the waterfowl kill in Michigan is determined through car counts and bag checks on selected areas (Mikula, 1965). Also, an estimate of total fish taken from certain selected lakes in Michigan is obtained with interviews and boat counts (Taube, 1965). This technique requires considerable man-days to perform.

Since adequate methods of inventorying total kill are already in use, I propose none of my own, but describe two of the better estimating methods adaptable for single marsh use. The best estimate would of course, arise from a check-in, check-out system where an absolute count is obtained, but because of the uncomplicated nature of the estimate and the infrequency of such a situation, I will not consider this system further.

THEORY

Both methods I am presenting are based on stratified random sampling and have computable confidence limits. The first is a mail survey as used by Palmer (1963) and the second a combination of the two personal interview techniques (Taube, 1965; Mikula, 1965). The one to be used in a particular situation must be chosen according to what information is desired, how much manpower is available, and how much money can be spent on it.

For the mail survey method, listings of hunters by name and address are necessary. Several ways are possible but the easiest probably is to sample cars, record license plate numbers, and place a questionnaire postcard in a conspicuous place on the auto. The name and address of all the car owners can then be obtained from the car license files. This allows both a check of the responses on passed-out cards and follow-up mailings to each non-respondent. The questionnaire design can eliminate much of the bias resulting from sampling just car owners. The drawback of this method is the hunter: you have to assume that he is honest and can identify waterfowl, and that in reporting kill he uses accepted and distinguishable names. The bias due to faulty memory is reduced by asking only about that day. If species kill estimates are not necessary, the hunter bias is further reduced. This method does not have the demanding manpower requirement of the other and is cheaper to operate.

The hunter interview method calls for having trained personnel record the hunting time and actually check all ducks bagged by interviewees. Estimates from interviews of both completed and incompleted hunts are possible as described by Taube (1965) for the intensive creel census. The data have to be handled differently.

For completed hunts:

$$\frac{\text{Total bag}}{\text{Total hours}} = \frac{\Sigma Y}{\Sigma X} = \text{bag per hour}$$

then total hours hunted times ducks bagged per hour estimates the total duck kill.

For incompleted hunts:

$$\frac{1}{b}\sum\frac{Yi}{Xi} = \text{bag per hour}$$

n = number of people contacted
Y = catch
X = hours
i = ith individual

This formula correlates the time hunted with the probability that the particular hunter is in the sample. Variances for either estimating technique can be calculated from:

$$\text{Var. } ES = E^2 \text{ var. } S + S^2 \text{ var. } E$$

$$E = \text{total hours}$$

$$S = \text{bag per hour}$$

$$ES = \text{total bag}$$

This method requires considerable manpower but assumptions as to the hunter are nonexistent.

FIELD USE

Both methods are based on a stratification of expected use by time unit by day with the sum of the time units within a day totaling the hours from opening till closing of shooting.

Suggested outline for conducting kill inventory

Instantaneous car counts are to be made at times selected by sampling with unequal probabilities. The sample space in reality then becomes the total number of car hours. Figures can be calculated either on the kill per carload of hunters or per hunter through a determination of the number of hunters per car.

Interview as many hunters as possible. If only completed hunts are sampled, the possible bias resulting from non-uniform kill of ducks over time is removed. This requires several trained people simultaneously for short periods of time throughout the season in order to obtain a sufficiently large sample.

Questionnaires for the mail survey method need to be placed on cars periodically throughout the season and can logically be distributed during the instantaneous car counts, thereby reducing the necessary field time. Several follow-up mailings will undoubtedly be necessary for obtaining a sufficient response to eliminate any non-response bias (unsuccessful hunters appear less likely to return questionnaires; Eberhardt and Murray, 1960) and to assure a sufficiently large sample to give meaningful estimates.

DISCUSSION

Since the above suggested methods are neither mine nor previously used by me, I have no data showing the ability of the methods to estimate total waterfowl kill on a single area. Data from Taube (1965) illustrating personal interviews and from Palmer (1963) illustrating the postcard mail survey results are appended (Table 11 and Table 12).

Variations of the proposed methods deal primarily with other ways of determining the population. For example, if the area were an island, instantaneous boat counts, either total or samples, could be used in lieu of car counts.

CONCLUSION AND SUMMARY

Previous techniques of vegetation-and brood production-inventorying neither provided reliable quantitative data nor gained the maximum amount of information for the total time expended. When waterfowl production is determined from breeding pair, nest density, and nesting success inventories, which are biased and inaccurate for that purpose, enough man-days to inventory production for most states are undoubtedly consumed.

To employ techniques of vegetation-inventorying on groups of plants taxonomically and morphologically different from those plants for which the survey was originally designed introduces an unmeasurable error before field work is even begun. Here again the ratio of useful data gained to total energy expended is too low.

The four inventory methods I have presented when used as directed should yield quantitative data of a useful nature with relatively little effort.

The accuracy of the brood estimating method (Appendix, Table 10) for the years it was checked was phenomenal, albeit it isn't that good since the method is subject to sampling error besides having an empirically derived cutoff point. But I am willing to accept slight errors in estimated total brood use to save time. Only nine man-hours were needed to inventory waterfowl use on the impoundment of the Rose Lake area and even this can probably be reduced by more than half.

When data from field surveys used for inventorying have confidence limits in the neighborhood of 25 percent, I am quite satisfied with the sampling procedure and sampling intensity. Especially when, as in the case of the vegetation survey on the Maple River State Game Area, little field time was needed to gain results for a large area. If for some specific purpose I wish to conduct another plant inventory on that area (even for a particular species) with, say, 10 percent confidence limits, I can determine the number of plots needed and how much field time would have to be expended, or if available field time is set I can determine what limits will result even before I set foot into the area.

I am not attempting to present these suggested methods as the ultimate. If I have seemed dogmatic it is because of my strong desire to stimulate waterfowl biologists and wetlands ecologists to search for better methods of inventorying based on their knowledge and on the work of those of similar interests who preceded.

LITERATURE CITED

Anderson, J. M. 1950. Some aquatic vegetation changes following fish removal. J. Wildl. Mgmt. 14(2):206-209.

Atwood, E. L. 1956. Validity of mail survey data on bagged waterfowl. J. Wildl. Mgmt. 20(1):1-16.

Beard, Elizabeth B. 1953. The importance of beaver in waterfowl management at the Seney National Wildlife Refuge. J. Wildl. Mgmt. 17(4):398-436.

__________________. 1964. Duck brood behavior at the Seney National Wildlife Refuge. J. Wildl. Mgmt. 28(3):492-521.

Bennett, C. L., Jr. 1960. Student assistant final report, Shiawassee National Wildlife Refuge. Saginaw, Michigan. 7 pp. (M.S.)

__________________, W. A. Matulis, and D. J. Drumm. 1961. Technical report of research studies at Erie Shooting Club marsh. 56 pp. (M.S.)

Bennett, L. J. 1938. The blue-winged teal: Its ecology and management. Collegiate Press, Ames, Iowa. xiv + 144 pp.

Berg, P. F. 1956. A study of waterfowl broods in eastern Montana with special reference to movements and the relationship of reservoir fencing to production. J. Wildl. Mgmt. 20(3):253-262.

Billings, W. D. 1951. Vegetational zonation in the Great Basin of Western North America. pp. 101-122 in Les bases ecologiques de la vegeveration de la vegetation des zones aides U.I.S.B. Paris.

Blackman, G. E. 1935. A study by statistical methods of the distribution of species in grassland associations. Ann. Bot. Lond. 49, 749-74 (Append. by M. S. Bartlett 775-7.).

Blankenship, L. H., C. C. Evans, M. H. Hammond, and A. S. Hawkins. 1953. Techniques for brood production studies. Contribution for the Miss. Flyway Council Techn. Comm. 14 pp. mimeo.

Brown, Dorothy. 1954. Methods of surveying and measuring vegetation. Commonwealth Bureau of Pastures and Field Crops. Bull. No. 42. Hurley, Berks, England. xv + 223 pp.

Burgess, H. H., H. H. Prince, and D. L. Trauger. 1965. Blue-winged teal nesting success as related to land use. J. Wildl. Mgmt. 29(1):89-95.

Cain, S. A. 1937. Andropogonetum Hempsteadi: A Long Island grassland vegetation type. Amer. Midl. Nat. 18:334-350.

Carney, S. M. and P. J. Godin. 1963. Wing collection survey in waterfowl status report 1963. U. S. Fish and Wildl. Serv., Spec. Sci. Report - Wildl. No. 75. pp. 3-4.

Cartwright, B. W. 1944. Waterfowl brood counts in Manitoba, Saskatchewan, and Alberta, 1935, 1938-42. J. Wildl. Mgmt. 8(1):79-80.

_______________. 1948. The western Canadian waterfowl breeding grounds. Trans. N. Am. Wildl. Conf. 13:63-68.

Clarke, G. L. 1954. Elements of ecology. John Wiley and Sons, Inc., New York. xiv + 534 pp.

Cochran, W. G. 1953. Sampling techniques. John Wiley and Sons, Inc., New York. xiv + 330 pp.

Coupland, R. T. 1950. Ecology of mixed prairie in Canada. Ecol. Monog. 20:271-315.

Crissey, W. F. 1960. Aerial inventory techniques in waterfowl management. 22nd Midwest Fish & Wildl. Conf. unpl. report.

Curtis, J. T. and R. P. McIntosh. 1950. The interrelations of certain analytic and synthetic phytosociological characters. Ecology 31(3):434-455.

Day, A. M. 1949. North American Waterfowl. Stockpole and Heck, Inc., New York, Harrisburg. xx + 329 pp.

Dobie, J. and R. E. Johnson. 1951. Pond mapping by aerial photographs. J. Wildl. Mgmt. 15(2):221-222.

________ and John B. Moyle. 1956. Methods used for investigating productivity of fish-rearing ponds in Minnesota. Minn. Dept. Conserv., Div. Game and Fish, Fisheries Research Unit Spec. Publ. No. 5. 54 pp.

Eberhardt, L. L. 1955. Preliminary revision of deer kill estimates, 1935-1951. Mich. Dept. Conserv. Game Div. Rept. No. 2030. 5 pp.

______________ and Rose M. Murray. 1960. Estimating the kill of game animals by licensed hunters. Proc. Social Stat. Sect. Ann. Meeting Ann. Stat. Assoc. 120:182-188.

______________. 1963. Problems in ecological sampling. Northwest Sci. 37(4):144-154.

Elder, W. H. 1950. Measurement of hunting pressure in waterfowl by means of x-ray. Trans. N. Amer. Wildl. Conf. 15:490-503.

Evans, F. C., P. J. Clark, and R. H. Brand. 1955. Estimation of the number of species present on a given area. Ecology 36(2):342-343.

Feller, W. 1950. Probability theory and its applications. John Wiley and Sons, Inc. New York. xii + 419 pp.

Gallop, J. B. and W. H. Marshall. 1954. A guide for aging duck broods in the field. Miss. Flyway Council Techn. Sec. 14 pp. mimeo.

Gates, D. H., L. A. Stoddart and C. W. Cook. 1956. Soil as a factor influencing plant distribution on salt deserts of Utah. Ecol. Monog. 26:155-175.

Geis, Mary B. 1956. Productivity of Canada geese in the flathead valley, Montana. J. Wildl. Mgmt. 20(4):409-419.

Generosoff, V. T. 1934. The culture of food and cover plants for waterfowl. All-Union Cooperative Associated Publishing Office. Leningrad. 128 pp. Abstracted in 1936 Wildlife Review No. 3:16-19.

Gevorkiantz, S. R. 1954. Problems in forestry inventory from the forester's point of view. Pages 251-262. In I. Kempthorne, T. A. Bancroft, J. W. Gowen, and J. L. Lush (eds.). Statistics and mathematics in biology. The Iowa State College Press, Ames, Iowa. ix + 632 pp.

Glover, F. A. 1956. Nesting and production of the blue-winged teal (*Anas discors Linnaes*) in Northwest Iowa. J. Wildl. Mgmt. 20(1):28-46.

Goodall, P. W. 1952. Some considerations in the use of point quadrats for the analysis of vegetation. Austral. J. Sci. Research Series B. 5(1):1-41.

Greig-Smith, P. 1957. Quantitative plant ecology. Academic Press Inc., New York. ix + 198 pp.

Griffith, R. 1948. Improving waterfowl habitat. Trans. N. Am. Wildl. Conf. 13:609-617.

Hammond, M. C. and W. R. Forward. 1956. Experiments on causes of duck nest predation. J. Wildl. Mgmt. 20(3):243-247.

Hanson, H. C. 1962. Dictionary of ecology. Philosophical Library Inc., New York. 382 pp.

Hasel, A. A. 1954. Problems in forest inventory: from the statistical point of view. Pages 263-272. In O. Kempthorne, T. A. Bancroft, J. W. Gowen, and I. L. Lush (eds.). Statistics and mathematics in biology. The Iowa State College Press, Ames, Iowa. ix + 632 pp.

Hawn, L. J. 1964. 1963 small game kill estimates. Mich. Dept. of Conserv. Research and Development Sect. Rept. No. 4. 8 pp.

Hayne, D. W. and L. L. Eberhardt. 1954. Nature of the bias of estimates computed from voluntary reports. Paper presented at the 16th Midwest Wildl. Conf., St. Louis, Missouri. 8 pp. (M.S.)

Heath, R. G. and M. E. Rosasco. 1963. Waterfowl kill survey. In waterfowl status report 1963. U. S. Fish & Wildl. Serv., Spec. Sci. Report - Wildl. No. 75. Pp. 1-3.

Hochbaum, H. A. 1948. Harvesting the waterfowl crop. Trans. N. Am. Wildl. Conf. 13:481-491.

Jessen, R. L. and R. Lound. 1962. An evaluation of a survey technique for submerged aquatic plants. Minn. Dept. Conserv. Sect. of Research and Planning, Game Invest. Rept. No. 6. 10 pp.

Kadlec, J. A. 1960. The effect of a drawdown on the ecology of a waterfowl impoundment. Mich. Dept. Conserv. Game Div. Rept. No. 2276. 181 pp.

__________. 1964. Michigan Department of Conservation. Michigan P.-R. Project W-40-R. Job 2. 43 pp.

Keith, L. B. 1961. A study of waterfowl ecology on small impoundments in southeastern Alberta. Wildl. Mono. No. 6. 88 pp.

King, R. T. 1937. Ruffed grouse management. J. Forestry. 35(6): 523-532.

Lee, F. B., R. L. Jensen, N. J. Ordal, R. I. Benson, J. P. Lindmeier, and L. L. Johnson. 1964. Waterfowl in Minnesota. Minn. Dept. Conserv. Div. of Game and Fish, Tech. Bull. No. 7. 209 pp.

Leedy, D. L. 1948. Aerial photographs, their interpretation and suggested uses in wildlife management. J. Wildl. Mgmt. 12(2):191-210.

Loveless, C. M. 1957. Clipping study techniques in marsh ecology investigations. Proc. Eleventh Ann. Conf. Southeastern Assoc. Game and Fish Comm. Pp. 119-124.

Martin, A. C. and F. M. Uhler. 1939. Food of game ducks in the United States and Canada. U.S. Dept. Agr. Tech. Bull. No. 634. 157 pp.

Mikula, E. J. 1965. Waterfowl hunting season Michigan 1964. Mich. Dept. Conserv. Game Sect. Report No. 2469. 6 pp.

Miller, H. J. 1949. Waterfowl breeding ground survey, 1949, in Michigan. Mich. Dept. Conserv. Game Div. Rept. No. 1038. 6 pp.

Moyle, J. B. 1945. Some chemical factors influencing the distribution of aquatic plants in Minnesota. Amer. Midland Nat. 34(2): 402-420.

Palmer, W. L. 1963. Non-hunting season public use of region III state game and forest lands compared to hunting season use. Mich. Dept. Conserv. Game Div. Rept. No. 2412. 7 pp.

Penfound, W. T. and E. S. Hathaway. 1938. Plant communities in the marshlands of southeastern Louisiana. Ecol. Monog. 8:1-56.

______________. 1945. A study of phytosociological relationships by means of aggregations of colored cards. Ecology 26(1):38-57.

Pielou, E. C. 1962. Runs of one species with respect to another in transects through plant populations. Biometrics 18(4):579-593.

Pirnie, M. D. 1935. Michigan waterfowl management. Mich. Dept. Conserv. Game Div., Lansing. xxi + 328 pp.

____________ and J. Foster. 1964. Summary of Erie research activities 1960 through 1963. Rept. submitted to members of the Erie Res. Comm. 90 pp. (M.S.)

Proctor, C. H. 1964. Scatter, stability and vigilance in the response errors of factual surveys. Paper presented at the 1964 Stat. workshop sponsored by the Southeastern Cooperative Fish and Game Stat. Project, North Carolina, state of the Univ. of North Carolina at Raleigh, North Carolina. 15 pp. (M.S.)

Rice, E. L. 1952. Phytosociological analysis of a tall-grass prairie in Marshall County, Oklahoma. Ecology 33(1):112-116.

Rogers, J. P. 1964. Effect of drought on reproduction of the lesser scaup. J. Wildl. Mgmt. 28(2):213-222.

Siegel, S. 1956. Nonparametric statistics for the behavioral sciences. McGraw-Hill Book Co., Inc., New York. xvii + 312 pp.

Siegler, H. R. 1941. A water plant census technique. J. Wildl. Mgmt. 5(4):423-426.

Sincock, J. L. and J. A. Powell. 1957. An ecological study of waterfowl areas in central Florida. Trans. N. Am. Wildl. Conf. 22:220-236.

Smith, R. H. and A. S. Hawkins. 1948. Appraising waterfowl-breeding populations. Trans. N. Amer. Wildl. Conf. 13:57-62.

Sondrini, W. J. 1950. Estimating game from licensee reports. Connecticut P.-R. Project 7-R. P.-R. Bull. No. 3. 50 pp.

Steel, P. E., P. D. Dalke, and E. G. Bigeau. 1956. Duck production at Gray's Lake, Idaho, 1949-1951. J. Wildl. Mgmt. 20(3):279-285.

Stewart, P. A. 1958. Some wood duck census methods and their evaluation. Ohio Cooperative Wildl. Research Unit Release 209. 13 pp. mimeo.

Stoke, S. M. and H. C. Lehman. 1930. The influence of self-interest on questionnaire replies. School and Soc. 32:435-438.

Stoudt, J. H. 1944. Food preferences of mallards on the Chippewa National Forest, Minnesota. J. Wildl. Mgmt. 8(2):100-112.

Subcommittee on Range Research Methods. 1962. Basic problems and techniques in range research. Natl. Acad. of Sci., Natl. Research Council, Washington, D. C. Pub. No. 890. xvi + 341 pp.

Swindale, D. N. and J. T. Curtis. 1957. Phytosociology of the larger submerged plants in Wisconsin lakes. Ecology 38(3):397-407.

Swindale, D. N. and L. R. Jahn. 1956. Results of sampling the submerged vegetation in some central and northern Wisconsin flowages, with notes on environment. Wisconsin P.-R. Project W-77-R-3 (phase D). Job No. I-A. 70 pp.

Taube, C. M. 1965. Evaluation of fish management procedures. Michigan D.-J. Project F-27-R. Work Plan No. 2. 41 pp.

Tryon, C. A., Jr. 1954. The effects of carp exclosures on growth of submerged aquatic vegetation in Pymatuning Lake, Pennsylvania. J. Wildl. Mgmt. 18(2):251-254.

Uhler, F. M. and F. B. McGilvrey. 1965. Waterfowl management through water-level control. Biennial Prog. Report - 1963 to 1944 Work Unit A-3.1 Bureau of Sport Fisheries & Wildl., Patuxent Wildl. Research Center, Laurel, Maryland. 49 pp.

Wandell, W. N. 1946. An intensive method of determining hunter numbers and activities. Trans. N. Amer. Wildl. Conf. 11:373-382.

Wright, B. S. 1948. Waterfowl investigation in Eastern Canada, Newfoundland and Labrador, 1945-1947. Trans. N. Amer. Wildl. Conf. 13:356-365.

APPENDIX

NECESSARY BACKGROUND INFORMATION

I. Air Photos

The first step is to obtain scaled, vertical air photos for base mapping and for stratifying vegetation (Gevorkiantz, 1954; Leedy, 1948). They are cheaper, more accurate, and far easier to make and use than are ground surveys (Dobie and Johnson, 1951).

A map accurate as to ground scale is a necessity since the total number of plots per vegetative community must be determined. Both Leedy (1948) and Dobie and Johnson (1951) give methods to determine map scale which allows results from a random sample to be applied to the entire stratum. Aerial obliques (Leedy, 1948) taken in color and at lower levels also help in making accurate stratifications. The better the original stratification, the easier and quicker is the sampling procedure for any accuracy selected (Cochran, 1953).

II. Soils

A soil map showing the general series is usually sufficient. The purpose of the map is fourfold: (1) when compared to the air photo, areas of homogeneous vegetative types are often found to conform to a soil series (Billings, 1951) so such a map will help the investigator to stratify the vegetation; (2) knowledge of the series can dictate what plant communities are possible (Gates et al., 1956) after some form of habitat manipulation; (3) rankness of aquatic plant growth is dependent on the firmness of the bottom (Pirnie, 1935; Martin and Uhler, 1939); and (4) a knowledge of the distribution of good diking soils such as clay is a necessary requirement before creating controlled floodings.

III. Limnology

A cursory limnological study is extremely desirable. Knowledge of turbidity, pH, temperatures, bottom contours, and availability of critical nutrients again will limit the kind, number, and distribution of vegetative communities (Moyle, 1945).

The greatest effort should be expended collecting data in the shallows. I have never observed dabblers utilizing bottom feeds in more than six feet of water except indirectly (e.g., baldpates stealing food from redheads).

Duck food availability studies should also be included. This entails making rough estimates of the abundance of suitable aquatic organisms and of the waterfowl food portions of purely aquatic vegetation. I have no technique to offer for sampling the vegetation other than raking up quadrats which are chosen randomly if possible and then rating the total edible amount on a selected scale devised by the investigator.

Duck food-producing vegetation both submerged and floating should undoubtedly be sampled twice during the growing period. At the Erie marsh my first inventory showed about 95 percent coverage of sago pondweed (*Potamogeton pectinatus*) in much of the open water area; by mid-July (second inventory) wild celery (*Vallisneria americana*) had replaced the sago and had as great a percentage of coverage as its predecessor. The sago had borne fruits which were also available for food along with the celery during the fall. In essence then, a double crop of waterfowl foods had been produced in the shallow areas.

Since the correlation between soil and/or water chemistry and aquatic plant communities and their distribution is poor, unrefined, and general (Kadlec, 1960) at our present level of knowledge, a fairly intensive limnological field study such as described by Dobie and Moyle (1956) doesn't seem justifiable if the guides are saving time and money.

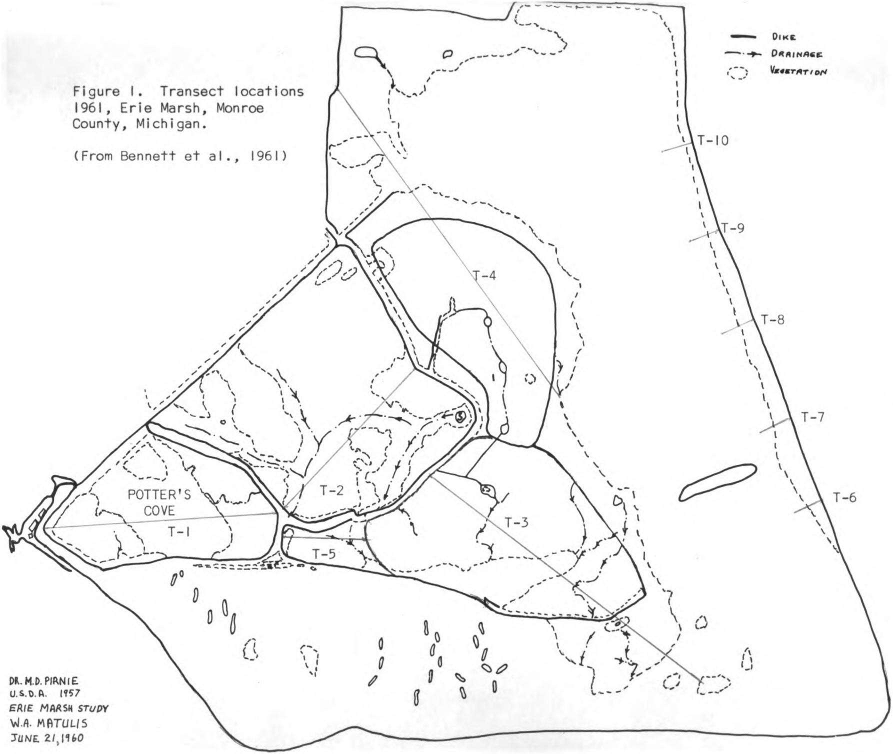

Figure I. Transect locations 1961, Erie Marsh, Monroe County, Michigan.

(From Bennett et al., 1961)

Table 7. Transect locations

Transect: T-1

Unit: Potter's Cove

Total distance: 1,966 feet

Direction: N 83° 30' E

Starting point (T-1A): On southwest corner of Potter's Cove dike
Ending point (T-1B): On northeast corner of Potter's Cove dike
Q-1 is 242' from T-1A in cattail
Q-2 is 178' from Q-1 in cattail
Q-3 is 276' from Q-2 on southside of sprayed strip
Q-4 is 455' from Q-3 on north side of sprayed strip
Q-5 is 517' from Q-4 ecotone of open water and cattail
Q-6 is 179' from Q-5 ecotone
Q-7 is 119' from Q-6 in meadow ecotone
T-1B is 356' from Q-7 in meadow

Transect: T-2

Unit: Sulfur Springs

Total distance: 1,858.7 feet

Direction: N 40° 30' E

Starting point (T-2A): Beneath dock at Sulfur Spring roll over
Ending point (T-2B): On Sulfur Spring dike west of channel to number 10 pond and just east of sharp bend in dike
Q-8 is 419.7' from T-2A in bulrush on southwest side of Horse's head 10' in from edge of open water
Q-9 is 343' from Q-8 on ecotone of cattail and bulrush in Horse's head
Q-10 is 300' from Q-9 on north side of Horse's head 10' in from edge of open water
Q-11 is 348' from Q-10 on north side of channel 10' in from edge of open water
Q-2B is 448' from Q-11

Transect: T-3

Unit: Mink Creek and Cain Point

Total distance: 3,354.9 feet

Direction: S 50° 45' E

Table 7 (continued) - Transect T-3 (continued)

Starting point (T-3A): On west Mink Creek dike approximately ½ the distance from north end of dike to start of research unit
Ending point (Q-21): On northwest end of largest island southeast of Cain Point
Q-12 is 676.4' from T-3A on north edge of dump spray strip
Q-13 is 65.9' from Q-12 on south edge of dump spray strip
Q-14 is 106.7' from Q-13 on north side of buckwheat patch
Q-15 is 400' from Q-14 at southeast corner of buckwheat patch
Q-16 is 113.5' from Q-15 on southeast side of highbank
Q-17 is 224.8' from Q-16 ecotone of cattail and open water
Q-18 is 388' from Q-17 ecotone of meadow and cattail
Q-19 is 404.7' from Q-18 on small pond south of south dike
Q-20 is 552.4' from Q-19 tip of Cain Point
Q-21 is 422.5' from Q-20 northwest corner of large island southeast of Cain Point

Transect: T-4

Unit: Secor and area to northwest

Total distance: 4,030 feet

Direction: S 53° 00' E

Starting point (T-4A): On west dike north of Secor unit just above sharp bend in dike
Ending point (Q-32): On ecotone of cattail and open water southeast of east Secor dike
Q-22 is 388' from T-4A on ecotone of meadow and cattail
Q-23 is 186' from Q-22 on ecotone of cattail and open water
Q-24 is 718.9' from Q-23 on ecotone of open water and cattail just north of Secor north dike
T-4B is 220' from Q-24 on inside edge of barrow pit inside north end of Secor unit
Q-25 is 321' from T-4B on north edge of sprayed strip
Q-26 is 304.2' from Q-25 on south side of sprayed strip
Q-27 is 83' from Q-26 on north side of millet patch
Q-28 is 300' from Q-27 on south side of millet patch
Q-29 is 638' from Q-28 in northwest corner of S-5
Q-30 is 100.6' from Q-29 on northern part of west side of S-5
T-4C is 317' from Q-30 on inside of barrow pit on inside of southern portion of east dike
Q-31 is 170' from T-4C on ecotone of open water and cattail
Q-32 is 284' from Q-31 on ecotone of cattail and open water

Table 7 (continued)

Transect: T-5

Unit: Research unit

Total distance: 1,022.2 feet

Direction: N 86° 30' E

Starting point (T-5A): On dike between research unit and pancake cut, about midway of the width of the research unit proper
Ending point (T-5B): On dike between research unit and Mink Creek south of T-3A (Mink Creek starting point)
Q-33 is 229.3' from T-5B whole unit is intermingled cattail and meadow vegetation, stakes mark the sharper and clearer ecotones
Q-34 is 95.7' from Q-33
Q-35 is 123.1' from Q-34
Q-36 is 184.4' from Q-35
Q-37 is 239.7' from Q-36
T-5B is 150' from Q-37

Transect: T-6

Unit: East Dike

Total distance: 330 feet

Direction: S 70° 00' W

Starting point (T-6A): is just south of Sand Island and 12' west (on the line) of the center of the road
Ending point (Q-39) on outer edge of cattail
Q-38 is 152' from T-6A on ecotone of meadow and cattail
Q-39 is 178' from Q-38 on outer edge of cattail

Transect: T-7

Unit: East Dike

Total distance: 584.5 feet

Direction: S 70° 00' W

Starting point (T-7A): is just north of Sand Island and 19' west (on the line) of the center of the road
Ending point (Q-43) is on the outer edge of cattail

Table 7 (continued) - Transect T-7 (continued)

Q-40 is 162' from T-7A on the ecotone of meadow and cattail
Q-41 is 61' from Q-40 on the ecotone of cattail and open water
Q-42 is 174' from Q-41 on the ecotone of open water and cattail
Q-43 is 187.5' from Q-42 on the outer edge of cattail

Transect: T-8

Unit: East Dike

Total distance: 575.2 feet

Direction: S 70° 00' W

Starting point (T-8A): is north along dike from T-7A and 26' west (on the line) of the center of the road
Ending point (Q-47): is on the outer edge of cattail (ecotone of cattail and the open water of East Bay)
Q-44 is 88.2' from T-8A on ecotone of meadow and cattail
Q-45 is 102.5' from Q-44 on the ecotone of cattail and open water
Q-46 is 225.5' from Q-45 on the ecotone of open water and cattail
Q-47 is 159' from Q-46 on the outer edge of cattail

Transect: T-9

Unit: East Dike

Total distance: 414 feet

Direction: S 70° 00' W

Starting point (T-9A): is on dike north of T-8A and 44' west (on the line) of the center of the road
Ending point (Q-51): is on the outer edge of cattail
Q-48 is 117' from T-9A on ecotone of meadow and cattail
Q-49 is 32' from Q-48 on ecotone of cattail and open water
Q-50 is 153' from Q-49 on ecotone of open water and cattail
Q-51 is 112' from Q-50 on outer edge of cattail

Table 7 (continued)

Transect: T-10

Unit: East Dike

Total distance: 276.5 feet

Direction: S 70^{o} 00' W

Starting point (T-10A): is north of T-9A on dike and 26' west (on the line) of the center of the road
Ending point (Q-54): is on the outer edge of a cattail
Q-52 is 46.5' from T-10A on ecotone of meadow and cattail
Q-53 is 137' from Q-52 on ecotone of cattail and open water
Q-54 is 93' from Q-53 on outer edge of cattail

(From Bennett et al., 1961)

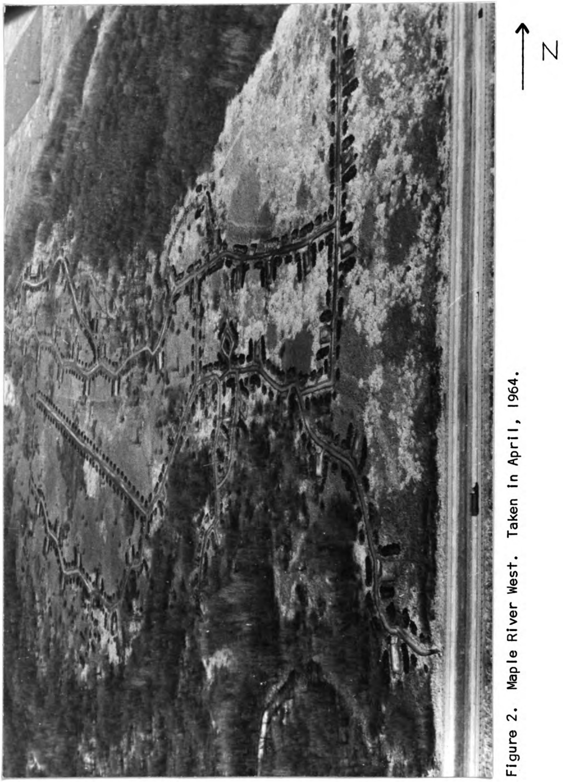

Figure 2. Maple River West. Taken in April, 1964.

VEGETATION SAMPLING INSTRUCTIONS FOR MAPLE RIVER WEST

The sampling program is divided into five different inventories, each having a unique set of instructions. I think the reason for this breakdown will be made self-evident upon reading through each series of instructions.

At every sample quadrat the data to be gathered are the same. Record the density, height, and seed production for each species, the percent cover per layer, presence or absence of plants too far under water to obtain above information, and depth of water. The seed production is to be a subjective rating, pick the appropriate category from the following choices: excellent, good, fair, poor, or none. Bear in mind that these ratings apply only to the species in question.

Ditches:

Measure with a map measurer total ditch distances, also keep a record of individual ditch distances. Divide the total and the individual ditch distances by 6.6'. This gives the total linear square milacre quadrats in the ditches (I choose to call these quadrat segments). Then pick quadrats at random. To locate these plots, count up the segments on the individual ditches until the correct quadrat segment is reached, then measure out on the map with map measurer and mark the segment. Pick random numbers one digit longer than necessary, then through an even-odd randomization choose which side of center the quadrat lies. Since the ditches are 14' wide and 2 milacre quadrats make only 13.2', .8' is left over. Therefore, every other plot should be shoved against the bank with those between on the center line. Pick the start position at random. Take the average distance of the "stalks" (distance from channel to pothole; the connection channel) and mark off that distance on the map of those potholes having extra long channels. Put all but the average stalk length into the ditch survey, place the marked off stalk length with the pothole. When measuring ditches, save all elongated stalks till last, then include in the ditch distances, also treat as an extra long stalk, the ditch length of the oddity called a donut.

Potholes:

Number all the potholes and then stratify them according to the following scheme:

Stratum I - Half or more of the water area covered with emergent vegetation.

Stratum II - Less than half - but at least with edges covered with emergent vegetation.

Stratum III - No vegetation visible from aerial photograph.

Potholes are to be picked at random for each stratum. The starting position for sampling a picked pothole is the corner that most nearly fits the stipulation "Diagonally across from stalk." Randomly pick a number between 1 and 6, multiply it by 6.6'. This distance is then to be measured off along the short leg of the pothole. Pick another number at random between 0 and 19. This distance is already in feet and is to be measured off along the long leg of the pothole from the start corner. At the intersection of the lines, perpendicular to the sides at the measured distances, is the first plot location. The milacre sample is to be alined within the intersecting lines wholly towards the ditch and away from the stalk corner. This means the first plot lies in the second quadrat formed by the intersection of the perpendiculars. Separate each plot by 2 feet from its neighbors and keep all plots along the line perpendicular to the short side. Run five plots in this line. The pothole area includes the "stalk." When the potholes are actually sampled, the length and width of pothole and length and width of the stalk are to be measured. Also measure the width of the stalk parallel with the ditch.

Bank Area:

A strip 16.5' wide and on each side of all ditches is to be treated as a separate entity. To sample this area, divide the total ditch length into 3.3' (treat the same as for ditches). When the 1/4 milacre quadrat segments have been determined by ditch over all ditches, randomly pick sample segments. Adjacent to the ditch and on either side there is a tier of 5 1/4 milacre squares. As each random number is obtained, take the next row number to determine which 1/4 milacre will be sampled. Also look at the next digit in the random number row to determine which side of the channel to census. Plots are to be located in the same manner as those in the ditches only measure back from the bank to the appropriate tier. Do not include the linear ditch distance of the donut.

Mound Area:

The mound area is the next 16.5' away from the ditch with the bank area inbetween. This is to be handled exactly the same as the bank area. Draw new random numbers to determine sample areas. Also include the donut in the mound stratum.

Outside Area:

From the air photos separate the timber from the herbaceous areas and stratify the herbaceous area into high and low vegetation. Use a planimeter and determine the area within each portion of the marsh (isolated by ditches, ditches and trees, etc.) as a separate entity using ditch borders as the outside limits where present. Then reproduce each area onto a grid pattern as was outlined for the potholes. Randomly pick milacre quadrats for all areas, treating them as a single entity within each stratum (to be marked on the grid patterns also) and throw out all plots that would fall within 40 feet of a ditch or in a pothole. Randomly pick one 1/4 milacre quadrat and sample just that one within each milacre. This plot will remain the same for all milacres, e.g., the southwest 1/4. Determine the location of each plot by counting down rows and across columns of square milacres until the correct one is reached. These distances can then be used to compute linear lengths in feet for pacing purposes. By computing the total marsh area, subtracting the timber, ditch, pothole, bank, and mound areas, you can determine the less important herbaceous plant area. The stratum areas can then be determined by proportions.

Table 8. The recovery of flood-killed cattail in Potter's Cove when water was removed.*

Water depth	Date	Species	Density per 1/4 milacre	Percent cover	Remarks
8-9"	8-1-61	*Typha angustifolia*			
		dead stems	33		Prolonged flooding has partially
		live stems	14		killed this stand of cattail.
		Lemna minor		40	
0"	6-14-62	*Typha angustifolia*			With no water, cattail recovers
		dead stems	7		and smartweed, an early succes-
		live stems	30		sion plant, becomes abundant.
		Polygonum sp.	195		
		Impatiens capensis	10		
		Cuscuta sp.	present		
0"	9-8-62				(Stake not found) Smartweed (*Polygonum lapathifolium*) generally covers 60% of the area and cattail about 40%.
0"	6-16-63	*Typha angustifolia*	30		The area has taken on the general aspects of a typical cattail stand.
		Impatiens capensis	210		
		Polygonum sp.	10		

*Data are from Transect I Quadrat I.

(From Pirnie and Foster, 1964).

Table 9. A transition from cattail to meadow in Potter's Cove.*

Water depth	Date	Species	Density per 1/4 milacre	Present cover	Remarks
12"	8-1-61	Typha angustifolia			Sample is at ecotone of cattail & meadow.
		dead stems	1		
		live stems	8		
		Asclepias incarnata	3		High water has killed most of the cattail.
		Leersia oryzoides	35		
		Eleocharis sp.	100±		
0"	6-14-62				
		Typha angustifolia	41		Water lowered. Cattail recovered. Bulrush & smartweed typical plants that follow drawdown.
		Polygonum lapathifolium	9		
		Hibiscus palustris	18		
		Leersia oryzoides		scattered	
		Eleocharis sp.	150		
		Scirpus validus	8		
		Sonchus arvensis	1		
0"	9-8-62				
		Typha angustifolia	35		Cattail edge extends 20 ft. beyond stake into meadow.
		Polygonum lapathifolium	5		
		Hibiscus palustris	15		
		Leersia oryzoides		present	
0"	6-16-63				
		Typha angustifolia	33		Cattail extends 20' beyond stake in meadow but is scattered and appears to lack vigor.
		Asclepias incarnata	12		
		Graminae		50	
		Nentha sp.	1		
0"	9-5-63				
		Typha angustifolia	5		Stake is on boundary between cattail and meadow.
		Asclepias incarnata	10		
		Leersia oryzoides	1500		
		Hibiscus palustris	1		

*Data from Transect I Quadrat 6.

(From Pirnie and Foster, 1964).

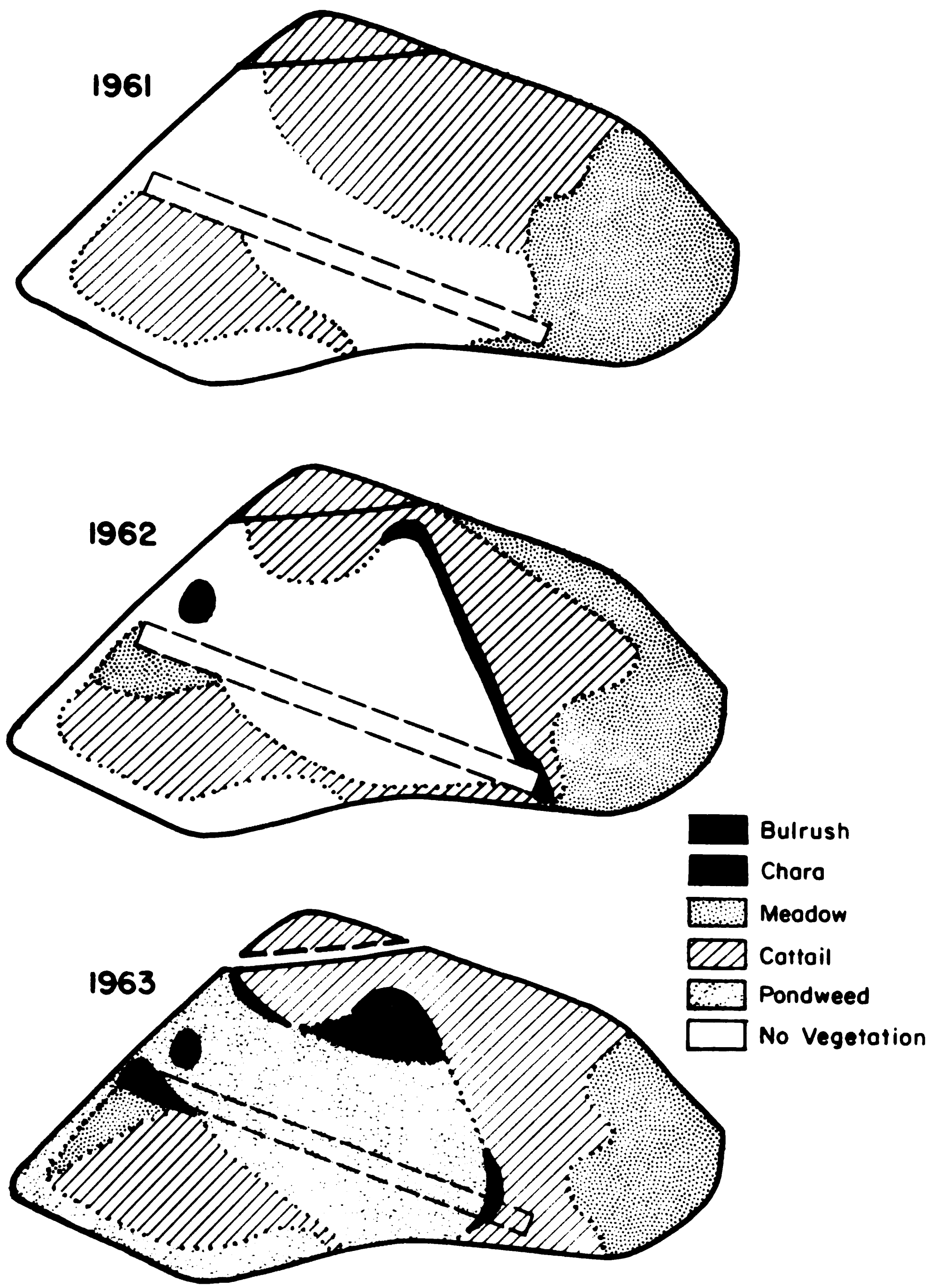

Figure 3. Erie Shooting and Fishing Club, Potter's Cove. Cover map of the vegetation.
(From Pirnie and Foster, 1964)

Table 10. Calculation of total brood production

		Mallard		Black duck		Wood duck		Blue-winged teal		Hooded merganser		Total	
		1961	1962	1961	1962	1961	1962	1961	1962	1961	1962	1961	1962
Known Production		8	12	4	2	4	7	2	4	0	1	18	26
Standardized Observations	n*	13	21	3	1	1	7	5	6	0	0	22	35
	b*	6	9	2	1	1	4	2	3	0	0	11	17
	B*	9	14	3	-**	-	6	2	4	-	-	19	29
All Shore Circuits	n*	11	18	6	1	5	15	2	7	0	2	24	43
	b*	6	10	2	1	2	7	1	4	0	1	11	23
	B*	10	17	-	-	-	-	-	-	-	-	18	42
July Shore Circuits	n*	7	7	2	0	2	12	2	7	0	0	13	26
	b*	5	6	2	0	2	7	1	4	0	0	10	17
	B*	9	12	8	-	8	12	-	6	-	-	20	32

* n--total broods seen; b--individual broods seen; B--calculated number of broods.

** Calculation not made when only one brood seen (b = 1).

(From Kadlec, 1964).

Table II. Creel census data, Duck and Fine lakes, 1958[1]

Lake	Total fishing Trips	Hours	Catch
Duck	26	80	83
Fine	12	30	55

Lake	Catch by species: Yellow perch	Blue-gill	Pump-kin-seed	Black crapple	Rock bass	Large-mouth bass	Small-mouth bass	Wall-eye	Pike
Duck	24	50	3	2	1	2,749	39	44	398
Fine	4	41	6	2	..	1,101	...	49	34

[1]Estimates are shown to the nearest thousand, except for large-mouth and smallmouth bass, walleyes, and pike, which are actual estimates.

(From Taube, 1965.)

Table 12. Summary of use

The following then presents the five components entering into my final estimate of non-hunting-season use:

		Man-hours
(1)	Basic use computed from postcard returns	906,000
(2)	Estimated nocturnal use not adequately sampled . .	300,000
(3)	Estimated use by people in cars that did not stop on game areas	200,000
(4)	Allowance for cars missed during daylight counts .	200,000
(5)	Estimated use March 2-April 28 before check began.	25,000
Total:	March 1-September 30, 1962	1,631,000

Types of Use

An analysis of 2,444 postcard returns indicated a wide spectrum of uses during spring and summer--from fishing to practicing musical instruments and hunting tadpole food!

Activity	Number of respondents	Percent of total
Fishing	1,291	53.0
Picnicking	328	13.5
Berry picking	296	12.2
Swimming	259	10.6
Camping	247	10.1
Sight-seeing	246	10.1
Boating	149	6.1
Mushroom hunting	127	5.2
Hiking	115	4.7
Loafing, resting	49	2.0
Visiting camper friends	22	0.9
Bird-watching and banding	22	0.9
Target shooting (gun)	19	0.8
Field trials	18	0.7
Archery practice	15	0.6
Water skiing	14	0.6
Dog training	12	0.5
Photography	10	0.4
Miscellaneous	125	5.1

Some respondents reported more than one activity. Therefore, column totals exceed 2,444 responses and 100 percent.

A decided seasonal variation occurred throughout the spring and summer. Mushroom hunting was a principal activity in early spring and again in September. Fishing was popular throughout the entire study period. Swimming, camping, and picnicking were popular mostly from July 4 through Labor Day. In September, dog-training, target shooting, and related interests associated with the forthcoming hunting season increased in important.

(From Palmer, 1963)